Fact finding study on patents declared to the 5G standard

The study was officially commissioned by the German BMWi - Federal Ministry for Economic Affairs and Energy

January 2020

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Disclaimer

This 5G patent study is fact finding. Results are neutrally presented and discussed, without making policy recommendations. The 5G patent study is based on publicly declared patents and submitted standards contributions that were identified for the 5G standard. Patent family statistics presented in the study are not verified standard essential. The study also makes no effort of an independent assessment of essentiality or assessment of validity of the declared 5G patents. Further this study does not provide any suggestions about the percentage of actual essential patents or a variation of essentiality among different 5G patent portfolios. Results of the study have been presented to and discussed with over 120 patents and standard experts as summarized in Appendix 3. The information and views presented in this study are those of the authors and do not necessarily reflect the official opinion of the Federal Ministry of Economics and Energy. In particular, the Ministry does not guarantee the accuracy of the data contained in this study. Neither the Ministry nor any person acting on behalf of the Ministry can be held responsible for the use of information contained herein.

Executive Summary

The long-term vision is that 5G will empower the invention of thousands of new products, technologies and services, increase productivity and allow for new industries to emerge. A global 5G network will unify mobile communication in order to connect individuals and devices to everything through the Internet of Things (IoT), with 5G technologies linking vehicles, ships, buildings, meters, machines, healthcare devices and other items with electronics, software, sensors and access to the Cloud. Increasing connectivity will drive new disruptive technologies such as autonomous driving, AI driven robots, augmented reality or many more. The fourth industrial revolution will rely on a stable, real-time communication allowing the constant exchange of massive amounts for data. The next telecommunication generation 5G standard is an important step to meet these new requirements of connectivity for future applications. Here 5G will offer the following improvements:

5G is expected to dramatically decrease the end-to-end latency. Latency rates can be seen as the gap time, or transmission time for a packet of data. In other words, the delay between the sending and receiving of information. From 200 milliseconds for 4G, 5G will go down to 1 millisecond (1ms) with 5G.[1] When streaming a live sports event, for example, latency is the delay or the seconds the streaming is behind the real event. When thinking about future applications in the healthcare sectors areas such as remote surgery, where the doctor is located thousands of kilometers away from the patient, a few seconds are critical to save someone's live and any delay of the transmission of high-resolution live videos is critical. Low latency rates are also important for real time data transmissions in smart factories where the identification of a defect machine or a misfunctioning production line is crucial to keep processes up and running. In the automotive sector when a future car drives autonomously through inner city traffic, real time traffic information about accidents or dangerous situations again very much depend on the prompt receipt of that information which is guaranteed through 5G low latency rates. In addition, the energy sector needs real time information about network stability as the electrification of cars will create new challenges on electricity grids. The monitoring of the electric grid also depends on real time information to avoid electric breakdowns. When it comes to critical information flow not only low latency rates will be important but especially latency reliability which will increase with 5G.

[1] https://www.gemalto.com/mobile/inspired/5G

5G further allows high data transfer rates which are crucial in connecting smart devices. For example, in order to make use of new artificial intelligence applications, massive amounts of training data is needed to automate and predict processes. The more training data the more accurate. The requirements for the sheer amount of transmitted data will therefore increase. 5G will allow up to 10 Gbps data rate which is a 10 to 100 times improvement over 4G.

5G will also allow low power consumption[2]. Especially when 5G is built into machines, cars, traffic lights or other devices, a lower power consumption will allow connected objects to operate for months or years without the need for human assistance. This will create new use cases and a wider installation of connected technology in any physical object. 5G will also allow sleep modes for 5G base stations which again saves energy.

The increasing connectivity will not only make use of 5G but will also rely on earlier generations like 3G and 4G. Still future applications will need more and more a low latency, stable, high bandwidth 5G network.

This study has investigated the patent situation for the 5G standard. Telecommunication standards are often protected by ten thousand of so called standard essential patents (SEPs). These patents claim inventions that read on any implementation of the standard. In other words, anyone who implements a standard like 3G, 4G or soon 5G will also have to use and implement all SEPs. Companies developing these standards have to commit to license any SEP under fair reasonable and non-discriminatory (FRAND) terms. This ensures that no patent owner can block any implementer from using the standard. However, patent owners have the right to request royalties for SEPs and any implementer has to pay a license fee in order to implement 3G, 4G or in the future 5G.

The past few years have shown that 3G and 4G patent holders have controlled how mobile technologies are used in the smartphone industry. Owners of 5G SEPs will likely become technology and market leaders, thus enabling 5G connectivity in various markets.

The study is based on publicly declared patents and submitted standards contributions that were identified for the 5G standard. Patent declarations cannot be interpreted as legally verified standard essential patents. Still patent declaration data is the best source to identify all potential essential 5G patents. The data analysis of this study was conducted using IPlytics Platform on January 1st 2020. The IPlytics Platform[3] data is based on declarations submitted to the ETSI IPR database[4] and standards contributions submitted at the 3GPP portal[5]. Both information on the patent data and the standards data were correlated to identify only 5G relevant information. Further the patent data was correlated to patent data from worldwide patent offices. The method of how to identify 5G patents and standards contributions was discussed and verified by an invited group of patent and standards industry experts that supported this study with technical expertise.

The results of this study show that the 5G standard is highly patented. In total 95,526 5G declarations patents have been declared for 5G which breaks down to 21,571 unique patent

[2] https://signalsresearch.com/issue/5g-the-greatest-show-on-earth-6/
[3] www.iplytics.com
[4] https://ipr.etsi.org/
[5] https://portal.3gpp.org/

families. Only 44% of these patent families have yet been granted. However, as most 5G patents are rather recently filed one will expect the rate of granted patents to further increase in the next years. Most 5G patents where declared between 2017 and 2019 showing a sharp increase year by year. And as the 5G standard development is not yet completed further patent declarations are expected in the upcoming years. It is also worth mentioning that 24% of the patents declared for 5G have before already been declared for 4G. This shows that some 4G technologies are still relevant for the new 5G specifications.

As of January 1st, 2020 Huawei (CN) has declared most 5G patents followed by Samsung (KR), ZTE (CN), LG (KR), Nokia (FI), Ericsson (SE) and Qualcomm (US). All of those top 5G patent owners have already been active in the 4G standard development. The study however identifies new market players as well. Here the Chinese companies Guangdong Oppo (CN), Vivo Mobile (CN), FG Innovation (CN), Spreadtrum Communications (CN) and the Taiwanese ASUSTeK Computer (TW) are new in the top patent owner list comparing 5G and 4G. The study shows however that the larger share of the Chinese newcomers' patent portfolios is yet filed locally in China and are yet not granted. Given that 5G is a recent technology the study shows that the patent portfolios of these Chinese companies are still very young and could very well still be filed and granted internationally.

This study also investigated companies' participation in the standards development, where technical contributions submitted to the 3GPP (3rd Generation Partnership Project) - the standard body that develops telecommunication standards such as 3G, 4G and 5G - were counted and analyzed. The main 4G standard developers such as Huawei, Ericsson, Nokia, Qualcomm, ZTE or Samsung and LG are again strong players for the 5G development. Here again the data shows increasing participation from new and upcoming Chinese players. When counting only approved 5G standard contributions, Huawei, Ericsson, Nokia and Qualcomm are the strongest players.

The study further discusses the implementation of the 5G standard in industries such as the automotive sector, the manufacturing industry, the energy sector, the media sector and the healthcare sector. Here the study investigates possible licensing scenarios for 5G. In this regard a new licensing platform was created a few years ago called AVANCI. This patent platform licenses 2G, 3G and 4G SEPs for the use of these patents in the automotive space and the IoT space. Companies from the automotive sector can get a one stop license to get access to all 2G, 3G and 4G SEPs of AVANCI members for a total of USD 15 per car. The study shows that a majority of SEP patent owners have joined AVANCI, however Asian companies such as Huawei, Samsung or LG as of today have not joined. For licensors in the automotive space or for licensors of any IoT applications it remains to be seen if there will be a patent licensing program for 5G and also if a majority of the SEP owners will join. Otherwise 5G implementors will have to negotiate licenses with each individual patent owner. The 5G licensing in general is yet hard to predict, which may create a certain legal risk for today's implementors.

Finally, the study discusses different interpretations of a FRAND license for 5G SEPs. The study concludes that current litigation on SEPs shows that many issues such as who will have to get a license, the OEM (Original Equipment Manufacturer) or the supplier, will the license be based on a component or a final product and will the license be a fixed rate or a percentage of the component or on the final product's net selling price, are still open for discussion.

1. Introduction

Patents that describe a claim that is essential for any implementation of a standard are called Standard Essential Patents (SEPs). The licensing of SEPs has increasingly led to litigation in recent years. The legal interpretation of the licensing conditions is not always clear, and the IP bylaws of the standard organizations often describe different requirements. Situations in which a patent is infringed during the implementation of a standard pose complex legal challenges for courts, public authorities and standard organizations. Within this legal framework, there are multiple political, academic and industry discussions around whether patents in standards promote innovation or represent a hindrance for the development of new technologies and products. If a company is involved in the standards development of a technology, it explicitly states to license any SEPs to third parties. To prevent the patent holder from demanding monopoly prices, however, licensing is subject to so-called FRAND (Fair, Reasonable and Non-Discriminatory) conditions. SEPs for standards such as WiFi, 3G or 4G mainly concern products from the information and communications industry. In contrast to 3G and 4G, the new 5G standard is likely to be applied much more widely and will also affect industries such as the automotive, manufacturing industries, energy or healthcare sectors. This study analyses patents as well as patent applications that have been declared essential for the 5G standards specification published by the European Telecommunications Standards Institute (ETSI). Not all declared SEPs are actually essential. According to the statutes of the standard organizations, companies should declare all such applications and patents under FRAND that could potentially be essential, even if the standard has not yet been finally specified. In this study, the 5G standard is defined according to the technology classification of the 3GPP (The 3rd Generation Partnership Project), the standardization group that develops the 5G standard. 3GPP lists all technical specifications that can be assigned to the 5G generation (see Appendix 1). SEPs are declared for certain technical specifications and standard projects. The list of 5G specification numbers from the 3GPP database serves to identify all 5G declared SEPs of the ETSI database and forms the core data for this study.

2. The interplay of patents and 5G technology standards

2.1. 5G and the Internet of Things (IoT)

In June 2018, the 3GPP consortium released the first version of the 5G standard (Release 15)[6]. In April 2019 the first 5G networks were released. The 5G standard specification is an important step in the further development of the next generation of telecommunications networks. However, it cannot be assumed that research and development on 5G will be completed with the completion of the first 5G specifications. On the contrary, the technological development of 5G has only just begun and, with the 5G Release 16, will be relevant for new applications such as autonomous driving, smart factories or remote surgeries in the healthcare sector. Over the next few years, further research activities will drive 5G technology development to create a connected world of device, human and machine interaction. 5G will enable inventions of new

[6] https://www.3gpp.org/images/articleimages/2019_NR_schedule_late_drop_pic3.jpg

products and services, increase productivity and create whole new business models. In the case of the IoT, the 5G standard will connect physical and virtual objects by connecting devices, vehicles, buildings and other objects with electronics, software or sensors. Embedded 5G technologies will, for example, enable machines or cars to exchange information yielding a direct integration of the physical world into computer-based systems. The interconnectivity of different systems and communication across multiple devices is based on the common specification of 5G standards.

2.2. The interplay of patents and standards

Information and communication technology (ICT) markets are characterized by short product life cycles and rapid technology development. ICT products are often technically interdependent or function indispensably together. Technology standards are fundamental for communication between ICT-controlled systems. Standards specify a common language so that different technologies or technology components can communicate and interact with each other. Standardized technologies of the 5th generation of telecommunications technology will make an important contribution to the network technologies. As technology becomes more complex SEPs will increasingly be integrated into new systems that enable communication between different technologies (Blind & Pohlmann 2016; Pohlmann, 2018a). Patents are intended to provide incentives for investment in research and development. Standards serve as a common platform so that technological innovations can function together. Patenting and standardization thus promote innovation jointly, but in very different ways. The aim of standardization is to disseminate and gain access to technologies (Blind & Pohlmann 2014). Standardized technologies are to be adapted worldwide so that innovative solutions work together on a common standardized platform. Patents, on the other hand, grant the holder of the intellectual property right a temporary monopoly on a technology in order to exclude third parties from its use. While standards aim at broad application, patents prevent the use of the technology by anyone but the patent owner (Blind & Pohlmann 2016). Standardization organizations and antitrust authorities have solved the problem as follows: In the view of antitrust law, the licensing of a patent where the claims are essential to a standard is considered to be its own isolated market. (Blind & Pohlmann, 2014). Since a patented standardized technology cannot be used without infringement of the patent, the patent holder holds a monopoly position for this technology. If a company participates in the standards development of a technology, it must commit to license these patents. To prevent the patent holder from demanding monopoly prices, however, licensing is subject to so-called FRAND (Fair, Reasonable and Nondiscriminatory) conditions (Blind & Pohlmann, 2014). In recent years, the different views on licensing under FRAND have increasingly led to court disputes and have been the subject of lively debates between market observers, political decision-makers and regulatory authorities (Pohlmann, 2018). Survey results show that companies feel a certain legal uncertainty regarding the licensing of SEPs (Blind & Pohlmann, 2014b). In particular, the lack of transparency about truly essential patents, the definition of FRAND, and the legal handling of patent enforcement were seen as problematic (Blind & Pohlmann, 2014).

2.3. The importance of SEPs for small and medium-sized enterprises (SMEs)

SMEs in particular are often unaware that the integration of open standard specifications may involve the use and infringement of SEPs. As an example, one could imagine a small company -a startup- that develops an intelligent smart home device that communicates with smartphones via W-LAN and 4G/5G constantly sending information to the cloud. In this example the standards W-LAN (802.11) as well as 4G/5G are covered by tens of thousands of globally active and granted patents. When such a start-up grows into a globally active company with million-dollar revenues, patent owners will demand royalties for the SEPs. However, the reasonable royalty for SEPs is not explicitly regulated or even transparent. Especially when patent owners or patent assertion entities threaten an injunction, companies are often forced to act quickly. Disproportionately high license fees can thus be imposed, which could have a negative impact on the growth and innovative clout of small and medium-sized enterprises. However, the use of standards (e.g. W-LAN, 4G/5G) is necessary for the competitiveness of the start-up described. In order to be able to prevent these situations, it is particularly important for small companies to identify possible use of SEPs at an early stage. Small and medium-sized enterprises often lack an overview of which companies hold SEPs and how these portfolios should be financially evaluated. In order to estimate a relative license, the total number of active and valid worldwide SEPs for certain standard specifications must be analyzed. Furthermore, public court decisions, public license terms of license pools or statements by large SEP holders can serve as a reference for the expected license levels.

The aim of this study is to inform and bring awareness to national and European policy makers as well as companies from different industries in Germany and Europe to the topic of SEPs in the area of 5G. In the course of a fact-based analysis, the study should create transparency about the occurrence of declared 5G patents.

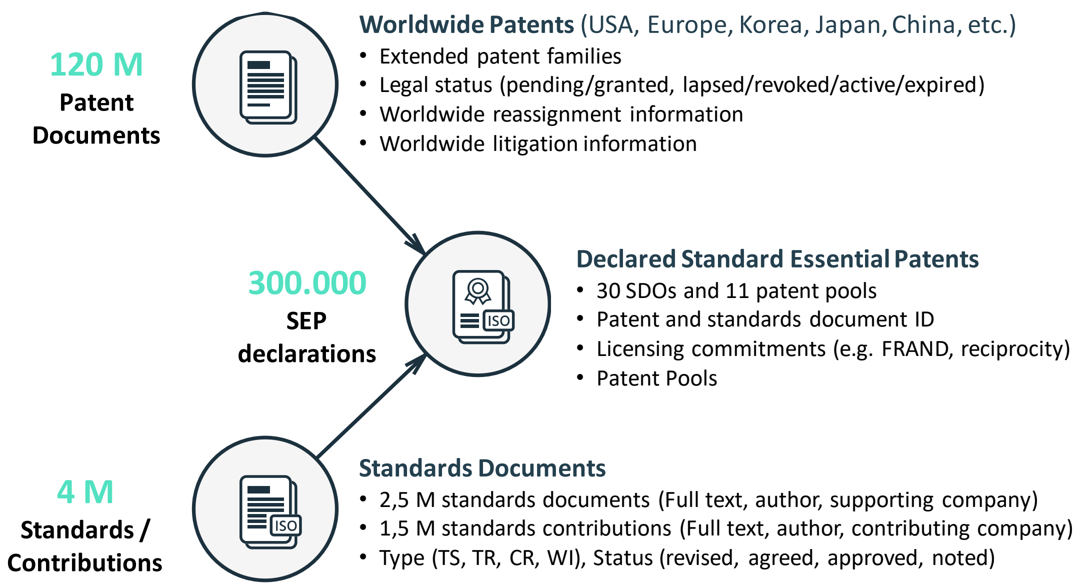
3. The landscape of patents declared to the 5G standard

3.1. Method of retrieving and correlating data on 5G patents

The quantitative investigation of this study analyses 5G relevant patent declarations published by ETSI. The standardization organization ETSI publishes patent declarations via a publicly accessible database (https://ipr.etsi.org). ETSI has statutes which state that every company involved in standardization is required to declare patent applications and granted patents as essential if they are, to the best of its knowledge and belief, essential for the implementation of a standard. The selection of relevant patents is based on the technical knowledge of the company, which makes a FRAND declaration in the course of a public patent disclosure and thus commits to license all declared applications and patents that are standard essential under FRAND. Standard organizations do not check whether the claims of the declared patent documents are essential for every implementation of a standard, i.e. whether they are standard essential (Pohlmann, 2016). Individual 5G declarations cannot legally be understood as proof of actual SEPs. Nevertheless, patent declarations are usually the only comprehensive and systematic source of information available for the analysis of 5G relevant patents. Patent declarations provide meaningful information that has already been used in several empirical studies in the past (Pohlmann & Blind, 2017; Baron & Pohlmann, 2018). Some studies have shown that although the ETSI database contains likely all essential patents, there are patents which are not essential for the implementation of the standard (Pohlmann & Blind, 2017).

The retrieval of information from declaration databases poses a challenge because the structure of declarations is not harmonized, application and patent numbers have different formats, and some numbers are subject to typos and mistakes. Company representatives typically submit a declaration form, which in some cases is handwritten. The declaration form is partly published as a PDF scan or imported into the digital format of the standardization organization's database. Patent declarations usually include a patent or application number, or a provisional number issued by the patent offices but not published. Patent declarations also include a standard specification number ("Technical Specification (TS)") and/or information on the standard project, as well as information on the company and the license commitment. Further information on the patent, such as title, abstract, description, patent claims, priority date, application or publication date, status (expired, abandoned , active), grant status (if the patent is already granted or still in application status), first applicant company, current owner company (if the patent is or has been sold), patent family (applications in other countries), inventor, patent classification (IPC/CPC), forward and backward citations or citations to non-patent literature, are not included in the patent declarations and must be obtained from third party patent databases. The IPlytics Platform[7] was used to link the declarations with the listed patent information described above. In addition to the ETSI patent declarations, IPlytics Platform also integrates patent data from other organizations such as the Institute of Electrical and Electronics Engineers (IEEE), the International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC), the International Telecommunication Union (ITUT), the Internet Technology Working Group (IETF) and many others (Figure 1).

Figure 1: IPlytics Platform database correlating full text world-wide patent data, patent declaration data and standards document data



[7] https://www.iplytics.com

IPlytics Platform is a full-text database that integrates worldwide patent documents with bibliographic information from worldwide patent offices as well as information on worldwide patent reassignments, worldwide patent litigation as well as declarations and standard documents in full text. Patent documents that are not originally available in English, such as Chinese, Japanese or Korean patent specifications, are automatically translated into English using the "Patent Translate Algorithm"[8]. Thus, all worldwide declarations can also be examined with regard to the patent's content. The IPlytics database combines documents from various patent offices that describe an invention into a so-called patent family. The technical documents of the first patent application are called priority documents. A group of patent documents that refers to the same priority documents is called a patent family. The grouping of patent families is based on the definition of the INPADOC[9] patent family. The term extended 'INPADOC patent family' groups together all patent documents that are directly or indirectly linked to a specific priority document. In the example below (Table 1), documents D1 to D5 belong to the same patent family, P1. National application numbers, international application numbers and domestic relations (e.g. divisional applications, renewals and partial renewals, etc.) are included in the family.

Table 1: Definition of INPADOC patent family

Patent Document	Associated Priority Document		
Document D1	Priority P1		
Document D2	Priority P1	Priority P2	
Document D3	Priority P1	Priority P2	
Document D4		Priority P2	Priority P3
Document D5			Priority P3

Patent declarations can refer either to a specific technical specification (TS) or to a standard project. The 5G standard alone refers to more than 554 different TS numbers that are summarized in different releases (see Appendix 1). The TS numbers belonging to the 5G standard project are not included in the ETSI patent declarations, but must, as shown in Figure 1, be obtained from the data of the standardization organization and in this case 3GPP. The 3GPP consortium is responsible for the development of the 5G standard specifications and defines which specification numbers belong to the 5G standard (see Appendix 1 and 2).

The combination of patent declarations with the bibliographic and content information of the patent documents in combination with 3GPP specifications enables declared applications and patents that relate to 5G to be easily searched, identified and analyzed. The method of how to identify 5G patents and standards contributions was discussed and verified by an invited group of patent and standards industry experts that supported this study with technical expertise.

[8] Find more information under: https://worldwide.espacenet.com/help?locale=en_EP&method=handleHelpTopic&topic=translation
[9] INPADOC, which stands for International Patent Documentation, is an international patent collection.

3.2. Empirical analysis of declared 5G patents and patent applications

The data for the analysis of 5G patents is based on the following criteria:

- The analysis takes into account all patent declarations published at ETSI up until 1 January 2020 and classified as 5G relevant.
- Patent declarations were classified as 5G relevant if the Technical Specifications (TS) of the declaration were marked as 5G technology by the 3GPP (see Appendix 1 and 2).
- All specifications marked as 5G technology are considered. This includes specifications marked for several standard generations, such as combinations of 4G and 5G or even 3G and 5G.
- Patent declarations were also classified as 5G relevant if the project description of the declaration contained information for standard projects describing "New Radio" or "5G".
- Since patent applications and patents across standard generations can be essential, patent declarations previously declared for 2G, 3G or 4G and now again declared for 5G were also considered.

The analysis of all patent applications and granted patents relevant for the 5G standard as of January 2020 resulted in:

- **95,526 5G declarations** (unique patents or patent applications).

Utility models were excluded from the analysis and therefore not considered, but they only concern 0.08% of all 5G declarations. Yet unpublished provisional application numbers (e.g. US Provisionals) were also not included in the analysis but concern only 0.15% of all 5G declarations. If the 5G declarations are grouped together as patent families, the INPADOC family definition results in a total of:

- **21,571 declared 5G families** (both families granted, and families not granted were counted).
- **98%** of these declared 5G families are living families, i.e. at least one registration or grant of the family has neither expired nor abandoned or rejected.
- **78%** of these declared 5G families have been registered at least at one of the following patent offices: European Patent Office (EPO), U.S. Patent Office (USPTO) or under the WIPO PCT procedure.
- **44%** of these declared 5G families include an application that has already been granted as a patent by at least one patent office.
- **24%** of these declared 5G families have already been declared to previous standard generations (2G, 3G or 4G) and are now also declared to 5G.
- **98%** of these declared 5G families were declared to be specifications classified by 3GPP as pure 5G specifications and did not describe combinations of 2G, 3G, 4G and 5G.

Table 2 shows the number of declared 5G families per company for companies that have declared ten 5G families and above. Company names were harmonized and grouped into company group structures (subsidiaries were assigned to the parent groups). Confirmed acquisitions such as Nokia's acquisition of Alcatel-Lucent were also taken into account.

The Chinese technology company Huawei has the largest portfolio with 3,147 declared 5G families, followed by Samsung (KR), ZTE (CN), LG (KR), Nokia (FI) and Ericsson (SE) (first column). Samsung is the strongest applicant if one counts only declared 5G families that have been filed at least with the EPO, USPTO or through the PCT[10] procedure (second column). The top 10 declaring companies together hold 82% of all submitted 5G declarations. These figures indicate that in the future there will probably be a small number of companies holding the vast majority of 5G patents.

If only the families declared as 5G that have been granted a patent by at least one office are counted, Samsung, LG and Nokia hold the most 5G families (column 3). The Chinese patent owners Huawei, ZTE, CATT, Vivo and OPPO hold a relatively small number of issued patents that have been declared as 5G. However, it must be kept in mind that the grant of a patent takes several years. Analysis of the lower portion of the study show that Chinese companies have declared very young 5G families, i.e. they have only recently applied for them. It often takes several years before a patent office grants a patent and one can assume that some of the 5G families filed by the Chinese will be granted in the near future.

[10] PCT – The International Patent System. The Patent Cooperation Treaty (PCT) assists applicants in seeking patent protection internationally for their inventions, helps patent Offices with their patent granting decisions, and facilitates public access to a wealth of technical information relating to those inventions.

Table 2: Number of declared 5G patent families by declaring company[11]

Declaring company	Number of 5G patent families (INPADOC)	Thereof filed at least the at the USPTO, EPO or PCT	Thereof at least granted in one office
Huawei Technologies (CN)	3,147	2,342	1,274
Samsung Electronics (KR)	2,795	2,633	1,728
ZTE Corporation (CN)	2,561	1,878	837
LG Electronics (KR)	2,300	2,236	1,415
Nokia (incl, Alcatel-Lucent) (FI)	2,149	2,074	1,584
Ericsson (SE)	1,494	1,461	768
QUALCOMM (US)	1,293	1,210	831
Intel Corporation[12] (US)	870	855	148
Sharp Corporation (JP)	747	706	449
NTT Docomo (JP)	721	642	346
Guangdong Oppo M, Telec, (CN)	647	612	36
China Aca, Of Telec, Tech, - CATT (CN)	570	353	71
InterDigital Technology (US)	486	455	299
Vivo Mobile (CN)	238	168	0
BlackBerry (CA)	139	136	132
NEC Corporation (JP)	122	115	82
ASUSTeK Computer (TW)	111	102	34
Lenovo Group Limited (CN)	97	97	22
HTC Corporation (TW)	93	94	43
KT Corporation (KR)	85	74	15
Apple (US)	77	72	48
ETRI (KR)	61	48	20
Fujitsu (JP)	58	18	54
Motorola Mobility (US)	55	54	49
MediaTek (TW)	38	38	29
WILUS Group (KR)	33	20	2
Panasonic (JP)	32	30	8
FG Innovation (CN)	30	30	4
Sony Corporation (JP)	17	17	18
ITRI (TW)	14	13	12
SK Telecom (KR)	11	8	0
Spreadtrum Communications (CN)	10	8	5

Figure 2 shows the number of patent families (granted as well as non-granted patent applications) by country of the corporate headquarters of the patent owner of 5G declarations. The figure shows that more than every third 5G declaration comes from a Chinese company.

[11] The 5G SEP Analysis was carried out on January 1st, 2020 and does not take into account SEP declarations published thereafter.
[12] As to several media sources, Intel's wireless patent portfolio was acquired by Apple.

Korean companies with 27.07% are ahead of European companies with 16.98% and US companies with 14.13% or Japanese companies with 8.84%.

Figure 2: Declared 5G families (granted or pending applications) per country of the corporate headquarters of the patent holder.

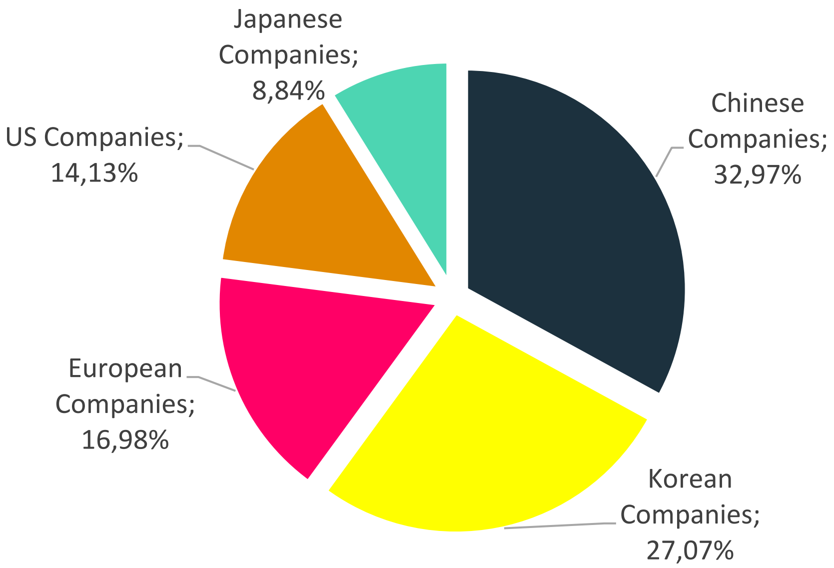


Table 3 aggregates the number of 5G families (both granted and non-grant patent applications) by country of origin of the patent holder. The results show that only just over 73% of the 5G families declared by Chinese companies have been filed internationally and only around 25% have already been granted by at least one patent office. This means that Chinese companies have by far the lowest grant rate and do not register as internationally as Koreans, Europeans, Americans or Japanese. European companies have the highest grant rate with just over 66%, followed by Korean companies with over 62% and Japanese companies with over 50%. European companies have registered over 91% of all 5G families either with the EPO or the USPTO or through the PCT procedure. Slightly lower but similarly high percentages are found in Korean, US and Japanese companies.

Table 3: Declared 5G families by country of origin of the patent owner

Country of origin of the patent owner	**Declared 5G families**	**Thereof filed at least the at the USPTO, EPO or PCT**	**Thereof at least granted in one office**
Chinese Companies	6,234	73.74%	25.57%
Korean Companies	5,119	89.65%	62.63%
European Companies	3,211	91.25%	66.33%
US Companies	2,591	87.96%	44.31%
Japanese Companies	1672	83.31%	50.06%

Table 4 shows at which patent offices the declaring companies (Top 20) have filed their 5G families. The percentage per patent portfolio filed with a patent office was measured. The results of the table show that Chinese companies with their 5G declarations have so far concentrated primarily on the Chinese Patent Office and the PCT procedure. In Europe, Japan or Korea, Chinese companies register very few 5G declared families. Overall, the PCT application is the most popular, followed by US applications and applications to the EPO.

Table 4: Percentage of 5G family applications at the respective patent office

Declaring Company	US	KR	WO	CN	EP	JP
Huawei Technologies (CN)	53.46%	8.72%	61.74%	73.54%	34.58%	10.79%
Samsung Electronics (KR)	100.00%	74.53%	72.70%	56.16%	51.47%	33.04%
LG Electronics (KR)	100.00%	53.40%	90.97%	48.51%	48.60%	34.15%
Nokia (incl. Alct.-Lucent) (FI)	90.48%	30.91%	77.49%	53.10%	77.27%	31.82%
ZTE Corporation (CN)	12.74%	2.94%	73.64%	91.01%	8.06%	4.50%
Ericsson (SE)	97.39%	12.91%	80.67%	42.99%	58.13%	26.94%
QUALCOMM (US)	100.00%	67.25%	86.17%	76.95%	82.59%	88.47%
Intel Corporation[13] (US)	57.84%	15.35%	90.21%	33.70%	21.91%	13.68%
Sharp Corporation (JP)	93.12%	6.15%	73.82%	55.49%	48.61%	70.08%
NTT Docomo (JP)	58.63%	18.04%	82.58%	50.54%	52.41%	61.59%
CATT (CN)	13.31%	3.92%	57.51%	75.43%	11.60%	2.56%
Guangdong Oppo (CN)	58.73%	51.06%	88.10%	55.56%	9.52%	46.83%
InterDigital Technology (US)	100.00%	100.00%	77.24%	79.13%	73.17%	100.00%
Vivo Mobile (CN)	4.66%	4.66%	87.05%	99.48%	0.00%	4.66%
ASUSTeK Computer (TW)	93.04%	52.17%	0.00%	49.57%	64.35%	41.74%
Lenovo Group Limited (CN)	100.00%	58.54%	82.93%	69.51%	67.07%	52.44%
NEC Corporation (JP)	100.00%	74.07%	81.48%	100.00%	96.30%	100.00%
BlackBerry (CA)	100.00%	55.13%	69.23%	70.51%	100.00%	53.85%
KT Corporation (KR)	38.36%	93.15%	41.10%	24.66%	1.37%	0.00%
Fujitsu (JP)	90.00%	48.33%	13.33%	36.67%	40.00%	58.33%
ETRI (KR)	57.63%	79.66%	37.29%	10.17%	5.08%	1.69%
Apple (US)	100.00%	51.06%	29.79%	34.04%	25.53%	19.15%
HTC Corporation (TW)	100.00%	39.29%	3.57%	100.00%	100.00%	67.86%
MediaTek (TW)	100.00%	0.00%	100.00%	100.00%	100.00%	4.17%
Sony Corporation (JP)	100.00%	47.83%	52.17%	100.00%	100.00%	100.00%

Figure 3 shows the proportion of declared 5G families by country of first filings. Most 5G declarations are first filed in the US (22.95%) followed by the European Patent Office (15.5%) and applications through the PCT procedure (14%) and applications in China (13.48%). Only about 0.34% of all patents declared for 5G are filed in the first instance at the German Patent and Trademark Office (DPMA). Since the standardization work of the 3GPP is carried out

[13] As to several media sources, Intel's wireless patent portfolio was acquired by Apple.

exclusively in English and is also published via English specifications, an initial application to non-English European office is quite rare.

Figure 3: Share of first filings of declared 5G patents by patent office

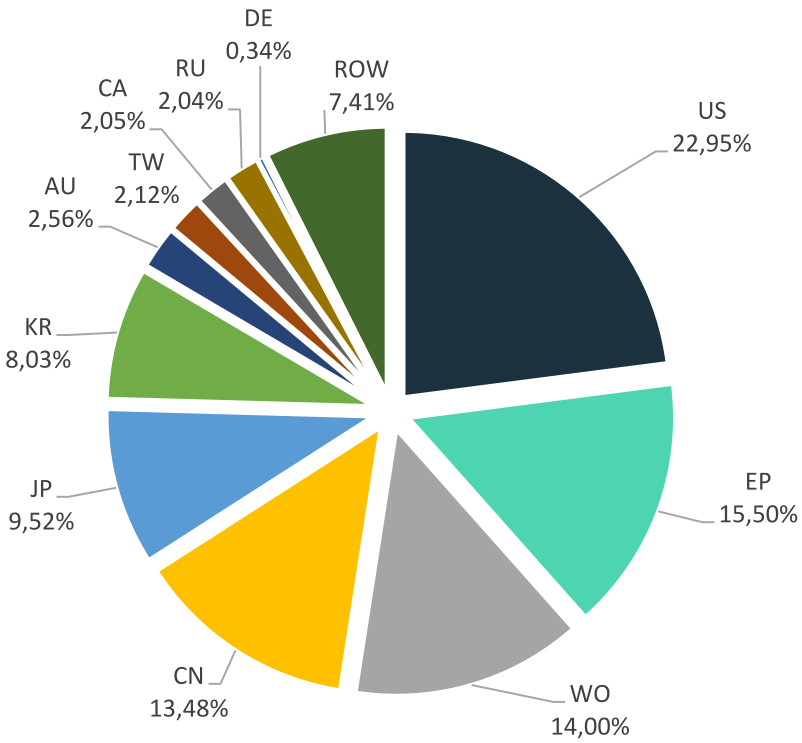


Figure 4a shows the number of declared 5G families counted by year of first priority, year of first application and year of first publication. Since patent applications are usually published 18 months after filing, a truncation for the years 2018 and 2019 must be considered. However, if the year of publication is considered, the number of declared 5G families increased sharply, especially in 2017, 2018 and 2019 a further increase is expected for the upcoming years. Figure 4b shows the number of declared 2G, 3G, 4G and 5G families by year of declaration. The figure shows that the total number of patent declarations has increased sharply since 2015 and will probably continue to do so in the upcoming years. It is interesting to note that even in 2018 and 2019 patents are still declared as 2G and 3G. Since 2018, most patent declarations have been declared as 5G. One has to keep in mind that the figure counts redeclared families for each standard generation, in other words a patent family declared to 4G and 5G is counted twice, once for each standard generation.

Figure 4a: Number of declared 5G families counted by year of first priority, year of first application and year of first publication

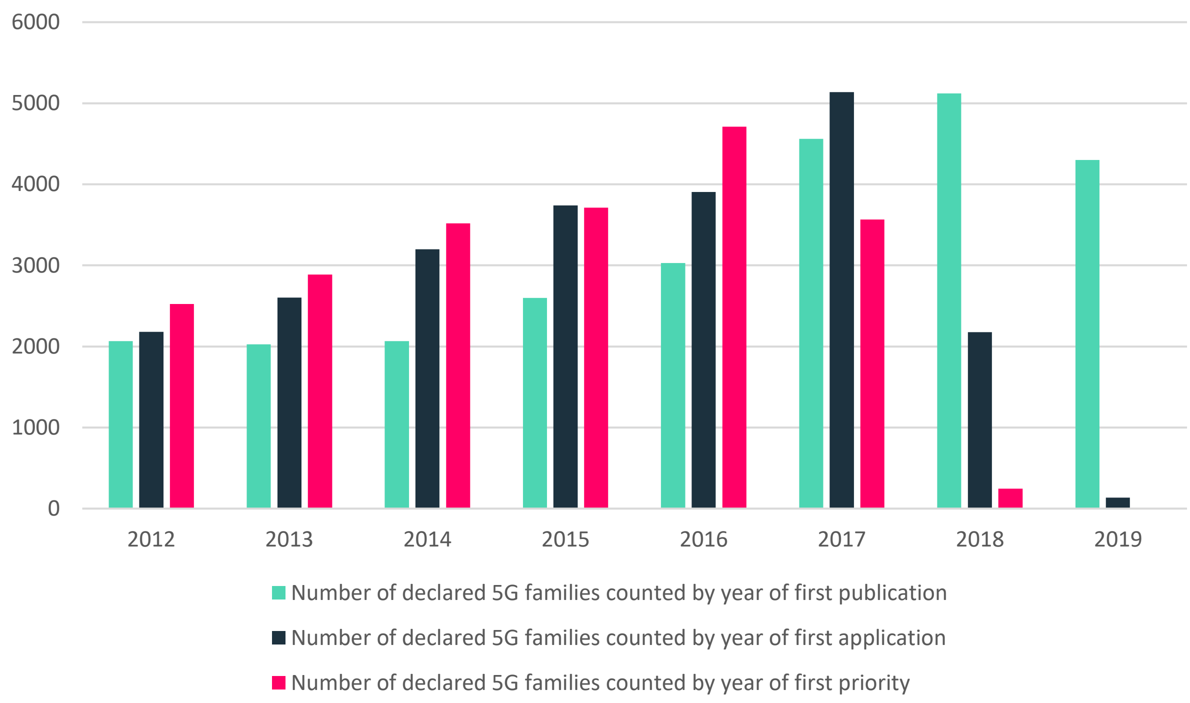
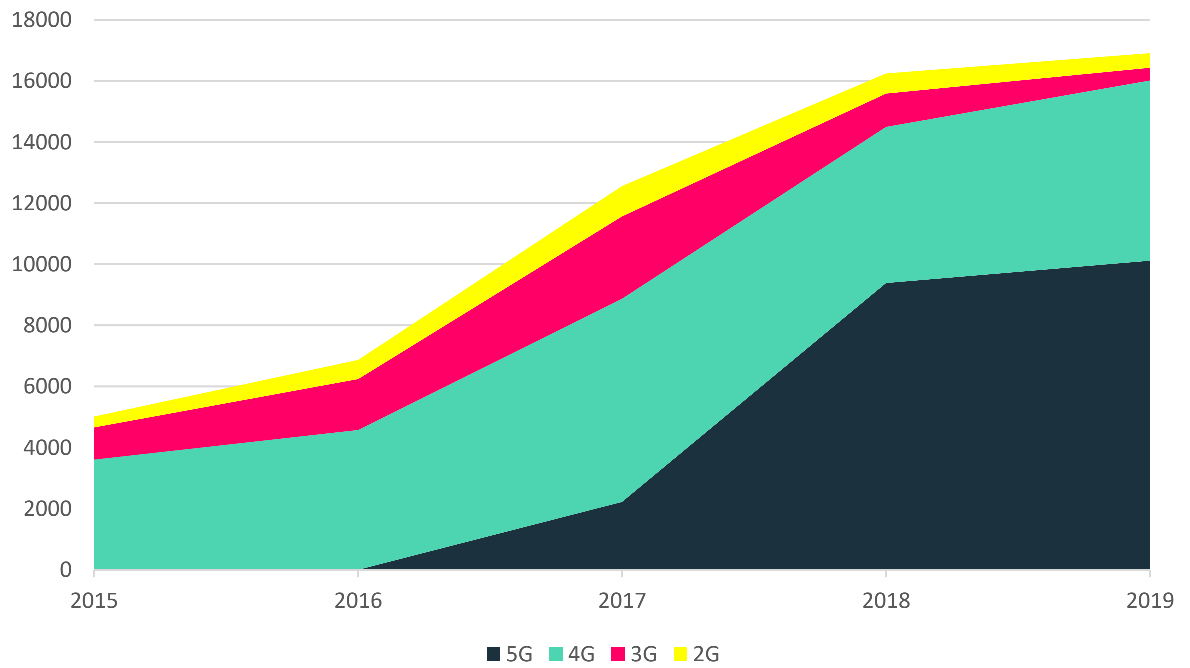


Figure 4b: Number of declared 2G, 3G, 4G and 5G families



3.3. Comparison of 4G and 5G declared patent portfolios

Table 5 shows the percentage of declared 5G families (both granted and non-granted patent applications) compared to 4G declared families (both granted and non-granted patent applications). The 4G declarations were identified by the same method using the technology specification of the 3GPP specifications (see Appendix 2). For 4G and 5G declarations, the proportion of company declarations by number of families was compared with the total number of 4G and 5G declarations to calculate a percentage and illustrate the differences between the two generations of 4G and 5G.

The comparison of 4G to 5G shows that Huawei declared 14.61% of all 5G families, which is 4.62 percentage points higher than declarations made for 4G (9.99%). Samsung, LG and ZTE also made a big leap from 4G to 5G. Nokia also has a larger share at 5G compared to 4G, just like Ericsson and Intel. Vivo (CN), OPPO (CN), ASUSTek (TW), FG Innovation (CN) and Spreadtrum Communications (CN) had no or hardly any families declared for 4G and are therefore new to the 5G market. The table counts all families of the standard generations 4G and 5G. Declarations of families made for both generations were also double counted for both generations. There may therefore be cases where companies declare a patent family first as 4G and then also as 5G. The figure also shows that so far only a few network operators, such as Deutsche Telekom, Vodafone, NTT Docomo or Orange, that submitted 5G declarations also submitted 4G declarations However, experts believe that due to the higher levels of downstream development of the 5G standard, in which network operators in particular are involved, 5G declarations from network operators should still be expected.

Table 5: Share of 4G and 5G declared families by declaring company

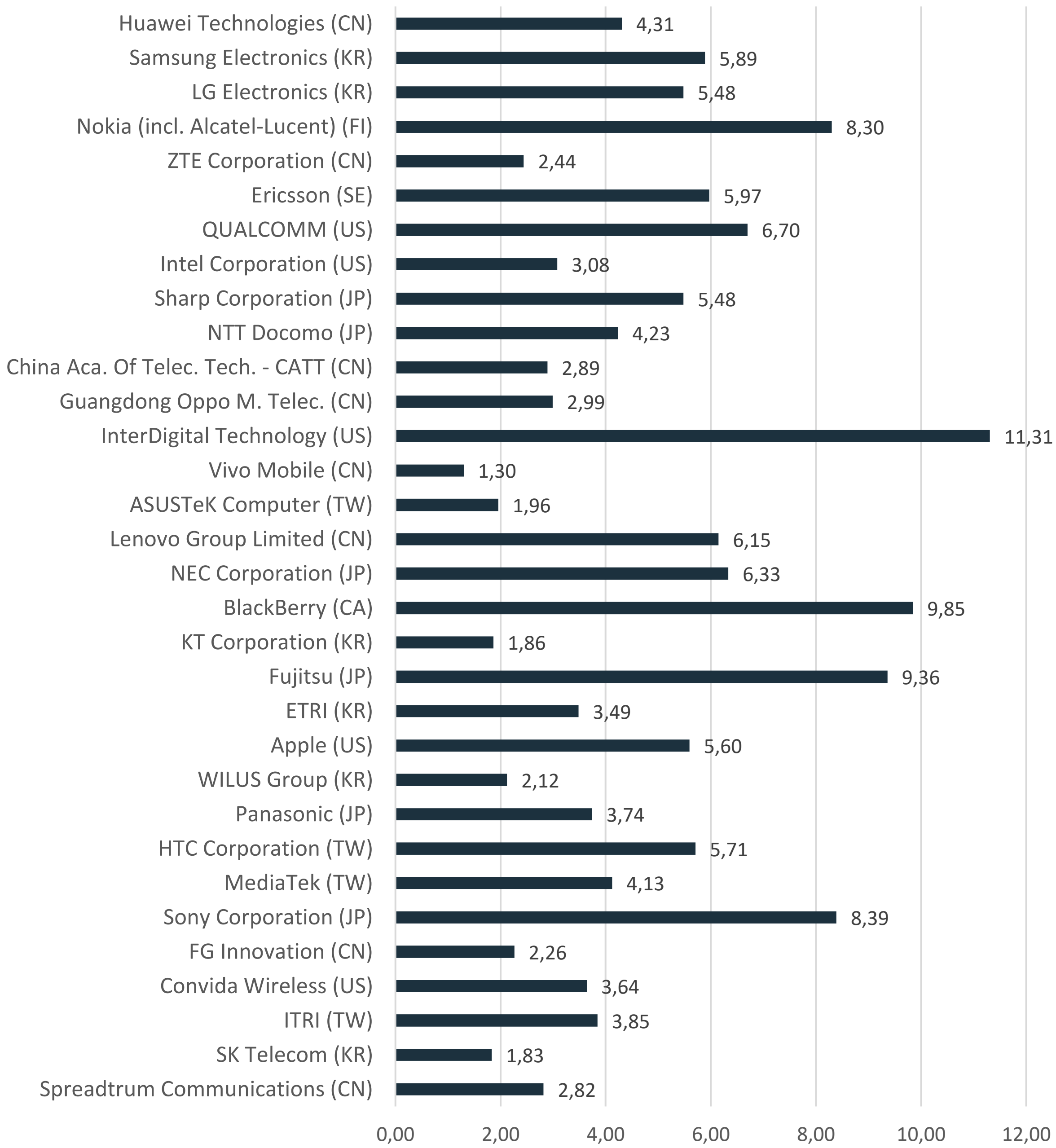
Declaring company	5G Share	4G Share	4G vs. 5G difference
Huawei Technologies Co., Ltd.	14.61%	9.99%	4.62%
Samsung	12.98%	10.92%	2.06%
ZTE Corp.	11.89%	7.22%	4.67%
LG Electronics	10.68%	10.97%	-0.29%
Nokia Group	9.98%	7.59%	2.39%
Telefonaktiebolaget LM Ericsson	6.94%	5.80%	1.14%
QUALCOMM Incorporated	6.00%	7.84%	-1.84%
Intel Corporation[14]	4.04%	2.37%	1.67%
Sharp Corp	3.47%	3.59%	-0.13%
NTT DOCOMO, Inc.	3.35%	3.66%	-0.31%
Guangdong Oppo Mobile Telecommunications	3.00%	0.39%	2.61%
CATT Datang Mobile	2.65%	3.72%	-1.07%
InterDigital	2.26%	3.38%	-1.12%
Vivo Mobile Communication Co. Ltd.	1.11%	0.00%	1.11%
BlackBerry	0.65%	0.78%	-0.13%
NEC Corporation	0.57%	1.73%	-1.17%
ASUSTeK Computer, Inc.	0.52%	0.11%	0.41%
Lenovo	0.45%	0.16%	0.29%
HTC Corporation	0.43%	0.70%	-0.27%
KT Corp.	0.39%	0.53%	-0.14%
Apple Inc.	0.36%	1.34%	-0.98%
Electronics And Telecommunications Research In.	0.28%	2.28%	-1.99%
Fujitsu Limited	0.27%	1.75%	-1.48%
Google Motorola	0.26%	1.98%	-1.72%
MediaTek Inc.	0.18%	0.39%	-0.21%
Wilus Institute Of Standards And Technology Inc.	0.15%	0.15%	0.01%
Panasonic Corporation	0.15%	1.51%	-1.36%
Fg Innovation Company Limited	0.14%	0.02%	0.12%
Sony	0.08%	1.15%	-1.07%
Industrial Technology Research Institute	0.07%	0.20%	-0.13%
SK Telecom	0.05%	0.06%	-0.01%
Spreadtrum Communications (Shanghai) Co., Ltd.	0.05%	0.00%	0.04%

[14] As to several media sources, Intel's wireless patent portfolio was acquired by Apple.

3.4. Analysis of 5G declared patent family age and value

Figure 5 shows the age structure of the declared 5G families for each company. To calculate the age structure, the average age (measured by the year of the first registration) of the declared 5G families per company was calculated. The analysis shows that companies such as Nokia, Qualcomm, InterDigital or Blackberry have declared 5G families that are already relatively old (8-11 years). New and recently filed patent portfolios are held by the Chinese companies ZTE, CATT, Vivo or OPPO. Intel and Huawei also have very young portfolios. A comparison of these figures with the grant rates from Table 1 shows a clear correlation between the age of the patent families and a high grant rate. One can therefore assume that some of the 5G families of the Chinese companies are still being granted.

Figure 5: Average age of the 5G portfolios



The 3GPP consortium did not start developing the first specifications for the 5G standard until 2015. Even though research and development on the new 5G technologies began several years before standardization began, many of the engineers active in 3GPP believe that new 5G inventions are unlikely to have emerged before 2012.

Table 6: Declared 5G families by priority date after 2012, declared only to 5G and to user equipment relevant specifications

Declaring company	Prio. date after 2012	Not declared to 2G 3G or 4G	In UE relevant groups
Huawei Technologies (CN)	2,618	2,839	3,000
Samsung Electronics (KR)	1,877	1,855	2,778
ZTE Corporation (CN)	1,994	2,564	2,494
LG Electronics (KR)	1,644	1,798	2,251
Nokia (incl, Alcatel-Lucent) (FI)	1,010	1,764	1,990
Ericsson (SE)	1,046	1,042	1,388
QUALCOMM (US)	822	879	1,270
Intel Corporation[15] (US)	834	846	852
Sharp Corporation (JP)	550	585	746
NTT Docomo (JP)	538	635	696
Guangdong Oppo M, Telec, (CN)	614	647	648
China Aca, Of Telec, Tech, - CATT (CN)	561	565	565
InterDigital Technology (US)	256	354	470
Vivo Mobile (CN)	238	238	238
BlackBerry (CA)	18	76	131
NEC Corporation (JP)	70	96	104
ASUSTeK Computer (TW)	109	111	111
Lenovo Group Limited (CN)	81	82	95
HTC Corporation (TW)	70	78	89
KT Corporation (KR)	84	84	79
Apple (US)	37	62	61
ETRI (KR)	50	58	61
Fujitsu (JP)	25	21	50
Motorola Mobility (US)	0	24	42
MediaTek (TW)	37	38	38
WILUS Group (KR)	33	33	33
Panasonic (JP)	28	29	32
FG Innovation (CN)	29	30	30
Sony Corporation (JP)	2	5	16
ITRI (TW)	10	14	12
SK Telecom (KR)	11	11	11
Spreadtrum Communications (CN)	10	10	10

[15] As to several media sources, Intel's wireless patent portfolio was acquired by Apple.

The first column of Table 6 counts 5G declared patent families with the earliest priority date after 2012. As to interviews with engineers from 3GPP, it is assumed that the main inventions for 5G technologies came about in the years following 2012. The counts of 5G declarations with a priority date after 2012 show a leading position for Huawei, followed by Samsung, LG and ZTE. Only 47% of all declared 5G patent families from Nokia have a priority date after 2012. Also, the 5G portfolios of Qualcomm (61% of the 5G declarations after 2012) and Ericsson (65% of the 5G declarations after 2012) show lower counts for 5G patent families with a priority date after 2012. In comparison, ZTE or CATT and Intel have declared 5G patents that have been invented mostly after 2012 (i.e. within the time period that is considered the most likely to include new 5G inventions).

In addition, IPlytics identified declared 5G patent families where at least one patent had already been declared to previous standards generations such as 2G, 3G or 4G (column 2). 90% of Huawei, 99% of ZTE, 96% of Intel and 93% of Sharp's declared 5G patent families have been solely declared to 5G. In comparison, Ericsson with a rate of 69% (declared only to 5G), Qualcomm's 70% and Nokia's 82% have also declared patents that were previously declared to 3G or 4G years before 5G was developed.

Finally, IPlytics counted 5G patent families declared to standards specification originating from groups RAN1, RAN2, RAN4, SA2, SA3, SA4 and CT1 that work on user equipment (UE), in comparison with groups that work on infrastructure technologies (e.g., RAN3). Again, Huawei declared the largest UE relevant 5G portfolio and the order of rank looks very similar to the overall declared number of 5G patent families.

Table 7 shows 5G declarations measured by the normalized number of forward citations and the normalized and weighted number of applied countries. In order to enable comparability of patent portfolios, all values are compared and standardized with average values from patent reference groups of the same country of application, publication year and IPC/CPC main class. Due to the uniform standardization, "benchmarking" of a patent portfolio with different ages can be carried out. All values are normalized to the average value of 1 and can be interpreted as follows:

- Values >1 reflect an above-average value of a patent portfolio compared to other patent portfolios of the comparison group.
- Values <1 reflect a below-average value of one patent portfolio compared to other patent portfolios of the comparison group.

The normalized number of forward citations is calculated using the number of "state of the art" citations received (as of January 2020), excluding self-citations. The number of citations is calculated individually for each patent document and then compared with patent documents from the same filing country, publication year and IPC/CPC main class. For example, if a patent document filed in Germany receives 6 citations from the publication year 2010 and the IPC/CPC main class H04W ("wireless communication networks"), this value is compared to the average value of all German patents from the publication year 2010 and the IPC/CPC main class H04W. For example, if this average value across all German, 2010, H04W patents is 3, the normalized value of forward citations based on 6 citations received is 2, since the patent document was cited twice as often as the average of all other comparable patent documents.

The value is then extrapolated to all 5G declared patent documents and aggregated to the respective patent portfolio.

A high number of normalized forward citations reflects a high technical relevance of the patent portfolio, since patent applications of other companies had to cite the patent portfolio as "prior art". Furthermore, a high normalized number of forward citations shows that the company restricts or even blocks the filing of other patents in the claims.

Table 7 shows, in the third column, that of the ten largest 5G portfolios, Intel, Samsung, InterDigital and Sharp have the highest averages of normalized forward citations. The declared 5G portfolios of the Chinese companies OPPO or Vivo have a very low average number of normalized forward citations. However, due to the normalization of the value above the annual average, the low values cannot be explained by the young age of the portfolio.

Table 7: Declared 5G patent families by average and normalized family size and forward citations

Declaring Company	Number of declared 5G patent families (INPADOC)	Average patent family size normalized by GDP	Average and normalized forward citations	Patent value index (citations x family size)
Huawei Technologies (CN)	3,147	1.45	0.59	0.85
Samsung Electronics (KR)	2,795	1.48	1.09	1.62
ZTE Corporation (CN)	2,561	1.40	0.96	1.35
LG Electronics (KR)	2,300	1.48	0.97	1.44
Nokia (incl. Alcatel-Lucent) (FI)	2,149	1.51	0.89	1.34
Ericsson (SE)	1,494	1.54	0.74	1.14
QUALCOMM (US)	1,293	1.81	0.64	1.16
Intel Corporation[16] (US)	870	1.69	1.25	2.12
Sharp Corporation (JP)	747	1.52	1.05	1.59
NTT Docomo (JP)	721	1.62	0.76	1.23
Guangdong Oppo M. Telec. (CN)	647	1.26	0.07	0.09
China Aca. - CATT (CN)	570	1.27	0.84	1.06
InterDigital Technology (US)	486	1.76	1.00	1.76
Vivo Mobile (CN)	238	1.53	0.03	0.04
BlackBerry (CA)	139	1.54	0.74	1.14
NEC Corporation (JP)	122	1.69	0.47	0.80
ASUSTeK Computer (TW)	111	1.53	0.69	1.05
Lenovo Group Limited (CN)	97	1.48	0.48	0.71
HTC Corporation (TW)	93	1.52	0.34	0.51
KT Corporation (KR)	85	1.11	0.55	0.61
Apple (US)	77	1.37	0.78	1.07
ETRI (KR)	61	0.95	1.39	1.31
Fujitsu (JP)	58	1.37	0.45	0.62
Motorola Mobility (US)	55	1.67	0.57	0.96
MediaTek (TW)	38	1.49	1.15	1.71
WILUS Group (KR)	33	1.18	0.49	0.58

[16] As to several media sources, Intel's wireless patent portfolio was acquired by Apple.

Panasonic (JP)	32	1.09	0.10	0.11
FG Innovation (CN)	30	1.67	0.47	0.79
Sony Corporation (JP)	17	1.12	0.52	0.58
ITRI (TW)	14	1.65	1.41	2.32
SK Telecom (KR)	11	1.32	0.10	0.13
Spreadtrum Communications (CN)	10	1.00	0.10	0.10

Furthermore, the normalized number of registered countries (weighted by country size measured by gross domestic product (GDP)) of a patent family was calculated. The number of countries the patent application was filed in reflects the value that the patent applicant assigns to his invention. A worldwide patent application as well as the maintenance of the patent is associated with high costs. The applicant therefore expects his invention to have a strong market relevance in several countries. An international application also shows the international strategy of the patent owner. The fact that a patent has been granted in many countries is also an indication of high validity. The weighting by country size reflects the international market potential. Table 7 in the second column shows that of the ten largest declared 5G portfolios, Intel and Qualcomm on average have the largest patent families. The Chinese companies CATT and OPPO have smaller values on average. The figures show that Chinese companies have so far concentrated primarily on the domestic market.

Multiplying the values of the normalized forward citations and the normalized patent family yields a patent valuation index. According to this index, Intel's 5G portfolio has the highest value. It is interesting to note that Intel recently sold exactly this 5G portfolio to Apple for an estimated one billion US dollars in the course of a larger transaction[17]. Also, high values can be attributed to the InterDigital and Panasonic 5G portfolio.

3.5. Analysis of declared 5G families by 3GPP group and per specification

Patent declarations are declared to technical specifications (TS). These specifications are developed by subgroups of 3GPP. Table 8 shows that the groups RAN1 and RAN2 have by far the largest number of declared 5G families.

Table 8: Declared 5G patent families per 3GPP subgroup

Group	**Description of the 3GPP subgroup**	**Declared 5G Families**
RAN1	Radio Layer 1 specification	12,932
RAN2	Radio Layer 2 and Radio Layer 3 RR specification	11,556
SA2	Architecture	1,650
RAN3	Iub Iur and Iu specification - UTRAN O&M requirements	1,506
CT1	MM/CC/SM (lu)	969
RAN4	Radio performance and protocol aspects	797
SA3	Security	378
SA1	Services	143

[17] https://www.apple.com/newsroom/2019/07/apple-to-acquire-the-majority-of-intels-smartphone-modem-business/

CT3	Interworking with external networks	138
SA4	Codec	127
SA5	Telecom Management	110
CT4	MAP/GTP / BCH/SS	101
SA6	Mission-critical applications	19
RAN5	Mobile terminal conformance testing	8
RAN6	Legacy RAN radio and protocol	1
CT6	Smart Card Application Aspects	1

To determine which 3GPP subgroups are most affected by patents, all 5G declarations have been counted by specification number as well as by the 3GPP subgroup. Declared 5G families can also be declared for several specifications and thus are also declared for several groups. If the two groups are added together and 5G declarations to both groups are only counted once (i.e. 5G families declared to both groups), a total of 17,618 declared 5G families can be assigned to either the RAN1 or RAN2 group. This number corresponds to more than 87% of the total number of 20,194 declared 5G families. RAN1 and RAN2 specify the so called "Layer 1" and "Layer 2" levels, while SA2 in comparison specifies the 5G architecture and is the subgroup with the third most declared 5G families.

Table 9 shows the top 20 TS for which most 5G declarations were counted. The 38 Series specifications count by far most declarations, followed by the 23 Series architectural specifications and the 37 Series connectivity specifications.

Table 9: Declared 5G families by standard specification

TS	Title	Group	Declared 5G Families
TS 38.213	NR; Physical layer procedures for control	RAN1	8,467
TS 38.331	NR; Radio Resource Control (RRC); Protocol specification	RAN2	8,404
TS 38.211	NR; Physical channels and modulation	RAN1	7,478
TS 38.214	NR; Physical layer procedures for data	RAN1	7,236
TS 38.212	NR; Multiplexing and channel coding	RAN1	6,141
TS 38.300	NR; Overall description; Stage-2	RAN2	4,645
TS 38.321	NR; Medium Access Control (MAC) protocol specification	RAN2	4,478
TS 38.322	NR; Radio Link Control (RLC) protocol specification	RAN2	1,865
TS 38.101	NR; User Equipment (UE) radio transmission and reception	RAN4	1,534
TS 23.501	System architecture for the 5G System (5GS)	SA2	1,119
TS 38.413	NG-RAN; NG Application Protocol (NGAP)	RAN3	946
TS 37.340	NR; Multi-connectivity; Overall description; Stage-2	RAN2	913
TS 38.323	NR; Packet Data Convergence Protocol (PDCP) specification	RAN2	896
TS 38.423	NG-RAN; Xn Application Protocol (XnAP)	RAN3	878
TS 38.215	NR; Physical layer measurements	RAN1	837
TS 23.502	Procedures for the 5G System (5GS)	SA2	739
TS 38.133	NR; Requirements for support of radio resource management	RAN4	624

TS 38.201	NR; Physical layer; General description	RAN1	557
TS 24.301	Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS); Stage 3	CT1	534
TS 38.473	NG-RAN; F1 Application Protocol (F1AP)	RAN3	519

3.6. Analysis of 5G standards contributions

Another approach for assessing the strength of 5G leadership is to analyze the involvement of companies in the development of the 5G standard. This approach is based on the assumption that the companies with the greatest influence on the 5G standard will also have the strongest 5G patent portfolios of the future. The development of the 5G standard is carried out in the 3GPP consortium, which has already successfully developed the 3G and 4G standards and is now specifying the 5G standard. 3GPP is contribution-based, which means that member companies can submit technical proposals for inclusion in the standard. Alternative solutions are often proposed by several 3GPP members. These proposals are voted on. However, these contributions are followed by suggestions for improvements, which are voted on again until all members agree to an approved solution according to the consensus principle. The resulting final specifications have thus been reviewed by hundreds of global experts. The experts usually work for companies that are often competitors in the market. 3GPP is therefore both a collaborative and highly competitive consortium. It requires considerable research and investment to make technically meaningful and convincing contributions to 3GPP. Companies can only gain credibility in 3GPP by regularly participating and developing the best specifications, which allows them to bring their own developed and patented technologies into the standard. The counting and analysis of submitted standard contributions thus shows how much share and influence companies have in the development of a standard such as 5G.

The 3GPP consortium publishes all standard contributions of its members and specifies exactly which companies have submitted contributions. The data also shows in which 3GPP subgroup these contributions were submitted and whether these contributions were approved by all subgroup members.

Standard contributions were again classified as relevant to 5G t if the related Technical Specifications (TS) could be related to 5G technologies classified by 3GPP (see Appendix 1 and 2). This classification was determined either by the identification of the related specification number or by the indication of the so-called “Work Items Agenda".

Table 9 shows the number of 5G relevant standard contributions submitted to 3GPP. In the first column, the total number of all 5G contributions submitted was counted. The order of the companies corresponds to the order of the number of declared 5G families. Thus, the difference between the number of 5G declarations and the number of standard 5G contributions can be compared.

With 26,372 contributions, Huawei submitted almost every fifth proposal for 5G to 3GPP and thus not only holds the most 5G declarations but has also submitted the largest share of 5G standard contributions, followed by Ericsson, Nokia and Qualcomm. These four companies are already responsible for over two-thirds of all 5G submissions. Companies such as LG, Samsung or ZTE submit fewer 5G contributions by comparison, although some of these companies have declared more patent families for 5G. Companies such as Blackberry (CA) or WILUS (KR) submit comparably fewer 5G contributions. FG Innovation (CN) has not even submitted anything in the 5G standardization so far.

In many cases, standard contributions are not submitted by one, but by a group of companies. Typically, there is one company that drafts a standard contribution and then joins forces with other companies to submit this contribution. The contributions in the first column were credited to all companies that submitted the standard contribution, regardless of whether they supported the contribution as the first or last company. However, if a contribution is attributed only to the first contributing company, the number of contributions is reduced and differs for each company, as shown in the second column.

Table 9: Number of 5G standard contributions

Contributing company	5G contributions	First contributor	Weighted share	In UE groups	Approved
Huawei Technologies (CN)	26,372	23,853	16,094	16,746	6,246
Samsung Electronics (KR)	7,003	5,768	5,678	5,492	1,334
LG Electronics (KR)	4,858	4,092	4,016	4,271	723
Nokia (incl. Alct.-Lucent) (FI)	15,452	13,138	7,350	10,004	4,147
ZTE Corporation (CN)	6,831	5,551	5,083	4,856	1,247
Ericsson (SE)	23,026	20,581	20,087	15,567	5,558
QUALCOMM (US)	10,484	8,970	8,767	8,028	2,179
Intel Corporation (US)	6,934	5,848	5,761	5,744	1,120
Sharp Corporation (JP)	311	256	262	310	99
NTT Docomo (JP)	3,480	2,739	2,723	2,600	659
CATT (CN)	3,854	3,142	3,135	2,979	619
Guangdong Oppo CN)	1,588	1,255	1,246	1,499	194
InterDigital Technology (US)	1,814	1,162	1,262	1,638	339
Vivo Mobile (CN)	1,443	1,268	1,277	1,394	143
ASUSTeK Computer (TW)	154	145	144	154	1
Lenovo Group Limited (CN)	1,282	351	469	1,275	272
NEC Corporation (JP)	1,442	932	996	1,095	302
BlackBerry (CA)	86	77	79	80	30
KT Corporation (KR)	226	4	58	98	40
Fujitsu (JP)	324	262	275	293	16
ETRI (KR)	770	443	469	591	183
Apple (US)	245	170	171	225	37
WILUS Group (KR)	55	50	49	34	30
Panasonic (JP)	144	143	143	132	53
HTC Corporation (TW)	151	92	87	149	33
MediaTek (TW)	1,637	1,307	1,310	1,493	322
Sony Corporation (JP)	455	353	355	450	234
FG Innovation (CN)	0	0	0	0	0
Convida Wireless (US)	267	147	126	267	69

ITRI (TW)	86	80	79	81	34
SK Telecom (KR)	358	11	101	302	74
Spreadtrum Comm.(CN)	541	524	528	537	19

Another method is not to allocate standard contributions to one enterprise, but to allocate contribution shares pro rata to several enterprises. For example, if there are four companies that submit a proposal together, each company receives a pro rata share of 0.25. The third column shows the pro rata shares of standard contributions. After this weighting, Ericsson submitted more pro rata standard contributions than Huawei for 5G, because Ericsson may have submitted many standard contributions alone, while Huawei submitted standard contributions together with other companies.

The fourth column only counts the contributions submitted in the groups (RAN1, RAN2, RAN4, SA2, SA3, SA4 and CT1).

4. Analysis of selected 5G application areas

5G will enable the fourth industrial revolution. Lower latency, higher bandwidths, consistent availability and quality assurance as well as low energy consumption will enable new applications in almost all industries. The following describes the five most important application areas for which the use of 5G will be relevant in the future.

4.1 5G applications in the automotive industry

The smart city promises the connection and communication of buildings, streets, traffic lights, and all road users. Combined public transport services, dynamic traffic management, intelligent parking meters and a more intelligent road infrastructure will support the integration of autonomous vehicles into road traffic. The low latency 5G network enables a vehicle to communicate with its environment in real time. The vehicle can dynamically adapt to its changing environment via the 5G network allowing for direct response. Thus, the number of accidents and road fatalities is to be drastically reduced. Fully autonomous vehicles are likely to evolve over several stages and manufacturers are already implementing autonomous functions such as "autonomous speed control", "automatic parking" and "lane departure warning". 5G will further accelerate this development towards fully autonomous vehicles. 5G will also solve the increasing demands on logistics by installing sensors in, containers, trucks, freight ships or rail traffic.

Similar to the mobile phone industry, where a transition from feature phones to smart phones has been observed over the past 10 years and new business models, platforms and market participants have changed the distribution of profits between companies, we will most likely soon see similar shifts and redistributions within the automotive industry. Most market experts predict dramatic changes in the automotive market due to disruptive technology trends, such as self-driving vehicles, electrification and connectivity over technologies such as 5G. The intelligent car of the future will exchange information with its environment. Vehicle-to-X systems enable communication between other vehicles, roads and infrastructure. The automotive industry could be one of the first sectors outside the computer and smartphone world in which 5G technology will play a central role. However, the integration of the highly patented 5G standard poses economic risks for vehicle manufacturers and suppliers. Licensing fees, for example for SEPs in mobile standards such as 3G, 4G and soon 5G, can easily amount to hundreds of millions of dollars per year when looking at royalty rates in the communications industry.

However, licensing practices in the automotive industry are different from those in the communications industry. Patents in the automotive industry are usually licensed vertically. A Tier 1 manufacturer rarely charges royalties from an original equipment manufacturer (OEM). Also, in licensing negotiations, royalties between Tier 1 suppliers and OEMs are usually based on a single component that has been improved by an invention. Patent licensing costs have therefore had little impact on vehicle prices. In contrast, patent licensing in the communications industry focuses mainly on the net sales price of the end product and is therefore usually directed at OEMs. Accordingly, license fees are significantly higher compared to manufacturers who do not have a patent portfolio for cross-licensing.

Statutes of standards organizations, such as those of ETSI, do not explicitly specify how the royalties for SEPs are to be calculated. As Daimler's recent request to the EU antitrust authorities[18] to review Nokia's SEP license claims has shown, expectations for the amount of a license differ dramatically between SEP holders in the communications industry (e.g. Nokia) and the automotive industry (e.g. Daimler). While double-digit royalties based on net sales of total products are common in the communications industry, such royalties are unthinkable in the automotive industry where marginal profits are comparatively low. Car manufacturers also argue that suppliers should take a license, while SEP holders want to negotiate directly with OEMs.

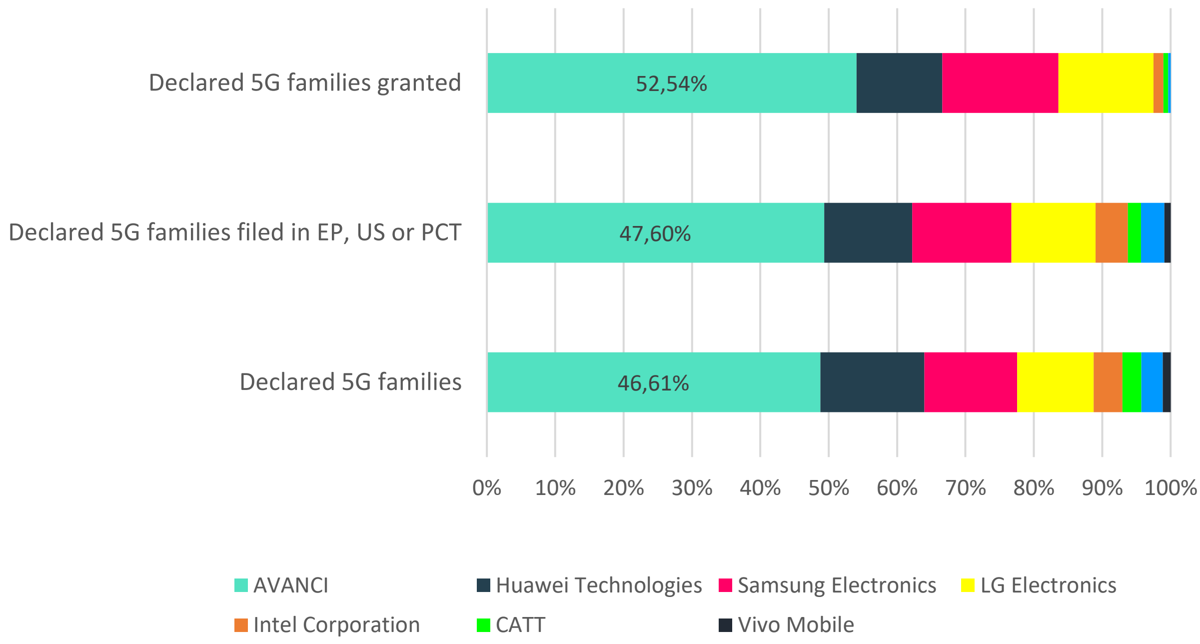
Avanci - a joint licensing initiative - offers a fixed price of $15[19] for the use of 4G (including 2G / 3G and eCall) in vehicles or IoT applications. First car manufacturers, e.g. BMW, Seat, MAN, Volkswagen, Audi, Porsche and then other OEMs have signed contracts with Avanci. Currently, automotive connectivity is mostly used in cases such as automatic emergency calls (e.g. eCall), smartphone signal enhancements, telematics or navigation. In the future, however, vehicles will rely more strongly on 5G technologies, for example to be able to drive through complex traffic situations. So far Avanci offers only one license for 2G, 3G and 4G SEPs. If, in the course of 5G roll out, cars become "smartphones on wheels"[20], the question arises as to whether the license fees for SEPs can rise to amounts comparable to those in the smartphone industry.

Even though Avanci has not yet set up a patent pool for 5G patents, figure 6 shows what proportion of the declared 5G patents Avanci would pool, assuming the same companies would

[18] https://www.reuters.com/article/us-eu-daimler-nokia-patents/daimler-asks-eu-antitrust-regulators-to-probe-nokia-patents-idUSKCN1RA2KF [as of January 1st, 2020]
[19] http://avanci.com/pricing/ [as of January 1st, 2020]
[20] https://www.theguardian.com/product-innovation-with-henkel/2018/oct/02/smartphones-with-wheels-what-the-car-of-the-future-will-be-like [as of January 1st, 2020]

also join a 5G pool. The figure shows three ways of counting the Avanci share: It is calculated according to all declared 5G families; according to all declared 5G families registered in at least the US, EP and PCT; and calculated according to all declared 5G families already granted in at least one patent office. For all three counting methods, Avanci as of January 2020 would include between 46-52% of all declared 5G families. This is mainly due to the large 5G patent portfolios declared for 5G by Huawei, Samsung, LG and Intel, which have not yet joined Avanci.

Figure 6: Share of 5G declared families by current licensees of the AVANCI patent pool assuming the same companies would join an AVANCI 5G pool



4.2 5G Applications in the manufacturing industry

The fourth industrial revolution will be driven by disruptive technologies such as artificial intelligence driven robots, cloud monitored machines, real time sensors that monitor and report back, automation technologies connected to the cloud or augmented reality remotely controlled machines. All of which will use 5G technology to enable communication between all physical parts of a factory to enable such disruptive technology. 5G will create a network of connected machines that will allow factories to collect, analyze and distribute data in real time. By improving connectivity manufacturers will be able to capture and access much larger amounts of data at much higher speeds more efficiently than ever before. This will be the backbone of production and related services of the future. Virtual reality tools will be used, to configure and test production lines in the virtual world. This enables a higher level of accuracy and productivity beyond human capabilities. Most automation is expected to be used for work that is considered unsafe, impossible, or tedious for humans. All processes that need human interaction can with 5G connectivity also be remotely handled.

4.3 5G applications in the energy industry

The energy sector faces many challenges and opportunities, many of which can be solved with new 5G-enabled services and applications. As energy networks become smarter, 5G is seen as an important link in supporting Machine Type Communications (MTC) to protect, control and regulate networks. The increasing number of smart meters can only be managed through a high capacity, high bandwidth infrastructure. The demand for electricity will continue to increase in the wake of electric mobility. Customers will benefit from real-time information on energy consumption at home, at work or in traffic, and on this basis will make efficiency adjustments. Intelligent 5G systems will enable energy suppliers to balance and manage the demand for energy resources.

4.4 5G Applications in the Media Entertainment Industry

The emergence of interactive content, together with the new role of consumers as content creators, has led to challenges in the media and entertainment sectors. Digital content is offered and consumed in a variety of new ways. The growing demand for video content is a challenge for today's mobile networks. 5G is a catalyst for the media and entertainment services market, where new business models will emerge that will force better collaboration between network service providers and their suppliers to enable the emergence of new services and business models. 5G networks will be able to support and scale new use cases to adapt it to future requirements.

4.5 5G Applications in Medicine and Healthcare

5G will improve many existing use cases while creating new ones that are not met by current technologies, such as remote patient examinations or even remote surgery. Due to lower latency and a higher capacity of 5G, healthcare systems will be able to offer intelligent remote monitoring for more patients. With 5G, users are increasingly confident that they can get the real-time data they need and deliver the care their patients expect. Critical health services need reliable connections. Highly reliable communication is essential for instant communication about the patient's condition - e.g. via HD-quality images and access to medical records - and for direct interaction during remote surgery.

4.6 5G families declared to security and network management standards

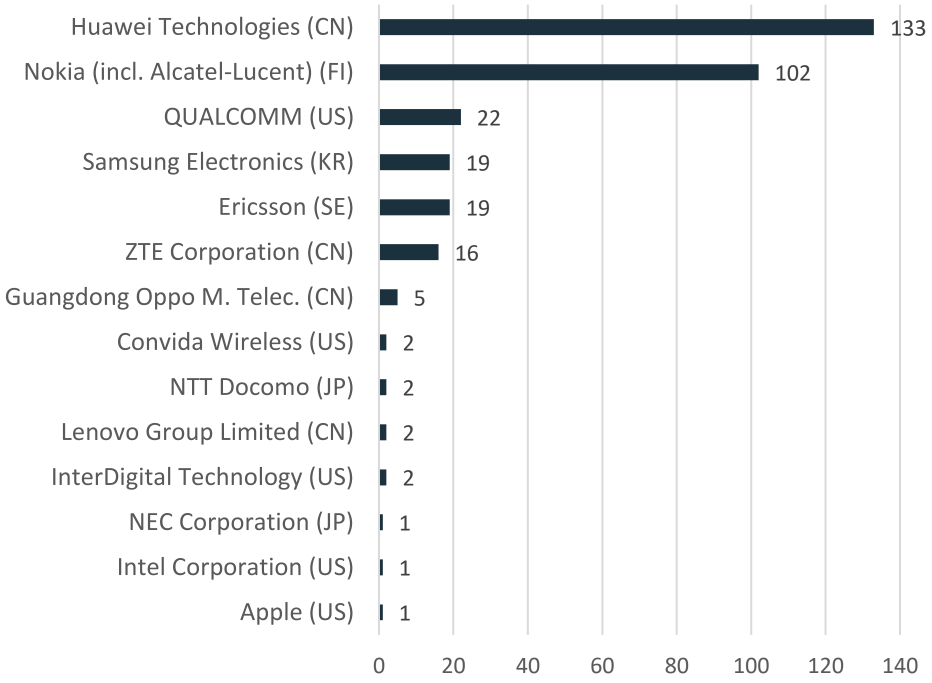
The 3GPP groups SA3 and SA5 deal exclusively with security and network management specification. For the analysis of security and network management all 5G declarations were identified which were declared to specifications of SA3-security or SA5-telecommunication management. Table 10 shows that the security architecture standard TS 33.501 and the TS 33.401 standard have the most declared 5G families.

Table 10: Number of declared 5G families by standard specification of the SA3 Security Group

TS	Title	Group	Declared 5G families
TS 33.501	Security architecture and procedures for 5G System	SA3	291
TS 33.401	3GPP System Architecture Evolution (SAE); Security architecture	SA3	54
TS 33.220	Generic Authentication Architecture (GAA); Generic Bootstrapping Architecture (GBA)	SA3	36
TS 33.402	3GPP System Architecture Evolution (SAE); Security aspects of non-3GPP accesses	SA3	28
TS 33.102	3G security; Security architecture	SA3	16
TS 33.203	3G security; Access security for IP-based services	SA3	9
TS 33.221	Generic Authentication Architecture (GAA); Support for subscriber certificates	SA3	6
TS 33.512	5G Security Assurance Specification (SCAS); Access and Mobility management Function (AMF)	SA3	4
TS 33.107	3G security; Lawful interception architecture and functions	SA3	4
TS 33.259	Key establishment between a UICC hosting device and a remote device	SA3	2
TS 33.246	3G Security; Security of Multimedia Broadcast/Multicast Service (MBMS)	SA3	2
TS 33.223	Generic Authentication Architecture (GAA); Generic Bootstrapping Architecture (GBA) Push function	SA3	2
TS 33.222	Generic Authentication Architecture (GAA); Access to network application functions using Hypertext Transfer Protocol over Transport Layer Security (HTTPS)	SA3	2
TS 33.122	Security aspects of Common API Framework (CAPIF) for 3GPP northbound APIs	SA3	2
TS 33.110	Key establishment between a Universal Integrated Circuit Card (UICC) and a terminal	SA3	2

Figure 7 shows the number of declared 5G families to the standard specification of the SA3 Security Group according to the declared 5G portfolios of the companies. Huawei and Nokia declared most 5G families to 5G security specifications followed by Qualcomm, Samsung, Ericsson and ZTE.

Figure 7: Number of declared 5G families to standard specification of SA3 Security Group by company



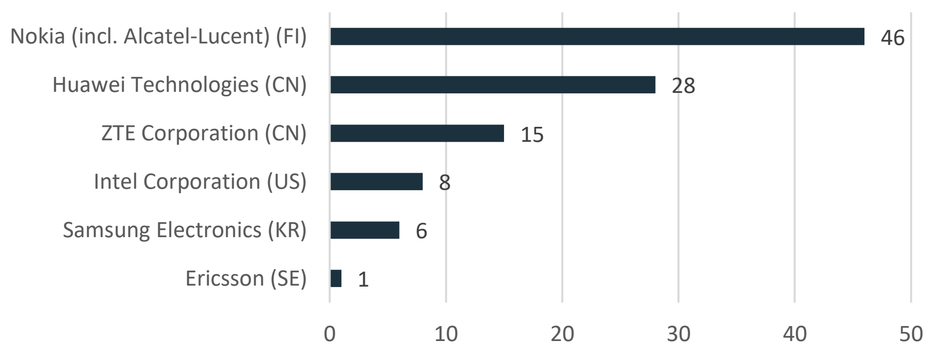
To analyze the 5G declarations on network management technologies, declarations on specifications from the SA5 group were analyzed. Table 11 shows that the SA5 specification TS 28.531 and the SA5 specification TS 32.422 have the most declared 5G families. In general, the 28-series TS is the series with the most 5G declarations for network management technologies.

Table 11: Number of declared 5G families by standard specification of SA5 Security Group

TS	Title	Group	Declared 5G families
TS 28.531	Management and orchestration; Provisioning	SA5	20
TS 32.422	Telecommunication management; Subscriber and equipment trace; Trace control and configuration management	SA5	14
TS 28.500	Telecommunication management; Management concept, architecture and requirements for mobile networks that include virtualized network functions	SA5	13
TS 28.510	Telecommunication management; Configuration Management (CM) for mobile networks that include virtualized network functions; Requirements	SA5	9
TS 28.511	Telecommunication management; Configuration Management (CM) for mobile networks that include virtualized network functions; Procedures	SA5	9
TS 28.512	Telecommunication management; Configuration Management (CM) for mobile networks that include virtualized network functions; Stage 2	SA5	9
TS 28.513	Telecommunication management; Configuration Management (CM) for mobile networks that include virtualized network functions; Stage 3	SA5	9
TS 28.530	Management and orchestration; Concepts, use cases and requirements	SA5	9
TS 28.628	Telecommunication management; Self-Organizing Networks (SON) Policy Network Resource Model (NRM) Integration Reference Point (IRP); Information Service (IS)	SA5	9

Figure 8 shows the number of declared 5G families to standard specification of the SA5 network management group by 5G portfolios companies. Nokia and Huawei hold the most 5G families for network management standards followed by ZTE, Intel and Samsung.

Figure 8: Number of declared 5G families to SA5 Security Group standard specification by company



5. Licensing models of SEPs – a view on the future licensing of 5G patents

According to various estimates, the revenue from royalties for 2G, 3G and 4G SEPs amounts to several billion annually[21]. For 5G, a further increase in volume is expected. On the one hand, the number of registered SEPs in this area has increased significantly, and on the other hand, a further increase in the use of new and existing telecommunications standards can be expected. The development of new application areas means that more and more new licensees will make use of 4G and 5G SEPs, for example in the context of the Internet of Things or Connected/Autonomous Driving. The licensing of 5G faces new challenges compared to previous generations. Whereas in the case of 2G (GSM) to 4G (LTE), mobile phone manufacturers were among the main licensees, this will now be extended to include car manufacturers and manufacturers of various devices connected to the Internet of Things.

The licensing of the relevant SEPs plays an important role for the dissemination and success of the 5G standard. In particular, the amount of royalty fees, and the specific licensing conditions negotiated are key aspects that we will describe in more detail below. While a concrete prediction of the amount of 5G royalty rates is not yet possible due to limited data and uncertain market conditions, a projection on the basis of known price statements is at least considered here, with existing values, if publicly available, for the previous standards 2G, 3G and 4G used as a benchmark. Furthermore, the most important framework conditions for the licensing of 5G are presented. These are determined by the FRAND principle and are the subject of developing jurisprudence, which is currently the focus of a debate between various interest groups.

As in the case of 3G and 4G, license fees for mobile phones have in the past usually been measured and negotiated on the basis of the sales price of an entire product. Projections are therefore heavily dependent on the future selling prices of these devices, which are influenced by factors other than 5G. Estimates assume an average retail price of smartphones of approximately $317 in 2021, while 5G-enabled devices are likely to be significantly more expensive, especially in the beginning[22]. Overall, little information on 5G license fees is available so far. As of January 2020, there are public statements from three companies on license fees for the use of their 5G-essential patents in mobile phones. For example, Qualcomm quotes a fee of 2.275% of the net resale value of a pure 5G mobile phone, whereas in the case of the use of a multi-mode modem, which offers both data transmission via 5G and via the 2G, 3G and 4G standards, the fee should be 3.25%[23]. The resale value used is to be capped at $400.00, which would lead to a maximum license fee of $9.10 and $13.00, respectively. Nokia and Ericsson have announced absolute maximum charges per 5G mobile phone of €3 (Nokia[24]) and $2.50 to $5.00 (Ericsson[25]) respectively.

[21]http://www.wiseharbor.com/pdfs/Mallinson%20on%20cumulative%20mobile%20SEP%20royalties%20for%20IP%20Finance%202015Aug19.pdf
[22] IDC, https://www.statista.com/statistics/788557/global-average-selling-price-smartphones/
[23] https://www.qualcomm.com/media/documents/files/qualcomm-5g-nr-royalty-terms-statement.pdf
[24] https://www.nokia.com/about-us/news/releases/2018/08/21/nokia-licensing-rate-expectations-for-5gnr-mobile-phones/
[25] https://www.ericsson.com/assets/local/patents/estimating-the-future-5g-patent-landscape.pdf

An extrapolation to a total 5G royalty per handset is currently not feasible for several reasons. Firstly, due to the price structures currently communicated, such a calculation would have to depend heavily on an assumed average selling price (ASP). However, this is not determined solely by the technologically induced increase in value upon the introduction of 5G but is subject to various other factors. The as of yet unforeseeable competitive dynamics will have an influence on sales prices and thus also on license rates. Moreover, it cannot necessarily be assumed that the license fees are linearly related to an average sales price. Rather, the percentage royalties themselves can also have an influence on pricing, so that, for example, the percentage licensing rate decreases with increasing sales prices.

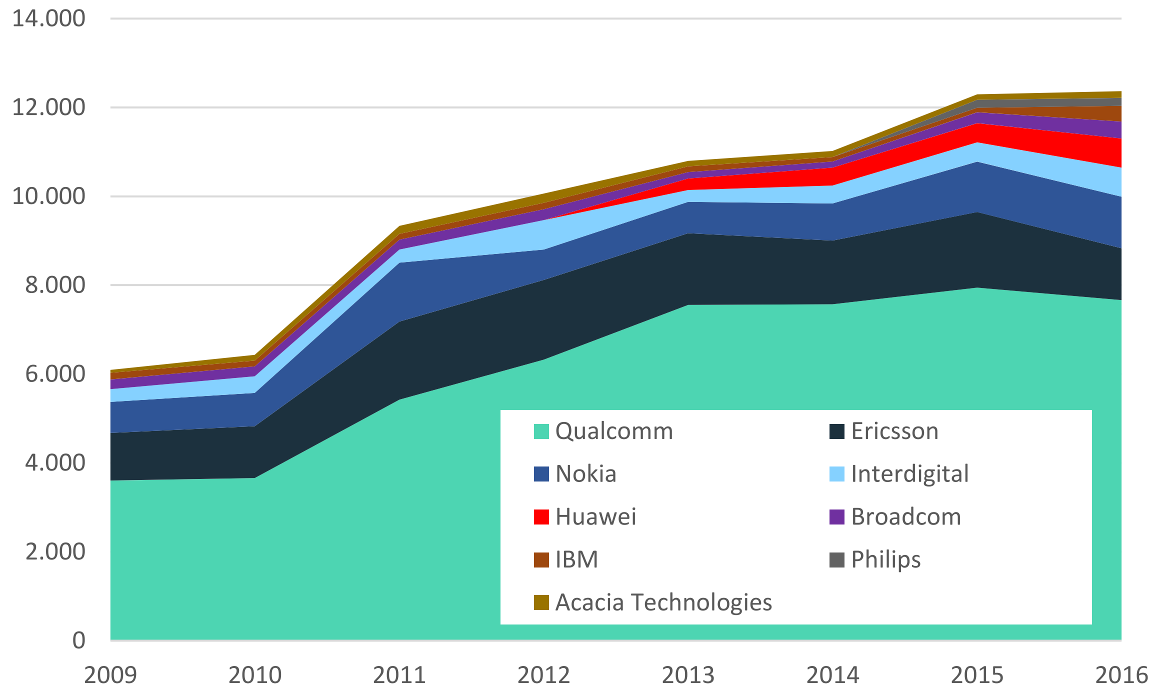
Furthermore, the company share of the total 5G SEP portfolio used for extrapolation, measured as the equally weighted share of all declared SEPs, does not necessarily reflect the understanding of the value of the licensors and licensees on which the fee structure is based. For technical or competitive reasons, individual patents may play a larger or smaller role in the license negotiations. Due to the number and technological complexity of all patents, an analysis of the essentiality and validity of all patents in this regard would only be possible at very great expense[26].

Current market developments, which determine ultimate sales prices and royalties, are also uncertain in the context of trade policy and make a comparison between the introduction of 4G and 5G difficult. The current trade war between the US and China may lead to unpredictable changes in 5G licensing, as evidenced by Huawei's announcement in September 2019 that it will be willing to sell its own 5G patents against the backdrop of US sanctions[27].

Not all owners of SEPs have set up a licensing program to use these patents. A study examining actual licensing revenues from patents used in mobile phones on the basis of public balance sheets of licensing companies showed that publicly communicated prices are usually significantly higher than the license fees actually paid later and that simple projections based on public price statements in the case of 4G overestimated the actual revenues from license fees by a factor of about 10 (Galetovic et al., 2018). Qualcomm, Ericsson and Nokia in particular generated high revenues from licensing patents for technologies used in mobile phones (see Figure 9). In 2016, these companies generated just under 70% of the revenues of all companies licensing these technologies[28]. Qualcomm was the clear pioneer, with approximately USD 7.7 billion or 54% of revenues.

[26] https://ec.europa.eu/growth/content/landscaping-study-standard-essential-patents-europe-0_en
[27] The Economist (2019). Piece offering. Ren Zhengfei may sell Huawei’s 5G technology to a Western buyer. Online: https://www.economist.com/business/2019/09/12/ren-zhengfei-may-sell-huaweis-5g-technology-to-a-western-buyer
[28] The patent owners Samsung, LG and Huawei did not provide any information on revenues from patent licensing.

Figure 9: TOP 10 companies with revenues from SEP licensing / mobile phone, including (but not limited to) 3G, 4G (in USD millions, source: Galetovic et al., 2018)



In 2016, 93% of the license revenues for mobile phones were generated by the 9 companies shown in Figure 9. However, the distribution of revenues does not necessarily reflect the proportion of SEPs held. Especially in the case of Huawei, against the background of the number of SEPs held, the increasing activity in patent-related law suits and also due to corresponding company-specific representations, the authors assume a future expansion of the license business.

The total revenues calculated here from licensing all the patents used in a smartphone, including the essential patents for telecommunications standards, amounted to 3.4% ($9.60) per smartphone in 2016, measured by the average selling price (Galetovic et al., 2018). According to the authors, this royalty rate could be as high as 5.6 %, varying the assumptions.

The diversification of the user base of telecommunications standards with the introduction of 5G also means that additional licensing models are becoming increasingly important. The model of licensing patents in a patent pool plays an important role for new SEP implementers such as the automotive industry in particular. In a patent pool, a consortium of different companies make patents available to each other by cross-licensing and also license them as a package to third parties. An example of this is the patent pool or the patent platform "Avanci", in which a large part of the licensors for essential patents of the telecommunications standards 3G and 4G are represented. For the companies involved in a patent pool, this offers the advantage of avoiding the possible complexity of licensing a large number of different relevant SEPs (a so-called "patent thicket") and avoiding transaction costs arising from negotiations with several licensors. Such patent pools could therefore play an important role, especially for companies entering the licensing market for the first time by connecting their products via 5G.

Due to the widespread implementation of the 5G standard, and the de facto lack of the possibility to use an alternative standard in many application areas, its implementers often find themselves in a "lock-in" situation. In principle, this could lead to SEP holders charging royalties above the actual value of the technology, which is described by the term "patent holdup". In addition, the licensing of complementary patents can lead to so-called royalty stacking. In this case, the manufacturer of a product would have to pay an excessive license fee to various patent owners (Lemley & Shapiro, 2006). On the other hand, the behavior of the licensee can also lead to unreasonably low fees or the complete circumvention of the payment of royalties. If, for example, the licensee refuses to pay license fees, delays any license negotiations, or takes legal action against the required license fee, it may be more cost-efficient for SEP holders to avoid a protracted conflict or the collection of a time-consuming and costly patent infringement procedure and to accept the low fees offered or to waive payment. This is called "patent holdout". Especially in the case of small licensees, where a SEP holder can only expect low license revenues due to small revenues, such a consideration can lead to a loss of license revenues. Due to the expansion of the license market to include small manufacturers of 5G-using IoT products, it is foreseeable that this problem will be of high relevance in the future. In order to counteract such forms of market failure, companies were also obliged, when introducing technologies into the 5G standard, to license all SEPs owned according to the FRAND rules, as stated, for example, in the Intellectual Property Rights (IPR) Policy of the European standardization organization ETSI[29].

The exact interpretation of FRAND and the associated reasonable amount of license fees is not precisely defined in the regulations of the standardization organizations (Baron, Contreras, Husovec & Larouche, 2019). As a result, the question of whether license claims meet the FRAND requirements is often a matter of dispute between licensors and licensees. The resolution of such conflicts before courts, often accompanied by injunctions, requires assessing the fairness of licensing, the appropriateness of royalties and any discrimination against individual companies. The courts' assessments of what prices are fair and reasonable for a certain patent portfolio may also be important in their outcome and methodology as a benchmark for future price developments in the licensing of 5G SEPs.

A comparison of different court judgements on the licensing of 2G, 3G and 4G SEPs by European, US and Asian courts reveals different methodological approaches to such assessments (Pentheroudakis & Baron, 2017). In principle, the challenge in determining a FRAND-compliant license fee for courts is usually to differentiate the intrinsic value of a SEP from the added value conferred by the integration into the standard or the associated standardization activities of different parties. In order to avoid the excessive aggregated burden of royalty stacking, methods with a top-down approach have been increasingly used in recent years to determine such fees. Examples of the application of such a method to disputes about 2G, 3G and 4G SEP licenses are the court proceedings between Unwired Planet and Huawei before the British High Court of Justice[30] and the court proceedings between Ericsson and TCL, in which a California District Court determined a FRAND-compliant license fee on the basis

[29] https://www.etsi.org/images/files/IPR/etsi-ipr-policy.pdf
[30] https://www.bailii.org/ew/cases/EWHC/Patents/2017/711.html

of a top-down calculation[31]. A top-down calculation is based on a total fee associated with a standard. A patent holder is awarded an appropriate portion of this fee. The fixed total fee is intended to represent a price that avoids a hold-up of a patent, for example by using, as in the case of Ericsson vs. TCL, price assumptions that existed before the definition of the standard, and were thus formed ex ante of a possible lock-in.

The share awarded to a licensor can be determined, for example, by comparing the number of SEPs owned to the total number of SEPs for a single SEP. Since it can be disputed in this calculation which patents are included as essential in the calculation, or how the patent portfolio is valued, the decision of the court, which is often based on third-party assessments, is also decisive here. The evaluation criteria used here are, for example, the citation frequency of a patent or the comparison with already negotiated, similar licenses. In the Ericsson v. TCL case, for example, the court adjusted down slightly the number of patents declared by Ericsson at ETSI as essential for 4G to counteract possible over-declaration.

Another aspect of pricing is the basis on which percentage royalties are applied. In general, two alternatives are distinguished here. In US court rulings in the past, compensation was often calculated on the basis of "smallest salable patent practicing unit" (SSPPU), i.e. a single chip or component of a product. When applied to a complete end product, such as a mobile phone, the license fee is calculated as a percentage of the total net sales price (total market value rule, EMVR). If necessary, this is additionally adjusted so that only the patent-based value contributions of the product are taken into account ("apportionment").

[31] http://home.tm.tue.nl/rbekkers/TCL_v_Ericsson_Decision.pdf

Figure 10: Level of royalties in court decisions on FRAND licensing of 2G, 3G and 4G SEPs for mobile phones. Fees as a percentage of the sales price of a mobile phone.

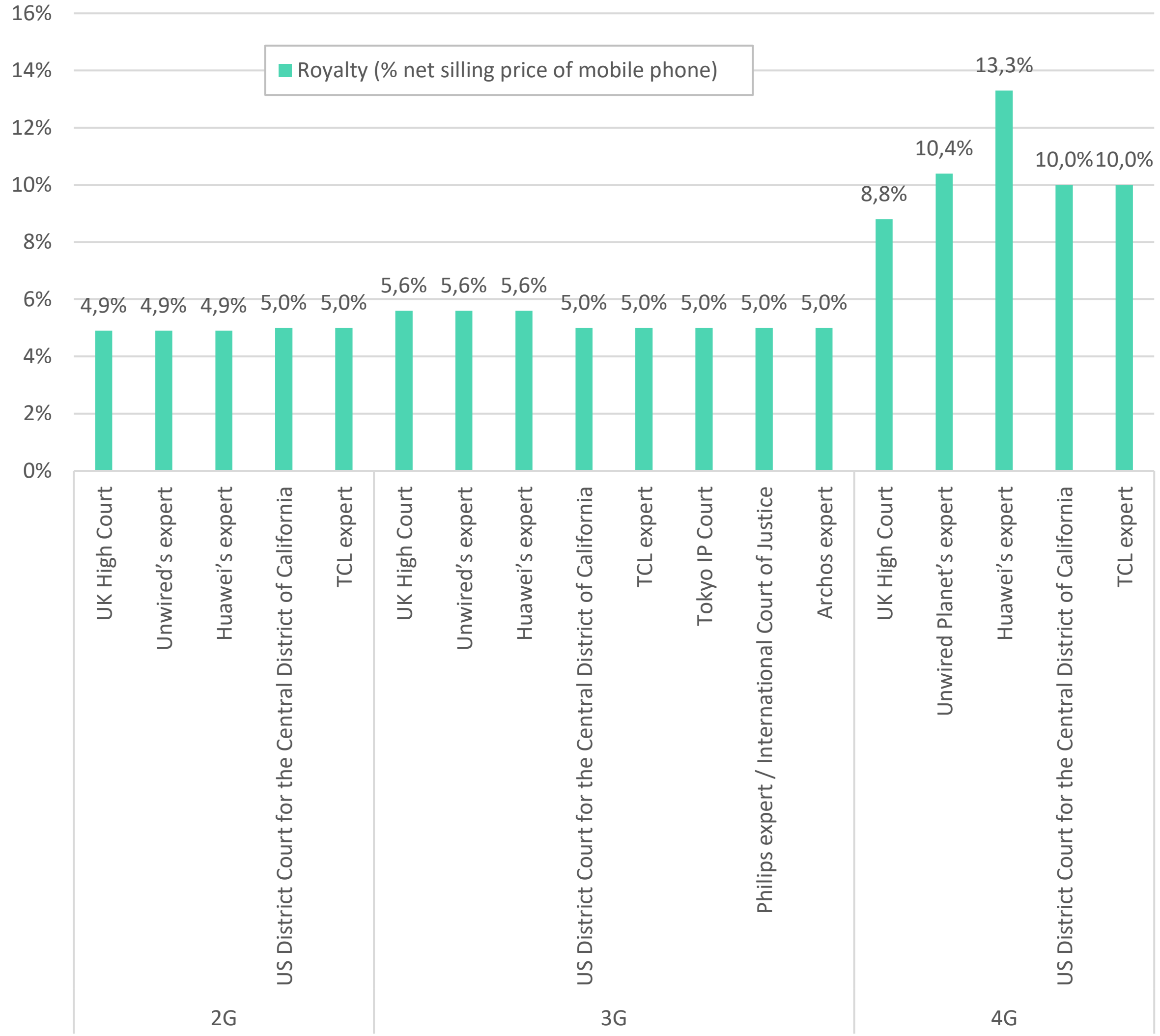


Figure 10 shows an overview of such court decisions regarding the total amount of FRAND royalties per standard paid by mobile phone manufacturers to companies with corresponding SEP portfolios[32]. In the upper part of the figure the values are listed which are considered by the respective courts to be appropriately aggregated license fees for all SEPs of the respective standard according to the FRAND principle. These are usually defined as a percentage of the resale value of a mobile phone (EMVR). While these underlying aggregated royalties for the 2G and 3G standards were set at just under 5% of the net sales price of a mobile phone, they were significantly higher at 4G at up to 13%.

It can be assumed that the top-down method described above will continue to be used by courts in the future to determine FRAND-compliant license fees for 5G SEPs. In view of the relatively constant price per SEP so far in conjunction with the increasing number of SEPs at 5G, the total

[32] Based on the evaluations in the relevant court cases. A relative fee of 5% was assumed for the "Philips expert / International Court of Justice" and "Archos expert" figures based on the absolute figures. For the value "TCL expert" / 4G, the maximum license fee was taken into account, and a range of 6 % - 10 % was defined in the court decision.

license revenues would then be expected to increase. It is still unclear, however, what proportion of currently declared patents will be recognized as essential in the future.

Criticism of the methods used by the courts is directed above all against the thin data basis on which the decisions are based (see, for example, Jorge L. Contreras, 2019). For example, the often opaque SEP licensing negotiations would make an assessment difficult, which could only rarely be based on information on the licensing fees of other market participants. The exclusive use of information from the plaintiff and defendant in combination with publicly available but often inaccurate price announcements makes the determination of FRAND fees inconsistent overall.

At the European level in particular, the focus of the courts is more often on the assessment of the actions of the parties involved in the license dispute and its FRAND conformity than on the determination of a single FRAND-compliant license fee, as practiced by US courts using sometimes quite complex methods (Pentheroudakis & Baron, 2017). In the Huawei v. ZTE[33] case, the European Court of Justice confirmed in 2015 that the enforcement of SEPs by court order, i.e. the prevention of the implementation of a standard affected by essential patents, may violate competition law because it may constitute an abuse of a dominant market position. In the course of the ruling, a legal basis was proposed for the creation of a negotiation scheme for FRAND-compliant licensing of SEPs. Accordingly, the SEP holder must give the patent infringer the opportunity to conclude a license under FRAND conditions and to this end enter into negotiations in accordance with customary business practices instead of taking action against the infringer by means of an injunction.

Especially with the introduction of 5G, a detailed regulation of FRAND conditions is gaining importance. In the course of the expanded mobile use of the Internet by other connected devices, new industries are confronted with the licensing problems of SEPs.

The basis created by the European Court of Justice (ECJ) has been taken up against this background in a communication from the European Commission (European Commission, 2017). It notes that "there is an urgent need to establish key principles that promote a balanced, smooth and predictable SEP environment". On the one hand, it calls for the data offered by standardization organizations on SEPs to be improved, and for transparency regarding the dependence on SEPs and the actual essentiality of declared patents (due to the existence of over-declaration) to be improved. It also calls for the development of concrete FRAND rules, which can be tailored to different licensees or sectors and products, but which in any case lead to the dissemination of the standard being promoted by taking into account the interests of both patent holders and licensees. Explicit reference is given to various criteria that need to be considered. For example, the determination of the amount of license fees should depend on the present value of the patent but remain independent of the market success of the product affected by the patent. In addition, as practiced in the top-down method used by courts, the total royalties should correspond to an overall price appropriate to the standard. The granting of licenses must not discriminate between users who are "in a similar situation". An analysis for the European Parliament (Mcdonagh & Bonadio, 2019) shares these views of the Commission. In addition,

[33] http://curia.europa.eu/juris/liste.jsf?num=C-170/13

the Commission proposes the consideration of further regulations, such as the fixing of a maximum license fee, the free licensing of undeclared essential patents, or the contractually guaranteed disclosure of license agreements with "similar" licensees in license negotiations ("most-favoured licensee clauses").

In response to the views of European institutions, there are various industry to further develop such regulations on FRAND licensing of SEPs. In a CEN Workshop Agreement ("CWA2", CWA 95000:2019, "Core Principles and Approaches for Licensing of Standard Essential Patents") supervised by the German standards organization DIN, the organizations "ACT | The App Association" and the "Fair Standards Alliance" had agreed on basic rules for the licensing of 5G SEPs. Companies such as Google, Apple, Microsoft, Cisco, Deutsche Telekom, Volkswagen and Daimler are represented in these organizations. These basic rules, which in the opinion of the CWA2-supporting groups make fair FRAND licensing possible, have the following core aspects. On the one hand, both preliminary injunctions and delay tactics during licensing negotiations should be avoided. Provisional injunctions should neither be threatened nor obtained, except in cases where compensation cannot be obtained by a court order. In addition, all potential users of the standard should be given the opportunity to license, regardless of their position in the value chain. The determination of a FRAND-compliant royalty should also be based on the value inherent in the SEP and not on the product in which it is applied. This implies in the most common cases the use of the SSPPU principle. As in the top-down methods used by courts, the royalty of individual licensors should result in an appropriately aggregated royalty. Furthermore, the licensing of SEPs should not be made dependent on the licensing of other patents from the licensor's portfolio as a package ("patent bundling"), unless this is done in mutual, voluntary agreement. The transparency of FRAND negotiations is to be increased by avoiding "too broad" confidentiality clauses. In addition, in license negotiations the information asymmetry regarding patents and previous negotiations should not be exploited by the licensor to the disadvantage of the licensee. Finally, FRAND conditions are to remain untouched by patent transfers. When dividing up a SEP portfolio, the sum of the new individual license fees should not exceed the previous license fee.

In the CEN Workshop Agreement ("CWA1", CWA 17431:2019, "Principles and guidance for licensing Standard Essential Patents in 5G and the Internet of Things (IoT), including the Industrial Internet") accompanied by the secretariat of the French standardization organization AFNOR, companies such as Nokia, Ericsson, Qualcomm, Dolby and InterDigital had previously made proposals for principles for licensing 5G SEPs under the merger "IP Europe". Here, somewhat different rules were proposed, which differed in particular with regard to the clarification of royalties in court, the confidentiality of licensing agreements, equal treatment in the licensing of companies implementing the standard and the benchmark for the amount of royalties. The latter should be based on the value of the patented technology to its users and may therefore differ significantly between different sectors.

A central point of contention between the parties represented in the drafts of CWA1 and CWA2 is whether the amount of royalties may depend on the extent to which SEPs are used or the resale value of the products using the standard, or whether there is a fixed limit due to the reference to the SSPPU principle. This is particularly important for the automotive industry. For example, a vehicle would fall into the category of high usage and high charges, while smaller devices could be subject to lower charges for the IoT. However, with a usage-independent, SSPPU-based license fee, it is conceivable that low fees for small devices could create precedents that could also lower fees in other areas, such as the automotive industry. Another controversial aspect is the question of who pays royalties in the value chain. The requirement in CWA 95000:2019 to grant licenses to all implementing companies in principle would mean that fees could already be paid by suppliers. These would then be measured by a cheaper intermediate product, which would also be of great relevance for the automotive industry in view of the avoided comparison of license fee and resale value of the end product. Overall, this regulation would lead to lower licensing revenues for SEP holders.

By expanding the circle of users and licensees, the introduction of 5G will lead to a more complex licensing landscape. This will make it necessary to develop and negotiate such new, more precise rules for FRAND-compliant licensing. Although the developed CWAs have no direct binding force, they are a central step on the way to agreement for such new rules, also due to the legitimacy of the broad participation of the industry. In order not to hamper innovations in areas such as IoT or autonomous driving technologies, it is important to find compromises that avoid the protracted resolution of licensing disputes by the courts, ensure adequate compensation for the developers of these new technologies, and promote their widespread use through appropriate licensing fees.

6. Conclusion and Discussion

5G has the potential not only to accelerate the fourth industrial revolution, but to make certain IoT application possible in the first place. Looking back at past standard generations, the level of communication has evolved from generation to generation. Mobile communication was introduced with 2G. The second-generation telecommunication standard for the first time allowed a location-independent communication. With 3G technologies and the introduction of the first smartphones, the Internet became mobile. Via 4G it is now possible to share content in real time via smartphone applications. The further development of generations from 2G to 4G has revolutionized accessibility, availability and access to information via the Internet. 5G however, will not only further accelerate communication between people, but will also allow communication with and between physical objects. 5G not only connects people, but also cars, roads, traffic lights, buildings, factories, electricity meters and medical instruments. The application of 5G will thus affect new industries beyond the computer and smartphone industry, such as the automotive industry, the manufacturing industry, the energy industry, the media industry or even the healthcare sector, industries that have had little contact with communication technologies such as 2G, 3G or 4G. However, the great potential of 5G also harbors risks for these industries.

The present study shows that the 5G standard is highly patented with 95,526 applications and patents, which together represent a total of 21,571 active families. Most of these 5G declarations date from the last two and a half years and with the further development of 5G, the number of patents will continue to increase. Recent years have shown that patent holders for 2G, 3G and 4G controlled the use of communication technologies in the smartphone and computer industries. Thus, 5G patent holders are also likely to become technology and market leaders.

Any company that owns SEPs for 5G can charge royalties to any 5G user. This creates a lucrative market for 5G patent holders, but on the other hand carries a legal risk for every 5G user as the rate of royalties for 5G patents is unpredictable. In the past, essential 2G, 3G and 4G patents were also acquired by patent assertion entities also called patent trolls in order to more aggressively enforce royalties for the acquired intellectual property rights. In many cases, this led to court disputes (Pohlmann & Opitz, 2013). An essential patent protects every implementation of a standard and is therefore infringed by any user of the 5G standard. Valid essential 5G patents can therefore pose unpredictable legal risks for companies whose products are based on 5G applications.

The results of the study show that more and more 5G patent owners are coming from China. The Chinese technology provider Huawei declared most families for 5G and registered them internationally in all countries. The statistics on standard contributions support Huawei's strong position in the development of the 5G standard. With expenditures of over 15 billion US dollars in research and development (R&D) in 2018, which according to Huawei's management were primarily invested in the further 5G development, Huawei is among those companies spending most dollars on 5G related R&D. However, the study also shows that companies such as Nokia, Ericsson and Qualcomm, which were leaders in previous 2G, 3G, and 4G generations, are also playing a leading role in developing the 5G standard. The Korean Samsung and LG have also strongly increasing patent numbers for 5G.

There are also companies that have not participated in the development of the previous generations 2G-4G and can therefore be described as new 5G market participants. The Chinese companies Guangdong Oppo (CN), Vivo Mobile (CN), the Taiwanese company ASUSTeK Computer (TW) and the Korean company WILUS Group (KR) are particularly noteworthy here. There is also a trend among the new market participants towards Asian companies that are increasingly participating in 5G standardization.

One of the biggest challenges for the implementation of the 5G standard will be the licensing of SEPs. Patent pools or patent platforms such as Avanci could provide a solution to bring licensees and licensors together on a single platform. So far, however, the previously mentioned strong Asian patent owners such as Huawei, ZTE, Samsung, LG, CATT, Guangdong Oppo or Vivo Mobile are the ones not joining such patent pool initiatives. The added value of a patent pool increases with the number of licensors. The more SEPs are licensed through a patent pool, the greater the benefit to the licensee and the lower the legal risk of being attacked outside the patent pool. It remains to be seen whether there will be a successful 5G patent pool and what proportion of 5G patents this pool can aggregate under one license.

Pools one the one hand must attract as many licensees as possible but also have to offer a license contract for licensees that is FRAND. Even though a patent platform like Avanci has already won some notable licensees, there are also companies, for example in the automotive industry, that have not yet accepted an Avanci license for 2G, 3G or 4G. The current lawsuit between Daimler and Nokia shows that some issues related to the licensing of SEPs have not yet been resolved. In this context, there is still discussion about who has to acquire a license for SEPs at all. Does this have to be the OEM, the manufacturer of a car, or should the supplier who produces the 5G module, pay the license? In the smartphone industry, licenses are sometimes calculated as a percentage of the resale value of the phone. Avanci, on the other hand, offers a fixed license amount regardless of the value of the device, such as the value of a car. In other words, a small car manufacturer pays for the use of 2G, 3G, 4G 15 US dollars per car just like the manufacturer of high-priced luxury cars. Another point of discussion is the proportionality of the amount of a license. There are opinions that this proportionality must be measured by the manufacturing value of a module. Others believe that the end product, for example the car, must be considered as a value in order to determine proportionality. The automotive industry is the first to have to discuss these issues and, in some cases, to clarify them in court. It remains to be seen whether the spread of 5G applications to other industries will lead to these open issues being further discussed and negotiated. If there is no agreement, this may lead to further litigation. The so-called "Smartphone Wars" of recent years have shown that there has been a large number of court disputes worldwide over the licensing of 3G and 4G. As the name suggests, these disputes have so far been largely confined to the smartphone industry. SEPs were usually a point of contention in these court disputes, but not always the trigger. It remains to be seen whether the implementation of 5G and the licensing of SEPs in sectors such as the automotive industry, the manufacturing industry, the energy industry as well as the media, entertainment industry and the healthcare sector will require 5G licenses to be litigated in court or whether there will be an agreement on the amount and scope of a 5G patent license.

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Appendix 1:

Spec No	Title	Generation	Release
TS 21.205	Technical Specifications and Technical Reports for a 5G based 3GPP system	5G	Rel-15
TS 22.186	Service requirements for enhanced V2X scenarios	5G	Rel-15
TS 22.261	Service requirements for next generation new services and markets	5G	Rel-15
TS 22.289	Mobile communication system for railways	5G,LTE	Rel-15
TS 23.222	Common API Framework for 3GPP Northbound APIs	5G,LTE	Rel-15
TS 23.501	System architecture for the 5G System (5GS)	5G	Rel-15
TS 23.502	Procedures for the 5G System (5GS)	5G	Rel-15
TS 23.503	Policy and charging control framework for the 5G System (5GS); Stage 2	5G	Rel-15
TS 23.527	5G System; Restoration procedures	5G	Rel-15
TS 24.501	Non-Access-Stratum (NAS) protocol for 5G System (5GS); Stage 3	5G	Rel-15
TS 24.502	Access to the 3GPP 5G Core Network (5GCN) via non-3GPP access networks	5G	Rel-15
TS 24.526	User Equipment (UE) policies for 5G System (5GS); Stage 3	5G	Rel-15
TS 24.568	WLAN connectivity for 5GS Management Object (MO)	5G	Rel-15
TS 26.118	Virtual Reality (VR) profiles for streaming applications	5G	Rel-15
TS 26.238	Uplink streaming	3G,5G,LTE	Rel-15
TS 26.259	Subjective test methodologies for the evaluation of immersive audio systems	5G	Rel-15
TS 26.260	Objective test methodologies for the evaluation of immersive audio systems	5G	Rel-15
TS 28.304	Control and monitoring of Power, Energy and Environmental (PEE) parameters Integration Reference Point (IRP); Requirements	2G,3G,5G,LTE	Rel-15
TS 28.305	Control and monitoring of Power, Energy and Environmental (PEE) parameters Integration Reference Point (IRP); Information Service (IS)	2G,3G,5G,LTE	Rel-15
TS 28.306	Control and monitoring of Power, Energy and Environmental (PEE) parameters Integration Reference Point (IRP); Solution Set (SS) definitions	2G,3G,5G,LTE	Rel-15
TS 28.307	Management of Quality of Experience (QoE) measurement collection Integration Reference Point (IRP); Requirements	3G,5G,LTE	Rel-15

TS 28.308	Management of Quality of Experience (QoE) measurement collection Integration Reference Point (IRP); Information Service (IS)	3G,5G,LTE	Rel-15
TS 28.309	Management of Quality of Experience (QoE) measurement collection Integration Reference Point (IRP); Solution Set (SS) definitions	3G,5G,LTE	Rel-15
TS 28.404	Telecommunication management; Quality of Experience (QoE) measurement collection; Concepts, use cases and requirements	3G,5G,LTE	Rel-15
TS 28.405	Management of Quality of Experience (QoE) measurement collection; Control and configuration	3G,5G,LTE	Rel-15
TS 28.406	Management of Quality of Experience (QoE) measurement collection; Information definition and transport	3G,5G,LTE	Rel-15
TS 28.530	Management and orchestration; Concepts, use cases and requirements	5G	Rel-15
TS 28.531	Management and orchestration; Provisioning	5G	Rel-15
TS 28.532	Management and orchestration; Generic management services	5G	Rel-15
TS 28.533	Management and orchestration; Architecture framework	5G	Rel-15
TS 28.540	Management and orchestration; 5G Network Resource Model (NRM); Stage 1	5G	Rel-15
TS 28.541	Management and orchestration; 5G Network Resource Model (NRM); Stage 2 and stage 3	5G	Rel-15
TS 28.542	Management and orchestration of networks and network slicing; 5G Core Network (5GC) Network Resource Model (NRM); Stage 1	5G	Rel-15
TS 28.545	Management and orchestration; Fault Supervision (FS)	5G	Rel-15
TS 28.546	Management and orchestration of networks and network slicing; Fault Supervision (FS); Stage 2 and stage 3	5G	Rel-15
TS 28.550	Management and orchestration; Performance assurance	5G	Rel-15
TS 28.551	Management and orchestration of networks and network slicing; Performance Management (PM); Stage 2 and stage 3	5G	Rel-15
TS 28.552	Management and orchestration; 5G performance measurements	5G	Rel-15

TS 28.553	Management and orchestration of networks and network slicing; 5G Core Network (5GC) performance measurements and assurance data	5G	Rel-15
TS 28.554	Management and orchestration; 5G end to end Key Performance Indicators (KPI)	5G	Rel-15
TS 29.122	T8 reference point for Northbound APIs	3G,5G,LTE	Rel-15
TS 29.222	Common API Framework for 3GPP Northbound APIs	5G,LTE	Rel-15
TS 29.413	Application of the NG Application Protocol (NGAP) to non-3GPP access	5G	Rel-15
TS 29.500	5G System; Technical Realization of Service Based Architecture; Stage 3	5G	Rel-15
TS 29.501	5G System; Principles and Guidelines for Services Definition; Stage 3	5G	Rel-15
TS 29.502	5G System; Session Management Services; Stage 3	5G	Rel-15
TS 29.503	5G System; Unified Data Management Services; Stage 3	5G	Rel-15
TS 29.504	5G System; Unified Data Repository Services; Stage 3	5G	Rel-15
TS 29.505	5G System; Usage of the Unified Data Repository services for Subscription Data; Stage 3	5G	Rel-15
TS 29.507	5G System; Access and Mobility Policy Control Service; Stage 3	5G	Rel-15
TS 29.508	5G System; Session Management Event Exposure Service; Stage 3	5G	Rel-15
TS 29.509	5G System; Authentication Server Services; Stage 3	5G	Rel-15
TS 29.510	5G System; Network function repository services; Stage 3	5G	Rel-15
TS 29.511	5G System; Equipment Identity Register Services; Stage 3	5G	Rel-15
TS 29.512	5G System; Session Management Policy Control Service; Stage 3	5G	Rel-15
TS 29.513	5G System; Policy and Charging Control signalling flows and QoS parameter mapping; Stage 3	5G	Rel-15
TS 29.514	5G System; Policy Authorization Service; Stage 3	5G	Rel-15
TS 29.516	5G System; Interworking between 5G Network and external Data Networks; Stage 3	5G	Rel-15
TS 29.518	5G System; Access and Mobility Management Services; Stage 3	5G	Rel-15
TS 29.519	5G System; Usage of the Unified Data Repository Service for Policy Data,	5G	Rel-15

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TS 29.520	5G System; Network Data Analytics Services; Stage 3	5G	Rel-15
TS 29.521	5G System; Binding Support Management Service; Stage 3	5G	Rel-15
TS 29.522	5G System; Network Exposure Function Northbound APIs; Stage 3	5G	Rel-15
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TS 29.524	5G System; Cause code mapping between 5GC interfaces; Stage 3	5G	Rel-15
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TS 29.531	5G System; Network Slice Selection Services; Stage 3	5G	Rel-15
TS 29.540	5G System; SMS Services; Stage 3	5G	Rel-15
TS 29.551	5G System; Packet Flow Description Management Service; Stage 3	5G	Rel-15
TS 29.554	5G System; Background Data Transfer Policy Control Service; Stage 3	5G	Rel-15
TS 29.561	5G System; Interworking between 5G Network and external Data Networks; Stage 3	5G	Rel-15
TS 29.571	5G System; Common Data Types for Service Based Interfaces; Stage 3	5G	Rel-15
TS 29.572	5G System; Location Management Services; Stage 3	5G	Rel-15
TS 29.573	5G System; Public Land Mobile Network (PLMN) Interconnection; Stage 3	5G	Rel-15
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TS 32.255	Telecommunication management; Charging management; 5G data connectivity domain charging; Stage 2	5G	Rel-15
TS 32.256	Charging management; 5G connection and mobility domain charging; Stage 2	5G	Rel-15
TS 32.290	Telecommunication management; Charging management; 5G system;	5G	Rel-15

	Services, operations and procedures of charging using Service Based Interface (SBI)		
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TS 33.126	Lawful Interception requirements	2G,3G,5G,LTE	Rel-15
TS 33.127	Lawful Interception (LI) architecture and functions	2G,3G,5G,LTE	Rel-15
TS 33.128	Security; Protocol and procedures for Lawful Interception (LI); Stage 3	2G,3G,5G,LTE	Rel-15
TS 33.501	Security architecture and procedures for 5G System	5G	Rel-15
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TS 37.340	NR; Multi-connectivity; Overall description; Stage-2	3G,5G,LTE	Rel-15
TS 37.355	LTE Positioning Protocol (LPP)	5G,LTE	Rel-15
TS 37.470	W1 general aspects and principles	5G,LTE	Rel-15
TS 37.471	W1 layer 1	5G,LTE	Rel-15
TS 37.472	W1 signalling transport	5G,LTE	Rel-15
TS 37.473	W1 Application Protocol (E1AP)	5G,LTE	Rel-15
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TS 38.101-1	NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone	5G	Rel-15
TS 38.101-2	NR; User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone	5G	Rel-15
TS 38.101-3	NR; User Equipment (UE) radio transmission and reception; Part 3: Range 1 and Range 2 Interworking operation with other radios	5G	Rel-15

TS 38.101-4	NR; User Equipment (UE) radio transmission and reception; Part 4: Performance requirements	5G	Rel-15
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TS 38.141-1	NR; Base Station (BS) conformance testing Part 1: Conducted conformance testing	5G	Rel-15
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TS 38.171	NR; Requirements for support of Assisted Global Navigation Satellite System (A-GNSS)	5G	Rel-15
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TS 38.300	NR; Overall description; Stage-2	5G	Rel-15
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TS 38.323	NR; Packet Data Convergence Protocol (PDCP) specification	5G	Rel-15
TS 38.331	NR; Radio Resource Control (RRC); Protocol specification	5G	Rel-15

TS 38.401	NG-RAN; Architecture description	5G	Rel-15
TS 38.410	NG-RAN; NG general aspects and principles	5G	Rel-15
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TS 38.421	NG-RAN; Xn layer 1	5G	Rel-15
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TS 38.423	NG-RAN; Xn Application Protocol (XnAP)	5G	Rel-15
TS 38.424	NG-RAN; Xn data transport	5G	Rel-15
TS 38.425	NG-RAN; NR user plane protocol	5G	Rel-15
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TS 38.461	NG-RAN; E1 layer 1	5G	Rel-15
TS 38.462	NG-RAN; E1 signalling transport	5G	Rel-15
TS 38.463	NG-RAN; E1 Application Protocol (E1AP)	5G	Rel-15
TS 38.470	NG-RAN; F1 general aspects and principles	5G	Rel-15
TS 38.471	NG-RAN; F1 layer 1	5G	Rel-15
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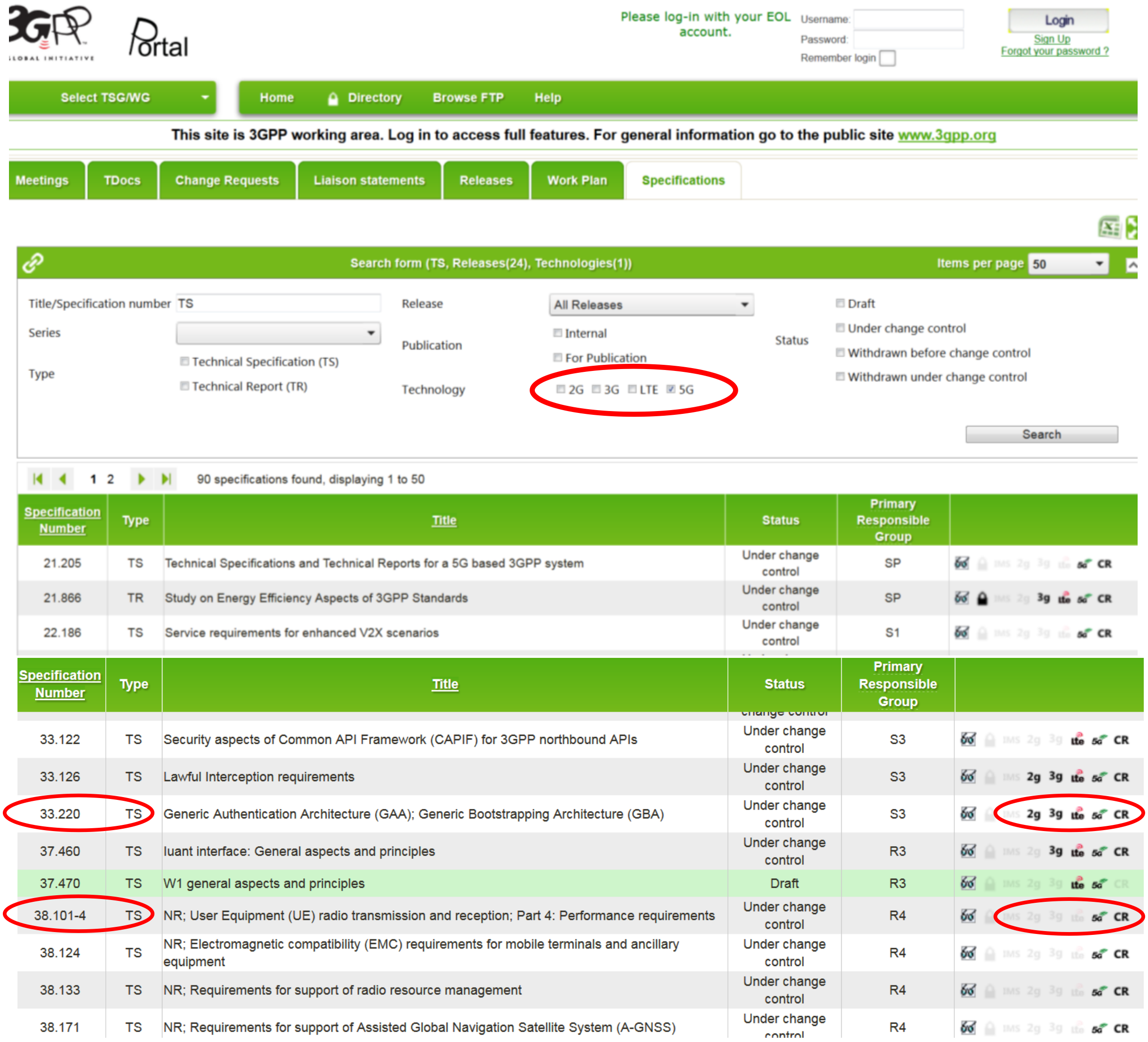
Appendix 2:



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Series:
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Technology: 2G, 3G, LTE, 5G (checked)
Status: Draft, Under change control, Withdrawn before change control, Withdrawn under change control

Search

1 2 — 90 specifications found, displaying 1 to 50

Specification Number	Type	Title	Status	Primary Responsible Group
21.205	TS	Technical Specifications and Technical Reports for a 5G based 3GPP system	Under change control	SP
21.866	TR	Study on Energy Efficiency Aspects of 3GPP Standards	Under change control	SP
22.186	TS	Service requirements for enhanced V2X scenarios	Under change control	S1
33.122	TS	Security aspects of Common API Framework (CAPIF) for 3GPP northbound APIs	Under change control	S3
33.126	TS	Lawful Interception requirements	Under change control	S3
33.220	TS	Generic Authentication Architecture (GAA); Generic Bootstrapping Architecture (GBA)	Under change control	S3
37.460	TS	Iuant interface: General aspects and principles	Under change control	R3
37.470	TS	W1 general aspects and principles	Draft	R3
38.101-4	TS	NR; User Equipment (UE) radio transmission and reception; Part 4: Performance requirements	Under change control	R4
38.124	TS	NR; Electromagnetic compatibility (EMC) requirements for mobile terminals and ancillary equipment	Under change control	R4
38.133	TS	NR; Requirements for support of radio resource management	Under change control	R4
38.171	TS	NR; Requirements for support of Assisted Global Navigation Satellite System (A-GNSS)	Under change control	R4

Appendix 3:

120 patents and standards experts at the 5G patent study presentation

The Technical University of Berlin and IPlytics GmbH invited worldwide industry experts to participate in the presentation of the 5G patent study results in Berlin Germany on January 24th 2020. The 5G study was commissioned by the German Federal Ministry for Economic Affairs and Energy (BMWi) with the goal to shed light on the patent situation for the 5G standard. The agenda of the event included the presentation of the fact-finding study as well as two discussion panels and a keynote speech. Over 120 high level patent experts from all major 5G patent owning companies such as Nokia, Ericsson, Huawei, Qualcomm, ZTE and Samsung were present as well as patent experts from the German industry such as Audi, Continental, BMW, Daimler, Volkswagen, Bosch, Siemens, Deutsche Telekom and Fraunhofer to debate the future of 5G patent licensing.

Tim Pohlmann CEO from IPlytics started with presenting the results of the 5G patent study. The purpose of the study was to unbiasedly present the results, without making policy recommendations. The 5G patent data is based on publicly declared patents and submitted standards contributions that were identified for the 5G standard. Pohlmann started the presentation with a disclaimer that patent declarations cannot be interpreted as legally verified standard essential patents (SEPs). However, patent declaration data is the best source to identify all potential essential 5G patents. The data analysis of the study was conducted using IPlytics Platform a patent tool based on declarations submitted to the ETSI IPR database and standards contributions submitted at the 3GPP portal. Both, information on the patent data and the standards data were correlated to identify only 5G relevant information. Further the patent data was correlated to patent data from worldwide patent offices. The method of how to identify 5G patents and standards contributions was previously verified by an invited group of patent and standards industry experts that supported this study with their technical expertise.

The presented results of the study showed that the 5G standard is highly patented. In total 95,526 patents have been declared for 5G which breaks down to 21,571 unique patent families. Only 44% of these patent families have yet been granted. However, as most 5G patents are rather recently filed one will expect the rate of granted patents to further increase in the coming years. Most 5G patents were declared between 2017 and 2019 showing a sharp increase year by year. And as the 5G standard development is not yet completed further patent declarations are expected in the upcoming years. It is also worth mentioning that 24% of the patents declared for 5G have previously already been declared for 4G. This shows that some 4G technologies are still relevant for the new 5G specifications.

The share of Chinese market players has been increasing

The results of the study show that Huawei (CN), ZTE (CN), Samsung (KR), LG (KR), Nokia (FI), Ericsson (SE) and Qualcomm (US) are among the leaders of 5G patents. The study further identifies new market players that were not around for the 4G development. Here the Chinese companies Guangdong Oppo (CN), Vivo Mobile (CN), FG Innovation (CN), Spreadtrum Communications (CN) and the Taiwanese ASUSTeK Computer (TW) are new in the top 5G patent owner.

The study also investigated companies' participation in the standards development, where technical contributions submitted to the 3GPP (3rd Generation Partnership Project) - the standard body that develops telecommunication standards such as 3G, 4G and 5G . The main 4G standard developers such as Huawei, Ericsson, Nokia, Qualcomm, ZTE and Samsung and LG are again strong players for the 5G development. Here again the data shows increasing participation from new and upcoming Chinese players.

Industry experts state: "The licensing of 5G patent will be complex"

After the presentation of the patent study results, industry experts were invited to discuss the future of 5G patent licensing.

All panelist agreed that the licensing of 5G patents will be more complex compared to 4G. The 5G standard will have more modules and technologies that can be combined. Thus, companies will implement different 5G specifications depending on the specific 5G use cases. Here a car will use other 5G features than a refrigerator. As different 5G specifications are subject to different standard essential patents it will be difficult to define which patents will be needed by the 5G user. Here patent owners will have to find efficient ways to package 5G licensing programs for different uses cases. Also, the panelist argued that it will be important to price differentiate royalty rates for different uses cases.

Can patent pools solve the stickiness of standard essential patent licensing?

The first panel of the event discussed the role of patent pools for future 5G licensing. The main rationale for patent pools is to solve the stickiness problem of licensing e.g. by saving transaction costs for both licensors and licensees. Especially when 5G will be used across multiple industries by a much larger number of companies (compared to the smart phone industry) transaction costs will inevitably increase. Here the goal of patent pools is to simplify licensing e.g. by providing a single contract for all licensors and by eliminating the discussion about patent quality as all patent pool members will have to agree and commit on the pool's terms and conditions. These terms and conditions for example define how the royalty will be shared among patent owners. When the industry agrees on these terms and conditions stickiness can be reduced. The success of a patent pool thus very much depends on the number and size of patent owners that join a patent pool. However, joining a patent pool maybe subject to a so called "chicken and egg problem" as companies might be hesitant to join a pool if, no one joined yet.

Some patent owners however felt that even with being a member of patent pools some sort of stickiness remains. Especially when licensors do not agree to the terms and conditions of the pool license yielding litigation in patent courts. Here being a member of a patent pool but, for example, not being involved in the ongoing litigation of other members, creates situations that are not always transparent and thus will not benefit the licensing strategy of the patent owners.

As of today, there is no 5G patent pool and all panelist agreed that there must be a critical mass of licensors and licensees to launch a successful pool. Very likely a 5G patent pool will have to create offerings for different 5G use cases and with a differentiation of pricing for 5G patents.

Panelist argued that there will likely be different models of aggregation on both sides of the table. Patent pools aggregate patent owners but on the other end there are also so-called defensive patent aggregators (e.g. such as RPX or the Allied Security Trust) that aggregate companies that need to license-in patented technologies.

Standard essential patents in the auto industry. A fresh new start or a clash of cultures?

AVANCI is the first patent pool with an offering that targets companies outside of the smartphone world: the automotive industry. When AVANCI started there were no licensing contracts in place and automotive manufacturers and standard essential patent owners were able to start from the very beginning to define how licensing contracts for the auto industry should be designed. This allowed a certain flexibility. In comparison the smartphone industry nowadays has a so called “moving train problem”. There are existing arrangements in place and existing contracts for the licensing of SEPs which need to be considered when setting up a new contract. Existing contracts create challenges and often limit the flexibility in defining new terms and conditions.

In the smart phone world typically the patent owners are licensors but often also act as licensees. Patent owners often compete downstream on the product market. In other words, licensing contracts are negotiated among competitors. In the case of licensing SEPs for the automotive industry the licensors are from the Telecommunication industry and do not compete with licensees from the auto industry. The panel stated that this made licensing negotiations easier as all licensors acted only as licensors and all licensees only acted as licensees.

However, looking at the Telecommunication industry and the auto industry, panelists felt that there is also still a clash of cultures when it comes to the licensing mechanisms.

In the Telecom industry:

- SEPs are licensed on the User Equipment level,
- consequently, licensing negotiations target the device manufacturer (OEM) and
- in some cases, royalties consider the net selling price of the final product

In the Auto industry:

- Patents are usually (cross --) licensed on vertical levels and
- suppliers may incorporate IP rights into their component supply contracts.
- Royalties are often based on a component selling price.

The panel participants as well as the audience (both experts from car manufacturers and experts from SEP owners) discussed back and forth why a component-based royalty, or why a product-based royalty approach is a reasonable solution. SEP owners claimed that the current AVANCI rate for 2G, 3G and 4G (and e-call) SEPs at 15 USD is very low and can be compared to the price of a onetime car wash or a 5-hour ticket in a parking lot. In comparison to a car wash or parking ticket, the 15 USD in AVANCI gives access to the majority of the 2G, 3G and 4G SEPs ensuring connectivity for the whole lifespan of a car. The auto industry however claimed that in comparison to the prices of the modules in a car that provide the connectivity, 15 USD is a very high price, especially given that prices have already been negotiated with suppliers for the upcoming years. The auto industry further made clear that such royalties for connectivity standards will need to be paid by the end consumer.

What are the challenges for future 5G licensing?

The panelist agreed that the first task for licensing of 5G patents is to find very simple licensing models, otherwise licensing will not be successful. The licensing of SEPs in the smartphone world is well understood, most panelists felt that the case of 5G will be comparable to the 3G or 4G licensing negotiations. However, licensing 5G patents outside of the smartphone industry will be a lot more challenging. As the application of 5G will be different from industry to industry, licensing mechanisms will need to be more flexible and there is no one-size fits all model that will work: E.g. connecting a refrigerator to other home appliance devices might be a much simpler application of 5G compared to 5G enabled security features in a car that are crucial to avoid car accidents. A uniform licensing model will not work. Likely the 5G royalties for the refrigerator will have to be lower compared to the auto use case. While such flexibility is needed, the industry at the same time needs to find mechanisms that allow to aggregate and package the licensing of 5G patents to avoid stickiness. For real IoT applications it is not feasible to discuss with each licensor individually. The panel agreed that there needs to be an aggregated solution, which could be a patent pool or another mechanism to join licensing efforts.

Another challenge is the long tail of the market. In other words, 5G will be implemented in, as an example, IoT applications and products produced and shipped by small revenue companies – e.g. the smart IoT startup from Berlin with a 10 million EUR revenue. Collecting royalties from tens of thousands of small companies will not be efficient if the royalty per company is too low. Patent owners will either have to bundle resources to chase all small 5G users or accept a certain rate of free riders that stay under the radar and use patented 5G technologies without paying royalties.

5G use cases and the competition of standards.

How 5G will be applied in the various IoT uses cases is something that no one can foresee today. End users will be the ones to decide where 5G will be used and if implementing 5G, for instance, in a car will be a value add especially when even today not even 3G or 4G base stations are available across all countries and regions. Someone who lives in a region where 5G will not be offered for the next 10 years may not need 5G connectivity in his or her car. A car that travels from place to places, however, may only make use of 5G technologies in larger cities and the car owner may still want connectivity even though access is limited to regions.

The discussion about the competing standards 802.11p and V2X 5G will depend on the connectivity use cases of a car. Both standards have advantages and it must be seen which one will be used more. Competition of standards will also mean competition on price and thus then on the royalties charged. Some panelists felt that the future car will be integrating both standards and use the technologies for different use cases.

As of now, 5G is a new standard and the licensing of 5G patents will be a topic for the future. The panelists argued that today might not be the right time to start licensing negotiations with the IoT device manufactures, but what should be started early on is how a license for IoT should be constructed. Very likely 5G will not be licensed alone but in combination with other standards subject to patents.