FIPS Project Office

5G Networks
and the Evolution to 6G

2020

Rostelecom

5G NETWORKS
AND THE EVOLUTION TO 6G

2020

Federal Institute of
Industrial Property (FIPS)
Project Office
PATENT ANALYTICS FACTORY

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5G NETWORKS AND THE EVOLUTION TO 6G

Patent Landscape

2020

Project
Office of FIPS
PATENT ANALYTICS FACTORY

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Dear friends,

Grigory IVLIYEV

Head of the Federal Service for Intellectual Property (Rospatent)

You are reading a new open patent landscape report prepared by the Project Office of FIPS and Rostelecom – a systemically important Russian telecom operator and the leader of the telecommunications market in Russia and in the former Soviet Union countries.

It is no secret that thanks to a breakthrough in communication technologies, the world around us has become a completely different place. The scale of information production and transmission has changed. Technological advances in one segment have provoked fundamental changes across all areas of human life: from the change of communication principles to the emergence of multi-billion businesses relying exclusively on the management of information flows and communication between customers and consumers or network subscribers. The explosive development of communication technologies has unlocked new opportunities for scientists, researchers, businesspersons, industrialists, innovators, and visionaries – all those who are not afraid to be the first to take advantage of technological advances.

Today the world is on the verge of a new revolution in communication technology. Multiple urban myths have already emerged around 5G, the next-generation communication solution, but global developers of the best technological solutions continue their race of innovation, which will not be stopped by scientifically unjustified fears. Immense amounts of money are currently invested in the development and legal protection of communication technologies and intellectual property in this segment on the global scale, which are comparable to the size of some national economies. This study will help you not only assess the real scale of impending changes and explore strategies of 5G market leaders, but also evaluate the potential new opportunities that 5G technology offers you. I am convinced that this publication will become for you not only an informative reading, but also a professional auxiliary practical tool for mastering new technology and market niches.

Enjoy your reading!

Dear colleagues,

You are reading a report of FIPS and Rostelecom in which we wanted to share with you new ideas, trends and development priorities in the evolution of 5G and 6G technologies, as well as to identify the key competence centers and partners to engage with in this area.

Boris GLAZKOV

Vice President for Strategic Initiatives PJSC Rostelecom

The development of these technologies as a fundamental communication infrastructure to digitalize the economy is currently a priority for our nation. It is safe to say that transforming the national economy and ensuring leadership in global technology markets is impossible without the development of national technologies. In this regard, it was important for us to track and assess the efforts of global leaders related to the development of 5G and 6G technologies.

Earlier Rostelecom conducted a research on *Global Trends, Scenarios of Development and Use of 5G Technology across Industries*,[1] in which the company comprehensively evaluated the capabilities of 5G technologies and their potential impact on real sectors of the economy, taking into account the evolution of these technologies.

Analytical insights and recommendations were prepared based on the results of the report to inform the national policy on advanced technology, ensure the national technological security and set the direction for 6G development.

We currently see an explosive growth in the number of applications for 5G technical patents. The publication activity on this topic over the last five years has grown by 36 times and outperforms such breakthrough areas as quantum technologies and artificial intelligence, second only to blockchain. China's Huawei is the leader in 5G, with its number of 5G patents almost twice as high as that of its competitors. Qualcomm, Samsung, Ericsson, and BBK Electronics share the second place, followed by AT&T, which actively participates in the development of 3GPP standards as reflected by the performance of their patent asset index.

[1] https://www.company.rt.ru/press/news/d455562/

AT&T's leadership is largely due to the research and development expertise of its laboratories (testing facilities) across 18 American cities, which date back to the joint research centers of AT&T and Bell. The company is building a wide range of 5G-based solutions to develop its own products relying both on its proprietary developments and on combined capabilities of technology leaders such as Huawei, Qualcomm, Samsung, Ericsson, BBK Electronics, and others. In addition, the world's first commercial launch of a 5G network in December 2018 in the United States helped the company to build its capabilities and develop new technical solutions.

We hope that our research will be an extremely useful source of information for all those interested in advanced communication technologies, and especially for Russian companies conducting or planning to conduct research and development related to 5G and 6G technologies and equipment. We wish you success and a pleasant reading!

INTRODUCTION

This patent landscape report on 5G/ IMT-2020 Networks and the Evolution to 6G was developed by the Project Office of FIPS together with PJSC Rostelecom.

The analytical materials presented in this report are based on patent information, that is information on registered patent applications and granted patents published by patent offices of all world countries.

Patent information has a number of qualities that make it an important source of information for identifying technology trends, on the one hand, and for understanding market processes, on the other hand.

First of all, we refer to the extent to which technological disclosure is compulsory: patent documents submitted for examination must contain much more detailed technological details to prove the novelty of the proposed technology / product as compared to scientific publications and online descriptions.

An important feature of patent information lies in its value stemming from the high costs for protecting the inventions (territories, topics): the more resources a company invests in patenting a technology / product, the more valuable the invention is. A proper analysis of aspects related to the patenting costs of companies allows exploring their business strategies and the potential to commercialize the technologies.

Combined with the openness, structure and uniformity of patent documents, patent information is the most important and comprehensive asset in the analysis of modern technology.

Patent family has been chosen as the unit of analysis for this study.

The patent family is all patent publications that relate to an invention. Patent families have several useful features: they rule out duplication, remove language barriers, indicate the geography of the invention, and reveal technology trends.

In most cases, the date used for a temporal analysis is the priority date of the patent application, unless another date is explicitly stated.

Priority is the first (priority) application for an invention filed by the applicant with one of the national patent offices. From the standpoint of patent analysis, the emergence of and changes in priorities over time witnesses the status and development of research and development in the relevant area. In this context, the choice of a priority date as a fundamental dimension for the temporal analysis allows focusing the research on technological aspects related to the emergence and development of 5G research and development centers.

In this study, priorities will often be compared to patent applications. The increase in the number of patent applications within a single family shows that applicant companies are interested in bringing their technologies to new markets.

In describing the results of the analysis, the term “patent” is used for the sake of brevity in the sense of “patent document” and “patent family” unless the number of patents (granted patents) is explicitly compared to the total number of patent documents and the number of patent families. This interchangeability of terms ensures a more compact and homogeneous presentation of the findings obtained as a result of the analysis.

The term “publication” is used when analyzing the structure of patent families and in some other cases when it is necessary to analyze together patent documents of different nature (applications, granted patents, search reports, etc.).

In order to differentiate between the object of patenting (the content of an invention) and patent documents (the invention protection form), the terms “technical solution”, “invention”, and “technology” are used with respect to the object of patenting in different contexts, meaning the same thing, i.e. the object of patenting.

In this study, the patent search and analytical representations are performed using professional information analytics systems such as Patentsight, Questel Orbit Platinum Edition, etc. Each of the systems has unique search and analytical capabilities, the combination of which offers the widest functional coverage and depth of research.

EXECUTIVE SUMMARY

29,578 patent families

Segment 1

Radio Access Network (NG-RAN) and User Equipment

Segment 2

Backhaul Network

Segment 3

Virtualization and Cloud Infrastructure

Technical solutions from the *Backhaul Network* segment have the largest concentration in the portfolios of leading companies and the largest share of patents received, which implies an increased level of competition and great prospects for commercialization.

Special attention should be paid to examination of technical solutions in this segment for Russian companies to build stable positions.

Distribution of patent families by technological segment

	Overall collection						
Number of families	29,578	26,758	9,254	9,694	15,301	9,914	15,635
SEP	**2,884**	**2,724**	**991**	**1,076**	**1,395**	**862**	

The overwhelming majority of patents held by market-leading companies are “standard essential patents” (SEP). It is impossible to introduce 5G network equipment to the market without SEP patent licenses.

This creates conditions for patent holders to gain exorbitant profits (“royalty gold mining”), and leads to high costs related to the legal use of technologies for manufacturers.

6 technological segments

Segment 4

5G Core

Segment 5

Functional Components for Network Management

Segment 6

Network Services and Digital Platforms

Leaders in SEP patenting

523 SEP
SAMSUNG

444 SEP
INTEL

421 SEP
ZTE

414 SEP
HUAWEI

— Number of patent families

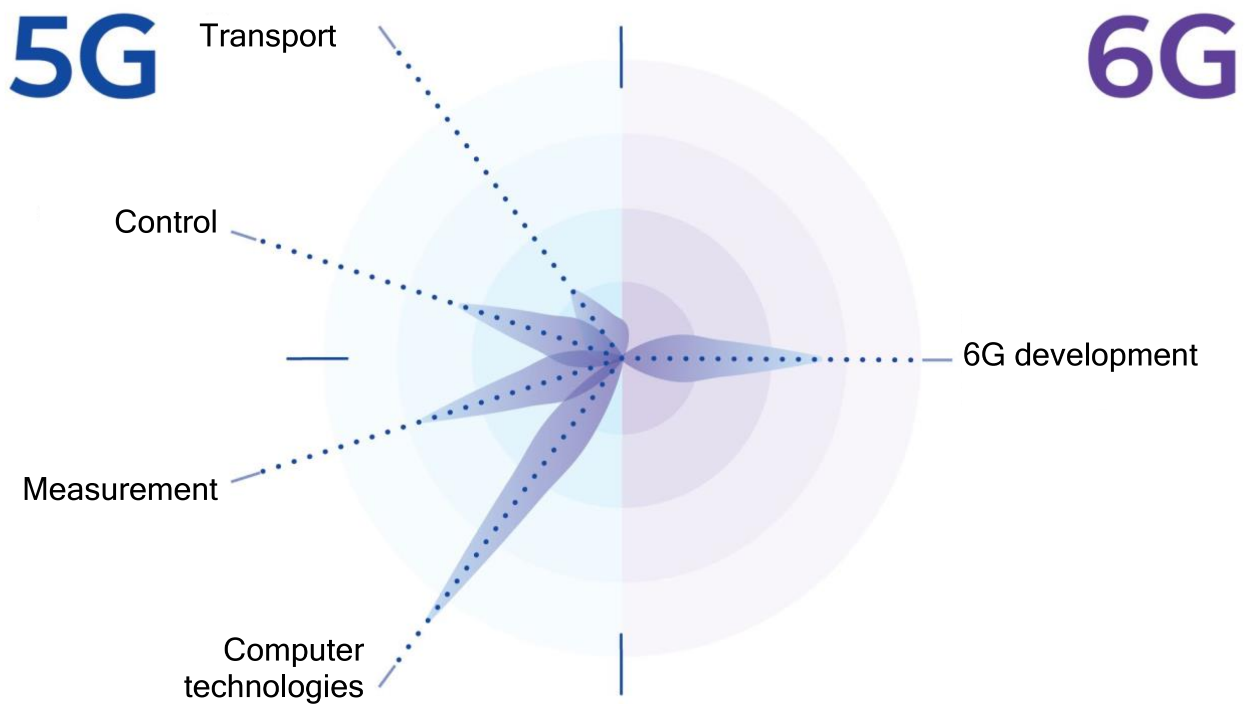
Obtaining important patents (SEP, with a wide geographical coverage, etc.) entails high costs for patenting integrated solutions.

The high level of competition from incumbents is shifting the technology focus towards SEP patenting, and many companies have already begun developing sixth generation (6G) communication technologies.

1,150 families in total mentioning 6G

29 families addressing 6G

There is some kind of profiteering with regard to 6G technologies when companies deliberately declare a 6G application for classic solutions that do not have a new technological equipment profile as compared to 5G.



The focus of the new policy for next-generation network development in Russia needs to be shifted towards strengthening Russia’s presence in the standardization process, especially in 6G (FG NET-2030 focus group, etc.).

A proactive approach to the creation and development of international standards will create favorable conditions for Russian companies to develop technical solutions closely related to industry standards.

6G trailblazers

CN109066104
Shenzhen Sunway Communication

CN110351404
AAC Technologies Holdings

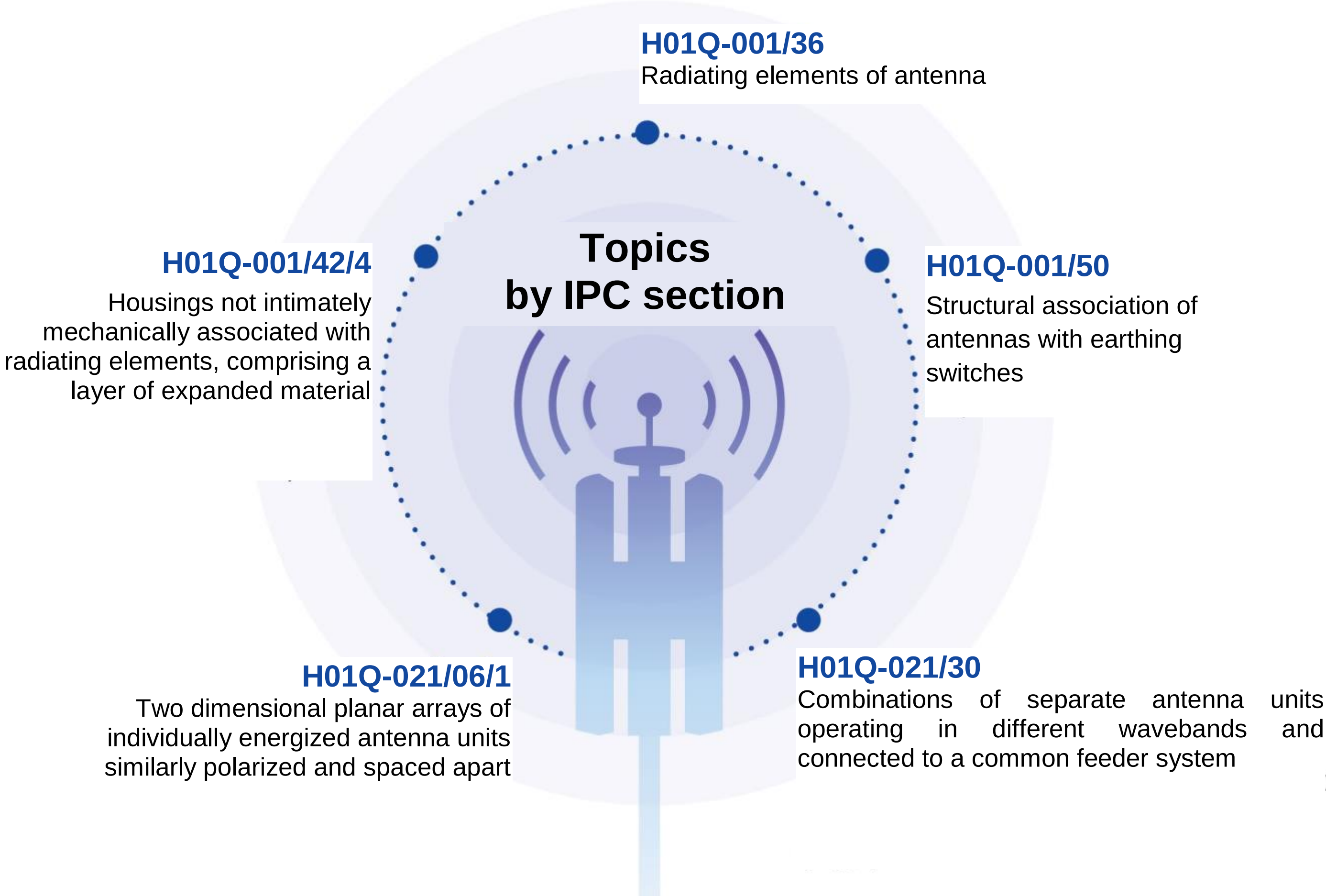
CN110430550
Beijing University of Posts & Telecommunications

CN110532631
Xidian University

US10588034
AT&T

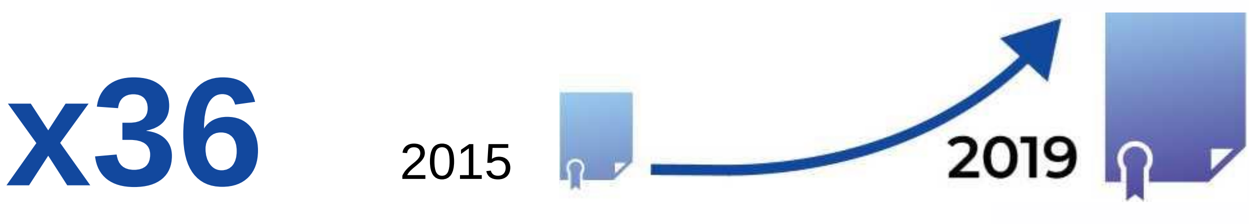
CN109728414
BBK Electronics

Relevant technical solutions mainly include developments by Chinese companies and universities, and they are primarily financed under national programs for the development of next-generation networks.



For Russia, it is advisable to analyze the goal-setting patterns used for 6G solutions, project portfolios and R&D areas under the Chinese national programs for the development of next-generation networks.

Dynamics of patent activity in 5G



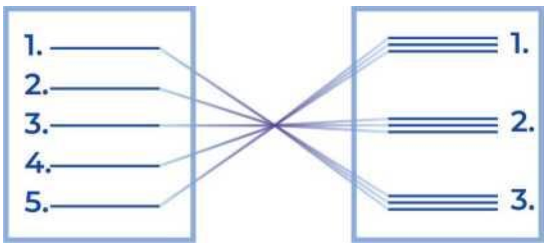
We see an explosive growth in the number of applications for 5G technical patents. However, the explosive growth in the number of applications for technical patents can lead to a risk of conflict with existing patents.

Number of families	26,758	9,254	9,694	15,301	9,914	15,635
Number of disputes with the patent office	**73**	**19**	**32**	**44**	**40**	**45**

! The fewer words (attributes) describe the object, the greater the scope of its legal protection is, and vice versa

Companies defend their technical solutions and provide the necessary arguments to prevent examination failures and ensure the patentability of their solutions.

Narrowing technology coverage

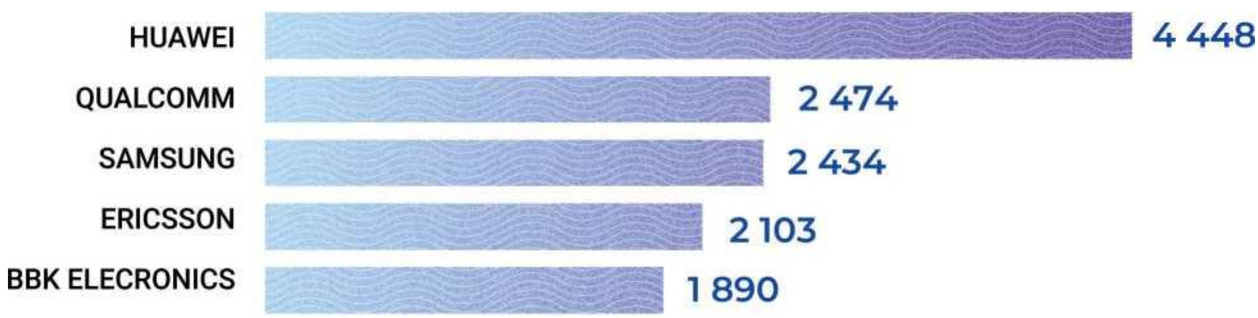


Under the pressure of patent examination, companies transform technical solutions into more specialized non-abstract solutions.

It is recommended to provide for an iterative patent examination process involving objections of patent experts.

Ranking of leading industry companies

Company / Number of patent documents



Industry incumbents apply enhanced patent strategies taking advantage of the specifics of US patent law (provisional, continuation in part applications, etc.).

Provisional application

- Only inherent to the US patent system
- Establishes a priority for which the principal (nonprovisional) application can be submitted
- The period for claiming a priority under a provisional application is 12 months
- Not published
- Does not contain claims

Continuation in part application

- Only in the US patent law
- Adds essential features to the parent application
- Expands the scope of protection provided by the parent application
- Creates a new simple family, different from the parent family.

To launch their technical solutions in foreign markets, Russian companies are advised to apply for patents in the United States to obtain the earliest priorities.

As the leader by the number of patent families, Huawei pays great attention to the evolution of technology by using proven technical solutions for its new patents.

Russian companies should look into the genesis of Huawei's technologies to understand the development sequence and continuity of its 5G and 6G technologies.

60%

of all inventions are created by 10 incumbents

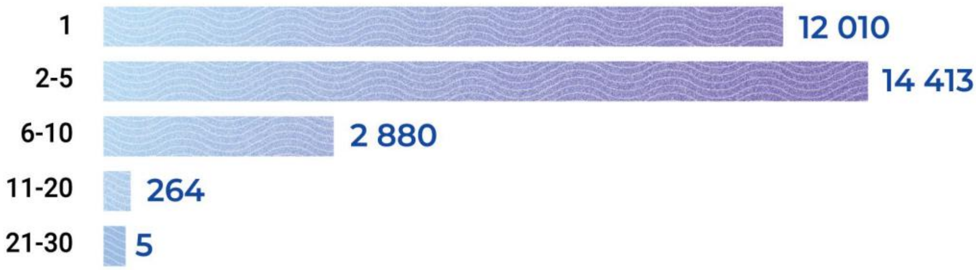
leader by the number of patents obtained jointly with the R&D sector

Large-scale cooperation is observed in this area between companies, universities, research organizations, and R&D centers, with sophisticated technical solutions designed by partners to launch technologies in the market faster and more efficiently.

Russian companies should look into areas that feature technological and business cooperation between organizations and focus on joint projects, where both Russian and foreign organizations act as partners.

Distribution of families by the number of countries covered

Number of countries covered / Number of families



A significant share of young families in the collection has a strong footprint across different countries.

	WO	CN	US	EP	KR	IN	JP	TW	BR	CA	AU
HUAWEI	3 821	3 689	1 578	1 473	383	963	316	1	452	130	112
QUALCOMM	2 291	910	2170	771	324	822	220	834	437	203	183
SAMSUNG	1 640	797	1 518	718	1629	561	61	21	2	16	50
ERICSSON	2 048	744	963	956	156	634	148	45	139	55	68
BBK ELECRONICS	1413	1 498	283	402	274	378	155	436	238	244	241

Qualcomm and **Ericsson** are implementing strategies with the widest geographical coverage, consolidating applications across 50 patent offices in their patent portfolios (in Asia, Africa, Europe, North and South Americas, and in Russia).

5G patenting is currently associated with a certain configuration of key countries, which have become the highest priority for filing applications (**US, China, South Korea, India, Japan, Canada, and Australia**).

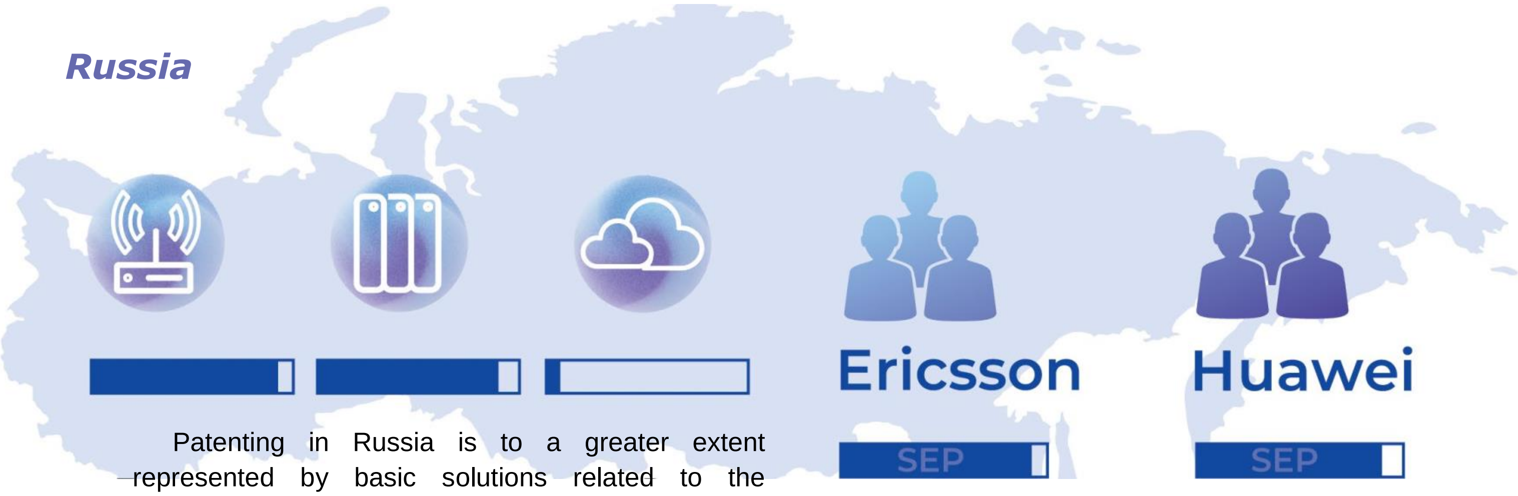
The most valuable are families with international and regional patenting procedures (**PCT and EPO**). Such patenting acts as a proxy when companies intend to bring their technical solutions to a large number of countries at once and allows significantly reducing the costs of patenting technologies.

When planning to patent new technical solutions, Russian companies are advised to provide for a wide geographical coverage and use the international patenting procedures of the PCT and EPO as a good tactic.

There is a strong flow of 5G talent between the incumbents.

Based on their experience gained at leading 5G research centers, some of them launch innovative startups to offer the market new integrated solutions.

Russia needs to establish Russian and foreign research centers with highly qualified personnel to conduct research and development unrelated to national technological security (“research sandboxes”).



Patenting in Russia is to a greater extent represented by basic solutions related to the segments of **radio access networks**, **user devices and 5G Core networks**. **Virtualization and Cloud Infrastructure** is the segment with the lowest level of competition.

The most active patent holders with SEP families in Russia are Swedish Ericsson and Chinese Huawei.

A promising area of research may include analysis of SEP patents that are not registered in Russia in the following context:

1) business: patents registered in countries with promising target markets for Russian products in terms of building strategies to circumvent key technical solutions;

2) technology: patents not registered in countries that are promising target markets for Russian products in order to look into the possibility of reproducing the most promising technical solutions for the development of 5G networks in Russia and launch of Russian products in foreign markets.

Key insights identified during the study as well as recommendations to the customer are provided on a wide range of analytical topics, including foreign patenting strategies, cooperation with foreign partners, R&D intensification, and so on. For the most important insights obtained as part of this study, we recommend conducting a more detailed analysis to better understand the situation and build a more accurate picture of global advances in 5G/6G research and development.

Developing recommendations on patenting Russian technical solutions based on patent analytics practices

In the extended patent landscape report, we paid particular attention to the patenting features and strategies of leading industry companies, including both Top 10 incumbents, and universities and smaller companies.

The accumulated analytics practices and key findings from the research can serve as a methodologically elaborated basis for developing comprehensive recommendations to Russian companies and research organizations on:

- proper definition of the scope of patenting for modern technologies and communication systems;
- an appropriate degree of technological disclosure and the most secure configuration of patent claims, ensuring the safest way to bring technical solutions to markets;
- correct strategies for bringing technical solutions to global markets, including the launch sequence, use of international patenting procedures, taking into account the profiles of certain markets, the use of the US market as a proxy for secure patent protection, etc.

Development of an industry-specific patent landscape for technology segments with high competition

The study identified technology segments with very high competition and a high share of SEP patents (patents based on international industry standards). In addition, the study revealed a pronounced watershed between patenting 5G (the highest possible saturation of the segment with the patents of incumbents, extremely high competition, fence SEP patents) and patenting 6G (emerging patenting patterns, scattered attempts to bring solutions to markets, low concentration of SEP-patents).

In these conditions, it is advisable to conduct an additional study of highly competitive technology segments using the industry patent landscape method with an in-depth technical analysis of individual groups of technologies, aerial equipment, etc.

As part of the industry patent landscape and in addition to the existing functionality, it is advisable to explore separately the following areas:

- search for patenting lacunas in highly competitive segments (technology segments, application areas, and individual markets), a separate analysis of patenting lacunas by 6G technology;
- a catalog of behavioral patterns of foreign incumbents;
- an interactive map of rights to 5G-technologies held by foreign companies operating in Russia.

GENERAL INFORMATION ON THE TECHNOLOGY

The fifth generation of cellular communication technologies is poised to transform the industries and society as we know them. 5G technologies will open a new wave of innovations, including cutting-edge trends in: the IoT (Internet of Things), AI (Artificial Intelligence) and AR (Augmented Reality), as well as many others. With the advent of 5G, mobile communications are no longer a technological advantage, but a basic need, a key resource for most industries. With the ubiquitous digitalization, the introduction of ICT in major business systems, the last generation of mobile networks affects all production processes, industries, and the economy as a whole, changing them quickly and dramatically. 5G technologies and services become the basis for digital transformation, infrastructural and technological foundation for new business models and industry development scenarios. While exploring the economic effect of 5G, Qualcomm found that the full implementation of the technology worldwide, which will be completed by 2035, will support a wide range of industries and potentially generate goods and services worth up to USD 13.2 trillion.[1] This impact of the technology significantly exceeds the contribution of all previous generations of networks. The requirements for the development of new 5G networks also extend beyond traditional mobile players, affecting numerous industries and related technology segments.

The evolving networks to serve everything from smartphones to robots at production sites require high-performance and highly reliable connections; 5G networks need to address the challenges of achieving maximum data speeds up to multiple Gbps, ultra-low latencies, higher reliability, an enormous network bandwidth, increased availability and stable interaction with a large number of users. In terms of their main purpose and basic capabilities, 5G services can be broken down into three large areas:

- enhanced Mobile Broadband (eMBB) with high data speeds (10 Gbit/s – 100 times higher than in 4G networks), focused on services for private users: access to multimedia, interactive services, and large data.

[1] What is 5G? // Qualcomm URL: https://www.qualcomm.com/invention/5g/what-is-5g

– Ultra-Reliable Low Latency Communication (URLLC), which has high and strict requirements for speed, latencies, bandwidth, and service availability time (less than 5 ms – 8 times lower than in 4G networks) and is focused on corporate and public sectors, for example, wireless control of production processes, automated load distribution in smart power networks, and integrated security systems in the transport industry.

– Massive Machine-Type Communications (mMTC) to connect a large number of devices (300,000 units at one base station – 100 times more than in 4G networks), as a rule, transmitting a relatively small amount of data and not too sensitive to latencies. The most important factors for such systems include network availability and low cost of terminal devices (most often sensors and sensors), and long battery-powered operation without recharging.

The requirements for a 5G radio access network will be determined by the totality of services supported by fifth generation networks, which are united by three main business models: eMBB, uRLLC, and mMTC or mIoT. This concept is known as the service-oriented architecture of the 5G network.

According to the specifications of 3GPP Release 15, the general arrangement of fifth generation networks is divided into two parts, as in the previous generation: 5GC (Core Network) and NG- RAN (Next Generation Radio Access Network).

In order to implement this strategy, 3GPP proposed several possible 5G (NR – New Radio) implementation scenarios (or options). All options are divided into two groups:

– Standalone (SA) - assuming the use of only one radio access technology, NR;

– Non-Standalone (NSA) - using both LTE and NR, which simplifies the initial deployment of 5G networks.

To deploy 5G in a Non-Standalone scenario, it is necessary to upgrade 4G-LTE network base stations to eLTE level (or enhanced LTE) to support the advanced functionality of interaction with 5G (gNb) base stations.

The standardization of this scenario (as part of 3GPP Release 15) was completed in January 2018.

An important aspect for the implementation of the options is the concept of Dual Connectivity specified by 3GPP in its Release 12, which implies the connection of user terminals (UE, User Equipment) to two base stations simultaneously (Master eNb and Secondary eNb). Non- Standalone implementation imposes additional requirements on the sophistication level of user equipment and the mobile network.

5G is the first and so far the only technology that allows flexible combination of platform services based on shared technology, and eliminates the need for corporate customers to build their own network infrastructure. These qualities make 5G the basis for scalable services, which significantly reduces the time of their development and implementation across a variety of industries. Experts are confident that in the next decade, thanks to a combination of many popular technological advantages, 5G will replace or supplement most wired and wireless network technologies in any industry automation.

5G systems will impact all industries, making more secure transportation, remote healthcare, precision agriculture, digital logistics and many other things a reality.

RESEARCH METHODS

01

This study uses FIPS' own patent landscape design and development methods. FIPS's approach is based on well-known patent landscape building methods, including those of WIPO, aimed at developing patent landscapes of varying degrees of detail and for different industries, as well as on the Guidelines for Preparing Patent Review (Patent Landscape) Reports,[2] approved by Order No. 8 of Rospatent dated January 23, 2017.

The methodology includes stages of building a patent landscape: developing a domain model, data systematization, analytical processing of collections of patent documents, validation of results, etc. Moreover, it pays special attention to engagement with the Customer at all stages of the life cycle of building a patent landscape.

DEFINING THE SCOPE AND BOUNDARIES OF THE PATENT LANDSCAPE

This stage is very important, since, in fact, it determines the necessary level of detail of the scope. An excessively wide coverage of the patent landscape would result in a reduced concentration of analytical representations of technology segments that are important for the study. An overly narrow patent landscape coverage would result in the exclusion of technology segments and/or key aspects relevant to the domain analysis.

Proper definition of the boundaries of the patent landscape ensures that the model includes only those technology segments that are necessary and sufficient for analyzing trends, geography, patenting subjects, as well as for a market and application analysis.

FIPS' methods related to the definition of the scope and boundaries of the patent landscape provides for organizing and conducting a series of interviews, workshops, and brainstorming sessions to discuss the content of the patent landscape.

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[2] Metodicheskiye rekomendatsii po podgotovke otchetov o patentnom obzore (patentniy landshaft) (Guidelines for Preparing Patent Review (Patent Landscape) Reports. - M.: FIPS, 2017. - 16 pp.

The preparation for brainstorms includes an analysis of documents both on strategic goal-setting and on technologies (technological news, blogs, research and development plans, etc.).

Expert discussions include expanding/updating the wording of the domain of the patent landscape and technological segments. In particular, it is of great importance to make the wording of the research topic comprehensive, ensuring the fullest possible coverage of patent documents.

DOMAIN MODEL

A separate stage of patent landscape development is related to the development of a model that includes the necessary and sufficient information to build a consistent and complete collection of patents for further analysis.

The domain model establishes the scale and scope of research and defines the key aspects that are important for building a balanced and complete information environment. In addition, the model is needed not only to search for the basic concept, but also to identify important groups of objectives, systems, technologies, and devices for which a separate analysis is performed.

The process of building a domain model consists in breaking it down into technology segments with their subsequent detailed analysis. A technology segment is a part of the domain, separated from the overall collection for standalone examination and analysis. A search is performed for each technology segment based on update queries, the patent collection is updated, and analytical concepts are built and interpreted. This approach allows covering the area as fully as possible while minimizing the number of unrelated technologies in the final collection.

According to the concept, the model of the 5G/ IMT-2020 Networks and the Evolution to 6G area includes six pillars, described in more detail below.

Radio Access Network (NG-RAN) and User Equipment

The NG-RAN radio access network consists of two types of base stations: gNB operating in the fifth generation network and NG-eNB operating in the fourth generation (E-UTRAN) or previous generation networks. All network elements are connected to each other via interfaces. An interface is a set of standardized links connecting different pieces of equipment. An interface that connects base stations is known as Xn and is responsible for keeping the subscriber in the network when moving from one base station to another. Both types of base stations are to be connected with the Xn interface, while the NG interface is responsible for connecting base stations with functional blocks. As well as in LTE networks, the NG interfaces vary for devices that interact with each other. In total, the 3GPP TR 23.799 specification released in December 2016 defines 15 types of NG interfaces.

The NG-RAN radio access network includes a set of base stations connected to 5G Core base network through the following NG interfaces: NG1 represents a “reference point” between the user device and AMF, NG2 connects the base station to AMF; the base station also connects with the User Plane Function (UPF) via an NG3 interface, which in its turn connects with the Session Management Function (SMF) via an NG4 interface, and the access to the internet and operator’s services is provided via an NG6 interface. The Application Function (AF) connects with the Session Management Function via an NG5 interface.

Backhaul network

The new 5G backhaul network architecture will significantly simplify and speed up network operations, reduce network costs, and provide system-wide orchestration and optimization to improve quality of service (QoS) and energy saving, as well as development of network application.[3]

Previous generation networks, 4G, use C-RAN (Centralized Radio Access Network), in which the functionality of the base station is statically divided between the radio centers and the processing units of the main frequency band, connected together through a direct backhaul network.

[3] X-haul fronthaul and backhaul network research // Ericsson | A world of communication URL: https://www.ericsson.com/en/blog/2015/7/x-haul-fronthaul-and-backhaul-network-research

This leads to increased heterogeneity, complexity and limited flexibility of the backhaul network and weak optimization for different key performance indicators (e.g. bandwidth, latency, energy efficiency) in different network and service contexts.

For 5G networks, Xhaul, defined as the overall flexible backhaul solution for future networks, is introduced to integrate backhaul and fronthaul networks with all their wired and wireless technologies into a shared transport network based on SDN (software defined networks) and NFV (network function virtualization) supporting overall control. This solution provides flexible and software-defined reconfiguration of all network elements in a multi-user and service-oriented unified management structure.

Xhaul is considered as a combination of different heterogeneous (both wired and wireless, legacy (outdated) and new) physical and channel technologies to implement a unified fronthaul and backhaul network traffic infrastructure.

The technical approach is based on two blocks:

1) management infrastructure, using a unified abstract network model to integrate the management plane (Xhaul Control Infrastructure, XCI) and the unified data plane, which includes innovative transmission technologies with high throughput and new switching architectures with determined latency (based on Xhaul Packet Forwarding Element, XFE), combining different heterogeneous transport technologies and using a single universal frame format.

2) The Xhaul infrastructure provides for management of new orchestration mechanisms with NFV support for intelligent context-sensitive network and IT resource allocation, providing greater flexibility in the dynamic allocation and centralization of network functions as well as new methods for end-to-end monitoring, forecasting, and follow-up of compliance with QoS parameters.

Virtualization and cloud infrastructure

One of the areas for development of the coming 5G wireless networks includes Network Function Virtualization (NFV).[4] The main idea of NFV is to separate network functions from hardware. The functions of the telecom operator are constantly expanding, and the network is expanding with them as the launch of any service involves the integration of additional equipment and space in the equipment rooms. This increases resource consumption. In addition, the equipment quickly becomes obsolete. Therefore, while in the traditional network model each network function requires an additional unit of equipment, a "hardware" component, in the NFV model one physical foundation is sufficient, with network functions expanded in the cloud.

This approach offers several advantages. First, as already mentioned, network function virtualization allows introducing new services without expanding the network infrastructure, which essentially reduces the cost of equipment and drives the economy of scale effect. It is estimated that NFV can reduce operators' capital expenditure (CAPEX) by up to 40%, and operating expenses (OPEX) by up to 50%.

Second, NFV simulates competition between providers of network functions. This is due to the fact that the technology is hosted in the telco-cloud infrastructure. Accordingly, providers of network functions hosted in the cloud come into play.

Third, NFV reduces the time to market for new services by three to four times.

Fourth, telecom operators become able to boost their average revenue per user (ARPU) and increase their subscriber bases by creating unique and differentiated services. Personalization of services will increase their value and become a new source of income for operators amid high competitive pressure in the market for traditional telecom services.

[4] Virtualizatsiya setevykh funktsiy NFV dlya setey operatorov svyazi // Portal o sovremennykh tekhnologiyakh mobilnoy i besprovodnoy svyazi G (Network Function Virtualization (NFV) for mobile networks. G: portal on advanced mobile and wireless communication technologies) URL: http://1234g.ru/novosti/nfv-v-setyakh-operatorov-svyazi

Thus, network function virtualization improves network performance while optimizing operator costs by reducing the expenses for equipment acquisition and maintenance and ensuring lower network power consumption. In addition, NFV makes it easier to design and launch new services, resulting in increased revenue from their use.

Virtualization will fundamentally change the business model of telecom operators. NFV is bound to move the telecom industry from the extensive method of scaling wireless networks to an intensive method by making them flexible and dynamic. NFV is the first step towards digital transformation of mobile operators and building a software-defined company.

5G Core network

A 5GC (Core Network) consists of two main devices that separate service and user functions. These devices are actually called “functions”:

AMF (Access and Mobility Management Function) is a function responsible for providing access and management of the network signal when transferring a subscriber;

UPF (User Plane Function) is a function responsible for transmitting user traffic.

In addition, the network architecture includes other “functions”: SMF (Session Management function) distributes IP addresses for user devices, manages and monitors traffic passing through the user plane function, selects UPF to move traffic to its destination; AUSF (Authentication Server Function), the authentication server function of the user device; UDM (Unified Data Function) is a repository of registration data, and information on security and various user subscriptions; PCF (Policy Control Function) manages the overall network behavior policy and the behavior policy of each network plane (user and service); AF (Application Function) executes queries to the session management function, and also has access to manage the device battery charge level.

Functional components for network management

Flexibility is a major requirement that 5G networks must comply with. Technologies that support a highly flexible network architecture, such as software-defined networks (SDN) and network function virtualization (NFV) are already in use. With these technologies, the network is divided into logical segments (network slicing), each configured according to the parameters required for the operation of certain services.[15] To ensure the flexibility of a 5G network, different hardware elements need to be implemented to support the deployment of various functions across different physical segments of the network. The ability to separate functions at the control plane and user data plane plays a key role in the architecture of a 5G core network. This separation allows scaling the resources at the control plane and at the user data plane independently of each other. This separation also allows placing the resources at the user data and control lanes in different parts of the network. For example, the control plane can be placed on a central site, thereby simplifying the control and operation processes.

The classic functionality of the control plane includes location data management, policy coordination, and session authentication. Therefore, the separation at this plane is natural. However, increased flexibility can lead to all levels of the system becoming more complicated and, as a result, to more expensive and longer operations. Automation solves this problem.

Network management needs to take into account three main phases of the service life cycle: creation, activation, and runtime:

– Creation of new (or customization of existing) services with minimum ttm (time to market) — the ability to break down the overall solution into components is necessary, so that services and slice types can be designed, verified, and validated rapidly.[5 *]

[5] Oporniye seti 5G: gibkost otkryvayet noviye vozmozhnosti dlya biznesa (5G Core Networks: flexibility unlocks new opportunities for business) // Habr URL: https://habr.com/ru/company/ericsson_ru/blog/281509/

– Activation of a service with minimum TTC (time to customer) — the ability to complete activation in a fully automated way will minimize lead times.

– Runtime — exposing the right capabilities to the user, service and SLA monitoring, and adapting to changing conditions (such as scaling and failovers) enable scalability for new services, all of which need to be fully automated.

The advantages of network segmentation, where each segment has its own capabilities are driven by two levels of management functionality. One level is responsible for services and products, including B2B. The other level is responsible for network segmentation itself.

Service life management includes the development and creation of different types of network segments and services, as well as their activation, taking into account the specific needs of users, monitoring, and upgrade (where necessary).

To launch a new service, a new network segment is created or, in some cases, the configuration of the existing one is changed. The segment can be managed independently or can cover other resources, including both traditional and new types of architecture (for example, separation of control and user data planes). Network segments can have control functions, some of which can be controlled by the operator and others by the user. The control layer uses several systems and interfaces to create and configure resources. This flexibility plays a key role in the automation and orchestration of the system and is achieved, for example, through the use of plug-ins.

Network services and digital platforms

The 5G standard introduces new types of services that were not previously available in previous generation networks or had more modest characteristics. The new or upgraded types have been divided into three groups. The services of the eMBB (Enhanced Mobile BroadBand) group are responsible for high-speed services, and they should provide data speeds that are 10–20 times higher than the existing networks. The second class of services, uRLLC (UltraReliable Low Latency Communication), are services with ultra-low latencies and packet loss. This group of services will reduce latencies to 1 ms delay (in 4G the delay between the base station and the mobile core of the network was 10 ms).

That is, the latency for this group of services also will improve by 10 times. The third group of new services known as mMTC (Massive Machine Type Communications) involves the connection of a large number of sensors or devices per square kilometer – up to a million devices per square kilometer.

SEARCH STRATEGY DEVELOPMENT

The purpose of the search stage is to obtain a collection of information for analysis, that is, find all patent documents that may affect the objectivity of the search in the research area in accordance with the search regulations providing for identifying the following data:

- information channels (patent funds, databases, etc.), search engines;
- the depth of search, which is determined by the patent lifespan in a given country, taking into account the possibility of their renewal;
- types of search that can be used;
- countries of search, including Russia;
- classification indexes for each item to be searched according to the International Patent Classification (IPC), and national classification systems across countries of search;
- types of patent documentation.

A special role in the search with a subsequent analysis is played by changes to the title, changes in organizational and legal forms, mergers / acquisitions of companies, technical errors of patent publications, which may occur at the stage of the preparation of application materials by the applicant, at the stage of preparation of the publication by the patent office, or at the stage of reloading bibliographic data into secondary sources of patent documentation. It should be noted separately that transliteration errors are especially significant when analyzing Russian names in English information systems.

The potential transfer of rights (disposal) from one patent owner to another can also be important. Such a transfer will not be reflected in the original publication, as it occurs at subsequent stages of legal protection. The information environment formed as a result of the search and updates will include structured and unstructured data, which are further analyzed using various filters, sorting tools, systematization, restrictions, etc.

At the search stage, it is import to generate and update search queries, filter intermediate search results, check the collection quality by comparing the results of search across different sources, make sure that only knowingly relevant documents are included in the resulting sample, etc., which drives the overall search strategy.

The quality of patent analytics largely depends on a properly chosen search strategy. In this landscape, a strategy combining research of industry companies, search for semantically related patent documents and a multi-dimensional set of search terms is used to build a sample of patent documents and form a comprehensive patent collection for analysis. The multi-dimensional set of search terms is developed in several iterations using the research model.

The research on 5G/6G patenting involves a number of challenges, mainly of technological nature.

The first challenge is related to the need to differentiate between technologies, systems, and methods directly related to the next-generation networks, and technical solutions in which 5G is mentioned as one of the possible applications (for example, wireless headphones that can work both in 5G networks and in all other networks). In the most contrasting cases, such differentiation is possible, for example, when the patent description says “...for 3G, 3.5G, 4G, 4.5G and 5G networks”, but in most cases it is difficult to make such differentiation. To solve this problem, an approach based on restricting search queries to certain technology segments of WIPO and the IPC and CPC (Cooperative Patent Classification) sections was used to clarify the technological scope of solutions. As a result, we were able to identify, within the overall body of documents, documents that, in one way or other, describe the network architecture, structural elements, various functions, and other important aspects of 5G/6G.

The second challenge is related to the fact that new technologies developed within the 5G stack are in many cases equally applicable to 4G networks and vice versa. In this context, patent documents may provide descriptions of new technologies (e.g., standalone new radio or NFV orchestrator) without referring them to 5G. In order to incorporate such documents into the collection, a list of special terms has been developed, which would be an integral part of the development of 5G technologies, such as the “NG-RAN” terminology field.

Another stage of building the collection included a patent search across the industry’s incumbents identified as a result of the preliminary search. This list includes more than 50 companies that are directly involved in the work on technological aspects of 5G network development. This search enabled us to update the IPC and CPC codes, and identify new areas of application where 5G technology is explored.

Taking into account the above features and for the purpose of a large-scale analysis of 5G/6G, the patent documents for the analysis were selected so as to achieve the most accurate positioning of technologies that are typical only for 5G/6G.

TRENDS

02

GENERAL INFORMATION ON THE COLLECTION

A refined search of patent documents from the priority date of January 1, 2010 related to 5G has revealed 100,104 patent documents (publications), which are grouped into 29,578 patent families. The search results are relevant as at February 1, 2020.

When considering the specifics of patenting and identifying more detailed trends, it is important to examine the correlation between several factors and their mutual development over time: patent families, publications, applications, and granted patents (Table 1).

Table 1 **General information on collections**

Collection title	Number of SEP families	Number of publications	Number of applications	Number of invention patents	Number of utility model patents
Overall collection	29 578 **2 884**	100 104	89 553	10 028	166
Segment 1 Radio Access Network (NG-RAN) and User Equipment	26 758 **2 724**	93 116	83 792	8 921	63
Segment 2 Backhaul Network	9 254 **991**	35 467	31 669	3 677	18
Segment 3 Virtualization and Cloud Infrastructure	9 694 **1 076**	31 083	28 471	2 490	10
Segment 4 5G Core	15 301 **1 395**	53 895	48 842	4 803	17

Table 7 (continued)

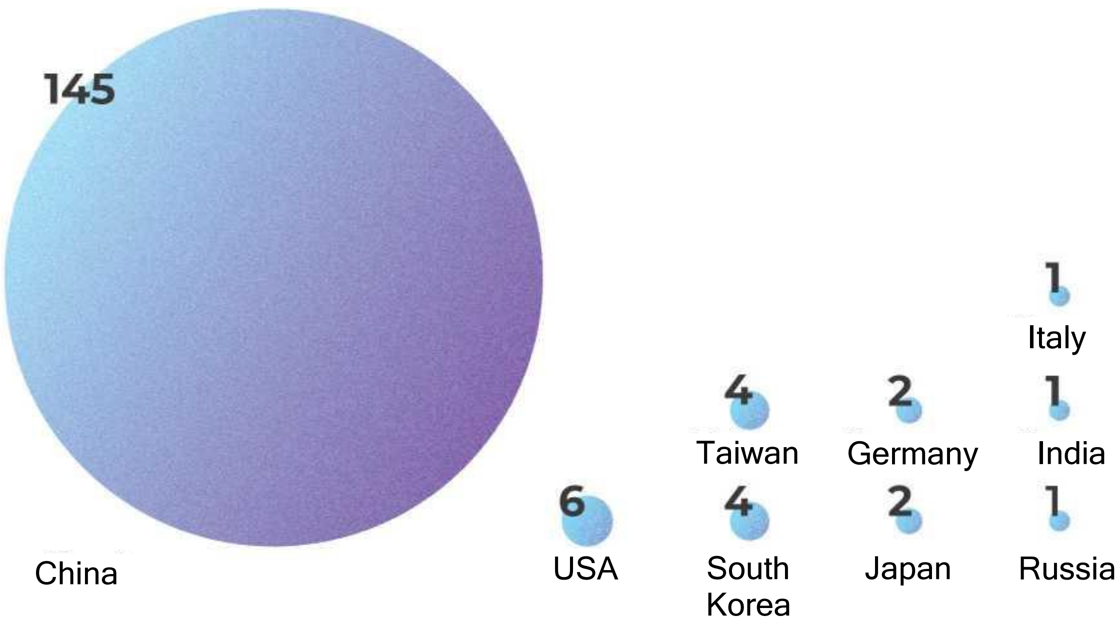
Collection title	Number of SEP families ↳ SEP	Number of publications	Number of applications	Number of invention patents	Number of utility model patents
Segment 5 Functional Components for Network Management	9 914 ↳ **862**	31 397	28 413	2 856	10
Segment 6 Network Services and Digital Platforms	15635	54 097	49 365	4 558	24

It should be noted that one family can cover a set of technologies related to different segments. As a result, the sum of quantitative parameters of collections by segment is not equal to the parameters of the overall collection.

All segments are represented by a large number of applications, which indicates the active phase of patenting in this area. However, it is necessary to take into account the fact that not all applications filed by applicants since 2017 have been published. The share of invention patents in the total number of publications is only 10%. Together with the huge number of applications, this situation is typical for emerging segments with a high patenting rate. The patenting process may take three or more years. Therefore, applications for most families of the overall collection are pending examination, while related technical solutions have no long research retrospective.

The collection also has 166 utility model patents. Useful models are usually subject to less stringent patentability requirements, shorter deadlines, and simplified application processing procedures. More than 80% of utility models are owned by Chinese companies and universities (Figure 1), including Shenzhen Sunway Communication (the company focuses on R&D and production of mobile terminal aerials and related modules, as well as connectors with high electromagnetic compatibility), BBK Electronics, Chongqing Real Estate College, State Grid Corporation of China (SGCC), ZTE, and others.

Figure 1 **Distribution of families with utility model patents by country**



Quite often, the contribution of Chinese applicants can be determined by the number of utility model patents in collections. Unlike foreign patents, national Chinese patents in most cases have a utility model patent form as they are much easier to obtain and the registration fee is quite affordable. Utility model patents are treated equally with invention patents and fall under national programs under which Chinese companies are granted tax benefits and government subsidies. Therefore, China uses more utility model patents than other countries, despite the fact that such technical solutions rarely meet high technical requirements and have low economic efficiency.

In this area, utility model patents are more common for smaller companies or research institutions that do not link their technical solutions to complex foreign patenting strategies. This shows that patenting 5G technology for large Chinese companies (e.g. Huawei) is associated with a complex process of fine-tuning their solutions and a high practical value, which allows them to compete in international markets.

PATENTING DYNAMICS

An analysis of patenting trends in the domain shows technology development over time helping to compare different periods of time to assess the increase (decrease) in the intensity of patenting of technical solutions and to explore the different relationships between metrics taking into account the retrospective.

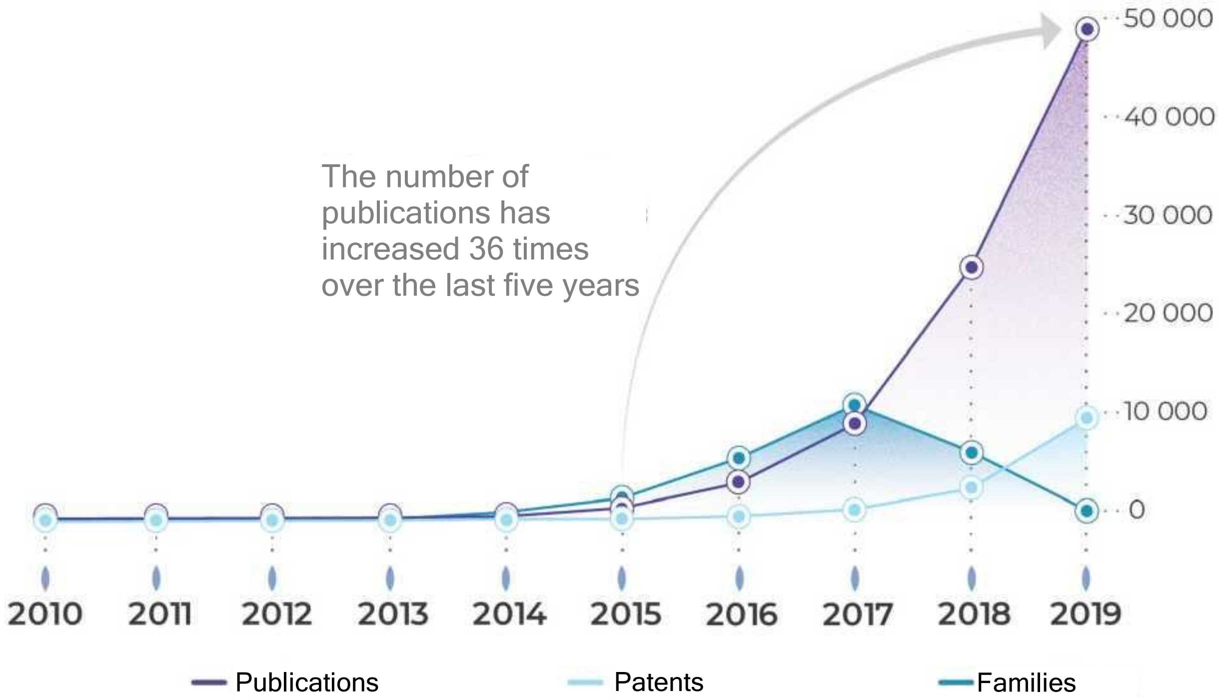
Various attributes of patent documents related to the dates of key events within their life cycle have been used as an information basis and a basis for building a set of metrics in our study of patenting trends. The key types of analysis are related to the application filing dates, the earliest priority, and the patent granting. Correlating these dates during the trend analysis allows identifying the development periods for technical solutions, as well as identifying the duration of improvement cycles for patent documents before a patent is granted.

An important area in the analysis of patenting trends also includes the comparison of three interrelated objects of research that describe the patenting pattern in the domain: patents, publications, and patent families. Such a comprehensive comparison provides an opportunity to apply a wide range of analytical concepts so as to assess the level of technological maturity and periods when products with a higher degree of integration emerge, and identify large-scale “takeovers” of high-potential patenting areas by companies as well as other factors.

Comparing the number of publications and patent families enables assessing the overall growth rate in patenting in terms of the increase in the amount of R&D (through an increase in the number of families) and stronger interest in entering other markets (increase in the number of publications). At the same time, the analysis of the number of patents vs. the number of families describes the maturity of the area and the level of technical solutions, while the comparison of the number of patents and publications can reveal the strategies that applicants most often use in this area to protect technical solutions.

The evolution of these metrics for the overall collection from 2010 to 2019 is shown in the chart (Figure 2).

Figure 2 **5G patenting dynamics**



An analysis of the data allows us to conclude that the area is experiencing an explosive growth in patenting from 2015 onwards. Moreover, the publishing activity has particularly intensified since 2017. This pace of development in the area suggests the emergence of breakthrough technologies, which marked the beginning of active development in 5G.

Rapid growth in the number of publications since 2018 amid a growing number of patents may indicate that incumbents are expanding their strategies of geographical coverage by solutions when companies start patenting their solutions in an increasing number of countries. This trend emerges in situations where companies are starting to expand their families by filing applications with national offices in other countries, as well as through international patenting procedures (e.g., the PCT) to expand their geographical coverage. Expanding the geographical coverage of patenting is usually a basic indicator of companies' intention to use their solutions in foreign markets to obtain economic benefits.

Apart from geographical expansion, this trend may be related to an expansion in the thematic coverage by the patenting area where companies apply for legal protection in the same jurisdiction.

In order to expand their thematic coverage, companies adjust standalone claims, which change the scope of legal protection as compared to previously filed applications. An increase in the scope of legal protection is typical for those families where applicants see competition risks. Accordingly, companies take preventive measures to limit the headroom for competitors with respect to their solutions. This situation demonstrates that there are technologies that are important from the standpoint of the applicant and have good outlooks for commercialization.

The intensity of patenting for technical solutions lags far behind the pace of family expanding both in terms of technology and geography (publications vs. patents). It has also been noted that the publication schedule was lagging behind the family expansion schedule between 2015 and 2017. This is primarily due to the fact that applications for which priorities are claimed are published 18 months after the filing date, while obtaining a patent for a technical solution takes on average two years or more. This pattern is presented as a correlation between the dynamics of the family schedule and the patent schedule with a difference of exactly two years between them, and the difference of one year with the schedule of publications. Therefore, there is an essential part of already existing technological advances that are hidden before the publication of applications by patent offices, as well as technical solutions for which patents have not yet been obtained.

There is an overall decrease in the family schedule in 2018, down by almost two times as compared to 2017. As a result, the dates of priorities were analyzed separately from the filing of the first application. The analysis revealed that the number of families in 2017–2018 was roughly the same, with more priorities claimed for 2017.

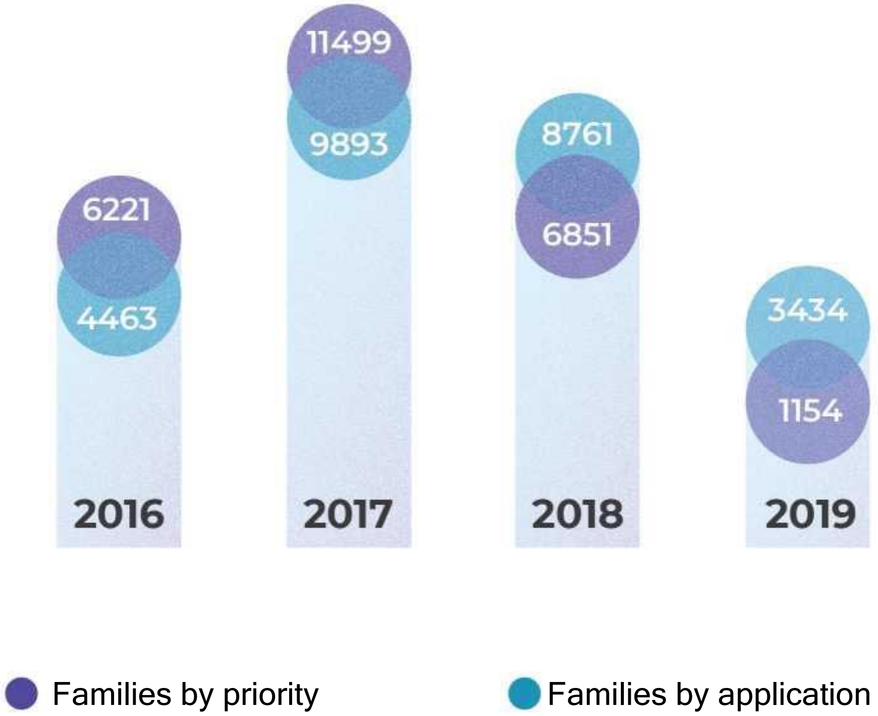
This situation may be related to the fact that in 2017 applications for key technologies were submitted, for which later families claimed priorities. For instance, almost 50% of the families with applications filed in 2018 claimed the priority for 2017. Each such family has a comment in the application description about what it is:

a) A continuation application for a parent application in which the invention has already been disclosed, but the applicant has not exhausted all possible implementations and applications of the invention;

b) A non-provisional application where a provisional application has been previously filed without claims being made (typical for the US patent system).

Figure 3

Ratio of the number of families emerged by the first priority date to the number of families emerged by date of filing of the first application

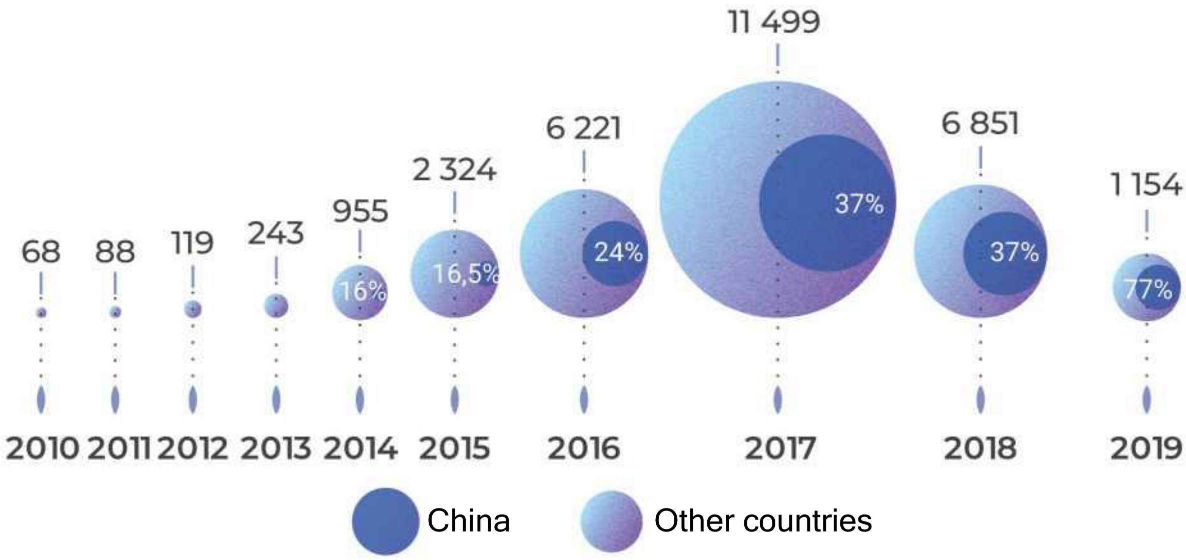


In both cases, an earlier priority than the application filing date for the family is claimed. Such mechanisms are mainly used by American companies Qualcomm and Intel, as well as by Swedish Ericsson, South Korean LG and Samsung. The main purpose of using such patent legislation mechanisms is to gain a competitive edge in the technology market, which is natural, given the explosive growth in the domain and the increasing patenting efforts by Chinese Huawei.

Chinese patent holders have contributed about 30% in the development of this technology segment, with Huawei leading the Chinese patenting market. Therefore, more than half of the 5G technology market is owned by large transnational corporations, while China has much less influence on the dynamics of patenting than in other areas.

Ratio between the share of Chinese patent families and the share of patent holders from other countries by the first priority date

Figure 4



MATURITY OF PATENT FAMILIES

The study of patenting strategies has an important place in the analysis of technology patenting as it helps identifying approaches to the choice of forms, methods and completeness of technology and product protection by companies in different countries. Important information on patenting strategies can be obtained by exploring the maturity of patent families.

Patent families are used in this case as a unit of analysis. There are several different approaches to analyzing patent families that allow for a more accurate search and consolidation of all patent publications related to a particular invention. This report uses the principle of grouping patent families based on Questel's Orbit Intelligence database. As defined in the Orbit Intelligence database, patent families include patent publications related to a single invention. These may be patent documents seeking protection in several countries or documents with a different scope of protection: divisional applications, or provisional applications related to the same invention.

The structure of a patent family depends on the patenting strategy chosen by the company and also includes search reports, translation publications, revised publications, and other patent documents related to the same invention.

The patent family concept is designed to simplify the understanding of the relationship between one invention and a number of related patent documents. It is aimed at solving search, technical, linguistic, and some business problems.

An important indicator of the maturity of patented solutions is provided by a study of the structure of patent families in the collection. Analyzing the size of patent families provides an understanding of the intentions of industry incumbents to develop operations (bring products to market) within their respective countries or focus on foreign markets. Patent families with three or more documents tend to be characteristic of mature and sophisticated technical solutions.

As there has been an intensification of patenting in China in recent years, the families of Chinese applicants have been separated from the overall collection and also ranked by the number of publications. Such differentiation is necessary to assess the business intentions of Chinese patent holders. At the same time, it should be taken into account that the general intensification of patenting in China has its own peculiarities, which mostly serve as indicators of government programs, social and tax benefits, or various forms of incentives.

Depending on the number of documents, families were divided into four groups.

The first largest group comprises families with one or two publications.

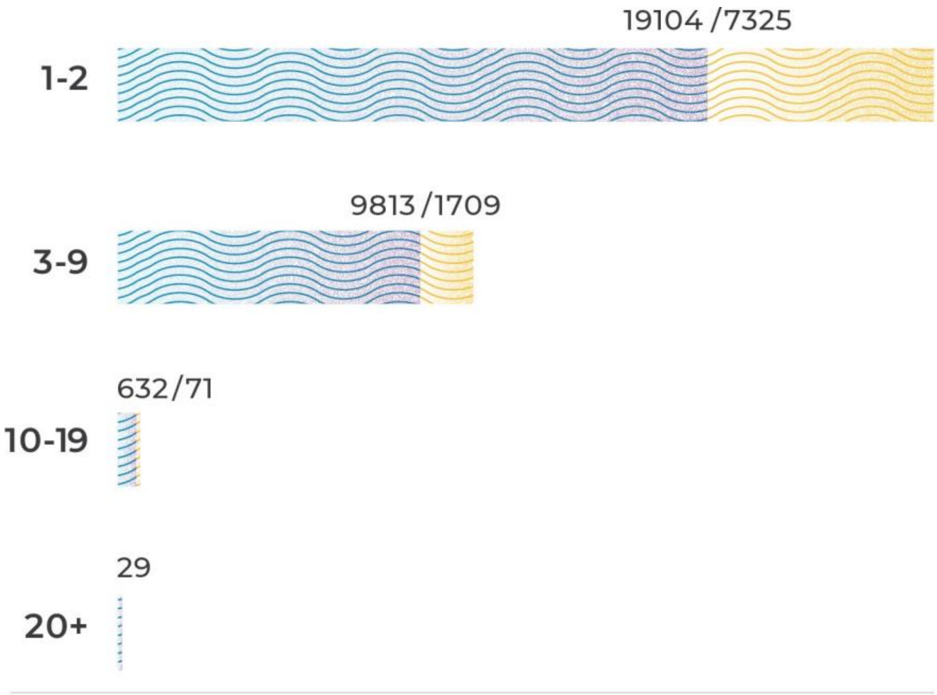
There are 19,000 such families in the collection, which accounts for 65% of the total number of families. This indicates that more than half of the families in the collection are localized in national markets. They are probably young and have the potential for further geographical expansion.

We have noted that China’s share in this group is greater than in others; accordingly, more than 50% of the families of Chinese patent holders represented in this group are focused on the Chinese domestic market. .

At the same time, the share of Chinese families in other groups of publications is almost 20%, indicating that Chinese companies also intend to enter the international market.

Distribution of overall collection families by the number of publications

Figure 5



Number of publications in the family / Number of patent families / China

The second most numerous group is the families with 3–9 publications, which make up 33% of the total number of families.

This group usually includes families where patent holders extend the technological scope of patents by submitting applications for different aspects of the same technology. Complex protection solutions for companies owning such families are more likely to implement protective patenting strategies. However, as a rapidly growing new area, this group may also include companies that, unlike their competitors, are more actively entering foreign markets that are of most interest to them. Among them are such companies as Qualcomm, Samsung, Ericsson, Nippon Telegraph and Telephone, and others.

The share of China is much lower here, but at the same time accounts for 18% of the total number of families in this group

Most of these families are owned by Chinese Huawei, which actively files applications under the PCT international patenting procedure, as well as in the US target market.

The third group consists of families with 10–19 documents.

There are about 2% of such families in the collection. As a rule, such families belong to companies that have launched their products and gained a foothold in the global market. Technical solutions of these companies are positioned to enter the markets of more than three countries. It can be noted that Chinese Huawei and BBK Electronics are present in this segment along with American Qualcomm and Swedish Ericsson. Therefore, developments of large Chinese patent holders are oriented towards the international market, while their technical solutions are commercially meaningful and applicable on a global scale and, in particular, in the Russian market.

The latter group accounts for less than 1% of the total number of families.

In this group, the geographical coverage is much wider than in other groups, as its families feature 20 publications and more. Companies apply for a large number of markets to strengthen their competitive positions, while at the same time building a pool of applications in target markets to cover the technological segment to the required extent and prevent other players from entering them. Such strategies are mainly used by large companies in respect of the most valuable and promising technologies from the standpoint of the applicant.

In general, such distribution of families by the number of documents implies that the markets are under development. At the same time, a large share of applicants prefer immediately submitting applications under regional and international patenting procedures to maintain their geographical priority with respect to the relevant technical solution. Combined with the dynamics of patenting, this trend opens up opportunities for rapid commercialization of technical solutions.

The data on the number of publications in patent families, patenting jurisdictions, the legal status of collection documents, and granted patents is used as an information basis to analyze the maturity of patent families. The FIPS' proprietary methodology provides for the analysis of patent families against a set of specific maturity metrics describing the completeness of legal protection cycles for equipment.

The following indicators have been selected for comparing these patent families:

1) total number of publications in the family;
2) number of patents granted in the family;
3) the number of jurisdictions in which at least one application of the family has been filed;
4) the number of countries in which the filing of applications has resulted in granted patents.

The correlation of the above criteria helps to identify the strongest families simultaneously in terms of both geographical coverage and completeness of the legal protection cycle, i.e., maturity of technology for entering international markets. The values of the indicators for the largest patent families are shown in the table (Table 2).

Families ranked by indicators

Table 2

Basic publication	Applicant	Number of publications in the family	Number of patents in the family	Number of jurisdictions in the family	Number of jurisdictions with patents
By the number of publications		↓			
US20150334729	QUALCOMM	124	34	28	12
US20180054783	QUALCOMM	60	5	11	2
US20170353256	QUALCOMM	58	2	11	1
US20170346535	QUALCOMM	44	4	9	1
US20170331670	ERICSSON	39	5	16	4
By the number of jurisdictions				↓	
US20170331577	ERICSSON	35	6	29	6

Table 2 (continued)

Basic publication	Applicant	Number of publications in the family	Number of patents in the family	Number of jurisdictions in the family	Number of jurisdictions with patents
US20150334729	QUALCOMM	124	34	28	12
US20160127991	QUALCOMM	39	9	22	7
WO2015/147717	ERICSSON	36	8	22	7
WO2016/141961	ERICSSON	34	8	21	7
WO2018/084755	ERICSSON	26	5	19	5

The analysis of the above indicators provides an understanding of strategies that companies follow when entering foreign markets.

All leading companies in terms of the total number of publications in the family have a wide geographical coverage, but countries that are most important for applicants in patenting markets include primarily those countries where at least one patent has been granted and there are significantly fewer such countries.

Almost all families of the ranking belong to US Qualcomm, which is actively engaged in 5G research and development and participates in the development of standards together with the 3GPP consortium.[6] The company specializes in the manufacturing of processors and chipsets.

The family with the basic publication **US20150334729** *Apparatus and method for interference mitigation utilizing thin control* has the largest number of jurisdictions where domestic patents are protected. The invention belongs to wireless communication systems. The technical result from the basic application for the invention consists in the use of a control channel structure to carry control information that relates to interference experienced by a user in order to mitigate the interference. Aspects of the disclosure provide enable the multiplexing of many different channels and signal forms, each of which can be optimized for different performance, latency time, and/or reliability requirements, including for 5G networks.

[6] 5G Timeline // Qualcomm URL: https://www.qualcomm.com/invention/5g/5g-timeline

This family is also a leader by the total number of publications and patents. The main principle of this family's structure is to apply for a priority by filing provisional unpublished applications (Figure 6). Priority for this technical solution is claimed for May 19, 2014, which does not coincide with the date of filing the initial application for the family, i.e., November 5, 2014. This family claims priority via provisional application US201462000443P, which is not published, as well as for via application US201462000454P. The largest number of publications in the family (highlighted in blue) refers to a method for interference mitigation utilizing thin control. The other part of the publications (highlighted in green) describes methods for inter-band pairing of carriers for time division duplex transmit- and receive-switching and its application to multiplexing of different transmission time intervals.

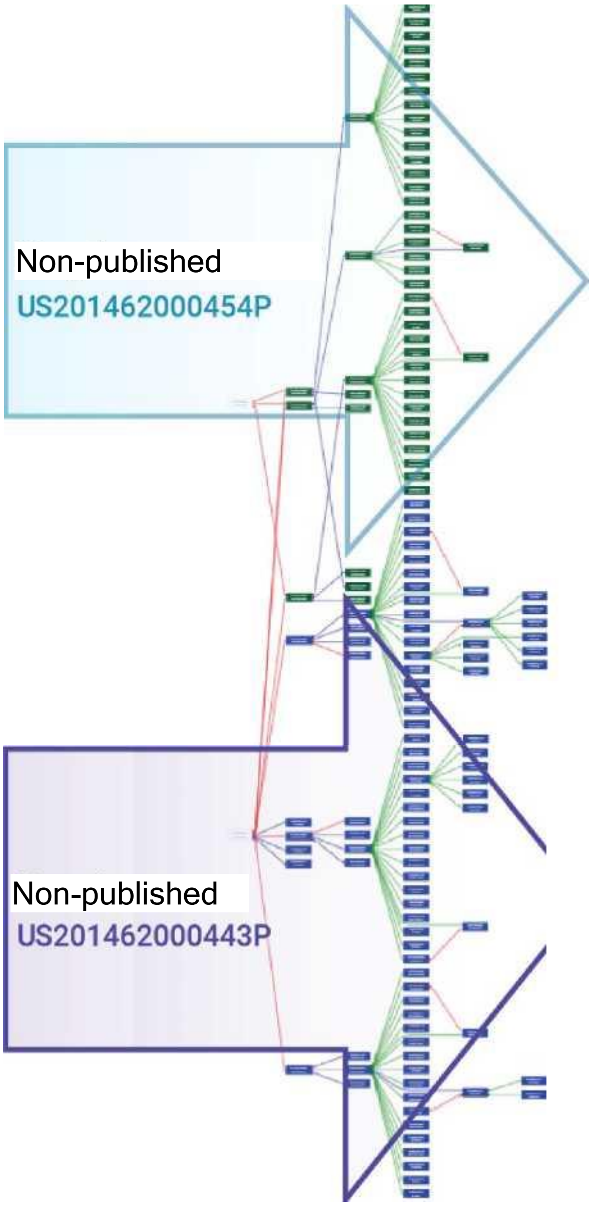
The family is active. The applications are submitted:

- in European countries via the regional patenting procedure through the EPO (Austria, Belgium, Switzerland, Czech Republic, Germany, Denmark, Spain, Finland, France, Great Britain, Greece, Hungary, Italy, Netherlands, Norway, Poland, Romania, Sweden, Portugal, Slovenia, and Turkey);
- via the PCT international patenting procedure (Australia, Canada, Brazil, Israel, Russia, Singapore, South Korea, China, Mexico, Thailand, New Zealand, India, Philippines, Vietnam, South Africa, and Japan);
- by direct filing with national patent offices (USA, Taiwan, Argentina, and Chile).

Patents were received for almost all of them. Patents received in Russia: RU2667044, RU2694149, RU2676873. Some applications in Argentina, Brazil, Chile, India, Singapore, Thailand, Vietnam, and USA are pending examination. The last publications of the family were recorded in 2020.

There are two standards that cite this family, ETSI-TS-38-212 *Multiplexing and channel coding* and ETSI-TS-38-213 *Physical layer procedures for control*, and therefore this family is considered to be a SEP family.

Figure 6 **The complex structure of the US20150334729 patent family**



RU2692039

METHOD FOR INTERBAND BANDING OF CARRIERS FOR SWITCHING TRANSMISSION AND RECEPTION OF DUPLEX WITH TIME DIVISION OF CHANNELS AND THEIR APPLICATION TO MULTIPLEXING OF DIFFERENT TRANSMISSION TIME INTERVALS

Linked by one PCT application, WO 2015/179146

RU2667044

APPARATUS AND METHOD FOR INTERFERENCE REDUCTION UTILIZING THIN CONTROL

Similarly, a large number of jurisdictions have an active family **US20160127991** *Dynamic switching of bandwidth to reduce power consumption in wireless communication devices* with a priority date of October 31, 2014. It was ranked among families with the highest number of jurisdictions, while having slightly fewer general publications. The technical solution refers to wireless communication systems and in particular to alarm formats with varying signal bandwidth and associated adaptations of transceivers to save power consumption in mobile devices and base stations.

Implementation options for this invention may be used for next-generation 5G networks. Russia (RU2690172) is also represented among the jurisdictions with the patents. This SEP family is cited by two standards: ETSI-TS-38-213 *Physical layer procedures for control* and ETSI-TS-38-321 *Medium Access Control (MAC) protocol specification*.

There are also three active Qualcomm families with basic publications (**520180054783, US20170353256, US20170346535**). The number of patents and jurisdictions in these families is significantly lower than that of the leading family. However, these families are young (their applications were filed in 2017), with applications still under review in a large number of countries (Australia, Brazil, Canada, China, India, Japan, and others), which indicates the possibility of obtaining patents in these jurisdictions later, as well as geographical expansion.

The families also belong to SEP (US20180054783 and US20170346535), which are cited in ETSI-TS-38-213 *Physical layer procedures for control* and ETSI-TS-38-214 *Physical layer procedures for data*, and US20170353256 in ETSI-TS-38-211 *Physical channels and modulation*, ETSI-TS-38-213 *Physical layer procedures for control*, ETSI-TS-38-214 *Physical layer procedures for data*, and ETSI- TS-38-300 *Overall description. Stage-2*.

All Qualcomm families described above actively use the special mechanism of the US patent legislation, which provides an opportunity to file provisional applications and claim priority in non-provisional applications. This system allows claiming priority for a technical solution before competitors can do so, thereby gaining an advantage in the 5G technology market.

Another company leading by the number of publications and jurisdictions in this family is Swedish Ericsson, which has launched live commercial 5G networks across four continents. The company creates base stations, which are the key to 5G performance.[7]

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[7] Ericsson 5G // Ericsson | A world of communication URL: https://www.ericsson.com/en/5g

Ericsson has also created a 5G platform that enables service providers to take advantage of the opportunity to upgrade their networks from 4G to 5G.

In general, Ericsson's families have a smaller total number of publications than Qualcomm. However, Ericsson has a higher number of jurisdictions with patents. At the same time, none of the above families is considered as SEP.

The family with the basic publication **WO2016/141961** *Formation of angular pattern with the use of antenna device* has a priority date based on the PCT application filing date, March 6, 2015. All applications in this family are filed through international and regional patenting procedures, including in the US, China, Russia (RU2656236, RU2656235), and Japan. The patent protection of the technical solution operates in the following countries: Australia, Belgium, Switzerland, China, Germany, Denmark, Spain, France, UK, Hungary, Italy, Japan, Mexico, Netherlands, Norway, Poland, Romania, Portugal, Russia, Sweden, Turkey, USA, and South Africa. The application is under review in Argentina, Brazil, Canada, Israel, and India. This family of Ericsson has the largest geographical coverage.

The technical solution of the family is related to antenna equipment. The solution provides for beam forming mechanisms to form an angular pattern using a multi-element antenna array comprising dual polarized elements.

The application for another family with the basic publication **US20170331670** was first filed in the US and then under the PCT procedure. A direct application was also filed in Russia, which is currently under review (RU2019118801 *Network architecture, methods, and devices for a wireless communications network*). This is a divisional application divided from the original application (RU2018143539 dated December 10, 2018, for which patent RU2693848 *Network architecture, methods, and devices for a wireless communications network* was obtained). At the same time, the patent RU2699387 *Optimization of rest mode measurement* was also obtained in Russia under a PCT application. The distinctive feature of this family is that in its bibliography contains a large number of authors of the invention (130). A similar invention **US20170331577** has a larger geographical coverage.

This invention relates to wireless communication networks and describes a network architecture, wireless devices, and wireless network nodes suitable for fifth generation (5G) wireless communication networks.

Its technical result consists in an increase in bandwidth. The related method involves evaluating measurement of demodulated and decoded information for each of the many resources against a predefined criterion, and then interrupting the measurement and evaluation measurement results when the predefined criterion is met.

The family with the basic publication **WO2018/084755** *Search space monitoring* was also included in the ranking. It has a smaller geographical coverage than other leading families, but the publications of this family have an interesting status. The priority of the family is claimed for the filing date of a PCT application (November 2, 2016), which was published in 2018. The European patent has been translated for Denmark, Hungary, Poland, and Spain. Many applications of this family, including those filed in Canada, Australia, Israel, India, and Taiwan, are open for public review and examination. After the period for public review expires, a patent is granted unless no third parties have challenged the materials of such application. Such status of application publication is not inherent to all national patent offices. Such mechanisms are most often used in Australia and Canada. This family contains a Russian patent, RU2708227 *Search space monitoring*.

The variants of implementation presented in this family belong to the a method and apparatus for wireless communication, a computer program, and a software product for search space monitoring. The technical result consists in the improved quality of search for a specific device. This is achieved through mechanisms for monitoring search spaces. The first method performed by a wireless communication device involves reception of the OFDM (Orthogonal Frequency-Division Multiplexing) symbol in the downlink slot. At least, part of OFDM wireless communication is contained in the search space of a particular device and in the common search space. The description of the technical solution uses LTE terminology in a future-oriented form to include equivalent 5G objects or functionality.

The family with basic publication **WO2015/147717**, also owned by Ericsson, is described below (Table 5).

Therefore, Ericsson's strategy is to enter international markets as quickly as possible using international and regional patenting procedures.

At the same time, the expansion of technological coverage is only observed in a narrow range of jurisdictions (mainly the US, Russia, China, and Japan).

In general, it is noted that Qualcomm and Ericsson companies are firmly established in international markets, maximizing their geographical coverage and competitive advantages in their technological areas.

The strength of the patent family is also an important criterion in the analysis of the patent collection. It serves as an indicator of the quality of patents that are owned by companies. When assessing it, not only the technological component of the development is important, but also various strategies related to the patenting and protection of technical solutions. Different indicators aggregated from patent information can be used to identify and evaluate such behavior of patent holders in a competitive environment.

The patent document strength index calculated by Orbit Questel was used in this report. The main advantage of Orbit Questel's comprehensive strength index consists in its objectivity and wide applicability regardless of the research area.

The comprehensive strength index is calculated based on a list of indicators, the values of which are multiplied by value factors. The weights of each indicator may vary depending on the parameters of patent documents.

The main characteristics of the patent family that form the basis for the strength calculation include:

1) family size;
2) forward citations;
3) legal force;
4) generality;
5) originality.

In addition to the “standard” values of the above indicators, it is important to take into account their potential adjustment against several criteria. For example, when calculating the citation index, it is necessary to take into account the age of the patent document.

Citing a family over a long period of time may indicate a continued interest in a key development in the domain. Both the number of forward citations and parameters of companies that cite a patent document play an important role in the analysis of citations

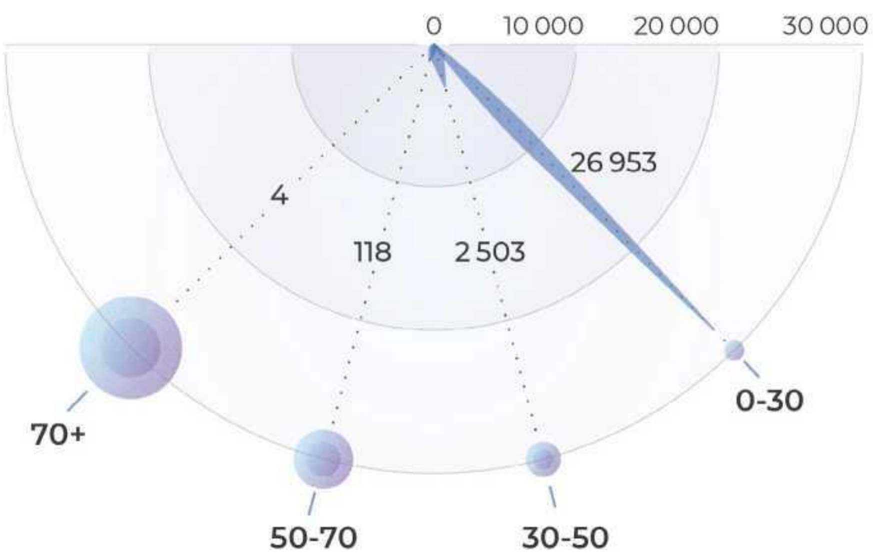
A document with a patent status will have a higher level of legal force than an application. At the same time, it is important to take into account the jurisdiction of the first filing (priority) and the availability of publications with foreign patent offices (patent strength in China is not equal to patent strength the US, all other indicators being equal). Litigations, objections, or revisions also indicate whether a patent family is strong in terms of legal force.

The generality index is based on IPC indexes derived from forward citation data: the index will be higher if a patent is cited in technical solutions with a wide range of applications (a large number of IPC indexes). The value of the index varies from 0 to 1; the closer the index is to 1, the more universal and widely applicable the technical solution is.

The originality index is calculated based on the number of IPC indexes derived from backward citation data. Values close to 1 indicate innovative, breakthrough technical solutions with respect to prior art. Values close to 0 indicate gradual improvements in technology.

Distribution of the strength of patent families by range

Figure 7



The strength distribution of families by range (Figure 7) shows that more than ninety percent of patent families (91%) have a strength index of less than 30 units. The share of patent families with strength values of 50+ is less than 1% of the entire collection.

This distribution is primarily due to the fact that most families in the collection are young and many of their indicators have low values, which leads to a strong differentiation between families, especially for those with longer life spans.

Table 3

Indicators of the strongest families in the collection

1	2	3	4	5	6	7
US20150334729	QUALCOMM	70+	74	11	0.64	0.81
WO2015/147717	ERICSSON	70+	83	10	0.68	0.84
US20160353465	HUAWEI	70+	107	5	0.6	0.73
US20170331670	ERICSSON	70+	118	8	0.74	0.84
By originality index						↓
US20160277513	HYUNDAI	0-30	7	2	0.92	0.96
US20180026945	MAGNA INT	0-30	1	1	0.0	0.96
US20190305416	INTEL	0-30	0	1	0.0	0.96
By generality index					↓	
WO2018/236196	LG ELECTRONICS	50-70	44	3	0.98	0.5
US20160277911	HYUNDAI MOTOR	30-50	27	2	0.94	0.94
US20180206100	REDSKY TECHNOLOGIES	30-50	101	1	0.94	0.89

1 Basic publication
2 Applicant
3 Strength range
4 Number of forward citations
5 Geographical coverage
6 generality index
7 Originality index

Families with the most balanced values for all strength indicators are shown on the left (Table 5).

Families with basic publications US20150334729 and US20170331670 belonging to Qualcomm and Ericsson correspond to the ranking based on maturity indicators and were described above. It should be noted that Ericsson's family with the basic publication **US20170331670** has the largest number of forward citations in the ranking, and high generality and originality indexes, although it is not a SEP family.

Another Ericsson family with the basic publication PCT WO2015/147717 was also included in the ranking of the strongest families of the collection. This is a SEP family cited in two standards, ETSI-TS-38-211 *Physical channels and modulation* and ETSI-TS-38-321 *Medium Access Control (MAC) protocol specification*. The family has a wide geographical coverage:

- Patents are granted in Canada, Japan, South Korea, Mexico, US, and Russia (RU2684758 *System and method for beam-based physical random access*), while the technical solution is also protected via the EPO regional patenting procedure in Austria, Switzerland, Germany, Denmark, Spain, Finland, France, the United Kingdom, Italy, the Netherlands, Norway, Poland, Portugal, Romania, Sweden, and Turkey;

- Applications are under review in Australia, Brazil, Chile, China, India, Indonesia, Philippines, Singapore, Taiwan, and Vietnam.

Priority is claimed under the provisional unpublished US application US201461970145P dated March 25, 2014.

The invention refers to a method applied in a wireless communication device for beam-based random access to a network node. The technical advantage of this solution consists in the elimination of the need for calibration and alignment of RF (radio frequency circuits) for the uplink and downlink, which reduces implementation costs and power consumption. An additional technical advantage may consist in that the computational complexity of the network node, such as eNodeB, will be reduced in line with the applied principle. The random access preamble identifier on the network node only needs to search for a subset of preamble sequences in each direction of the receiver's uplink.

This subset is equivalent to a subset of random access sequences that are translated into the same downlink beam as the uplink beam. The technical solution's embodiments include operation within next-generation 5G networks.

The strongest families also include Huawei's family with its basic US publication **US20160353465** *System and method for virtualized functions in control and data plans*. The family has granted patents in China, Japan, and the United States, as well as applications pending at the EPO, and in Brazil and India under the PCT international patenting procedure. Both PCT applications claim priority for the provisional unpublished US application US201562169243P dated June 1, 2015. The generality and originality indexes of this family are lower than those of the strong families of Qualcomm and Ericsson, even despite the high rate of citations. This is due to the fact that citations are represented by a smaller number of IPC subclasses than those of competitors. This family is cited by three 5G standards 5G (ETSI-TS-23-501 *5G; System Architecture for the 5G System*, ETSI-TS-23-502 *5G; Procedures for the 5G System*, ETSI-TS-23-503 *5G; Policy and Charging Control Framework for the 5G System; Stage 2*), and therefore it belongs to SEP families.

The invention relates to communication networks and, in particular, to the system and method for providing virtualized functions in control and data planes and for operating a communication network with network segments. The invention provides for systems and methods for operating network segments in a next-generation 5G wireless communication environment.

Its originality and uniqueness indexes were considered separately, which allowed expanding the area of search for valuable solutions for the implementation of various patenting strategies.

Sorting families by the originality index has revealed families with the most non-standard technologies as compared to the basic prior art in the context of IPC classes of other families cited by this family. These families have a low level of forward citation and low geographical coverage.

Hyundai patented **US20160277513** *Vehicle and method of sharing information with adjacent vehicles*", a technical solution related to a vehicle that is capable of sharing information by forming a local network with adjacent vehicles, and to the vehicle control. Communication between vehicles is based on 5G technology. This family's technical solution has not only a high originality index, but also a high generality index. Priority for this family is claimed via a Korean application dated March 19, 2015. Its geographical coverage includes three countries (South Korea, the US, and China). Moreover, the application was rejected in the US, and the applications are still pending in China and South Korea.

Sorting by the generality index has revealed families with a high level of forward citations, as these technical solutions are cited by companies that own families with a wide range of IPC indexes.

Their list is led by LG Electronics' family of products with the basic publication **WO2018/236196** *Method and apparatus for performing access barring checks*. Priority is claimed via the non-published US provisional application US201762523786P dated June 23, 2017. The family is young but has a wide geographical coverage in terms of applications pending examination (Australia, Brazil, Canada, Chile, Mexico, Philippines, Singapore, and Vietnam). Only South Korea has granted a respective patent so far. The technical solution describes a method for performing access barring checks for user equipment (UE) in a wireless communication system as well as a supporting apparatus. This method is implemented in a 5G network architecture.

This method includes:

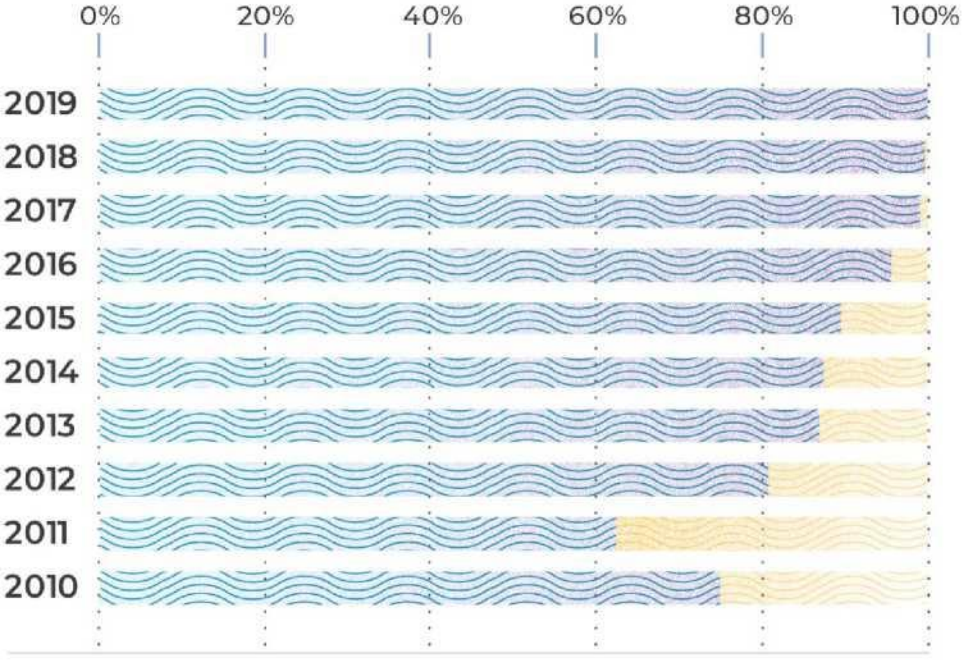
- receiving a list of barring information wherein each of the barring information includes a barring factor and a barring time;
- obtaining information on an access category related to barring information included in the list;
- performing the access barring check for the access category based on the barring information;
- performing uplink transmission if an access attempt is allowed for the access category.

Therefore, we can conclude that evaluating families in terms of different maturity and strength indexes helps us identify different valuable technical solutions that contribute significantly to the development and improvement of the current global level of technology. The above strategies and practices for patenting 5G technical solutions can be applied to implement one's own patenting and intangible asset management strategies.

LEGAL STATUS OF PATENT DOCUMENTS

The study of the legal status of the collection's patent documents enables assessing the applicants' interest in the development of this technology segment (the ratio between the number of filed and the number of withdrawn applications) and the maturity of the segment (the ratio between the number of granted – in this case, they include families that contain at least one active document – and terminated patents).

Figure 8 **Ratio of active and inactive families**



Active family / Inactive family

In addition to an expanded understanding of the status of patent documents, families can be roughly divided into active and inactive (Figure 8) to assess changes in the legal status of families during the period under review. This helps to analyze interests in the 5G technology market in retrospective.

An active patent family is a patent family that includes at least one valid patent or one application pending examination (or has a non-expired processing period).

An inactive patent family is a patent family that does not include any valid patent document (because the patent validity has expired, or the application has been withdrawn, or otherwise).

2011 shows the largest number of families that are no longer active. At the same time, the share of such families has been declining significantly and all the families that have emerged from 2017 are still active. ZTE and Intel have the largest number of inactive families, among which SEP families have also been identified. The most common reasons for becoming an inactive family is the application having been withdrawn or delay in meeting the timelines for national patenting phases because applications for most of these families are filed directly for a regional or international patent. This suggests that companies are willing to claim a level of technology that will be cited in a standard, but do not seek to obtain a national protection document. This may be due to the fact that applicants understand in advance that their solution is not patentable under any patentability criterion.

The above collection has a very high share of applications pending examination – 77% (Figure 10). Chinese Huawei has the highest number of families with applications pending examination, filed mainly in 2017, which is in line with the overall filing trends among all applicants. Chinese BBK Electronics and ZTE are also included in the ranking. US corporations are represented by Qualcomm and Intel, EU by Ericsson, and South Korea by Samsung and LG. Priorities are mostly claimed in PCT applications, but the countries of basic publications include both the US and China.

There is an active research and search for new technical solutions in this area. About three quarters of all inventions are pending review, and this only refers to published applications.

Applications are published 18 months after the filing date. This means that there is still a significant part of already existing technologies that remains hidden until applications are published by patent offices. In this connection, patenting in the area has risks of interfering with solutions that have already been claimed. In such case, the implementation of a patenting strategy requires a number of preventive measures such as ordering preliminary searches in patent offices, monitoring published applications, and tracking applications with an opposition status.

There are 76 cases of disputes on applications with patent offices (mainly US and South Korean patent offices) in the overall collection. South Korean LG and Chinese Huawei are leaders by the number of such disputes. These disputes were resolved by the companies, with a patent granted under all applications for all such families. This shows that the companies defend their technical solutions and provide the necessary arguments to reverse the decision of experts to reject an application so as to ensure the necessary technological coverage.

The most common cause for the emergence of opposition statuses is that applicants typically formulate their claims with a very wide coverage when patenting 5G technologies. Later on, during the examination stages during correspondence between the applicant and the patent office, the technological coverage is gradually narrowed until it meets the patentability criteria. Such a patenting strategy allows the applicant to benefit not only from early priority, but also from the widest possible right to technology approved by the patent office.

However, such an approach has its own risks: the filing of an application may be delayed due to correspondence between the applicant and the Office, or a wide range of rights may be contested by competing companies.

In the latter case, the situation will directly depend on the quality of patent review by the receiving patent office. In this connection, applicants, as a rule, use this practice in the leading patent offices: USA, EPO, South Korea, or Japan.

Example of a change in the scope of the claims in application KR1020190055761

Figure 9

Method for transmitting information about the condition of a user equipment channel in a wireless communication system and its usage

KR1020190055761 (A) – invention application	KR102049422 (B1) – invention patent
1.1 n a wireless communication system 1 PUSCH which is conducted by **the first or second** 2 PUSCH (physical uplink shared channel) **transmission method, and receiving the control information; after the reception of the content and control information** of the first **or the second transmission 1 PUSCH** 2 PUSCH, 1 PUSCH **is a first permanent CSI** (channel state information) (semi field persistent) **and** report, **the UL data is 2 PUSCH and, wherein the transmission of 2 PUSCH and 1** PUSCH overlap in time with transmission of **the first case, the terminal does not transmit** the first and the second 2 PUSCH 1 PUSCH **for** said transmission.	1. In a wireless communication system 1 PUSCH which is conducted by 2 PUSCH (physical uplink shared channel) **or in a method of transmitting, from the base station to receive (downlink control information) DCI; DCI and after receiving, the transmission of the transmission of the first 1 PUSCH time 2 PUSCH based upon whether the second base station overlap in the first one** of the first **1 PUSCH and 2 PUSCH are transmitted to the base station, wherein said first** 2 PUSCH 1 PUSCH **data channels, and a permanent terminal** (channel state information) (semi field persistent) **CSI** report **transmission of the first 1 PUSCH (uplink shared channel) comprising UL field SCH 2** PUSCH **the** overlap in time with **the** transmission of, **wherein** the first and the second 1 PUSCH **2** PUSCH **are not transmitted to** said **transmitting**.
2. Method according to claim 1, wherein the control information is DC I (downlink control information) method.	**2. AMEND STATUS: Delete**
3. Method according to claim 1, wherein the control information received from a base station method.	**3. AMEND STATUS: Delete**
4. Method according to claim 1, wherein the base station 1 PUSCH or 2 PUSCH to be transmitted to the method.	**4. AMEND STATUS: Delete**
5. Method according to claim 1, CSI is persistent during a predetermined interval at a predetermined interval with said transmitted CSI method.	5. Method according to claim 1, CSI is persistent during a predetermined interval at a predetermined interval with said transmitted CSI method.
6. Method according to claim 1, the uplink data is (uplink shared channel) UL field SCH method.	**6. AMEND STATUS: Delete**
7. (User Equipment; UE) is a **terminal**, a transceiver for transmitting and receiving wireless signals (Transceiver); and a processor operatively coupled to the transceiver; thereon, wherein the processor, **and** receiving **the control information**; after **the reception of the content and control information of the first or second transmission 1 PUSCH and 2 PUSCH, wherein 1 PUSCH is a (semi field persistent) permanent CSI and report (channel state information), the UL data is 2 PUSCH and, 1 PUSCH and** 2 PUSCH **of** the **first transmission** overlaps in time with the transmission **case, the terminal does not transmit the first and the second 1 PUSCH 2 PUSCH characterized in that** the transmitting terminal.	7. (User Equipment; UE) is a **mobile station**, a transceiver for transmitting and receiving wireless signals (Transceiver); and a processor operatively coupled to the transceiver; thereon, wherein the processor, receiving **from the base station (downlink control information) and DCI; DCI and** after **receiving the, the first and the second transmission 1 PUSCH 2 PUSCH (physical uplink shared channel) transmission based on whether temporal overlap of the first one of the first 1 PUSCH and 2 PUSCH are transmitted to the base station, the first and second data channels 1 PUSCH and 2 PUSCH, and a permanent terminal (channel state information) (semi field persistent) CSI report transmission of the first 1 PUSCH (uplink shared channel) comprising UL field SCH** 2 PUSCH the overlap in time with the transmission **of, wherein the first and the second 1 PUSCH 2 PUSCH are not transmitted to** the transmitting terminal.
8. Method according to claim 7, wherein the control information includes said DCI (downlink control information) terminal.	**8. AMEND STATUS: Delete**
9. Method according to claim 7, wherein the control information received from the base station to the terminal.	**9. AMEND STATUS: Delete**
10. Method according to claim 7,1 PUSCH or 2 PUSCH the first base station is transmitted to the terminal.	**10. AMEND STATUS: Delete**
11. Method according to claim 7, during a predetermined interval is a persistent CSI transmitted **CSI** at a predetermined interval with said terminal.	11. Method according to claim 7, **CSI is persistent during a predetermined interval** at a predetermined interval with said **transmitted CSI** terminal.
12. Method according to claim 7, the uplink data is (uplink shared channel) UL field SCH the terminal.	**12. AMEND STATUS: Delete**
Deleted from the claim	**Added to the claim**

An example of such "migration" of the scope of rights in the patent claim includes a technical solution of South Korean LG with the basic publication KR1020190055761 *A method for transmitting channel state information of a user equipment in a wireless communication system and used the same* (Figure 9).

On the left is the claim of the initial application KR1020190055761 (A) submitted on November 14, 2018. It is represented by two independent and ten dependent claims. The fragments that have undergone changes during the examination are highlighted in red. As can be seen, only one dependent claim has remained unchanged (claim 5). The claims of the patent granted under this application (KR2049422 (B1)) one year later are highlighted in green on the right. The independent claims (claim 1 and claim.7) have changed substantially, with the number of words in each claim having increased, which indicates a reduction in the scope of patent rights. As a general rule of patenting, the use of a large number of features narrows down the scope of legal protection. This reflects the principle of "inverse ratio", according to which the smaller the number of words (features) describing an item is, the wider the scope of its legal protection is, and vice versa.[8] At the same time, out of ten dependent claims one (claim 11) has been changed and eight (claims 2-4 and claims 6, 8–10, 12) have been removed from the patent claims. In addition, a new application KR1020190132960 (A), containing two independent and two dependent claims relating to base stations, which were mentioned in the dependent claims of the original application, was divided from the application during the patenting prosecution.

The intensive growth in the number of applications with a large share of active patents (19%) and a small number of withdrawn applications over a short period during which the families emerged may indicate that the patenting strategies of companies are carefully developed before filing an application. In addition to choosing the right form and scope of legal protection for new solutions, applicants actively use various mechanisms of their national legislation to establish the earliest possible priorities, monopolizing 5G technology markets.

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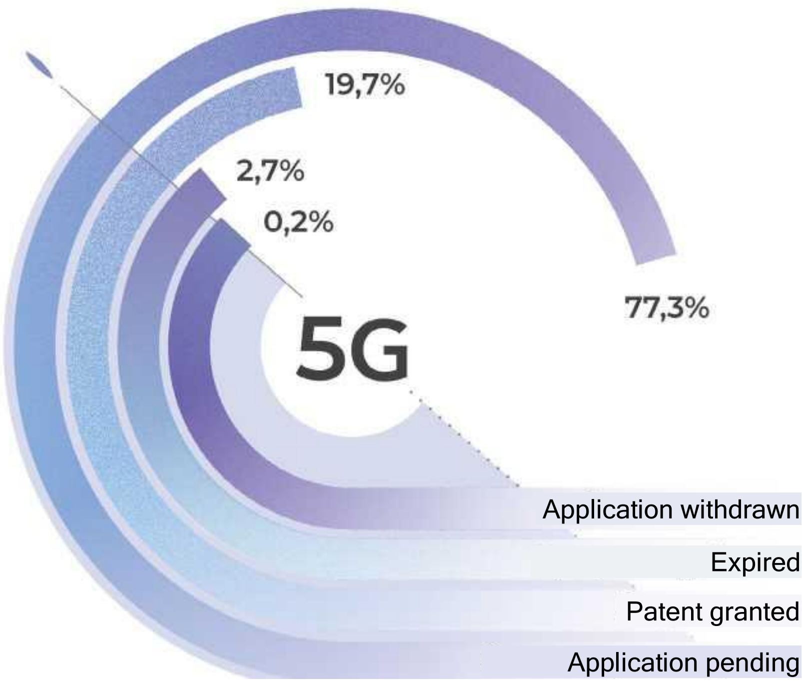
[8] Patent claims and patent scope // Alan C. Marco, Joshua D. Sarnoff, Charles A.W. // deGrazia, Research Policy, Volume 48, Issue 9, November 2019 URL: https://www.sciencedirect.com/science/article/abs/pii/S0048733319301052

Legal status of the overall collection of patent documents

Figure 10



The largest number of families by date of patent granting is observed in 2019, which ensues from the large number of applications filed in 2016–2017. The United States is the leading country by the number of patents granted, where this indicator is almost three times higher than the number of patents granted in China. Among the patent holders, the largest patent portfolio of granted patents belongs to Samsung, followed by Qualcomm, Huawei and Ericsson.

The 5G segment is characterized by a high level of activity of applicants in terms of filing applications, which indicates a high level of interest in the technology among developers. At the same time, a small retrospective of market development implies that it is a new technological segment with tight competition; as a result, companies face opposition statuses during the patenting prosecution. At the same time, its stage of technological development allows clarifying the scope and boundaries of legal protection for obtaining patent documents for more specialized technical solutions, as all basic solutions of 5G architectures are monopolized by companies holding SEP patents.

COMPANIES AND PEOPLE

03

The analysis of patentees allows identifying the industry's leading companies as well as individual inventors that offer valuable technical solutions in the domain. We used the information describing the applicants, patent holders, inventors (authors), and third parties related to the patent family as database for our patentee analysis.

An important element in the analysis of technology patenting includes a detailed analysis of the incumbents, their strategy of research and development (development focus areas), changes in development over time within their technical focus area, as well as a market analysis of each leading company that enters the global market.

Also an important part of this section includes a study on the activity of specific companies and inventors to understand their protection strategies, identify developers of basic and breakthrough technologies, as well as the timelines for their stay in the market.

In order to study potential areas for cooperation and analyze best practices in joint activity between the industry's leading companies when carrying out the analysis of patentees, we explored the technological links between global market players.

ANALYSIS OF PATENTING BY LEADING COMPANIES

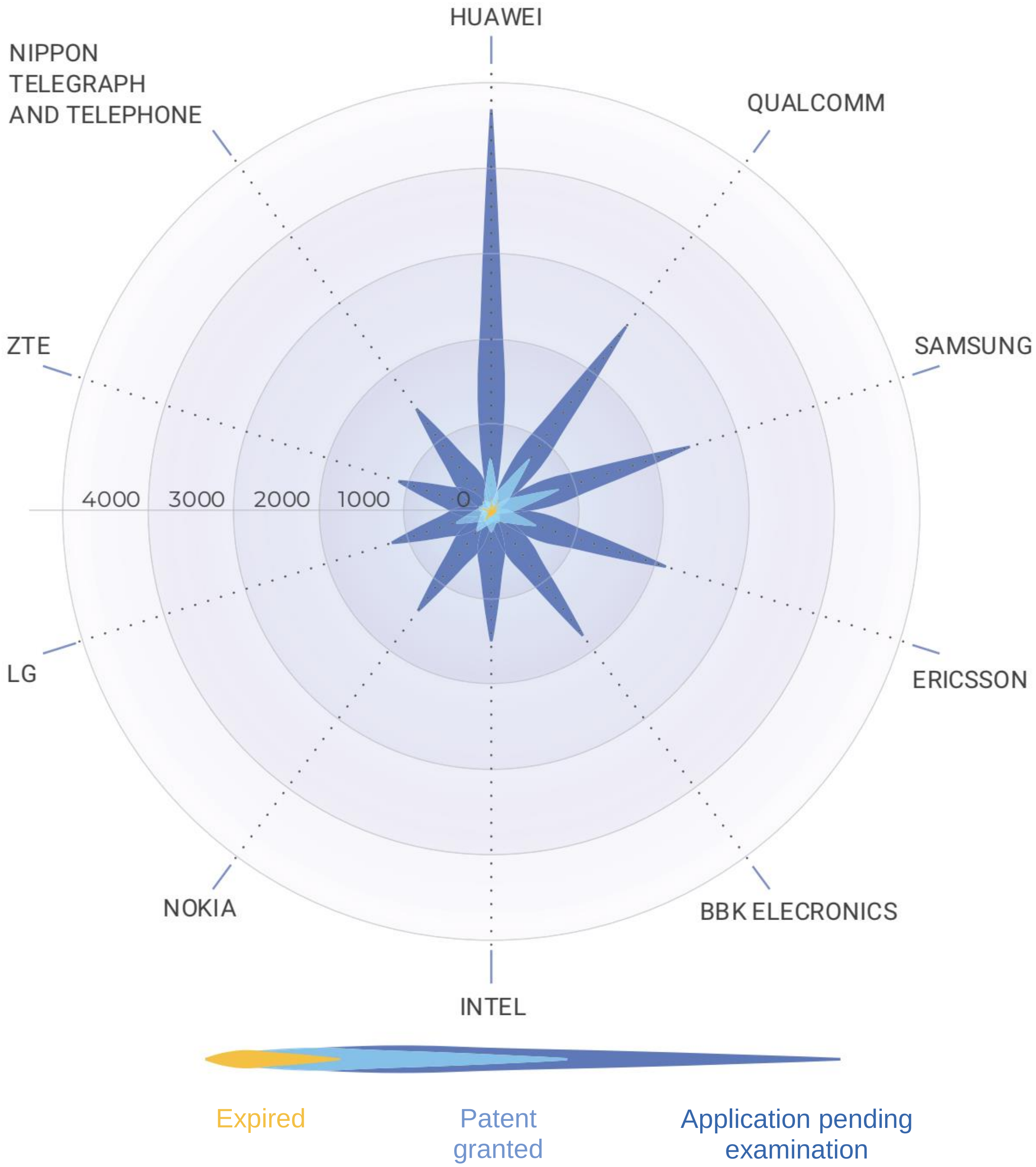
An analysis of the patentee ranking (Figure 11) by the number of patent families allows identifying industry leaders, the general state of the competitive environment in the area, as well as elements of corporate patent protection strategies related to the ratio between active and inactive patents and applications in the total patent portfolio of the company.

The list includes Chinese, US, South Korean, Japanese and European companies that specialize in the development of wireless communication systems. At the same time, the collection includes a small number of universities and research organizations, which indicates the great commercial importance of the developments.

Applications pending examination occupy the largest share in all portfolios of leading companies, which indicates the ac tive market development phase and tight competition among between the market players, including in terms of technologies.

Ranking of the industry's leading companies

Figure 11



Chinese Huawei is the leader by the number of 5G families, which is almost two times higher than that of its competitors. Huawei's modular and comprehensive 5G solutions provide operators with commercial networking opportunities.[9] Among other things, Huawei designs and manufactures 5G base stations. The company has been actively patenting its developments in recent years, as indicated by a significant proportion of families with applications pending examination.

The next group of companies has about 2,000 families in their patent portfolios. These are Qualcomm, Samsung, Ericsson, and BBK Electronics. However, Samsung is the leader by the number of 5G patents. The company is actively involved in developments related to 5G mobile networks, including antenna equipment. Samsung is also the leader among 5G smartphone providers.[10] Apart from Samsung, Qualcomm, Ericsson, and Huawei also have a large number of granted patents in their collections.

Samsung Exynos Modem 5100 presented in August 2018 is the world's first 5G modem fu lly compliant with 3GPP Release 15 (Rel. 15) specifications for 5G New Radio (5G-NR) mobile networks.

Taking into account the date when the patent was granted, it is safe to say that these companies have the longest 5G research and development retrospective. Patents were also granted to South Korean LG Electronics, which is one of the leading companies producing and selling 5G smartphones,[11] and Finnish Nokia, which has more than one hundred 5G projects underway, including those related to the equipment to launch commercial networks and build network architecture and cloud infrastructure.[12]

9 Huawei 5G // Huawei URL: https://www.huawei.com/minisite/russia/5g/

10 Samsung kontroliruyet tri chetverti rynka 5G-smartfonov (Samsung controls three fourths of the market for 5G smart phones) // DailyComm. News, reviews and analytics of the market URL: http://www.dailycomm.ru/m/49530/

11 Samsung kontroliruyet tri chetverti rynka 5G-smartfonov (Samsung controls three fourths of the market for 5G smart phones) // DailyComm. News, reviews and analytics of the market URL: http://www.dailycomm.ru/m/49530/

12 Oborudovaniya 5G khvatit na vsekh (There will be enough 5G equipment for all) // ComNews.ru | Digital transformation news URL: https://www.comnews.ru/content/202302/2019-10-14/2019-w42/ oborudovaniya-5g-khvatit-vsekh

The third group of companies in the ranking has the largest share of inactive patent families. These patent families include Intel, Nokia, and ZTE. Applications for the families of these companies were mostly filed between 2015 and 2017 and none of them were granted a patent. This suggests that there were circumstances during the patenting prosecution that led to the early termination of the family. They include failure to comply with the patentability criteria (inventive step, novelty); attempts to patent abstract ideas that do not fall under patent protection; inappropriate filing of claims; and the lack of response to an official request from the patent office on the application. For example, Chinese ZTE actively filed applications in the US, most of which were rejected by the US patent office, with the company later withdrawing its respective application in China. Therefore, it can be concluded that for large Chinese companies, the US is a priority market for patenting technologies.

In late 2018, Intel introduced the XMM 8160 modem, which supports fifth-generation mobile networks along with other 5G modems such as Qualcomm X50, Huawei Balong 5000, and MediaTek Helio M70.

This area has a high level of monopolization, with key technologies and 5G architectures belonging to a very narrow group of players: 60% of all inventions are created by ten leading companies. This creates a high level of competition and significant barriers to market entry for small and medium-sized companies. Research and development in such market conditions call for significant investments as they require the development of new technologies. This situation is not inherent to any other segments of digital technologies (quantum technologies, artificial intelligence, etc.).

Chinese companies and universities that were not included in the ranking were also analyzed separately (Figure 12). Those among them that have the largest number of families include Xiaomi, a 5G smartphone manufacturer, and China Mobile, the largest telecom operator in China. Although typically high, no high patenting activity was found in Chinese universities in this collection.

The leaders among all research institutions include the South Korean Electronics and Telecommunications Research Institute (ETRI).

China is represented by the China Academy of TelecommunicationsTechnology, a professional 5G research institute in China, which published the *5G Security Report* in 2020 to strengthen cooperation among 5G players and promote 5G development.[13]

On October 31, 2019, China's three leading national mobile operators – China Mobile, China Unicom and China Telecom – launched the world's largest commercial 5G network.

[13] 5G Security Report // CAICT | China Academy of Information and Communications Technology URL: http://www.caict.ac.cn/english/yjcg/bps/202002/t20200204_274119.htm

Ranking of Chinese patent holders not included in the main ranking

Figure 12

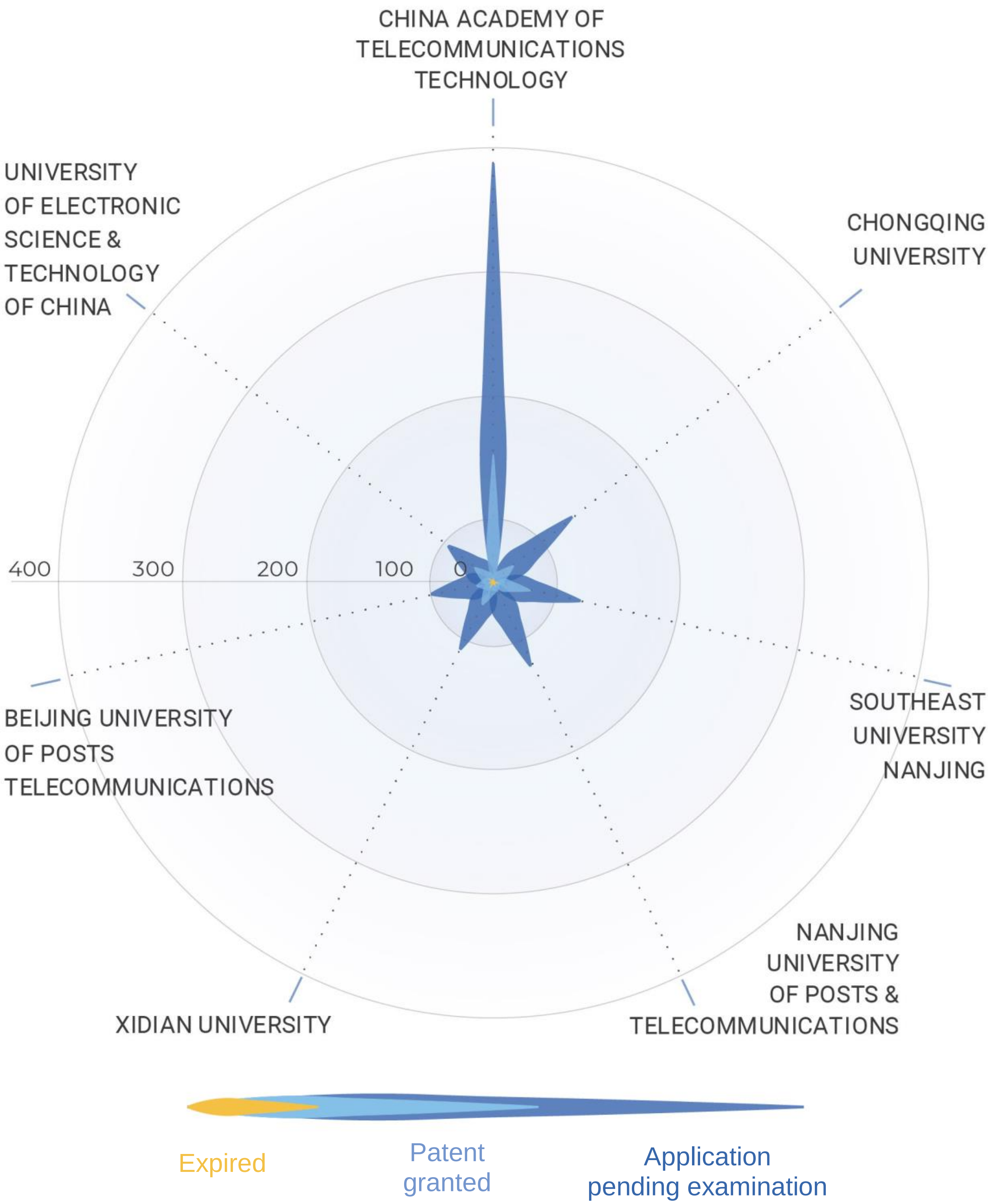
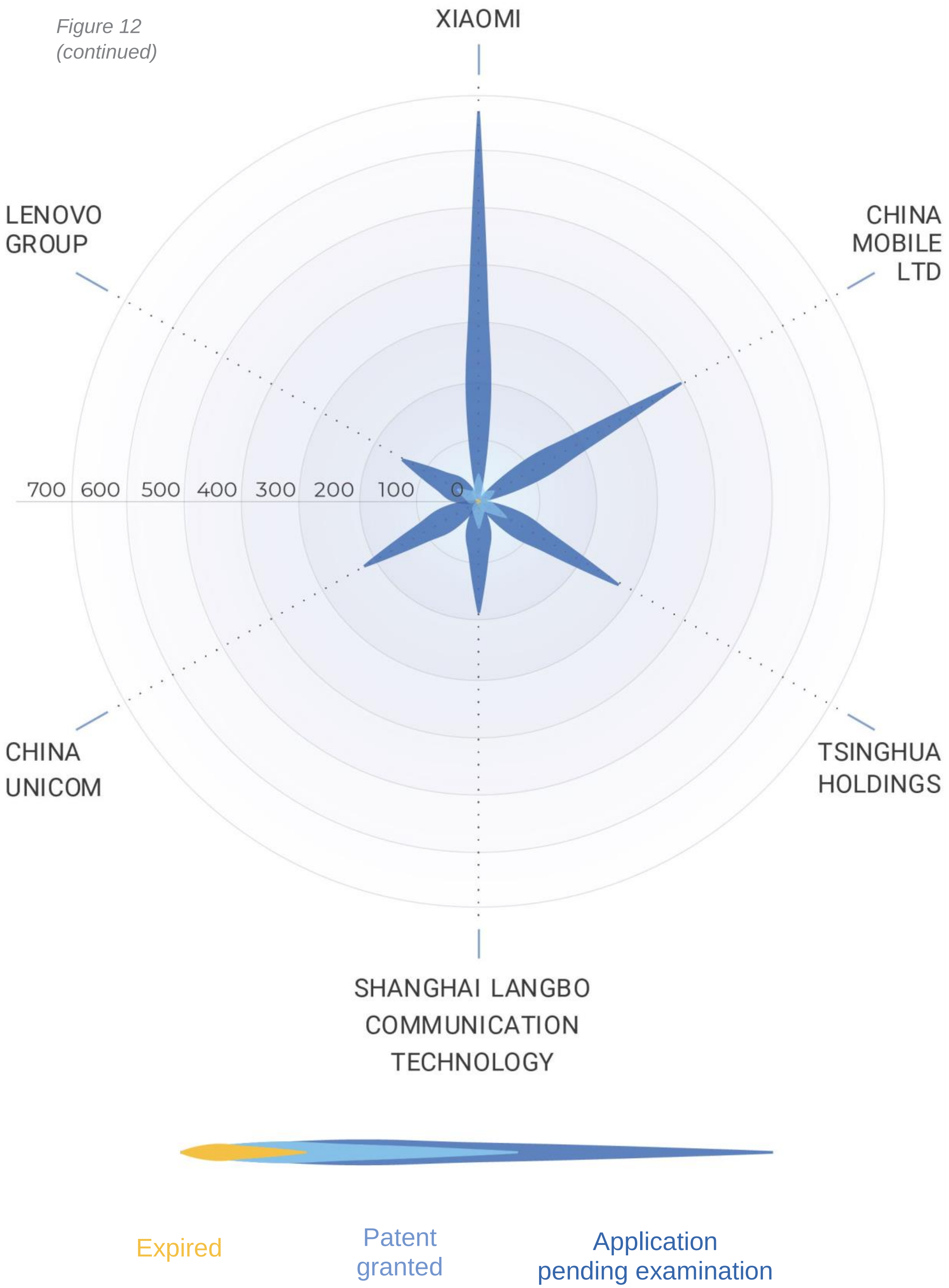


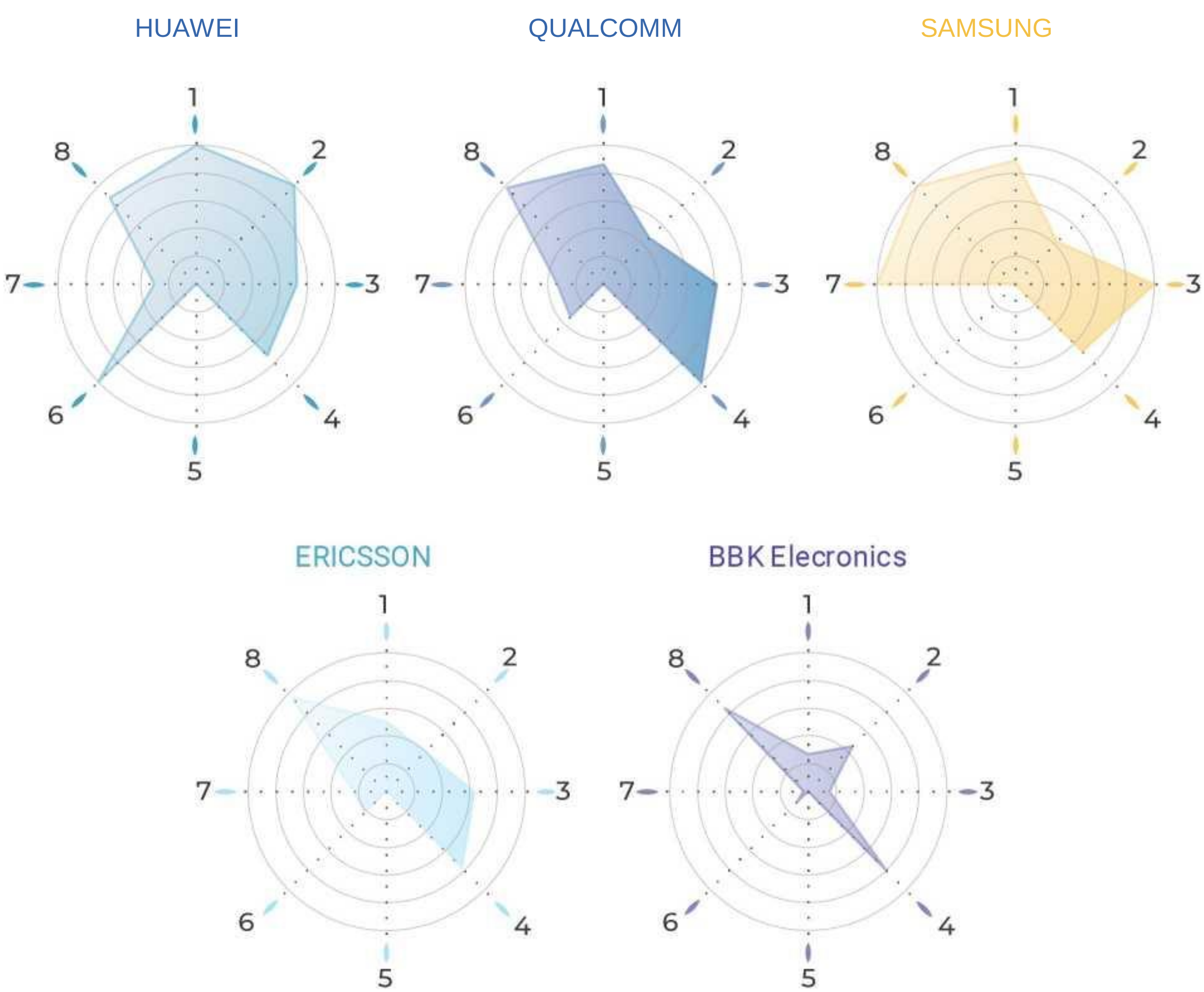
Figure 12
(continued)



Below is a comparison of key strength indicators of patent portfolios held by the leading companies, including Huawei, Qualcomm, Samsung, Ericsson, and BBK Electronics (Figure 13).

Comparison of portfolios of leading companies by strength

Figure 13



1 Portfolio value

2 Number of applications pending examination

3 Number of patents granted

4 Family size

5 Patent disputes with third parties

6 Patent disputes with the patent office

7 Forward citations, excluding self-citation

8 Originality

The strength of a patent portfolio is calculated as the sum of all strength indicators of the families in the collection related to a particular patent holder. Chinese Huawei has the largest strength of the patent portfolio, while another Chinese company, BBK Electronics, has the smallest strength among the companies in the list. China's Huawei also has the largest number of applications pending examination, indicating that it has been the most active 5G company in recent years. At the same time, Samsung and Qualcomm have a greater number of patented solutions, which suggests a longer research retrospective as compared to their Chinese competitors. Qualcomm has the largest family size; accordingly, its technical solutions are more protected both technologically and geographically.

At the same time, Huawei has a high rate of disputes with the patent office. This may be due to the fact that new technologies developed within the 5G stack are in many cases equally applicable to 4G networks, and vice versa. For applicants, this implies putting more effort into developing their invention claims, especially in those countries where the requirements for detailed elaboration of patent documents are more stringent For example, a detailed analysis of Huawei's disputes revealed that the overwhelming majority of these disputes are with the US Patent Office.

An analysis of citation-based indicators also provides an understanding of the value of technology in the companies' portfolios. Samsung's high citation rate indicates that the company's technical solutions are key to the 5G segment. The calculation of this indicator does not include self-citation, which allows for a more accurate differentiation of technologies that are of interest to competitors in the 5G market. The originality index of the patent portfolios held by leading companies was also analyzed. The index is calculated as an average value of originality indexes of all families in the collection belonging to a given company. The portfolios of Samsung, Qualcomm, and Ericsson have the highest originality index.

For a more complete understanding of the existing patent activity of companies it is necessary to consider the changes in patenting patterns of the leading companies over time, which will allow us to more objectively evaluate their current interest in the development of 5G solutions (Figure 14).

Emergence of patent families of the leading companies from the overall collection over time

Figure 13

Company	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Region
HUAWEI	0	0	6	22	97	266	973	2000	947	47	CHINA
BBK Elecronics	1	0	0	1	3	21	233	833	681	116	CHINA
ZTE	2	3	2	11	34	84	277	427	210	67	CHINA
XIAOMI	0	0	0	0	0	1	40	173	178	147	CHINA
CATT[1]	0	0	0	0	7	19	89	197	152	0	CHINA
CHINA MOBILE LTD	2	0	0	1	15	19	71	153	82	3	CHINA
QUALCOMM	3	6	3	10	49	117	489	1094	700	2	USA
INTEL	0	2	0	5	32	172	520	500	200	14	USA
AT T	0	0	2	1	3	15	48	129	78	1	USA
SAMSUNG	1	6	20	45	275	385	538	817	343	1	KOREA
LG	0	0	5	22	41	90	258	576	263	65	KOREA
SK GROUP	0	0	0	0	3	16	99	133	82	0	KOREA
KETRI[2]	0	0	0	1	12	27	62	98	52	0	KOREA
ERICSSON	1	4	0	9	70	210	481	904	422	1	EUROPE
NOKIA	12	19	23	54	87	182	299	384	276	1	EUROPE
NTT[3]	1	0	0	1	6	143	301	397	260	0	JAPAN
SHARP	4	15	10	4	23	26	123	208	100	0	JAPAN
SONY	0	0	1	10	11	30	88	115	72	0	JAPAN
FUJITSU	2	3	2	0	5	23	77	83	55	0	JAPAN
MEDIATEK	0	6	2	2	3	11	54	155	98	0	TAIWAN

[1] CHINA ACADEMY OF TELECOMMUNICATIONS TECHNOLOGY
[2] KOREA ELECTRONICS TELECOMMUNICATIONS RESEARCH INSTITUTE
[3] NIPPON TELEGRAPH AND TELEPHONE

China is the country with the largest number of leading companies that are actively patenting 5G solutions (38% of the total patent portfolio of leading companies). The total patent portfolio of leading Chinese companies is twice as large as the portfolios of the US and South Korea. The second place is shared by South Korea and Japan. The contributions of companies from the US (18%), Europe (15%) and Taiwan (1%) have also been observed. In general, the Asian region has the largest share of leading companies (67%) with an obvious leadership of China. At the same time, general patenting trends are observed across regions with similar patterns.

The greatest activity of leading patenting companies falls on the period from 2016 to 2018 with the highest rates in 2017. In 2017, the patenting leaders included Huawei, Qualcomm, Ericsson, BBK Electronics, and Samsung. It should be noted that patenting in this area has been rapidly growing, with a market and a set of leading companies built in less than five years. The list for the last year of the period under review mainly contains families of Chinese companies. These figures may be related to the simplified patenting procedure applicable to Chinese residents where the period between patent granting and the date of application filing averages about a year. Accordingly, applications are published faster than in other patent offices around the globe.

The companies most involved in the innovation environment started patenting 5G technologies as early as 2013 to secure their top positions in the segment, which has enabled many of them to become patent leaders. Nokia, a Finnish company, has the longest patenting retrospective, while Japanese Sharp shows an unstable patenting pattern at the early stages despite its long retrospective.

Back in 2014, Nokia and NTT Docomo agreed to collaborate on 5G research and standardization and to work together on the proof of concept (PoC) for 5G.[14] Already in 2015, the company demonstrated 5G radio equipment using millimeter and centimeter wavelengths to support maximum bandwidth, as well as new frame structures to achieve single-digit millisecond latencies.

[14] 5G Press Releases // Nokia Corporation URL: https://www.nokia.com/networks/5g/5g-press-releases/

In the same year, the company unveiled its AirFrame Data Center Solution, the first 5G cloud platform that combined the benefits of cloud computing technology with stringent requirements for the network core and architecture. Over five years, the company's active position in the 5G research has helped it strengthen its cooperation with various developers, expand the technological coverage of its solutions, and enter into multiple contracts with telecom operators for 5G networks deployment. In February 2020, the company announced the launch of a new functional end-to-end network for 4G and 5G New Radio (NR) and became the first vendor to offer this capability.

Therefore, the leading companies are actively patenting in this segment, consolidating their competitive position and creating a significant level of technology that prevents other players from building up their 5G technology stack.

SEP FAMILY ANALYSIS

Additional risks of patenting in this segment are related to the fact that the vast majority of monopolies' patents are "standard essential patents" (SEP). It is believed that without SEP licenses no company can bring telecommunication equipment to market or create a 5G network architecture.

This creates a favorable environment for SEP patent holders to gain superprofits ("royalty gold mines")[15] and involves high costs for manufacturers related to the legal use of patented technologies.

Samsung is the leader by the number of SEP families. The group of leading companies also includes Intel, ZTE, and Huawei. Other companies have a much smaller number of SEP families. For SEP families, the patenting time pattern is shifted by one year forward as compared to the overall patenting dynamics. This situation is logical, as SEP patents are basic patents for the technology segment and form the basis for further development and expansion of technology.

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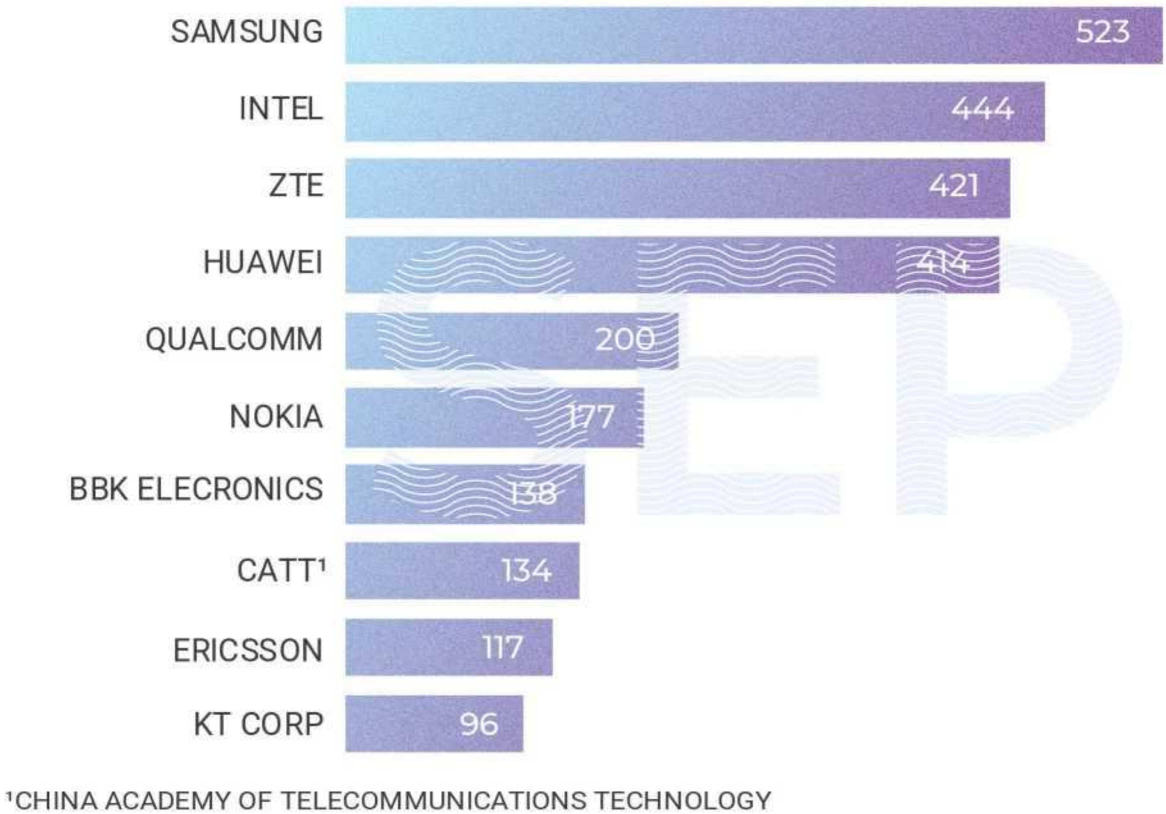
[15] China dusts the U.S., Finland, and South Korea with 34% of key 5G patents // VentureBeat | Transformative tech coverage that matters URL: https://venturebeat.com/2019/05/02/china-dusts-the-u-s-finland-and-south-korea- with-34-of-key-5g-patents/

Figure 15 **Ranking of leading companies by the number of SEP families**



Patent holder / Number of patent families

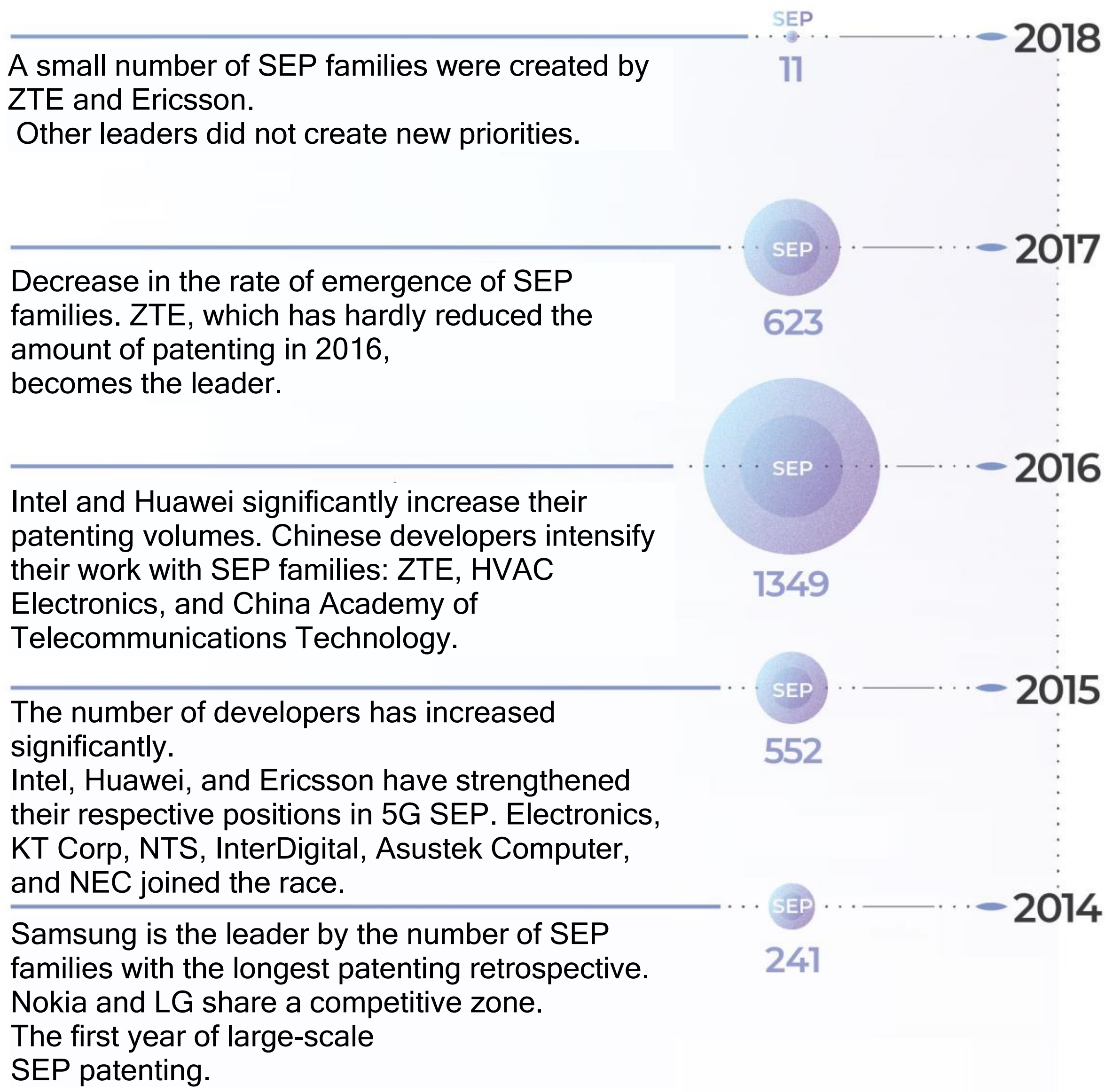
SEP families mainly emerge in the United States and China, while the dynamics of their emergence in these countries differ. The United States has a more consistent increase in the number of families, while China entered the market abruptly in 2016 (Figure 16). The dynamics of the emergence of SEP-families is based on the priority dates, which allows correlating existing solutions with previous solutions and identifying the newest ones in terms of technology. This method seems to be the most appropriate, since companies tend to claim priority for similar technologies in older applications in order to consolidate their competitive positions.

Samsung has the longest patenting retrospective of SEP families, consistently conducting its 5G research and development to smoothly increase its patenting rates.

Intel and Huawei, along with Samsung, began to implement patent protection for 5G technology earlier than other companies. The peak of patenting with respect to the industry's basic technologies was in 2016, when the maximum activity of all players was recorded. The technologies patented in that year have become the most fundamental for the new 5G communication standards and are cited by international standards and many other companies.

Evolution of the market for SEP families over time

Figure 16



In 2017, Chinese ZTE became the leader, with almost no decrease in patenting volume compared to the previous year, which allowed it to consolidate its leading position in the overall ranking of companies with SEP families.

Ericsson and LG did not decrease their rates of SEP patenting either, which demonstrates their significant contribution to the further development of 5G patenting. At the same time, for most other companies, the patenting rates have significantly decreased, including the leading Samsung, Intel, Huawei, and Qualcomm. The only company that has seen an increase in SEP patents is KT, a Korean company, the largest provider of integrated wireless and wireless telecommunications services in South Korea. The company not only develops a 5G network as a standard for service users, but also actively participates in the development of smart cities and buildings using 5G technology in South Korea.

In January 2020, KT Corporation, Korea's largest telecommunications company, and Samsung Medical Center (SMC) announced that they had jointly developed an innovative 5G-based medical service package as a first step towards establishing a "smart hospital".

In 2018, ZTE and Ericsson were the only SEP patentees, indicating the novelty of the basic technology with respect to emerging standards.

The maximum number of all SEP family priorities is actually claimed in PCT international applications. Hence, the companies try to bring their SEP developments at once to the international market in order to secure for them the status of a certain state-of-the art technology and, accordingly, a certain advantage in the market.

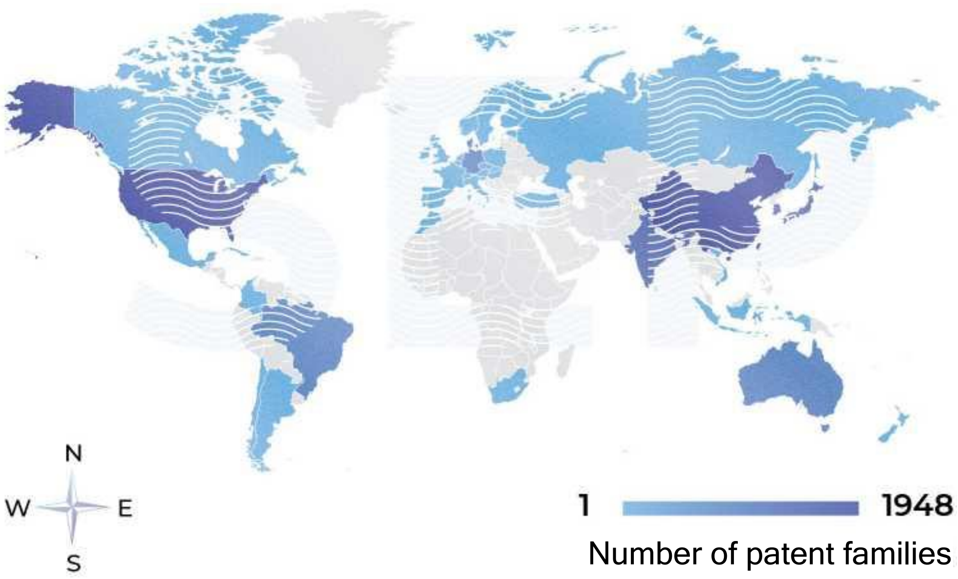
Other priorities for SEP families belong to the US, China, and South Korea. Other countries (Vietnam, India, Brazil, Japan, Israel, Australia, the UK, Singapore, Thailand, and Greece) are represented by a much smaller number of families with priorities. Such families primarily belong to BBK Electronics (31%), Huawei (20%), and Samsung (17%).

The remaining geographical coverage of SEP families includes 46 countries.

In particular, the protection has been extended to European countries, via EPO applications, African countries via applications filed with the African Regional Intellectual Property Organization (ARIPO), and Eurasian countries via applications filed with the Eurasian Patent Office (EAPO).

Breakdown of SEP Families by geography

Figure 17



The largest number of SEP families is currently protected in China. A slightly smaller number of families are protected in Europe. Moreover, applicants choose the regional patenting procedure through the EPO as a protection strategy. Among European countries, the largest number of SEP families is protected in Germany, the Ireland, Switzerland, the Netherlands, Austria, France, Italy, and Spain. The US ranks the third by the number of protected SEP families.

In other countries, SEP families are mainly protected through the PCT international patenting procedure. Once filed with WIPO, applications enter the national phase where a national examination is carried out and the decision to grant or refuse a patent is taken locally. Countries where SEP patents are valid include India, South Korea, Japan, Brazil, Taiwan, Australia, Canada, Vietnam, Singapore, Mexico, Israel, Philippines, Russia, South Africa, and some others.

ANALYSIS OF PATENT PROFILES OF COMPANIES

This section provides an analysis of leading companies. The analysis used metrics developed within the PatentSight analytical system. All of these metrics are described below to the extent that PatentSight, as a copyright holder, discloses in open sources available to the system's users. The metrics have been tested for practical application in different areas. In particular, the European Commission used the *Technology Relevance* metric developed by PatentSight to evaluate the Dow DuPont[16] merger. The purpose of the European Commission's review of these companies was to determine how their merger would affect the competitive situation in individual markets.

Another indicator, the Patent Asset Index, is actively used by such large companies as BASF, Siemens, and many others. The Patent Asset Index is designed as an objective measure to assess technological and innovative value. The calculations are made for the patent portfolio as a whole and take into account both the number of patented solutions and their value and quality. The methods for calculating this metric were scientifically researched and designed based on PatentSight's experience with innovation and patenting strategies.

The Patent Asset Index is defined as an aggregate metric of the competitive impact of all patents in a portfolio. It can be calculated for a portfolio as a whole as well as for groups of patents within a portfolio (e.g. a group of patents in a particular area that was used for the preparation of this report).

Competitive Impact is a key metric used to calculate the Patent Asset Index. It helps evaluate the business value of a specific patent and is based on a combination of two other indicators:

[16] Merger deals increasingly scrutinized using patent analysis // PatentSight | Innovation Insights URL: https://www.patentsight.com/patentsight-press-center/ merger-deals-increasingly-scrutinized-using-patent-analysis

technology relevance and market coverage. Competitive impact is derived algorithmically from the patent database and related legal and business information. It can be calculated for a patent portfolio, a part of it or a single patent. It is a relative indicator that allows comparing the business value of the patent under study with an average patent within the same area. Accordingly, a competitive impact equal to two indicates that the patent in question, for which this metric was calculated, has twice as much force as an average patent within the same area. The method for calculating competitive impact was validated in a large-scale research study, which included comparison of more than 64,000 patents.

Technology relevance determines the value of an invention in terms of technological advance. It is calculated on the basis of the number of citations of the patent in question in later documents. Citations with respect to which the patent office's patent examiner has identified the patent in question as prior art are also taken into account.[17] This metric has also been tested in a number of research studies. The number of patent citations is adjusted according to the patent lifespan, the citation strategies of patent offices ,and the technology segment. Technology Relevance is also a relative metric that enables comparison of patents among themselves. For example, a Technology Relevance metric equal to two means that the patent affects the technology segment's development twice as much as an average patent from the same segment.

The concepts of internal and external technology relevance are also distinguished.

Internal Technology Relevance is calculated based on citations made only by the patent holder and indicates the internal technological value for the developer itself.

[17] During their substantive examination of a claimed solution, patent examiners are guided by standards, which distinguish different types of patent citations depending on whether the cited document may affect the decision to grant a patent or not. In this case, the metric is calculated based on information on citation of a certain type.

External Technology Relevance is calculated based on citations made exclusively by third parties. Such technical solutions have a high technological value for other companies operating in the segment.

Market Coverage is a metric that demonstrates what market share a patent in question covers. The more markets are protected by the patent, the greater its business value.

The market coverage of a patent portfolio is estimated as the size of the markets in which active patents and applications pending examination are present. The market size is determined based on the relevant country's GDP. The size of the US market, which is considered to be the largest market in the world is taken as 1. Thus, a market coverage equal to two means that the aggregate size of the markets in which the patent portfolio is active is twice as large as the US market.

As noted earlier, these metrics have proven to be as reliable and useful in the course of multiple research studies and in practice. As a result, they are used in this report to enhance its value for the Customer from the business standpoint in making its decisions regarding the development of the Customer's own strategies.

The evolution of the Patent Asset Index over time on an accrual basis was examined for the leading companies of the collection (Figure 18).

Chinese Huawei has not only the largest 5G patent portfolio, but also the largest Patent Asset Index. The largest increase in the Patent Asset Index was observed in the last three years. For example, in 2018 the Patent Asset Index of Huawei's portfolio increased threefold year-on-year, and in 2019 by almost 56% year-on-year. Another Chinese company, BBK Electronics, has also demonstrated explosive growth rates over the past two years. In 2019, the index more than doubled as compared to 2018. However, the overall Patent Asset Index of BBK Electronics as at the end of 2019 is still lower than 30% than that of Huawei, which has consolidated its position with its index growing already in the first quarter of 2020. Other Chinese companies with the highest Patent Asset Indexes have mainly started to exert competitive impact since 2016.

Among them are ZTE, Xiaomi, China Information and Communication Technologies Group, which includes the China Academy of Telecommunications Technology, and China Mobile LTD. Meanwhile, the Patent Asset Index of ZTE started growing earlier than that of others, while Xiaomi has posted the highest index growth among them during the last year.

Changes in the patent asset index of leading companies over time on an accrual basis

Figure 18

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
HUAWEI	0	0	0	0	31	169	662	2 093	6 706	10443
QUALCOMM	3	11	29	77	114	137	598	1 347	4 345	8 962
BBK Elecronics	0	4	4	4	3	21	50	464	3 243	7 136
SAMSUNG	2	7	19	53	119	535	1 671	2498	4 215	6 600
ERICSSON	6	14	21	30	34	138	526	1 280	2 860	5 396
INTEL	0	1	1	11	27	78	348	1 428	3 450	3 529
LG	0	0	0	8	48	133	286	708	2 014	3 365
NOKIA	40	77	122	178	301	495	779	1 226	1 770	2 394
ZTE	0	3	11	11	21	71	240	637	1 579	1 942
XIAOMI	0	0	0	0	0	1	7	95	795	1 865
NTT[1]	0	0	0	0	0	2	60	382	826	1 437
AT&T	1	1	5	6	10	11	31	81	267	1 434
SONY	0	0	0	0	24	43	98	366	816	1 375
InterDigital	6	5	8	13	11	19	77	584	993	1 329
CICTG[2]	0	0	0	0	2	4	30	95	471	1 113
MEDIATEK	0	0	1	7	12	12	40	70	343	934
SHARP	0	3	25	57	75	81	117	216	542	804
Convida Wireless	0	0	0	0	0	0	0	120	231	546
CHINA MOBILE LTD	0	0	0	0	0	3	15	60	191	341

[1]NIPPON TELEGRAPH AND TELEPHONE

[2]CHINA INFORMATION AND COMMUNICATION TECHNOLOGIES GROUP

ZTE offered several key 5G technologies.[18] These include multi-user shared access (MUSA), which can significantly increase the number of connections supported by the system. ZTE applied the MIMO technology in a 4G network and successfully rolled out commercial Pre-5G products for operators worldwide. In September 2016, ZTE was the first to complete Phase 1 testing of the key 5G technologies organized by the Chinese Ministry of Industry and Information Technology. The tests confirmed the operability of several key 5G technologies of ZTE, including massive MIMO, 5G HF, MUSA & MUST multi-user shared access and 5G network architecture. As early as in October 2016, ZTE was recognized by the ITU Expert Group for its 5G high-frequency hybrid channel model based on a 3D digital map. The channel model has been included in the framework of IMT-2020 (5G) technical evaluation report. This situation stimulated a threefold increase in its Patent Asset Index in 2016 and 2017.

Xiaomi is an online company with its sales driven by smartphones and IoT-connected smart equipment. In July 2018, Xiaomi signed a strategic cooperation agreement with China Mobile to develop IoT-based applications that fully utilize 5G technology. In December 2019, Xiaomi released the cheapest 5G smartphone on the market. The Chinese smartphone manufacturer is planning to invest at least CNY 50 billion (USD 7.2 billion) in 5G, Artificial Intelligence (AI) and the Internet of Things (IoT) technologies over the next five years,[20] as the company needs to support its business growth in a highly competitive environment in the segments, including against Huawei. Therefore, the recent years have become for the company a starting point in its race for the market share of 5G technologies, which made it possible to significantly increase the competitive impact in the market due to the relevance of its technologies, while having a much smaller patent portfolio.

US Qualcomm and Swedish Ericsson show similar accelerated growth, being the leaders in terms of their Patent Asset Indexes in their respective segments as at the end of 2019.

[18] G: Stepping into Future // ZTE URL: https://www.zte.com.cn/china/topics/zte-5g-en/stepping.html

[19] 5G // Mi Blog URL: http://blog.mi.com/en/tag/5g/

[20] Xiaomi to invest $7.2 billion in 5G, AI, and IoT over five years // ZDNet | Technology News, Analysis, Comments and Product Reviews URL: https://www.zdnet.com/article/xiaomi-to-invest-us7-2-billion-on-5g-ai-and-iot-for-coming-five-years/

These companies have been demonstrating an increase in their Patent Asset Indexes since 2011, which is due to the valuable solutions they developed during the early stages of the market emergence. By the end of this period, Qualcomm outperformed Ericsson by 40% in the terms of the Patent Asset Index. However, when assessing the leading positions, we should consider not only the development of regional markets with respect to the technologies under review, but also the specialization of companies operating in this area.

Other American companies in this area include Intel and AT&T. Intel is the world's leading supplier of network equipment, which has also encouraged the company to actively invest in 5G network equipment. The greatest increase in the Patent Asset Index of the company was recorded in 2017–2018. However, the growth rates significantly decreased in 2019. In February 2020, the company introduced a wide range of hardware and software tools, including a 10-nm Intel Atom® P5900 system-on-a-chip (SoC) for wireless base stations, which is a critical element for early deployment of 5G networks, as well as other devices optimized for 5G networks.[21] Obtaining patents for these developments is likely to have a major impact on the company's Patent Asset Index in 2020.

AT&T is the leading American mobile operator. In 2019, the company's audience grew by more than five times. This is the highest value of the index in 2019 among all leading companies. Such changes may be due to the fact that in December 2018, AT&T was the first to launch 5G in the US on a large scale.[22] In addition, since 2016, the company has been one of the leading wireless operators promoting 3GPP's 5G standards agenda, which is reflected in the positive changes in its Patent Asset Index.

Among South Korean companies, we can mention Samsung, which was the leader in terms of the 5G Patent Asset Index from 2015 to 2017, and only in 2018 it was beaten by Huawei and Qualcomm.

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[21] Intel Announces Unmatched Portfolio for 5G Network Infrastructure // Intel Newsroom URL: https://newsroom.intel.com/news-releases/5g-network-portfolio-launch/#gs.12aa69

[22] 5 Facts on AT&T 5G // AT&T Newsroom URL: https://about.att.com/ecms/dam/pages/5G/5%20Facts%20On%20ATT%205G_02.20.2020%20(1).pdf

At the same time, Qualcomm and Samsung have patent portfolios of similar sizes, but have a fairly large difference between their respective Patent Asset Indexes, which indicates a different rate of increase in their respective patent values and market coverage.

Another leading South Korean company in 5G is LG, the largest smartphone manufacturer and service provider in South Korea. In 2016, LG Electronics and Intel announced that they were collaborating to develop and test 5G based telematics technology for vehicles in order to accelerate market penetration through specific solutions.[23] Later, in 2017, LG and Qualcomm began research to develop 5G technologies for vehicles and C-V2X (Cellular Vehicle-to-Everything) technologies required for the success of next-generation unmanned vehicles.[24] The company was one of the first to develop a smartphone with 5G support for the consumer market in 2019. This smartphone is equipped with a mobile platform and a Qualcomm modem designed to operate over 5G networks. Also in 2019, LG and Swisscom signed a cooperation agreement to distribute 5G commercial services in Europe, which has attracted the interest of many European operators.[25] Accordingly, its innovative contribution to 5G technologies allowed the company to consistently build up its Patent Asset Index in the segment.

Of particular note is Finnish Nokia, which has the longest patenting retrospective, as well as had the highest Patent Asset Index before the market matured. For the most part this is due to the fact that its patent descriptions contain references to 5G technologies as possible applications, although they do not directly describe the respective solutions.

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[23] LG and Intel Develop and Pilot 5G Telematics Technology for Next Generation Cars // LG Newsroom URL: http://www.lgnewsroom.com/2016/02/lg-and-intel-develop-and-pilot-5g-telematics-technology-for-next-generation-cars/

[24] LG and Qualcomm to Jointly Research and Develop Next-Gen Connectivty Solutions for Cars // LG Newsroom URL: http://www.lgnewsroom.com/2017/10/lg-and-qualcomm-to-jointly-research-and- develop-next-gen-connectivty-solutions-for-cars/

[25] LG Partners with Swisscom to Bring 5G to Europe // LG Newsroom URL: http://www.lgnewsroom.com/2017/10/lg-and-qualcomm-to-jointly-research-and-develop-next-gen-connectivty-solutions-for-cars/

However, these technical solutions became central for building a strong competitive impact between 2006 and 2013 when the market featured only a small number of developers.

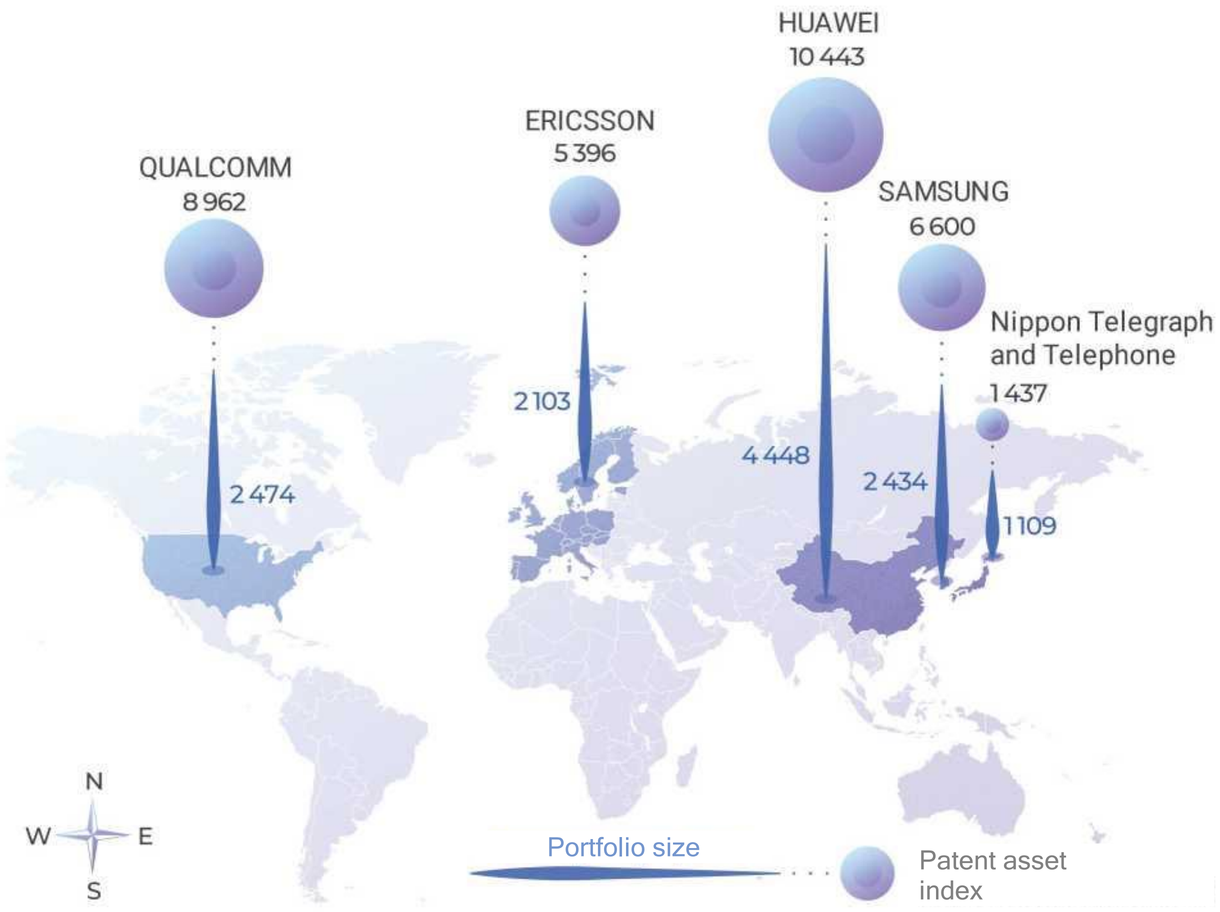
Japanese Sharp is another company that started building up its Patent Asset Index at early stages. The company aims to create an ecosystem of the future in which its cutting-edge developments in 8K (the latest ultra-high-definition television standard), 5G, and AIoT (a word invented by Sharp combining AI (Artificial Intelligence) and IoT (Internet of Things))[26] will directly interact. Sharp supports technologies that promote Smart Cities, which are bound to use 5G. In spite of the fact that the company's Patent Asset Index is lower than that of its competitors that are directly engaged in 5G, Sharp's strategic development model provides for long-term innovations, which can lead to an increase in its Patent Asset Index going forward when 5G technologies become widespread.

Accordingly, by 2017, the level of 5G development established a foothold for an abrupt increase in Patent Asset Indexes of those companies that had already contributed to relevant research and stimulated the launch of developments by other companies which had just joined the 5G innovative environment club At the same time, companies are attempting to occupy their own technological niches, establishing multiple cooperative relationships in the 5G segment to mitigate tight competition and streamline R&D costs.

Leading companies have been grouped by their country of origin and ranked for leadership in their regions. Huawei is the leader In China, and Swedish Ericsson in Europe. In the US the leading position is held by Qualcomm, and in South Korea by Samsung. Leading companies also include Japanese Nippon Telegraph and Telephone, which is the leader in its country.

[26] 8K + 5G and AIoT Solutions // Sharp Global URL: https://global.sharp/brand/globalevents/ifa2019/8k/?_ga=2.46253543.1325338551.1584786541-1496803126.1584786541

Figure 19 **The patent asset index of five leading companies**



The patent profiles of Huawei, Qualcomm, Samsung, Ericsson, and Nippon Telegraph and Telephone[27] are presented below.

[27] All economic data is taken from public sources and official publications, including Statista | Global No.1 Business Data Platform URL: https://www.statista.com/

HUAWEI

Founded in: 1987

Headquarters: Shenzhen, China

Headcount: 194,000 (2019)

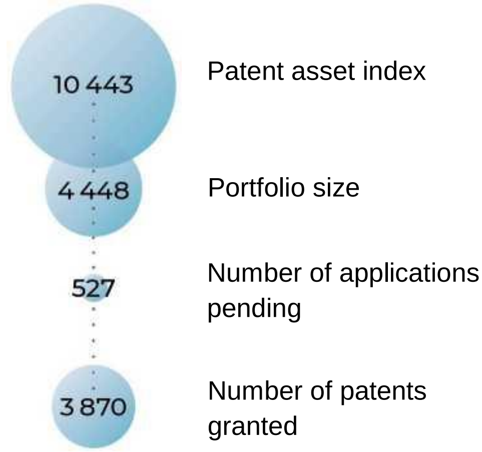
including 45% involved in R&D

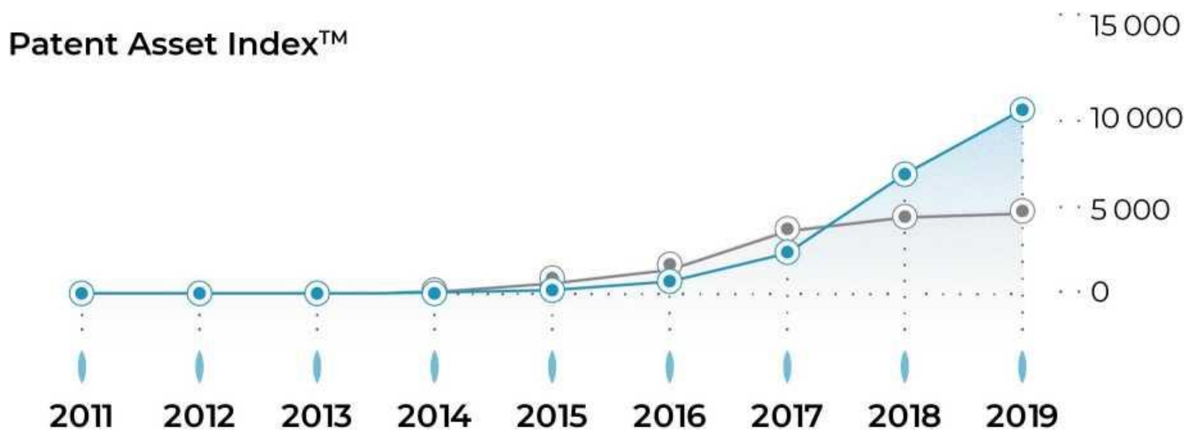
Annual income:

USD 121.72 billion (2019)

R&D expenses:

Over USD 15 billion





-- Portfolio size -- Patent Asset Index™

Huawei Technologies Co. Ltd. Is one of the world's largest telecommunications companies. Established in 1987 by Zhen Zhengfei, a former engineer of China People's Liberation Army.

Originally focused on the manufacturing of telephone switchboards, Huawei has expanded its business to include telecommunication networking, operational and advisory services, and equipment for enterprises within and outside China, as well as the manufacturing of communication devices for the consumer market. The company offers its products and services in more than 170 countries.

Huawei outperformed Ericsson in 2012 as the largest manufacturer of telecommunications equipment in the world and outperformed Apple in 2018 as the second largest smartphone manufacturer in the world after Samsung.[28]

The company has 21 research institutes in China, the US, Canada, the UK, Pakistan, Finland, France, Belgium, Germany, Colombia, Sweden, Ireland, India, Russia, Israel, and Turkey. Almost half of the company's employees are involved in research activities. Two out of five Huawei research groups in France are working on algorithms and standards for next-generation 5G networks. In 2018, the company stated it would increase its annual research and development (R&D) expenditures from USD 15 billion to USD 20 billion as it aspired to become the world leader in 5G technology.

The company's first families were registered in 2012, with its largest growth was demonstrated by 2017. Between 2015 and 2016, the number of families quadrupled, which led to a 3.5x growth of the Patent Asset Index for the company's entire portfolio in 2017, with the index growing faster and faster since then. Huawei is a leader in terms of the average growth rate of the Patent Asset Index since 2013 as compared to other leading companies. The number of its valuable technical solutions is likely to have increased over these years and have been mentioned in a large number of citations or brought to a large number of markets. At the same time, the growth rates of indicators in both charts over the entire period under review are gradually decreasing. This fact shows a direct correlation between the Patent Asset Index and the number of patent families in the patent portfolio's structure.

The Patent Asset Index is the sum of the competitive impact metrics for all families in a company's patent portfolio. Therefore, it is also important to consider the dynamics of the competitive impact index and its components – technology relevance and market coverage indexes.

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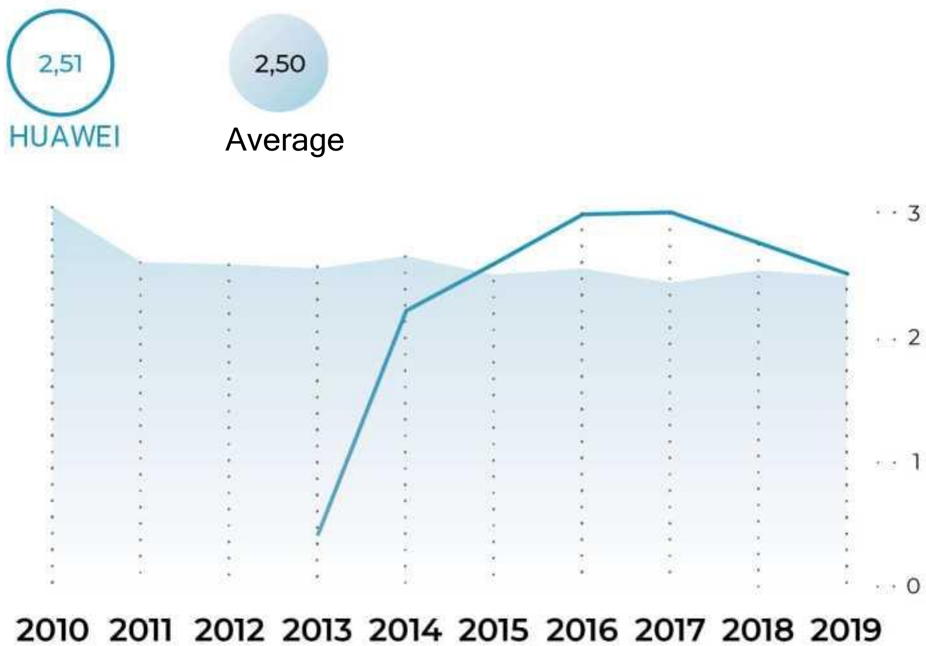
[28] Huawei planiruet obognat Apple i Samsung v 2019 godu (Huawei is planning to outperform Apple and Samsung in 2019 // Forbes.ru URL: https://www.forbes.ru/tehnologii/371641-huawei-planiruet-obognat-apple-i-samsung- v-2019-godu

Huawei’s Patent Asset Index

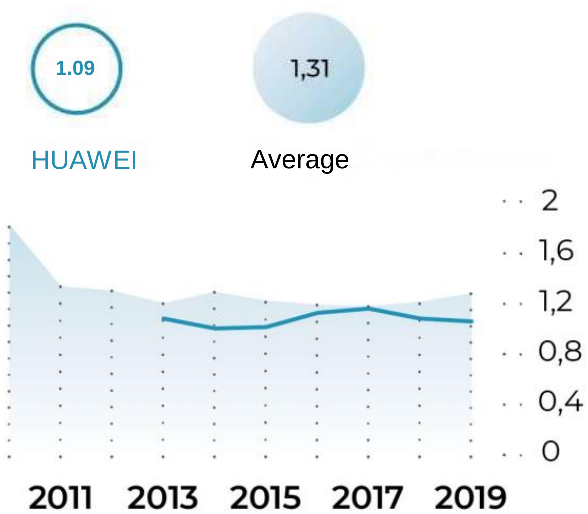
Figure 20

Competitive Impact™



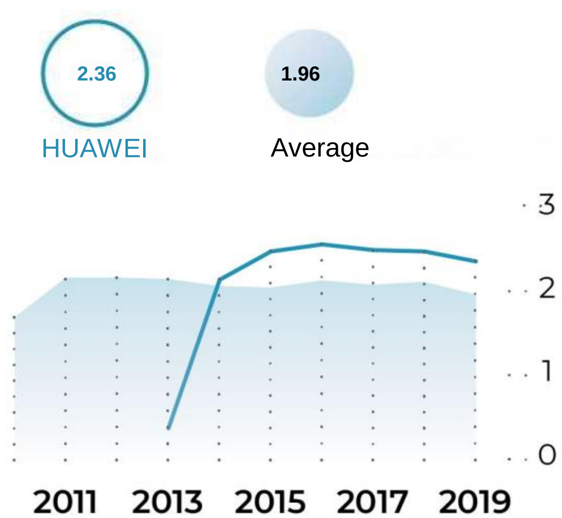
Competitive Impact™ - competitive influence

Technology Relevance™



Technology Relevance™

Market Coverage™



Market Coverage™

In 2014, the company abruptly increased its competitive impact in the field of 5G. The index continued to grow and exceeded the industry's overall figures in 2015. The maximum competitive impact was achieved in 2016 and 2017 when the company demonstrated the highest patent activity in creating SEP families. Currently, its index is in line with the average index, but data on applications published and patents granted will allow obtaining the most accurate figures for recent years. A decrease in the index at the end of the period under review may be due to an increase in the share of new patent families in the patent portfolio. Younger families have low geographical expansion and citation rates, which serve as components of the competitive impact index. Therefore, it is necessary to consider the metrics that make up the index.

Technology relevance is calculated based on the number of citations. According to PatentSight's methodology, the number of citations is adjusted depending on the patent's lifespan, the citation strategy of the patent office, and the technology segment. The adjustments are necessary because it is important to smooth out the effect of younger patents, which have not yet received sufficient citations, but may contain valuable solutions.

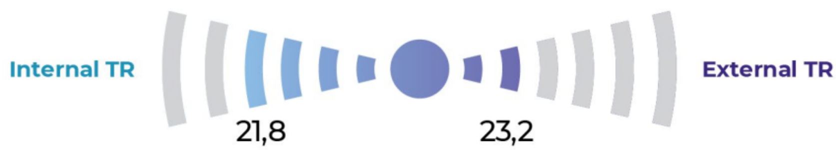
The analysis of the company's patent portfolio has revealed that the number of its patent families is growing quite rapidly. However, the average technology relevance level of other companies operating in this field is higher than that of Huawei. This is primarily due to the fact that new developments rarely start to be cited from the moment they appear, so there may be some time lag in calculating this metric (developments that appeared at the beginning of a period may have started to be cited much later).

At the same time, it should be noted that the metric's value of Huawei never falls below one. This means that, in any case, throughout the period under review Huawei's solutions had a greater impact on development of the technology than an average solution in the same area.

Families with the highest internal and external technology relevance have also been identified for Huawei (Figure 21).

Huawei's families with the highest ITR and ETR rates

Figure 21



CN106982458	US20170164349
2017	**2016**
Method and device for selecting network slices	Method and system for performing network slicing in a radio access network

75,5	Competitive Impact™	**72,9**
3	Market Coverage™	**2,8**
25	Technology Relevance™	**25,9**

The family with the basic publication CN106982458, *Method and device for selecting network slices*, has the highest internal technology relevance rate. The family is active. The priority date is claimed based on the first application filing date of the family in China (March 9, 2017). Currently, the family is patented only in China. The second application of the family was filed under the international patenting procedure PCT on February 23, 2018.

The invention describes a method and device for selecting network slices to address a prior art problem consisting in the inability to guarantee the user the same experience in a guest network as in its home network. Network slicing is considered, among others, in a 5G architecture environment.

The method contains the following phases:

- The first VPLMN SSF receives a slice selection request, and the slice selection request is used for the roaming terminal device. The slice selection request also includes condition information that the requested network slice should satisfy;

- the first SSF sends the condition information to a second SSF of the home public land mobile network (HPLMN);
- the first SSF receives the slice information sent by the second SSF that satisfies the condition information;
- the first SSF selects a second network slice for the terminal device based on the slice information of the first network slice.

There are 26 citations of the family, including 23 citations that belong to Huawei. The rest of the citations belong to ZTE, Nokia, and BBK Electronics. The competitive impact of this solution is quite high and is achieved mainly due to its technology relevance given that the market coverage of the family is low.

The family with the basic publication **US20170164349** *Method and system for performing network slicing in a radio access network* has the highest external technology relevance rate. The first application was filed with the US Patent Office on November 18, 2016, but priority is claimed in the provisional unpublished application S201562264629P dated December 8, 2015. The family includes four applications under the PCT international patenting procedure, which then enter national patenting phases in Japan, India, South Korea, Brazil, and China. Applications under the regional patenting procedure through the EPO have also been filed, for which patent protection is already in place in Germany, Austria, the United Kingdom, and Ireland.

The family is also part of network slicing methods. The invention describes a method and system of resource allocation in a radio access network, which includes association of each of the many services with a slice, which is allocated a unique set of network resources, and the transfer of information via the radio access network for at least one service using a slice associated with at least one service. The interface between the base network and the RAN is provided to allow traffic from the network core to be routed to user equipment through access points that may be 5G base stations.

The family US20170164349 is a SEP family and is cited by the same standards as the family US20160352551 (Appendix G. List of standards citing Huawei’s family with the basic publication US20160352551). .

Among the cited companies are Comcast, AT&T, Ericsson, Nippon Telegraph and Telephone, Verizon, Qualcomm, and others. At the same time, the competitive impact of this development is lower than that of CN106982458, because it emerged much earlier.

The market coverage of Huawei's developments includes 17 countries. Most of its patent documents are registered in China and under the PCT international patenting procedures. When performing an analysis, it is also important to take into account that market coverage is calculated for existing patents and applications pending examination, which means that younger families will have a slightly lower market coverage than those that have already been granted patents.

The company's market coverage is wider than the segment's average since 2014, while the maximum coverage was recorded in 2016 reflecting a large number of registered/active patent documents across different countries. It may also be highlighted that its market coverage has slightly decreased in recent years, indicating that there are young families in the patent portfolio where the geographical coverage strategies have not been implemented yet.

Huawei's cooperative ties

Table 4

Patent holder	Joint patent holder	Joint patent asset index	Joint portfolio size
Huawei	Tsinghua University (China)	17	8
Huawei	SUN WENQI	8	1
Huawei	University of Toronto	6	2
Huawei	Softbank	5	2
Huawei	University of Notre Dame	3	4
Huawei	POE WINT YI	3	1
Huawei	Rice University	1	2
Huawei	University of Texas System	1	1
Huawei	Xi´an Jiaotong University	1	1
Huawei	Fraunhofer	0	1
Huawei	AWEI TECH	0	1

The cooperative ties of Huawei, i.e. the companies with which it has joint 5G patents, were analyzed separately (Table 4).

Among them are Tsinghua University, Xi'an Jiaotong University (China), University of Toronto (Canada), University of Notre Dame (France), Rice University, University of Texas System (USA), as well as the Fraunhofer Society for the Advancement of Applied Research, and several individuals. Only 0.5% of all families of the company are patented together, while the patent asset index of joint patents is quite low. Most technical solutions, including the most valuable ones, are exclusively owned by Huawei.

Among the companies identified we have identified SoftBank, a Japanese holding company, which also operates in telecommunications. SoftBank is the first network operator in Japan that is planning to launch 5G services. SoftBank and Huawei conducted joint 5G network tests and even obtained joint patents. However, it was Finnish Nokia that was chosen as a strategic partner for 5G implementation, while Swedish Ericsson was announced as the supplier of equipment for radio access networks.[30]

Thus, Huawei is actively applying for new technical solutions, trying at the same time to obtain protection in foreign markets through international and regional patenting procedures. Meanwhile, the company focuses its technology in the national market to a large extent, which is characteristic of Chinese developers, as China's digital technology market is one of the leading markets. The company carries out almost all research and development using its own financial, human, and other resources.

[29] SoftBank to be 1st to launch 5G network service in Japan // ComSoc | Technology Blog URL: https://techblog.comsoc.org/2020/03/06/softbank-to-be-1st-to-launch-5g-network- service-in-japan/

[30] Huawei loses key 5G network customer as SoftBank turns to Nokia and Ericsson in JapaN // South China Morning Post URL: https://www.scmp.com/news/china/article/3012528/huawei-loses-key-5g-network-customer-softbank-turns-nokia-and-ericsson

QUALCOMM

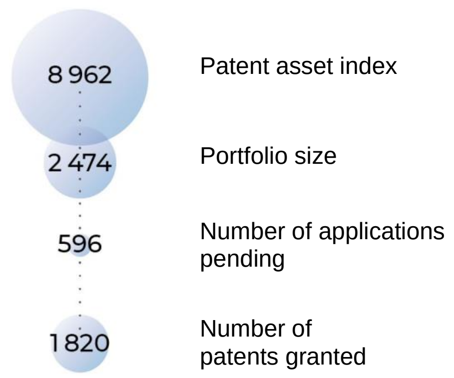
Founded in: 1985

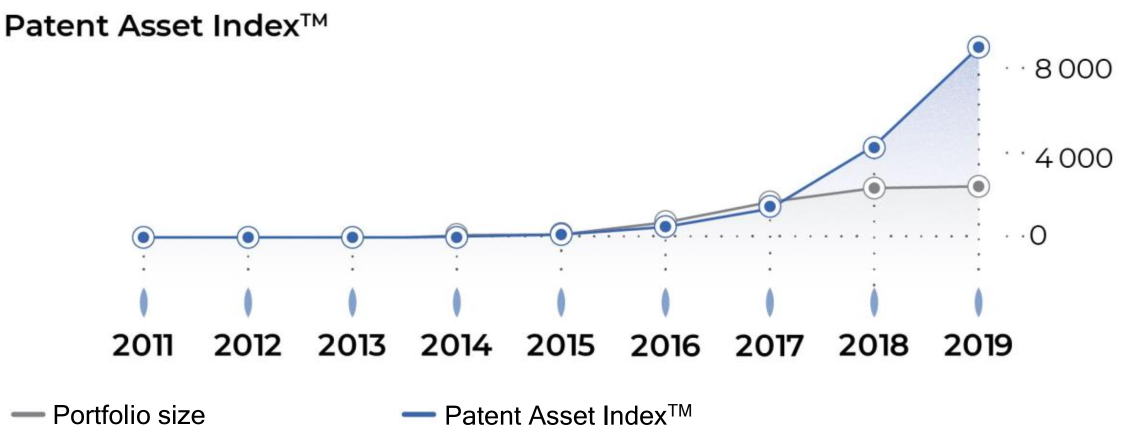
Headquarters: San Diego, California, US

Headcount: 41,000 (2019)

Annual income:
USD 24.27 billion (2019)

R&D expenses:
USD 5.4 billion (2019)





Qualcomm is an American multinational semiconductor and telecommunication equipment manufacturer, which develops and sells wireless communication products and services. The company receives most of its revenue from chipset production and patent licensing business. Qualcomm is best known for its chips that connect cell phones to networks, as well as Snapdragon processors, which are the "brain" of mobile devices.

The company is headquartered in San Diego, California, USA, and has 224 offices around the world. Its parent company is Qualcomm Incorporated (Qualcomm), which has several subsidiaries:

- Qualcomm CDMA Technologies (QCT) sells all Qualcomm products and services (including chipsets);
- Qualcomm Technology Licensing (QTL) is responsible for business licensing;
- Qualcomm Technologies, Inc. (QTI) manages most of Qualcomm's research and development activities.

The company has employees in more than 30 countries, including Europe, Argentina, Australia, Brazil, Canada, Egypt, India, Indonesia, Israel, Japan, Mexico, Russia, Singapore, South Korea, Taiwan, the USA, and Vietnam. In 2018, Qualcomm announced its plans to establish three technology and testing centers in Taiwan in collaboration with the government and Taiwanese enterprises to commercially develop 5G and other advanced technologies. The collaboration with Taiwanese companies is designed to help develop 5G-related technologies and accelerate the market entry of solutions. The centers are supposed to develop out-of-the-box solutions that will help small and medium-sized enterprises to enter the 5G market without exorbitant capital expenditures.[31]

The first families of the company were registered before 2010. Its highest patenting intensity was recorded since 2017. Similarly to Huawei, Qualcomm's patent asset index exceeded the portfolio size only in 2018. Between 2015 and 2017, the number of families increased threefold annually, which led to an increase in its patent asset index in subsequent years. The size of Qualcomm's patent portfolio is twice as smaller as the size of Huawei's patent portfolio, but its patent asset index is lower only by 15%. This situation indicates that the performance of many families in the patent portfolio of the American company exceeds the performance of the Chinese company's solutions, and, accordingly, have a greater competitive impact in the 5G segment.

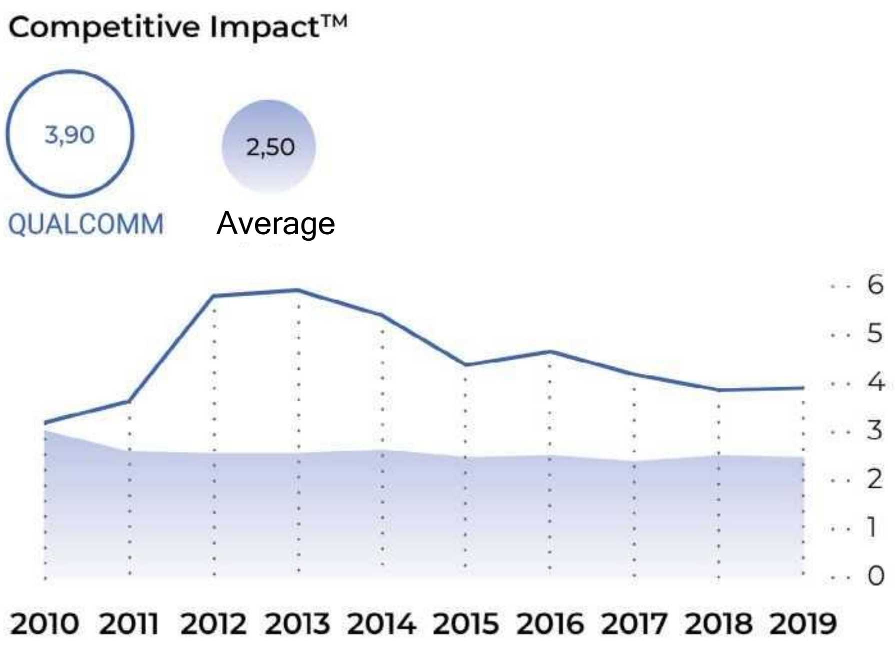
Qualcomm's competitive impact index was the highest between 2012 and 2014, when the market was in its infancy and the number of competitors in the industry was much smaller. The company then slightly lost its competitive position in the industry with the entry of such companies as Huawei, Ericsson, and others. On average, its competitive impact index has decreased by 34%. .

[31] Qualcomm to establish 5G R&D center in Taiwan // Telecom Asia URL: https://www.telecomasia.net/content/qualcomm-establish-5g-rd-center-taiwan

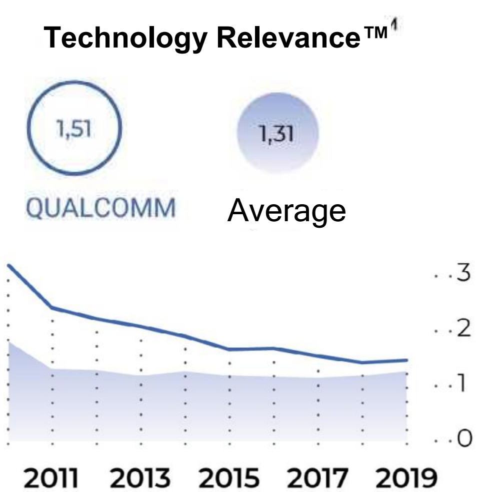
However, at present, the technical solutions in the company's patent portfolio, for which the index is calculated, are four times more powerful than the average patent in the same segment. The average competitive impact index per patent family was about 3.9.

Qualcomm's Patent Asset Index

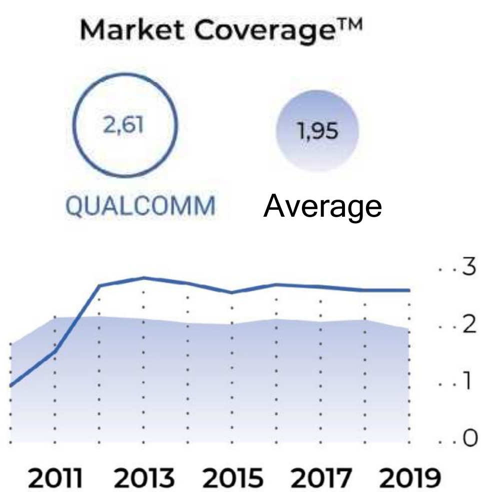
Figure 22



Competitive Impact™ – конкурентное влияние



Technology Relevance™

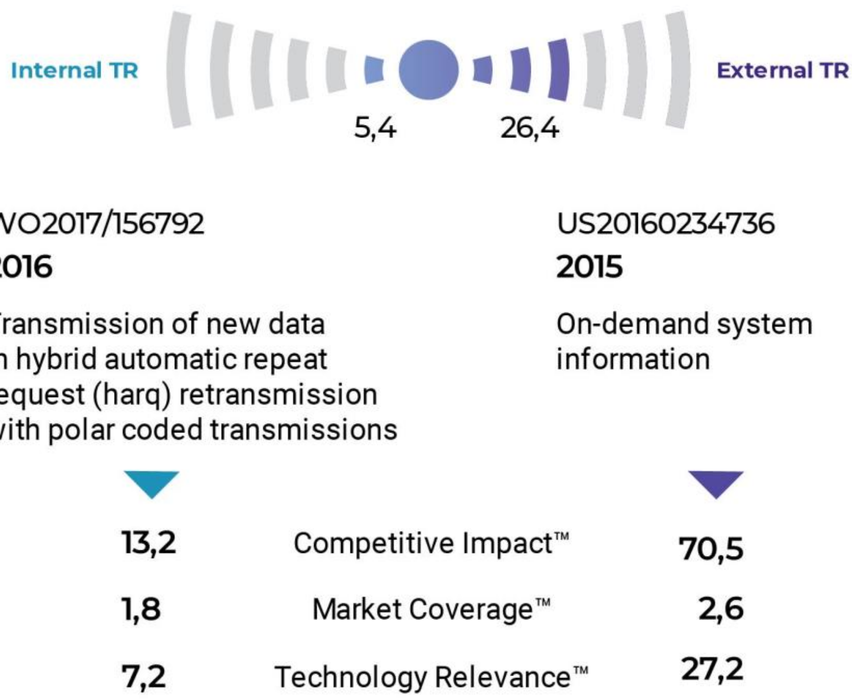


Market Coverage™

The technology relevance decreases throughout the period under review, which may be associated with an increase in the size of the patent portfolio (an increase in the share of young uncited families), despite the fact that, according to PatentSight's methods, the metrics are adjusted for the patent lifespan. This situation is possible, for example, when the patent lifespan is short, which is typical for this segment, since the majority of families emerged in 2016-2018. Accordingly, the technology is rapidly growing and the relevance of previous developments is declining.

Figure 23

Qualcomm's families with the highest ITR and ETR rates



Qualcomm has low internal technology relevance levels, because it rarely cites its own developments. The family with the basic publication **WO2017/156792** *Transmission of new data in a hybrid automatic repeat request (HARQ) retransmission with polar coded transmissions* has the maximum number of own citations. The family is active. The application filing date (under the PCT procedure through the Chinese patent office) coincides with the priority date of March 18, 2016.

The family has no granted patents, but it has applications under review in China, the US, India, and at the EPO.

The family describes the transmission of new data in a hybrid automatic repeat request (HARQ) with polar-coded transmission. To support communication with the use of polar codes, the incremental redundancy hybrid automatic repeat request algorithm (HARQ-IR) can provide increased throughput by including new information not based on the transmission of the original packet into the HARQ retransmission. The number of information bits in each HARQ retransmission can be monitored to control the trade-off between the increased bandwidth and reduced Block Error Rate (BLER).

This family is cited by Chinese Huawei and South Korean LG, while the Chinese company has more citations than self-citations. Its competitive impact index is low due to the low number of citations and a small geographical coverage.

The family with a high external technology relevance rate has a high competitive impact index as well as a higher market coverage index. The basic publication **US20160234736** *On-demand system information* is an American application filed on July 20, 2015. Priority is claimed in the provisional unpublished application US201562114157P dated February 10, 2015. The family uses international (PCT) and regional (EPO, EAPO) application procedures. Its patents are granted in Australia, the USA, and Taiwan, with applications pending examination in Brazil, China, India, Japan, South Korea, Tunisia, and the EPO and EAPO.

The technical solution relates to wireless communication systems, and more specifically to the transmission of on-demand system information in a wireless communication system that has a user equipment (UE oriented network. The wireless network can provide system information either by means of a fixed periodic broadcast, or by means of a broadband transmission or in response to a request from user equipment (UE). The wireless network can transmit a signal that indicates to user equipment within its coverage area that system information must be transmitted in line with a fixed periodical schedule or in response to a request sent by user equipment.

The described technology is also applicable to next-generation 5G communication networks.

The family has 55 citations including by Sharp, Apple, NEC, Sony, Huawei, LG, ZTE, and many others. The family is also cited in ETSI-TS-38-331 *5G; NR; Radio Resource Control (RRC); Protocol specification*, indicating that it belongs to the 5G SEP families.

The market coverage of Qualcomm's technologies has been consistently high since 2012, which indicates that the company has been implementing strategies of wide geographical expansion of its technical solutions throughout the entire period (2012–2019). Such strategy allows the company to have 25% more geographical coverage of its solutions than the average coverage of other companies in this segment.

Table 5

Qualcomm's cooperative ties

Patent holder	Joint patent holder	Joint patent asset index	Joint portfolio size
Qualcomm	NORTON ROSE FULBRIGHT US LLP	4	1
Qualcomm	OPENET TELECOM LIMITED	4	1
Qualcomm	MANOKAKOS ALEXANDROS	3	1
Qualcomm	Clorox	3	1

The company conducts scientific research mostly on its own, as evidenced by the small number of joint patents. Single cases have been revealed with international law firm Norton Rose Fulbright, Irish software provider Openet, American consumer products manufacturer Clorox, and Manokakos Alexandras, an individual.

Qualcomm made a significant contribution to the creation of the 5G market formation and the development of 5G technologies at early states, which has resulted in its high competitive level. At the same time, the company is striving to provide maximum geographical coverage for its developments, securing strong partnerships with leading companies in promoting 5G technologies around the world.

SAMSUNG (Electronics)

Founded in: 1969

Headquarters: Samsung Town, Seoul, South Korea

Headcount: 309,630 (2018)

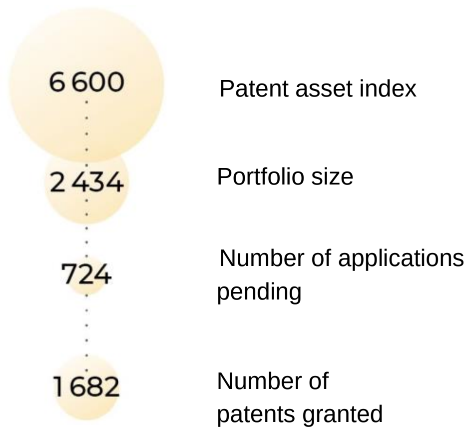
Over 10,000 in R&D

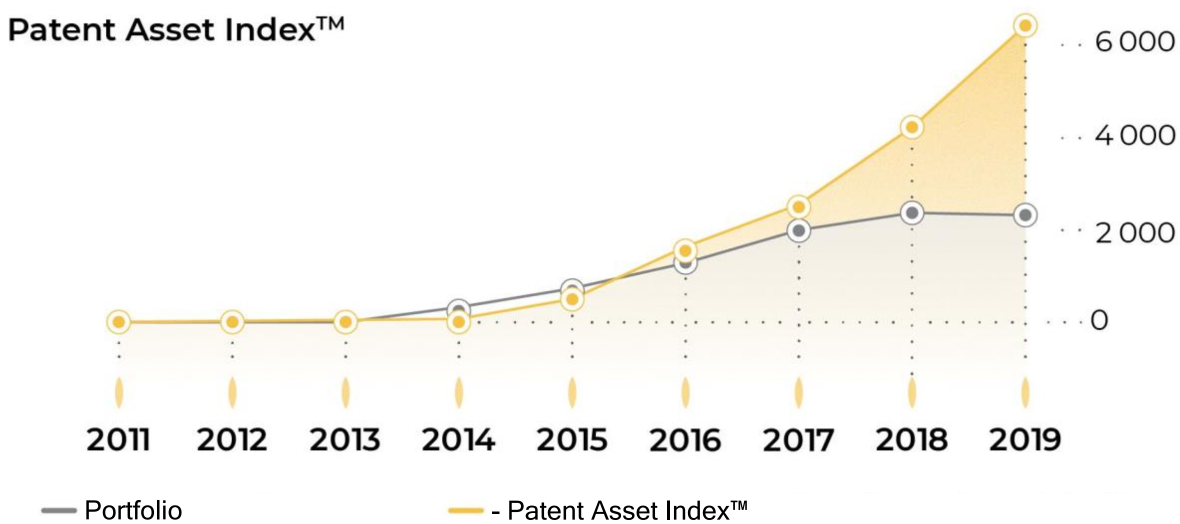
Annual income:

USD 206 billion (2019)

R&D expenses:

USD 17.5 billion (2019)





Samsung is a South Korean multinational conglomerate headquartered in Samsung Town, Seoul. Samsung Company was founded by Lee Byung Chul in 1938 as a trading company. Over the next three decades, its operations were diversified into food, textiles, insurance, securities, and retail sectors. Samsung entered the electronics industry in the late 1960s as Samsung Electronics.

Currently, Samsung Electronics is a sectoral branch of Samsung. Samsung Electronics is the world's largest IT company, consumer electronics manufacturer, and chip manufacturer, which will be discussed in this section.

Samsung is a major manufacturer of electronic components such as lithium-ion batteries, semiconductors, chips, image sensors, camera modules, and flash memory devices for customers such as Apple, Sony, HTC, and Nokia. The company is the world's largest manufacturer of cell phones since 2011, as well as the world's largest memory microchip manufacturer. In July 2017, Samsung Electronics overtook Intel as the largest semiconductor chipset manufacturer in the world. In May 2013, Samsung announced that it successfully tested the 5G technology with increased speed. Samsung has been an active 3GPP member for over 20 years and leads the technical development of 4G LTE standards. Building on its experience and technical leadership gained over many years, Samsung began standardizing 5G in September 2015.

Samsung Electronics has manufacturing capacities and sales networks across 80 countries with over 300,000 employees worldwide.

All its research and development activities are conducted by a special division, Samsung Research. Samsung Research works in cooperation with 14 foreign research centers in 12 countries (the USA, the UK, Russia, Israel, Poland, Ukraine, Jordan, India, Indonesia, Philippines, China, and Japan) and 7 global Artificial Intelligence centers (in the USA, Russia, South Korea, Canada, and the UK) to speed up implementation of innovative technologies and expand its global research and development capabilities. This strategy maximizes technology collaboration through active open innovation with renowned universities, research institutes, and partner companies around the world. Over 10,000 employees worldwide are involved in research.

One of Samsung Research Russia's research centers is based in Moscow. The center hosts a research laboratory focusing on artificial intelligence (AI) and collaborating with leading research organizations in Russia.

The research center is actively developing 5G solutions. Samsung pioneered mmWave for 5G and led the development of major 5G technologies such as massive MIMO, beam formation, and LDPC channel coding.

In 2020, the company expects the demand for SG devices to grow due to the expansion of the fifth generation network worldwide.[32] In the network equipment segment, Samsung participates in the expansion of 5G coverage in South Korea and plans to contribute to the growth of the technology in other global markets, such as the US and Japan.

In 2020, the company will expand its line of differentiated products such as single-chip 5G systems based on 5- and 7-nm EUV technologies, or products with high resolution – 108+ Mp image sensors. In 2020, demand for application processors, radio frequency equipment and high-resolution image sensors is expected to soar due to the growth of the 5G market.

Unlike Huawei and Qualcomm, the company's patent asset index began to exceed the size of the patent portfolio as early as in 2016, reflecting Samsung's earlier research, which was a breakthrough amidst weak competition in the area.

There is also a balanced growth in Samsung's patent portfolio between 2013 and 2018 when the average annual growth rate of its families was 48%. The decrease in patenting in recent years is due to a 18-month delay in publications.

At the same time, the growth rate of the its patent asset index has not been uniform throughout the period. A maximum growth in the patent asset Index has been recorded starting from 2018 when the growth of the company's patent portfolio began to slow down. This situation is due to the increasing competitive impact of previously patented technologies due to the increase in the number of its components.

For instance, the competitive impact index of the company since 2012 has been exceeding the average competitive impact in the region. The maximum increase in the competitive impact is observed by 2016. After that, there was a certain decline in the competitive impact associated with a large number of companies entering the market in 2017 and 2018.

[32] Samsung Electronics obyavlyayet finansoviye rezultaty tretyego kvartala 2019 goda (Samsung Electronics announces the financial results for 2019) // Samsung Newsroom URL: https://news.samsung.com/ru/ samsung-electronics-announces-financial-results-for-the-third-quarter-of-2019-2

It should be noted that Samsung’s competitive impact in 5G increased again in 2019, primarily due to an increase in its technology relevance index.

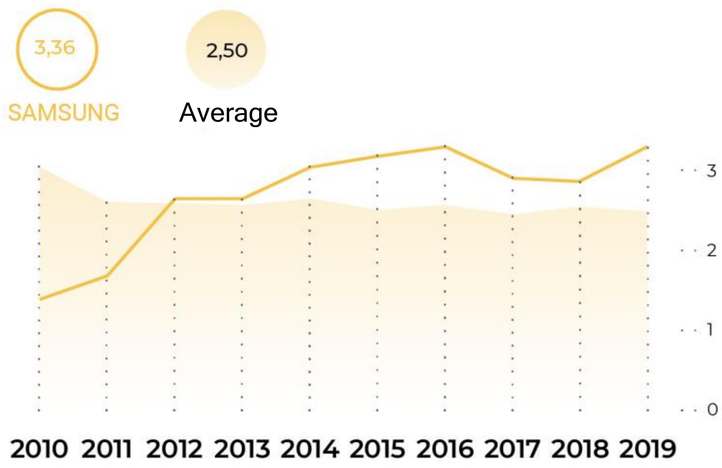
Samsung has a longer period of maintaining its patents in force as compared to competitors due to a longer retrospective of 5G research while many of its new technologies are cited by other companies. This performance conditioned the growth in the technology relevance index in 2018 and 2019. It should be noted that until 2015 the technology relevance index of Samsung was less than the average values in the segment, but in 2014 it began to rapidly grow due to an increase in external citations.

At the same time, the company’s market coverage index demonstrates the opposite dynamics. From the beginning of the period under review and until 2017, the geographical coverage of the company’s solutions was quite wide and exceeded the average coverage of its competitors’ solutions. The maximum index level was reached in 2013 and was 2.5 times higher than that of the average patent in the segment. However, after that the coverage of the company's developments began to decline and in 2018 it was lower than the average level of its competitors’ indexes. This situation may be due to the fact that in recent years the company did not claim priorities for younger families, which significantly reduced the number of newly emerging families in terms of priority dates over these years, which has, accordingly, affected all related indicators.

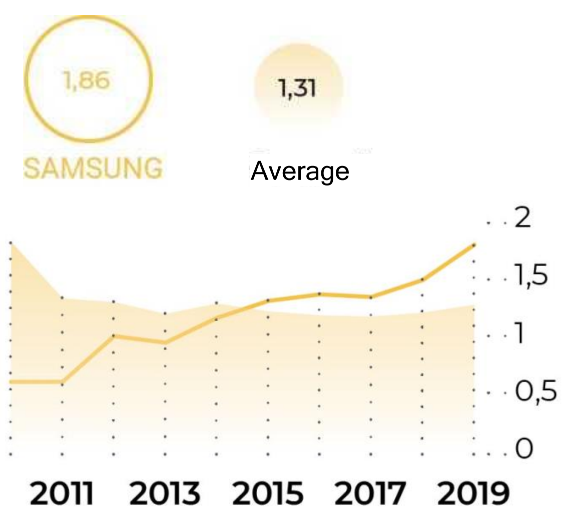
Samsung's Patent Asset Index

Figure 24

Competitive Impact™

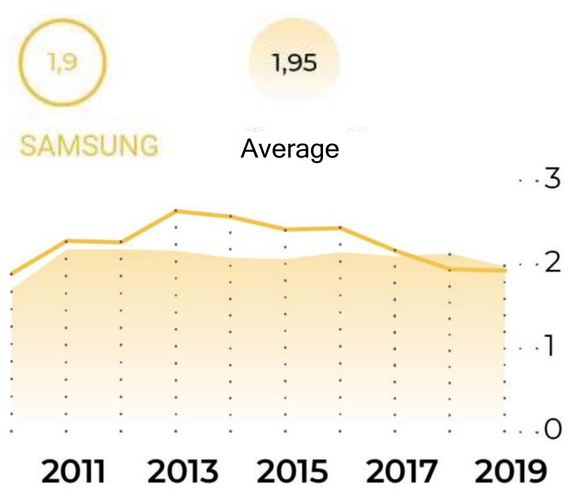


Technology Relevance™



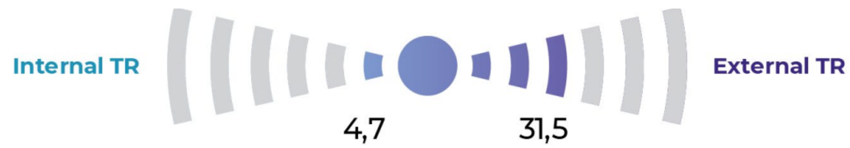
Technology Relevance™

Market Coverage™



Market Coverage™

Figure 25 **Samsung's families with the highest ITR and ETR rates**



KR20160125708
2015
Method and apparatus for transmitting and receiving image data for virtual-reality streaming service

US20170188391
2016
Methods and apparatus for resource collision avoidance in device to device communication

KR20160125708		US20170188391
37,6	Competitive Impact™	**62,9**
2,2	Market Coverage™	**1,7**
17,1	Technology Relevance™	**36**

We identified Samsung's families that have the highest internal and external technology relevance rates. It should be noted that all families with self-citations also demonstrate quite high external technology relevance indexes. Moreover, self-citation levels in such families are always lower than citations of Samsung's solutions by third parties.

The family with the basic publication **KR20160125708** *Method and apparatus for transmitting and receiving image data for virtual-reality streaming service* has the highest internal technology relevance index. The family is active and its priority date is the same as the date of filing the application with the South Korean Patent Office (April 22, 2015). The family contains a PCT application for which a patent has been granted in the USA. Some applications are pending examination in China, Korea, and at the EPO.

The invention relates to the communication method to convert IoT technology to a 5G communication system to support higher data transfer rates than in a 4G system. The technical solution can be applied to intelligent services based on the 5G communication technology and IoT related technology (e.g. smart homes, smart buildings, smart cities, etc.).

A method for receiving image data for a virtual-reality streaming service by an electronic device according to an embodiment of the present invention comprises: a step in which the electronic device determines whether to execute an adaptive virtual-reality streaming service on the basis of a bandwidth state; and a step in which, if it is determined to execute the adaptive virtual-reality streaming service, the electronic device requests and receives, from a server, the image data for the adaptive virtual-reality streaming service on the basis of head-tracking information and bandwidth information collected in advance.

The family is a SEP family. It is cited by ETSI-TR-26-918 as well as by companies such as Google, Microsoft, LG, and others. It should be noted that this technical solution is an example of 5G networks applied outside the perimeter of traditionally associated technologies, which creates the basis for developing complex technical solutions and a wide range of industry applications.

This family with a high competitive impact also has a high external technology relevance index. At the same time, its geographical coverage index is lower than that of the prior family. The basic publication is the US publication **US20170188391** *Methods and apparatus for resource collision avoidance in vehicle to vehicle communication* with a filing date of December 16, 2016. Priority is claimed in the US provisional unpublished application US201562272045P dated December 28, 2015. The family is active. The patent has been granted only in the United States so far. At the same time, an application was filed under the PCT procedure, while the national phase was entered only in South Korea. Also through this procedure, an application was filed with the European Patent Office. All of them are currently pending examination.

The patent documents describe methods and apparatus for resource collision avoidance in vehicle-to-vehicle communication. The method to sense the first vehicle’s user equipment (UE) for collision avoidance in a wireless network comprises:

– receiving a set of scheduling assignment (SA) information allocated to a set of second vehicle UEs;

- decoding the set of SA information, each of which includes SA information to each of the set of second vehicle UEs. The SA information performs energy sensing operation for resources to be used to determine additional potential SA transmission;
- determining available resources for the data transmission from the first vehicle UE based on the performed energy sensing and SA sensing;
- skipping a channel sensing operation on at least one subframe that is used for the data transmission from the first vehicle UE;
- transmitting data among resources identified as unused in next transmissions from second vehicle UEs.

Such vehicle-to-vehicle communication can be carried out in next-generation 5G networks.

The family is also a SEP family and is cited in ETSI- TS-36-213 *LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures*. The family has 53 citations, including those by Ericsson, Intel, Huawei, Qualcomm, BBK Electronics, and Nokia. This technical solution also represents an option for sectoral application of 5G technology.

Samsung's strategy with regard to research and development activities is demonstrated by a large number of its joint technical solutions with various universities. South Korean Yonsei University has the largest number of such joint patents. However, the highest joint patent asset index was identified with Sungkyunkwan University, the oldest university in South Korea, and Korea Advanced Institute of Science and Technology (KAIST), the leading academic and research university in South Korea, which regularly hires international faculty members, including from the United States. Samsung has strong cooperative relations with Korean research institutions. Apart from leaders, this list also includes Korea University, Seoul National University, Pohang University of Science and Technology (Postech), Chonnam National University, Hanyang University, Ulsan National Institute of Science and Technology, and Inha University.

Thus, the company has strong cooperative ties with research organizations in the national market, which ensures the effective distribution of financial and human resources in the company's research efforts. In addition to South Korean universities, Samsung has joint patents with the University of California (USA) and Delhi Technological University (India), which are due to the presence of its research centers in these regions.

Samsung's cooperative ties

Table 6

Patent holder	Joint patent holder	Joint patent asset index	Joint portfolio size
Samsung	Sungkyunkwan University	33	16
Samsung	Yonsei University	29	33
Samsung	Korea Advanced Institute of Science and Technology	27	18
Samsung	Korea University	17	17
Samsung	Seoul National University	12	11
Samsung	Pohang University of Science and Technology	11	8
Samsung	University of California	8	3
Samsung	Delhi Technological University	5	3
Samsung	Chonnam National University	3	2
Samsung	Hanyang University	2	2
Samsung	Ulsan National Institute of Science and Technology	1	1
Samsung	Inha University	1	1

Thus, Samsung implements cooperative strategies involving leading research organizations to effectively implement its innovative technologies and expand the global coverage of its developments. In recent years, Samsung's developments cause an increasing interest from its 5G competitors, and as a result, they are positioned as basic technical solutions for 5G.

ERICSSON

Founded in: 1876

Headquarters: Stockholm, Sweden

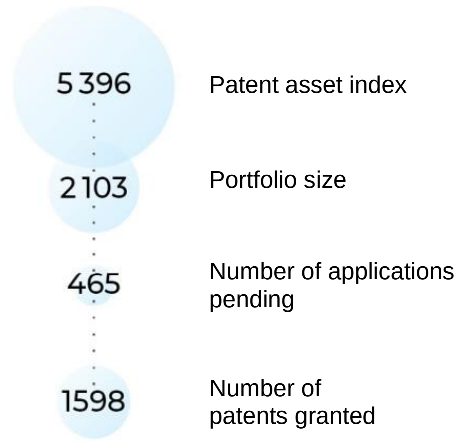
Headcount: 99, 417 (2019)

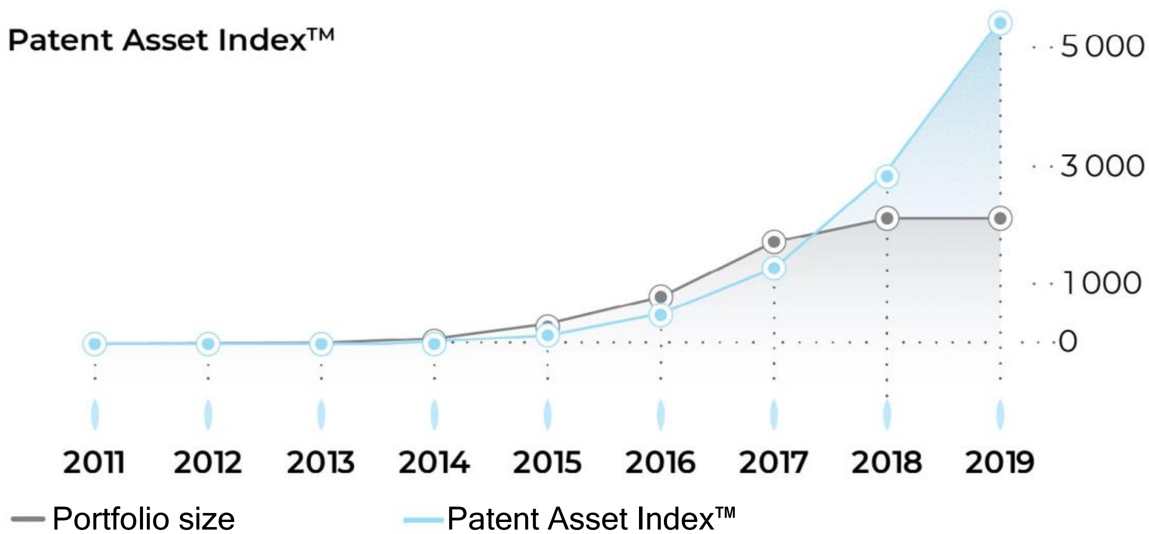
Annual income:

USD 24.03 billion (2019)

R&D expenses:

USD 3.76 billion (2019)





Ericsson is a Swedish international network and telecommunications company, which offers ICT services, software and infrastructure for telecom operators, traditional telecommunications equipment and internet (IP) equipment, mobile and fixed broadband services, etc.

The company was founded by Lars Magnus Ericsson in 1876. Since 2016, its headquarters are located in Stockholm, Sweden. The company employs almost 100 thousand people, and operates in about 180 countries. As at September 2019, Ericsson had more than 49,000 granted patents, including multiple patents related to wireless communications.

Ericsson is the first company to launch live commercial 5G networks across four continents. To date, 70 percent of the leading service providers assessed via global public 4G network tests use Ericsson radio stations and base bands, which are key to 5G performance. The company maintains cooperative ties with six of its six chipset providers, enabling 5G technology development to support a variety of devices. Ericsson has partnered with many carriers around the world who have already signed contracts to build commercial 5G networks. These include AT&T, Verizon, KT, T-Mobile, Vodafone, SK Telecom, US Cellular, and many others.

Ericsson has structured its research and development on three levels, depending on whether the products or technologies will be presented to customers and users. Its research and development arm is part of Group Function Technology and covers several aspects of network architecture: wireless access networks; radio access technologies; broadband technologies; packet technologies; multimedia technologies; service software; electro magnetic interference (EMI) safety and stability; and global services. Group Function Technology cooperates with several major universities and research institutes, including Lund University in Sweden, Eötvös Lorand University in Hungary, and Beijing Institute of Technology in China. Ericsson is also involved in research collaboration under several European research programs such as GigaWam and OASE. The company is also the European leader by the number of patents related to GSM / GPRS / EDGE, WCDMA I HSPA and LTE standards (SEP patents).

Ericsson is the leading contributor in the 3GPP's key RAN1 and RAN2 working groups, receiving over 16% of all 4G and 5G approvals. Ericsson also filed a groundbreaking 5G patent application in the second quarter of 2016, in which numerous inventions were integrated into a full 5G network architecture (**US20170331670** and **US20170331577**).[37] This application was the largest patent application for a cellular communications patent from the point of view of the number of inventors (130). [33]

[33] Ericsson files landmark 5G patent application // Ericsson | A World of Communication URL: https://www.ericsson.com/en/news/2017/11/ericsson-files- landmark-5g-patent-application

Japanese SoftBank will deploy radio access network equipment, including products from the product mix of Ericsson's radio system, which will allow it to improve the existing LTE network when optimizing 5G network.[38] SoftBank and Ericsson have been testing 5G technology since 2015 and have since expanded their cooperation to include 5G testing in several bands, including 28 GHz and 4.5 GHz. At the same time, SoftBank will deploy Nokia's 5G AirScale technology throughout Japan, which will enable it to offer 5G mobile broadband services, ultra-reliable low-latency communication (URLLC), and enhanced machine type communication services (eMTC).

The most active phase of patenting for the company was recorded in 2017, after which its intensity growth rates significantly decreased, which may be due to an 18-month delay in publications. At the same time, the company's patent asset index begins to increase intensively from 2017, exceeding as a result the overall number of families in 2018. The average growth rate of the patent asset index is 5% lower than that of other leading companies. The company's active involvement in the development of 5G standards allows it to implement a large number of fundamental solutions and effectively develop patent claims to overcome legal barriers and patent its inventions. This is evidenced by the high share of granted patents in the company's patent portfolio as compared to competitors.

In the context of the company's innovative development, the dynamics of its patent asset index depends on the competitive impact index of the company's solutions. Almost throughout the period under review, Ericsson's competitive impact index has been slightly higher than the average index across the region, while in 2018 it was even below the average. However, we should take into account that if the index is higher than one, then the company's technical solutions will in any case have a greater competitive impact (in this case higher by 2.7 times) than the average solution in the segment.

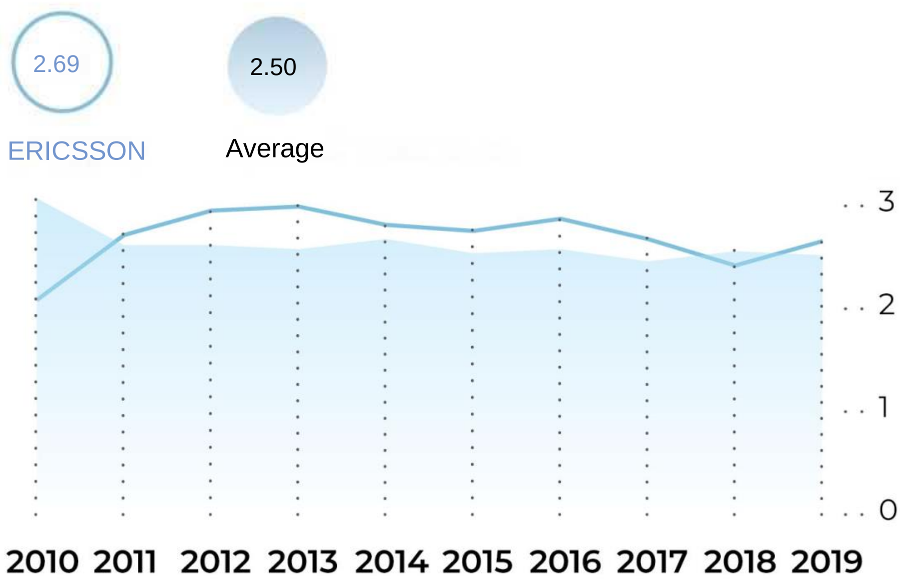
The competitive impact index measures the usefulness of a patent for creating a sustainable competitive advantage. This usefulness consists of the technology relevance at the current level of market development and the extent to which such competitive advantage is used in large markets, which is measured as "market coverage".

[34] SoftBank signs 5G deals with Ericsson, Nokia // Telecom Asia URL: https://www.telecomasia.net/content/softbank-signs-5g-deals-ericsson-nokia?src=related

Ericsson's Patent Asset Index

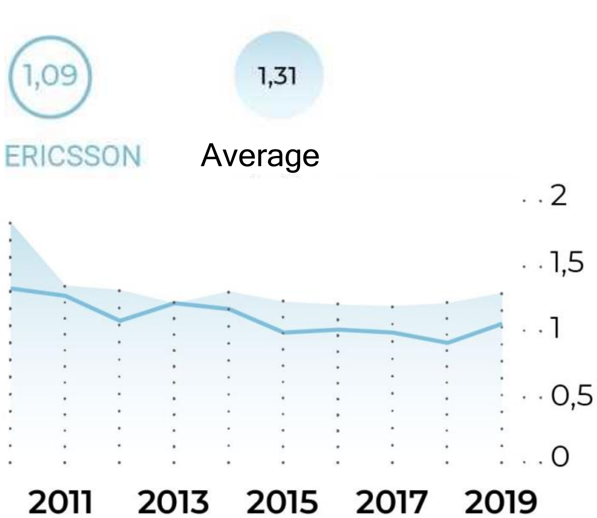
Figure 26

Competitive Impact™



Competitive Impact™

Technology Relevance™



Technology Relevance™

Market Coverage™

Market Coverage™

The technology relevance index showed varied trends over the period, but the overall trend is negative. On average, the index decreased by 17% over the entire period. The company's maximum technical relevance was recorded in the beginning of the period under review and in 2013. Patents related to the beginning of the period mainly describe 4G-related technologies, but could be applied to next-generation networks as well. The company's lowest index was recorded in 2018. Accordingly, the decrease in competitive impact was primarily due to a reduction in Ericsson’s technology relevance index.

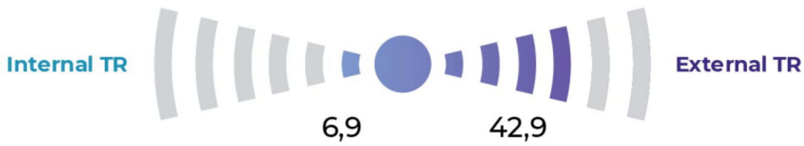
Its geographical coverage index also shows divergent trends during the period under review. For instance, from 2012 to 2014, the dynamics was negative, while between 2014 and 2016 it suddenly became positive. However, the company’s overall index level is quite high and exceeds the average index levels of its competitors operating in the region, including all leading companies (except Qualcomm). It may be noted that high competitive impact levels of the company are supported by the wide geographical coverage of its developments, as well as by a large share of families with granted patents. The market coverage index peaked in 2016, which also saw the largest number of families with patents granted to the company. Some decline in recent years may be due to young families with a small geographical coverage and applications pending examination, as well as to families that have no published applications so far.

Similarly to Qualcomm, Ericsson’s families have low internal technology relevance rates, i.e. low self-citation levels.

The family **WO2016/141961** *Formation of angular pattern with the use of antenna device* has the highest internal relevance index while having a wide geographical coverage and being included in the ranking by the number of jurisdictions covered (Table 2). At the same time, the relevant technical solution has a low external relevance rate due to the low number of its citations by other companies. Besides self-citation, only Chinese Huawei is present here. Despite this family has an average competitive impact level due to applications filed in a large number of jurisdictions, including through international and regional patenting procedures.

Qualcomm's families with the highest ITR and ETR rates

Figure 27



WO2016/141961		US20170331670
2015		**2016**
Beam forming using an antenna arrangement		User equipment procedures to control uplink beamforming
27,4	Competitive Impact™	**141,8**
3,3	Market Coverage™	**3**
8,3	Technology Relevance™	**47,4**

The family with the basic publication **US20170331670** *Network architecture, methods, and devices for a wireless communications network*, which is included in the ranking for both its maturity and strength indexes (Table 2 and Table 3) has the maximum external technology relevance level. The family has a high technology relevance index and high competitive impact in the 5G segment. A total of 132 citations have been identified, including 11 self-citations.

Ericsson's cooperative ties

Table 7

Patent holder	Joint patent holder	Joint patent asset index	Joint portfolio size
Ericsson	Toshiba	5	1
Ericsson	Maeaettanen Helka Liina	3	1
Ericsson	Zheng Yanli	2	1
Ericsson	IBM	1	1

Despite the fact that Ericsson claims to cooperate with research organizations, its patent portfolio contains almost no joint developments. Therefore, it can be assumed that its terms of cooperation specify that all intellectual property resulting from these efforts and can be formalized and protected under applicable laws will belong to Ericsson. At the same time, the company has joint patents with large companies such as Japanese Toshiba and American IBM, as well as with individuals. The patent asset index of these portfolios is also insignificant.

Ericsson is the European leader in terms of the number of families in its portfolio, the number of patents granted, the patent asset index, the market coverage of its patent portfolio, and the number of submissions for 5G standardization to 3GPP. All this positions the company as an active developer of technologies (and standards). However, the company's technology relevance index is lower than that of its competitors due to its low citation rate. Taking this fact into account, it is necessary to bear in mind that the citation strategies of patent offices differ, with American publications usually receiving the highest citation rates, as the USA is one of the most competitive markets, and the requirements for the drafting of American patent documents are among the strictest.

NIPPON TELEGRAPH AND TELEPHONE CORPORATION

Founded in: 1952

Headquarters: Tokyo, Japan

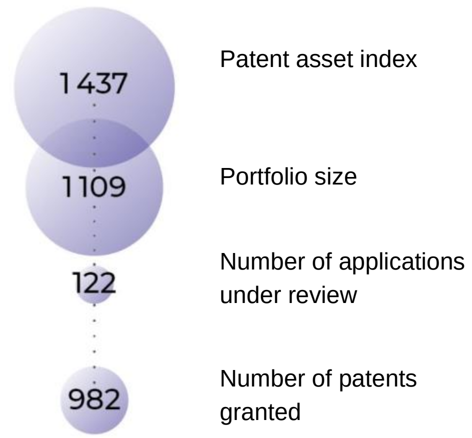
Headcount: 282 550 (2018)

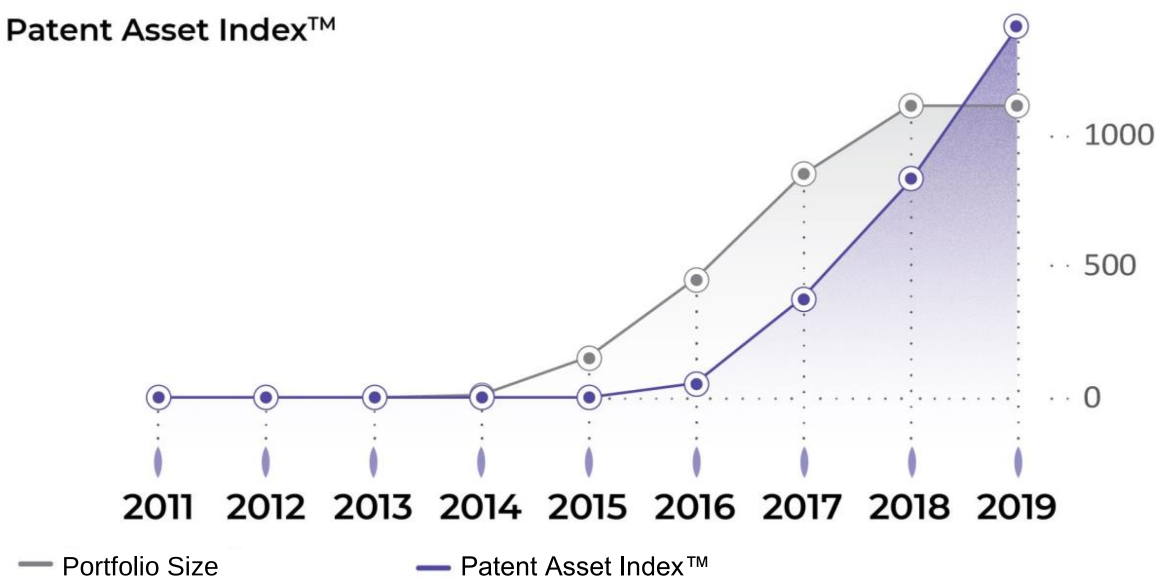
Annual income:

106.9 USD billion (2018)

R&D expenses:

1.9 USD billion (2017)





Nippon Telegraph and Telephone Corporation is a Japanese telecom corporation widely known as NTT. Its headquarters are located in Tokyo, Japan. The company was founded in 1952 as a state monopoly for telecommunication services in Japan and became a private company only in 1985. The Japanese government still owns about one third of NTT's shares.

The company ranks 55th in Fortune Global 500, being the fourth largest telecommunications company in the world by revenue, and the fifth largest public company in Japan after Toyota, Mitsubishi Corporation, Honda, and Japan Post Holdings as of September 2019.

The company owns four research centers. Three of them are located in Japan (Service Innovation Laboratory Group, Information Network Laboratory Group, and Science and Core Technology Laboratory Group), and the fourth, NTT Research center, in Palo Alto, California, USA.

In August 1991, the NTT Docomo branch was separated from Nippon Telegraph and Telephone (NTT) to take over the functions of a mobile operator. By 2010, NTT Docomo became Japan's largest mobile operator. The company is the author of the W-CDMA technology and mobile i-mode services.

NTT Docomo has been engaged in 5G research since 2010 and currently holds discussions on 5G across various research institutes and projects around the world. To date, more than 150 of its articles have been published at international and national conferences and in magazines. In addition, the company's website contains the *5G White Paper*[35] (2014), which outlines the company's principal goals and objectives for the implementation of a 5G communications network in Japan in time for the Tokyo Olympics in 2020. NTT Docomo is also conducting research and development to provide a wide range of 5G capabilities to support future expansion of M2M communications and the Internet of Things (IoT). To this end, NTT Docomo is conducting pilot tests in collaboration with leading global suppliers to confirm the feasibility of a wide range of 5G mobile communication technologies.

In 2019, NTT Docomo and a provider of glass solutions, AGC Group, partnered with Ericsson to complete what companies consider to be the world's first 5G communication test using a built-in glass antenna.[37] According to the companies, the glass antenna prototype is able to overcome the problems associated with the fact that the 5G broadband spectrum is unable to penetrate through windows.

[35] Docomo 5G White Paper // NTT DOCOMO Home URL: https://www.nttdocomo.co.jp/english/corporate/technology/whitepaper_5g/index.html

[36] NTT Docomo 5G Trials: List of Publications // NTT DOCOMO Home URL: https://www.nttdocomo.co.jp/english/binary/pdf/corporate/technology/rd/tech/5g/docomo_5GTrials_List_of_Publications_English.pdf

[37] Docomo, Ericsson complete 5G glass antenna trial // Telecom Asia URL: https://www.telecomasia.net/content/docomo-ericsson-complete-5g-glass-antenna-trial

It can potentially be attached to window surfaces in buildings, vehicles, and railroad cars to provide a stable high-speed 5G connection in indoor environments.

In January 2020, NTT Docomo released an official document on 6G (sixth generation mobile communication systems), which the company plans to launch on a commercial basis by 2030. The White Paper[38] summarizes the relevant technical concepts and expected various options for the use of the evolving 5G and new 6G communication technologies, as well as technological components and performance targets.

The company's 5G patent portfolio has significantly grown after 2014, just after the publication of the *5G White Paper*. The positive trend established in the following years features an average growth rate of about 45% annually. The growth rates of the company's patent asset index lags behind the growth of its patent portfolio size by two years on average. This situation is due to the fact that the principal metrics for the calculation include granted patents and the number of citations by third parties, which typically have the lowest values when assessing young families. The patent asset index exceeded the number of families only in 2019, largely due to the lack of information about new families for that year. As a result, the company has the shortest patent retrospective among all leading companies.

The low patent asset index ensues from the low competitive impact of its technologies over the entire period under review. The competitive impact of NTT has never exceeded the average competitive impact of other companies in the segment, and until 2016 it was less than one. This indicates that the company's patent value has never been greater that the value of the average patent in this area. The average value for the entire period is 1.3, i.e. the competitive impact of the company's patents is 30% higher than the industry's average.

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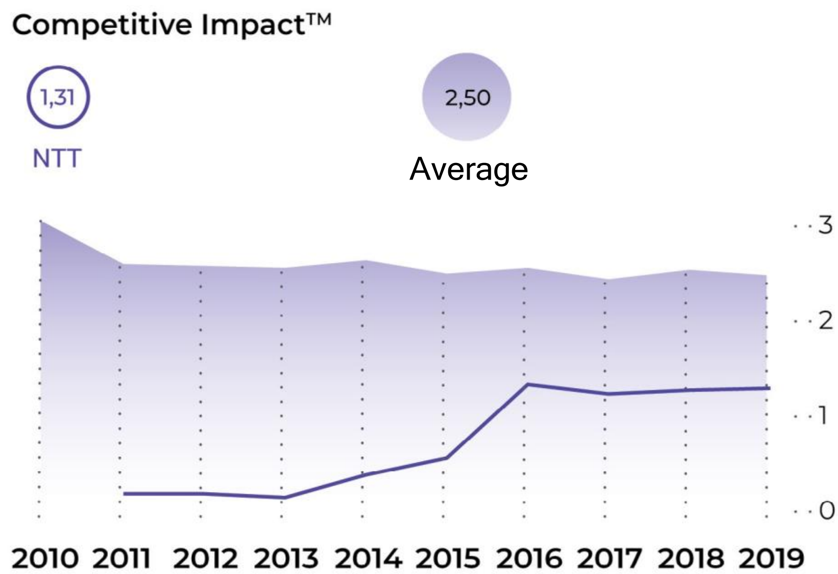
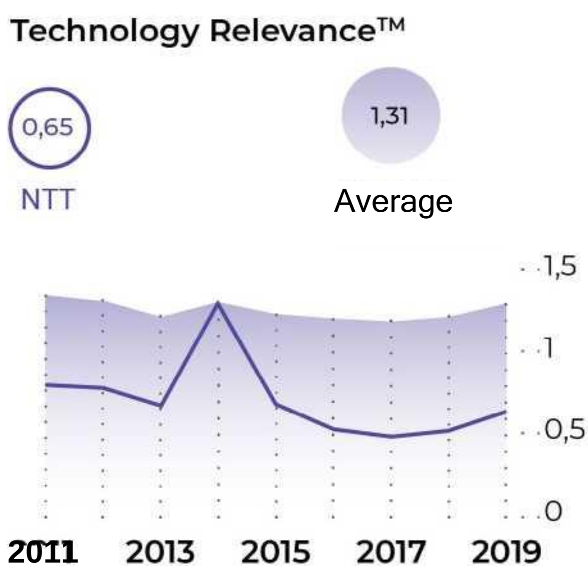
[38] White Paper. 5G Evolution and 6G // NTT DOCOMO Home URL: https://www.nttdocomo.co.jp/english/binary/pdf/corporate/technology/whitepaper_6g/DOCOMO_6G_White_PaperEN_20200124.pdf

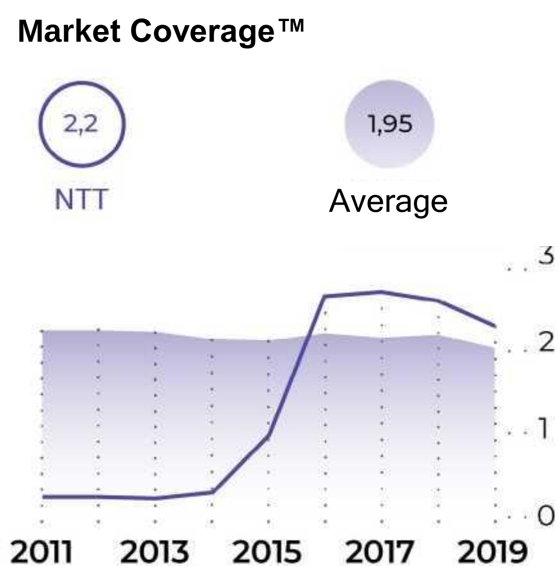
Figure 28 **Nippon Telegraph a nd Telephone's Patent Asset Index**



Competitive Impact™



Technology Relevance™



Market Coverage™

The low competitive impact of NTT's patents was due to their low technical relevance. The only year in which its developments reached the average technology relevance level was associated with the release of the *White Book*, which may have stimulated some developments in this area.

Then other players, whose technical solutions were cited more often, started to actively appear in the 5G market and the company's technology relevance significantly decreased again. Currently, it is less than one.

At the same time, the company's market coverage rate increased significantly in 2016 (eight times higher than in 2015), when patents were obtained in various jurisdictions, which led to some increase in its competitive impact. The slight decline in recent years is due to the fact that the number of families by the priority date decreased by 34% in 2018, while there were no such families at all in 2019.

NTT has low rates of both internal and external technology relevance due to the low number of citations (Figure 29).

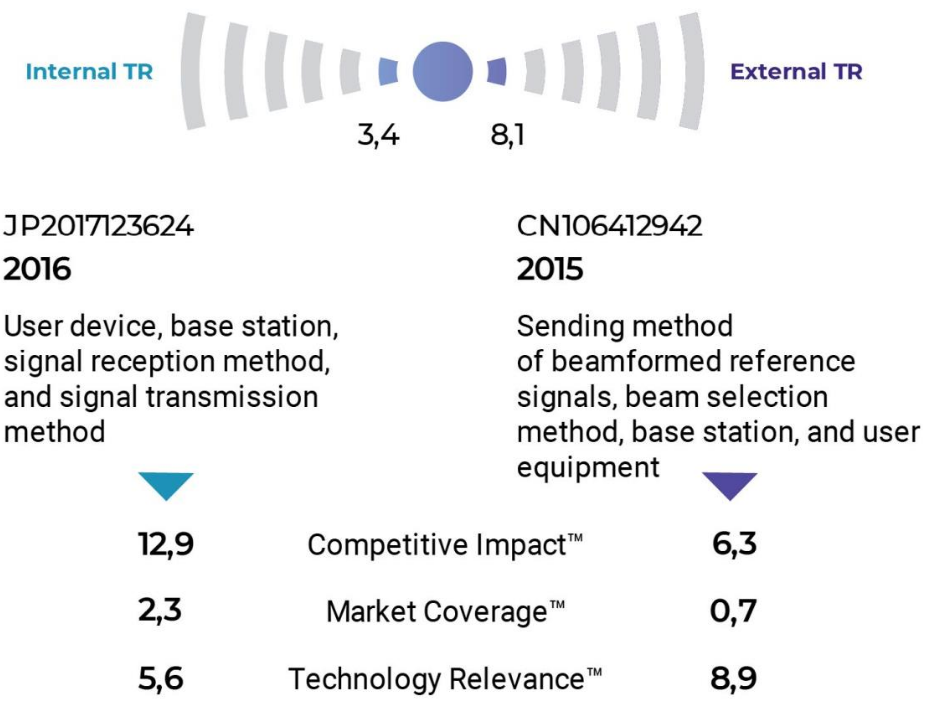
The family with the basic publication **JP2017123624** *User device, base station, signal reception method, and signal transmission method* has a low internal technology relevance rate and a low external technology relevance rate. The family is active. Its first priority is claimed in the national application of the family dated January 8, 2016. The family's applications have been filed in China, the United States, and the EPO through the PCT international patenting procedure. A patent was already received in the US on October 1, 2019. The authors of the invention include Kazuaki Takeda, Satoshi Nagata, Qin Mu, Liu Liu, and Huiling Jiang.

The technical solution describes a user device, a base station, a signal reception method, and a signal transmission method. A user device communicates with a base station in a narrowband radio communication system using a physical downlink control channel or a physical downlink shared channel that includes multiple resources of a predetermined unit in a time domain. The user device includes an acquirer that obtains a repetition number indicating a number of times each of the multiple resources is repeatedly and consecutively transmitted in the time domain, and a receiver that receives, from the base station, the physical downlink control channel or the physical downlink shared channel in which each of the multiple resources is consecutively repeated the number of times indicated by the repetition number.

The invention’s version can be applied in next-generation 5G communication systems.

Only five citations have been identified for the family, three of which are self-citations. 11 citations refer to prior art. That is, its backward citation rate is higher than that of forward citation.

Figure 29 **Nippon Telegraph and Telephone’s families with the highest ITR and ETR values**



The family with the basic publication **CN106412942** *Sending method for beam reference signal, beam selection method, base station, and user equipment* has the highest external technology relevance rate. China was the first jurisdiction, in which the relevant technical solution was published. Its priority date coincides with the date of filing the first application for the family (July 31, 2015). The family applies the international PCT filing procedure, which has been used for the transition to national phases in China and Japan. The patent has been granted only in Japan.

The technical solution describes a method for sending a beam reference signal, and a method for selecting the beam, base station, and user equipment.

The invention provides a method for transmitting a beam reference signal (BRS), and a method for selecting the beam, base station, and user equipment (UE). The sending method for the BRS contains: preliminary saving of the corresponding relationship between the BRS information and the beam index; for each potential beam, the BRS corresponding to each candidate beam is generated and sent to UE. The base station can send the BRS carrying the beam index to UE to enable UE to select the beam. This technical solution provides an efficient transmission method that can be used in next-generation 5G networks.

The family has 12 forward citations, including by Ericsson, ZTE, Asustek Computer, Huawei, Intel, Qualcomm, and Sony. The overall competitive impact of this family is even lower than that of the family with a high internal technology relevance rate.

NTT's joint patenting is virtually non-existent. The only case identified is with Waseda University, a private research university in Japan, which entered into a comprehensive academic and industrial cooperation agreement with the company in 2008 to establish a full-fledged partnership at the organizational level in the field of information and telecommunications.[39]

NTT is the Japanese market leader by size of its 5G patent portfolio, but it is not the only company actively involved in the launch of 5G networks in Japan (e.g. SoftBank). At the same time, its competitive impact on a global scale is much lower than that of leading companies. NTT primarily implements 5G development through its branch, NTT Docomo, which is a Japanese telecommunications operator. In this regard, the range of technical solutions patented by leading 5G technology manufacturers is much wider, which explains NTT's larger focus on this segment and a smaller patent portfolio size among the respective companies.

In general, over a short period of time a group of companies emerged in the 5G market, which have actually cornered the market, securing a high patent asset index and wide geographical coverage for their patent portfolios.

[39] Collaborations with Universities Leading to Open Innovation in NTT's R&D // NTT Technical Review URL: https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr201110fa1.html

This situation makes it difficult for even large companies to enter the market. Citation mainly covers a group of earlier technologies, which determine the level of relevance and originality for all other background art, which results in certain barriers to patenting. The high level of competition from monopolies is shifting the technology focus towards SEP patenting, and many companies have already begun developing sixth generation (6G) communication technologies.

Therefore, all leading companies expect that 5G technologies will become the market growth driver in 2020. The launch of commercial 5G networks will help identifying new barriers and challenges of the forthcoming long-term development period, which will directly affect the patenting dynamics. At the same time, the development of subsequent advanced 5G technologies will serve as the basis for patenting basic 6G technologies.

ANALYSIS OF THE COMPETITIVE ENVIRONMENT OF LEADING COMPANIES

To understand the competitive environment in the 5G market, it is necessary to analyze in which countries leading companies publish their technical solutions (Figure 30). One family can be published in a large number of jurisdictions; therefore, it will be repeatedly duplicated during the assessment of this metric and will not coincide with the total number of families owned by one company. This analytical representation includes not only active families, because inactive families also determine the state of the art when the relevant application is filed, securing for themselves a competitive and technological pool in a certain country.

The highest publication intensity is registered for international publications under the PCT patenting procedure. This situation indicates that all leading companies consider their entry into the international market entry as a priority. This is due to the aspirations of companies to claim their leadership, including to find partners for joint research to share best practices of both parties to respective agreements, carry out network tests with leading developers from another segment, or sign commercial agreements on the deployment of 5G networks with operators.

The Chinese and American markets are also of interest for companies. However, China has a strong presence of national developers such as Huawei, BBK Electronics, and ZTE. BBK Electronics, which is the market leader in Israel, Singapore, Australia, and Canada, has the largest geographical coverage.

At the same time, the USA is of interest for the leading companies from South Korea, Europe, and Japan, as well as for national developers. Meanwhile, its national developers are keen to gain a wide geographical coverage. Qualcomm has the highest coverage index, being a leader not only in the national market, but also in India, Brazil, Singapore, and Taiwan. Intel has a smaller geographical coverage, but a strong position in Germany.

The greatest publishing activity in the South Korean market is demonstrated by Samsung, which actively cooperates not only with international partners in 5G, but also with the national research universe. At the same time, Samsung is the leader by the number of publications in the UK and actively publishes in India.

Ericsson has a high number of international PCT publications, which exceeds the number of its publications in the national and European markets. This situation confirms the company's status as a player at the international level. At the same time, Ericsson is the leader in European patenting through the EPO, which indicates the company’s desire to consolidate its leadership in the 5G market. Its leadership is contested by Huawei, which also actively publishes its technical solutions in Europe. Among other things, Ericsson has more publications compared to its competitors in Argentina, Russia, and Mexico.

The leading companies have a presence in at least eight most important markets, which include China, the USA, South Korea, India, Japan, Canada, Australia, and Russia. This list can be extended to Taiwan, Brazil, Mexico, Singapore, and Vietnam, but publications of Chinese ZTE are not present in those countries, while those of American Intel are not present in Vietnam. Nippon Telegraph and Telephone is the leader in the Japanese market, despite the fact that all leading companies have publications in Japan.

Activity of incumbents in the general collection by country

Figure 30

	WO	CN	US	EP	KR	IN	JP	TW	BR	CA	AU	VN	MX	SG	DE	GB	IL	RU	PH	AR
HUAWEI	3821	3689	1578	1473	383	963	316	1	452	130	112	334	13	12	0	0	0	34	0	0
QUALCOMM	2291	910	2 170	771	324	822	220	834	437	203	183	11	10	124	0	0	9	7	11	8
SAMSUNG	1640	797	1 518	718	1 629	561	61	21	2	16	50	20	6	2	8	50	0	2	3	0
ERICSSON	2048	744	963	956	156	634	148	45	139	55	68	32	119	13	5	0	28	50	23	84
BBK Elecronics	1413	1 498	283	402	274	378	155	436	238	244	241	76	93	112	0	0	102	7	28	1
INTEL	1093	331	731	281	46	37	36	101	14	4	5	0	4	1	132	0	0	4	0	0
NOKIA	1174	417	620	552	70	144	78	38	21	19	10	23	6	12	5	5	1	11	13	2
LG	1078	291	656	329	363	59	110	1	38	26	39	25	22	28	2	0	0	2	13	0
ZTE	824	987	136	165	26	18	25	0	0	7	6	0	0	0	0	0	0	2	0	0
NTT[1]	1033	450	398	379	28	70	546	14	71	30	30	20	18	10	0	0	9	2	7	1

[1]NIPPON TELEGRAPH AND TELEPHONE

At the same time, out of all European countries, only France has no direct publications by leading companies.

Below is a breakdown of the patent asset indexes of leading companies across leading jurisdictions (Figure 31). This distribution was calculated only for those jurisdictions where patents or patent applications are active as at the reporting date. Patents granted or patent applications pending examination are considered as active. This approach is due to the fact that using the competitive impact index that serves as a basis for calculating the total portfolio value makes no sense for inactive patents, since their competitive impact is equal to zero.

For most leading companies, the most valuable developments are those that they launch in the international market through the PCT international patenting procedure (applications with the WIPO). However, for Chinese Huawei and ZTE, the patent asset index is more focused on the national market.

The same is true for Samsung, which has the highest patent asset index in the national market of South Korea. However, for Chinese companies, international patenting also plays an important role, which is reflected in the high patent asset index of families with international patenting, but for South Korean Samsung, the value of its international portfolio ranks only fifth after patenting in Europe, while the size of the company’s international portfolio is the largest compared to other portfolios. Samsung’s patenting volume in China is much smaller than in the US, but its competitive impact in the Chinese market is higher. Accordingly, patent applications submitted in the most technologically developed triad of countries in terms of 5G (the USA, China, and South Korea) are more important for the company.

Huawei, Ericsson, ZTE, Nippon Telegraph and Telephone, and LG have the same structure in terms of their leading patent offices with the highest patent asset indexes (WIPO, EPO, the USA, China, South Korea, and Japan), which demonstrates that these jurisdictions are the most promising for the leading countries to launch their solutions, but are also the most competitive ones.

At the same time, the patent asset indexes of Samsung and Nokia in the UK market are higher than in Japan and South Korea, respectively. Company

BBK Electronics significantly differs from other leading companies in that it has a different geographical distribution of its patent value. The value of its portfolios in the markets of Taiwan, Australia, and Canada is higher than in the USA and South Korea.

The US Qualcomm has large patent portfolios in China, India, and Taiwan, while the value of its portfolio in India is lower and is not included in the ranking of key countries, unlike a much smaller patent portfolio in Brazil, which has a high patent asset index. The company's patent portfolio in South Korea is smaller than in Brazil, with an index difference of 16% in favor of the latter jurisdiction. The company has a high patent asset index for the international filing of PCT and US applications, which correlates with the size of the portfolio. Its patent asset index is also strong in Taiwan where Qualcomm is a leader in terms of its overall competitive impact and patent portfolio size.

Japanese Nippon Telegraph and Telephone has a high patent asset index for PCT applications. The size of its patent portfolio in the national market is larger than that in China, but their patent asset index is approximately the same. The average competitive impact of a family in each country is obtained by recalculating the patent asset index per family. Accordingly, the competitive impact of Nippon Telegraph and Telephone's developments in the Chinese market is higher than in the national market.

In the Russian market, it is Swedish Ericsson's portfolio that has the greatest value, as well as the portfolio of Huawei, which correlates with their leading positions by portfolio size in Russia. Qualcomm is the last company in Top 3, but the portfolio's priority for the company itself is much lower than for its competitors.

The analysis of publications and breakdown of patent asset indexes of the leading companies by country has revealed that there is a certain set of key countries that has the highest priority for filing applications for 5G patenting. The analysis has also shown that families with international publications have the highest value. The patent portfolio in Europe is the most valuable for Huawei, Ericsson, and ZTE. At the same time, companies are trying to identify less popular markets to consolidate their leadership positions there.

Key markets for leading companies in the collection

Figure 31

Patent Asset Index™	China	WIPO applications	EPO applications	US	South Korea	Japan	Brazil	Canada	Australia	UK	Russia
HUAWEI	9105	7678	4283	4213	1306	1296	920	608	528	403	304
	WIPO applications	US	China	Taiwan	EPO applications	South Korea	Brazil	Canada	Japan	Australia	
QUALCOMM	7201	6983	3784	3398	3038	1432	1201	1019	1012	976	135
	South Korea	US	China	EPO applications	WIPO applications	UK	Japan	Germany	Ireland	Switzerland	
SAMSUNG	5350	4455	3718	3320	2796	570	557	448	377	334	38
	WIPO applications	China	EPO applications	US	South Korea	Japan	Mexico	Australia	Canada	UK	
ERICSSON	3804	2339	2327	2297	871	836	703	621	615	589	525
	WIPO applications	China	Taiwan	EPO applications	Australia	Canada	US	South Korea	Singapore	Mexico	
BBK ELECRONICS	6473	5502	1667	1645	1104	1087	1039	958	472	442	25
	WIPO applications	US	China	EPO applications	Germany	South Korea	Taiwan	Japan	Hong Kong	UK	
INTEL	1995	1559	1090	863	383	247	180	174	100	54	1
	WIPO applications	US	China	EPO applications	Japan	UK	South Korea	Germany	Ireland	Switzerland	
NOKIA	1466	929	877	829	190	183	182	179	126	111	25
	WIPO applications	US	South Korea	China	EPO applications	Japan	Australia	Germany	Ireland	Switzerland	
LG	2646	1407	1099	1057	1027	414	142	129	119	115	14
	China	WIPO applications	EPO applications	US	South Korea	Japan	Australia	Canada	Germany	Ireland	
ZTE	1701	1498	378	313	114	110	19	18	16	14	2
	WIPO applications	China	Japan	EPO applications	US	South Korea	Canada	Australia	Brazil	Germany	
NTT[1]	879	685	682	568	498	54	54	45	39	33	7

[1]NIPPON TELEGRAPH AND TELEPHONE

CITATION LINK ANALYSIS

An analysis of document citations helps identifying owners of the most valuable 5G solutions for companies, technological cooperation between applicants as well as holders of basic technologies. The citation index is fundamental for calculating the technology relevance of a particular company. At the same time, citation indexes are affected by several factors: the patent lifespan, the citation strategy of patent offices, as well as differentiation between external and internal, and direct and backward citations. For instance, for young families with a short lifespan, the values will be significantly lower, although the technology may be interesting and relevant and will receive a large amount of citations in the future.

Forward citations mean the number of different patent families (companies) citing a given family of patents (company) in their prior art search reports. Forward citations are used to measure inventive quality in terms of technological or economic values.

Backward citations means the number of patent families (companies) that have been identified in the prior art search reports for a given family of patents (company). Backward citations are used to measure the inflow of knowledge to a given technical solution from other technologies.

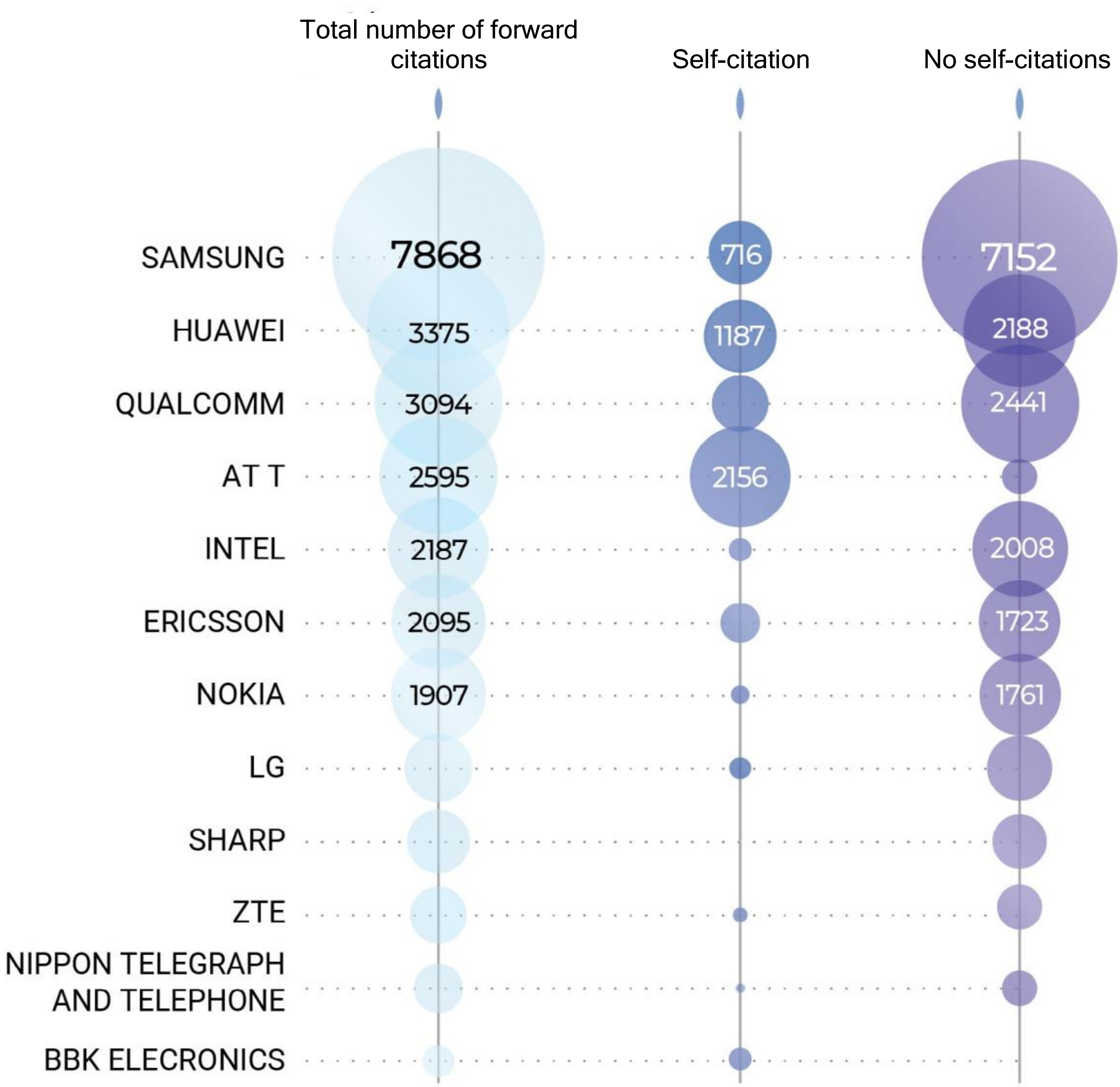
External citations mean citations of the technical solution (company) by third parties only (other companies in their patents). External citations are mainly counted for forward citations and indicate companies that have the greatest influence on the segment under review. Citation of a technical solution by leading companies allows assessing its influence on the solutions of other companies, as well as whether a solution is a basic one and whether the company is the holder of the basic technologies.

Internal citations or self-citations are citations of a company’s proprietary technical solutions in its own patents. It is much harder win against a company with a large number of self-citations than a company that mainly applies for individual patents. This is a good indicator that a company can build technology clusters, creating strong technological coverage in the segment and preventing competitors from entering the market.

The following is a detailed analysis of citation links in the collection presented in the form of a citation map. The collection turned out to have a large number of citation links between leading companies, as well as with other companies that actively implement the latest 5G technologies in their operations. A full citation map is included in Appendix D. Citation Map of 5G Developers.

Ranking of companies by total number of direct external and internal citations

Figure 32



The map shows that the leading companies have the highest density of citations. Accordingly, the companies are actively developing technologies based on already known solutions, trying to improve prior art or to finalize something new. Large-scale citation in the segment results in a number of technological links between solutions. Samsung, Huawei, and Qualcomm are the leaders by the number of direct and backward citations (Figure 32). At the same time, BBK Electronics, which is among the leaders by the number of families, has a much lower citation rate and was only included in the internal citation ranking.

The analysis of forward citation links between companies revealed that Samsung has the largest number of common citation links (external and internal) in the collection and is also the leader by the number of external citations. Qualcomm, Huawei, and Intel were included in the second group with the number of external citations being about two thousand links. At the same time, Huawei is the leader by the total number of citations, while Qualcomm has the highest number of external citations, which is corroborated by its high self-citation rate.

American telecom operator AT&T has the highest rates of self-citation. The leading companies, Samsung, Qualcomm, and Ericsson, have significantly lower rates of self-citation, which indicates less incremental improvements by these companies, or their use of other mechanisms to expand technological coverage (such as national legislation mechanisms, etc.).

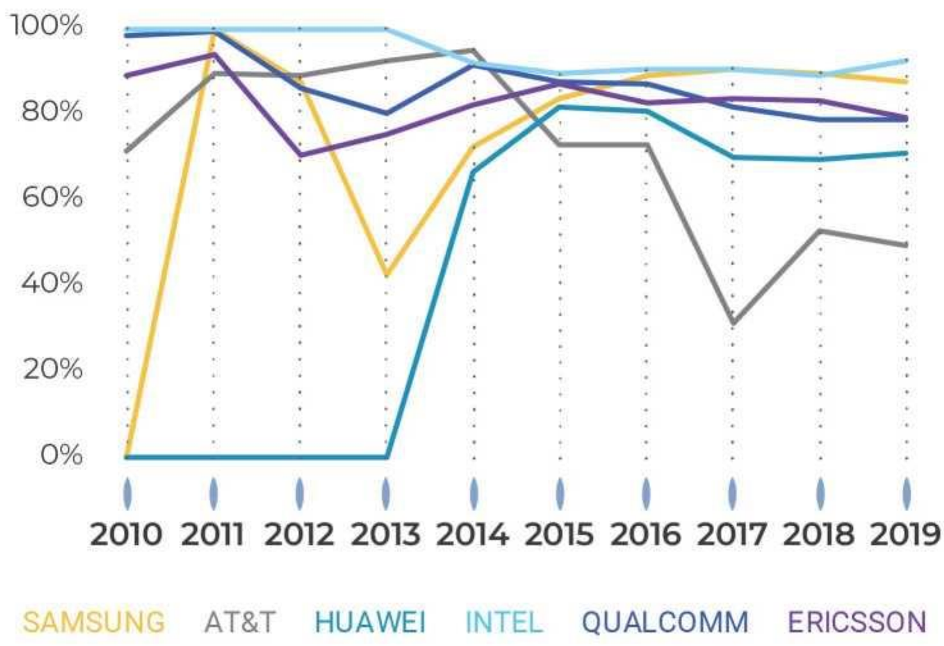
The leading companies were then analyzed for changes in their shares of external and internal citation rates over time (Figure 33). External citations refer to citation links with other companies. Internal citation describes a situation when a company cites its own developments, being at the same time the object of direct and backward citation.

On average, all companies have had about 80% of external citations and 20% of internal citations in recent years, with the exception of AT&T whose share of external citations first decreased in 2015 and then abruptly fell in 2017 when 70% of AT&T’s citations were internal citations. In recent years, its rate of external citation has slightly increased, but the company was not able to achieve its average values (90% external citation) that it had prior to 2015. These figures indicate that AT&T’s developments are mostly of value to the company itself, while third parties are more interested in the developments of other companies in this area.

Intel demonstrates the most stable rate of external citation, which has not fallen below 90% over the entire period. This witnesses that the company's citation rates are primarily based on citations of other companies, while the company rarely cites its own solutions.

The ratio between external and internal citations for leading companies by year

Figure 33



Samsung and Huawei have a shorter citation retrospective than other leading companies. For instance, Samsung started to be actively cited by third parties in 2011. However, by 2013, its external citation index fell to 43%. During these years, its developments were mostly cited by the company itself. By 2015, Samsung's external citation index recovered to 80% and since 2016 the company maintains a 90% external citation rate. Such uneven distribution of the index dynamics suggests that in certain periods Samsung's technologies were in higher demand by other companies. At the same time, the company also cites its own solutions, which indicates improvements in the company's own technology.

Huawei has the shortest citation retrospective of all companies in the list. The first 5G families of the company emerged in 2012 and as early as in 2014 its external citation index already reached 67%. In 2015 and 2016, this figure slightly rose to 80% and then fell back to 70%, remaining stable over the past three years. This indicates that the company actively cites its own developments, while its technical solutions are of great interest for third parties.

The citation structure of Qualcomm and Ericsson evolved in a similar way. In 2013–2014, their external citation rates slightly decreased in favor of internal citations, but for the rest of the period the latter were at 80% of external citations. This situation suggests that citation rates of Qualcomm and Ericsson are based mainly on citations by other companies.

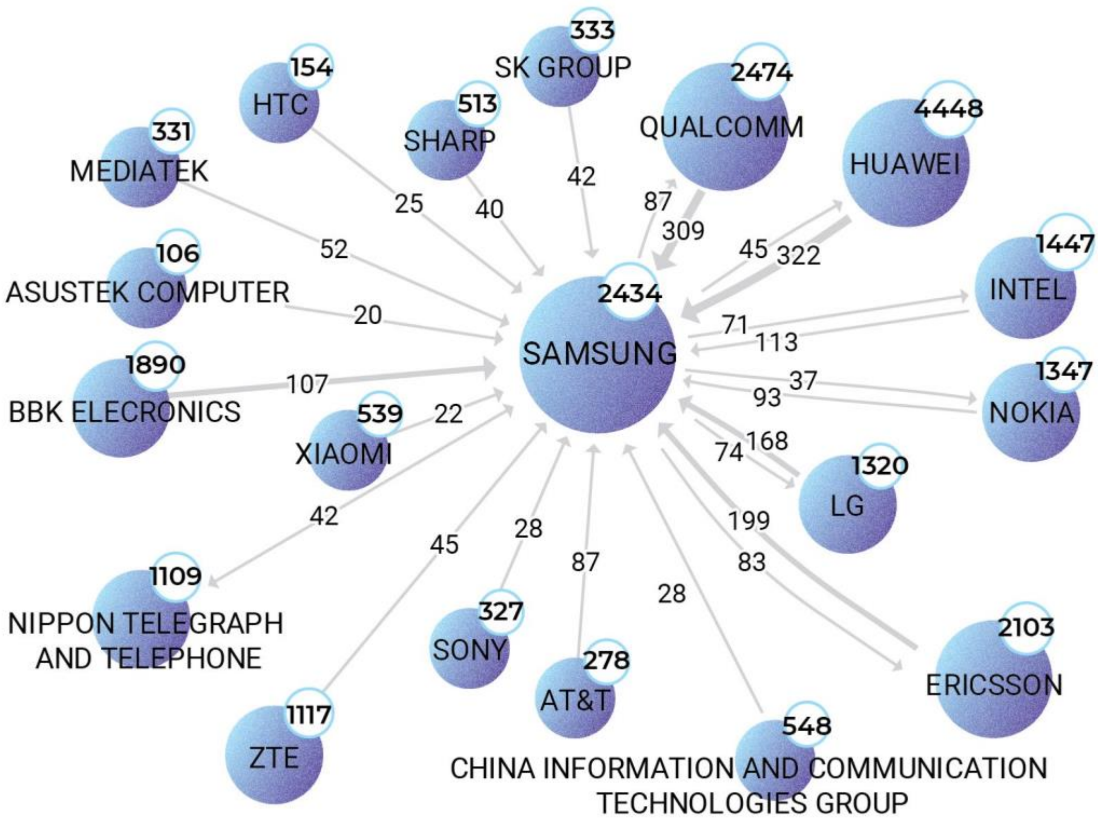
Based on internal and external citation data, we identified several most interesting citation focuses for interpretation. The following companies were chosen as the focus groups: Samsung as the leader by the number of overall citations; Huawei as the leader by the number of families; and US AT&T, which has a high proportion of self-citations.

Forward citations (where other companies refer to Samsung's developments in their technical solutions) represent a significant proportion of Samsung's total citations (Figure 34). Among them are Chinese ZTE, Xiaomi, and BBK Electronics, Taiwan Asustek Computer, HTC, and Mediatek, Japanese Sharp, Sony, and Nippon Telegraph and Telephone, American AT&T, and South Korean SK Group. Among them, BBK Electronics and AT&T have the highest number of citations. In turn, the company cites patent documents of Qualcomm, Huawei, Intel, Nokia, LG, and Ericsson, with large numbers of citations from Qualcomm and Ericsson. However, the share of Samsung's forward citations is much higher than that of backward citations. For example, Huawei cited Samsung's developments 322 times and Qualcomm, 309 times. Therefore, we can conclude that Samsung has technologies that are of great interest for many companies operating in the segment, including the incumbents. This allows positioning the company's developments as basic 5G technologies.

On the other hand, the existence of mutual citations between large companies may indicate joint projects in which they patent solutions related to the same area of technology, but in different and narrower technology segments (for example, a technical solution related to an antenna device vs. a technical solution related to user equipment).

Samsung's citation map

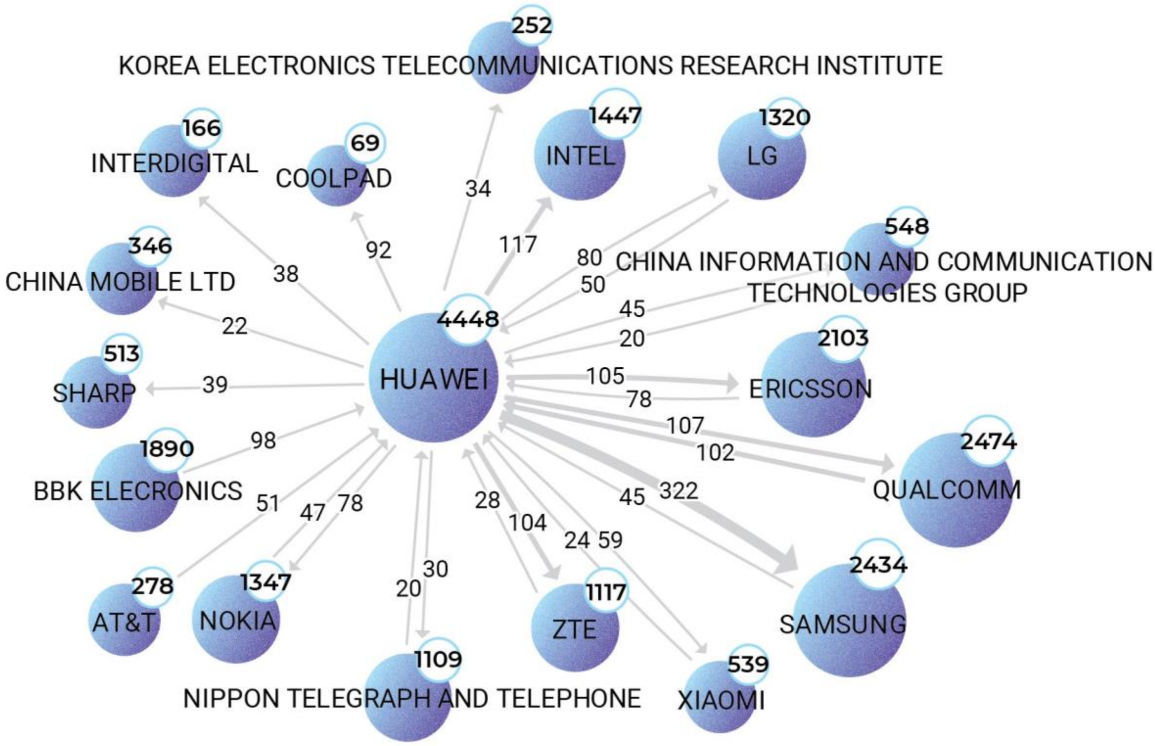
Figure 34



Another citation focus is on Chinese Huawei. (Figure 35). The Chinese company mostly cites South Korean Samsung, with which it was found to have a mutual citation. The company actually has a large share of mutual citations. Other companies with mutual citations include all incumbents, as well as China Information and Communication Technologies Group, which includes China Academy of Telecommunications Technology. Huawei also unilaterally cites Intel, Coolpad, Sharp, China Mobile, InterDigital, and South Korean Electronics And Telecommunications Research Institute (ETRI). AT&T and BBK Electronics are among the companies that cite Huawei's developments.

Thus, Huawei is represented by a wide range of mutual citations with leading companies, which confirms the assumption of strong interrelations between solutions in the emerging markets.

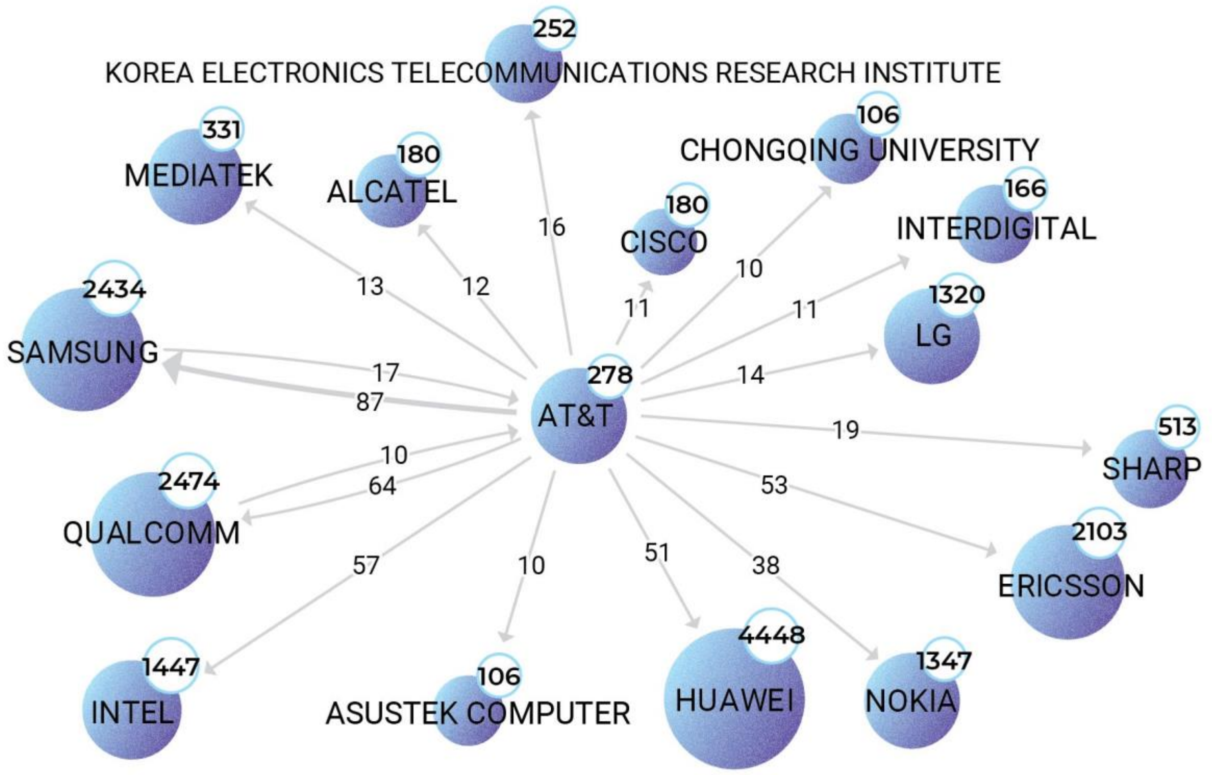
Figure 35 **Huawei's citation map**



American AT&T was another focus of our citation analysis (Figure 36). It has a distinctive citation environment, in which 90% of citations are backward citations. In other words, the company actively cites technical solutions of other companies, with very few cases when other companies cite its developments. Mutual citations were identified for Qualcomm and Samsung, with the former citing American publications of Samsung among others. This is primarily due to the citation rules of the US Patent Office. AT&T cites solutions of companies from South Korea, China, Taiwan, Finland, Japan, and Sweden, and has one of the widest geographical profiles in terms of citation. Therefore, the company, as the US largest telecom operator, monitors technical solutions of the leading 5G companies for timely cooperation and implementation of advanced technical solutions for the deployment of 5G networks in the US while patenting its own solutions within its field of specialization.

AT&T's citation map

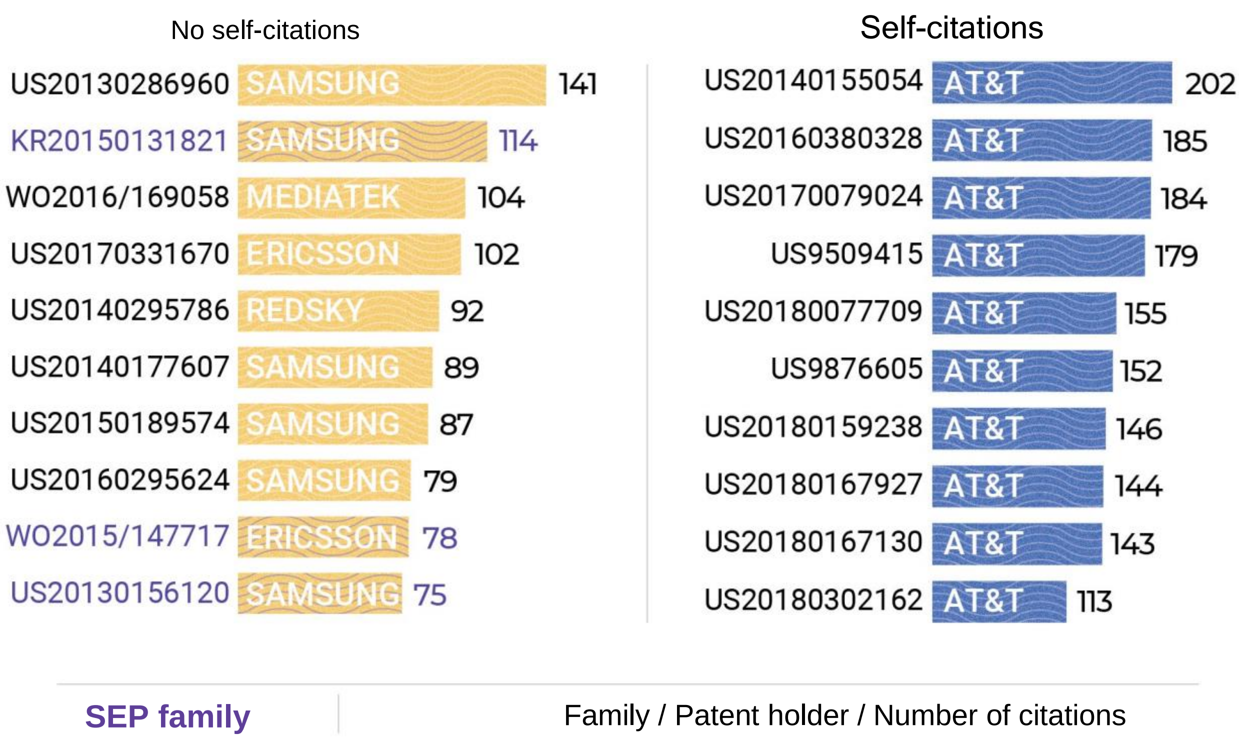
Figure 36



An analysis of the company's citation links identified that Samsung is a developer of basic 5G solutions, which are actively cited by all leading companies operating in the segment, allowing the company to gain the leading position by the number of forward citations. At the same time, Huawei, the leader by the number of patent families, is actively engaged in self-citation, creating a powerful technology cluster in its patent portfolio. Due to the wide technological reach of its developments, other companies may face barriers to market entry. AT&T, in its turn, has a citation profile that differs from others. First of all, it is a leader for internal citation, i.e. it has been building up a wide technological coverage of its 5G developments in the American market, while monitoring advanced technologies of the global community to develop its own technical solutions.

Below is a distribution of basic patent publications of the most cited families in the collection (Figure 37).

Figure 37 **The collection's most cited families**

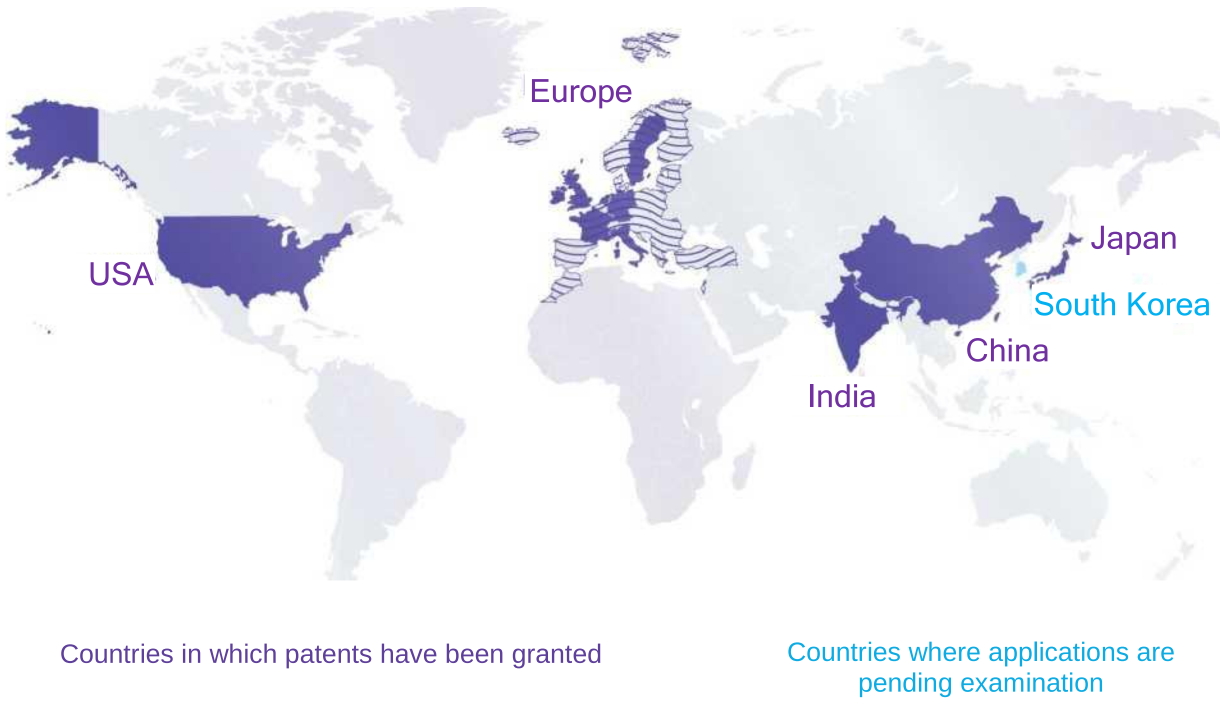


The ranking of families most cited by other companies primarily comprises Samsung's publications. However, they also include publications of Swedish Ericsson, Taiwan Mediatek, and Indian Redsky Technologies.

Samsung has the largest number of the most cited families in the ranking. Two of them are SEP families: one with the basic publication KR20150131821 and the other, US20130156120.

The family with the basic publication **KR20150131821** *Apparatus and method of transmitting/receiving signals in mobile communication system supporting carrier aggregation* is active and has a priority date of May 16, 2014, which coincides with the filing date of the family's first application. The patent is protected in a large number of countries and has an application pending examination in South Korea (Figure 38).

Geographical coverage of Samsung's families (KR20150131821) *Figure 38*



The family features 14–16 claims, four of which are independent, and others are dependent claims with a complex structure. The authors include Kim Soenghun, Kim Sangbum, Jang Jaehyuk, and Jeong Kyeongin. The technical solution relates to methods and systems to converge a 5th generation (5G) communication system with the Internet of Things (IoT) technology. The disclosure applies to smart services based on 5G with IoT. This technical solution has a large number of citations by AT&T in its numerous patents. It has also been cited by Sharp, ZTE, LG, Intel, NTT Docomo, and some players. This family is also cited by one standard, ETSI-TS-36-321*Medium Access Control (MAC) protocol specification*.

Another SEP family (cited in ETSI-TS-38-214 *Physical layer procedures for data*) has the American **US20130156120** as the basic publication. The family is active with the priority date of December 19, 2011. Its first application was filed on November 16, 2012. Therefore, this family claims priority in the provisional unpublished application US201161577533P. The patent includes 28 claims, including three independent ones.

The authors of the invention include Josiam Kaushik, Abu-Surra Shadi, Li Ying, Rajagopal Sridhar, and Pi Zhouyue. Patents for the invention were received in China, Japan, and the USA, with applications pending examination in India and at the European Patent Office. The invention describes reference symbol transmission, specifically an apparatus and method for reference symbol transmission in an OFDM system. Orthogonal Frequency Division Multiplexing (OFDM) symbols are grouped into a slot for scheduling granularity. For example, thirty OFDM symbols form a slot in a 5G system. This technical solution is actively cited by Huawei, Qualcomm, Intel, American Magnolia Broadband, and other companies.

Samsung's families, other than SEP families, had their first publications in the US, with applications filed under the EPO regional patenting procedure. They are all active families and have a large number of citations. All sets of illustrations contain, among others, the same images relating to base stations. The family with the publication **US20130286960** describes an apparatus and method for control channel beam management in a wireless system with a large number of antennas. A base station (BS) is configured to perform a coordinated transmission to at least one user equipment (UE) unit. The BS includes several antennas and processing circuitry coupled to the antennas and configured to transmit the physical downlink control channel (PDCCH) to at least one user equipment unit. The PDCCH is included in one or more transmission (Tx) beams. The Tx beam is defined by a cell specific reference signal (CRS) transmitted via the Tx beam. Communication between the base stations can take place via a 5G network. The family with the publication **US20140177607** also relates to base stations and describes a method and apparatus for random access in a communication system with a large number of antennas. **US20150189574** describes methods for dormant cell signaling for an advanced network and also relates to base stations. The family **US20160295624**, however, describes methods and apparatus for resource pool design for vehicular communications. In one of the variants of the implementation, V2X (vehicle-to-everything) type communication is carried out over a 5G network.

Ericsson has two families in the ranking.

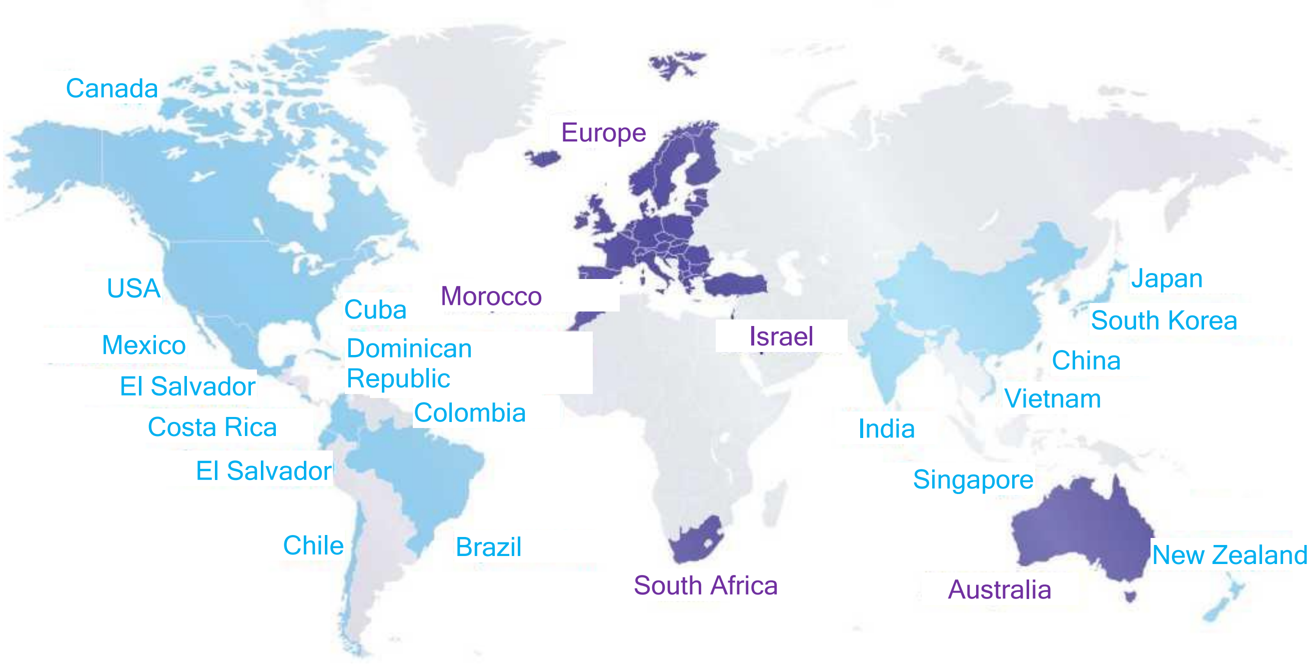
The family with the basic publication **US20170331670** *Network architecture, methods, and devices for a wireless communications network* has already been mentioned earlier as a unique family with a record number of 5G authors. 130 inventors claim to be authors in this family. The full list of authors is provided in Appendix E. *List of authors in the Ericsson family* (US20170331670). The family is active with the priority date of May 13, 2016, which coincides with the date when the first application of the family was filed. The last publication is dated January 23, 2020 being an application filed with the US patent office. The publications also include an application published in Russia (RU2019118801).

A similar family with the basic publication **US20170331577** was identified, which has the same name and the same description. It is also an active family and has the same priority date. It should be noted that the family with the basic publication US20170331577 has no applications in Russia, but a larger geographical coverage of other countries. The family also has publications dated 2020.

Geographical coverage of Ericsson's families

Figure 39

1. US20170331577

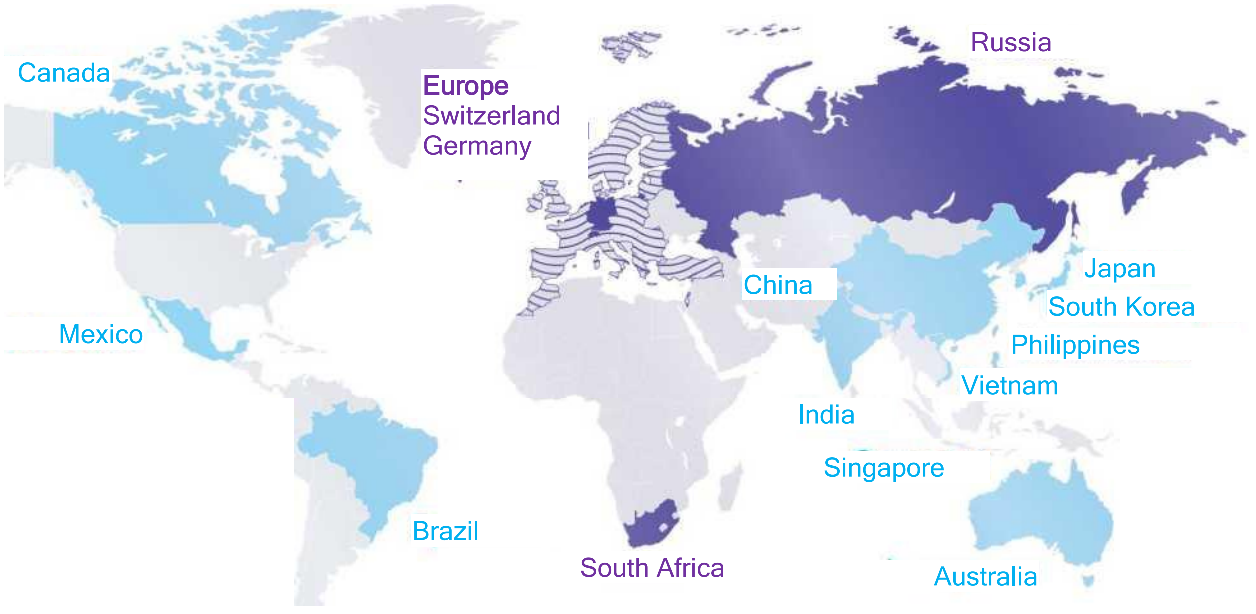


Countries in which patents have been granted

Countries where applications are pending examination

Figure 39 (continued)

2. US20170331670



Countries in which patents have been granted

Countries where applications are pending examination

The US20170331670 family has a smaller geographical coverage, including a smaller number of jurisdictions where the relevant solution is protected by a patent.

Other differences identified between the families relate to patent claims. The US20170331577 family features 321 claims, with claims from 1 to 181 cancelled. Six of the claims are independent, while the dependent claims have a complex structure of relationships. An international application filed under the PCT procedure and in some other countries features 150 claims. The Russian patent in the family US20170331670 includes 69 claims and the American patent features 105 claims, while claims from 1 to 67 cancelled for the USA. International applications filed under the PCT procedure feature 30 claims on average.

In both families, the technical solution describes a complete 5G architecture, including devices, shared network architecture, wireless nodes, methods and algorithms, and also demonstrates how to connect all of these components into a single fully functioning network. Previously, companies mostly patented individual network elements. Accordingly, this complex technical solution has become the basic solution for this area and is actively cited by incumbents and other companies.

The two families have different citation rates. The US20170331670 family with a smaller geographical coverage and fewer claims is cited by 40% more often. Apart self-citation, the citing companies include Samsung, Mediatek, Nokia, Blackberry, Qualcomm, SK Group, Huawei, NEC, LG, Asustek Computer, Sharp, and many others. The US20170331577 family has a large share of citations by Qualcomm. Thus, the two families refer to the same complex technical solution with the same priority and somewhat differ in their technological and geographical coverage aiming to consolidate the competitive position in the market as effectively as possible.

Another Ericsson family with the basic publication **WO2015/147717** is included in the ranking of the strongest families in the collection and is also a SEP family (Table 5). The Russian patent features 59 claims. The PCT international application contains 30 claims, ten of which are independent claims. This family is cited by all leading companies operating in the segment. Applications of ten families that cited this family were rejected. They include Samsung, Huawei, Nokia, and Sharp. All rejections were received from the US Patent Office.

Mediatek is a fabless semiconductor company engaged in the development of components for wireless communications and optical data storage systems. The family with the publication **WO2016/169058** *An on-demand reconfigurable control plane architecture (ORCA) integrating millimeter-wave small cell and microwave macro cell* is active. Its priority date was April 24, 2015. Priority is claimed for the filing date of a PCT international application. However, the PCT application is a continuation-in-part application with respect to another PCT application, which creates a chain of parent applications. The last publication is dated February 4, 2020 and is a patent granted in the USA. Its authors include Sang Aimin Justin, Zhang Yuanyuan, and Jheng Yu-Syuan. The proposed On-demand Reconfiguration C-Plane Architecture (ORCA) for Macro-assisted Millimeter Wave (mmWave) small cells is designed to meet 5G expectations of dense deployment of small cells and UEs and beamformed intermittent Gbps links. Millimeter wave (mmWave) communications are a very promising technology for small 5G cells. In practice, this new system will coexist with legacy or advanced microwave systems such as E-UTRAN LTE macrocellular systems for a long time to come.

Considering the typical scenarios where a macro cell offers umbrella coverage for clusters of small cells, several control plane (C-plane) architectural choices of macro-assisted 5G mmWave systems from both UE and network's perspectives are evaluated. Interestingly, 80% of citations of this solution come from AT&T. There are single citations of this solution by other citing companies such as Nokia, Huawei, Ericsson, Qualcomm, and Samsung.

Redsky Technologies is India's leading provider of E911 local and cloud solutions. Its family with the basic publication **US20140295786** *Method and system for an emergency location information service (e-lis) from wearable devices* is an active family with the priority date of May 16, 2006. The filing date of the first application for this family is June 13, 2014. Thus, the priority is claimed for another family. A detailed analysis has revealed that this US patent application is a continuation-in-part (CIP) application. This mechanism is an essential part of the US patent legislation. Such an application forms a new family with added essential features different from those of the parent application and expanding the scope of protection of the original technical solution by priority date. The latest publications are dated March 10, 2020 and represent a patent granted in the US. The authors of the invention are Nicholas M. Maier and Gerald R. Eisner. The invention features 20 claims, three of which are independent and 17 are dependent on claim 1. There is no mention of 5G in the claims. The description of the invention contains information about a method and system for determining and verifying a location of wearable mobile devices (e.g., digital glasses, watches, smartphones, etc.) in emergency situations with emergency messages. One of the invention's embodiments can operate over 5G as a communication network, Therefore, this invention is not directly related to 5G technology, but is a clear example of how the scope of application of this technology can be expanded across other industries. This technical solution is actively cited by Apple, T-Mobile, Microsoft, Qualcomm, AT&T, Fujitsu, Intel, Ericsson, and many other companies.

Its self-citations only include AT&T's documents.

In these families there are publications that do not mention 5G at all. These include the earliest publications of the family. In this regard, it was found that the company patents a technology related to telecommunications in general and then files new applications, in which the claims and description are slightly modified, with the addition of paragraphs stating that relevant broadband access networks include 5G. These publications got into the earlier family, as priority is sought for earlier applications, and there are improvements in the basic technology.

In addition, the families in the collection were analyzed for the ratio between their internal and external technology relevance rates, as they are directly related to internal and external forward citation rates (Figure 40). All families with the highest rates relate to 2016–2017, and almost all families belong to different patent holders; accordingly, we can conclude that the performance of patenting companies in the 5G market varies significantly.

AT&T is the leader for internal technology relevance, with its family with the basic publications US20140355525 *Remote distributed antenna system* and US20160359523 *Network termination and methods for use therewith*. In this case, the external relevance of technical solutions does not exceed 2. The competitive impact values of these families are about 30 points, which is the minimum value of all families in the list.

The family with the basic publication **US20140355525** *Remote distributed antenna system* is an active family. Priority is sought in the first American application for this family (May 31, 2013). The family has an average geographical coverage. Its patents were granted in Canada, China, Japan, Mexico, and the USA. Applications are pending examination in Brazil, India, South Korea, and at the EPO. This family has a wide technological coverage: applications with different claims have been filed with the US patent office, which provide a high level of protection of the technical solution as well as protection against competitors.

This invention relates to wireless communication, in particular, a remote distributed antenna system that uses signals in certain ranges, such as microwaves. In order to enable connection to a network to increase the number of mobile devices, a distributed antenna system is provided that allows one or more base stations to have antennas that are distributed over a wide area.

Small cells can be deployed in addition to traditional macro cell deployments, which will require a widely distributed network with high bandwidth to support them. Nodes can be configured to communicate with mobile or fixed devices over a wireless interface that complies with one or more communication protocols (e.g., 5G). 5G networks are not mentioned in all documents of the family, but, for example, in the patent of this family US9999038.

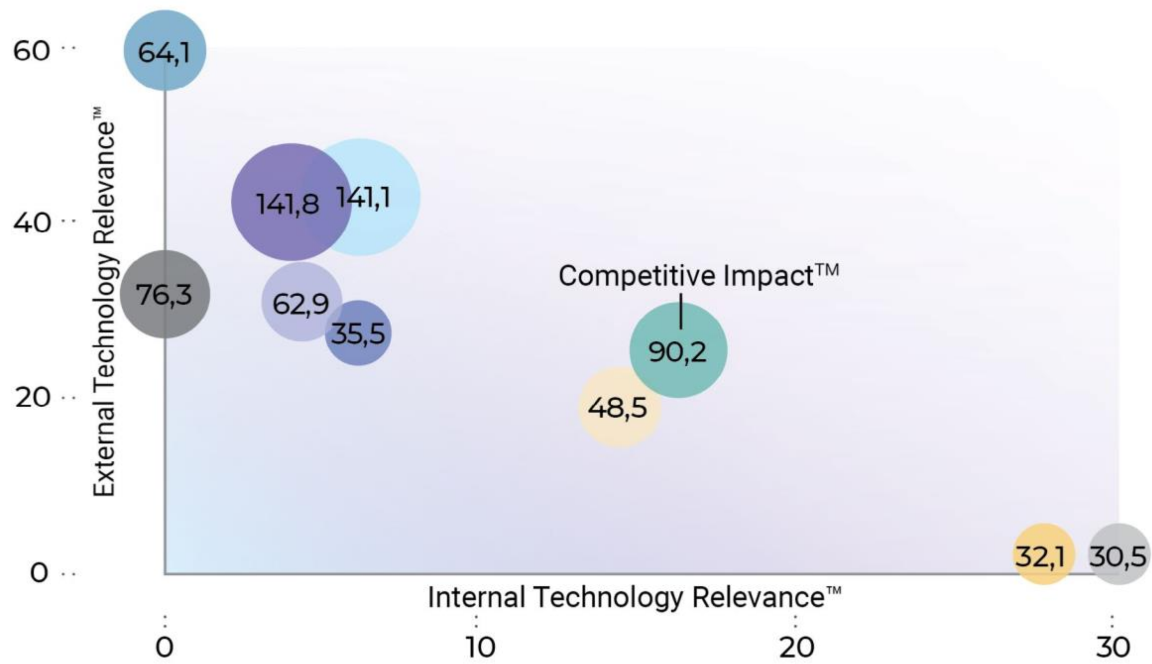
The family with the basic publication **US20160359523** *Network termination and methods for use therewith* is also an active family. Its priority date coincides with the date of filing the first application of the family (June 3, 2015). The technical solution is protected in Mexico, the USA, Germany and Switzerland; applications are filed in Brazil, Canada, China, India, Japan, and South Korea through the PCT international patenting system.

The patent documents describe a network termination that includes a downstream channel modulator that modulates downstream data into downstream channel signals to convey the downstream data via a guided electromagnetic wave that is bound to a transmission medium of a guided wave communication system. The host interface sends the downstream channel signals to the guided wave communication system and receives upstream channel signals corresponding to upstream frequency channels from the guided wave communication system. The upstream channel demodulator demodulates upstream channel signals into upstream data. Signals sent to and from the communications interface can be modulated signals such as orthogonal frequency division multiplexed (OFDM) signals formatted in accordance with a Long-Term Evolution (LTE) wireless protocol or a 5G protocol.

The family with the publication US20140355525 has 3,017 prior art citations and 224 citations from other companies. The family with the publication US20160359523 has 2,994 prior art citations and 207 forward citations, mostly self-citations. Therefore, these families have some of the highest rates of backward citation and self- citation in the collection.

The collection's leading families by the ratio between ITR and ETR indexes

Figure 40



- US20170331670 **ERICSSON**
  Network architecture, methods, and devices for a wireless communications network
- CN107018542 **ZTE**
  Method and apparatus for processing information on the status of a network system and on the data carrier
- US20170142591 **HUAWEI**
  System and methods for network management and orchestration for network slicing
- US20170332359 **CONVIDA WIRELESS**
  Physical Downlink Control Channel (PDCCH) operations to facilitate numerology operations
- US20170303259 **ETRI KOREA**
  Communication method and apparatus using network slicing
- US20170188391 **SAMSUNG**
  Methods and apparatus for resource collision avoidance in vehicle to vehicle communication
- CN106507497 **HUAWEI**
  Method for uplink data transmission, terminal device and network device
- US20170339609 **LG ELECTRONICS**
  Method and apparatus for determining PDU session identity in wireless communication system
- US20160359523 **AT&T**
  Network termination and methods for use therewith
- US20140355525 **AT&T**
  Remote distributed antenna system

The family with the basic publication US20170303259 Communication method and apparatus using network slicing of South Korean Electronics & Telecommunications Research Institute (ETRI) has the highest external relevance index. The date of filing its first application is April 17, 2017. Priority is claimed in the South Korean application KR20160047216A. The family has publications only in one jurisdiction, the USA.

This family has a competitive impact index twice as high as that of the AT&T family. At the same time, its internal technology relevance index is 0, that is, it has self-citations or other indicators of internal relevance. The number of citations by other companies is 50. Among them are Ericsson, Nokia, Huawei, Cisco, Verizon, LG, Samsung, ZTE, Lenovo, BBK Electronics, Qualcomm, and AT&T.

The invention describes a communication method and apparatus using network slicing. A communication apparatus performing communication with a user equipment receives a predetermined request from the user equipment, selects a single network slice instance to be allocated to the user equipment from among a plurality of network slice instances in the communication apparatus in response to the request, selects a single network function instance to be allocated to the user equipment from among a plurality of network function instances included in the selected network slice instance. The network slice instance is in an instantiated form of a network slice that includes at least one network function and resource for providing a network service having a predetermined capability and characteristic to the user equipment. One example embodiment may also provide a communication method and apparatus using network slicing that may provide the flexibility of a 5G core network architecture according to the introduction of network virtualization technology, and enables a network provider to achieve the effectiveness maximization and cost reduction according to a network system and resource management.

The family has 50 forward citations, including by Huawei, Ericsson, Nokia, Verizon, Samsung, LG, and some other companies. Huawei and Ericsson cite this family more than others.

Another family in the ranking with an internal relevance index equal to zero and a rather high external relevance index belongs to Convida Wireless. The family has a higher competitive impact index than the family belonging to ETRI due to a higher market coverage index.

Convida Wireless[40] is a joint venture between Sony Corporation of America and InterDigital, which specializes in the Internet of Things technology and develops specifications and standards for wireless 5G. Convida is an active member of the 3GPP, RAN1, and RAN2 radio access network working groups, which include collaborating with other delegates including InterDigital and Sony, as well as delegates from Huawei, Qualcomm, and other companies on identifying reliable solutions and specifications that help promote the 5G standard.[41]

The basic publication of the family, **US20170332359** *New radio downlink control channel* is a publication of a US application dated May 11, 2017. Priorities are sought for the preceding year in several US provisional unpublished applications. The family uses international and regional application procedures (PCT and EPO). Applications are pending examination in China, India, Japan, South Korea, and at the EPO. A patent is granted in the USA for the basic application of the family.

The invention describes a new radio downlink control channel. New radio download numerology allocation information may be obtained through master information block data, system information block data, radio resource control signals, or signals or a physical downlink numerology indication channel, and used along with a reference signal detected in a search space to obtain resource element positions in an antenna port reference signal in a resource block that belongs to a particular band slice according to a reference signal allocation scheme for a band slice numerology

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[40] Convida Wireless URL: https://www.convidawireless.com/

[41] Advancing the 5G Wireless Standard at Convida Wireless: An Insider Look // MathWorks URL: https://www.mathworks.com/content/dam/mathworks/white-paper/convida- interdigital-qa.pdf

A physical download control may then be decoded based upon one or more resource elements of the reference signal, allowing the connection of, e.g., an enhanced mobile broadband (EMB), massive machine type communication (MMTC), or ultra-reliable/low-latency (URLL) application to a communications network thereby. The description discusses an example of a 5G system that supports different numerologies.

The US20170332359 family has 47 straight and the same number of backward citations. All the leading companies of the segment, as well as Apple and Verizon, are among the citing companies.

ZTE's and Ericsson's families have the highest competitive impact of all relevant companies. This is primarily due to the fact that these families have both high overall technology relevance and high market coverage indexes. An Ericsson family with the basic publication **US20170331670** *Network architecture, methods, and devices for a wireless communications network* is included and described in the ranking of the strongest families in the collection. It also has a low internal technology relevance index.

A ZTE family with the basic publication **CN107018542** Method and apparatus for processing state information in network system, and storage medium has slightly higher internal and external technology relevance rates. However, due to a lower market coverage index, its overall competitive impact is lower than that of the Ericsson family. The ZTE family is an active family. Priority is claimed based on the filing date of the Chinese application (March 27, 2017). The family contains two publications: one national and one under the PCT procedure.

The invention refers to a method and apparatus for processing status information in a network system. The processing method of status information includes:

- The first equipment in the first network receives information on the status provided by the provisioning equipment, with such status information used to indicate the usage status of the Bearer ID; the Bearer ID is a session identifier of the bearer channel on the other side of the network, while the first network and the second network are network systems of different types;

- The first equipment determines the Bearer ID corresponding to the Quality of Service (QoS) flow in the first network;

– The first equipment updates the received status information in accordance with the determined Bearer ID.

The method, apparatus and data carrier are used to address the problem of absent information on a unidirectional channel session for preliminary distribution of the target side in the QoS flow during the switching between 4G and 5G using the correlation method.

The family with the publication CN107018542 has one backward citation and 49 forward citations. The citing companies include mainly Huawei, BBK Electronics, and ZTE itself.

The ranking also includes families of Chinese Huawei, which have different average internal and external technology relevance rates. This suggests that Huawei often cites its own developments in prior art. The family with the basic publication in the US has a higher competitive impact in the area than the family with the basic publication in China.

The family with the basic publication **US20170142591** Systems and methods for network slice management is an active family. The priority of the family is claimed in a provisional unpublished application US201562255102P dated November 13, 2015. The patent was granted in the USA. Relevant applications are pending examination in China, India, and at the EPO.

The invention relates to a system and method for managing network slices. A method of generating a network slice is provided in the description. The method comprises a network slice orchestrator (NWSO) receiving from a network slice manager (NWSM) a request for a new network slice, the NWSO adding a new service to the new network slice, the NWSO determining a network slice descriptor (NWSD) for the new network slice, the NWSO transmitting to a resource orchestrator (RO) a request for an instantiation of the network slice using enhanced network function virtualization management and orchestration (E-MANO). A method of modifying a network slice is also provided. Such a communication network can serve a variety of devices, including wireless devices. The principal example of such a network is a 5G network, which is reconfigurable and can slice the network as described in the invention.

The family has 67 forward citations, including by leading companies and Huawei itself. At the same time, the family is a SEP family and is cited in standards such as ETSI-TS-23-501 5G; System architecture for the 5G System (5GS) and ETSI-TS-23-502 5G; Policy and charging control framework for the 5G System (5GS); Stage 2.

Another Huawei family with the basic publication CN106507497 Methods for uplink data transmission, terminal device and network device is also an active family. Its priority date is the same as the date of filing the first application for the family in China dated September 8, 2015. Other family publications include direct patent filings in the US and PCT applications in India and at the EPO.

The invention discloses an uplink data transmission method, a terminal device, and a network device. The method includes:

- sending, by a terminal device to a network device, information used to request a grant-free transmission resource;
- receiving, by the terminal device, resource indication information sent by the network device, where the resource indication information is used to indicate a grant-free transmission resource that is allocated by the network device to the terminal device according to the information used to request the grant-free transmission resource;
- and determining, by the terminal device according to the resource indication information, the transmission resource used for performing grant-free transmission.

According to the uplink data transmission method, the terminal device, and the network device in embodiments of the present invention, contention-based uplink data transmission can be implemented, and data transmission efficiency of a system can be improved. The technical solutions in the embodiments of this invention may be applied to different communication systems, including 5G.

The family has 42 forward citation and 24 backward citations. Citing companies include Nippon Telegraph and Telephone, ZTE, BBK Electronics, Lenovo, Nokia, and Ericsson.

Other families include Samsung's **US20170188391** Methods and apparatus for resource collision avoidance in device to device communication previously described as the family with the highest external technology relevance rate among Samsung's solutions; and LG's family with the basic publication **US20170339609** Methods and apparatus for determining PDU session identity in wireless communication system, which has average technology relevance and competitive impact indexes and a low market coverage. The family requests priority in the unpublished provisional application US201662337349P dated May 17, 2016, and has only two publications in the United States (an application and a patent).

Disclosed are a method and apparatus for determining a PDU session identity in a wireless communication system. A method for determining, by a session management function (SMF) node, a packet data network (PDU) session identity during handover of user equipment (UE) in a wireless communication system, may include:

- receiving a request message for requesting the establishment of a PDU session for the UE from an access and mobility management function (AMF) node, wherein a handover for the UE from a first wireless communication system to a second wireless communication system has been determined, determining a PDU session identity for the PDU session established for the UE when the request message is received,

- and sending a response message including the determined PDU session identity to the AMF node in response to the request message.

Furthermore, an embodiment of the invention proposes a method for allocating a PDU session identity when a PDU session for a UE is established in a next-generation (5G) wireless communication system in order to guarantee service continuity for a PDN connection which is used in a legacy wireless communication system.

The family has 41 forward citations and 13 backward citations. Companies that cite the family the most include Huawei, LG, and Samsung.

Thus, among the most cited families of the collection are mainly Samsung's publications, two of which are not only interesting for the leading companies operating in the area, but also serve as the basis for standards such as ETSI-TS-36-321 *Medium Access Control (MAC) protocol specification* and ETSI-TS-38-214 *Physical layer procedures for data*, which dramatically increases their value for the segment under review. It should be noted that these families are not included into strength rankings, because their geographical coverage and the number of patents granted are much lower than those of the competitors. At the same time, some Ericsson families are represented on a par with them: a SEP family, which is one of the strongest in the collection (Table 5), and a unique family of complete 5G network architecture with a large number of authors. Families included in the ranking due to their ratio of internal and external technology relevance indexes also helped identify families that have not been previously mentioned: Huawei, which has a high contribution to both indexes, AT&T, which has a huge number of backward citations of prior art, and ZTE, which has one of the highest competitive impact indexes. Moreover, we identified families of Convida Wireless and Korea Electronics & Telecommunications Research Institute (ETRI) that are making significant contributions to 5G development. This data allows concluding that different metrics and their combinations help identify technical solutions that are relevant to the segment.

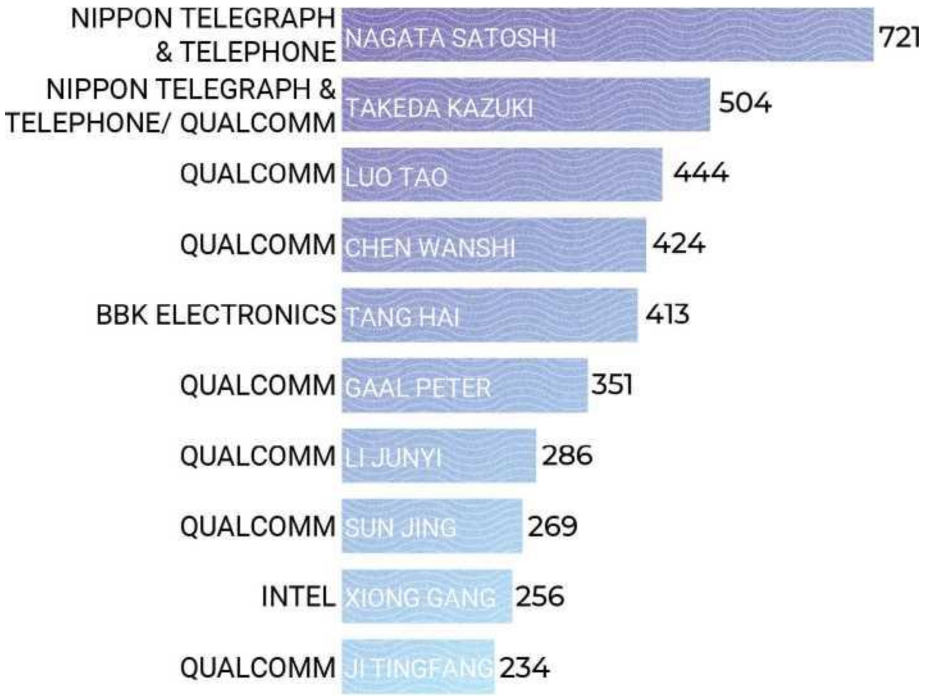
ANALYSIS OF AUTHORS

An important element of the analysis within the patent landscape includes the analysis of individuals who hold patents. This analysis allows identifying the holders of key competencies in order to build cooperative ties in joint development, in a more detailed study of social profiles and academic activities of leading developers in the 5G segment, as well as in making decisions on hiring promising developers.

Employees of Nippon Telegraph and Telephone are leading the ranking of authors by the number of families (Figure 41)

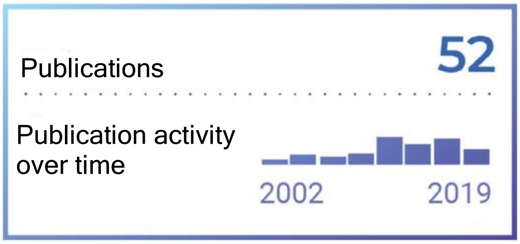
Ranking of authors by the number of families

Figure 41



Patent holder / Inventor / Number of patent families

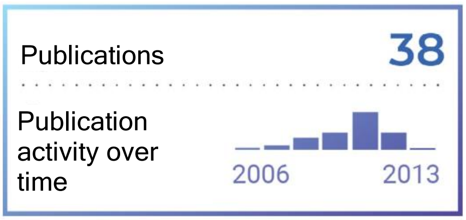
Satoshi Nagata[42] is a Senior Research Engineer at NTT Docomo. He received his M.E. degree from Tokyo Institute of Technology, Tokyo, Japan. After joining NTT Docomo, Satoshi Nagata worked for the research and development for wireless access technologies for LTE, LTE-Advanced. He is currently working for 5G and 3GPP standardization.He had contributed to 3GPP for many years, and contributed 3GPP TSG-RAN WG1 as a vice chairman during November 2011 to August 2013, and also contributed as a chairman during August 2013 to August 2017. He is currently a vice chairman of 3GPP TSG-RAN since March 2017.



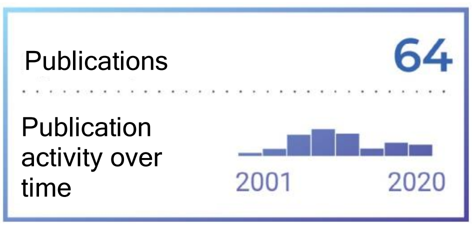
[42] Satoshi Nagata // IEEE Xplore Digital Library URL: https://ieeexplore.ieee.org/author/37268899800

Satoshi Nagata has some seven publications in industry-specific magazines and over 45 conference report publications.[43]

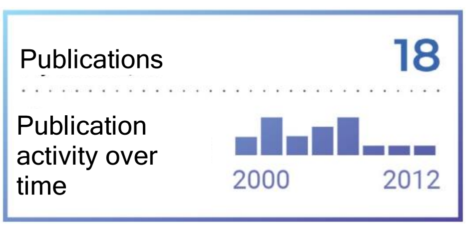
Qualcomm is represented by the largest number of authors, including:



Kazuki (Fred) Takeda. He graduated from Tohoku University in 2006 and holds a degree in electrical engineering, electronics and communications engineering. Kazuki Takeda was working as an Assistant Manager at NTT Docomo from 2013 to 2019. However, he is currently a Staff Engineer at Qualcomm. He also has about 37 publications of his conference speeches. Thus, we observe 5G experts moving from one company to another.



Tao Luo. He holds a PhD degree from Beijing University of Posts and Telecommunications (BUPT). His research interests include mobile communication, the Internet of Vehicles, and privacy preservation.



Wanshi Chen. He holds a PhD degree in electrical engineering from the University of Southern California, USA. Wanshi Chen has over 17 years of experience in telecommunications in leading telecom companies including operators, infrastructure vendors, and user equipment vendors, such as China Mobile and Ericsson.[44] From 2006, he has been with Qualcomm Corporate R&D contributing to system design, prototyping and implementation, and standardization of 4G LTE/LTE-Advanced and more recently 5G (New Radio or NR). He has been attending 3GPP TSG RAN1 for over 10 years, representing Qualcomm and playing an instrumental role in 4G and 5G standardization, as a Vice Chairman from August 2013 for 4 years, and as Chairman starting from August 2017.

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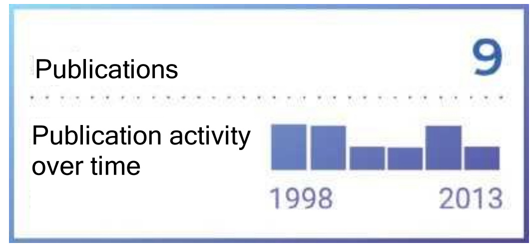
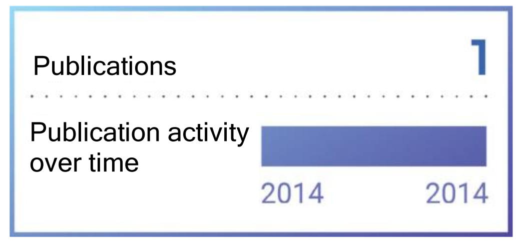
43 All information on publications and dynamics of the authors' scientific publications are taken from IEEE Xplore Digital Library URL: https://ieeexplore.ieee.org/

44 Wanshi Chen // Crunchbase URL: https://www.crunchbase.com/person/wanshi-chen#section-overview

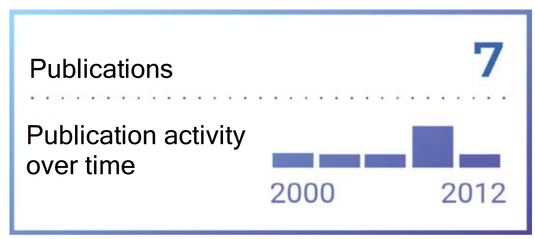
Peter Gaal. Hungarian electrical engineer, researcher. He graduated from Technology University Budapest and has a PhD degree of the University of Southern California, USA.
Systems engineer at Qualcomm since 1999.



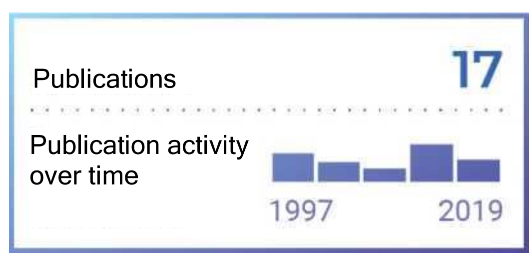
Junyi Li. Junyi Li received his PhD degree in electrical engineering from Purdue University and an MBA degree from the Wharton School, University of Pennsylvania. He received the Purdue University Outstanding Contribution to Electrical Engineering and Computer Science Award in 2012. He is currently the Vice-President of Engineering with Qualcomm Incorporated.



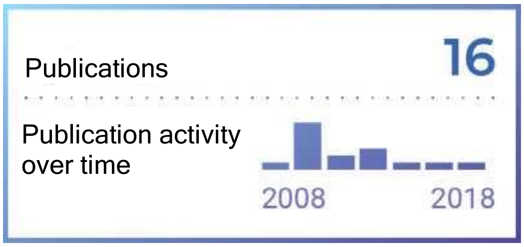
Jing Sun. He received his PhD in Electrical Engineering from Ohio State University in 2004. He is a system engineer with Qualcomm, specializing in 5G NR research and standardization. Jing Sun has been working for the company for over 15 years.



Tingfang Ji.[45] He is a graduate of Tsinghua University in China. He received his PhD in Electrical Engineering from the University of Michigan in 2001. He joined Qualcomm in 2003 where he is currently a Senior Director of Engineering. He has been involved in system design of multiple advanced wireless systems including IEEE 802.20, 4G UMB, 4G LTE. LTE. Since 2014, he has been leading the system design of 5G NR sub-6-GHz radio access technology, with a focus on key NR concepts such as low-latency frame structure, scalable numerology, UL-based mobility, and wide-area wideband TDD massive MIMO.
His team also made instrumental contribution to an industry-first sub-6-GHz 5G NR compliant live demo at Mobile World Congress (MWC) 2017.



[45] Tingfang Ji // IEEE Xplore Digital Library URL: https://ieeexplore.ieee.org/author/38338259300



Other authors with a large number of families include **Gang (Gary) Xiong**,[46] a 5G Wireless Standard Engineer at Intel.[47]
He graduated from Harbin Institute of Technology and received his PhD degree in electrical engineering from Lehigh University in 2011. From 2003 to 2007, he was a team leader at DSP Department, ZTE Corporation Shanghai R&D Center, China, where he led a baseband group for baseband design and DSP development of GSM/EDGE base station system, and he was also involved in baseband design of TD-SCDMA and WiMAX systems.

His current research interests include PHY and MAC layer wireless communication, cross-layer design, and optimization of wireless networks.

Another aspect that allows identifying the most influential developers in behavioral analysis is citation analysis. The most cited authors are usually holders of basic technologies. Information about the cited patents can help identify highly competent employees. Later on, these employees may be subjected to more in-depth research into their activities, including an analysis of their publication activity in specialized journals, speeches at conferences, and activity in professional social communities.

The most cited authors of the collection, without taking into account self-citation, include inventors who are mentioned in Samsung's patent families.

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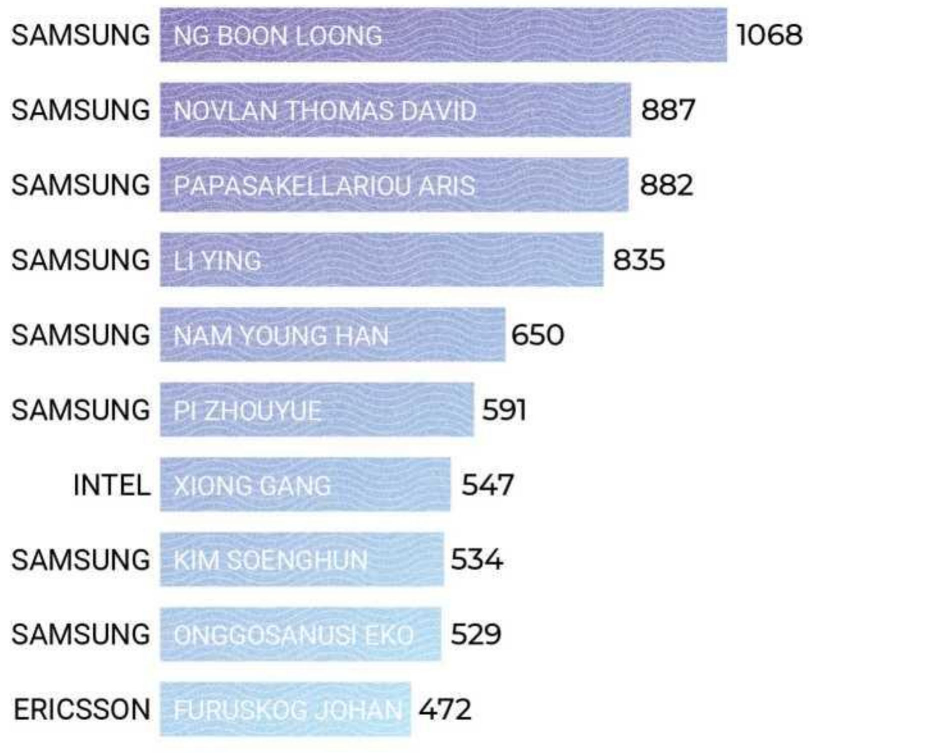
[46] LinkedIn URL: https://www.linkedin.com/in/gangxiong/ru?trk=people-guest_people_search-card

[47] Gang Xiong // IEEE Xplore Digital Library URL: https://ieeexplore.ieee.org/author/37304555100

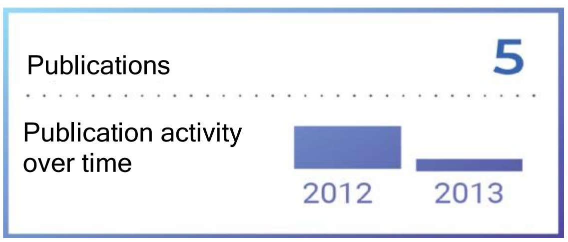
Citation ranking of authors from the overall collection

Figure 42

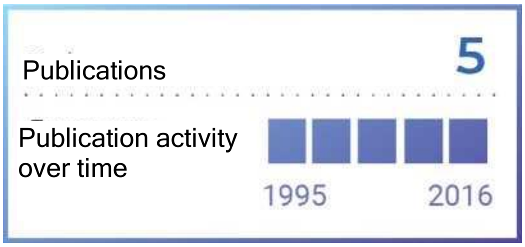


Patent holder / Inventor / Number of patent families

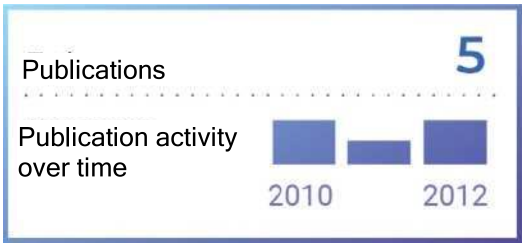
Boon Loong Ng received his Bachelor of Engineering (Electrical and Electronic) degree and his PhD degree in Engineering from the University of Melbourne, Australia, in 2001 and in 2007, respectively.[48] Since 2018, he has been leading a R&D team that develops system and algorithm design solutions for commercial 5G and Wi-Fi technologies. He is currently the Research Director of the Standards and Mobility Innovation (SMI) Lab, Samsung Research America, Plano, TX, USA. He had contributed to 3GPP RAN L1/L2 standardizations of LTE, LTE-A, LTE-A Pro, and 5G NR technologies, from 2008 to 2018.



48 Boon Loong Ng // IEEE Xplore Digital Library URL: https://ieeexplore.ieee.org/author/37085488568



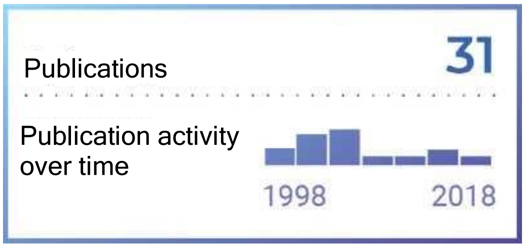
Aris Papasakellariou.[49] Mr. Papasakellariou graduated from the University of Athens, Greece in 1991 and received his Master's and PhD degree in Physics from the Rice University in 1993 and 1996, respectively. He joined Samsung Elestonis in 2007 and has been working on 3GPP standardization since 2005.



Ying Li.[50] She graduated with honors from Xi'an Jiaotong University, China, and received her PhD degree in electrical engineering from Princeton University, New Jersey, in October 2008. She has been with Samsung Telecommunications America, Dallas, TX, since October 2008, where she is involved in research, development and standardization of heterogenous networks for next-generation wireless communications.

She is actively involved in IEEE 802.16m standardization, especially to support femtocells, where she chaired ad-hoc sessions of the IEEE 802.16m technical working group. Her research areas include wireless networks, heterogeneous networks, content distribution, cross-layer design, and optimization.

Kim Soenghun.[51] Kim Soenghun is a graduate of Chung-Ang University, Seoul, Korea, in electrical engineering. Mr. Soenghun has been a senior research fellow at the Samsung Research Center since 2014. Before that, he worked in Samsung Electronics as a chief engineer. He has been a Samsung delegate in 3GPP for more than 15 years. He participated in the RAN2 LTE-A standardization project. Technical solutions with his authorship form the basis for standards in the area.



Eko Onggosanusi.[52] He received his PhD in Electrical Engineering from the University of Wisconsin–Madison in 2000 and is a Standards Director at Samsung Research America, Dallas, Texas.

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[49] Aris Papasakellariou // IEEE Xplore Digital Library URL: https://ieeexplore.ieee.org/author/37344580100

[50] Ying Li // IEEE Xplore Digital Library URL: https://ieeexplore.ieee.org/author/37405728400

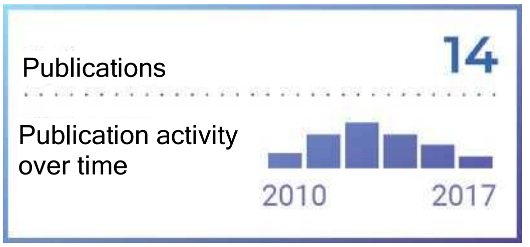
[51] LinkedIn URL: https://kr.linkedin.com/in/soenghun-kim-118629b4/ru

[52] LinkedIn URL: https://www.linkedin.com/in/eko-onggosanusi-aa405b1b/ru?trk=people-guest_people_search-card

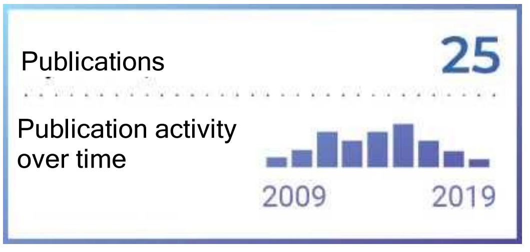
Before joining Samsung in 2014, he was a manager at Texas Instruments. As a delegate to 3GPP RAN1 since 2005, he has contributed to numerous HSPA, LTE and 5G NR physical layer specification components.[53] He has also been a 3GPP speaker for EBF / FD-MIMO and eFD-MIMO.

Another group of most cited authors include former Samsung employees who have joined another company.

Thomas David Novlan.[54] He graduated from the University of Texas at Austin in 2007 and received his PhD in Electrical Engineering in 2012. He was a technical trainee at Qualcomm in 2008, then in 2010 at Intel and in 2011–2012 at AT&T. After that, in 2012, he joined Samsung Research America and since 2014 has been engaged in research, development and standardization of next-gen wireless technologies.



However, in 2016 he left the company to join AT&T, where he is now engaged in research and development of 5G+ systems, cellular network modeling, performance evaluation, and optimization. He is also AT&T's current representative for 3GPP RAN WG standards.



Young-Han Nam.[55] He received his bachelor's degree in electrical engineering and master's degree in biomedical engineering from Seoul National University, Seoul, South Korea, in 1998 and 2002, respectively, as well as his PhD in electrical engineering from Ohio State University, Columbus, OH, USA, in 2008.[56]
He was chief engineer at the Laboratory of Standards and Mobility Innovation at Samsung Research America, where he directed research on 5G base station algorithms. From 2008 to 2017, he was actively involved in the development of 3GPP, 4G LTE and 5G NR PHY-level standards, and led discussions on massive MIMO.

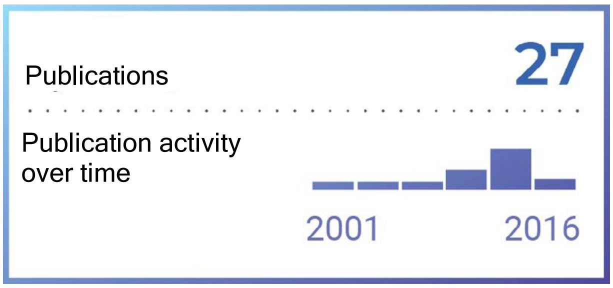
[53] Eko Onggosanusi // IEEE Xplore Digital Library URL: https://ieeexplore.ieee.org/author/37329512300

[54] LinkedIn URL: https://clck.ru/NCc3W

[55] LinkedIn URL: https://clck.ru/NCc4D

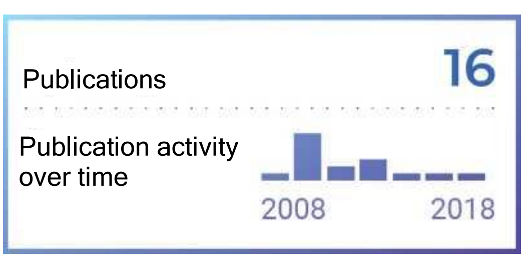
[56] Young-Han Nam // IEEE Xplore Digital Library URL: https://ieeexplore.ieee.org/author/37394869700

He contributed to the part related to 3GPP RAN1 5G channel modeling research for the editing of the 38.900 / 38.901 technical report. He is currently Director of Mavenir,[57] the industry's only comprehensive provider of cloud networking software from 5G applications/service levels to packet core and RAN.



Zhouyue Pi.[58] He holds a bachelor's degree from Tsinghua University (honors), a master's degree from Ohio State University and an M.B.A. degree from Cornell University (honors). He is currently the Chief Technology Officer of Straight Path Communications Inc. (Verizon) where he leads strategic research and product development in 5G, Gigabit broadband, and backhaul solutions.

Prior to joining Straight Path, Mr. Pi was a Senior Director at Samsung Research America, where he led system research, standardization, and prototyping activities in 4G and 5G. Mr. Pi pioneered the development of millimeter-wave 5G. He co-authored the world's first invention and first journal article on Millimeter-wave Mobile Broadband. He also led the development of the world's first 5G baseband and RF system prototype that successfully demonstrated the feasibility of 5G mobile communication at 28 GHz. Before joining Samsung in 2006, Mr. Pi was with Nokia Research Center where he was a leading contributor to Nokia's 3G research, standardization and modem development efforts.



The leading authors by the number of forward citations by other companies also include Intel's developer **Gang (Gary) Xiong**, who is also a leader by the number of families, as well as Ericsson's developer Johan Furuskog.

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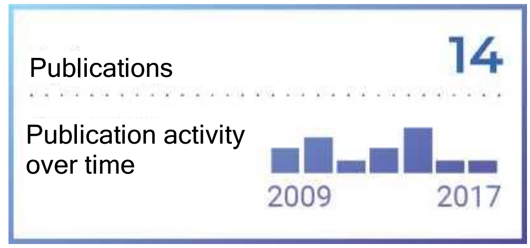
[57] LinkedIn URL: https://www.linkedin.com/company/mavenir?trk=public_profile_topcard_current_company

[58] Zhouyue Pi // IEEE Xplore Digital Library URL: https://ieeexplore.ieee.org/author/37269226900



Johan Furuskog received his master's degree in engineering physics from Uppsala University, Uppsala, Sweden, in 2007.[59] After graduating from university, he joined Ericsson Research as a researcher, where his work has mainly concerned test-bed development and field trials with focus on MIMO channel characteristics and LTE multi-antenna performance.
Johan is currently involved in different test-bed projects, which target the design and deployment of future systems for radio access (including 5G) as well as in developing the concept and evaluation of new components for the LTE standard.

Accordingly, we see that 5G talents intensively move between incumbents, including leading 5G developers leaving Samsung to join other companies. Some of them form innovative start-ups based on the experience gained in the leading corporate 5G research centers to offer new sophisticated solutions in the market to meet the emerging demand for the deployment of 5G networks and related infrastructure.

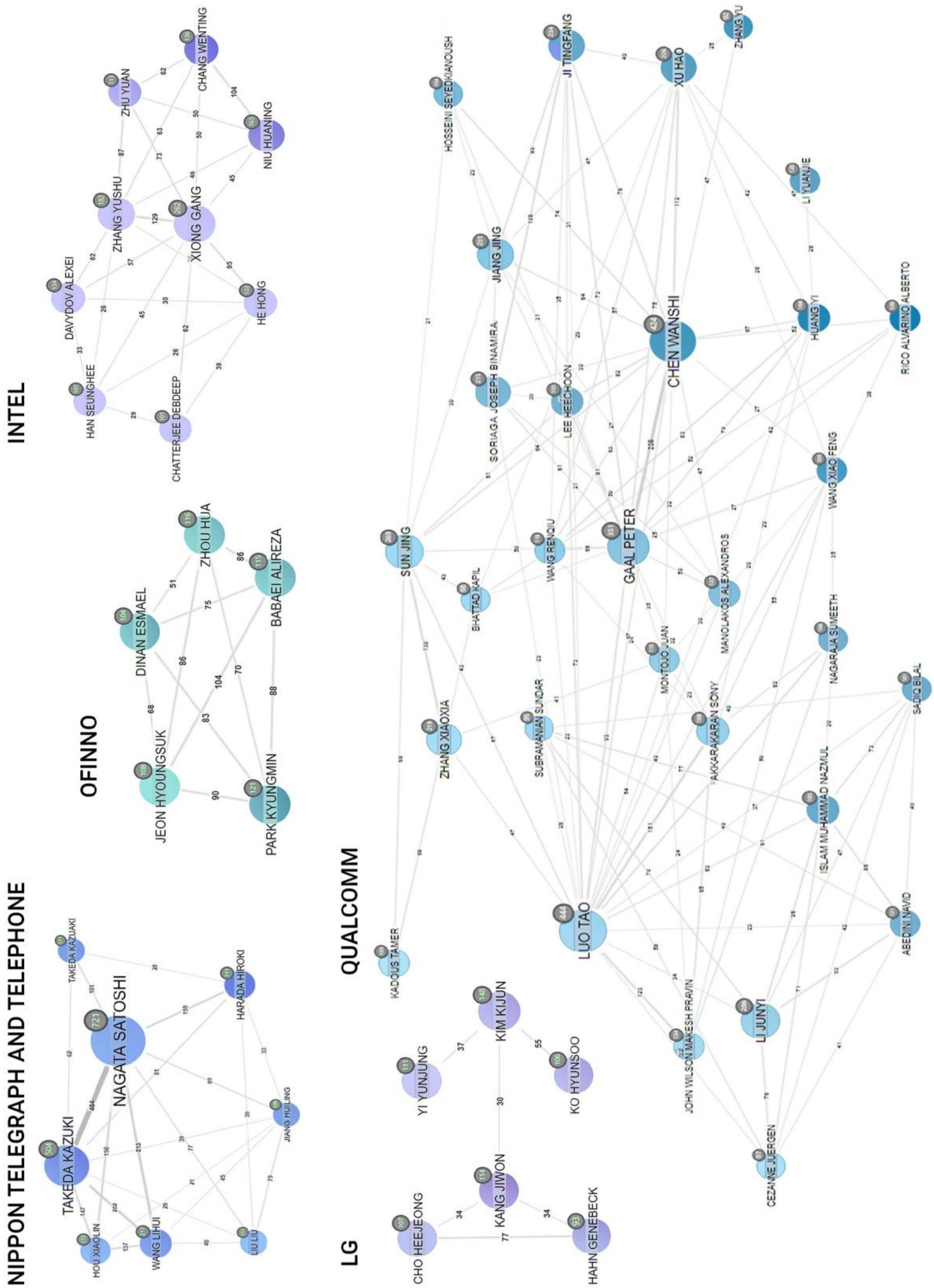
At the same time, there is a large number of cooperative ties between authors working in this area. A full map of cooperation between authors is provided in Appendix F. Map of cooperative ties between 5G technology authors. This indicates a high level of interaction between research groups in the context of an emerging market with tough competition.

Qualcomm, represented by many groups of researchers all over the world, has the largest number of cooperative ties between authors. The structure of cooperation between authors indicates the global level of research activities, which is achieved through effective interaction among people from different countries.

[59] Johan Furuskog // IEEE Xplore Digital Library URL: https://ieeexplore.ieee.org/author/37302863200

Figure 43

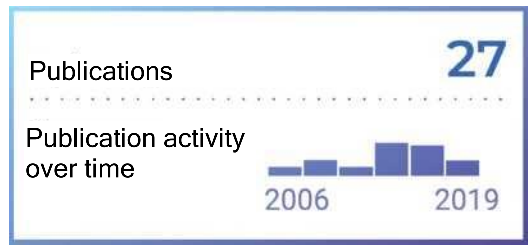
Cooperation among authors from the overall collection



Nippon Telegraph and Telephone and Intel have a smaller number of authors involved in the development of 5G solutions, but a greater concentration of research studies within a narrow circle of specialists.

LG is also engaged in collaboration on 5G, but the number of its collaborators does not exceed three per technical solution.

At the same time, some authors have been identified seen in the patents of companies other than included in the list. For example, **Alexey Davydov**,[60] an author and senior engineer at Intel,[61] is often mentioned in joint patents between Intel and Apple.



Ofinno also has a large number of cooperative ties. At the same time, the above developers are also authors in patents of other companies. For example, Jeon Hyoungsuk in patents of Comcast Corporation (American Telecommunication Corporation), Park Kyungmin in patents of LG, Apple, Samsung, and Comcast, Zhou Hua in patents of Fujitsu, and Babaei Alireza in patents of Comcast. One of the authors of patents, Dinan Esmael, is the founder and CEO of a company.

Ofinno[62] is a research laboratory based in Northern Virginia, USA, which specializes in inventing and patenting future technologies such as 5G Radio and Core, IoT, V2X, and ultra-reliable low latency communication. The company is a pioneer in wireless switching technology. Ofinno's 5G patents were listed along with Apple, MediaTek, Deutsche Telekom, Xiaomi, and Convida Wireless patents as the "ones to watch" by Derwent™[63]. Ofinno has filed more than a thousand patent applications, addressing complex technological challenges for 5G wireless technologies.

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[60] Alexei Davydov// IEEE Xplore Digital Library URL: https://ieeexplore.ieee.org/author/37544143600

[61] LinkedIn URL: https://ru.linkedin.com/in/alexei-davydov-78a1925/ru?trk=people-guest people search-card

[62] Home | Ofinno URL: https://ofinno.com/

[63] Ofinno 5G Wireless Patents Identified as «Ones to Watch» // Home | Ofinno URL: https://ofinno.com/

It should be noted that the cooperation map does not feature the leading companies by the number of families, i.e. Huawei, Samsung, and Ericsson. This may be due to the fact that the metrics chosen as the basic indicators to build the cooperation map included the following: at least 20 patent families per author and at least 20 cooperative ties between authors on the map. Accordingly, the relevant companies have lower numbers of patent families and cooperative ties. For large companies, this means that research is more diversified and small groups of researchers have narrower specializations.

The analysis shows that authors with the highest number of patents are not always the most cited ones. For instance, the leaders by the number of families include Japanese inventors from Nippon Telegraph and Telephone and inventors from Qualcomm, an American transnational company, while the most cited authors are inventors who work or worked at Samsung. At the same time, the analysis of authors and cooperative ties allowed us to identify specialized innovative startups that are focused on 5G developments, including Ofinno, an American research laboratory, and Mavenir, a provider of software for cloud networks.

PATENTING GEOGRAPHY

04

An analysis of geographical aspects of patenting is an important step in the development of the patent landscape, which allows identifying:

- countries that are patenting leaders in the domain;
- attractive territories for protection of technical solutions for companies that indicate:
- target markets to sell innovative products;
- potential territories to build production centers (based on the financial and economic feasibility and/or availability of inexpensive and qualified production resources).

Data on the geographical and administrative jurisdiction of patented technical solutions was used as an information basis to explore the patenting geographies. The specific jurisdiction of the publication was primarily used as the key basis for the analysis of geography.

It should be noted that the analysis of the patenting geography in combination with the analysis of patenting strategies within the patent family helps building insights into various aspects of the patenting geography. For example, an analysis of the country of the application's first filing is highly likely to help identify the invention's place of origin, while an analysis of the countries of subsequent filing are more likely to help identifying promising target markets (potentially attractive production centers). The first application can turn out to be an application filed under international or regional patenting procedure. In such case, the family is most likely to be a continuation of another one, with an earlier priority.

Ratings of the leading countries across a number of metrics serve as the principal tools to analyze the patenting geography. An analysis of priority countries reveals the countries that are most likely to be the developers of technical solutions, meaning that research groups are operating in such countries. An analysis of countries of publications shows the most attractive markets for promoting technologies. An analysis of patenting dynamics by country can identify an increase in technological competences across regions.

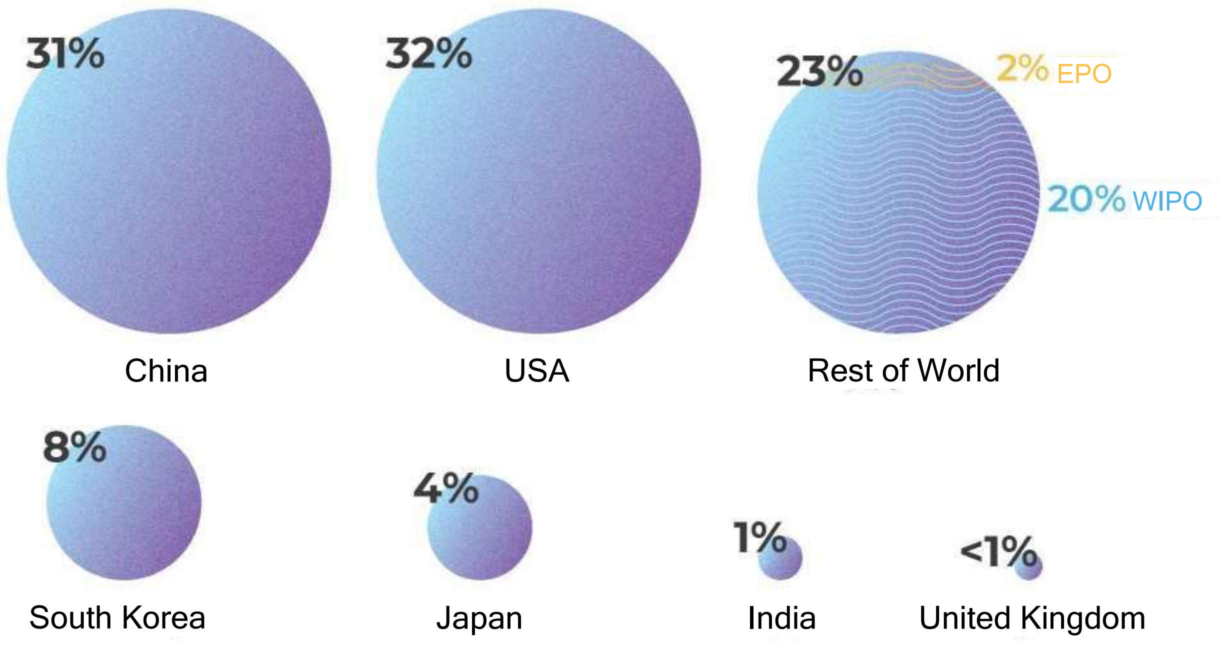
In the section below, we will discuss the patenting geography in more detail.

EMERGENCE OF PATENTING ACROSS COUNTRIES

One of the key types of geography-driven analytics includes the analysis linked to patenting priorities. Patenting priorities are closely linked to the origin of research and development and can help identifying not only countries with developed behavioral analysis competences, but also regional research and development centers of multinational corporations.

Ratio between patenting priorities by geography

Figure 44



The USA and China are the leading countries developing new technical solutions in 5G (Figure 44). The countries share the top place in the ranking, with only 1% difference by the number of priority families. The US and Chinese priority families together account for 63 percent of the collection, which has a significant impact on the competitive 5G environment.

Many transnational companies strive to file applications for their technical solutions primarily in the US through their research centers and affiliates, as the US market is currently saturated with mobile operators who are ready to deploy 5G commercial networks. The leaders in the US market include local national developers Qualcomm (20%) and Intel (13%). The rest is distributed among the incumbents: LG (10%), Ericsson (9%), Samsung (6%), Mediatek (3%), Nokia (3%), AT&T (2%), Sharp (2%), as well as Apple, HTC, Ofinno, and Verizon (1% each). This strategy is typical even for some families of the leading Chinese company, Huawei (4% of priorities in the US market). Although, in general, Chinese companies (BBK Electronics, ZTE, China Information and Communication Technology Group, Xiaomi, China Mobile, Tsinghua Group, and many others) choose China as their priority country, which allows them to saturate the national market with a large number of 5G priorities. At the same time, Huawei, BBK Electronics, and ZTE make a significant contribution to the country's leadership, accounting for more than 50% of all priorities.

Interestingly, companies often choose the international filing phase under the PCT procedure as the priority process (20% of the collection). As a rule, the choice of the PCT international procedure demonstrates the intentions of companies to protect their technical solutions across a large number of countries. PCT patenting operates as a proxy when companies intend to bring their technical solutions to a large number of countries at once with subsequent transition to national phases. The use of PCT procedures considerably reduces the total cost of technology patenting.

This distribution of priorities is confirmed by high patent asset indexes of solutions that are brought to the international level (Figure 31). An analysis of the subsequent transition of solutions to national phases indicates that an overwhelming majority of companies use the PCT procedure for patenting across numerous markets around the world. This includes filing regional patenting applications through the EPO to position solutions in the European market; filing applications in South American countries such as Chile, Brazil, Peru, Argentina; and filing applications in the Asian region: China, South Korea, Japan, Malaysia, Taiwan, Philippines, and Singapore, as well as filing in Russia.

Moreover, for patenting in European countries, companies choose to file applications through the PCT procedure with subsequent filing through the EPO. Direct priorities are claimed through the EPO only in 2% of cases by several companies such as Sony, Deutsche Telekom (a German telecommunication company, the largest in Europe), and Alcatel (Nokia).

South Korea is represented by 8% of direct priorities, i.e. priorities obtained through the national patenting phase. The majority of such priorities (over 50%) belongs to Samsung. Other Korean companies that have the highest share of priorities include KT Corporation (Korea's largest provider of integrated wire and wireless telecommunication services in South Korea), Korea Electronics & Telecommunications Research Institute (a Korean research institution financed by the government), LG, and SK Telecom (a South Korean mobile operator). Accordingly, the South Korean market is also represented by both 5G equipment providers and mobile operators that ready to participate in the deployment of next-generation networks.

The situation in Japan is similar to that in South Korea. In Japan, more than 60% of priorities belong to Nippon Telegraph and Telephone, which is both a supplier of equipment for 5G networks and a telecoms operator. Among other Japanese companies we can name NEC, Sony, Fujitsu, and SoftBank. The list also includes priorities owned by SK Innovation, a South Korean corporation, which has 8% of the total share of priorities in Japan.

India and the UK account for 1% of the priorities. In India, priorities are distributed among the research and development centers of Samsung (44%), Qualcomm (24%), and Nokia (17%). In the United Kingdom, priorities are divided between TCL Corporation (a Chinese company designing and manufacturing cell phones and the telecommunication equipment, among other things, having about 60%) and Samsung (30%).

The remaining 17 countries account for 1% of the priorities. It is distributed among Germany, Greece, Taiwan, Sweden, France, Finland, Australia, Italy, Russia, Singapore, Turkey, Vietnam, Spain, Israel, Mexico, Malaysia, and Portugal.

At the same time, no priority was identified in Canada.

It should be noted that Ericsson as the leading company by the number of families has virtually no priorities with the national patent office of Sweden, while most of its priorities are claimed in the US and under PCT applications. Accordingly, 5G incumbents monopolize the markets, taking advantage of their priorities from applications filed through international patenting procedures, as well as through their research branches.

Below we discuss how priorities (i.e., new research and development) emerge over time in the leading patenting countries (Figure 45). Such dynamics allows judging about the intensity of 5G technology emergence across countries.

Priorities have been emerging throughout the period under review only in four countries: the USA, China, South Korea, and Japan. The USA, China and South Korea have similar development dynamics in this area, differing by patenting volumes. The greatest intensification of family emergence in terms of priorities is noted between 2016 to 2018. The maximum number of priorities in the USA, China and South Korea was claimed in 2017. In Japan, the maximum number was recorded in 2016, followed by a decline in the number of families for which priorities were sought.

The desire of companies to obtain the earliest possible priorities is just natural in a rapidly growing market in an area with high commercialization prospects. The volumes of patenting under the international PCT procedure are also growing along with the number of priorities in leading countries. This indicates the commercial importance of developments with such priorities. The hyperactivity of Chinese companies, which are claiming their leadership across international markets, also serve as an additional incentive for intensifying the efforts. Mechanisms of regional patenting through the EPO are used much less frequently than international procedures, and the level of priority emergence through the EPO is much lower. This suggests that most companies are focusing on the international market, implementing large-scale strategies of geographical coverage.

Lower priority emergence rates were observed in India, the UK, and Germany after 2014.

At the same time, the patenting retrospective in India is slightly longer than in Germany or the United Kingdom. Patenting in other countries is fragmented and shows no stable dynamics. A slight acceleration in patenting was observed in Taiwan, Sweden, and Greece during the same periods as for the leading countries. Single cases of priority emergence were observed in Vietnam, Turkey, Singapore, Russia, and Italy.

Figure 45

Dynamics of priority emergency by country

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
US	26	38	54	102	340	830	2234	3855	2085	31
CN	17	23	27	32	157	385	1512	3647	2409	896
WO	7	14	19	52	189	506	1261	2213	1350	159
KR	2	4	8	25	182	257	445	874	476	62
JP	15	6	4	8	21	184	436	352	157	4
EP	0	0	5	18	39	62	171	217	116	0
IN	0	1	0	4	17	52	65	163	104	0
GB	0	0	0	0	3	13	38	80	43	0
DE	0	0	0	0	3	20	36	25	6	0
GR	0	0	0	0	0	1	1	32	49	0
TW	0	0	0	0	0	2	5	14	8	0
SE	0	0	0	0	0	1	0	9	21	0
FR	0	0	0	0	1	4	6	5	9	0
FI	0	0	0	0	0	2	0	2	10	0
AU	0	0	0	0	0	2	4	5	2	0
IT	0	0	0	0	1	0	0	4	2	0
RU	0	0	0	0	0	0	3	0	1	0
SG	0	0	0	0	0	1	3	0	0	0
TR	0	0	0	0	0	1	0	1	1	0
VN	0	0	0	0	0	0	0	0	0	2

GROWTH OF PATENTING ACROSS COUNTRIES

Technology expansion analysis is another form of territory-based analysis of patent documents. In contrast to the analysis of technology emergence, this type of analysis is based on the publication dates of patent documents and allows us to draw conclusions about promising areas where technical solutions can be distributed. The dynamics of publishing activity across leading countries is linked to the expansion by companies to patent territories. In this respect, the growing volumes of patenting in relation to a particular country indicates an increase in the attention paid to this country by the world's leading companies from different countries.

Changes in the publication activity of countries between 2010 and 2019 (Figure 46) have a similar structure both for countries with high publication rates and for countries with lower publication rates. A similar distribution demonstrates that the level of patenting worldwide is rapidly increasing, but the intensity of publications varies from country to country. The overall increase in publication volumes during the period under review does not begin until 2014–2015.

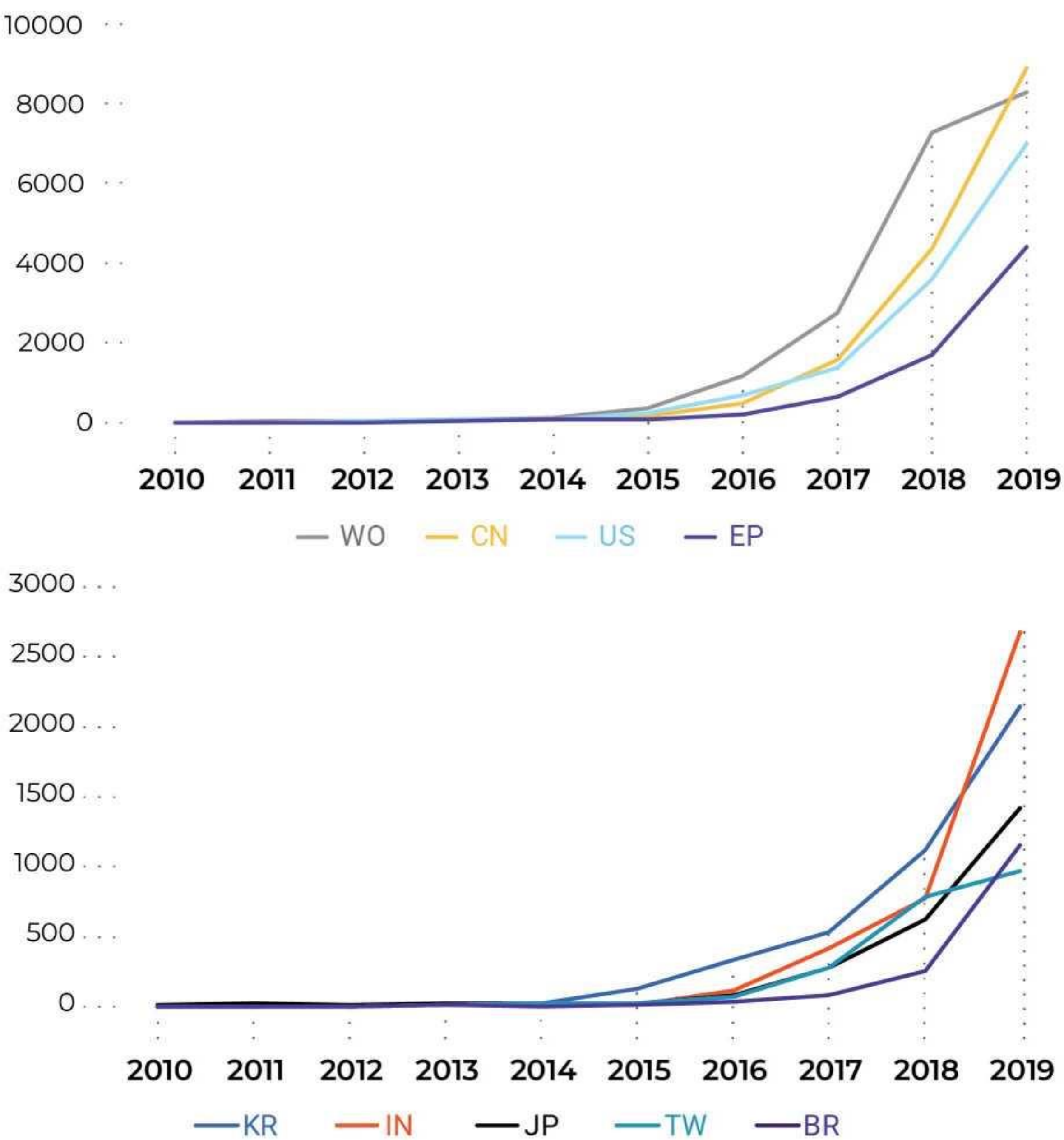
China and the US are maximizing their publishing activity during the period under review and were the undisputed leaders by the end of 2019 among all countries. Both countries are the most promising patenting markets for 5G incumbents. A slightly greater intensity of publications in China over the past few years was due to the fact that American, Japanese, European, and other companies are filing applications both in the US and in China, but only leading Chinese companies are filing applications in the US (including Huawei, ZTE, and BBK Electronics, given that the US market is not a patenting priority for the latter two). Many other Chinese companies are patenting their inventions exclusively in their national market. The patenting upsurge by China started one year before than in all other countries, while the US had a higher overall level of publications before 2017.

The publication activity in other countries also showed a positive trend. South Korea showed the strongest performance over the entire period. However, over the last year there was a significant surge in the publication activity in India, which enabled the country to consolidate its leading position among countries with lower levels of publications.

In general, for all countries, the intensification and peak of publications fell on 2019. In Taiwan, on the contrary, the intensity of publications decreased in 2019. India, Japan, Taiwan, and Brazil had a later start in their publication activity (2016).

Dynamics of publication activity in the general collection across countries

Figure 46



The PCT international patenting procedure demonstrates the highest publication rates since 2015. Such activity indicates the intention of companies to first enter foreign markets with their solutions in order to maximize the geographical coverage of their families and secure priorities for a particular technology. A significant increase in the density of international publications in 2018 indicates the phase of active commercialization of 5G solutions. The decline in 2019 may be due to an 18-month delay in publications. In general, the publication activity under the PCT procedure, which significantly exceeds the publication activity in individual countries, indicates that all technical solutions being developed aim to obtain financial benefits from patenting. This is also confirmed by the fact that the bulk of patents in the collection comes from commercial companies, which spend significant amounts of money on scientific research and implementation of technical solutions to be offered for sale in the market. Accordingly, 5G also demonstrates a high level of commercialization.

It should be highlighted that the procedure of regional patenting through the EPO is also gaining popularity when it concerns the expansion of geographical coverage for solutions. The difference from the PCT system is that the EPO grants a patent, which gains national importance in countries for which it was requested. In fact, this mechanism is one of the most effective ones for large-scale patenting in the European market.

An analysis of strategies employed by companies to enter markets of different countries is primarily based on exploring the ratio between the first and subsequent filings (Figure 47).

Offices of first filing refer to countries where research and development in the domain are conducted and where the first applications are filed. Most often, the office of first filing coincides with the applicant's country of residence, which allows identifying strategies employed by applicants to exercise their patent rights.

Offices of second and subsequent filings indicate target markets and/or whether the company is intending to deploy manufacturing in respective jurisdictions. In addition to these objectives, the choice of countries for the geographical expansion of patent protection may also be aimed at restricting competitors' headroom and serves as a preventive measure to prevent potential offenders.

Ratio between offices of first filing and offices of subsequent filing

Figure 47

Publication countries (markets)

Priority countries (research and development)

	WO	CN	US	EP	KR	IN	JP	TW	BR	CA	AU	VN	MX	SG	DE	GB	IL	RU	PH	AR
US	7230	3208	7186	3057	1350	1711	750	1444	647	412	357	133	162	176	146	14	48	62	45	67
CN	4682	8681	1339	1242	359	707	249	78	302	105	83	181	13	3	3	0	4	10	2	0
WO	5477	2740	1916	1931	593	1120	508	514	496	332	309	211	144	131	30	0	109	55	42	28
KR	1138	468	1219	425	1786	249	47	16	2	5	31	9	3	1	9	0	0	3	3	0
JP	985	566	675	516	90	126	978	56	89	57	58	34	50	32	6	0	15	28	12	3
EP	438	182	234	510	66	46	75	18	20	6	5	3	6	5	6	0	3	3	1	0
IN	268	97	195	97	94	254	6	35	26	9	5	1	1	20	3	6	0	0	2	1
GB	139	29	58	31	18	10	9	0	1	2	0	1	0	0	0	162	0	0	0	0
DE	47	35	42	22	7	2	8	0	2	0	0	0	2	0	76	0	0	1	0	0
GR	43	2	43	2	2	4	0	16	3	2	1	0	0	2	0	0	0	0	0	0
TW	1	18	23	3	0	1	2	31	0	0	0	0	0	0	1	0	0	0	0	0
SE	31	1	3	1	2	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
FR	18	4	14	13	1	1	1	0	1	2	0	0	0	1	0	0	1	0	0	0
FI	8	7	9	4	1	1	1	0	0	0	0	0	0	0	3	0	0	0	0	0
AU	12	2	5	3	0	2	2	1	0	1	5	0	0	0	0	1	0	0	1	0
IT	7	2	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
RU	3	2	3	3	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0
SG	4	3	3	2	1	2	1	0	0	0	0	1	0	4	0	0	0	0	0	0
TR	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VN	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0

According to the studies, 23 countries are offices of first filing, 46 countries are offices of subsequent filing, including the PCT international procedure, as well as regional filing through the European Patent Office, the Eurasian Patent Office (EAPO), and the African Regional Intellectual Property Organization (ARIPO). Meanwhile, the USA and China are the most preferred countries for bringing solutions to the market. The number of countries where technical solutions are developed is much smaller and differs from the countries of subsequent publications in terms of their patenting structure and density, which indicates a wide geographical coverage of technical solutions developed by a small group of developer countries.

The geographical coverage of offices of second filing coincides with the jurisdictions where active SEP families are protected. This suggests that the SEP families that are the most valuable for patent holders have the largest geographical coverage and, accordingly, indicate their intention to maximize the geographical coverage of their patents.

China and the United States are ahead of all other countries by a wide margin in terms of the number of proprietary developments. In terms of geographical coverage, the US has the highest density (42 countries and filings through the WIPO and the EPO), followed by China (19 countries and filings through the WIPO and the EPO), and South Korea (18 countries and filings through the WIPO and the EPO). All three countries file applications at the national level, as well as in India, Japan, Taiwan, Brazil, Canada, Australia, Vietnam, Mexico, Singapore, Germany, Russia, and the Philippines. Furthermore, the US has publications in the United Kingdom, Argentina, Spain, Denmark, Hungary, Hong Kong, Poland, Portugal, Malaysia, Turkey, New Zealand, Austria, Thailand, Cuba, Morocco, Slovenia, Tunisia, Costa Rica, Lithuania, the Dominican Republic, El Salvador, as well as the EAPO and the ARIPO. The US and China are also publishing in Israel, South Africa, Chile, and Colombia. China and South Korea have no direct filings or publications in European countries and in a number of South American and African countries. Japan (24 countries, including Peru, Thailand, Turkey, Spain, Chile, Costa Rica, as well as the EPO and the WIPO) and India (20 countries, including New Zealand, as well as the EPO and the WIPO) also have a wide geographical coverage.

Despite the large number of developments made for the national market, US companies are also launching their solutions in a large number of other countries. This results in a wide geographical coverage of the USA, as well as in the highest rate of its PCT patenting.

US applicants entering the international market prefer to cover the largest number of jurisdictions with a single application; therefore, it is more important for them to secure foreign protection through the WIPO than through the EPO, which only covers European countries. Despite this, the US is also the leader in European patenting, as after applying to the WIPO the country enters the European patenting phase. At the same time, China is ahead of the USA in terms of the number of developments in the national market, while its PCT patenting volumes are almost twice as low as its national patenting.

China and applicants who specify the USA when filing applications under the PCT procedure demonstrate the greatest activity in the US market (in addition to their national markets). Applicants from South Korea, Japan, and India also patent their developments in this manner. The Chinese market is attractive for applicants from the United States, Japan, South Korea, and India, and it is often specified in PCT applications. The third largest market for international patenting is South Korea where national and American applicants are mainly represented; South Korea is also often the country of choice for the PCT patenting procedure. Chinese applicants, however, are much less likely to apply in this country than American applicants. Moreover, the Indian market, where a large number of applications are observed, is of particular importance for Chinese applicants. Top 3 in the Indian market also include the USA and publications through the PCT patenting procedure. In general, we observe a strong activity of US applicants across all markets represented, including the leading patenting position in Taiwan, which exceeds the volumes of national patenting.

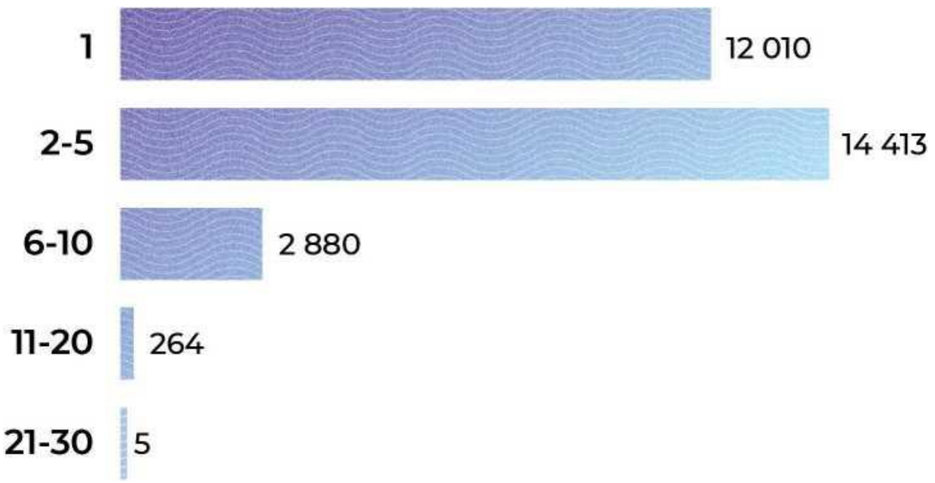
Other countries also focus on a large number of jurisdictions in addition to their respective national markets, but with at a lower scale.

A distribution of families by the number of jurisdictions covered (Figure 48) shows that the highest concentration of families can be observed within the range between two and five jurisdictions. The list of countries includes unique two-letter codes of international (WO) and regional forms of protection (EP, EA, AP), which are not countries *per se*, but are used in patent documents to identify the geographical expansion of families. More than 50% of collections are valid in two or more jurisdictions, and in most cases such families have international or regional forms of protection. At the same time 11% of families in the collection cover quite a large number of jurisdictions with direct filings (from six jurisdictions, taking into account the national phases under the PCT procedure).

It should be highlighted that European countries are taken into account only if there are publications pending national phases or in case of direct filings; otherwise European countries are considered as one EP jurisdiction (however, patent protection is valid in all countries mentioned in the application).

Figure 48

Distribution of families by the number of jurisdictions covered



Number of jurisdictions covered / Number of families

Thus, the most typical patenting strategy in the 5G segment consists in securing a wide geographical coverage across a large number of foreign jurisdictions, including gaining a strong technological position in patenting under international procedures (PCT) while national patenting volumes are less significant. Applicants choose simplified regional and international patenting systems to reduce the financial burden of maintaining their patent portfolios. The high level of this type of patenting indicates the willingness of companies to promote their technical solutions in foreign markets, building the relevant level of competition and securing economic benefits.

PATENTING IN RUSSIA

The market for patenting 5G technical solutions in Russia was analyzed separately.

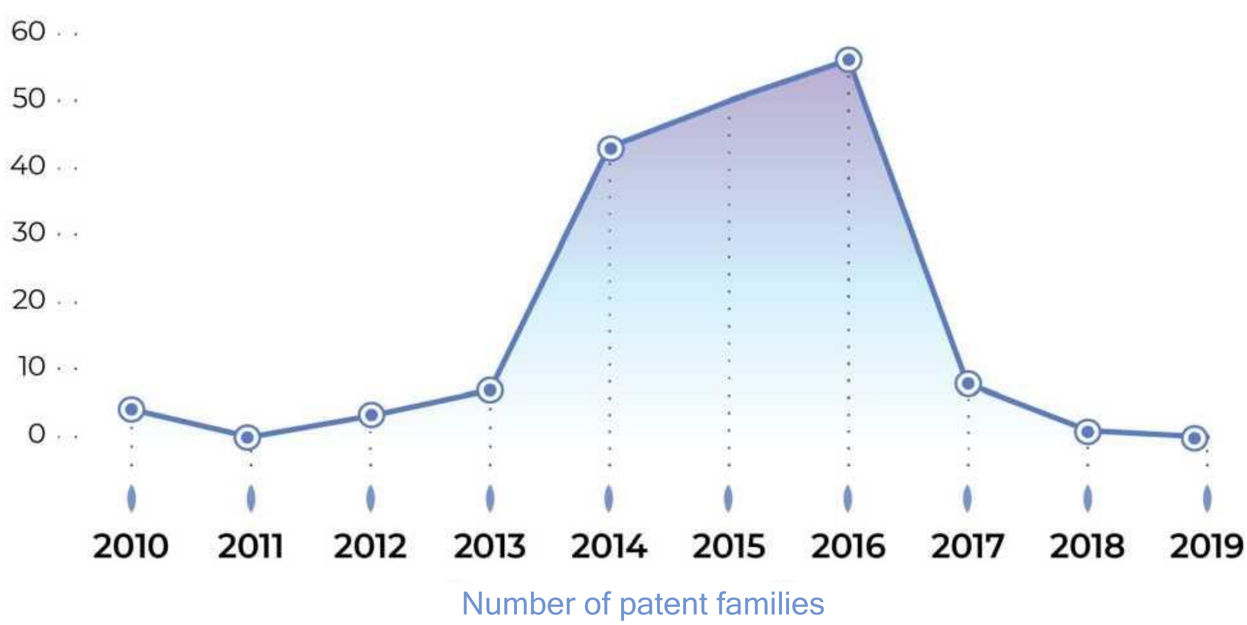
176 patent families that mentioned publications in Russia were identified in the collection.

The patenting dynamics in the Russian segment is illustrated by a distribution of family emergency indicators (Figure 49). The priority date was chosen as such indicator.

The bulk of families have priorities dated between 2014 and 2016. Almost 90% of all priorities of families that have publications in Russia emerged during this period. However, for four families, priorities are sought for earlier applications dated before 2010. Therefore, the patenting peak in Russia coincides with the global intensification phase of family emergence.

Patenting dynamics in Russia, 2010–2019

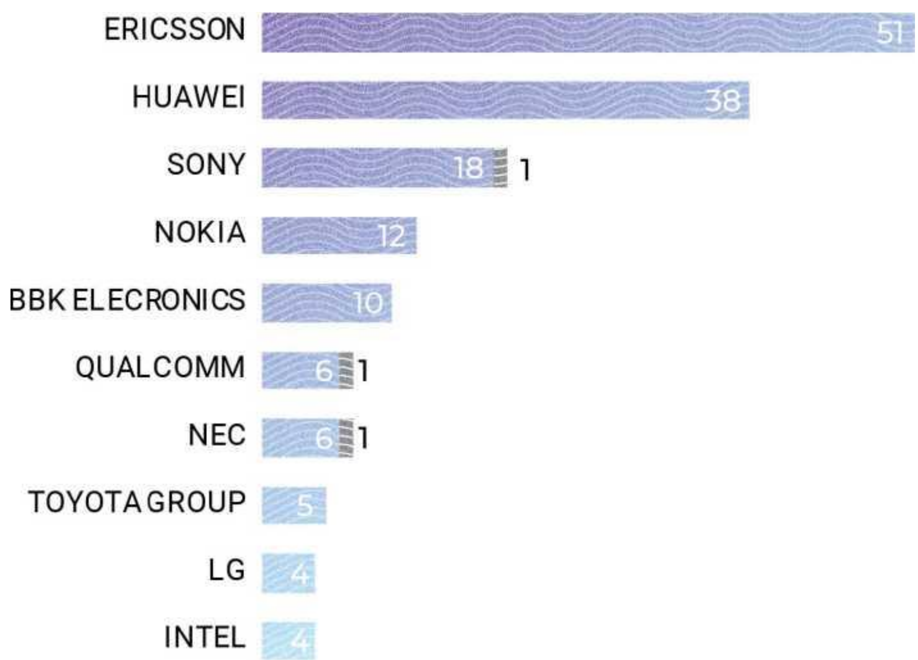
Figure 49



All families with publications in Russia are active families. Only 5 families do not have granted patents (Figure 50). These include several families of Sony, Qualcomm, and NEC. All other families have granted patents. Among them are 5G incumbents, including the leader of patenting in Russia, Swedish Ericsson. Chinese Huawei, which also has publications in Russia, is also represented by a fairly large number of families. Other companies in the ranking have much lower figures.

Among them is Japanese Toyota, which has patented solutions (**RU2690953**, **RU2696509**) related to the transport communication. One of the potential embodiments of every solution described therein uses a 5G network.

Figure 50 **Leading patent holders in the Russian market**



Patent holder / Patent granted / Expired

A distribution of family emergence across companies over time allows identifying the principal periods of activity for the leading players (Figure 51). In 2014, most families was created by Huawei, and in 2015/2016 it was European Ericsson that took the lead. Sony has an even distribution of priorities throughout the peak period. Chinese BBK Electronics and Japanese NEC created some families in 2016, apart from Ericsson and Huawei. Japanese Toyota established its priorities mainly in 2016 and 2017. South Korean LG also demonstrated its peak activity in the Russian market during the same period.

Distribution of family emergence across leading companies in Russia

Figure 51

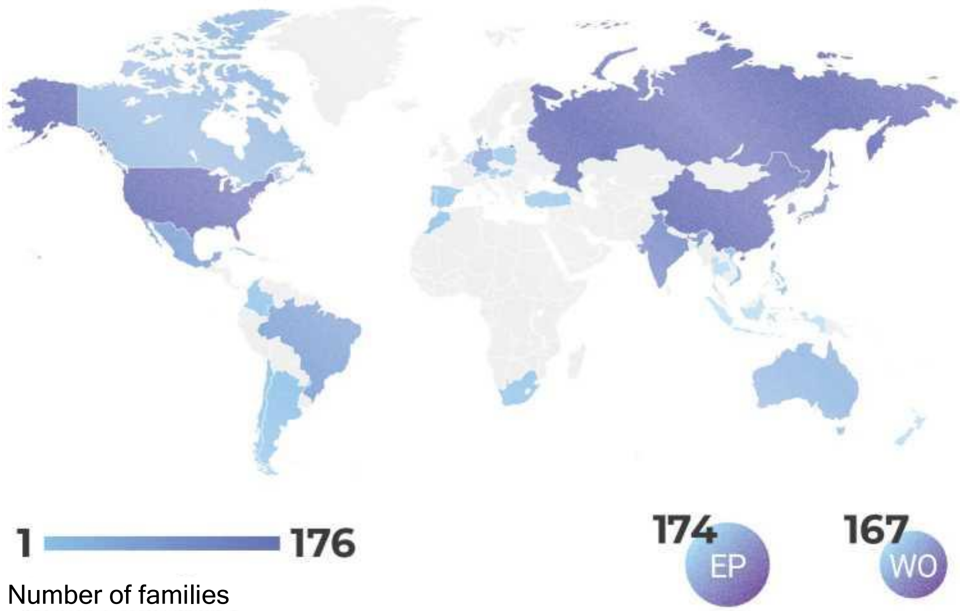
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
ERICSSON	1	0	0	1	7	21	19	1	0	0
HUAWEI	0	0	1	2	18	8	9	0	0	0
SONY	0	0	1	3	5	5	5	0	0	0
NOKIA	3	0	1	1	1	1	2	1	0	0
BBK ELECRONICS	0	0	0	0	0	3	7	0	0	0
NEC	0	0	0	0	0	3	4	0	0	0
QUALCOMM	0	0	0	0	4	2	1	0	0	0
TOYOTA GROUP	0	0	0	0	0	0	1	4	0	0
INTEL	0	0	0	0	4	0	0	0	0	0
LG	0	0	0	0	0	0	2	2	0	0

When building development strategies in the 5G/6G segment in Russia, companies need to take into account the geographical aspects related to the patenting of technical solutions. The geographical distribution of families across countries of publication allows identifying in what other countries applicants publish their technical solutions if one of the family's publications was made in Russia. China and the United States are among the leaders by the number of publications as these countries are the principal jurisdictions of first filing for such applicants. There are also a large number of technical solutions published in India, South Korea, Brazil, Mexico, Canada, Australia, and Vietnam simultaneously with publications in Russia. Singapore, Taiwan, South Africa, the Philippines, Israel, Denmark, Chile, Argentina, and Spain have fewer such simultaneous publications. There are also isolated cases of co-publications in other countries.

At the same time, 167 families have applications filed under the PCT procedure. In all these families, applications in Russia were filed through the international patenting procedure. Only nine families, which belong to Toyota, Nokia, Volkswagen, and a Russian organization, filed their applications directly in Russia. It can also be highlighted that 98% of families with publications in Russia have filed applications for regional patenting through the EPO. The only families that do not have such applications are the Huawei family (**WO2016/090576**) and the family of a Russian organization.

Figure 52

Geographical distribution of publications for families present in Russia



An analysis of priority countries helps identifying the country of origin of a technical solution, and, accordingly, national applicants in the 5G segment. In Russia, the first priority was sought only by one organization – the Institute for Information Transmission Problems (Kharkevich Institute) of the Russian Academy of Sciences. This family has one publication, **RU193265** *5G wireless signal multiplexing device*, which is a patent for a utility model. The authors of the invention include Russian inventors Alexey Kureev, Evgeny Khorov, and Artem Krasilov, an American, Ian Fuat Akyıldız, and an Indian Kak Ahan. The patent was granted on October 21, 2019. The low share of Russian companies and research and development institutions in the overall patenting volumes, combined with an aggressive policy of patenting monopolies, creates serious threats to efforts of Russian companies both in Russia and in promising markets where Russia could operate.

Due to the fact that patent protection is tied to the country in which the application was filed, the technical solutions of Huawei or another monopolist company not registered in Russia are not associated with serious risks related to technology and equipment development and exclude the possibility of patent disputes or claims.

In this regard, we also identified technical solutions of monopolies that relate to SEP families and are registered in Russia. There are 67 such families and all of them are active families. Patents were granted to almost all of these families, with applications filed in Russia under the PCT international patenting procedure.

The most active patent holders with SEP families in this jurisdiction include Swedish Ericsson, Chinese Huawei, Chinese BBK Electronics, Finnish Nokia, and American Intel and Qualcomm. Moreover, Ericsson and Huawei are leaders by the number of SEP patents that mention user equipment. Ericsson (**RU2016141578**) is the leader by the number of patents mentioning an interface for 5G networks, physical network resources, and network cores. Huawei (**RU2673710**) is leading by the number of patents mentioning base stations, network transmitters, and 5G network architecture. Qualcomm (**RU2016144752**) features patents describing uplink and downlink channels, as well as bandwidth for 5G networks.

We also identified the most valuable technical solutions for Russia in terms of strength indexes (Table 8).

Indicators of the strongest families in Russia

Table 8

1	2	3	4	5	6	7
US20150334729	QUALCOMM	70+	74	11	0,64	0,81
WO2015/147717	ERICSSON	70+	84	10	0,68	0,84
US20170331670	ERICSSON	70+	120	8	0,74	0,84
WO2015/080646	ERICSSON	60+	70	7	0,72	0,79
US20160352551	HUAWEI	60+	66	6	0,66	0,75

1 Basic publication 2 Applicant 3 Strength range 4 Number of forward citations

5 Geographical coverage 6 Generality generality 7 Originality

The family with the basic publication US20150334729 owned by Qualcomm and the families with the basic publications WO2015/147717 and US20170331670 owned by Ericsson are the strongest families in the collection by indicators and are described in the Maturity of Patent Families section.

Also among the strongest families in Russia are the technical solutions of Ericsson and Huawei, which have been included in the lower strength range (60+) and have lower values of other indicators.

The family with the basic publication **WO2015/080646** *Network node, wireless device, methods, for sending and detecting, respectively, synchronization signal and an associated information* is an active family. Its priority date, November 27, 2013, does not coincide with the filing date of the first application (PCT), October 3, 2014. The priority is claimed in the provisional unpublished American application US201361909752P. The family has a smaller geographical coverage than the families of incumbents. Applications to Russia are filed through the PCT international patenting procedure, as well as directly in Russia. Applications are pending examination in India, Indonesia, South Korea, Russia, and Singapore, as well as at the EPO. Patents are protected in Australia, Canada, China, Israel, Japan, Russia (under a PCT application), and the USA. The authors of the invention include Mattias Frenne, Dirk Gerstenberger, and Jokhan Furuskog.

The technical solution relates, in general, a network node and methods performed by a network node for sending to a wireless device a first synchronization signal and an associated information message, for synchronization of the wireless device with the network node. Existing methods of transmitting synchronization signals from a network node to a wireless device are designed to cover a wide area at lower carrier frequencies than those intended for use in future systems, including 5G. This can lead to multiple synchronization failures when used in next-generation communications systems. The objective of the invention embodiments described in the document is to improve wireless network performance by increasing transmission bandwidth. In some embodiments, the network may use beam forming to transmit synchronization signals to the wireless device. N OFDM symbols within a subframe are used to send the synchronization signal.

This family has one of the highest generality indexes, which indicates a wider application of technical solutions across different technological groups as compared to other solutions.

But its originality index is lower than that of families in the strength group 70+, which indicates a lower technology innovation level. At the same time, this family is a SEP family cited in five standards: ETSI-TS-36-212 *Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding*; ETSI-TS-36-213 *Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures*; ETSI-TS-38-212 *5G; NR; Multiplexing and channel coding*; ETSI-TS-38-213 *5G; NR; Physical layer procedures for control*; and ETSI-TS-38-214 *5G; NR; Physical layer procedures for data*", as well as by many leading 5G companies.

Another Huawei family with the basic publication **US20160352551** *System and scheme of scalable OFDM numerology* is also an active family. The priority date June 1, 2015 is claimed in the provisional unpublished American application US201562169342P. The filing date of the family's first application is May 31, 2016. The first application of the Chinese company is filed with the US patent office. The technical solution is protected in Australia, China, Japan, Russia, and the USA. Applications are pending examination in Canada, India, Vietnam, and the EPO. An application was filed in Russia under the PCT procedure and a relevant patent was granted in 2018. The inventors include Litsin Chzhan, Kar Kin Au Kelvin, Tszjanlehj Ma, Ven Tun, and Tofikul Islam.

The invention pertains to radio communication, in particular to a system and scheme of scalable OFDM numerology. Its technical result increases the overall performance of the system. The method of configuring communication with the device includes:

- receiving an indication of a value of a first subcarrier spacing and a value of a first sub-frame duration;
- transmitting the signal configured for the first type of numerology signal to be applied to the first sub-frame, with the value of the first subcarrier spacing and the first sub-frame having a scaled relationship to the value of the second subcarrier and sub-frame duration.

The scaled relationship of the value of the first subcarrier spacing to the second subcarrier spacing involves multiplication by a first scaling factor, and the scaled relationship of the value of the first sub-frame duration to the second sub-frame duration involves multiplication by a second scaling factor, and wherein the first scaling factor is reciprocal of the second scaling factor. The description of the invention includes examples of applying various numerology schemes in 5G networks.

This family is a SEP family and is cited by 13 5G standards. A full list of standards is provided in Appendix G. *List of standards citing Huawei's family with the basic publication US20160352551*. At the same time, the family has lower levels across all metrics (citation, geographical coverage, generality, originality) than the relevant families of Qualcomm and Ericsson.

This indicates that monopolies are actively patenting their 5G solutions in the Russian market. Russian companies do not have patents for inventions, which leads to difficulties for independent development of technologies at the national level. Deployment of 5G networks in Russia is associated with high financial costs for the purchase of existing licensed technologies from incumbents, as well as with the need to build cooperative and financial ties with suppliers of 5G equipment for telecom operators.

AREAS OF APPLICATION

05

An analysis of the scope of application of technical solutions gives an idea of the technological specialization in this area. Such analysis is primarily based on the distribution of patent families across 35 technology classification areas of the World Intellectual Property Organization (WIPO)[64] and a comparison of patent classification codes (IPC) across a number of criteria.

The technological classification areas are designed to link the international patent classification with actual sectoral markets and applications of patented technologies. The development of these groups primarily aimed to create a tool to compare the economies of individual countries using patent information.

The following requirements were set for the development of this segment system, which was to be implemented as fully as possible:

- all IPC indexes were to be included in this classification;
- the size of the segments was to be balanced (segments are too large to have vague boundaries and not too small to cover just a small number of highly specialized technologies);
- segments were to be based only on IPC indexes (and be understandable to users who do not have in-depth IPC expertise);
- the number of segments was not be too small or too large to allow for a detailed analysis, on the one hand, and to avoid any structure that is too complex to understand;
- segments need to be explicitly different in terms of their technical content.

[64] Concept of a Technology Classification for Country Comparisons // WIPO URL: https://www.wipo.int/export/sites/www/ipstats/en/statistics/patents/pdf/wipo_ipc_technology.pdf (accessed on: 30.03.20).

Thus, this hexagonal map (Figure 53) is a valuable tool for analyzing the domain in relation to markets and applications of solutions described in patents.

An important area for analysis includes the comparison of how different applications of technical solutions evolve over time. To this end, this section presents a comparison of hexagonal maps comparing two patent periods: early (2010 to 2014) and late (2015 to 2019). The hexagonal maps with different background fill intensity indicate the number of patent documents for each of the 35 technology classification areas.

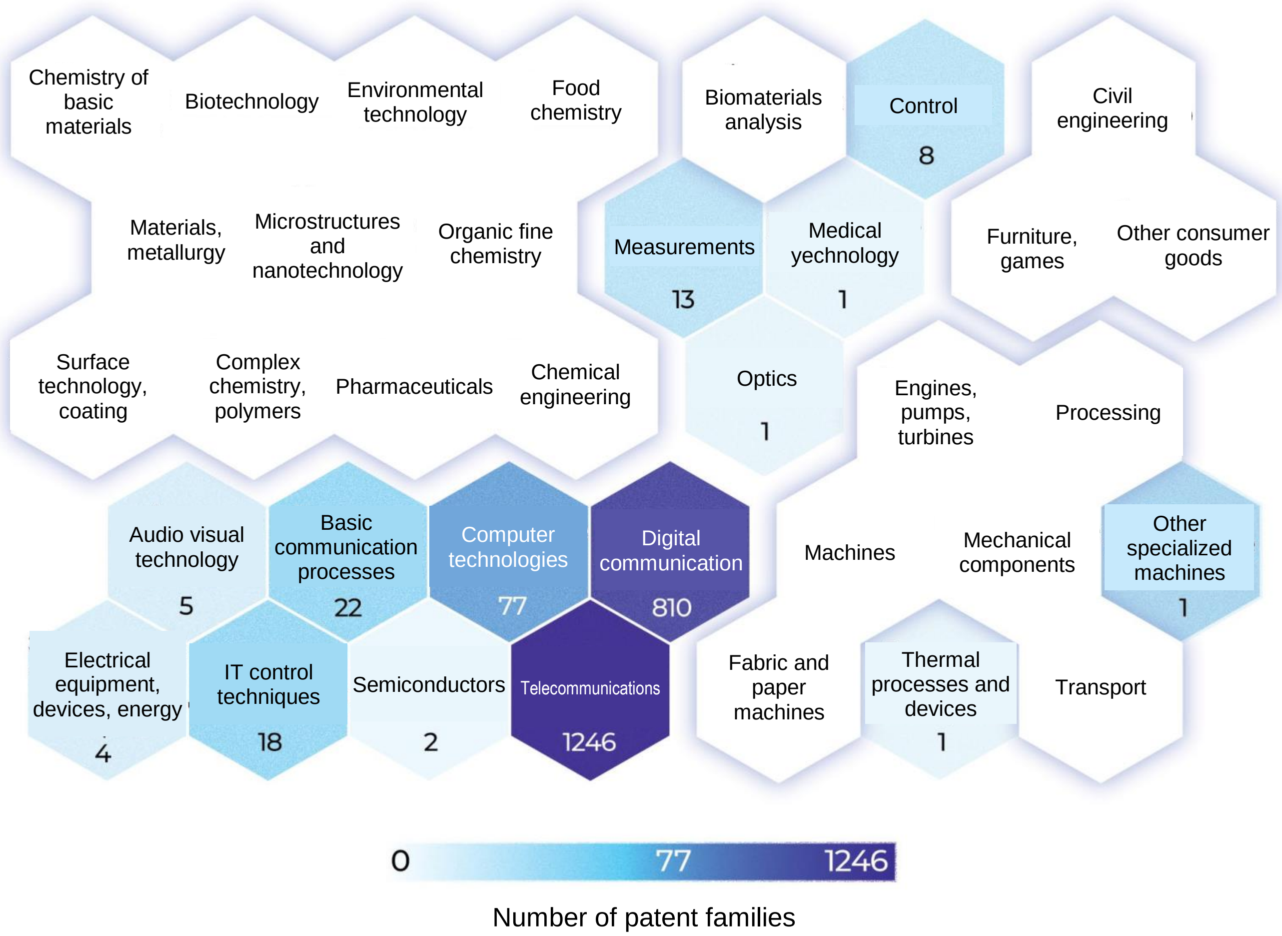
Telecommunications, *Digital Communications*, and *Computer Technologies* are the principal applications for technologies up to 2014 – these segments account for the majority of patent families. Some families are also included in the *Key Communication Processes* segment. Over the five-year period, there have been cases when technical solutions emerged in areas that are not the key focus area in the 5G R&D segment. They include: *Audiovisual Technologies*, *Control*, *Measurement*, *Electrical Equipment, Devices, Energy*, and *IT Methods for Control*. There are also isolated technical solutions in the following segments: *Other Consumer Goods*, *Medical Technologies*, *Optics*, *Thermal Processes and Devices*, and *Semiconductors*.

The peak of patenting activity falls on 2014 when 60% of families of the period emerged. Samsung demonstrated its peak activity between 2010 and 2014 (22% of the total number of families). The number of its patent families during this period is thrice as high as the number of families owned by its nearest competitors, Nokia and Huawei. Ericsson, Qualcomm, LG, Sharp, and ZTE also have a small number of families. However, other companies have significantly fewer families. Samsung is the leader across all major segments of *Telecommunications*, *Digital Communications*, *Computer Technologies*, and *Key Communication Processes*. Nokia and Huawei have the highest number of families in the *Telecommunications* segment, while Ericsson and Qualcomm feature a large number of families in the *Digital Communications* segment.

Most families in the collection emerging during this period originated in the United States. It is in this country that almost 40% of the priorities were registered.

The USA is the most active country in *Telecommunications*, *Digital Communications*, and *Computer Technologies*, China in *Telecommunications*, and South Korea in *Telecommunications*, *Digital Communications*, and *Key Communication Processes*. The further expansion of publications includes China, South Korea, Japan, India, Brazil, Russia, Vietnam, Canada, and Australia. At the same time, India occupies a special place, which ranks fourth by the number of publications during that period. Hence, it was the first group of countries that started patenting their 5G technical solutions.

Figure 53 **Distribution of technological areas in 2010–2014**

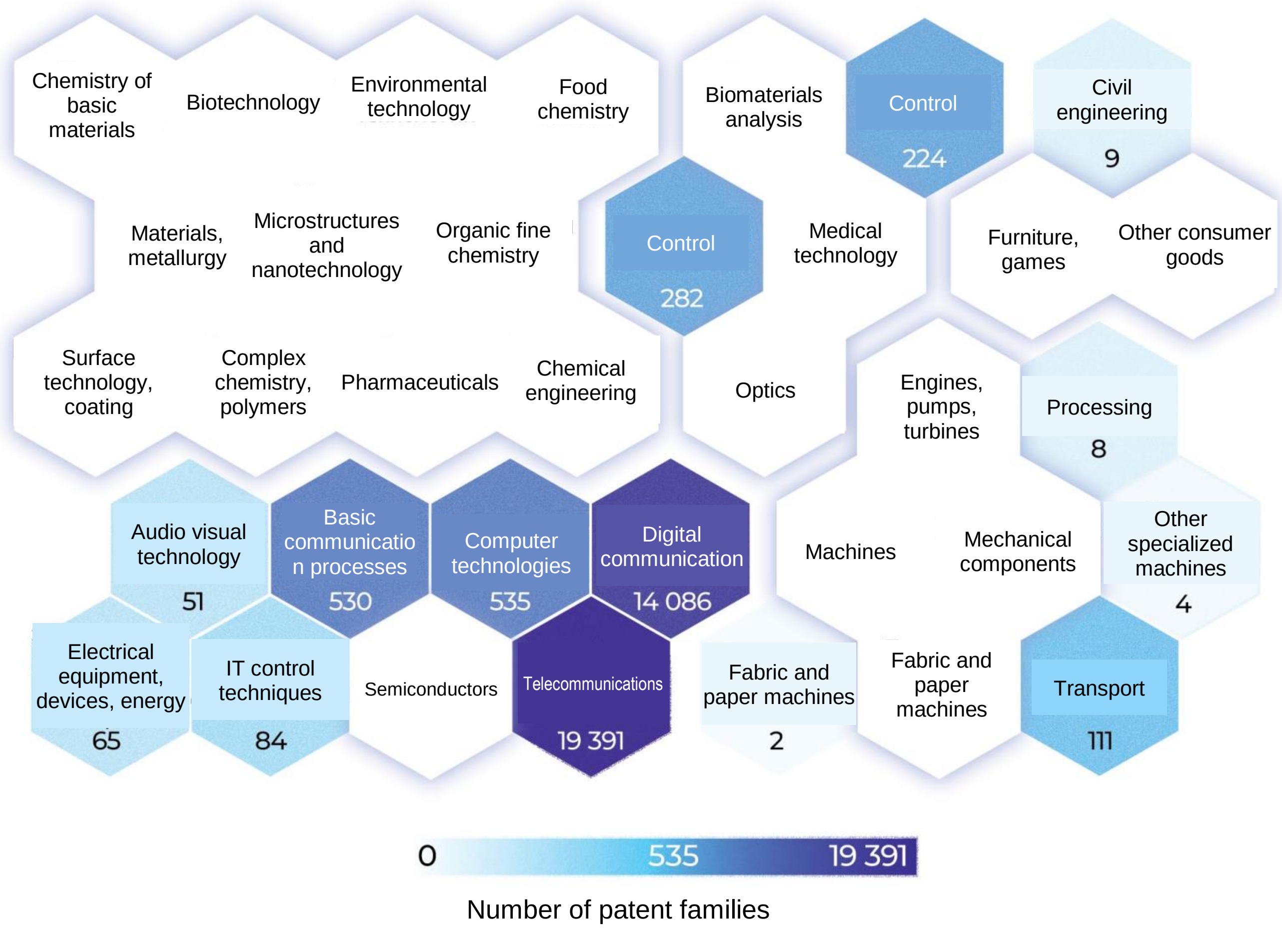


An analysis of the hexagonal map from 2015 to 2019 allows concluding that the main focus of developments has not changed. Telecommunications and Digital Communications remain the leading segments. However, the ratio between the major segments has changed: the gap between the leading areas has narrowed by 7% due to a stronger growth in the Digital Communications segment.

On the whole, the activity in the *Digital Communications* segment grew by 17 times, and in the *Telecommunications* segment by 15 times. Such explosive technological growth testifies to a rapid increase in the level of technology in 5G over the last five years.

Distribution of technological areas in 2015–2019

Figure 54



In terms of numbers, patenting in the *Key Communications Processes* segment was comparable to patenting in the *Computer Technologies* segment, while the *Control* and *Measurement* segments were evenly increasing their number of families. The *Electrical Equipment, Devices, Energy* segment became more popular (with its patenting level increasing eightfold) than *Audiovisual Technologies* (a fourfold increase). We would particularly highlight a large number of families in a segment that was previously missing from the list, the *Transport* segment, which indicates that the scope of application of the technologies has expanded over the last five years.

At the same time, segments with isolated cases of patenting such as *Medical Technologies*, *Optics*, *Thermal Processes and Devices*, *Semiconductors* have been replaced by *Civil Engineering*, *Processing*, and *Fabric and Paper Machines*.

The largest number of technical solutions of this period emerged in 2017. The number of families that emerged in 2016 and 2018 is half as many. In general, over the past five years, the configuration of leading companies in the industry has changed significantly. Over this period, Chinese Huawei became the leading patenting company representing 15% of the total number of families. American Qualcomm rose to the second position, while Samsung and Ericsson shared the same position by the number of families of patents. Nokia fell significantly behind in this technology race, overtaken by LG and ZTE, as well as by new leaders such as Intel, BBK Electronics, and Nippon Telegraph and Telephone, which did not have a large number of families between 2010 and 2014. Huawei, Ericsson, Samsung, Qualcomm, BBK Electronics, ZTE, and Nippon Telegraph and Telephone have the strongest positions in the *Telecommunications* segment. The leading positions in the *Digital Communications* segment were taken by Huawei and Qualcomm. Intel and LG also prefer to patent in this segment. Qualcomm consolidated its position in the *Key Communications Processes* (**US20190356420**), *Control* (**US20180199160**), and *Measurement* (»(**US20190364536**) segments. The *Computer Technologies* segment is shared among Samsung, LG, Intel, and Nokia. In addition, LG is active in *Audiovisual Technologies* (**US20200053277**), *Transport* (**US20200001774**) and Control (**KR1020190137732**).

Most families in the collection during this period originated in the United States and China, which contributed equally to the development of this area during the period. A large number of families also emerged in South Korea and Japan during this period. Of particular note are the priorities of India, which emerged as the result of the efforts of Samsung (**WO2018/203713**), Qualcomm (**WO2020/005459**), and Nokia (**WO2020/002127**), which are represented in the list by their respective research and development departments. All leading countries that are engaged in relevant developments are active in the principal segments, that is, *Telecommunications* and *Digital Communications*. However, the USA has greater coverage of other technology segments and a larger proportion of families than others. Meanwhile, China is ahead of the USA in *Audiovisual Technologies* and *Electrical Equipment, Devices, Energy*. South Korea is more active in *Measurement*, *Transport* and *Audiovisual Technologies*. Apart from the principal segments, Japan has patents in *Control* and *Transport*.

Further geographical expansion extends to a much wider range of jurisdictions than during the period of 2010–2014. At the same time, the international PCT procedure has been chosen as the next step for a significant share of families.

For instance, the last 5 years have seen a significant increase in the patenting volumes in the relevant segments as compared to the previous period. Companies have developed networks of research centers, which allowed them to expand the number of priority jurisdictions, as well as subsequently expand their geographical presence through international and regional patenting systems. At the same time, the majority of developments remained in segments related to telecommunications and other communications processes. Of particular note is the emergence of the *Transport* segment, which has started to develop in recent years. It is supposed that recently patented technical solutions describing the application of 5G networks in transport communications will become the basis for the development of the related industry.

Moreover, as mobile communication technologies are being extended to infrastructure in a wide range of industries, in addition to the telecommunications sector, competition for infrastructure technologies and international standardization is gaining momentum. In Europe, China, and the USA there are already open discussions about the need for research on 6G, the next generation after 5G, and the first research projects are already underway around the world.

TERMINOLOGY FIELD ANALYSIS

In addition to the scope of application of the technical solutions, we analyzed the keywords and word combinations that are most frequently found in the text of patents. Based on them, we built a thematic map to describe the distribution of patent families by principal thematic groups (Figure 55). This view allows identifying concepts and terms that are most frequently used by applicants to describe their developments. This thematic map is distinctive in that its structural logic groups patent documents (points) around designated centers of attraction (thematic groups) according to their semantic proximity.

The more patent documents are similar to each other in terms of their topics, the closer they are located on the map. Analyzing the thematic map can provide ideas for new developments or help identifying protected technologies in the relevant area. The thematic map also indicates potential technology clusters protected in the relevant environment.

Particular attention in our analysis of patenting strategies was paid to exploring the emergence of young patent families. In this regard, technology clusters on the thematic map are represented by young families, which have a high potential for geographical coverage expansion and for commercialization of their products in the future.

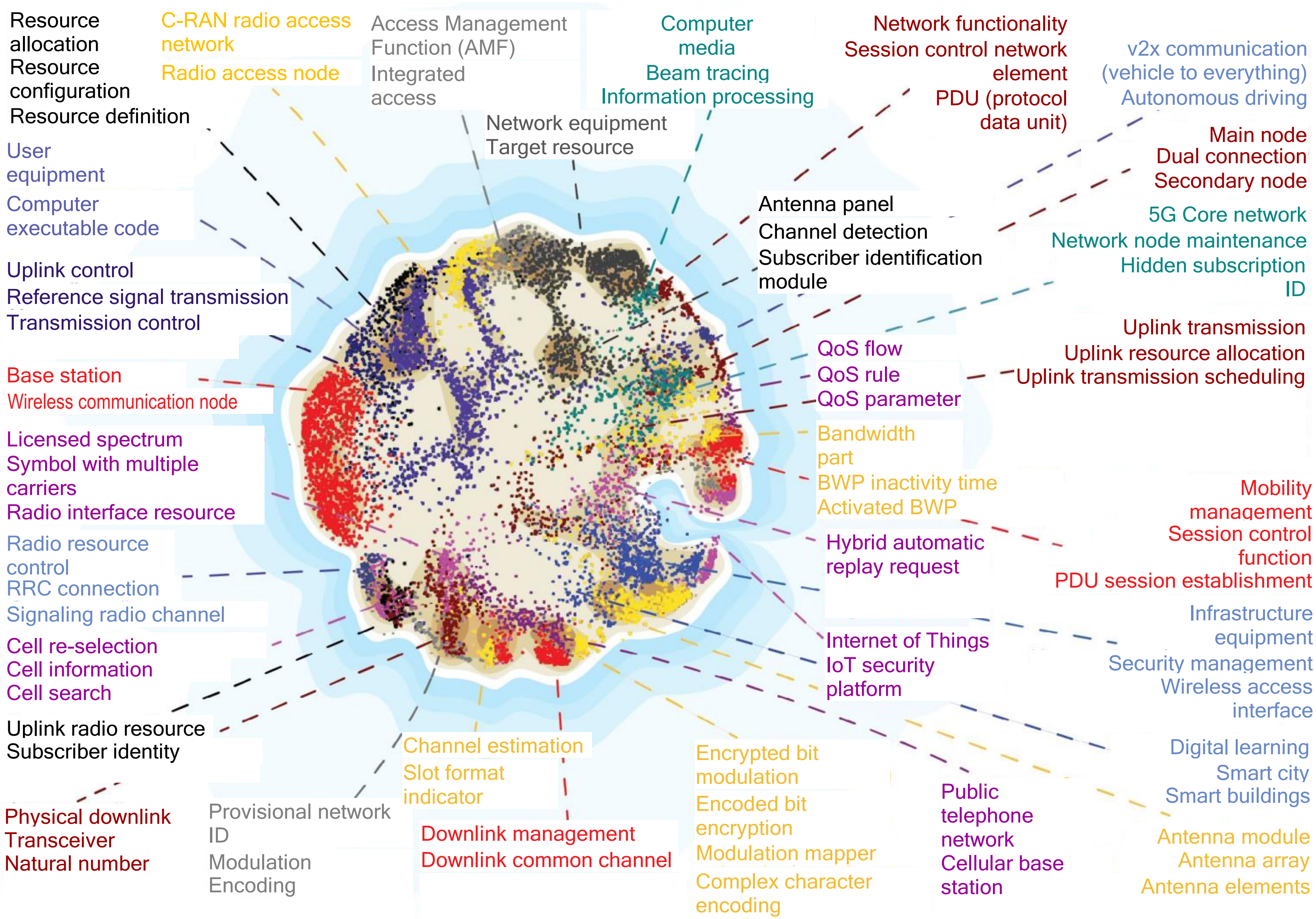
The majority of patent documents on the map feature word combinations that use different terms to describe wireless communication, radio access networks, nodes, and various network terminals. Since these are common terms specific to the 5G area, they have been excluded from thematic groups.

The highest concentration of patent families is found around the terminology group describing base stations (CN110622612) and their structural elements. Families describing the reference signal transmission (CN110535580) and control of such transmission over an uplink (CN110351865) feature some overlaps with this group.

A large number of documents in the descriptions also mention user equipment, but the patenting of this group is more dispersed, because these word combinations are correlated with other more specific terms. The closest terminology groups for documents with user equipment cover the definition, configuration, and allocation of network resources (WO2019/232786), as well as radio access nodes and Cloud RAN (US20190289497). The solutions have specific technological parameters, resulting in these groups are shown as separate “elevations”. Patent families describing 5G RAT networks have a thematic overlap with access management functions (AMF) (WO2019/222995) integrated access (EP3589059) and backhaul network (US20200015295), which in turn overlap with the entire terminology block of network elements and special equipment, which provides information transmission, control over network resources, and interaction between all nodes.

Thematic map of patent document distribution

Figure 55



The latter group is rather isolated and related in terms of technology only to patents that describe computer data carriers, information processing methods, and beam tracing systems (CN110212963). At the same time, patents related to special network equipment give rise to a new set of technical solutions that are related to communication channel definition and network subscriber identification modules (CN110546899).

Other parts of the thematic map have more complex thematic ties, with multiple overlaps, while relevant technical solutions are better grouped into specific areas. For example, terms related to cellular base stations and information processing and transmission equipment form the basis for the lower segment. Patents pertaining to downlink channel control (**US20190313378**), which are closely connected with the patenting of such channels (**CN110417523**) feature more specific technical solutions. Technologically close patents related to downlink patents pertain to encrypted bit modulations, bit encoding, and complex character encoding (**CA3033533**). A separate block of patents based on network equipment cover the control and management of radio resources (RRC protocol) (**WO2019/213805**), as well as manipulations with network cells (search, re-selection, retrieving cell information) (**US10477426**).

A group of technical solutions pertaining to the wireless access interface and infrastructure equipment network security as a key element (**WO2019/220006**) has the largest patenting coverage in the next part of the thematic map. Many security systems described in patents are closely linked to the Internet of Things, including to the new mobile communication standard for NB-IoT telemetry devices (**US20190372696**). The development of infrastructure equipment is associated with the research and patenting of solutions to optimize antenna modules for next-generation networks, including to improve the antenna array and other antenna elements (**US20190342046**).

Solutions designed to combine 5G networks with smart technologies such as Smart City, Smart Buildings, Digital Learning, and Smart Medicine form a somewhat standalone group of families (**US20190342046**).

They are based on antenna equipment, a wireless interface and uplink data transmission (**US20190342046**) with the functionality to plan and allocate resources.

The expansion of patents related to the NB-IoT standard has given rise to the development of a set of solutions related to SMF and AMF network management functions (**US20190159015**), bandwidth parts (BWP) (**KR1020190100042**), including inactivity and activation time analysis, as well as communication quality and priority management technology for different traffic classes (QoS) (**US20190116129**). In turn, the study of the bandwidth part (BWP) has a technological connection with the uplink information transmission forming complex technical solutions with a high share of mutual penetration with solutions related to the 5G core and network node maintenance (**WO2019/198054**).

A small percentage of solutions on the thematic map applies to 5G patenting for V2X communication (transfer of information from the vehicle to any object that may affect the vehicle, and vice versa) (**KR1020190092268**). The vehicle communication system supports the development of unmanned driving technology and other related areas.

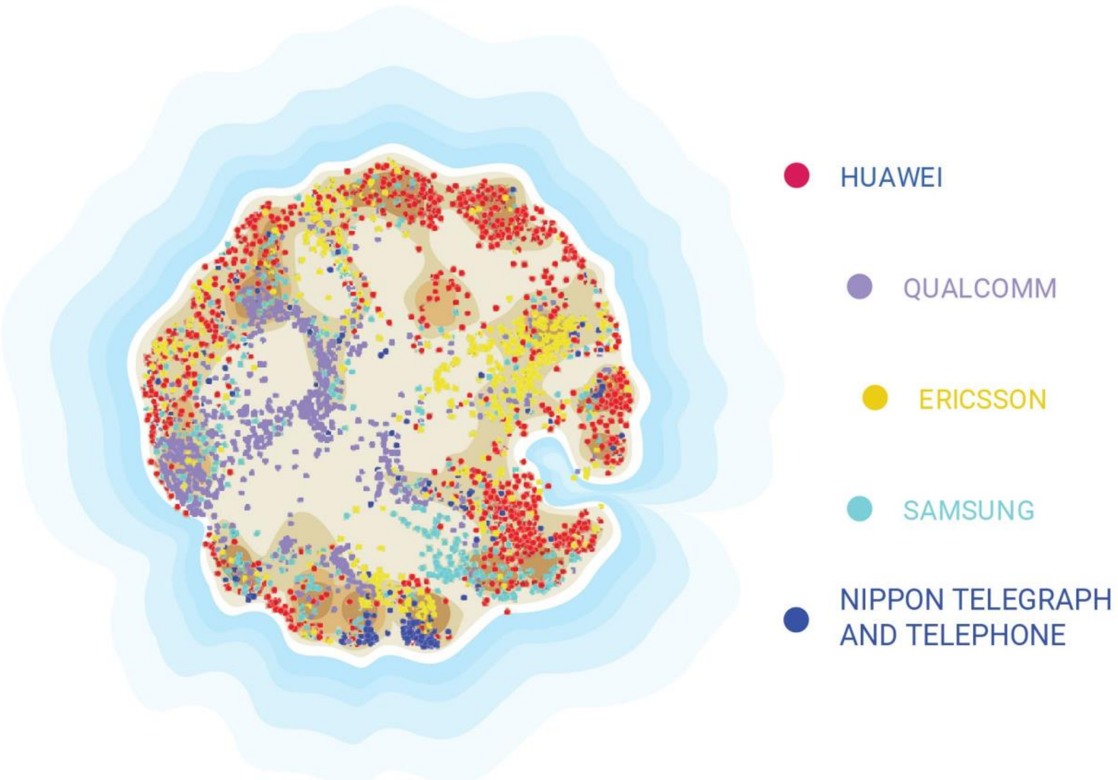
Thus, thematic groups define interdependent technology clusters, which are connected with each other through basic solutions and differ in certain specifications.

The thematic map also includes a distribution of 5G portfolios owned by leading companies (Huawei, Qualcomm, Ericsson, Samsung, and Nippon Telegraph and Telephone) (Figure 56). Such distribution of company's patent portfolios allows identifying potential technology clusters protected by these companies. An analysis of portfolios held by two or more players helps identifying competing companies, including areas of heavily overlapping interests and consolidation in a particular thematic segment. Such areas may be especially useful for patent portfolio acquisition and licensing. Areas with a low level of overlapping may demonstrate opportunities for new development, or portfolios for sale. The density of color points shows tight competition in most technology clusters.

The largest coverage of the thematic map is demonstrated by Chinese Huawei, which is actively patenting inventions related to 5G infrastructure, including network nodes (**CN110475287**)), antenna panels (**CN110557847**), base stations, computer processing units (**CN110572817**), receiving and transmitting terminals, and wireless interface (**CN110418413**)).

Some groups of inventions also pertain to network resource control (**CN110351882**), signal encoding and modulation (**N109327226, WO2019/22839**), SMF and AMF functions (**CN110519809, W02020/001440**), and quality of service (QoS) management (**US20190394279**).

Figure 56 **Thematic map of patent document distribution by company**



Qualcomm has a large share of technical solutions related to user equipment (**US20200008143**)), processors (**US20190394791**), information processing, and intelligent computing. In its turn, user equipment includes technologies for distributing channel state information (CSI) (**W02020/006652**), PRACH message generation (**US20190364599**), recovery after a radio line failure (**US20190380052**), transmission planning (**US20190387532**), encoding schemes (**WO2019/241967**), etc.

A large number of solutions also cover base stations, including mobile device location determination (**US10517061**), data transmission principles (**WO2019/236985**), improvements to resource management (**WO2019/226724**), efficient selection of RSMA distribution code (**US20190373582**), receiving and transmitting a reference signal (**US20190361111**), transmission of information between next-generation and legacy systems (**WO2019/227278**), and the division of resources between a priority access license (PAL) and shared access license (**US20190394790**). Of particular note are Qualcomm's solutions for IoT and IoE (**US20190327784**, **US20190261294**).

Ericsson is present in almost all technology clusters on the thematic map. The highest density of solutions is observed around 5G base stations (**WO2019/198054**), network nodes (primary (**WO2019/219667**) and secondary) (**WO2019/215673**, **WO2020/005127**, **WO2019/151916**), bandwidth parts (BWP) (**WO2019/137340**), and user equipment (**WO2019/231384**, **WO2019/215553**, **US20190182881**).

Associated technologies such as dual connection (**WO2019/219668**), hidden subscription identifier (**WO2019/193562**), QoS parameters (**US20190349834**), reference signal (**WO2019/235981**), service-oriented architecture (**WO2019/168458**), resource planning (**WO2019/243249**) and control (**WO2019/226107**), transmission in licensed and unlicensed spectrums (**WO2019/233828**), downlink control information (**WO2019/215706**), measurements of network parameters (**WO2019/194725**, **WO2019/190383**), and beam selection (**WO2019/164429**) are actively patented in combination with basic terms.

Samsung has a large concentration of patents centered around smart technologies, being almost a monopolist in this cluster (**US20190356601**, **KR1020190142182**, **KR1020190130487**)). Small groups of the company's families are also present in virtually all technology clusters, but the greatest emphasis is placed on antenna equipment (**KR1020200005013**) and network cell control (**KR1020190083233**).

Nippon Telegraph and Telephone has the highest concentration in the lower part of the thematic map. Patents demonstrate the maximum concentration of word combinations "user terminal" and "base station" linked to terms "downlink control information" (DCI) and "physical downlink shared channel" (PDSCH) (**WO2020/008649**, **WO2020/003444**, **WO2020/003542**).

Significant contributions to the development of the V2X communications cluster are made by Qualcomm (**US20190380152**), LG (**WO2020/004688**), Hyundai (**KR1020190090696**), Intel (**US20190306754**), and Huawei (**WO2019/161925**). Another cluster of complex character encoding is practically not represented by 5G incumbents. The main players here include Ofinno and Comcast, which are implementing bandwidth part (BWP) encoding (**US20190132110**, **US20190289513**), distribution of channel state information (CSI) (**US20190149213**, **US20190141546**), and beam failure recovery (**US20190305840**, **US20190306765**).

Therefore, technical solutions of companies are specialized according certain technology clusters. Huawei and Ericsson have a broader technology profile, which allows them to contribute to all thematic groups.

ANALYSIS OF IPC SECTIONS

Another important source of information used when identifying trends includes patent document fields associated with IPC codes, which denote specific technologies and technology groups with varying degrees of detail.

The International Patent Classification (IPC) codes serve as the principal tool for classifying patent documents and, as a result, one of the basic foundations for patent analytics. According to the requirements for patent registration, the applicant should specify such a code, which enables an objective technological analysis of patent documents. IPC codes are assigned to each technical solution by the relevant patent examiner as a result of examination. Due to the fact that many solutions are complex ones, they can be assigned several IPC codes at the same time.

In addition to the IPC, there are many other classifications, each meeting the requirements of a particular patent office, most often a national one. The IPC is considered to be the most universal classification, as it covers most countries of the world.

However, the Cooperative Patent Classification (CPC) initiated jointly by the European and US Patent Offices has been gaining traction in recent years. The aim of this project is to develop a unified system of classification of technical documents, in particular patent publications, which would be used by all patent offices. The relevant requests take into account the increasing role of more detailed classifications, including the IPC.

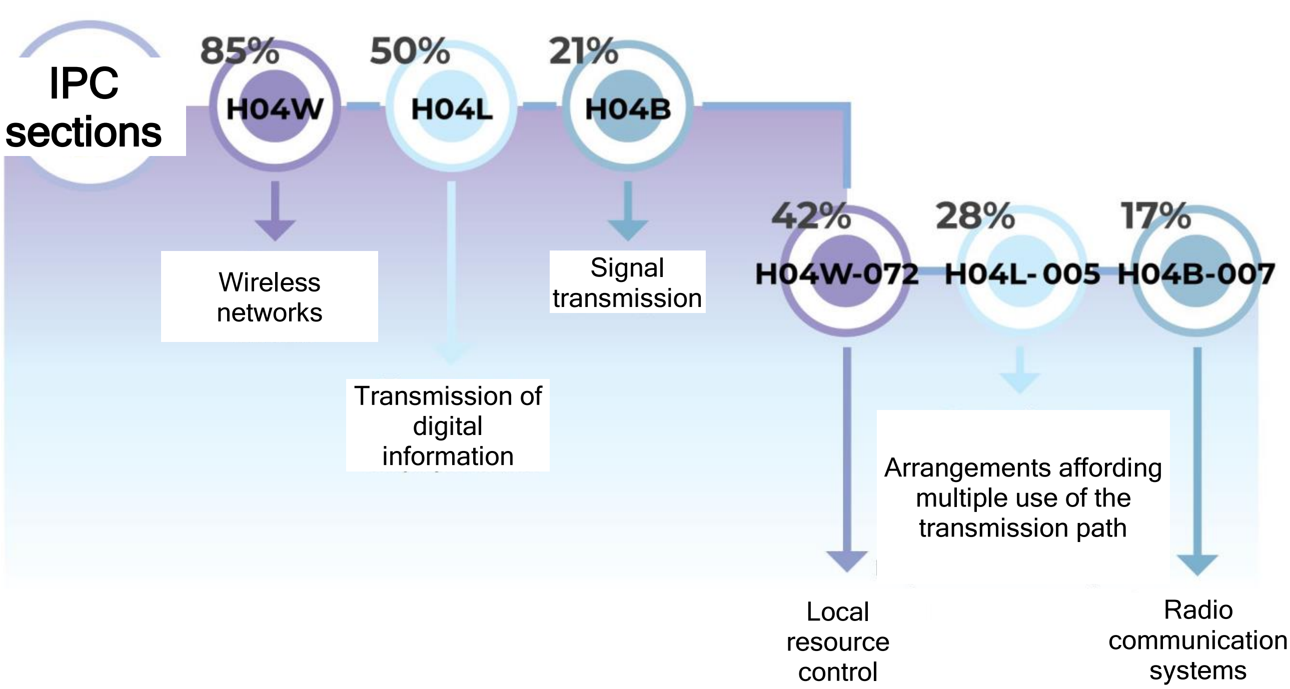
The IPC has a hierarchical structure and consists of sections (A–H), classes (e.g., C09), subclasses (e.g., C09K), groups (e.g., C09K–008) and subgroups (e.g., C09K–008/584). Each next level provides a greater degree of detail in the description of technical solutions. Common terms for all levels include: indexes, codes, or sections.

As a rule, the most frequently occurring IPC codes refer to the most popular and actively developing technological trends within the area under study.

The families in the collection were analyzed in terms of the most frequently occurring IPC codes. Such an analysis was performed across IPC subclasses, groups, and subgroups. The full results are presented in *Appendix I. Distribution of families by IPC section*".

The leading IPC sections, %

Figure 57



The H04W *Wireless communication networks* subclass contains the largest number of patent families – 85% (25,060) of the collection's families. The H04L *Transmission of digital information, e.g. telegraphic communication* and H04B *Transmission* subclasses are also quite common. The most common IPC group is H04W-072 *Local resource management, e.g. wireless traffic scheduling or selection or allocation of wireless resources*, which covers 12,445 patent families (42% of the collection). Among the sections with a slightly smaller share of families are H04L-005 *Arrangements affording multiple use of the transmission path* (28%) and H04B-007 *Radio transmission systems, i.e. using radiation field* (17%).

The leading subgroup belongs to the leading H04W subgroup and covers 9,947 families of the collection (34%): H04W-072/04 *Wireless resource allocation,* including the subgroup H04W-072/08 *Wireless resource allocation based on quality criteria* (5%). The next subgroup, H04W-072/12 *Wireless traffic scheduling*, is substantially inferior to the above subgroups, accounting for only 14% of the collection's families. Other specialized categories of the H04W subclass are found in no more than 10% of the collection's patent families: H04W-074/08 *Non-scheduled access, e.g. random access, ALOHA or CSMA [Carrier Sense Multiple Access]* (9%), H04W-024/10 *Scheduling measurement reports* (7%), H04W-076/27 *Transitions between radio resource control [RRC] states* (5%).

The distribution of sections in the H04L subclass mostly covers the main groups without specifications H04L- 005/00 *Arrangements affording multiple use of the transmission path*, H04L-001/00 *Arrangements for detecting or preventing errors in the information received*. The largest number of families in a specialized subgroup was found in H04L-027/26 *Systems using multi-frequency codes* (2,092 families / 7%).

The H04B subclass has the largest number of families (2,972 / 10%) in the H04B-007/06 subclass, *Multi-antenna system using two or more spaced independent antennas at the transmitting station*. Other subgroups have significantly lower figures: 3% in H04B-007/08 *Multi-antenna system using two or more spaced independent antennas at the receiving station* and H04B-007/0413 *MIMO systems*.

The collection has a high concentration of patent families in the leading H04W section. A more detailed analysis of sections shows that the solutions are distributed across a large number of highly specialized subgroups, which also pertain to other subclasses. Such distribution indicates that virtually all technical solutions have something to do with wireless communication networks, but the internal spectrum of technologies in this area is rather diversified having quite a wide thematic coverage.

Dynamics of patenting across I PC groups in the overall collection

Figure 58

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
H04W-072	4	13	11	20	28	70	295	828	2267	3870	626
H04L-005	0	0	1	2	8	27	132	367	1177	2012	323
H04B-007	1	2	2	14	23	74	221	500	1047	1619	238
H04L-001	0	1	7	7	5	24	93	285	893	1368	227
H04W-036	1	6	9	15	29	60	127	268	772	1202	172
H04W-024	0	3	8	6	18	41	98	221	565	1213	146
H04W-028	1	2	1	7	12	26	85	265	682	1089	173
H04W-076	0	4	6	10	16	21	66	195	507	981	148
H04W-074	0	0	1	2	3	16	59	188	543	947	147
H04W-048	2	1	3	5	24	38	109	251	544	893	127
H04W-004	4	5	8	9	22	44	97	220	416	781	84
H04W-052	0	5	6	7	7	30	78	157	411	758	116
H04L-029	3	2	9	12	12	27	53	139	320	557	74
H04L-012	1	4	8	6	7	21	55	132	310	565	66
H04W-016	1	4	5	7	11	33	80	151	334	475	78
H04L-027	2	2	3	3	6	15	46	129	345	414	89
H04W-008	0	1	3	6	7	16	48	126	217	389	63
H04W-056	0	0	1	3	3	16	36	79	238	399	68
H04W-012	0	0	0	1	3	9	29	73	192	326	54
H04W-088	1	3	4	9	8	14	31	70	135	220	28
H04B-017	0	0	0	1	2	7	15	30	118	189	31
H04B-001	1	1	1	3	3	8	24	57	115	201	15
H04W-068	1	1	1	1	1	2	15	37	136	184	31
H03M-013	0	0	0	0	0	3	6	23	125	150	35
H01Q-001	0	0	0	0	16	9	8	20	59	120	13
H04L-025	0	0	0	0	1	9	21	53	76	115	13
H04W-040	1	1	3	1	5	11	29	38	69	96	20
H04J-011	0	1	1	2	4	10	20	49	95	94	21
H04W-060	0	0	2	2	2	3	7	17	52	71	15
H04W-064	0	0	0	1	0	1	5	12	42	75	9

An analysis of the dynamics of the number of patents belonging to different IPC groups (Figure 58) allows identifying the most significant areas of application of technical solutions in behavioral analytics, as well as those whose popularity is decreasing.

The interest in patenting is increasing across all sections throughout the period under review. The leading sections do not demonstrate any decrease in the interest from patent holders. Patenting activity across sections particularly increased since 2016 when the growth across the following groups and their subgroups began:

- H04W-072 *Local resource management, e.g. selection or allocation of wireless resources or wireless traffic scheduling* (**US20190394759**);
- H04B-007 *Radio transmission systems, i.e. using radiation field* (**KR102060157**),
  - H04B-007/06 *Multi-antenna system using two or more spaced independent antennas at the transmitting station* (**US20190253218**),
  - H04B-007/0456 *Selection of precoding matrices or codebooks, e.g. using matrices antenna weighting* (**CN110601735**),
  - H04B-007/0413 *MIMO systems* (**CN110504996**);
- H04W-036 *Handoff or reselecting arrangements* (**WO2019/246446**);
- H04W-048 *Access restriction; Network selection; Access point selection* (**US20190364492**),
  - H04W-048/16 *Discovering; Processing access restriction or access information* (**WO2020/001146**),
  - H04W-048/18 *Selecting a network or a communication service* (**US10517039**);
- H04W-004 *Services or facilities specially adapted for wireless communication networks* (**US20200008036**),
- H04W-052 *Power management, e.g. TPC (Transmission Power Control), power saving or power classes* (**CN110602776**),

- H04W-052/02 *Power saving arrangements* (**WO2019/245641**);

- H04W-016 *Network planning, e.g. coverage or traffic planning tools; Network deployment, e.g. resource partitioning or cell structures* (**CN110602717**),
  - H04W-016/14 *Spectrum sharing arrangements* (**US20190364435**).

Patenting covering the H04L subclass mainly intensified a year later. Less popular subgroups H01Q- 001 *Details of, or arrangements associated with, antennas* (**CN110635219**), H04W-040 *Communication routing or communication path finding* (**US20190394700**), H04W-060 *Registration, e.g. affiliation to network; De-registration, e.g. terminating affiliation* (**CN110636604**), and H04W-064 *Locating users or terminals for network management purposes, e.g. mobility management* (**KR1020190140850**) reached the 2016 levels of the leading sections only by 2019.

The H04W-072 group, *Local resource management, e.g. selection or allocation of wireless resources or wireless traffic scheduling*, is leading by the number of families for the last five years. Meanwhile, patenting in the other leading groups has been growing smoothly with an even distribution of patenting in the last year (10%–17% of patent families).

The following groups have the shortest patenting retrospective in the area: H03M-013 *Coding, decoding or code conversion, for error detection or error correction; Coding theory basic assumptions; Coding bounds; Error probability evaluation methods; Channel models; Simulation or testing of codes* (**WO2019/191923**), H04W-064 *Locating users or terminals for network management purposes, e.g. mobility management*, H04W-012 *Security arrangements, e.g. access security or fraud detection; Authentication, e.g. verifying user identity or authorization; Protecting privacy or anonymity* (**WO2019/242545**), and H04B-017 *Monitoring; Testing* (**US20190393970**).

The H04W-024/02 group, *Supervisory, monitoring or testing arrangements* was distinguished from others as represented by a large number of growing subgroups, including H04W-024/02 *Arrangements for optimizing operational condition* (**WO2019/243874**), H04W-024/08 *Testing using real traffic* (**WO2019/245307**), and H04W-024/10 *Scheduling measurement reports* (**WO2019/245294**).

In general, the collection demonstrates a positive dynamics for all IPC groups and subgroups with a compound annual growth rate of 111%. This indicates that the segment is experiencing a phase of active patenting and rapid growth of the technical level.

The distribution of patent families by IPC groups across countries allows identifying the most promising areas for each region (Figure 59).

In all countries reviewed, we highlighted solutions covered by the leading subclasses H04W *Wireless communication networks*, H04L *Transmission of digital information, e.g. telegraphic communication*, and H04B *Transmission*. The greatest technological coverage of publications is observed in the USA, in which there are solutions with 30 unique subclasses. Solutions that are brought to the international level through the PCT procedure also have a similar coverage. China and South Korea have a slightly smaller coverage of subclasses. Solutions from other countries are mainly concentrated in leading subclasses with isolated cases of solutions covered by other sections.

The distribution of IPC groups shows dense patenting in a larger number of jurisdictions. Virtually all 30 leading groups cover China, the USA, South Korea, India, Japan, Taiwan, Brazil, Canada, Australia, Vietnam, Mexico, Singapore, Germany, the United Kingdom, Israel, and Russia. The only exceptions are H01Q-001 *Details of, or arrangements associated with, antennas* for Brazil, Canada, Vietnam, Mexico, Singapore, Israel, and Russia, H04L-025 *Modulated carrier systems* for Mexico, Singapore, Israel, and Russia, H04W-040 *Communication routing or communication path finding* for Vietnam, H04J-011 *Orthogonal multiplex systems* for Germany and the United Kingdom, and H04W-064 *Locating users or terminals for network management purposes, e.g. mobility management* for Singapore, the United Kingdom, Germany, and Israel.

Distribution of IPC groups by country for the overall collection

Figure 59

	WO	CN	US	EP	KR	IN	JP	TW	BR	CA	AU	VN	MX	SG	DE	GB	IL	RU
H04W-072	3760	2635	2085	1265	732	704	555	384	318	207	203	118	82	82	30	39	53	23
H04L-005	1866	1473	1054	672	410	454	104	237	191	95	90	44	33	54	19	12	12	15
H04B-007	1506	1185	1029	590	344	318	196	135	95	70	53	39	23	23	26	13	12	8
H04L-001	1378	1041	747	506	248	320	92	160	128	60	53	47	11	28	11	7	10	8
H04W-036	1153	943	658	441	191	229	99	78	57	38	36	21	19	11	15	12	3	4
H04W-024	1003	1045	454	277	135	145	101	89	56	40	35	25	11	10	7	4	9	7
H04W-028	1018	833	495	341	269	166	172	59	73	43	36	25	18	17	7	12	6	6
H04W-076	891	598	556	366	173	189	148	104	64	38	34	26	12	6	6	6	5	4
H04W-074	950	595	575	339	186	161	95	120	63	30	30	27	23	14	4	9	7	4
H04W-048	887	610	536	372	183	198	144	127	77	28	35	43	24	17	9	7	7	5
H04W-004	591	643	442	250	107	102	69	53	25	17	14	9	7	9	24	3	3	11
H04W-052	662	507	462	243	131	133	86	83	48	33	23	14	10	8	12	6	3	5
H04L-029	502	385	331	192	88	100	37	50	28	19	16	6	4	8	9	4	5	8
H04L-012	461	376	373	191	78	83	58	40	23	10	6	10	9	3	3	0	3	5
H04W-016	402	389	316	218	106	109	120	63	50	27	22	20	11	10	11	10	5	5
H04L-027	433	285	339	227	140	121	122	60	61	38	34	34	23	17	5	5	10	14
H04W-008	353	329	213	161	84	72	51	17	20	5	8	5	3	3	5	1	1	2

The USA and China alone are represented by more than one thousand families (over 4% of the collection's families) the leading groups such as H04W-072, H04L-005, H04B-007, as well as in H04L-001 *Arrangements for detecting or preventing errors in the information received* and H04W-024 *Supervisory, monitoring or testing arrangements* for China. The maximum concentration of all IPC groups is observed in PCT publications, except for some groups, including H04W-024 *Supervisory, monitoring or testing arrangements*, H04W-004 *Services or facilities specially adapted for wireless communication networks*, H01Q-001 *Details of, or arrangements associated with, antennas*, H04L-025 *Modulated carrier systems* , which are marked by the largest number of families in China, and H04B-001 *Details of transmission systems, not covered by a single one of groups H04B 3/00-H04B 13/00; Details of transmission systems not characterized by the medium used for transmission*.

The greatest interest in patenting in European countries whose markets companies enter after filing their applications with the EPO is observed in the following groups: H04W-072, H04L-005, H04B-007, H04L-001, H04W-076 *Connection management*, H04W-074 *Wireless channel access, e.g. scheduled or random access*, H04W-048 *Access restriction; Network selection; Access point selection*, H04L-027 *Modulated-carrier systems*.

The most frequently mentioned subgroups were also examined for the leading countries. All countries demonstrate enhanced patenting intensity in subgroups H04W-072/04 *Wireless resource allocation* and H04L-005/00 *Arrangements affording multiple use of the transmission path*, but other sections show some differences.

For China, most patents are covered by the following subgroups: H04W-036/00 *Handoff or reselecting arrangements*, H04L-001/00 *Arrangements for detecting or preventing errors in the information received*, H04W-024/02 *Arrangements for optimizing operational condition*, H04W-056/00 *Synchronization arrangements*, H04L-012/24 *Arrangements for maintenance or administration*, H04W-024/08 *Testing using real traffic*, H04B-007/0456 *Selection of precoding matrices or codebooks, e.g. using matrices for antenna weighting*, and H04B-007/0413 *MIMO systems*.

The US has more families under H04W-072/08 *Wireless resource allocation based on quality criteria*, H04W-004/00 *Services or facilities specially adapted for wireless communication networks*, H04W-048/18 *Selecting a network or a communication service*, H04L-029/06 *Arrangements, apparatus, circuits or systems for communication control; communication processing for plural communication lines characterized by a protocol*; H04L-027/26 *Systems using multi-frequency codes*, H04B-007/06 *Multi-antenna system using two or more spaced independent antennas at the transmitting station*, and H04W-074/08 *Non-scheduled access, e.g. random access, ALOHA or CSMA [Carrier Sense Multiple Access]* .

South Korea has been patenting in the subgroups H04W-072/12 *Wireless traffic scheduling*, H04B-007/06 *Multi-antenna system using two or more spaced independent antennas at the transmitting station*, H04L-001/00 *Arrangements for detecting or preventing errors in the information received*, and H04L-027/26 *Systems using multi-frequency codes*. India actually has more families in the leading subgroups and the same distribution across less popular subgroups.

Japan has lower patenting rates in the H04L-005/00 section than other leading countries. The highest activity is observed in the following subgroups H04W-072/12 *Wireless traffic scheduling*, H04L-027/26 *Systems using multi-frequency codes*, H04B- 007/06 *Multi-antenna system using two or more spaced independent antennas at the transmitting station*, H04W-074/08 *Non-scheduled access, e.g. random access, ALOHA or CSMA [Carrier Sense Multiple Access]*, H04W-024/10 *Scheduling measurement reports*, and H04W-028/06 *Optimizing, e.g. header compression, information sizing*.

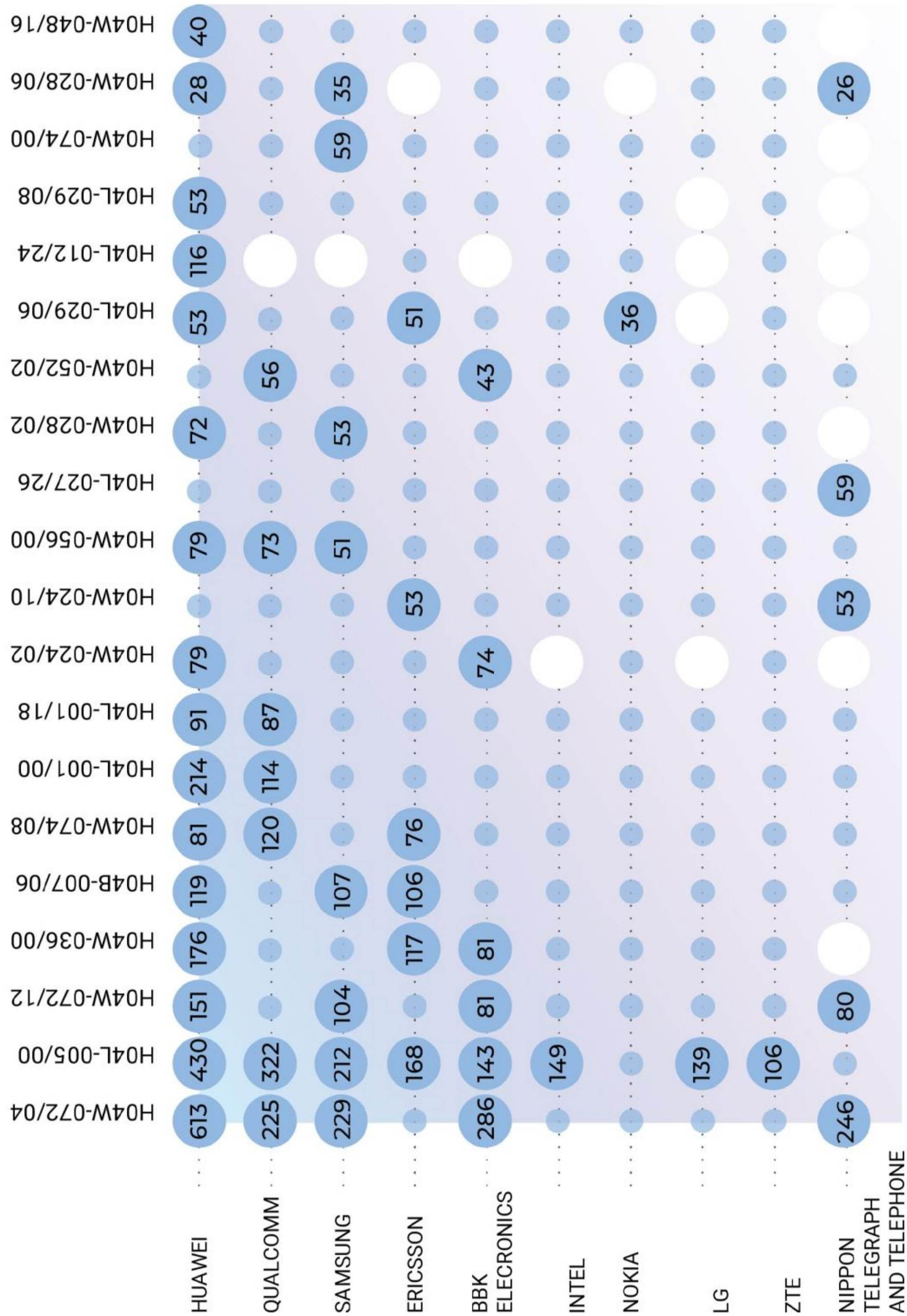
Publications in Russia are covered by the following sections: H04L-027/26 *Systems using multi-frequency codes*, H04L-029/06 *Arrangements, apparatus, circuits or systems for communication control; communication processing for plural communication lines characterized by a protocol*, and H04W-004/00 *Services or facilities specially adapted for wireless communication networks*, H04L-001/00 *Arrangements for detecting or preventing errors in the information received*, and H04W-024/10 *Scheduling measurement reports*. Patenting gaps are observed in groups H01Q-001 *Details of, or arrangements associated with, antennas*, H04L-025 *Modulated carrier systems*, H04B-001 *Details of transmission systems, not covered by a single one of groups H04B 3/00-H04B 13/00; Details of transmission systems not characterized by the medium used for transmission*, H04W-068 *Notification of users, e.g. alerting for incoming communication or change of service*, and in more detail in subgroups H04L-001/18 *Automatic repetition systems, e.g. van Duuren system*, H04W-028/06 *Optimizing, e.g. header compression, information sizing*, H04W-024/08 *Testing using real traffic*, H04W-072/08 *Wireless resource allocation based on quality criteria*, H04B-007/0456 *Selection of precoding matrices or codebooks, e.g. using matrices for antenna weighting*, and H04B-007/0413 *MIMO systems*.

The IPC subgroups were also examined in relation to patent holders to explore companies' technological specifications (Figure 60).

The incumbents vary in their patenting patterns in this area. Huawei has the largest technological coverage in terms of the number of IPC subgroups and is the leader in subgroups H04W-072/04 *Wireless resource allocation*, H04L-005/00 *Arrangements affording multiple use of the transmission path*, H04L-001/00 *Arrangements for detecting or preventing errors in the information received*, H04L-012/24 *Arrangements for maintenance or administration*, H04L-029/08 *Arrangements, apparatus, circuits or systems for transmission control procedure, e.g. data link level control procedure*, and H04W-028/02 *Traffic management, e.g. flow control or congestion control*, and many others.

Figure 60

Distribution of leading companies across IPC subgroups



Qualcomm, in its turn, is virtually not represented by patent families in the subgroup H04L-012/24 *Arrangements for maintenance or administration*, while holding leading positions in subgroups H04L-005/00 *Arrangements affording multiple use of the transmission path*, H04W-074/08 *Non-scheduled access, e.g. random access, ALOHA or CSMA [Carrier Sense Multiple Access]* , H04L-001/18 *Automatic repetition systems, e.g. van Duuren system*, H04W-056/00 *Synchronization arrangements*, H04W-052/02 *Power saving arrangements*, and H04W-016/14 *Spectrum sharing arrangements*.

Samsung is more active in the H04W-072/04 subgroup than Qualcomm and is also leading subgroups such as H04W-072/12 *Wireless traffic scheduling*, H04B-007/04 *Multi-antenna systems using two or more spaced independent antennas*, including H04B-007/06 *Multi-antenna system using two or more spaced independent antennas at the transmitting station*, H04W-074/00 *Wireless channel access, e.g. scheduled or random access*, H04W-028/06 *Optimizing, e.g. header compression, information sizing*, and H04W-004/00 *Services or facilities specially adapted for wireless communication networks*. A few patent families belong to the subgroup H04B-007/0413 *MIMO systems*, in which Huawei and Nippon Telegraph and Telephone lead the way.

Ericsson is actively patenting in almost all leading subgroups, taking the lead in H04W-036/00 *Handoff or reselecting arrangements*, H04B-007/06 *Multi-antenna system using two or more spaced independent antennas at the transmitting station*, H04L-001/18 *Automatic repetition systems, e.g. van Duuren system*, H04W-024/10 *Scheduling measurement reports*, H04L-029/06 *Arrangements, apparatus, circuits or systems for communication control; communication processing for plural communication lines characterized by a protocol*; H04W-048/18 *Selecting a network or a communication service*, H04L-001/16 *Arrangements for detecting or preventing errors in the information received in which the return channel carries supervisory signals*, *e.g. repetition request signals*; and H04B-007/04 *Multi-antenna systems using two or more spaced independent antennas*.

The smallest number of families is observed in sections H04W-028/06 *Optimizing, e.g. header compression, information sizing*, and H04B-007/0413 *MIMO systems*.

BBK Electronics has virtually no patents in H04L-012/24 *Arrangements for maintenance or administration*, H04B-007/0456 *Selection of precoding matrices or codebooks, e.g. using matrices for antenna weighting*, H04B-007/0413 *MIMO systems*, and H04B-007/04 *Multi-antenna systems using two or more spaced independent antennas*. The company has strong positions in subgroups H04W-036/00 *Handoff or reselecting arrangements*, H04W-024/02 *Arrangements for optimizing operational condition*, H04W-024/10 *Scheduling measurement reports*, H04W-052/02 *Power saving arrangements*, and H04W-024/08 *Testing using real traffic*.

Nippon Telegraph and Telephone has a large share of families in subgroups H04W-072/12 *Wireless traffic scheduling*, H04W-074/08 *Non-scheduled access, e.g. random access, ALOHA or CSMA [Carrier Sense Multiple Access]*, H04W-024/10 *Scheduling measurement reports*, H04L-027/26 *Systems using multi-frequency codes*, H04W-028/06 *Optimizing, e.g. header compression, information sizing*, and H04B-007/0413 *MIMO systems*.

A low level of patenting is observed for Nippon Telegraph and Telephone in subgroups:

- H04W-024/02 *Arrangements for optimizing operational condition* as well as for Intel, Sharp, LG, Mediatek;
- H04W-028/02 *Traffic management, e.g. flow control or congestion control*, as well as for Mediatek and Sony;
- H04L-029/06 *Arrangements, apparatus, circuits or systems for communication control; communication processing for plural communication lines characterized by a protocol* as well as for LG, China Information and Communication Technologies Group, Xiaomi, Sharp, SK Group, and Sony;

- H04L-012/24 *Arrangements for maintenance or administration*, as well as for LG, Xiaomi, Sharp, SK Group, Mediatek, and Sony;
- H04B-007/0456 *Selection of precoding matrices or codebooks, e.g. using matrices for antenna weighting* as well as for Xiaomi, Sharp, SK Group, and AT&T;
- H04L-029/08 *Arrangements, apparatus, circuits or systems for transmission control procedure, e.g. data link level control procedure*, as well as for Xiaomi, Sharp, Mediatek, and Sony;
- H04W-074/00 *Wireless channel access, e.g. scheduled or random access*, as well as for China Information and Communication Technologies Group, Mediatek, and AT&T;
- H04W-024/08 *Testing using real traffic*, as well as for Sharp and Sony;
- H04W-076/10 *Connection set-up*, as well as for AT&T; and
- H04B-007/04 *Multi-antenna systems using two or more spaced independent antennas* as well as for Xiaomi, China Mobile, Mediatek, and Sony.

Intel and Nokia have a more even distribution of families across subgroups with an average presence in all leading sections. Patenting by other companies is more fragmented and represented mainly in a narrow range of sections pertaining to the major groups.

Special mention should be made regarding IPC subclasses that are covered by the smallest number of companies in the 5G segment. These sections include H04L-012/24 *Arrangements for maintenance or administration*, H04W-074/00 *Wireless channel access, e.g. scheduled or random access*, H04B-007/0456 *Selection of precoding matrices or codebooks, e.g. using matrices for antenna weighting*, H04W-004/00 *Services or facilities specially adapted for wireless communication networks*, H04L-001/16 *Arrangements for detecting or preventing errors in the information received in which the return channel carries supervisory signals*, *e.g. repetition request signals*, H04B-007/0413 *MIMO systems*, H04W-016/14 *Spectrum sharing arrangements*, and H04B-007/04 *Multi-antenna systems using two or more spaced independent antennas*.

The analysis of IPC sections in the collection revealed a positive dynamics of technology development, which is experiencing a considerable increase in technical solutions in the segment over the last five years. The principal part of technical solutions is concentrated in the thematic section of H04W *Wireless communication networks*, which is divided into multiple more detailed groups. At the same time, sections related to transmitting arrangements, network resource management and actual radio communication systems, covering different subclasses, are the leading themes among the IPC groups. This distribution indicates a common technology vector in patenting, but varies depending on company specialization. This conclusion is confirmed by the structure of specialized IPC sections (subgroups) in the portfolios of leading companies, which have significant differences even within the same subclass.

TECHNOLOGY SEGMENTS

06

In this Technological Segments section, we analyze collections across segments, which have been identified in the overall collection using a set of key expressions and terms. As a result of brainstorming sessions and expert validation, the following technology areas were approved and recognized as revealing all aspects of 5G patenting to the fullest extent:

1) Radio Access Network (NG-RAN) and User Equipment

2) Backhaul network;

3) Virtualization and cloud infrastructure;

4) 5G Core;

5) Functional components for network management

6) Network services and digital platforms

The method for building collections by segment provides that one family can contain patent documents attributable to different segments. As a result, patent documents do not have clear restrictions for belonging to a certain segment. This is quite natural since the relevant segments are technologically close while companies often patent complex solutions, claiming several developments within the same family.

GENERAL ANALYSIS BY SEGMENT

We analyzed patent information for the selected technology segments within the most valuable array of patent documents. This approach ensures a deep analysis of technological trends and provides an opportunity to identify sectoral companies, their protection strategies, as well as specific high-potential technical solutions. Taking into account our integrated approach to the research, the purpose of the analysis in this section was to identify the most interesting trends and metrics related to each individual segment or their overall evolution over the past ten years.

General metrics of collections by segment

Table 9

Number of families	26758	9254	9694	15301	9914	15635
SEP families	2724	991	1076	1395	862	1564
Families owned by Top 10 patent holders, %	69%	79%	77%	72%	69%	75%
Number of disputes with the patent office	73	19	32	44	40	45
Average family size	2,8	3	2,6	2,8	2,5	2,8
Average originality level	0,68	0,71	0,67	0,67	0,66	0,69

Segment 1
Radio Access Network (NG-RAN) and User Equipment

Segment 2
Backhaul Network

Segment 3
Virtualization and Cloud Infrastructure

Segment 4
5G Core

Segment 5
Functional Components for Network Management

Segment 6
Network Services and Digital Platforms

We analyzed the following most important metrics of the collection (Table 9):

- Presence of SEP families;
- Number of families owned by Top 10 companies in the collection;
- Availability of disputes with patent offices on patentability criteria;
- Average family size by the number of publications;
- Average originality Index.

These indicators enabled us to estimate the development of standardization in the region, the level of market monopolization by leading companies, the interest of applicants in obtaining patents in certain territories, the general publication activity, which indicates the degree of readiness for commercialization of solutions, as well as whether the developed technologies are breakthroughs with respect to prior art or are a gradual improvement of existing technical solutions.

Families were broken down by technological segment, with segments *Backhaul Network*, *Virtualization and Cloud Infrastructure* and *Functional Components for Network Management* including 30% of the collection's documents, and segments *5G Core* and *Network Services and Digital Platforms*, 50% each. Accordingly, the *Backhaul Network*, *Virtualization and Cloud Infrastructure*, and *Functional Components for Network Management* segments contain the rarest terms in the collection.

Of particular note is the *Radio Access Network (NG- RAN) and User Equipment* segment where the terminology base very often coincides with the terms that are observed across the collection's patent families on the whole (for example, user equipment). As a result, a significant part of the overall collection's documents (90%) were included in the first segment. In this connection, the patenting dynamics, patent holder ratings, and other indicators of this segment are similar to those of the overall collection.

The significant overlap between families in the technology segments indicates that applicants are trying to patent the most comprehensive solutions, including both basic solutions and more specialized ones. For example, a technical solution can simultaneously describe a base station and network nodes, as well as data transmission methods, functional components for network management, and any network service (US20170331670).

In terms of the number of SEP families, the leading segments, apart from the first segment, are those related to core networks, network services, and digital platforms. The *Virtualization and Cloud Infrastructure* segment has the largest number of SEP families and the *Functional Components for Network Management* segment has the smallest number of SEP families.

The segments with the highest concentration of technical solutions in the portfolios of leading companies include *Backhaul Network*, *Virtualization and Cloud Infrastructure*, and *Network Services and Digital Platforms*. The overall level of monopolization in all segments, as well as in the overall collection, is quite high. This is primarily due to the fact that SEP patenting gives rise to barriers for other companies to enter the market, driving not only a global technical level, but also 5G communication standards. This situation carries potential development risks for all other companies that have not managed to enter the technology race at the early stages of the segment's development.

The smallest number of disputes with patent offices is observed in the *Backhaul Network* segment, while the *Radio Access Network (NG- RAN) and User Equipment* segment covers almost all cases of the overall collection. At the same time, 25% of families in which disputes were identified are SEP families. KT and Nokia have the largest number of disputed SEP families in the *5G Core* segment. Moreover, all oppositions in all segments were successfully overcome and the processing of applications continued. This means that companies challenge partial rejections by patent offices based patentability criteria and seek patenting of their technical solutions by changing the claims, which indicates that companies are serious about their intentions in the 5G segment.

The *Functional Components for Network Management* segment has the lowest number of publications, while the *Backhaul Network* segment has the highest number of publications. On average, all segments have about three publications per family. When calculating the average size of a family, a large number of young families are taken into account that did not sufficiently develop their publications either in terms of geographical coverage or technology. However, for a young segment, the average family size of more than two families may be an indication that many applicants are not only trying to apply at the national level. Accordingly, the size of indicators across segments indicates that the segment is young but has great potential for development. This is also confirmed by the fact that families with a longer application filing retrospective feature complex publication structures with a greater emphasis on geographical expansion.

The average level of originality across the overall collection coincides with the level of originality of the *Radio Access Network (NG- RAN) and User Equipment* segment due to a significant overlap between their documents. Technical solutions in the *Backhaul Network* segment demonstrate the highest originality index.

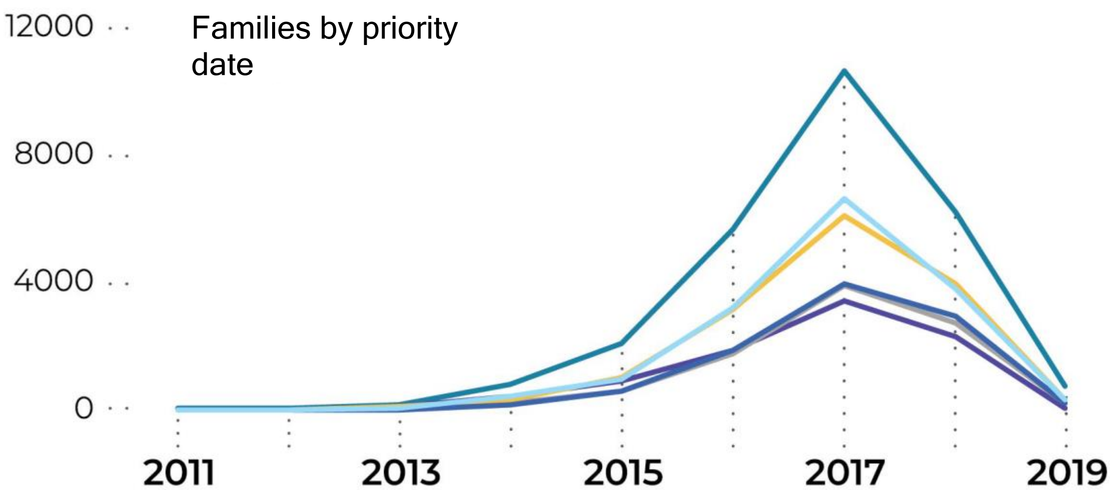
Other segments feature the same level of originality as the overall collection. Moreover, the index of some segments such as *Virtualization and Cloud Infrastructure*, *5G Core,* and *Functional components for Network Management* is lower than the average level of the overall collection. Such index demonstrates that technologies in the *Backhaul Network* and *Network Services and Digital Platforms* segments have a breakthrough value for the industry to a larger extent than solutions of other segments. However, the general level of originality of collections indicates the development of fundamentally new technologies as compared to prior art, in particular at Qualcomm, Huawei, Ericsson, and Samsung.

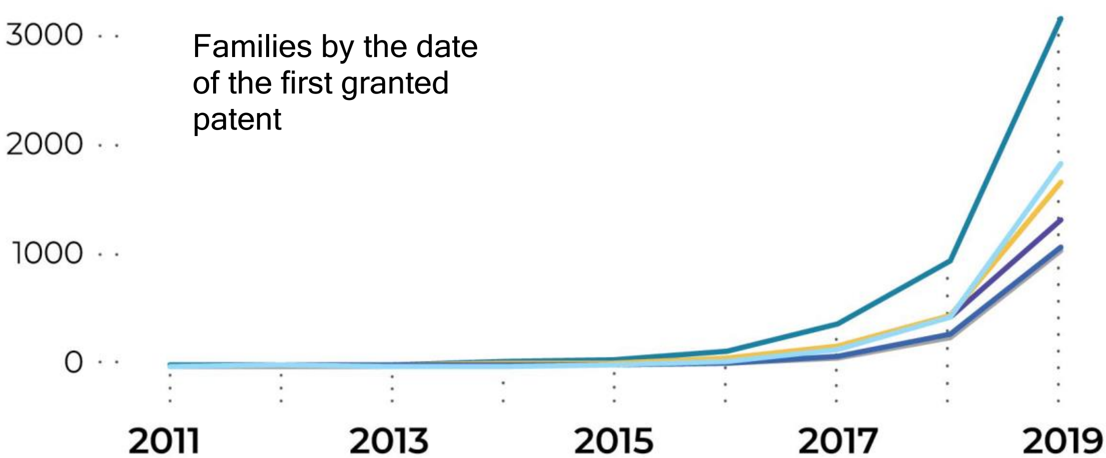
The development dynamics for each segment reflects the general patenting trend in the area (Figure 61). A chart describing families by priority date is in line with the chart for the overall collection. Since applicants in the area are trying to obtain the earliest possible priority date, including for families that define the standards, the distribution of patents by priority date underwent a certain artificial shift, which determined the patenting peak in 2017. However, if we consider the distribution of families by the date when their first patent was granted, we will see that the maximum number of families is concentrated in 2019. By comparing these charts, you can see how families have evolved over time in terms of the ability of patent portfolios to effectively protect their developments. This ability is implemented through managing the process from filing the application to obtaining the patent.

Accordingly, in the *Radio Access Network (NG- RAN) and User Equipment* segment only 20% out of nineteen thousand patent families, which emerged in 2017, were granted patents two years later. The lowest share of granted patents was observed in the segment *Virtualization and Cloud Infrastructure* segment, and the highest share in 30% was observed in the *Backhaul Network* segment. The *Backhaul Network* segment has the lowest number of families in the collection as compared to others, as well as a lower indicator of family emergence by priority date in 2017–2018. However, its share of granted patents in relevant families exceeds that of the *Functional Components for Network Management* segment during the entire period, and until 2019 it demonstrated figures similar to those of the *5G Core* and *Network Services and Digital Platforms* segments. Such dynamics may indicate that companies have the strongest commercial interest in the *Backhaul Network* segment.

Dynamics of patenting by segment

Figure 61





- Radio Access Network (NG-RAN) and User Equipment
- Backhaul Network
- Virtualization and Cloud Infrastructure
- 5G Core
- Functional Components for Network Management
- Network Services and Digital Platforms

The compound annual growth rate (CAGR) of patent portfolios for all segments of the collection is quite high. The *Virtualization and Cloud Infrastructure* and *Network Services and Digital Platforms* segments have a CAGR exceeding 100%. The *5G Core* segment has the lowest annual growth rate.

A more detailed analysis of periods identified peaks of a significant patenting growth across the segments. For example, between 2010 and 2017, almost all segments demonstrated an explosive growth of emerging families as expressed by an annual growth rate exceeding 100%. The only segment that had an average growth rate below 100% was the 5G Core. Until 2018, the average family growth rates in the *Virtualization and Cloud Infrastructure* and *Network Services and Digital Platforms* segments were 153% and 141%, respectively. Other segments demonstrated average annual family growth rates of 110%–115%.

After 2017, all segments experienced a significant decline in family emergence, which is reflected in their respective compound annual growth rates. From 2017 to 2019, they averaged 11%–14%. The most considerable increase in the number of families during this period was demonstrated by the *Functional Components for Network Management* segment. Accordingly, until 2018 an important increase in patenting in the *Virtualization and Cloud Infrastructure* and *Network Services and Digital Platforms* supported the high average annual growth rates for the entire period. At the same time, the intensification in the *Functional Components for Network Management* segment in the last few years also contributed to the increase in the average growth rates over the entire period pending examination.

The analysis of legal statuses for technological segments confirms that the market is still emerging and that applicants show enhanced interest in research, since all of them have a large number of applications pending examination as compared to the number of granted patents (Figure 63). At the same time, there was a significant increase in the number of patented technical solutions in 2019, especially in the *Backhaul Network* segment, which is the leader by the number of families with granted patents as compared to other legal statuses in this collection. This might suggest an increased level of commercialization in the segment as companies attempt to obtain patents as early as possible.

Compound Annual Growth Rate (CAGR) of families by segment

Figure 62

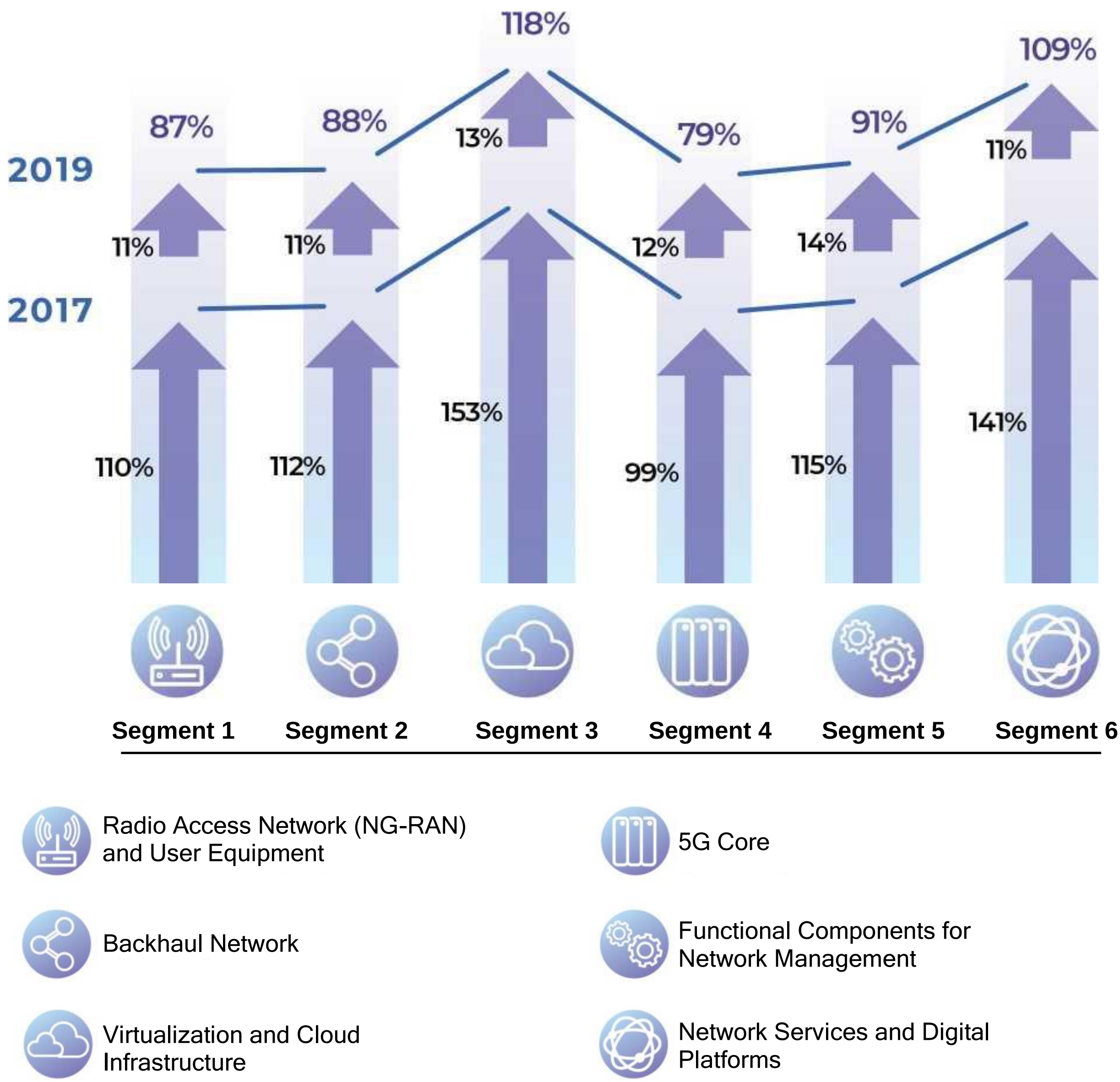
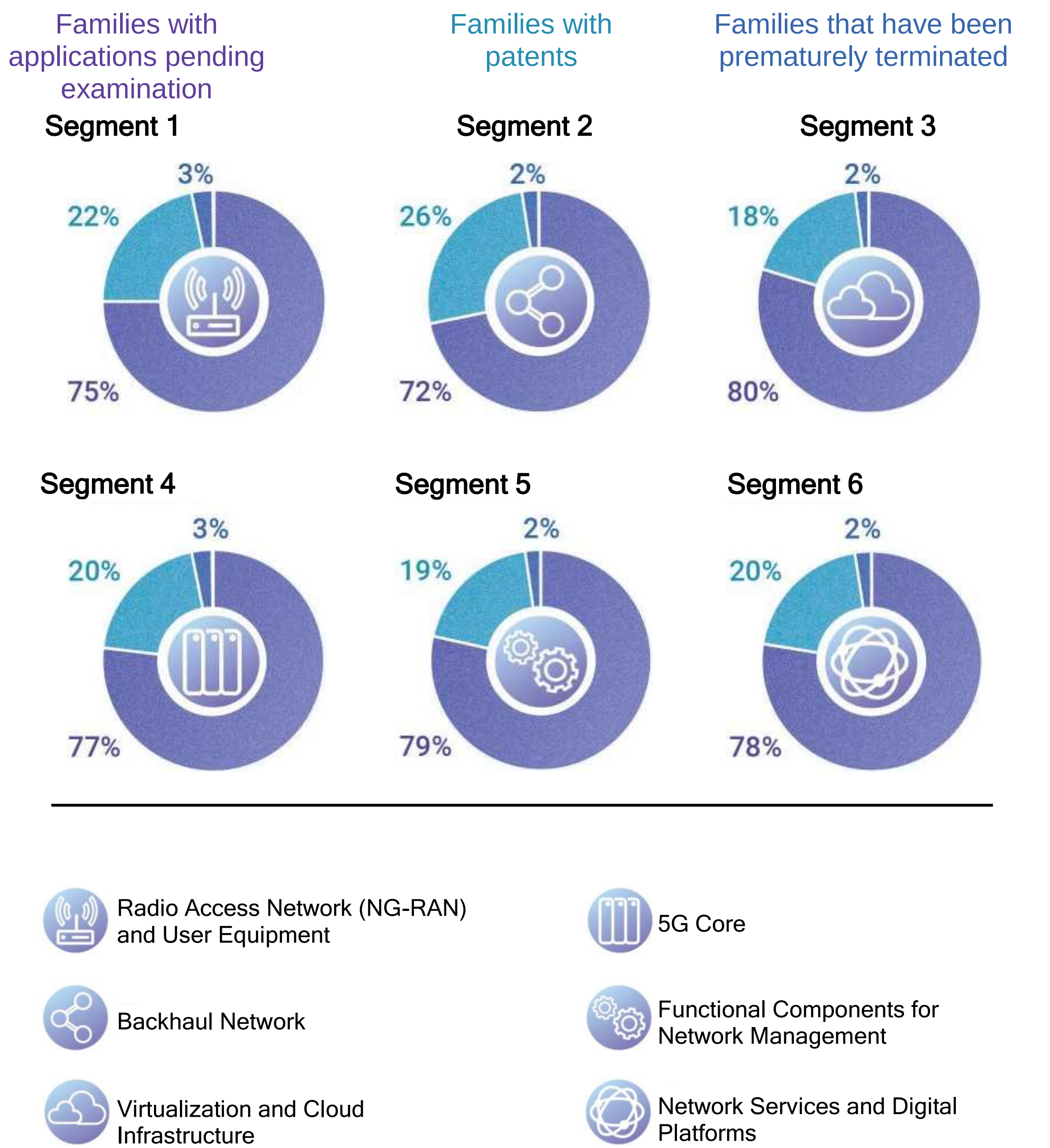


Figure 63 **Legal statuses of collections by technology segment**



The presence of families that have been prematurely terminated witnesses that the global technology level is represented by a large number of basic solutions, which causes certain difficulties in patenting. SEP patents play a significant role in this, and as a result some technical solutions (no more than 3%) are recognized as unpatentable by patent authorities.

The largest number of such solutions is actually represented in the basic segments such as *Radio Access Network (NG- RAN) and User Equipment* and *5G Core*. These segments also account for a high number of withdrawn applications.

ANALYSIS OF PATENT HOLDERS BY SEGMENT

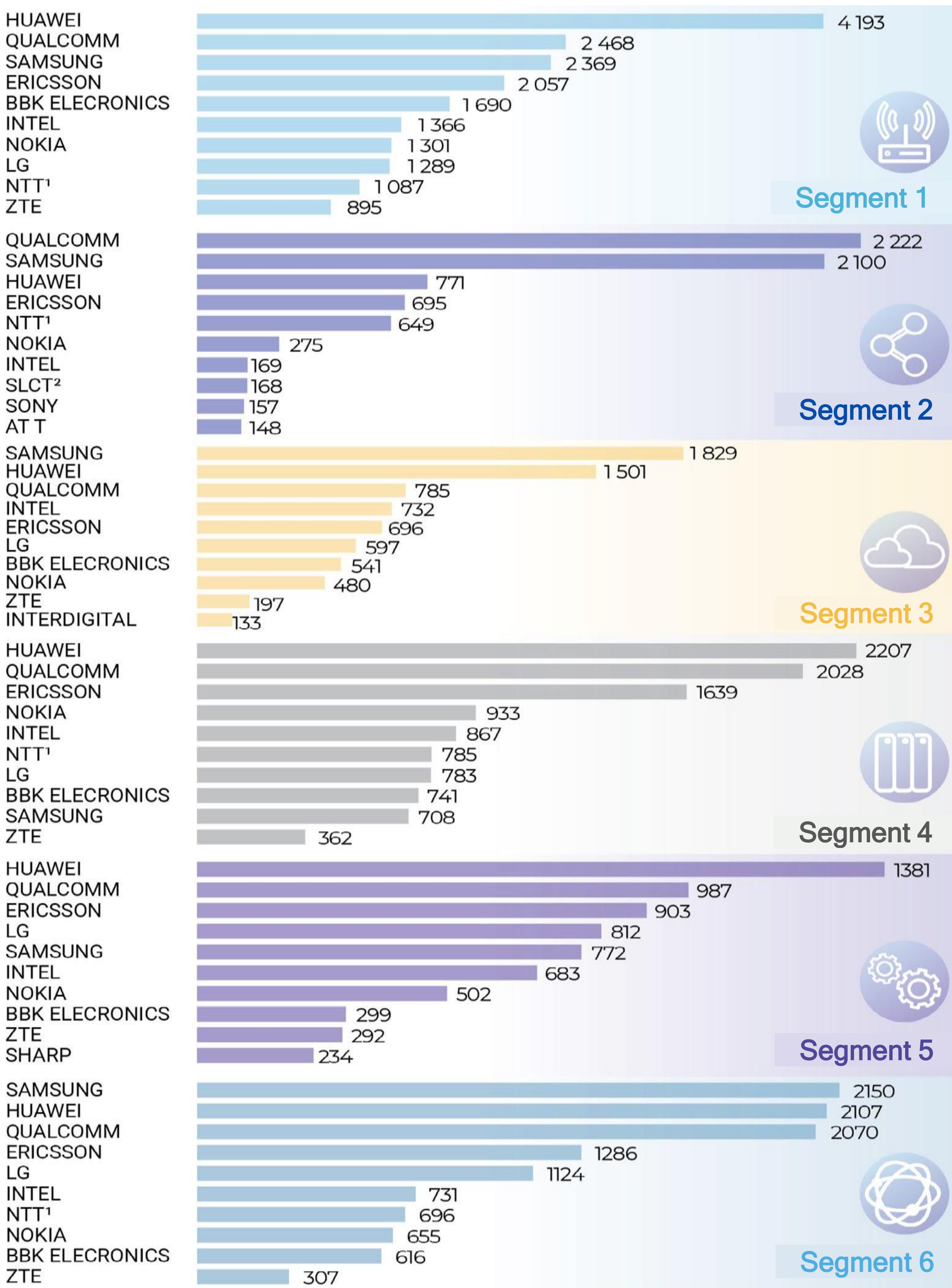
An analysis of patent holders by technology segment showed that almost all leading companies cover several research areas at once (Figure 64). These findings are confirmed by the presence in the patent portfolios owned by leading companies of complex technologies that pertain to several technology areas at once.

Meanwhile, the companies that were included in the segment-based ranking are different from other rankings. The ranking of the *Radio Access Network (NG- RAN) and User Equipment* segment is similar to the overall ranking of patent holders because the collections feature a large number of the same families. Huawei is the leader in the *Radio Access Network (NG- RAN) and User Equipment*, *5G Core*, and *Functional Components for Network Management* segments. The contrast with the leader's portfolio size is most striking in some segments, including *Radio Access Network (NG- RAN) and User Equipment* and *Functional Components for Network Management*.

Two incumbents, Qualcomm and Samsung, have the leading positions in the *Backhaul Network* segment, contributing the most to the development of this segment. Portfolios of Huawei, Ericsson, and Nippon Telegraph and Telephone in this segment are three times smaller. The ranking also includes the Chinese telecommunications company Shanghai Langbo Communication Technology and AT&T, an American mobile operator. Chinese incumbents BBK Electronics and ZTE, and South Korean LG are not represented in the ranking.

The *Virtualization and Cloud Infrastructure* segment also has two leading companies: Samsung and Huawei. However, the difference in portfolio sizes between the leaders and other companies is smaller than in the previous segment. The ranking includes InterDigital while not citing Nippon Telegraph and Telephone.

Figure 64 **Patent holder ranking by segment**



¹NIPPON TELEGRAPH AND TELEPHONE
²SHANGHAI LANGBO COMMUNICATION TECHNOLOGY

The *5G Core* segment demonstrates a more balanced distribution of families in company portfolios. Three incumbents at once have the leading positions in this segment: Huawei, Qualcomm, and Ericsson. Nokia has quite a strong position in the segment, while Samsung is seriously lagging behind in developing these technologies.

The *Functional Components for Network Management* segment has a structure of patent holders similar to that of the *5G Core* segment, but relevant patent portfolios have smaller sizes, while LG and Samsung have a larger number of solutions than Intel and Nokia. Japanese Nippon Telegraph and Telephone is not represented in this segment at all. Its place is occupied by technical solutions of another Japanese company, Sharp.

Similarly to the *5G Core* segment, the *Network Services and Digital Platforms* segment demonstrates an even distribution of families owned by leading companies. At the same time, Samsung, Huawei, and Qualcomm have the leading positions in the segment, while Ericsson and LG have 40% fewer portfolios.

The size of the patent portfolio is only one indicator that can be estimated when evaluating leading positions. The strength of the patent portfolio is also a key criterion. The patent portfolio’s strength indicates the quality of patents that are held by companies. The patent portfolio’s strength is estimated based on the sum of strengths of all families within the portfolio of a given company belonging to a particular segment. The remaining lifespan of the patent is also taken into account, provided that it expires naturally. In this case, inactive families are considered to be equal to zero.

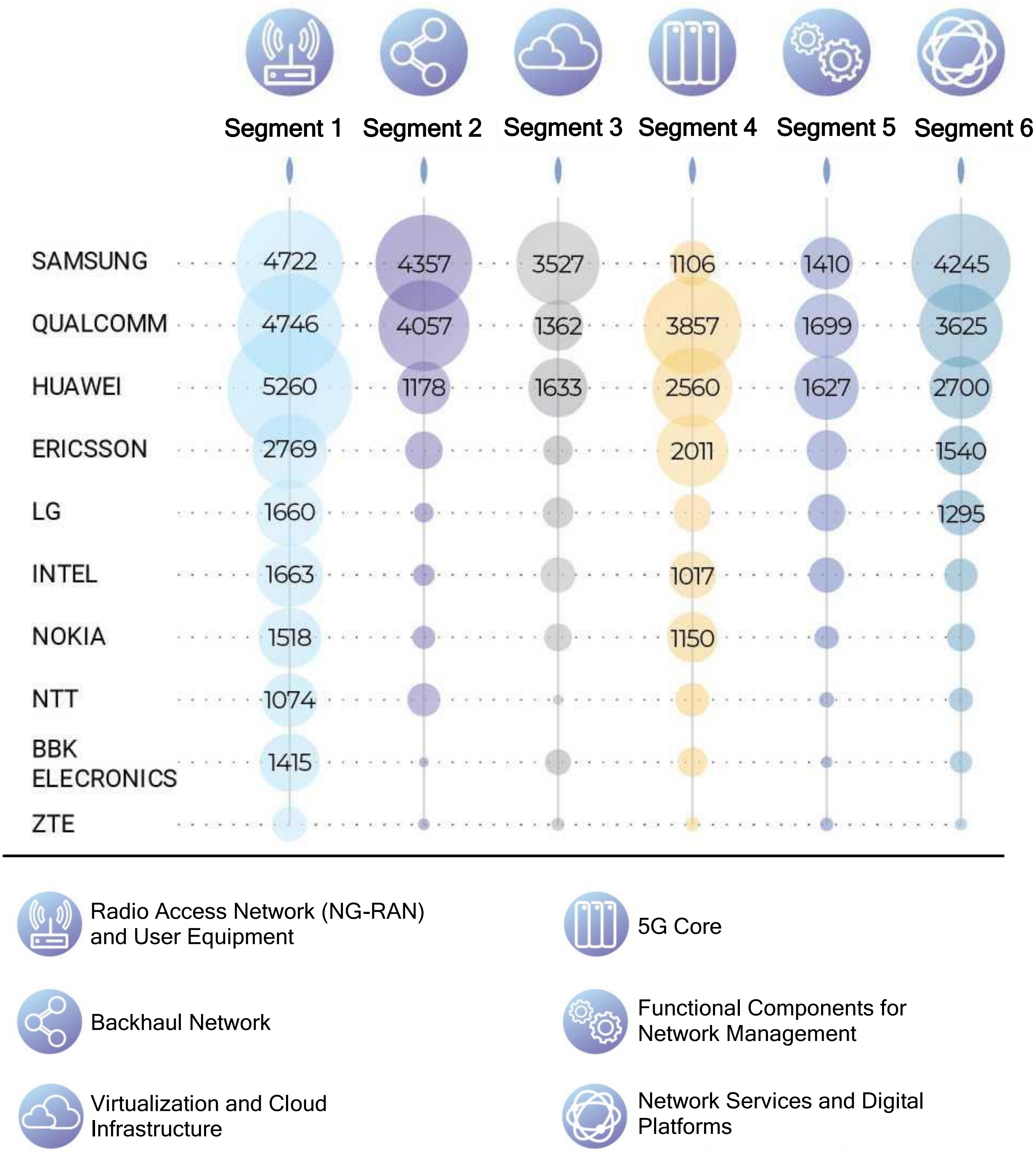
The leading companies were ranked by the sum of strengths of patent portfolios in all considered technological segments and presented graphically (Figure 65).

Samsung and Qualcomm are the leading companies by the strength of their patent portfolios. They are followed by Chinese Huawei with some gap. At the same time, the total size of Huawei’s patent portfolio exceeds the size of Samsung’s and Qualcomm’s patent portfolio, while its strength is 20% lower. This situation may be due to the fact that the calculation of strength takes into account both the average geographical coverage, with Qualcomm having a significantly larger coverage, and technological relevance, which indicates a large number of citations of technical solutions by third parties (with Samsung leading by the number of citations).

At the same time, it is actually Samsung, Qualcomm, and Huawei whose patent portfolios have a high level of strength across all relevant segments.

Figure 65

Breakdown of the patent portfolio of leading companies by strength



The *Radio Access Network (NG- RAN) and User Equipment* segment demonstrates a strong patent portfolio as its size significantly exceeds the size of its portfolios in other segments. LG is an exception as the size of its portfolio is approximately equal to the size of its portfolio in the *Network Services and Digital Platforms* segment, while the strength of its portfolio in the *Radio Access Network (NG- RAN) and User Equipment* segment is higher by 20%.

Samsung pays less attention to patenting in the *5G Core* and *Functional Components for Network Management* segments, having the highest index in the *Backhaul Network* segment, despite having a smaller portfolio than in the *Network Services and Digital Platforms* segment.

Qualcomm has a high strength indicator as compared to the size of its portfolio in the *5G Core* segment, while LG has a strong patent portfolio in the *Network Services and Digital Platforms* segment.

Ericsson has the strongest patent portfolios in the *5G Core* and *Network Services and Digital Platforms* segments. While its portfolios in the *Backhaul Network* and *Virtualization and Cloud Infrastructure* segments have the same size, the strength of the portfolio in the *Backhaul Network* segment is 20% higher.

Other leading companies (Intel, Nokia, Nippon Telegraph and Telephone, BBK Electronics, and ZTE) have the strongest patent portfolios in the *5G Core* segment. Nippon Telegraph and Telephone has a higher patent portfolio strength in the *Backhaul Network* segment than in the *Network Services and Digital Platforms* segment, which has more families. Nippon Telegraph and Telephone and BBK Electronics have the weakest patent portfolios in the *Virtualization and Cloud Infrastructure* and *Backhaul Network* segments, respectively.

Accordingly, each company has patenting priorities in different segments, which determines their specialization, as well as patenting strategies, affecting the resulting strength in a particular segment.

The leading 5G companies were also distributed by the average lifespan of patents in their patent portfolios. The average patent lifespan is calculated from the date of the family’s first publication.

Such distribution helps identify the life cycle of innovations produced by companies and evaluate their position in the technology market and their interest in protecting their developments. Moreover, the longer the patent lifespan is, the higher the likelihood is that third parties would cite or challenge the invention.

Patents have short lifespans in all segments, because there is a large number of young families, which have not more than two years since their first publication. A large number of families owned by Huawei, Qualcomm and Ericsson mainly feature short retrospectives of 1.4, 1.3, and 1.5 years, respectively. The longest portfolio lifespan is observed in the *Radio Access Network (NG- RAN) and User Equipment* and *Backhaul Network* segments for Huawei, in the *Radio Access Network (NG- RAN) and User Equipment* and *5G Core* segments for Qualcomm, and in the *Radio Access Network (NG- RAN) and User Equipment* and *5G Core* segments for Ericsson.

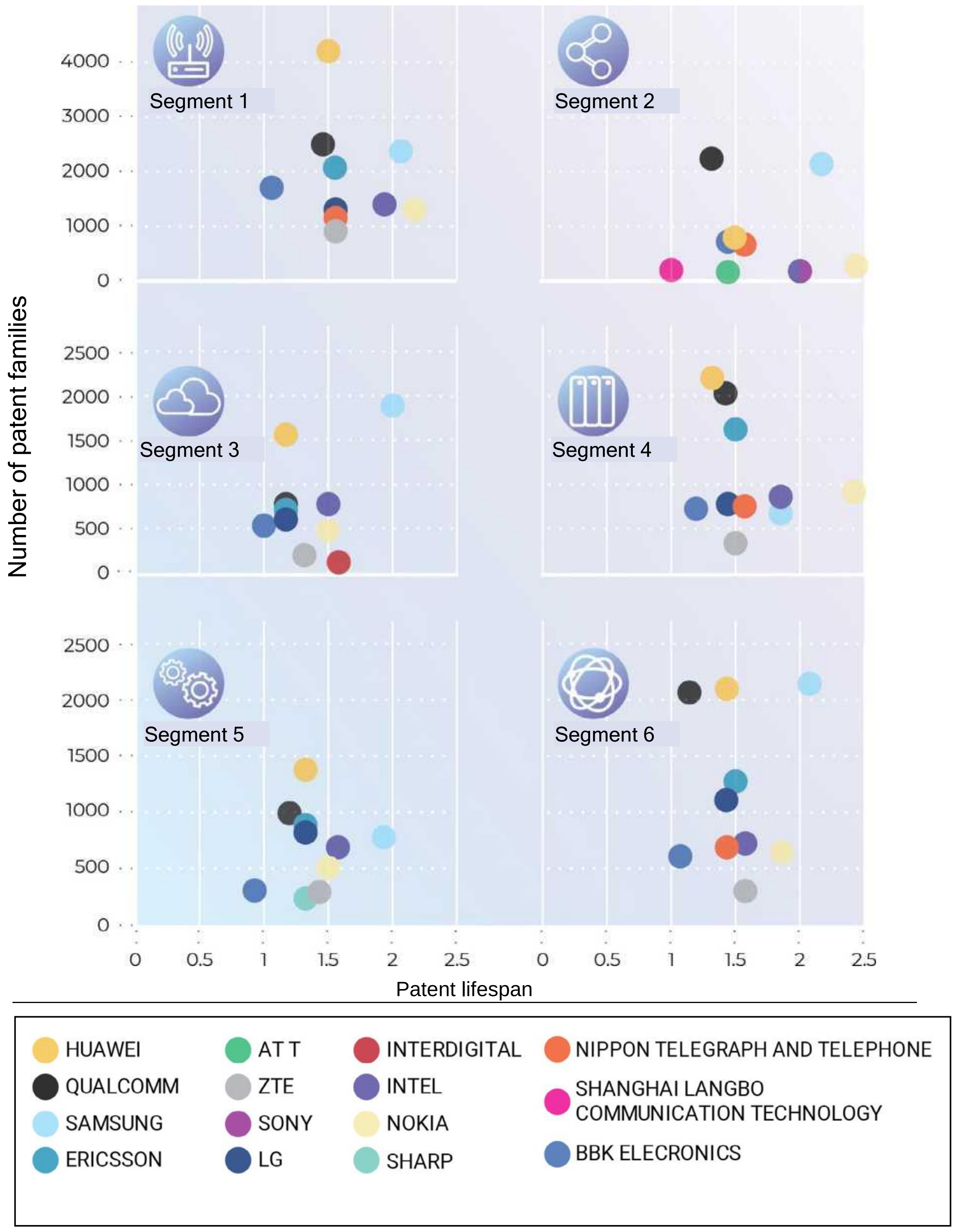
In the *Radio Access Network (NG- RAN) and User Equipment* segment, the average patent lifespan is 1.66 years. The portfolio lifespan of Nokia and Samsung exceeds two years. Nokia has a patent portfolio of an average size, like Intel and LG, but the average patent lifespan of LG is much shorter. BBK Electronics has the shortest patent lifespan in this segment. This company also has the shortest patent lifespans in other segments.

The *Backhaul Network* segment features the largest number of companies with an average patent lifespan of two years or longer. These include Nokia, Samsung, Intel, and Sony. Huawei has one of the longest family lifespans in its portfolio in this segment. Chinese Shanghai Langbo Communication Technology supports its technical solutions for not more than a year.

The V*irtualization and Cloud Infrastructure* and *Functional Components for Network Management* segments have the shortest average patent lifespans within the collection. Only Samsung has an average patent lifespan of two years in the *Virtualization and Cloud Infrastructure* segment.

Average patent lifespan for leading companies by segment

Figure 66



The *5G Core* segment has average patent lifespan values. Nokia is the leader in this segment, with its technical solutions having a patent lifespan of almost 2.5 years. Patent lifespans of Intel and Samsung are close to two years.

ZTE, Nokia, and Intel have the longest patent portfolio lifespans in the *5G Core* segment, although they have the smallest number of families. Samsung, Huawei, and Qualcomm have the largest number of families in the patent portfolio. However, only Samsung has been supporting its technical solutions for more than two years.

On the whole, Samsung and Nokia have the highest patent lifespans in the collection. At the same time, the *Backhaul Network* segment has the highest average patent lifespan across segments (1.68 years). BBK Electronics has the shortest patenting retrospective, which characterizes it as a very young player in the market for 5G technologies. Despite the size of their portfolios, the incumbents, that is, Huawei, Qualcomm, and Ericsson, also have a short retrospective in terms of their patent lifespans.

ANALYSIS OF PATENTING GEOGRAPHY BY SEGMENT

Below is a distribution of patenting priority countries (where research and development take place) by technology segment (Figure 67). All segments feature priorities established in 12 countries (the USA, China, South Korea, Japan, India, the United Kingdom, Greece, Germany, Sweden, France, Finland, and Italy), as well as priorities under PCT and EPO applications.

The USA has the widest possible specialization across all technology segments and is the leader by the number of priorities. China has a similar profile, but in the *5G Core* segment its priorities claimed under PCT applications have a higher position and the largest number of families, apart from the *Radio Access Network (NG- RAN) and User Equipment* segment.

Japan and Finland have a large number of families with priorities in the *5G Core* segment, India, the UK, Germany, Sweden, and France in the *Network Services and Digital Platforms* segment, and Greece and Italy in the *Backhaul Network* segment.

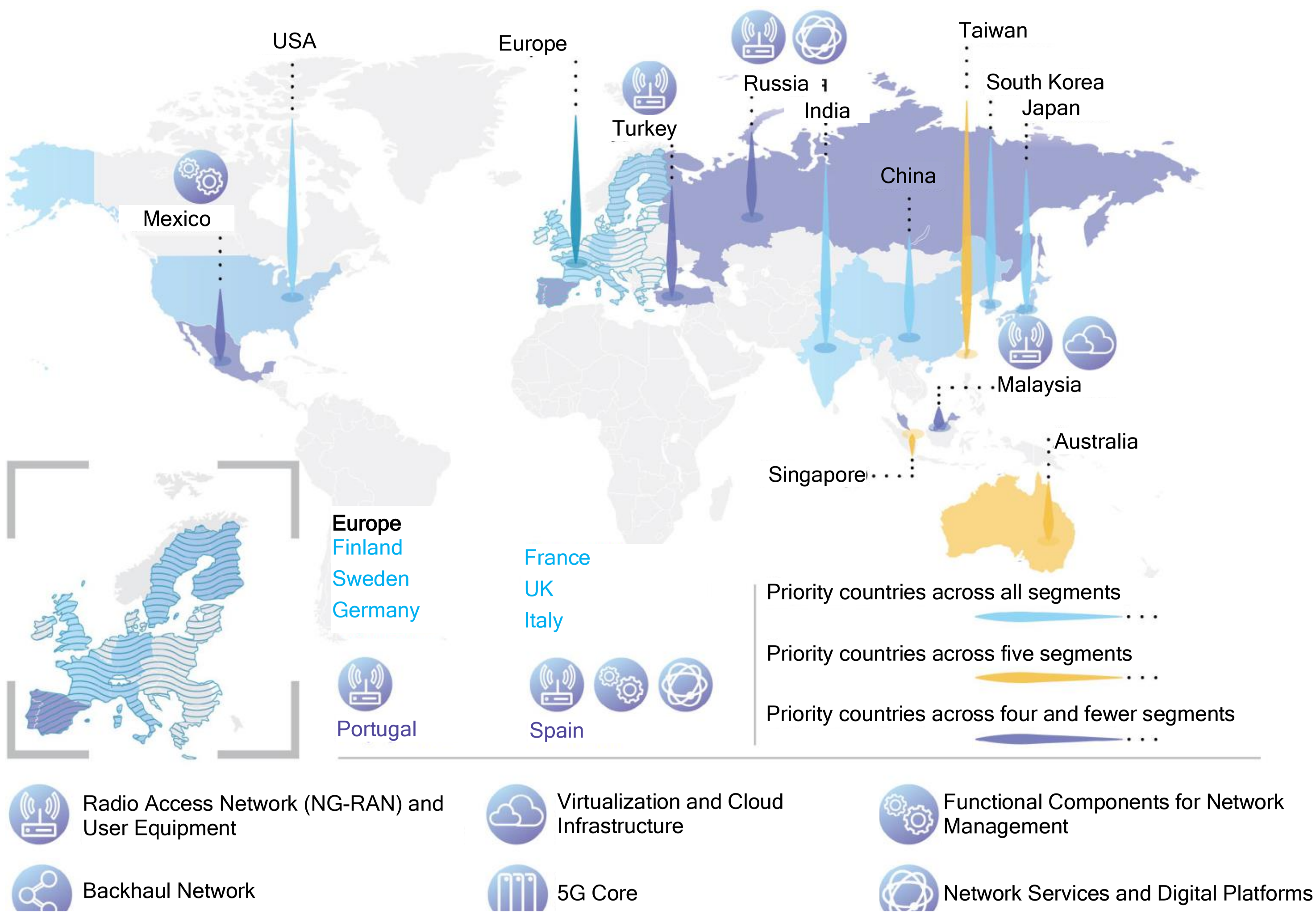
The *Radio Access Network (NG- RAN) and User Equipment* segment is represented by the largest number of priority countries. Among them (except the leading countries) are Australia, Russia, Singapore, Spain, Malaysia, Portugal, Turkey, and Taiwan. Russian priorities are observed for Samsung (**RU2016143930**) and the Institute for Information Transmission Problems (Kharkevich Institute) of the Russian Academy of Sciences (**RU193265**).

The *Backhaul Network* segment has a high share of priorities from South Korea, while in other segments the country has a large number of priorities, but its position in the ranking is lower. The segment also features priorities that emerged in Singapore and Taiwan. This segment has the smallest number of countries where priorities emerged.

Apart from the leading countries, the *Virtualization and Cloud Infrastructure* segment features priorities emerged in Australia, Malaysia, and Singapore, the *5G Core* segment – in Singapore, Australia, and Taiwan, the *Functional Components for Network Management* segment – in Australia, Spain, Mexico, and Taiwan, and the *Network Services and Digital Platforms* segment – in Spain, Russia, Singapore, and Taiwan.

Besides the countries that develop technical solutions, we analyzed the distribution of countries that provide the greatest contribution to patenting across all technological segments. The map for each country is based on the index of active families in each segment, that is, families with active patents or applications pending examination were analyzed. As a result, we can identify target markets where applicants are trying to protect their developments to a greater extent. On the one hand, this situation drives the need to bring strong technical solutions to these markets given the positive prospects for rapid commercialization. On the other hand, the active position of applicants in certain markets helps them expand the focus of international patenting and gain a niche in a less competitive environment.

Distribution of priority countries by segment



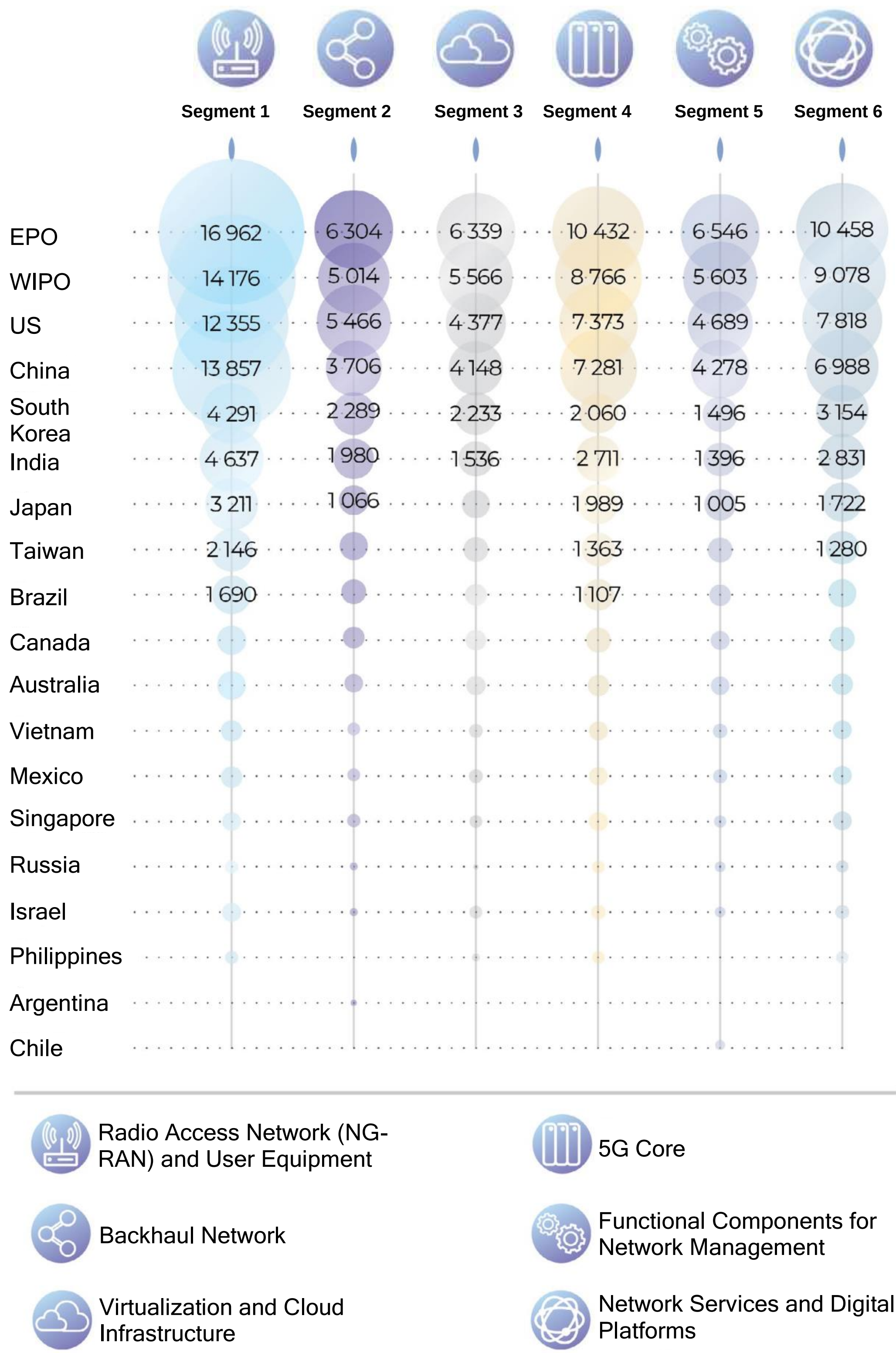
The area features strong geographical coverage with a large number of countries where all technology segments are protected. They include the leading countries such as the USA, China, South Korea, India, Japan, Taiwan, Brazil, Canada, Germany, the United Kingdom, and Australia, as well as protection under the PCT procedure and through the European Patent Office. In general, patenting across all segments covers the entire list of jurisdictions (50 patent offices).

A high priority of regional patenting through the EPO and international patenting under the PCT procedure is observed in all segments. Among European countries, the highest patenting volumes are observed in Germany, the United Kingdom, Ireland, Switzerland, and Austria.

At the same time, segments vary by their patenting priorities across countries. For example, most solutions in the *Radio Access Network (NG-RAN) and User Equipment* segment are protected in China, while the US market has a higher priority for other segments. Patenting in India has a higher priority in the *Radio Access Network (NG- RAN) and User Equipment* and *5G Core* segments, while solutions in other segments are protected to a greater extent in South Korea. Both India and South Korea have the largest number of active families in the *Network Services and Digital Platforms* segment. Japan, Taiwan, and Brazil have the same priority in terms of segments, which determines their position in the rankling. However, the largest number of families with patents and applications pending examination for Japan, Taiwan, and Brazil is observed in the *5G Core* segment.

Other countries with active patent protection and an average number of families include Canada, Australia, Vietnam, Mexico, Singapore, Israel, and the Philippines. In Canada, Singapore, Vietnam, Mexico, Israel, and the Philippines, a large part of patents pertains to the 5G Core segment, and in Australia to the *Network Services and Digital Platforms* segment.

Figure 68 **Geographical distribution of active patents across technological segments**



Active families in Russia are distributed across segments as follows:

- Radio Access Network (NG- RAN) and User Equipment – 161 families;
- Backhaul Network – 57 families;
- Virtualization and Cloud Infrastructure – 32 families;
- 5G Core – 103 families;
- Functional Components for Network Management – 50 families;
- Network Services and Digital Platforms – 89 families.

Patenting in Russia is mainly represented by the basic solutions related to the radio access networks, user devices, and 5G Core segments. The *Virtualization and Cloud Infrastructure* segment has the lowest level of competition.

DESCRIPTION OF THE MOST VALUABLE TECHNICAL SOLUTIONS BY SEGMENT

We selected the most valuable patent families for each segment based on the ranking of the strongest technical solutions, which includes families with the largest geographical coverage and presence in leading countries, the number of citations by other companies, as well as generality and originality of developments. The most interesting publications of these families from the standpoint of potential technology advances or the profile of the problem that is being addressed were described by experts specializing in the respective areas. The descriptions of these patent documents are given below.

Radio Access Network (NG-RAN) and User Equipment

User equipment procedures to control uplink beam forming

Patent owner: Ericsson

Basic publication of the family US20170331670 (A1)

Application filing date: May 13, 2016

Described publication of the family: US2018227166 (A1)

Application filing date: May 11, 2017

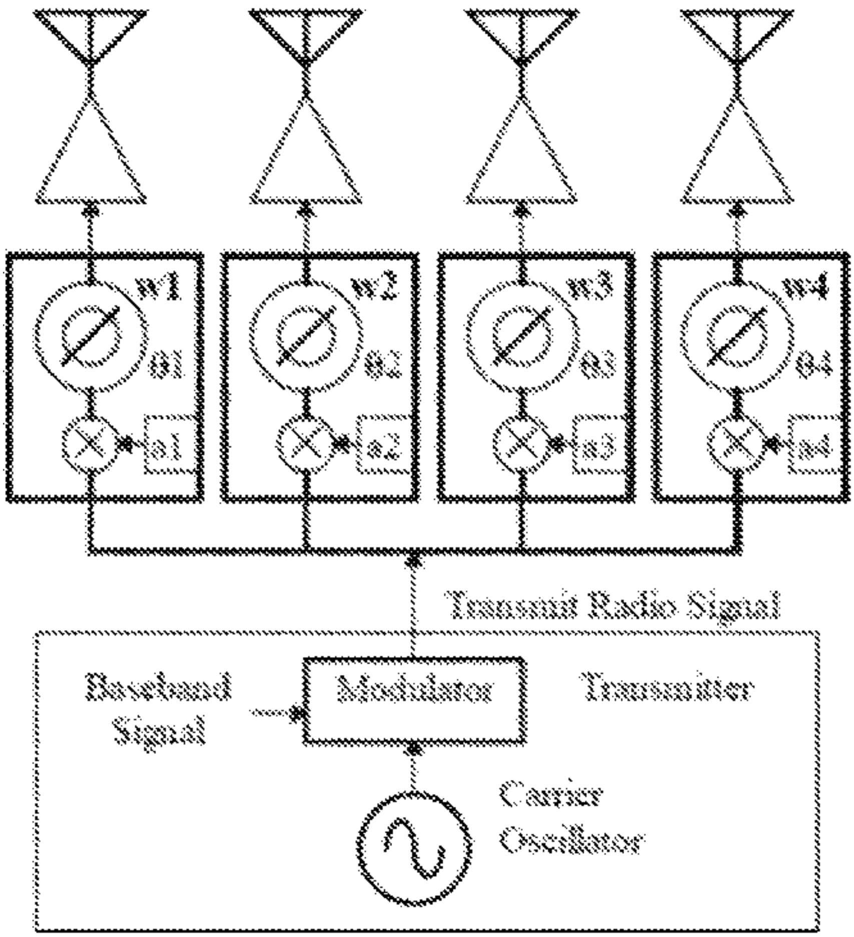
This patent document is owned by Ericsson, the world's leading developer and manufacturer of telecommunication equipment for mobile communication networks. The above technical solution WO2017/196244 is a part of the US20170331670 family, which has a wide geographical coverage in more than 20 countries. In Russia, two patents belonging to this family, RU2699387 *Optimization of rest mode measurements*, and RU2693848 *Network architecture, methods and arrangements for a wireless network* have been granted, while one application, RU2019118801 *Network architecture, methods and arrangements for a wireless network* has been filed, but the patent has not been granted yet for this application. We did not find any Russian application that would be directly related to the uplink beam steering procedures. The family has a large number of taforward citations, among which there are also cases of self-citation. Besides, the family has a high originality index of technical solutions.

The patent document deals with the uplink beam steering, which is one of the key technologies for 5G mobile communication networks, providing a higher energy and bandwidth efficiency as compared to prior generation networks. This technology enables forming the main beam of a certain width from the subscriber's device and maximizing its amplification in the required direction.

The required beam is formed from an antenna array by controlling the phase and amplitude of signals emitted by its elements.

Example of forming a transmission beam with four antenna elements

Figure 69



The narrow beam forming technology provides the following advantages as compared to the use of omnidirectional antennas:

– increase the communication range between the user equipment and the base station by concentrating the radio emission in a narrow direction;

- increase the uplink data rate by reducing multipathing on the side of the base station receiver while reducing the level of interference between user equipment devices.

The disadvantage of using the beam forming technology includes higher power consumption by the user equipment, because each separate transmitting circuit in the beam forming device contains a separate amplifier, as well as additional analogue components that consume additional energy.

The patent document describes embodiments of the beam forming arrangement in the user equipment, mitigating the above advantage of this technology.

It is also proposed to manage the number of active transmitting elements of the user equipment's antenna depending on the required signal strength at the input of the base station receiver and based on the estimation of signal propagation losses in the radio channel. This approach allows minimizing the number of antenna elements involved in the transmission of the signal and thereby minimizing energy consumption by the subscriber's device while maintaining the required signal level. The required signal strength at the input of the base station receiver, in its turn, can be determined based on the required uplink data rate.

The patent document also includes a rather general description of Ericsson's invention and actually protects the idea of the uplink beam steering in any wireless user equipment based on estimating the require signal strength at the receiver's input and estimating signal propagation losses in the radio channel.

This patent document may restrict developers of user equipment in using the uplink beam forming technology, which is important for LTE-Advanced Pro, 5G, and 6G devices.

Apparatus and method for interference reduction utilizing thin control

Patent owner: Qualcomm

Basic publication of the family: WO2015/179134 (A1)

Application filing date: November 5, 2014

Described publication of the family: RU2016144752 (A)

Application filing date: May 7, 2015

This patent document is held by Qualcomm, one of the world's largest wireless communication and chip development and research companies. This technical solution has a wide geographical coverage, represented by more than 40 national patent offices, with patents granted in most of the relevant countries. Multiple PCT applications as well as EPO applications are used to implement geographical expansion strategies. Through one of such PCT procedures, an application was filed in Russia, under which the patent RU2676873 was obtained. A large number of patents granted and an immense number of publications were used as the principal metrics to establish that this family has a high level of strength.

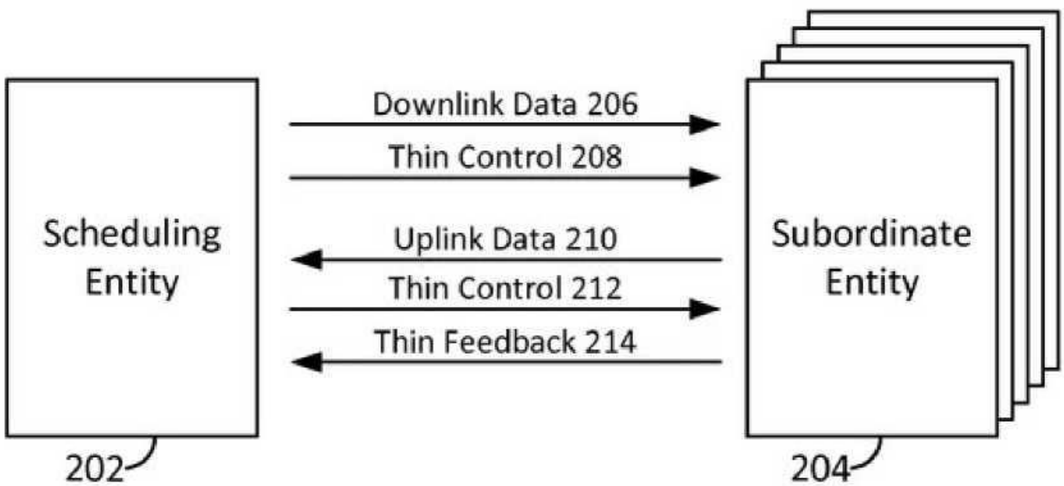
Furthermore, the relevant technical solution has a high originality index, which is due to a large number of different solutions from other leading companies in the cited prior art.

The patent document addresses methods for creating 5G devices and using a mechanism for thin control of data exchange with wireless devices, which enables a reduction in mutual interference experienced by the user.

The document also describes approaches to flexible control of data exchange with a wireless device that allows the use of different frequency and time signal structures depending on the needs of applications and user devices. The use of different structures of frequency and time resources available in a 5G radio interface provides a wide range of opportunities for flexible network configuration when providing different services.

The use of different transmission time intervals and their different combinations, including integration of short transmissions into long transmissions, is ensured by a thin channel structure in which the control channel can carry information about usage planning, allocation of channel resources, etc. to inform the receiving devices in order to take appropriate measures to reduce interference.

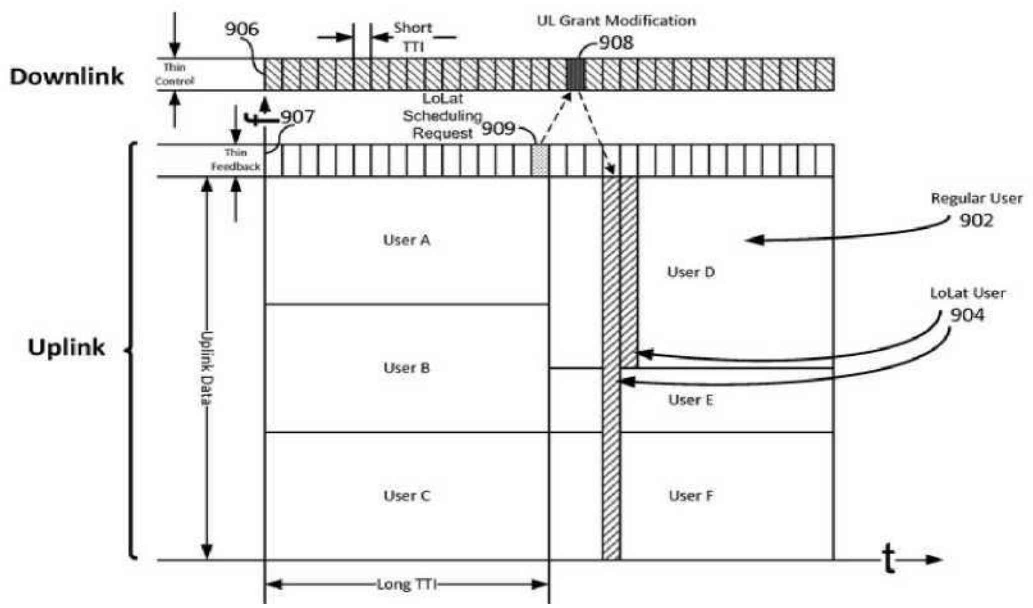
Figure 70 **A block diagram illustrating an example of a planning object that communicates with one or more subordinate objects (5G wireless devices)**



A thin control channel (and/or thin feedback channel) provides an adaptive mechanism that allows the transmitting device to adapt data transmission time intervals in a more dynamic manner.

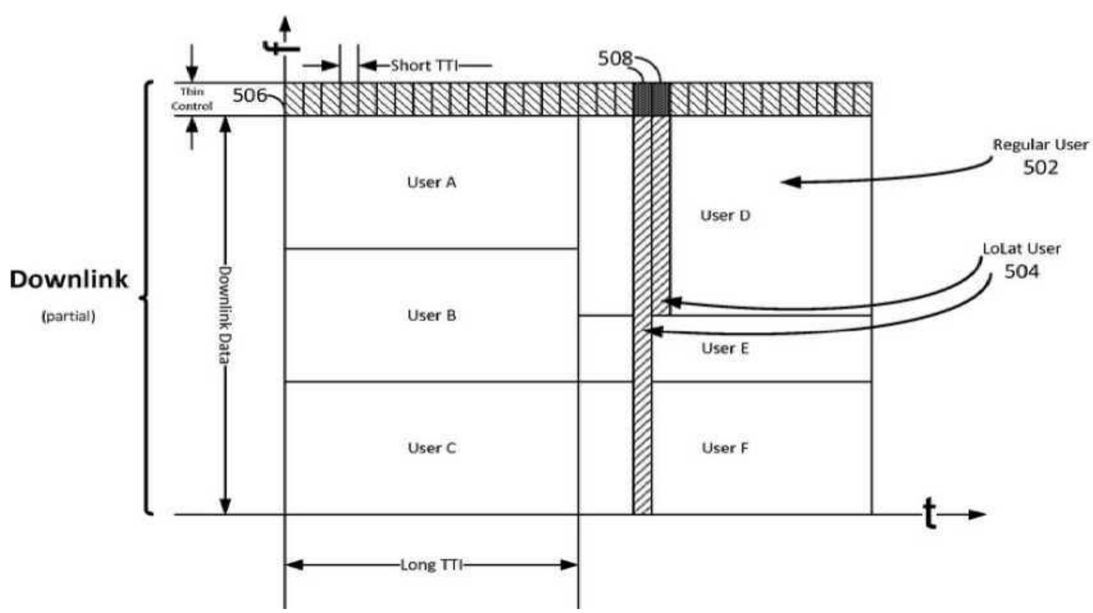
Flow chart illustrating a downlink to the user and its multiplexing using a thin channel.

Figure 71



Flow chart illustrating an uplink from the user and its multiplexing using a thin control channel.

Figure 72



The solution proposed by the company was included in the specifications of 3GPP's Release 15 for the NR radio interface of 5G systems. Accordingly, this patent may restrict designers of products for 5G radio access networks and next generations in using interference reduction mechanisms using a precision control mechanism.

Backhaul Network

Initial access and radio resource management for integrated access and backhaul (IAB) wireless networks.

Patent holder AT&T

Basic publication of the family: US20180092139 (A1)

Application filing date: February 2, 2017

Described publication of the family: US20190141762 (A1)

Application filing date: April 5, 2018

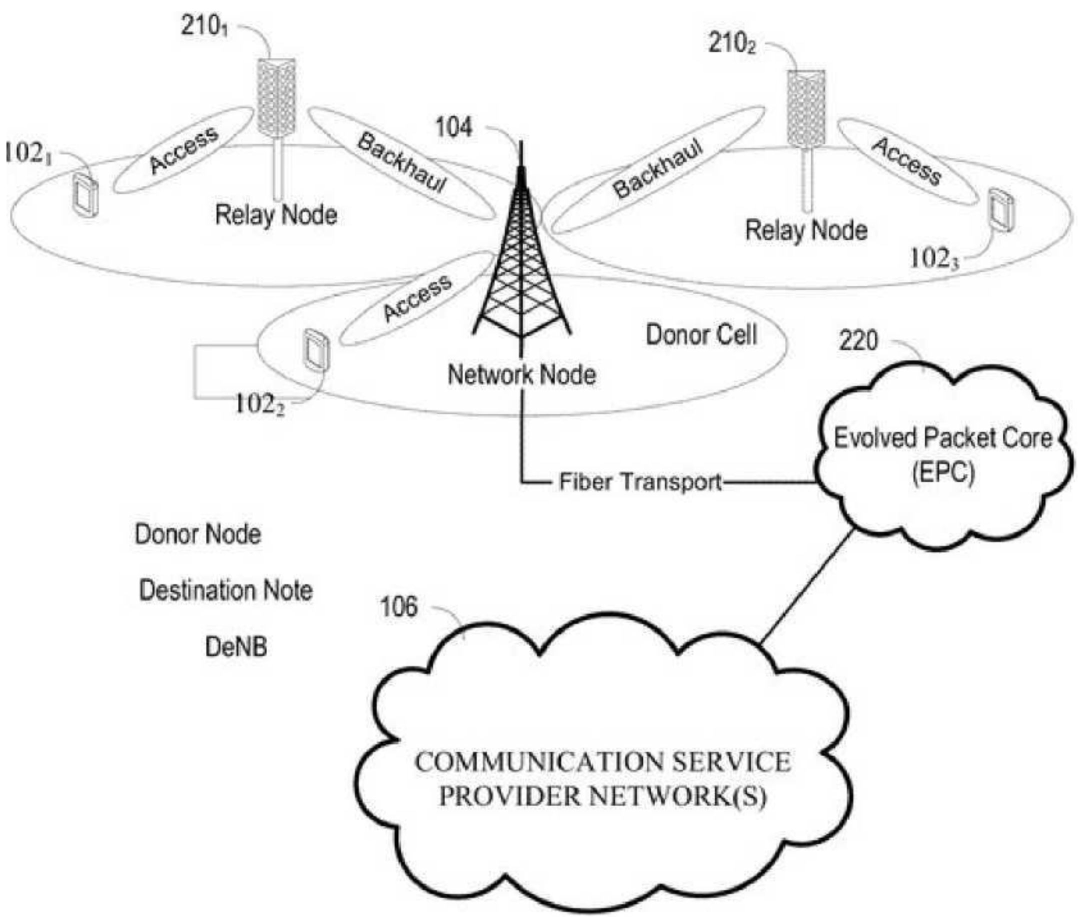
AT&T, one of the world's largest telecommunications companies, is the owner of this patent. So far, the above technical solution has been granted a patent only in the USA. PCT applications were filed through the international patenting procedure in South Korea, China, Japan, and India, as well as to the European Patent Office to obtain protection in European countries. This patent has not registered in Russia. No similar patents were registered in Russia, either.

The family contains more than 200 references to backward citations, which cover a wide list of IPC sections (technology themes) that were used to develop this solution. All this ensures a high originality index for this technical solution as compared to prior art. However, due to the small share of patents in the family and few forward citations, the strength of this technical solution is somewhat lower than that of other solutions in this segment.

The relevant patent document deals with the approaches to developing systems and methods to integrate wireless transport communication between relay transmission devices, as well as to organize access communication between user equipment and relay transmission devices, including in 5G networks or other next-generation networks.

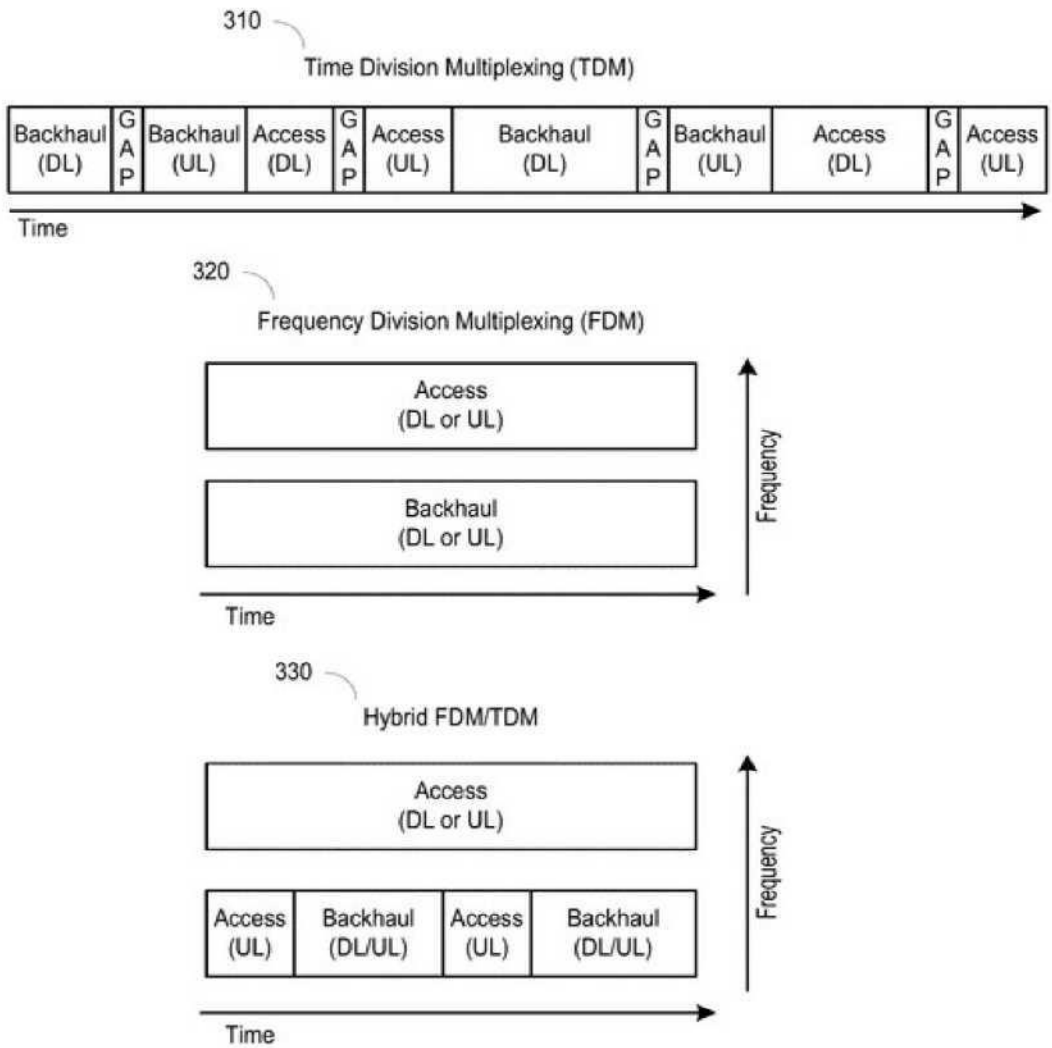
An embodiment of a wireless communication system

Figure 73



The figure illustrates a wireless communication system that has a network node device, a relay node device, and user equipment in accordance with various embodiments of the invention.

Figure 74 **An example of a multiplexing scheme**



The figure illustrates examples of different multiplexing schemes that can be used in line with different aspects and embodiments of this patent.

Method and apparatus for random access in communication systems with a large number of antennas.

Patent holder Samsung

Basic publication of the family: US20140177607 (A1)

Application filing date: December 18, 2013

Described publication of the family: US20140177607 (A1)

Application filing date: December 18, 2013

The family is owned by Samsung, one of the world's largest manufacturers of high-tech components, including full cycle production of integrated circuits, telecommunications equipment, household appliances, audio and video devices. This technical solution has a small geographical coverage. The initial application was filed with the US Patent Office, for which a patent was obtained in 2016. Simultaneously with the filing of the initial application, the PCT-patent mechanism was used to consolidate patent rights in China, South Korea, and Europe. In addition to the USA, a patent has recently been granted in China. The company has not brought this technical solution to Russia.

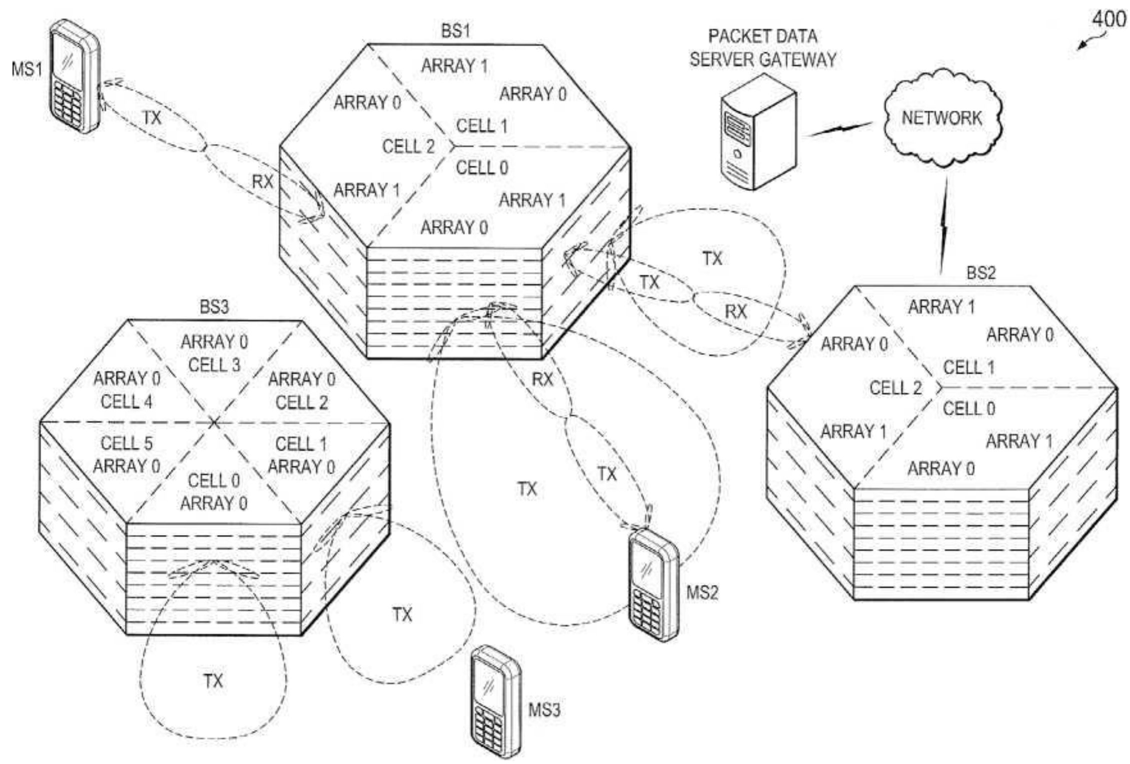
The family has a high strength index because of a large number of forward citations, which include Qualcomm, Ericsson, BBK Electronics, Huawei, Intel, and many other companies. This indicates that the technical solution is perceived as valuable by other 5G market participants. The originality and generality indexes of this invention are above average.

The relevant patent document discusses approaches that relate to the organization of methods for setting up a random access channel (RACH) in millimeter-wave mobile broadband systems, which are used by mobile phones to request their own SDCCH service channel. Among other things, the document describes in detail methods and tools to perform channel-adaptive random access in a wireless network with a large number of antennas, which is extremely important in fifth-generation (5G) communication networks, in which the declared network bandwidth is 1,000 times greater than in previous generation networks.

These figures illustrate the advantages of this technical solution. In particular, a wireless communication system that has a network node device, a relay node device, and user equipment depending on the various applications of this patent.

Figure 75

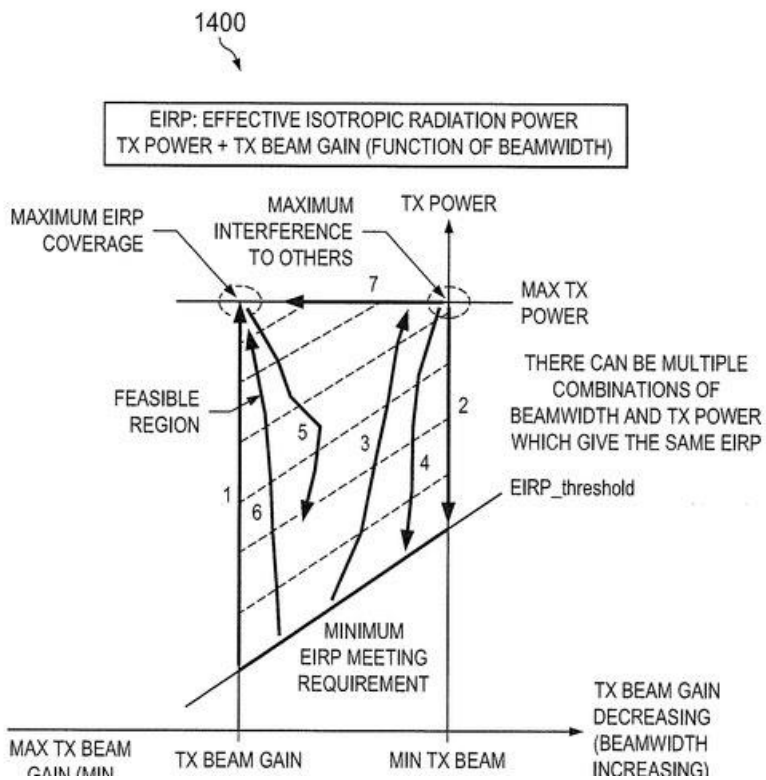
Implementation of a wireless communication system in line with a relevant embodiment



As well as the routes along which the user equipment output control transmission signal passes depending on the various applications of this patent.

User equipment output control transmission signal routing

Figure 76



Virtualization and cloud infrastructure

System and method for virtualized functions in control and data planes

Patent holder: Huawei

Basic publication of the family: US20160353465 (A1)

Application filing date: May 31, 2016

Described publication of the family: US2016353367 (A1)

Application filing date: May 31, 2016

The owner of this patent document is Huawei, a leading global developer and manufacturer of telecommunications equipment, including network and user equipment for mobile networks. The technical solution has an average geographical coverage. Relevant patents are received in China, Japan, and the USA, as well as in European countries (Switzerland, Austria, and Germany). Applications are pending examination in India and Brazil. This patent has not been registered in Russia.

This family has a high strength index due to a large share of patents granted within the family. The family also has a large number of forward citations. At the same time, the originality and generality indexes of this technical solution are lower than other strong solutions within this segment. This suggests that the applicability and comprehensiveness of this solution are somewhat lower.

The patent document deals with the mobile network architecture based on slicing the network and network elements into network slices. This architecture enables setting up virtualized and independent logical networks on the same physical network infrastructure. Each network slice is an isolated end-to-end network tailored to fulfill diverse requirements requested by a particular group of user applications.

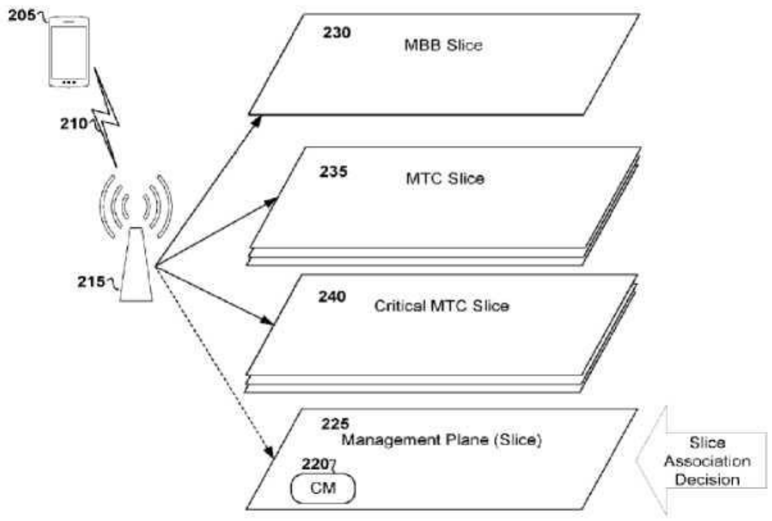
The patent protects various embodiments for creating, managing, and using virtual network slices in a mobile network.

The network architecture described in the patent plays a central role to support advanced 5G mobile networks that are designed to efficiently embrace a plethora of services with very different service level requirements. This architecture allows separating different types of traffic with different amounts of data transmission and with different requirements on network latencies, speed, security, and reliability of data transmission.

The realization of this service-oriented architecture leverages the concepts of software defined networking (SDN) and network function virtualization (NFV) that allow the implementation of flexible and scalable network slices on top of a physical network infrastructure.

Network slices on the control plane

Figure 77



Typical network slices of next-generation mobile networks are:

- A slice for providing mobile broadband (MBB) access services characterized by high requirements for data transmission speed. Examples of such services include high-definition video streaming, as well as uploading/downloading of large files.
- A slice to provide machine-type communication (MTC) services characterized by a small volume of transmitted data, high density of user terminals (Internet of Things devices) and stringent requirements for long autonomous operation. Examples of such services include automated energy consumption metering (electricity, heat, water, gas) and process monitoring (for example, monitoring of temperature and atmospheric air pollution).
- A slice to provide critical Machine Type Communication services characterized by stringent requirements on communication reliability and low latency of data transmission between terminal devices.

Examples of applications for these services include automated industrial system control and automated transport control, including unmanned vehicles.

Based on its business needs, a mobile operator, in addition to typical network slices, can also slice the network into additional slices, such as separate network slices for Mobile Virtual Network Operators (MVNO), which use its infrastructure to provide communication services under their own brands.

The patent describes the following aspects of network virtualization of mobile network functions:

- variants of mobile network architecture, which uses network slicing;
- network slice management options and procedures for creating new network slices;
- variants for implementing a management and orchestration (MANO) subsystem to maintain network slices;
- variants for creating a network slice for a user terminal during registration;
- variants for connecting the user terminal to a network slice, with the description of data flow diagrams;
- variants for managing the communication infrastructure control, which connects the infrastructure of different operators, supports multiple network slices, and is used by many operators to provide communication services;
- variants for managing the communication infrastructure with the joint use of the spectrum by mobile operators.

The mobile network architecture and approach to network slicing proposed by Huawei has been included in the specifications of 3GPP's Release 15 for 5G systems. Considering that the patent covers almost all elements of a 5G system, it will impose restrictions on developers and manufacturers of equipment and software for 5G networks.

It should also be noted that the invention described in this patent is of interest for developers of future mobile communication systems, such as 6G.

On-demand reconfigurable control plane architecture (ORCA) integrating millimeter-wave small cell and microwave macro cell

Patent holder: Mediatek

Basic publication of the family: WO2016/169058 (A1)

Application filing date: April 24, 2015

Described publication of the family: US20170374703 (A1)

Application filing date: September 7, 2017

The owner of this patent document is Mediatek, a large chip manufacturer. The technical solution is patented in Switzerland, Germany, the United Kingdom, and Ireland through the regional patenting procedure of the EPO, as well as in the USA. Relevant applications are pending examinations at the patent offices of Brazil and China. No applications have been filed in Russia.

The technical solution has a high generality index, as the patent is cited by technical solutions covering a wide list of IPC sections. This demonstrates that the solution is applicable in various technology segments.

The patent document addresses approaches to building the control plane architecture to effectively integrate small cells (SC) within a radio frequency range above 10 GHz and macro base stations (MBS) within a range below 6 GHz.

According to the requirements for 5G networks, they must support the operation of user devices and applications with different service level requirements:

- applications that require high data speeds;
- applications that require low power consumption of user devices;

- applications that require the ability to support a large number of user devices located in high-density areas;
- applications that require low network latency.

The use of different structure of frequency and time resources available in a 5G radio interface unlocks a wide range of opportunities for flexible network configuration when providing various services. For example, applications critical to latency levels should use subcarriers with a broad spectrum and shorter symbol rate, while applications requiring low power consumption of user devices should use “narrower” subcarriers.

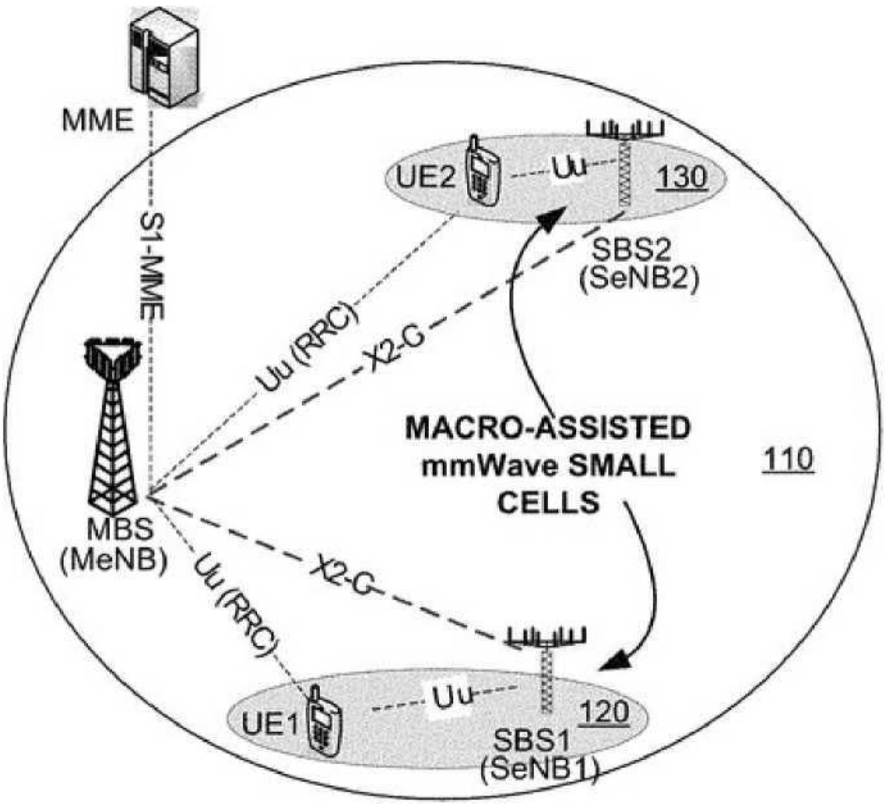
The proposed architecture keeps the basic hardware unchanged overlaying several logical superstructures through on-demand software configuration. On-demand reconfigurable architecture is designed to meet the need for a dense deployment of small cells and a large concentration of subscribers to provide gigabit speeds. Despite the fact that small cells in the radio frequency range above 10 GHz can operate independently, the complementary use of layers of macro base stations and small cells offers the following advantages:

- more reliable mobility support;
- resilience to signal interruptions in the radio frequency range above 10 GHz;
- increased bandwidth capacity of the small cell and increased coverage area through control channel transmission using macro base stations within the range below 6 GHz.

The proposed method is based on the use of additional software, which supports a specific use scenario based on the density of base stations, the level of mobility of subscriber terminals, as well as application scenarios and performance requirements. Such criteria help evaluate the system’s configurable architecture on a case by case basis.

Existing LTE HetNet Dual Connectivity architecture

Figure 78

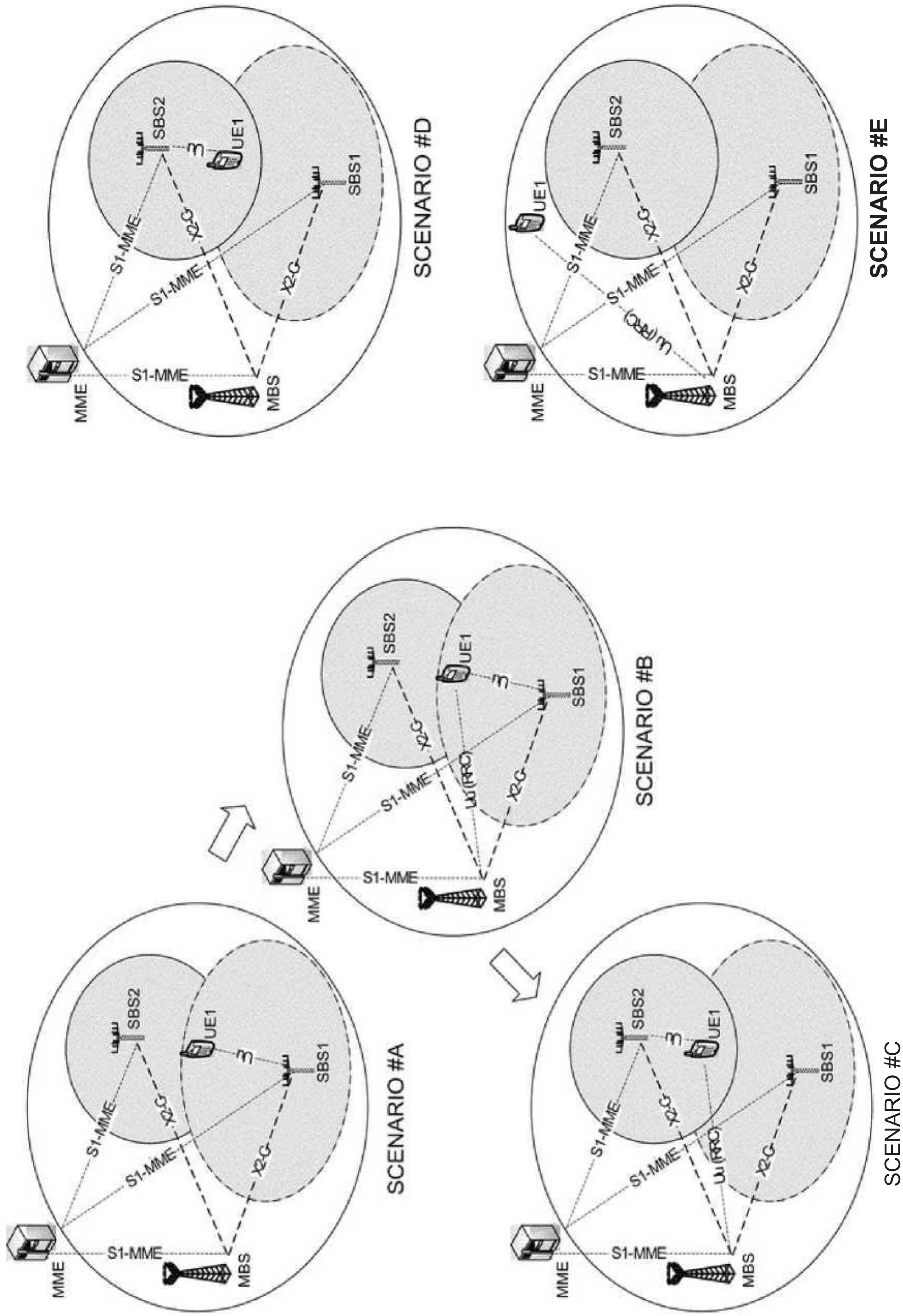


Examples of such scripts can include:

- transfer of the control channel from MBS to SC for densely placed low-mobility user equipment;
- transfer of the control channel using SC for highly mobile user equipment;
- separation of the management functions between MBS and SC (dual connection) for low-mobility user equipment.

Use scenarios for reconfigurable architecture

Figure 79



The solution offered by the company is not included in the specifications of 3GPP's Release 15 for the 5G NR radio interface. However, in future this patent may restrict developers of products for 5G radio access networks and next-generation equipment in using the on-demand reconfigurable control plane architecture.

5G Core

Method and apparatus for performing access barring check

Patent holder: LG Electronics

Basic publication of the family: Continuation in part of the international application WO2018/236196 (A1)

Application filing date: June 25, 2018

Described publication of the family: US2019159108 (A1)

Application filing date: January 18, 2019

This patent is owned by South Korean LG Electronics, the world's largest manufacturer of consumer electronics and home appliances, including consumer mobile devices (smartphones and tablets). The relevant technical solution has been patented only in South Korea. Relevant PCT applications are pending examination in Australia, Brazil, Canada, Chile, China, Mexico, Singapore, Vietnam, and the Philippines. No patents have been granted for this technical solution in Russia.

Despite the low citation rates, geographical coverage and share of patents in the family, the technical solution has a very high level of flexibility. These findings are corroborated by the fact that the solution is cited by companies from different industries that are not directly related to 5G technologies.

The patent document focuses on managing network access barring for different classes of services and classes of devices with different access priorities. Access barring is necessary to be able to bar network access for low-priority services and provide the necessary level of service for high-priority services. For example, calling emergency services should have a higher priority than regular services such as internet access and regular voice calling, or, for example, regular services may have a higher priority than data services for Internet of Things devices.

In case of network or base station overload, the base station can transmit information about barred network access for a certain class of devices or a certain type of services as part of broadcast system information, such as System Information Block (SIB).

The classes of devices can be written in the USIM card of the user terminal. The user terminal checks whether it is denied access to the cell, using the barring parameter obtained as part of the SIB information, and information about the class of device recorded in the USIM card, and does not attempt to access the network if access to this class of devices is barred.

Before connecting to the network to obtain a certain type of service (voice calls, data transmission, video calls, etc.), the user terminal can also verify whether access to the network for the requested service based on data received as part of the SIB information.

Access barring can be checked for any services except calls to emergency services.

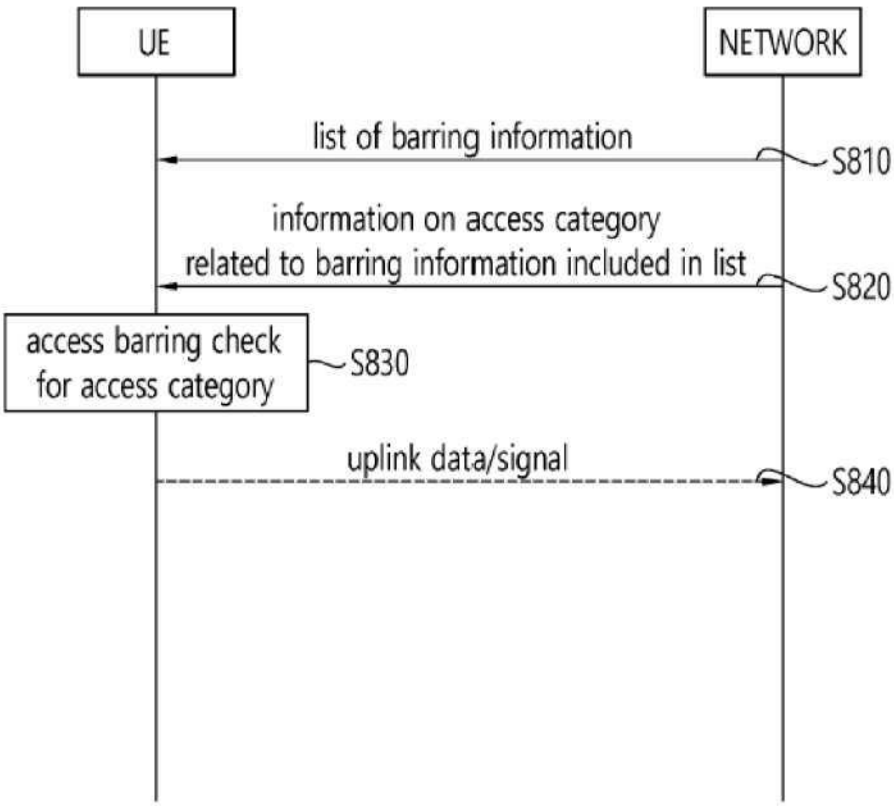
When applying the principles of network slicing to a wireless network, each network slice can be assigned a specific type of service. In such case, access barring can also be checked when trying to connect the user terminal to a specific slice. Information about existing network slices is transmitted by the network to the user device during registration.

The application describes a method for user equipment to check whether access to a wireless system by the user device is barred, which includes:

- receipt by the user terminal of the list of barring information from the network, which contains the barring parameters and duration of the barring;
- receipt by the user terminal of information about the class of the device or type of service, checking of the access barring for a certain class of devices or type of service;
- connection to the network and data transmission if access is allowed.

Access management procedure based on an access barring check for access category

Figure 80



Considering that the access barring check applies to both user equipment functions, and to radio access network functions, as well as to core network functions, this patent may restrict product developers of all 5G system subsystems.

It should also be highlighted that although the use of the patented method is demonstrated through the example of a 5G system, this method can be used in various wireless communication settings, including GSM, UMTS, EPS (LTE/LTE-Advanced), Wi-Fi, WiMAX, and next-generation mobile communication systems.

Network node, wireless device, methods therein, for sending and detecting, respectively, synchronization signal and an associated information

Patent holder: Ericsson

Basic publication of the family: WO2015/080646 (A1)

Application filing date: October 3, 2014

Described publication of the family: RU2017144638 (A)

Application filing date: October 3, 2014

This family is owned by Swedish Ericsson, one of the largest manufacturers of telecommunications equipment. The family has a rather large geographical coverage. The basic publication of the family is an international application filed under the PCT procedure, after which relevant applications were filed as part of national patenting phases in Canada, Australia, Singapore, Israel, China, South Korea, the USA, Japan, Russia, India, and were filed with the EPO. Two independent applications have also been filed in Russia and the USA. Relevant patents were received in Australia, Canada, China, Israel, Japan, Russia, and the USA.

This technical solution belongs to SEP patents and has a high strength index due to its wide geographical coverage ensured by granted patents as well as a large number of citing companies, including mainly Chinese companies (Huawei, ZTE, BBK Electronics, etc.). The originality and generality indexes of this invention are above average.

The patent covers approaches and methods for sending the first synchronization signal and the associated information message to a wireless device to synchronize the wireless device with the network node and accelerate the detection of the first synchronization signal and the associated information message.

The objective of the approaches and methods outlined in this patent document for sending the first synchronization signal to a wireless device consists in improving the performance of the wireless network (including next-generation 5G networks) by providing improved approaches and methods for sending synchronization signals.

Existing methods for transmitting synchronization signals from a network node to a wireless device are designed to cover the global zone with lower non-continuous carrier frequencies than those that are expected to be used in next-generation systems. The current methods may lead to numerous synchronization failures when used in communication systems that use high frequency carriers, such as those planned to be used in next-generation 5G networks. The relevant approaches and methods for sending the first synchronization signal and the associated information message to a wireless device are designed to solve the above problem.

Below is a description of one of the methods to send the first synchronization signal and the associated information message to the wireless device to synchronize the wireless device with the network node.

Example of sending the first synchronization signal

Figure 81

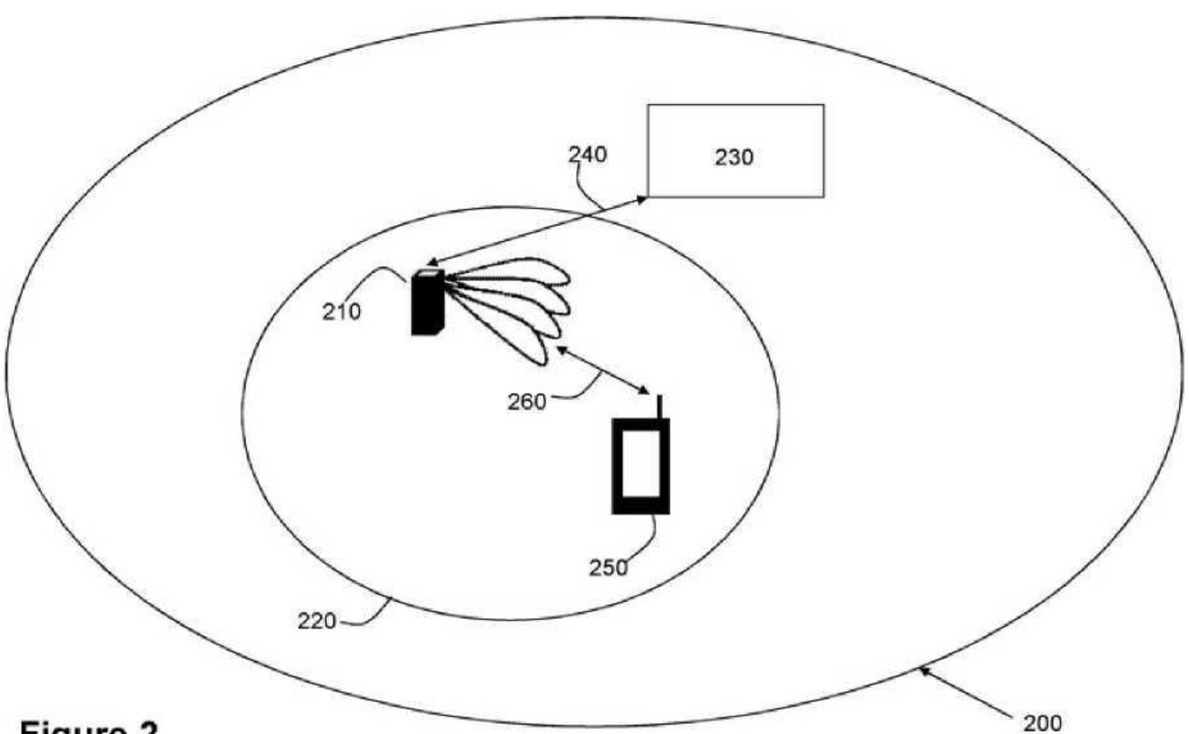


Figure 2

The network node and the wireless device operate in a common wireless network. The network node sends the first synchronization signal of N OFDM characters in the subframe, at least once per time and frequency position in each of the N OFDM characters. Along with each first synchronization signal sent, the network node sends a relevant information message into a predetermined time and frequency position in the OFDM symbol. The predetermined time and frequency position refers to the time and frequency position of the first synchronization signal. The related information message is related to the first synchronization signal.

Functional Components for Network Management

Systems and Methods for SDT to Interact with NFV and SDN

Patent holder Huawei

Basic publication of the family: US20160212017 (A1)

Application filing date: January 20, 2016

Described publication of the family: US20160212017 (A1)

Application filing date: January 20, 2016

This family is owned by Chinese Huawei, one of the largest telecom equipment manufacturers. The basic application of the family was filed with the US Patent Office and received a patent for the invention in 2019. The family also includes a PCT application, which extends the invention's geographical coverage to China, South Korea, Brazil, Japan, India, and Vietnam. Relevant patents were granted under the regional patenting procedure through the EPO in the United Kingdom, Switzerland, Germany, and Ireland. This technical solution is not protected in Russia.

Despite a low originality and generality index, this technical solution involves shark companies, that is, companies that have more than 30% of forward citations of the technical solution.

These companies include AT&T and Cisco (a transnational company, which develops and sells network equipment designed mainly for large organizations and telecommunications companies). This situation indicates that this technical solution is of value for these companies. This technical solution is also often cited by companies that operate beyond the 5G segment, which may indicate that the solution is highly important for related industries.

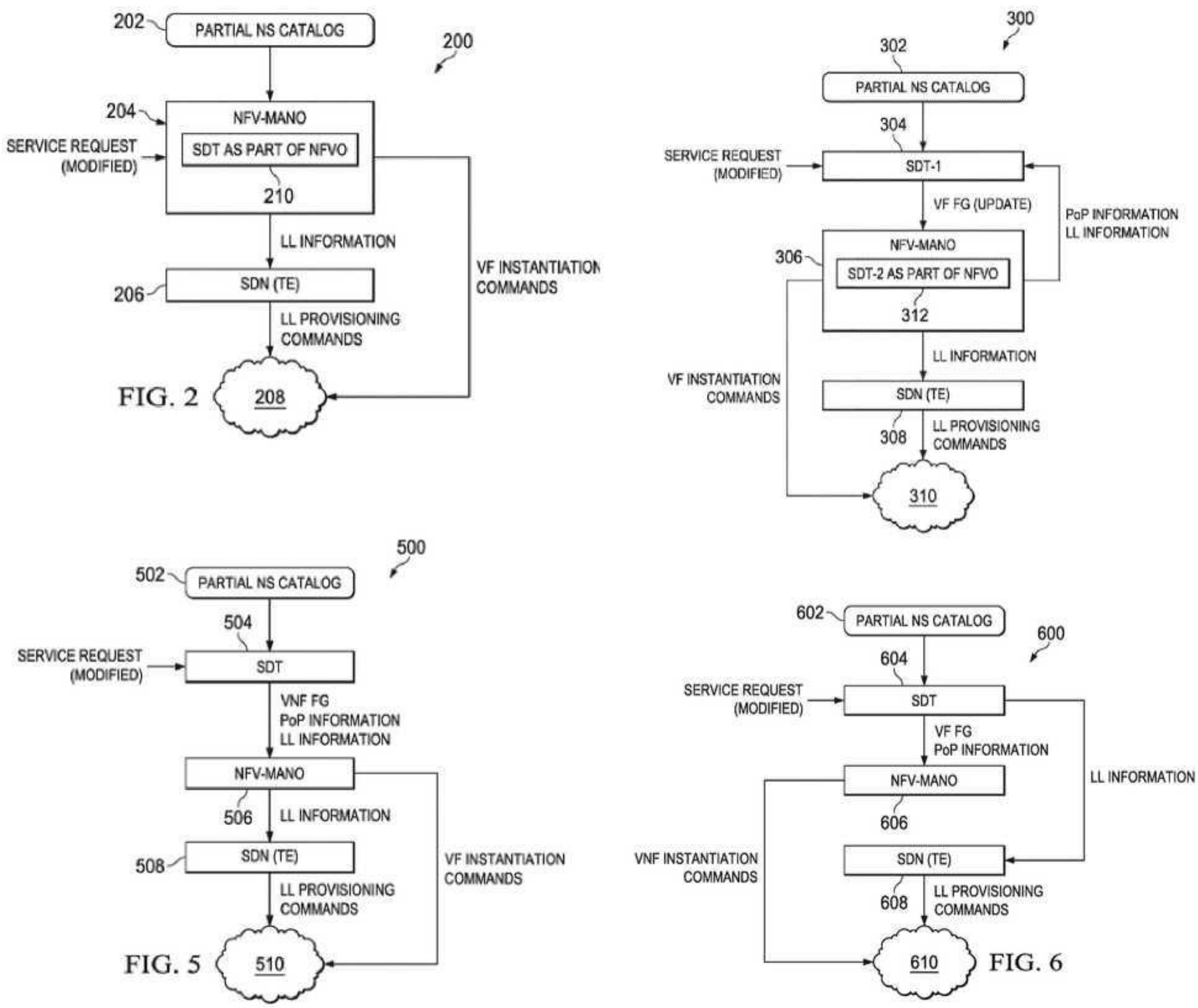
The patent document addresses approaches to the use of software-defined topology (SDT), and ways of its interaction with network function virtualization (NFV) and software-defined network (SDN).

The use of SDN/NFV technologies has the following advantages:

- high scalability of the network, flexible centralized management of the network and network resources;
- reduced capital expenditures for purchasing equipment; reduced operating costs through the use of virtual network functions;
- improved energy efficiency through the use of high-performance data center servers;
- reduced time for launching new network services;
- possibility to use equipment of different vendors;
- improved security;
- the use of cloud platforms in data centers in the operator's periphery to improve service quality.

The virtual network (NFV) infrastructure and software-defined network (SDN) infrastructure create the conditions for accelerated implementation of new services and new network protocols and functionality, and provide an opportunity for integrating innovative applications of third-party developers.

Figure 82 **SDT implementation options outside NFVO**



The proposed methods describe the embodiment of software-defined topology (SDT) both as part of a Network Function Virtualization Orchestrator (NFVO), as part of an ETSI-standardized MANO management and orchestration system, and outside of NFVO (NVF-MANO). The document also describes an embodiment featuring distributed software-defined topology and an embodiment featuring its implementation as a separate controller.

In fact, software-defined topology (SDT) allows forming standalone logical network topologies for each service (virtual functional points of presence (network addresses and virtual functions), logical links between service traffic sources, and corresponding resource requirements).

The solution proposed by the company does not involve implementation of 3GPP specifications or ETSI standards. In the future, however, this patent may restrict software developers in designing solutions that are aimed at organizing on-demand reconfigurable control architecture for network function virtualization (NFV) and software-defined networking (SDN).

Methods and system description for performing network slicing in a radio access network.

Patent holder: Huawei

Basic publication of the family: US20170164349 (A1)

Application filing date: November 18, 2016

Described publication of the family: US20170164349 (A1)

Application filing date: November 18, 2016

This family is owned by Chinese Huawei, one of the largest telecom equipment manufacturers. The basic application of the family is filed with the US Patent Office, for which the patent was granted. The family also has four PCT applications, which expand the geographical coverage to China, Japan, South Korea, India, Brazil, and European countries (Germany, Austria, Switzerland, the United Kingdom, and Ireland).

The family has high strength indexes due to a large number of jurisdictions with granted patents. In addition, the solution contains an approximately equal number of direct and backward citations. Moreover, citations of prior art include both Huawei's proprietary solutions, and the solutions of many leading companies in the 5G segment, while forward citations include AT&T acting as a predator, accounting for about 15% of forward citations. This demonstrates that this technical solution is of value for this company.

The patent addresses approaches to the implementation of methods for selecting virtual networks or slices in a radio access network (RAN).

At the same time, the implementation of virtual network or slice functionality related to 5G Core is proposed to be viewed as a separate entity outside this solution.

According to the requirements for 5G networks, the network slicing functionality within a single or combined 5G networks implies the division of a physical 5G architecture into a plurality of virtual networks or slices. Each network slice includes management level functions, user traffic level functions, and a radio access network (5G-NR or non-3GPP networks). Based on the NFV/SDN architecture, each slice has its own characteristics and aims to solve a certain business problem.

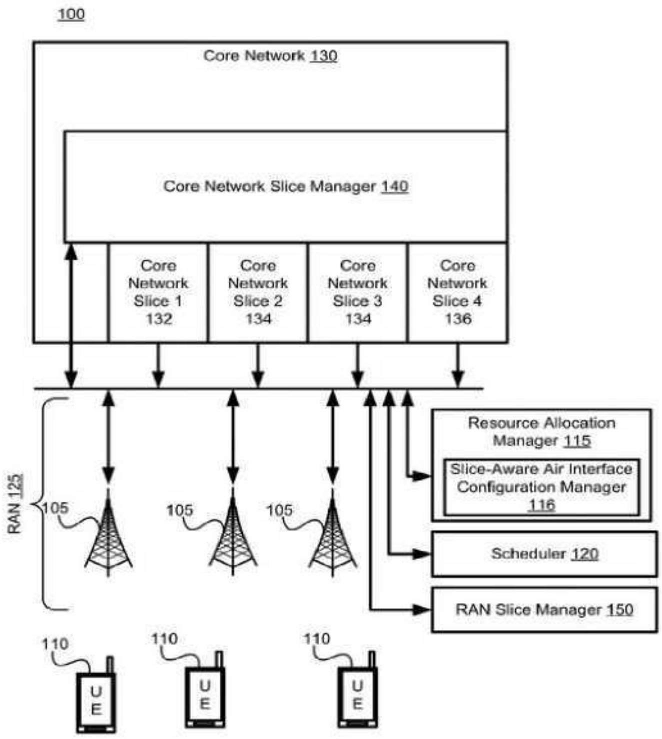
Each manufacturer or operator can define additional network slices, for example, a dedicated network slice for critical communications, intra-corporate communications, etc. A specific user equipment (UE) can be served simultaneously by one or more network slices (eight at the utmost).

The proposed methods describe the implementation of multiple network slices as part of one or more 5G networks in different ranges, exclusively with regard to the radio access network because the used resources of 5G Core are static unlike radio access resources, which are dynamically changing depending on the location of the user and the time of day.

The solution actually describes options for using the slice manager for different radio access network configurations (modulation, numerology, bands, etc.), implementing resource backup, and interaction with the 5GC (5G Core) network slice manager.

Slice manager for different radio access network configurations

Figure 83



Implementation of traffic routing from the 5G Core slice to the radio access network (RAN) slice

Figure 84

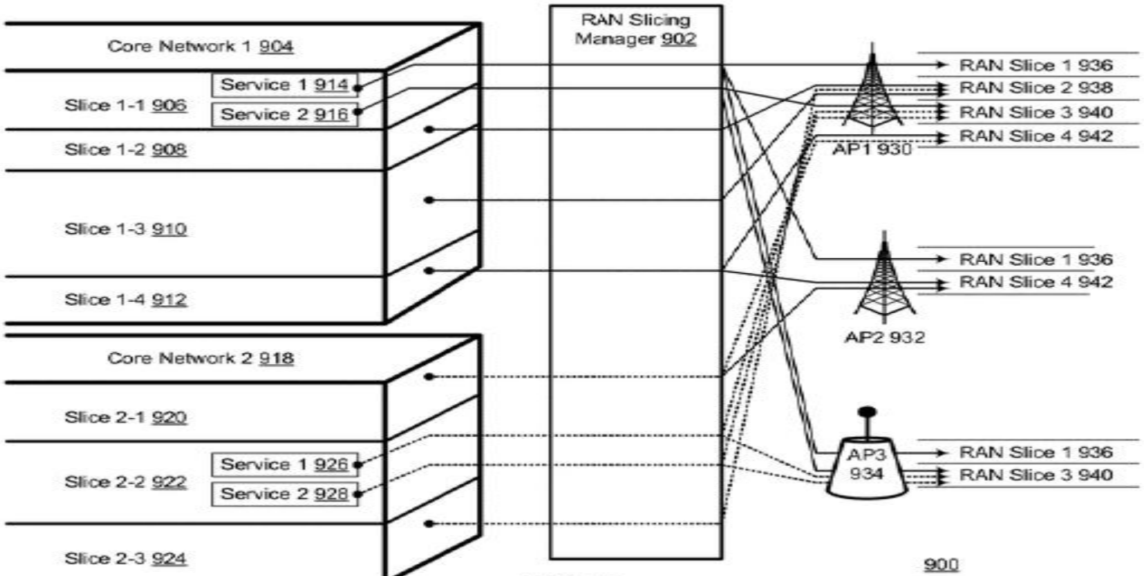


FIG. 9

The solution proposed by the company does not involve implementation of 3GPP specifications or ETSI standards. However, in the future, this patent may restrict developers or service providers in implementing the slice manager functionality for different radio access network configurations.

Network Services and Digital Platforms

Device, system and method employing a unified flexible 5G air interface

Patent holder Apple, Intel

Basic publication of the family: WO2016/130175 (A1)

Application filing date: August 11, 2015

Described publication of the family: US2018007673 (A1)

Application filing date: August 11, 2015

This patent is owned by Intel (the world's largest manufacturer of electronic devices and computer components, including microprocessors and chipsets) and Apple (the largest manufacturer of personal and tablet computers, audio players, phones, and software). The patent for this technical solution has been granted only in the USA, with the application pending examination in China and at the EPO. This patent has not been registered in Russia, but a similar patent, RU2673710, has been registered by Huawei.

The family has an average patent asset index, which translates into an average strength of the technical solution. Interestingly enough, this family involves cooperation and joint development of two large companies, as well as a high percentage of citations from all 5G incumbents.

The patent document addresses approaches to the creation of a unified 5G radio access network based on a flexible radio interface allowing the use of different frequency and time structure of signals depending on requirements of applications and user equipment.

According to the requirements for 5G networks, they must support operation of user devices and applications with different requirements on the service level:

- applications that require high data speeds;
- applications that require low power consumption by user equipment;
- applications that require the ability to service a large number of user devices located in high-density areas;
- applications requiring low network latency.

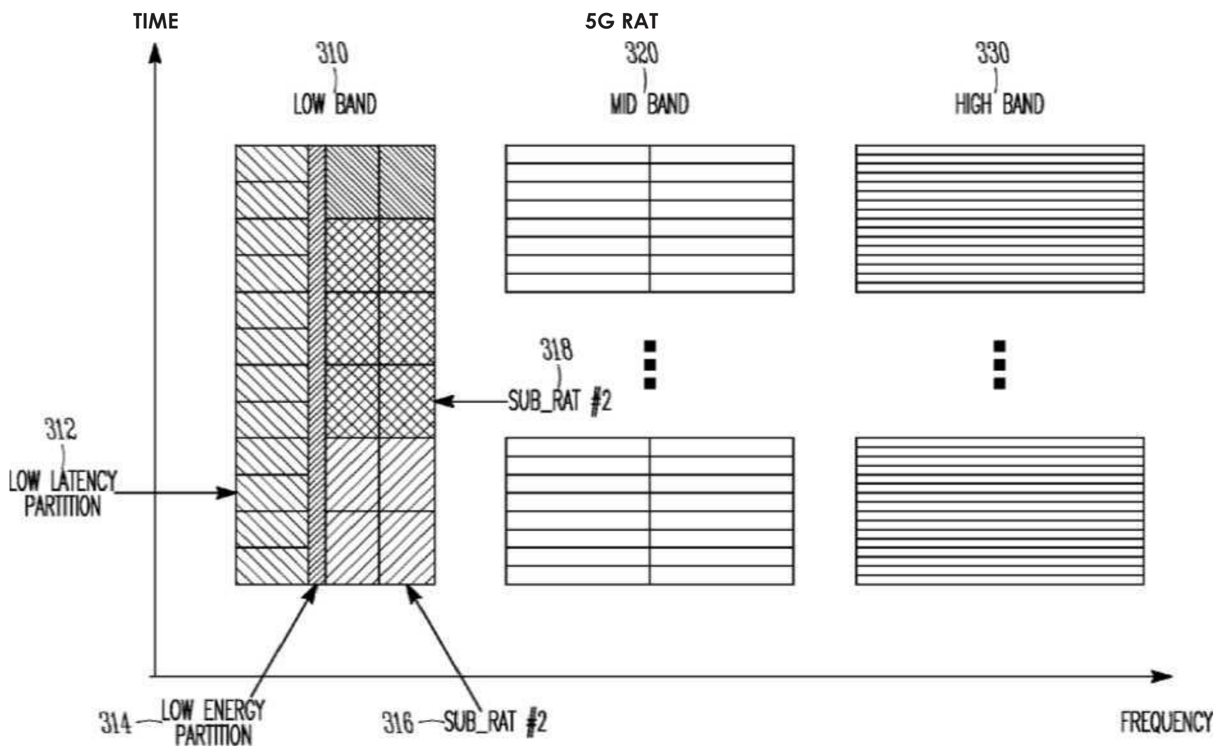
The use of different structures of frequency and time resources of the 5G radio interface provides a wide range of opportunities for flexible network configuration when providing different services. For example, applications critical to latency levels should use subcarriers with a broad spectrum and shorter symbol rate, while applications requiring low power consumption of user equipment should use narrower subcarriers.

5G networks can also use a wide range of frequency bands from 450–6,000 MHz and 24,250–52,600 MHz, which can also be selected depending on the requirements of applications. For example, applications requiring high bandwidth can use high frequencies that support a large channel bandwidth.

The patent’s authors propose the use a flexible set-up of the spacing between subcarrier frequencies and the symbol rate (i.e., configurable numerology) in 5G networks. The use of different numerologies is possible both in different frequency bands and in the same frequency band.

The 5G radio interface can combine different frequency bands and subbands with different numerology.

Figure 85 **5G Flexible Radio Access Technology (FRAT) Implementation Scheme**



For compatibility with existing LTE/LTE-Advanced mobile communication systems, it is proposed to use the same values as in LTE/LTE-Advanced systems (Δf=15 kHz, T=66.7 μs) as the base values of the spacing between subcarriers and the symbol rate, respectively. Other values of the spacing between the subcarriers and the symbol rate are selected as a multiple of the base values.

$\Delta fi = K*\Delta f$ and $Ti = (1/K)*T$,

where K is an integer. The type of numerology in this case can be defined or configured in blocks of broadcast system information such as Master Information Block (MIB), System Information Block (SIB) or special RRC signaling for the user equipment.

The patent provides examples of different numerologies for the 5G radio interface (Table 10–12).

First example of the numerology of the 5G radio interface

Table 10

Frequency range	Subcarrier frequency spacing	Transmission time interval	Donwlink signal	Uplink signal
< 3 GHz (low-power devices or IoT)	1,5 kHz	10 ms	OFDM	SC-FDMA
< 3 GHz	15 kHz	1 ms	OFDM	SC-FDMA
3 - 6 GHz	75 kHz	0.2 ms	UW-OFDM	UW-DFT-s-OFDM
6 - 30 GHz	480 kHz	0.1 ms	UW-OFDM	UW-DFT-s-OFDM
> 30 GHz	1.5 MHz	0.1 ms	DFT-s-OFDM	DFT-s-OFDM

A second example of a 5G radio interface numerology

Table 11

Range frequencies	Spacing subcarrier frequencies	Time interval transmission	Signal down link	Signal up link
< 3 GHz (low-power devices or IoT)	1,5 kHz	10 ms	UW-OFDM	UW-OFDM
< 3 GHz	15 kHz	1 ms	UW-OFDM	UW-OFDM
3 - 6 GHz	75 kHz	0.2 ms	UW-OFDM	UW-OFDM
6 - 30 GHz	480 kHz	0.1 ms	UW-DFT-s-OFDM	UW-DFT-s-OFDM
> 30 GHz	1.5 MHz	0.1 ms	OFDM	OFDM

A third example of a 5G radio interface numerology

Table 12

Range frequencies	Spacing subcarrier frequencies	Time interval transmission	Signal up link	Signal up link
< 3 GHz (low-power devices or IoT)	1,5 kHz	10 ms	OFDM	OFDM
< 3 GHz	15 kHz	1 ms	OFDM	OFDM
3 - 6 GHz	75 kHz	0.2 ms	OFDM	OFDM
6 - 30 GHz	480 kHz	0.1 ms	UW-DFT-s-OFDM	UW-DFT-s-OFDM
> 30 GHz	1.5 MHz	0.1 ms	UW-DFT-s-OFDM	UW-DFT-s-OFDM

The invention proposed by Intel was included in the specification of 3GPP's Release 15 for the NR radio interface of the 5G system. Accordingly, this patent can restrict developers of products for 5G radio access networks and next-generation equipment in using configurable radio interface numerology.

Systems and methods for multiple access with sparse code.

Patent holder: Huawei

Basic publication of the family: US20140140360 (A1)

Application filing date: December 28, 2012

Described publication of the family: RU2603280 (C1)

Application filing date: November 18, 2013

This patent is held by Huawei, the world's largest manufacturer of electronic devices and telecom components. The family has a basic publication in the United States, with the relevant filed back in 2012. This means that the company immediately entered the most competitive market with its solution.

Besides the USA, patents for this technical solution have been granted in Australia, Canada, China, Japan, South Korea, Russia, and Vietnam through the PCT international patenting procedure and through the EPO regional patenting procedure in Austria and Switzerland. Relevant applications are pending examination at the patent offices of Brazil, India, Singapore, and Indonesia. The family is an active family, with the last application filed in the USA in 2019. In Russia, a patent (RU2603280) was obtained through the PCT international patenting procedure in 2016.

The technical solution has high rates of forward citations, geographical coverage, and the share of patents in the family, which translates into a fairly high rate of strength. At the same time, more than 50% of its citations are self-citations, which contributes to mutual ties between technical solutions ensuring the company's wide technological coverage in the 5G segment.

According to the requirements for 5G networks, they must support the operation of user equipment and applications while also supporting a large number of user devices located in high-density areas.

The patent document discloses a sparse code multiple access (SCMA) encoding technology, through which binary data streams are encoded directly into multi-dimensional codewords. The SCMA encoding technologies described in the document circumvent quadrature amplitude modulation (QAM) symbol mapping when encoding binary data directly to multidimensional codewords, thereby improving encoding as compared to conventional CDMA encoding. The SCMA encoding technologies provide multiple access by assigning a different codebook for each multiplexed layer, as opposed to using a unique extension sequence (eg, LDS signatures, etc.), which is common in conventional CDMA encoding.

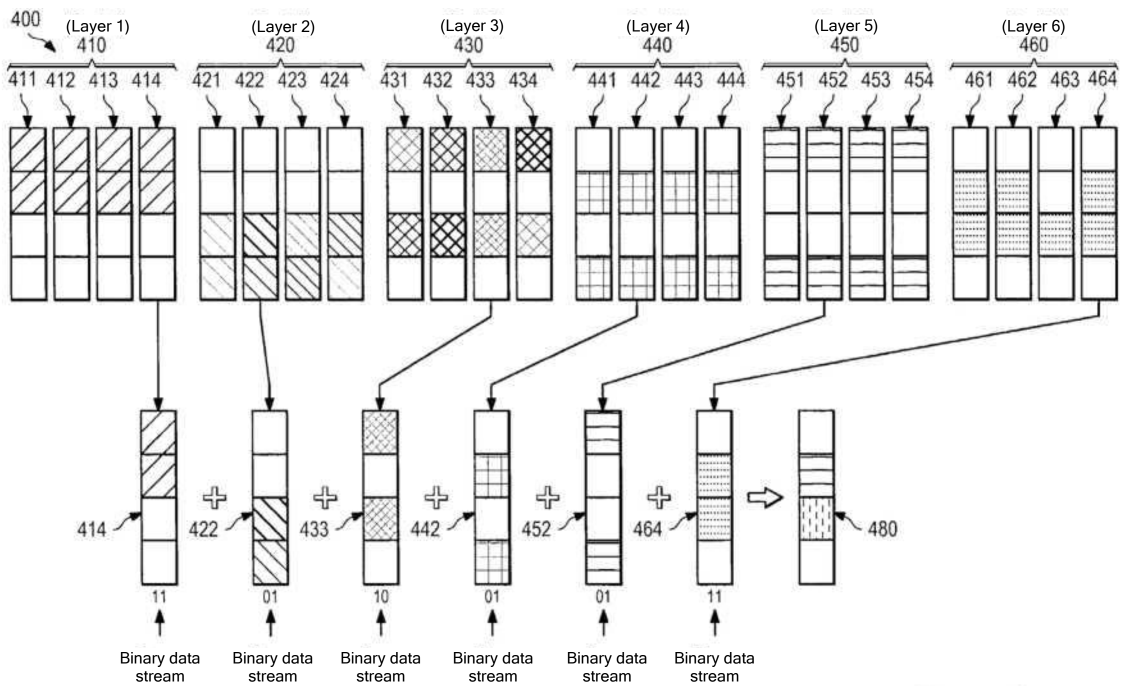
The patent provides for various embodiments of the invention:

- a data multiplexing method;
- a data receiving method;
- a method for designing the sparse code multiple access (SCMA) code.

Different embodiments of the invention realization, which describe systems and methods for *Sparse Code Multiple Access*, allowed the authors to claim in most cases that they achieved certain technical advantages, including the possibility to service an extremely large number of active users one 5G cell.

No delivery confirmation is required when using the *Sparse Code Multiple Access* technology to divide users. In this technology, bit streams of different users within the same spectrum are directly converted into a code word using what is known as codebook from a specific set. These codes are conventionally called quasi-orthogonal. They are quite numerous and have a two-dimensional structure. That is, the input signal is superimposed on the codebook after which the converted signal is sent to the radio interface. The signal is extracted on the receiving side also with the use of a codebook.

Figure 86 **SCMA encoding architecture**



ADDITIONAL ANALYSIS OF THE 6G TECHNOLOGY SEGMENT

Due to the fact that 5G technologies were actively patented in 2017, and the market has significantly advanced since then, many companies around the world are thinking about implementing next-generation (5G+) technologies by accumulating resources for research and development and expanding the existing global technology boundaries. For example, in 2018, China announced that it started developing a 6G mobile communication standard.[65]

At the same time, when patenting their technical solutions, global 5G incumbents already indicate the potential use of their solutions in 6G networks, attempting to secure a competitive position in this technology segment.

[65] 6G // Wikipedia | The free encyclopedia URL: https://ru.wikipedia.org/wiki/%D0%A1%D0%B2%D1%8F%D0%B7%D1%8C_6G

The very concept of 6G assumes a wider understanding of networks including standards not only for mobile, but also for fixed communication networks. That is why in some cases they are designated as NET-2030 or 6G/NET-2030. 6G communication networks are assumed to use terahertz and subterahertz frequency bands, and support significantly lower latencies in data transmission as compared to 5G/IMT-2020 networks.

Currently, there are several research teams whose proposals and visions are competing with each other and who are engaged in the research of technologies that they claim to become part of 6G/NET-2030. At the early stages, their R&D efforts are focused on the use of technologies that could not be implemented in 5G/IMT-2020 networks, but are expected to become available for implementation by the industry when the next generation of data transmission technologies after 5G/IMT-2020 will be implemented.

The International Telecommunication Union set up the FG NET-2030 focus group. Already in May 2019, the group drafted and adopted its document entitled *Network 2030 - A Blueprint of Technology, Applications and Market Drivers Towards the Year 2030 and Beyond*.[66] In January 2020, it published another document, *Representative use cases and key network requirements for Network 2030.*[67] PJSC Rostelecom is involved in the activities the FG-NET-2030 focus group as a representative of Russian operators.

To build a 6G collection, we selected documents that contain the expression “sixth generation mobile network” or its potential variations. As a result, we identified 1,150 families that are already using the relevant terms.

Almost all families in the collection pertain to the 5G segment, but they contain assumptions about integration into future 6G networks as potential embodiments. Only 29 families of the collection are directly related to 6G development (in particular, antenna systems).

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[66] Network 2030. A Blueprint of Technology, Applications and Market Drivers Towards the Year 2030 and Beyond // ITU | International Telecommunication Union URL: https://www.itu.int/en/ITU-T/focusgroups/net2030/Documents/white_Paper.pdf

[67] FG-NET2030 - Focus Group on Technologies for Network 2030 // ITU | International Telecommunication Union URL: https://www.itu.int/dms_pub/itu-t/opb/fg/T-FG-NET2030-2020-SUB.G1-PDF-E.pdf

Realizing the importance of comprehensive preparations for infrastructure solutions, companies prefer protecting some of their know-hows preparing for an expansion similar to that in the 5G segment.

Table 13 **General information on the 6G Technology collection**

Family collection Number	Number of families → SEP	Number of publications	Number of applications	Number of invention patents	Number of utility model patents
6G Technology segment	1 150 → 357	3 236	2 781	362	15

The number of patents in the collection is slightly higher (11%), while most of its publications are also related to applications, which indicates an increased interest of applicants in this segment, as well as that a large number of young families are currently at the patent prosecution stage.

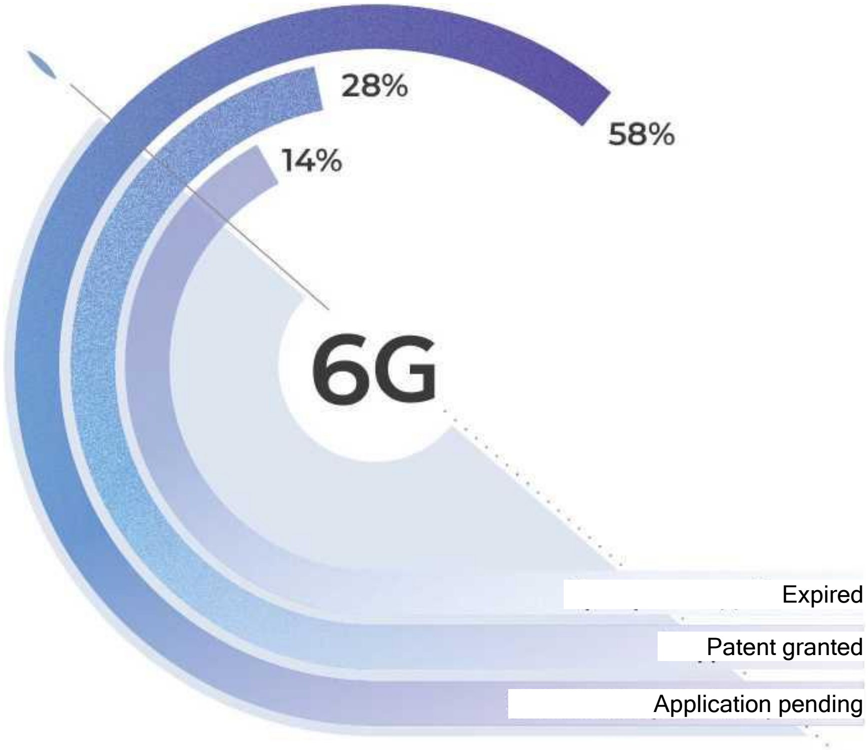
It should be highlighted that SEP families within the collection relate to the 5G technology base. We did not identify any solutions related to 6G standardization.

As for the legal status of patent families in the collection, the distribution is as follows (Figure 87). The share of families with applications pending examination is much lower in this collection than in the overall collection (almost 20%), while the share of families with patents granted and already inactive is higher (8% and 11%, respectively).

The majority of inactive families are owned by Intel, a US company. All families are international continuations of publications where the validity of related PCT applications has already expired and the applicant has failed to enter the national patenting phase. That is, for some reason, the company has decided not to continue the patent prosecution in PCT countries. Such situation may be due to the fact that the company aims to establish the global state-of-the-art level to increase barriers to entry for the relevant competitive market rather than to protect its patent rights in individual jurisdictions.

Legal status of the *6G Technology* segment

Figure 87



Families with granted patents are also mainly owned by Intel (70% of the families). We may also highlight Apple and HTC that own 8% and 3% of the families with patents, respectively. The patenting is mainly concentrated in the United States (27% of families) and China (18%). Regional patenting through the EPO also accounts for 12% of families with granted patents (Germany, the United Kingdom, Ireland, Switzerland, France, the Netherlands, Austria, Estonia, Slovakia, Belgium, Cyprus, Greece, Hungary, and Sweden). Other countries have 5% or less families in this group. These include Taiwan, Hong Kong, South Korea, Japan, India, Brazil, Canada, Russia, Mexico, Australia, Chile, Israel, Singapore, and Vietnam. Patents in Russia have been granted to Intel (**WO2016/118184, US20160165635, WO2016/022924**) and relate to user equipment, time allocation methods, device-to-device (D2D) signaling, and radio network energy consumption management methods.

Intel owns 48% of families with applications, while Chinese companies, including Huawei (13%) and BBK Electronics (9%), account for another part of such families. Most families with applications under review are in China (26% of families). Applications filed in the US and through the regional patenting procedure through the EPO (Germany, UK) account for another 20%. Another 15% of families with applications were filed through the PCT international patenting procedure. Other countries that have relevant applications pending examination include Taiwan, Japan, India, South Korea, Brazil, Canada, Australia, Singapore, Vietnam, Israel, the Philippines, and Mexico.

Hence, the relevant list of countries with granted patents and applications pending examination is slightly different from others. The focus of applicants is shifting towards the Asian region, claiming leadership in 6G technology development.

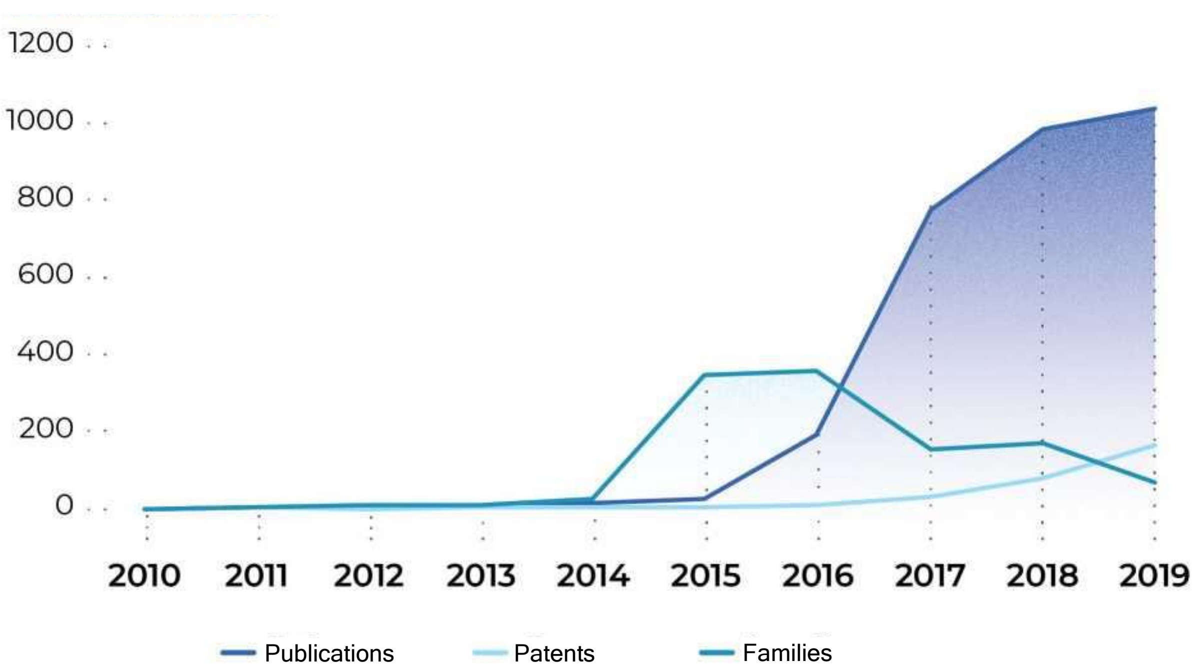
Similarly to the overall collection, we analyzed changes in metrics of patent families, patents, and publications over time for the 6G segment (Figure 88). Most families emerged between 2015 and 2016. Intel owns more than 90% of the families that emerged during this period. Apple is the application for other families (about 5%). These solutions apply to signal allocation devices, i.e. allocation of signaling, i.e. of overhead other than pilot signals (15% of families in the H04L-005/00/53 subgroup of CPC, **WO2017/155563**), allocation of pilot signals, i.e. of signals known to the receiver (9% of families in the H04L-005/00/48 subgroup of CPC, **WO2017/099834**) and multi-antenna systems using two or more spaced independent antennas at the receiving station with simultaneous transmission of weighted versions of the same signal to form a beam (9% of the families in the H04B-007/06/17 subgroup of CPC, **WO2017/048311**), as well as terminals adapted for operation in multiple networks, e.g. multi-mode terminals (7% of the families in the H04W- 88/06 subgroup of CPC, **US20190191487**). These thematic groups were identified based on the IPC and CPC sections of the relevant families. However, the publication activity, which increased dramatically in 2017 and 2018, reflects the period when Intel's families actually emerged, as applications are published in 18 months, after which the number of publications in the family begins to increase.

In 2017-2018, the number of priorities almost halved.

During this period, Intel (29% of the families), Huawei (20%), BBK Electronics (15%), HTC (7%), Cable Television Laboratories (a non-profit research laboratory founded in 1988 by US cable operators, 7%), and some other companies were among the most actively patenting companies. The following IPC and CPC subclasses cover 7% of the families in the collection each: H04L-005/00/48 (arrangements for allocating pilot signals **US20190261369**), H04W-072/04/2 (wireless resource allocation involving control information exchange between nodes in downlink direction of a wireless link, i.e. towards terminal), **WO2018/171436**), H04W-076/27 (manipulation of established connections, in particular transitions between radio resource control (RRC) states, **US20190254106**, **WO2019/233419**). A slowdown in the number of publications in 2019 was due to the fact that fewer families emerged over the previous one and a half years, while families with a longer retrospective did not substantially evolve. The average size of families that emerged in 2015–2016 is three publications per family, while that of young families emerging in 2017–2018 is two publications per family.

Patenting in the 6G Technology segment over time

Figure 87



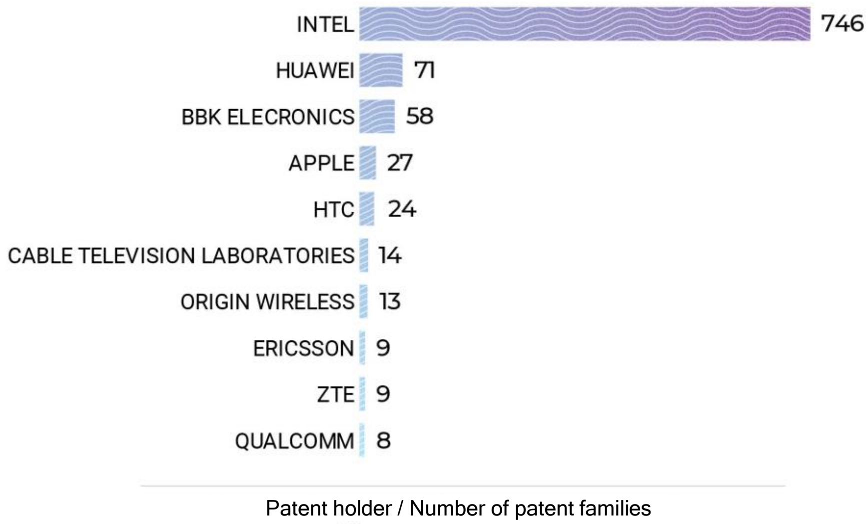
Therefore, the 6G segment still lacks technologies that would describe potential embodiments. Patent collections of recent years that mention 6G in their descriptions are primarily based on the technological component of 5G networks.

The patenting peak of 2015–2016 driven by Intel's developments is mainly due to 6G technologies mentioned in the descriptions in secondary role.

This situation has significantly affected the ranking of patent holders in the *6G Technology* segment. The leader in the segment is Intel, which owns more than 65% of the collection's families. Along with Intel, the ranking includes Huawei, BBK Electronics, Apple, HTC, and Cable Television Laboratories. A small number of families are held by Ericsson, ZTE, and Qualcomm.

Figure 88

Ranking of patent holders by segment



Patent holders whose families have 6G terms found in their patent names and abstracts were analyzed separately. There are 29 such families in the collection. They are owned by Shenzhen Sunway Communication (**CN109066104**), a Chinese company engaged in the research and development of mobile terminal antennas and related modules and connectors with high electromagnetic compatibility; AAC Technologies Holdings (**CN110351404**), a Chinese manufacturer of acoustic components; Chinese research institutions Beijing University of Posts & Telecommunications (**CN110430550**) and Xidian University (**CN110532631**); AT&T (**US10588034**), China BBK Electronics (**CN109728414**), and certain other companies that relate primarily to Chinese applicants.

The topics of these families cover the following IPC codes: H01Q- 001/36 (Structural form of radiating elements), H01Q-001/50 (structural association of antennas with earthing switches), and H01Q- 021/30 (Combinations of separate antenna units operating in different wavebands and connected to a common feeder system). CPC sections covered by these families include: H01Q-021/06/1 (Two dimensional planar arrays of individually energized antenna units similarly polarized and spaced apart), and H01Q-001/42/4 (Housings not intimately mechanically associated with radiating elements, comprising a layer of expanded material). Therefore, the first 6G/sub-6G solutions refers to antennas and their elements and are mainly owned by developers from China, which has publicly announced the launch of 6G technology development.

CONCLUSIONS

As part of this exercise, we analyzed patent information within the patent landscape to gain informed insights into the current condition and trends in high-potential R&D and innovative development areas in the 5G segment.

The analysis focused on five areas: trends, strategies, geography, patentees, and selected technology segments. The introduction of patent landscape tools into the practice of strategic innovation management (industry- or company-wide) provides a number of advantages:

1) integrated protection of R&D solutions and services important for the innovative development of the company;

2) accelerated market launch of new technological solutions and services;

3) improved internal R&D cost effectiveness;

4) reduced risks associated with the selection of ineffective patenting strategies (monopolized areas, tight competition, etc.);

5) tailored recommendations on licensing and patent protection strategies for different innovators.

The results of a patent landscape analysis can be used to further develop medium- and long-term strategies of intellectual property protection, analyze the competitive environment in high-tech research and development areas, and identify promising technological trends within the industry.

At the operational management level, an industry patent landscape can be used to update and monitor the implementation of the innovation development program (IDP), as well as to build and manage research and development portfolios and programs.

The key findings and recommendations obtained as a result of an extended patent landscape analysis are presented in the *Executive Summary*.

As part of the work on this report, we compiled and analyzed a collection of 29,578 patent families containing over 100,000 patent documents.

The 5G segment is in the active phase of patenting technical solutions, which indicates that the segment is immature and demonstrates high technology development rates. In this respect, patenting in this segment is associated with risks of collision with solutions that have already been claimed. In this context, implementing a patenting strategy requires a number of preventive measures such as ordering preliminary research in patent offices, monitoring published applications, and tracking applications with an opposition status.

It should be noted that all applications with an opposition status are overcome by companies, and all such families with applications were granted a patent. This testifies to the fact that companies defend their technical solutions and provide necessary arguments to overcome rejections and ensure patentability of their solutions, including changes in invention claims.

In such case, it is recommended to provide for an iterative patent examination process involving objections from patent experts, while patenting next-generation technical solutions with a wide technological scope as early as possible.

A large number of families in the segment are seeking priorities for 2017. The desire of companies to claim the earliest possible priorities is quite natural in a rapidly growing market with strong commercialization prospects.

One of the ways to achieve such competitive advantages as manifested by patenting strategies of incumbents consists in using special mechanisms of the existing patent legislation, which allow obtaining priorities for technical solutions before the first publications of relevant families. These mechanisms include:

a) continuation-in-part applications under a parent application, in which the invention has already been disclosed, but the applicant has not exhausted all potential embodiments and applications of the invention;

b) non-provisional applications where a provisional non-published application has been previously filed without an invention claim (typical for the US patent system).

Despite a significant share of young families within the collection, many of them have already significantly expanded their geographical coverage across different countries. The widest geographical coverage strategies are implemented by Qualcomm and Ericsson, concentrating applications filed in 50 patent offices in their patent portfolios (including in Asia, Africa, Europe, North and South Americas, and in Russia).

There is a high level of monopolization in the segment where key technologies and 5G architectures belong to a very narrow group of players: 60% of all inventions are created by ten incumbents. This leads to a high level of competition and significant barriers to market entry for other companies. Research and development in such market conditions require heavy investments as they involve developing innovative technologies. This situation is not observed in any other digital technology segments (quantum technologies, artificial intelligence, etc.). At the same time, patenting 5G technologies for large Chinese companies (for example, Huawei) is also associated with detailed development of solutions and quite high practical importance, which allows them to compete in international markets and gain leading positions in relevant rankings.

The bulk of technical solutions is concentrated in the H04W *Wireless communication networks* segment, which is subdivided into multiple more detailed groups. At the same time, among the leading IPC groups include groups related to transmitting arrangements, network resource management, and actual radio communication systems, which cover different subclasses. This distribution indicates a common technological trend in patenting, but varies depending on the company’s specialization. These findings are corroborated by the structure of specialized IPC sections (subgroups) in the portfolios of leading companies, which significantly differ even within subclasses. Huawei and Ericsson have the broadest technological profile that enables them contributing to all thematic groups.

The companies most involved in the innovation environment began patenting technologies related to 5G back in 2013 to consolidate their leadership in the segment, which has allowed many of them to become patenting leaders by now.

Additional risks of patenting in the segment are associated with the fact that the vast majority of patents held by monopolies are standard essential patents (SEP). It is believed that without SEP licenses, no company can bring telecom equipment to market or create 5G network architecture. The largest number of SEP families is currently protected in China. A slightly smaller number of families are protected in Europe.

The high level of competitive impact by monopolies companies is shifting technology focuses towards SEP, while many companies have already begun developing sixth generation (6G) communication technologies. The development of subsequent advanced 5G technologies will serve as the basis for patenting 6G basic technologies. Moreover, since mobile communication technologies cover infrastructure in a wide range of industries besides telecommunications, the competition for developing infrastructure-related technologies and international standardization in related areas such as *Transport* is growing.

Samsung has technologies that are of great interest for many companies operating in this area, including other incumbents. Therefore, the company's developments can be considered as basic technologies for the 5G segment. At the same time, Huawei, which leads by the number of patent families, is actively engaged in self-citation, thereby creating a powerful technology cluster within its patent portfolio. Due to the wide technological reach of its solutions, other companies may experience barriers to market entry. AT&T, in its turn, is a leader by the number of internal and backward citations, building a wide technological coverage of its 5G solutions in the US market while monitoring the evolution of global advanced technologies to inspire the development of its own technical solutions.

Leading 5G talents actively move between incumbents, including leading 5G developers who are leaving Samsung to join other companies. Some of them form innovative start-ups based on the experience gained in the leading corporate 5G research centers to offer new sophisticated solutions in the market to meet the emerging demand for the deployment of 5G networks and related infrastructure.

As a result, authors begin actively cooperating to develop various technical solutions. No less important in promoting the cooperation is the 3GPP consortium, which supports the development of technical specifications and technical reports for network technologies and radio access in mobile systems, enabling developers from different companies to apply their technological competencies.

In terms of 5G patenting, there is a certain configuration of key countries that are considered to be the highest priority markets for filing applications (the USA, China, South Korea, India, Japan, Canada, and Australia). At the same time, the most valuable families are those with international publications. PCT patenting operates as a proxy when companies intend to bring their technical solutions to a large number of countries at once with subsequent transition to national phases. The use of PCT procedures considerably reduces the total cost of technology patenting.

It should be highlighted that the procedure of regional patenting through the EPO is also gaining popularity when it concerns the expansion of geographical coverage for solutions. The difference from the PCT system is that the EPO grants a patent, which gains national importance in countries for which it was requested. In fact, this mechanism is one of the most effective ones for large-scale patenting in the European market. At the same time, companies are trying to identify less popular markets to consolidate their leadership positions there.

PATENTING IN RUSSIA

Patenting in Russia follows the global trends of technological development. The Institute for Information Transmission Problems (Kharkevich Institute) of the Russian Academy of Sciences is the only national developer in Russia. The rest of the market is distributed among the leading companies such as Ericsson, Huawei, and some others. When building development strategies in the 5G/6G segment in Russia, companies need to take into account the geographical aspects related to the patenting of technical solutions. Therefore, technical solutions of Huawei or another monopoly that are not registered in Russia are not associated with serious technology and equipment development risks excluding the possibility of patent disputes or claims.

The most active patent holders with SEP families in Russia are Swedish Ericsson, Chinese Huawei, Chinese BBK Electronics, Finnish Nokia, and American Intel and Qualcomm.

Analyzing SEP patents held by monopolies that are not registered in Russia may also become a promising area for further research. SEP patents in this group can be analyzed in two contexts:

1) business: patents registered in countries with promising target markets for Russian products in terms of building strategies to circumvent key technical solutions;

2) technology: patents not registered in countries that are promising target markets for Russian products in order to look into the possibility of reproducing the most promising technical solutions for the development of 5G networks in Russia and launch of Russian products in foreign markets.

When planning to patent new technical solutions, Russian companies are advised to provide for a wide geographical coverage at the earliest stages. International patenting procedures of the PCT and regional patenting procedures of the EPO and the EAPO can be used as a good tactic to secure such geographical coverage. Russian companies are advised to apply for patents in the United States to build patent protection strategies.

Patenting in Russia is mainly represented by the basic solutions related to the radio access networks, user devices, and 5G Core segments. The *Virtualization and Cloud Infrastructure* segment has the lowest level of competition.

The weak activity of national developers in Russia combined with an aggressive policy of patenting monopolies creates serious threats to the independent technological development both at the national level and in target markets that offer strong opportunities for Russia. Deployment of 5G networks in Russia is associated with high financial costs for the purchase of existing licensed technologies from incumbents, as well as with the need to build cooperative and financial ties with suppliers of 5G equipment for telecom operators.

To reduce the impact of these factors, it is advisable for Russian companies to explore areas of technological and business cooperation between organizations and focus on joint projects, where both Russian and foreign organizations act as partners. At the same time, Russia needs to establish Russian and foreign (with Russian participation) research centers with highly qualified personnel to conduct research and development unrelated to national technological security (“research sandboxes”).

The focus of the new policy for next-generation network development in Russia needs to be shifted towards strengthening Russia’s presence in international standardization committees, especially in 6G (FG NET-2030 focus group, etc.). A proactive approach to the creation and development of international standards will create favorable conditions for Russian companies to develop technical solutions closely related to industry standards.

TECHNOLOGY SEGMENTS

The general level of originality of collections across segments indicates the development of fundamentally new technologies as compared to prior art, in particular at Qualcomm, Huawei, Ericsson, and Samsung. On the whole, Samsung and Nokia have the highest patent lifespans in the collection. BBK Electronics has the shortest patenting retrospective, which characterizes it as a very young player in the market for 5G technologies. Despite the size of their portfolios, the incumbents, that is, Huawei, Qualcomm, and Ericsson, also have a short retrospective in terms of their patent lifespans

The *Radio Access Network (NG- RAN) and User Equipment* segment has a terminology base similar to the overall collection due to user equipment and the general concept of radio access networks. In this regard, a significant part of documents within the overall collection (90%) was included in the first segment, which led to similar pattern in patenting development over time, rankings of patent holders, and other metrics as compared to the overall collection.

5G networks

The *Backhaul Network* segment outperforms other segments across multiple metrics. In particular, they include high values of the average patent lifespan, the highest concentration of technical solutions in the portfolios of leading companies, and the highest share of granted patents. All this indicates that the segment has the prospects of the fastest commercialization rates, as well as an increased level of competition. Qualcomm and Samsung are the major contributors to this segment. At the same time, Samsung has the highest portfolio strength index in this segment. The smallest number of disputes with patent offices, combined with high originality indexes implies that the segment's technologies are of a ground-breaking significance for the industry as compared to other segments. An analysis of technical solutions from this segment is of particular importance for Russian companies to build sustainable positions.

Apart from the first segment, the *Network Services and Digital Platforms* segment is the leader by the number of SEP families thanks to a high share of patenting by Samsung, which has a fairly large portfolio of patents in this segment. The technological novelty index of this segment is also high, which indicates an accelerated pace of development as compared to other segments and high activity by applicants.

KT and Nokia have the largest number of disputed SEP families in the *5G Core* segment. In addition, almost all indicators in this segment are below average, including the overall growth rate. Therefore, the patenting intensity in this segment is much lower than in other segments. This reduces the level of monopolization in the segment and leads to a lower competitive pressure. Qualcomm has the strongest portfolio in this segment.

The *Functional Components for Network Management* segment has the smallest family size, which indicates a higher share of very young families in the collection. At the same time, this segment has the highest growth rate of families in recent years. Increased patenting in the *Functional Components for Network Management* segment is contributing to the growing interest of leading companies and the strength of their patent portfolios in this technology area.

The *Virtualization and Cloud Infrastructure* segment has the highest patenting growth rates until 2018, which has ensured a high level of monopolization in the region. Its patenting rates have decreased significantly in recent years. At the same time, the segment has the lowest share of granted patents. Along with the high activity of patenting in retrospective, it can be assumed that the granting of patents in this area is associated with some difficulties related to the actual concepts of virtualization and cloud infrastructure, which leads to longer examination of solutions by patent offices.

RECOMMENDED FURTHER STEPS (FORWARD-LOOKING PROJECTS)

The study was carried out in the form of an extended patent landscape. Since the studied segment has multiple aspects with an unlimited number of areas for potential analysis, we analyzed a wide range of criteria, including geography, patenting strategies, etc.

Key insights identified during the study as well as recommendations to the customer are provided on a wide range of analytical topics, including foreign patenting strategies, cooperation with foreign partners, R&D intensification, and so on. Recommendations to the customer are given with regard to STI (science, technology, and innovation) policy making and STI governance, with specific recommendations on developing individual technological areas for Russian companies on the whole, regardless of to their profiles, available technologies, existing cooperative ties, etc.

For the most important insights obtained as part of this study, we recommend conducting a more detailed analysis to better understand the situation and build a more accurate picture of global advances in 5G/6G research and development.

For example, we recommend addressing the following aspects to respond to the identified key insights (Table 16).

Further actions to respond to the identified key insights (high-potential projects)

Potential further action	Rationale
Developing recommendations on patenting Russian technical solutions based on patent analytics practices	In the extended patent landscape report, we paid particular attention to the patenting features and strategies of leading industry companies, including both Top 10 incumbents, and universities and smaller companies. The accumulated analytics practices and key findings from the research can serve as a methodologically elaborated basis for developing comprehensive recommendations to Russian companies and research organizations on: – proper definition of the scope of patenting for modern technologies and communication systems; – an appropriate degree of technological disclosure and the most secure configuration of patent claims, ensuring the safest way to bring technical solutions to markets; – correct strategies for bringing technical solutions to global markets, including the launch sequence, use of international patenting procedures, taking into account the profiles of certain markets, the use of the US market as a proxy for secure patent protection, etc.

Potential further action	Rationale
Development of an industry-specific patent landscape for technology segments with high competition	The study identified technology segments with very high competition and a high share of SEP patents (patents based on international industry standards). In addition, the study revealed a pronounced watershed between patenting 5G (the highest possible saturation of the segment with the patents of incumbents, extremely high competition, fence SEP patents) and patenting 6G (emerging patenting patterns, scattered attempts to bring solutions to markets, low concentration of SEP-patents). In these conditions, an additional study of highly competitive technological segments needs to be carried out using the industry patent landscape methodology with an in-depth technical analysis of individual groups of technologies, antenna equipment, etc. As part of the industry patent landscape and in addition to the existing functionality, it is advisable to explore separately the following areas: – searching for patenting gaps in highly competitive segments (technological areas, applications, and individual markets), a separate analysis of patenting gaps for 6G technologies; – a catalog of behavioral patterns of foreign leading companies; – an interactive map of foreign companies' rights to 5G technologies applicable in Russia.

ABOUT THE FIPS PROJECT OFFICE

Federal Institute of Industrial Property (FIPS) Project Office
PATENT ANALYTICS FACTORY

The FIPS Project Office (#ProjectOfficeFIPS) provides technology and business advice based on patent analytics across a wide range of applications at the governmental and corporate levels: selecting the technology segments to invest; patent technology intelligence; analyzing research and development prospects; assessing the competitiveness of Russian technologies; supporting the export of Russian products to global markets; analyzing and evaluating major patent portfolios.

A unique advantage of this research consists in the involvement of highly qualified specialists of FIPS specialized in the examination of patent applications and patents. The analysis is performed across all patent information published in the world using a wide range of Russian and foreign patent analytics tools.

Products and services of patent analytics provided by the FIPS Project Office are applied by large and medium Russian companies both at the strategic and operational levels.

The FIPS Project Office's approaches to an in-depth industry analysis based on patent data are recognized worldwide. The World Intellectual Property Organization (WIPO) has recognized the FIPS Project Office as a WIPO-level pre-qualified provider of patent analytics and included it in its closed register of patent analytics providers with an opportunity to participate in WIPO tenders.

http://new.fips.ru/patent-analytics

ABOUT PJSC ROSTELECOM

PJSC Rostelecom is Russia's largest provider of digital services and solutions, with presence in all market segments and covering millions of households, governmental and private organizations.

Rostelecom holds leading positions in the market of high-speed Internet access and pay-TV services. Its broadband services are used by more than 13.0 million subscribers, paid TV by 10.2 million, including over 5.4 million subscribers connected to Interactive TV.

Rostelecom is the telecom operator of choice for Russian governmental authorities and corporate users at all levels.

Rostelecom is a recognized technology leader in innovative solutions for e-government systems, cyber-security, data centers, cloud computing, biometrics, healthcare, education, and utilities.

Rostelecom's stable financial position is confirmed by the following credit ratings: BBB– from Fitch Ratings, BB+ from Standard & Poor's, as well as AA(RU) assigned by the Analytical Credit Rating Agency (ACRA).

Rostelecom

DISCLAIMER

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APPENDICES

APPENDIX A. ABBREVIATIONS

3GPP	3rd Generation Partnership Project
AF	Application Function
AMF	Access and Mobility Management Function
ARPU	Average revenue per user
AUSF	Authentication Server Function
B2B	Business-to-business
BLER	Block Error Ratio
BRS	Beam Reference Signal
BWP	Bandwidth Parts
C-RAN	Cloud Radio Access Network
CSI	Channel State Information
C-V2X	Cellular Vehicle-to-Everything
CAPEX	Capital expenditures
D2D	Device-to-device
DCI	Downlink Control Information
ETR	External technology relevance
eMBB	Enhanced Mobile Broadband
ETSI	European Telecommunications Standards Institute
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
gNB	gNodeB (gNb) Base Stations for 5G
HARQ	Hybrid automatic repeat request
IT	Information technologies
IoE	Internet of Everything
IoT	Internet of Things
ITR	Internal technology relevance
LDPC	Low-Density Parity-Check
LTE	Long-Term Evolution
M2M	Machine-to-machine
MAC	Medium Access Control
MANO	Management and orchestration
MIMO	Multiple Input Multiple Output
MME	Mobility Management Entity
mMTC	Massive Machine Type Communications
MUSA	Multi User Shared Access
NB-IoT	Narrowband Internet of Things
NFV	Network Functions Virtualization

RAN	New Generation Radio Access Network
NSA	Non-Standalone
NSSF	Network Slice Selection Function
NST	Network Slice Template
OFDM	Orthogonal frequency-division multiplexing
OPEX	Operating expenses
PCF	Policy Control Function
PCT	Patent Cooperation Treaty
PDCP	Packet Data Convergence Protocol
PDSCH	Physical Data Shared Channel
PDU	Protocol Data Unit
PRACH	Physical Random Access Channel
QoS	Quality of Service
RACH	Random Access Channel
RAT	Radio Access Technology
RRC	Radio Resource Control
RSMA	Resource Spread Multiple Access
SDCCH	Stand-alone Dedicated Control Channel
SDN	Software-defined networking
SEP	Standard Essential Patent
SLA	Service Level Agreements
SMF	Session Management Function
SSF	Slice Selection Function
UDM	Unified Data Function
UE	User equipment
UPF	User Plane Function
uRLLC	Ultra Reliable & Low Latency Communications
V2X	Vehicle-to-Everything
XCI	Xhaul Control Infrastructure
XFE	Xhaul Packet Forwarding Element
WIPO	World Intellectual Property Organization
EAPO	Eurasian Patent Office
EPO	European Patent Office
SE	Search engine
IPC	International Patent Classification
CPC	Cooperative Patent Classification
FIPS	Federal Institute of Industrial Property

APPENDIX B.
TERMS AND DEFINITIONS

Term	Definition
Patent Cooperation Treaty	Patent Cooperation Treaty is an international treaty covering patent law and signed in 1970. The PCT is intended to “simplify and render more economical the obtaining of protection for inventions where protection is sought in several countries”.
World Intellectual Property Organization (WIPO)	An international organization that administers a number of key international conventions related to intellectual property.
Offices of first filing	The offices to which the initial application for an invention is filed. Most often an office of first filing is located in the country of the applicant’s residence.
Offices of second and subsequent filings	Entities with which further applications are filed to expand respective target markets and/or to expand production to respective jurisdictions.
Active patent family	A family with at least one active patent or application pending examination.
European Patent Office	The executive arm of the European Patent Organization. The European Patent Organization’s employees examine European patent applications and make decisions on granting patents for inventions. The EPO implements the procedures provided under the European Patent Convention.
International Patent Classification indexing code	A code consisting of letters and other symbols to denote a structural unit of the International Patent Classification.
Collection of patent documents	An array of patent documents built using search queries

Term	Definition
International Patent Classification	A hierarchical patent classification system. The IPC is a means for uniform classification of patent documents on an international scale. Created in accordance with the Strasbourg Agreement in 1971, with the World Intellectual Property Organization performing administrative functions under the Agreement. The classification is updated on a regular basis.
Domain model	A structured representation of the research area covering the priority technology segment including the most important technology and product patenting areas. The model is a system of pillars (typically, six to eight). Each pillar contains a set of elements characterizing this pillar.
	When preparing a patent landscape, the search strategy is developed and technical analysis is performed within the context of each element of the model.
Inactive patent family	A family in which no patent document is active (the patent has expired, the application was withdrawn, or for other reasons).
Protection of intellectual property	Protection based on various principles and procedures, which grants a temporary monopoly on the results of intellectual activities to the creators of industrial property in the form of property rights, as well as non-property perpetual authors' right.
Patent analytics	A set of methods, techniques, tools, and metrics enabling an analysis of research and development trends based on patent information.
Patent collection	A set of patent documents related to the researched area. It is built by applying a search strategy to the consolidated database of the FIPS.
Patent family	A collection of patent publications related to a single invention that are linked by a common priority(-ies).

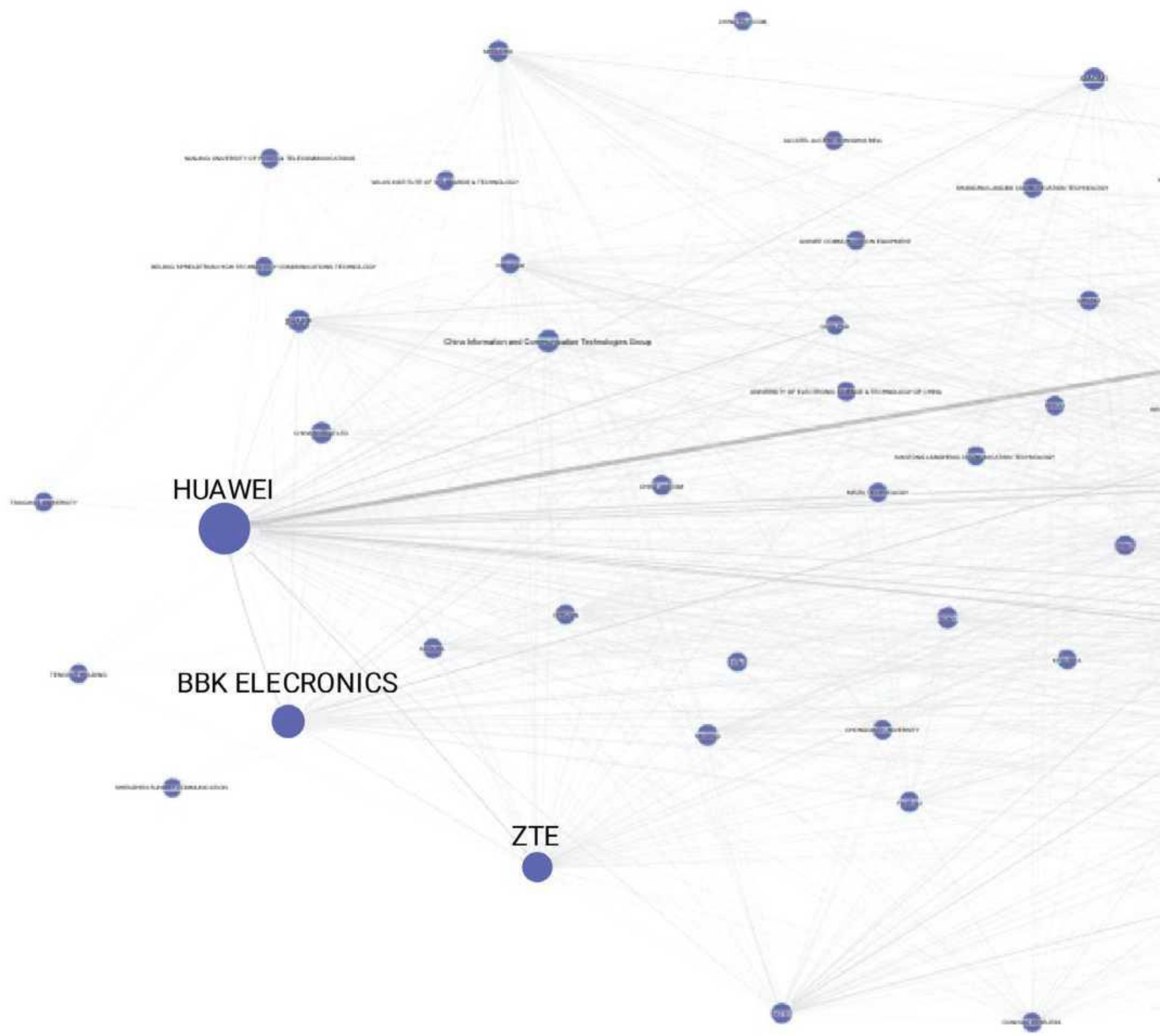
Term	Definition
Patent landscape	An in-depth analysis of innovative products, forward-looking technologies, and research and development areas as compared to leading Russian and foreign solutions over for a long period of time, informed by patent data linked to technological priorities of the relevant company (corporation, or economic sector).
Domain	The subject matter of a patent landscape analysis determined by the Customer.
Relevant (irrelevant) patent document	A document related (unrelated) to the research domain on the whole or related to a specific pillar (element) of the domain model. The document relevance check is carried out at the stage of patent collection quality control.
Technology segment	A part of a domain taken from the overall collection for separate examination and analysis. A search is performed for each technology segment based on refine queries to update the patent collection, analytical concepts, and their interpretations.

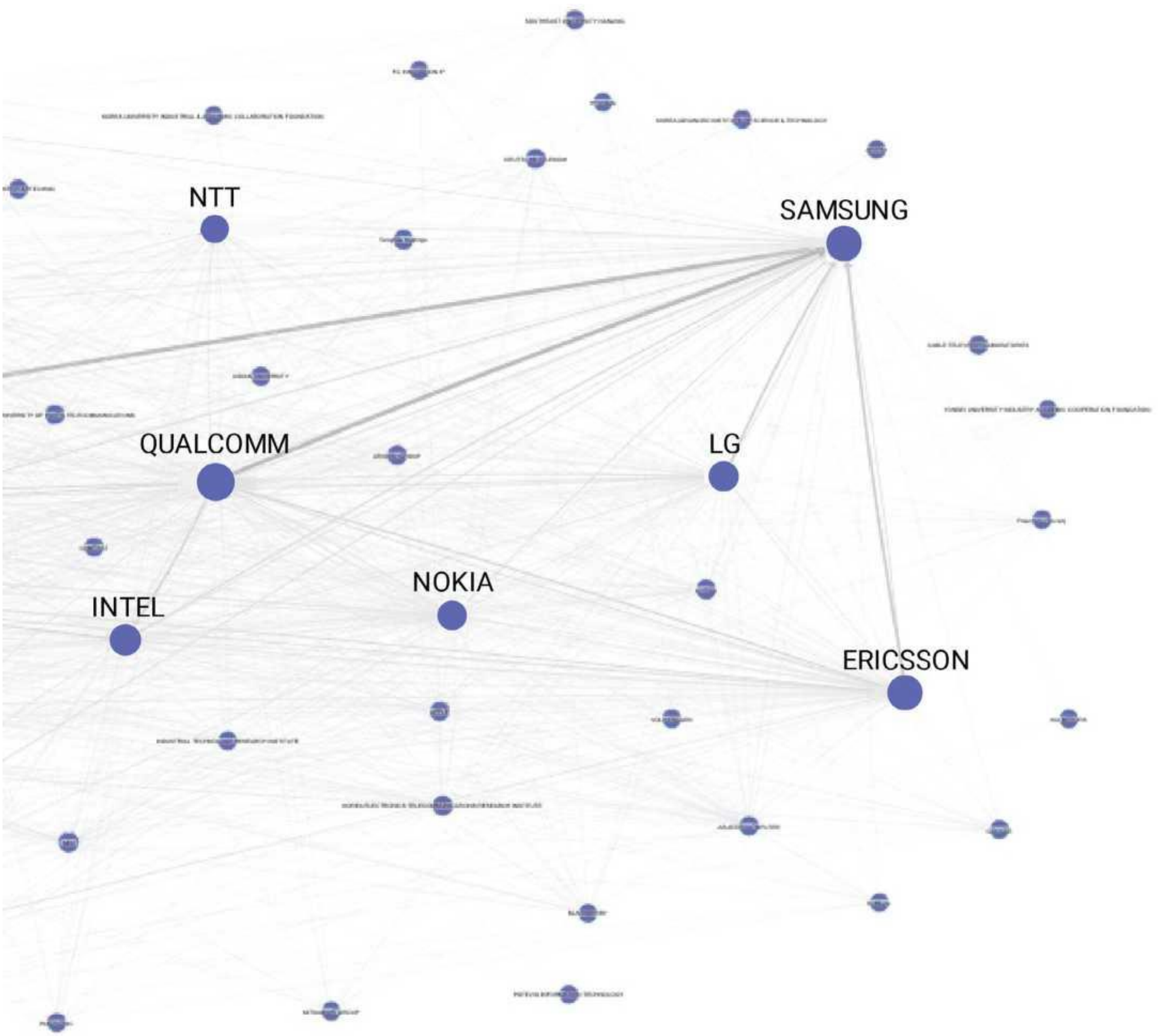
APPENDIX C.
LIST OF TWO-LETTER CODES OF COUNTRIES AND AGENCIES

AP	ARIPO
AT	Austria
AU	Australia
AR	Argentina
BR	Brazil
CA	Canada
CL	Chile
CN	China

CO	Columbia
CR	Costa Rica
CU	Cuba
DE	Germany
DK	Denmark
DO	Dominican Republic
EA	EAPO
EP	EPO
ES	Spain
FI	Finland
FR	France
GB	United Kingdom
GR	Greece
HK	Hong Kong
HU	Hungary
IL	Israel
IN	India
IT	Italy
JP	Japan
KR	South Korea
LU	Luxembourg
LT	Lithuania
MA	Morocco
MX	Mexico
MY	Malaysia
NZ	New Zealand
PH	Philippines
PE	Peru
PL	Poland
PT	Portugal
RO	Romania
RU	Russia
SE	Sweden
SG	Singapore
SI	Slovenia
SV	El Salvador
TH	Thailand
TN	Tunisia
TR	Turkey
TW	Taiwan
US	US
VN	Vietnam
WO	WIPO
ZA	Republic of South Africa

APPENDIX D. CITATION MAP OF 5G DEVELOPERS




NTT
SAMSUNG
QUALCOMM
LG
NOKIA
INTEL
ERICSSON

APPENDIX E. LIST OF AUTHORS IN THE ERICSSON FAMILY (US20170331670)

Parkvall' Stefan
Abrakhamsson Richard
Aktas Ismet
Alriksson Peter
Ansari Junaid
Ashraf Shehzad Ali
Asplund Henrik
Athley Fredrik
Aksel'sson Khokan
Aksmon Joakim
Aksnes Jokhan
Balachandran Kumar
Bal'demair Robert
Bark Gunnar
Berg Jan-Erik
Bergstrem Andreas
Bjorkegren Hakan
Brahmi Nadia
Capar Cagatay
Karlsson Anders
Cedergren Andreas
Coldrey Mikael

Da Silva Icaro L J
Dal'man Ehrik
El Essaili Ali
Engstrom Ulrika
Ericson Marten
Ehriksson Ehrik
Fallgren Mikael
Fan Zhuj
Fodor Gabor
Frenger Pal
Friden Jonas
Froberg Olsson Jonas
Furusker Anders
Furuskog Jokhan
Garcia Virgile
Gattami Ather
Gunnarsson Fredrik
Gustavsson Ul F
Khagerman Bo
Kharrjusson Fredrik
He Ning
Hessler Martin

Hiltunen Kimmo
Hong Songnam
Kh Jui Dennis
Huschke Jorg
Irnich Tim
Jacobsson Sven
Jalden Niklas
Jarmyr Simon
Jiang Zhiyuan
Jokhansson Martin
Jokhansson Niklas
Koorapaty Havish
Karipidis Eleftherios
Karl Sson Patrik
Khayrallah Ali S
Kilinc Caner
Klang Goran N
Kronander Jonas
Landstrom Sara
Larsson Christina
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Lindbom Lars
Lindgren Robert
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Lindqvist Fredrik
Liu Jinhua
Lomar Torsten
Lu Tsyansi
Mankhol M Lars
Maric Ivana
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Pejsa Janne
Petersson Sven
Pradas Khose Luis
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Kveset Olav
Ramachandra Pradeepa
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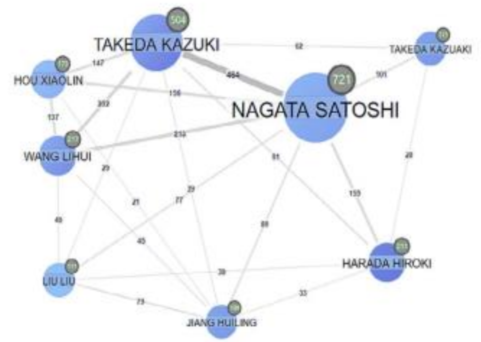
Rejal Andres
Rimhagen Thomas
Ringh Emil
Rugeland Patrik
Rune Jokhan
Sachs Joachim
Sahlin Henrik
Saxena Vidit
Seifi Nima
Selen Yngve
Semaan Eliane
Sharma Sachin
Shi Cong
Skold Johan
Stattin Magnus
Stjernman Anders
Sundman Dennis
Sundstrem Lars
Tercero Vargas Miurel Isabel
Tidestav Claes
Tombaz Sibel
Torsner Jokhan
Tullberg Hugo
Vikberg Yari
Von Vricha Peter
Vager Stefan
Val’deen Tomas
Vallen Anders
Vallentin Pontus
Wang Hai
Vang Khel’mersson Ke
Van Tszjan’fyn
Van I-Pin’ Ehrik
Werner Karl
Wiberg Niclas
Wittenmark Emma
Yilmaz Osman Nuri Can
Zaidi Ali
Chzhan Chzhan
Zheng Yanli

APPENDIX E. THE MAP OF COOPERATION BETWEEN 5G TECHNOLOGY DEVELOPERS

NIPPON TELEGRAPH AND TELEPHONE



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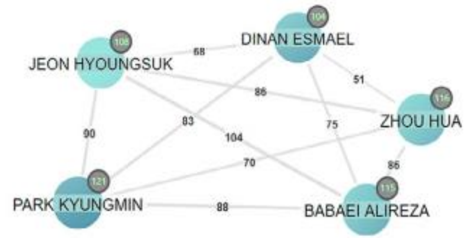
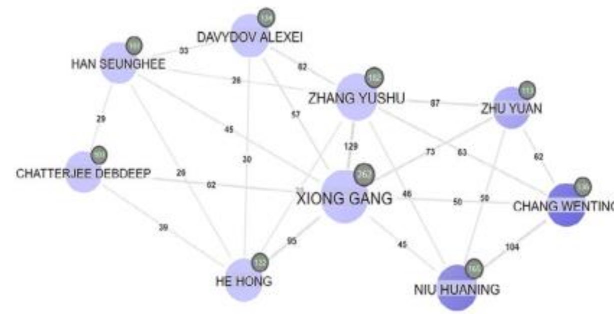
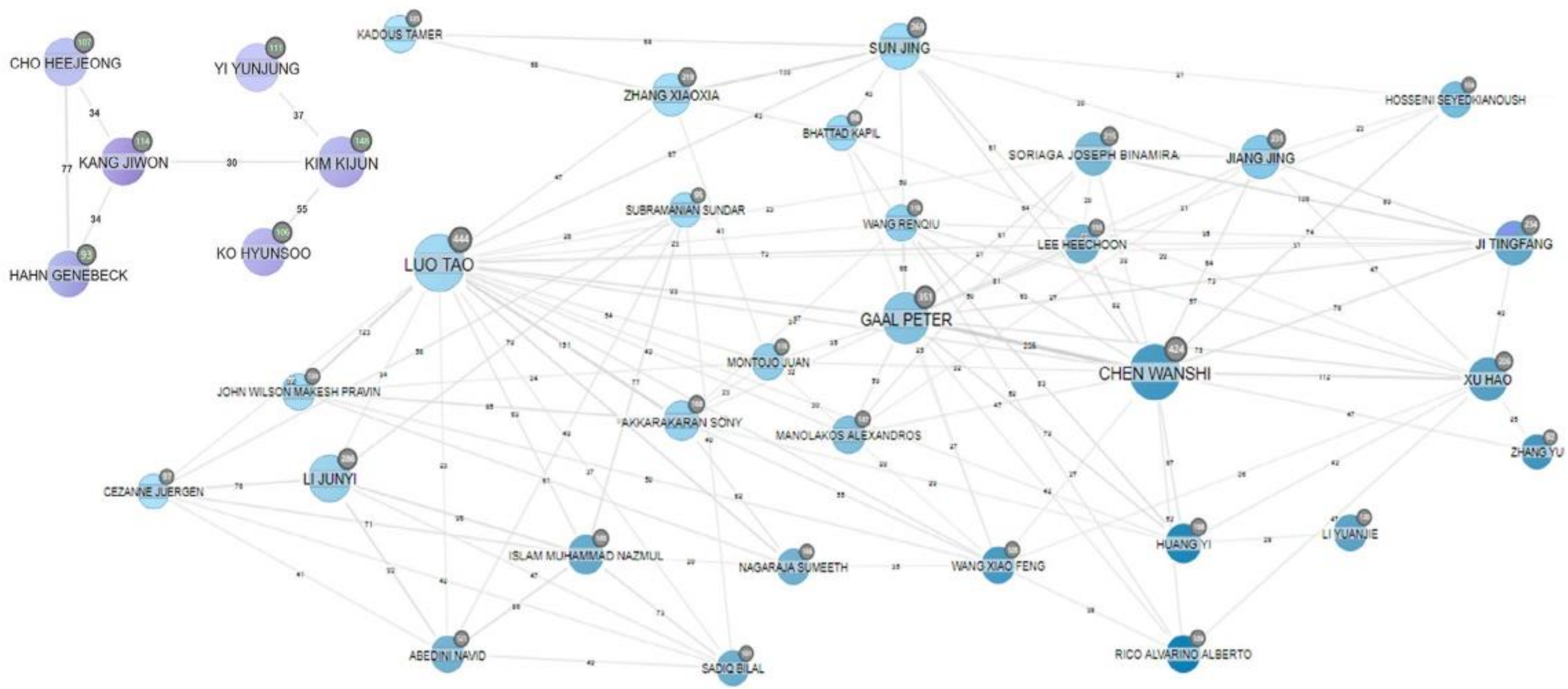


INTEL



LG

QUALCOMM



APPENDIX G LIST OF STANDARDS CITING HUAWEI'S FAMILY WITH THE BASIC PUBLICATION US20160352551

Standard number	Standard title	Version	Number of other patent families cited in the standard
ETSI-TS-37-340	Universal Mobile Telecommunications System (UMTS); LTE; 5G; NR; Multiconnectivity; Overall description; Stage-2	version 15.5.0 Release 15	308
ETSI-TS-38-211	5G; NR; Physical channels and modulation	version 15.2.0 Release 15	4,371
ETSI-TS-38-212	5G; NR; Multiplexing and channel coding	version 15.2.0 Release 15	3,595
ETSI-TS-38-213	5G; NR; Physical layer procedures for control	version 15.6.0 Release 15	4,524
ETSI-TS-38-214	5G; NR; Physical layer procedures for data	version 15.3.0 Release 15	3,950
ETSI-TS-38-215	5G; NR; Physical layer measurements	version 15.4.0 Release 15	293
ETSI-TS-38-300	5G; NR; Overall description; Stage-2	version 15.3.1 Release 15	2,474
ETSI-TS-38-321	5G; NR; Medium Access Control (MAC) protocol specification	version 15.3.0 Release 15	2,322
ETSI-TS-38-323	5G; NR; Packet Data Convergence Protocol (PDCP) specification	version 15.2.0 Release 15	413
ETSI-TS-38-331	5G; NR; Radio Resource Control (RRC); Protocol specification	version 15.7.0 Release 15	4,071
ETSI-TS-38-413	5G; NG-RAN; NG Application Protocol (NGAP)	version 15.3.0 Release 15	386
ETSI-TS-38-423	5G; NG-RAN; Xn Application Protocol (XnAP)	version 15.1.0 Release 15	329
ETSI-TS-38-473	5G; NG-RAN; F1 Application Protocol (F1AP)	version 15.4.1 Release 15	161

APPENDIX I. DISTRIBUTION OF FAMILIES BY IPC SECTION

IPC subclasses	Description	Number of families	Share of the total number of families in the collection
H04W	Wireless networks	25,060	84.7%
H04L	Transmission of digital information, e.g. telegraphic communication	14,700	49.7%
H04B	Transmission	6,292	21.3%
H04J	Multiplex communication	1,174	4.0%
H01Q	Antennas, i.e. radio aerials	557	1.9%
H04M	Telephonic communication	526	1.8%
G06F	Electric digital data processing	480	1.6%
H03M	Coding; decoding; code conversion in general	450	1.5%
G01S	Radio direction finding; radio navigation; measuring distance or speed using radio waves; locating or detecting objects using the reflection or re-radiation of radio waves; similar systems using other types of waves	224	0.8%
H04N	Image transmission, such as television	144	0.5%
IPC groups	Description	Number of families	Share of the total number of families in the collection
H04W-072	Local resource management, for example, the selection or allocation of wireless resources or scheduling of wireless traffic	12,445	42%

IPC groups	Description	Number of families	Share of the total number of families in the collection
H04L-005	Arrangements affording multiple use of the transmission path	8,160	28%
H04B-007	Radio communication systems, i.e. systems using radiation	5,124	17%
H04W-076	Connection control	4,989	17%
H04L-001	Devices for detecting or preventing errors in received information	4,522	15%
H04W-024	Supervisory, monitoring or testing arrangements	4,190	14%
H04W-028	Managing network traffic or a resource	4,184	14%
H04W-088	Devices specifically designed for wireless communication networks, such as terminals, base stations, or access point devices	3,516	12%
H04W-048	Access restriction; network selection; access point selection	3,281	11%
H04W-036	Handoff or reselecting arrangements	3,268	11%
H04W-074	Wireless access, such as scheduled or random access	3,229	11%
H04W-004	Services specially adapted for wireless communication networks; Facilities therefor	3,183	11%
H04L-029	Arrangements, apparatus, circuits or systems, not covered by a single one of groups 1/00–27/00	2,760	9%

IPC groups	Description	Number of families	Share of the total number of families in the collection
H04W-016	Network planning, such as service zones or traffic planning tools; network deployment, such as resource allocation or cell structure	2,704	9%
H04L-027	Modulated-carrier systems	2,398	8%
H04L-012	Data switching (data transmission) networks	2,397	8%
H04W-052	Power management, e.g. TPC (Transmission Power Control), power saving or power classes	2,187	7%
H04W-008	Network data management	1,917	6%
H04W-056	Synchronization arrangements	1,515	5%
H04B-017	Monitoring; Testing	1,282	4%
H04W-084	Network topologies	1,209	4%
H04W-012	Security arrangements, e.g. access security or fraud detection; Authentication, e.g. verifying user identity or authorisation; Protecting privacy or anonymity	1,067	4%
H04L-025	Modulated-carrier systems	920	3%
H04B-001	Details of transmission systems, not covered by a single one of groups H04B 3/00-H04B 13/00; Details of transmission systems not characterized by the medium used for transmission	870	3%

IPC groups	Description	Number of families	Share of the total number of families in the collection
H04W-092	Interfaces specially adapted for wireless communication networks	846	3%
H04W-080	Wireless network protocols or protocol adaptations to wireless operation, e.g. WAP	780	3%
H04W-068	Notification of users e.g. alerting for incoming communication or change of service	726	2%
H04J-011	Orthogonal multiplex systems	663	2%
H04W-040	Communication routing or communication path finding	600	2%
H04W-060	Affiliation to network, e.g. registration; Terminating affiliation with the network, e.g. de-registration	552	2%
IPC subgroups	Description	Number of families	Share of the total number of families in the collection
H04W-072/04	Wireless resource allocation	9,947	34%
H04L-005/00	Arrangements affording multiple use of the transmission path	7,829	26%
H04W-072/12	Wireless traffic scheduling	4,003	14%
H04B-007/06	Multi-antenna system using two or more spaced independent antennas at the transmitting station	2,972	10%
H04L-001/00	Arrangements for detecting or preventing errors in the information received	2,696	9%

IPC subgroups	Description	Number of families	Share of the total number of families in the collection
H04W-074/08	Non-scheduled access, e.g. random access, ALOHA or CSMA [Carrier Sense Multiple Access]	2,693	9%
H04W-036/00	Handoff or reselecting arrangements	2,324	8%
H04L-027/26	Systems using multi-frequency codes	2,092	7%
H04L-001/18	Automatic repetition systems, e.g. van Duuren system	1,927	7%
H04W-024/10	Scheduling measurement reports	1,924	7%
H04W-028/02	Traffic management, e.g. flow control or congestion control	1,544	5%
H04W-056/00	Synchronization arrangements	1,509	5%
H04W-076/27	Transitions between radio resource control (RRC) states	1,428	5%
H04L-029/06	Arrangements, apparatus, circuits or systems for communication control; communication processing for plural communication lines characterized by a protocol	1,407	5%
H04W-072/08	Wireless resource allocation based on quality criteria	1,396	5%
H04L-029/08	Arrangements, apparatus, circuits or systems for transmission control procedure, e.g. data link level control procedure	1,373	5%

IPC subgroups	Description	Number of families	Share of the total number of families in the collection
H04W-024/02	Arrangements for optimizing operational condition	1,298	4%
H04W-074/00	Wireless channel access, e.g. scheduled or random access	1,214	4%
H04W-016/28	Cell structures using beam steering	1,137	4%
H04W-088/08	Access point devices	1,127	4%
H04W-088/06	Terminal devices adapted for operation in multiple networks, e.g. multi-mode terminals	1,096	4%
H04W-048/16	Discovering, processing access restriction or access information	1,090	4%
H04W-052/02	Power saving arrangements	1,086	4%
H04W-024/08	Testing using real traffic	995	3%
H04W-076/10	Connection set-up	964	3%
H04B-007/08	Multi-antenna system using two or more spaced independent antennas at the transmitting station	930	3%
H04L-012/24	Arrangements for maintenance or administration	914	3%
H04B-007/0413	MIMO systems	847	3%
H04W-088/02	Terminal devices	847	3%
H04W-004/00	Services or facilities specially adapted for wireless communication networks	844	3%