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Strategic connectivity in 5G and 6G and remote surgery: The case of Germany

Conectividade estratégica em 5G e 6G e cirurgia remota: O caso da Alemanha

Conectividad estratégica en 5G y 6G y cirugía remota: El caso de Alemania

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Abstract
This article addresses the topic of 5G and 6G as a Technological Innovation System (TIS) along with the industrial application of Remote Surgery as an empirical case, exploring three main contributions. Firstly, this research contributes to the connection of the Technological Innovation Systems perspective and 5G and 6G networks in a quantitative viewpoint at national and international levels. Secondly, it contributes to Knowledge Production (F2) and Diffusion (F3) studies through Bibliometrics and software uses. Third, it contributes to the studies of a connection in 5G and 6G networks in the Remote Surgery empirical case application on TIS analytical background. Methodologically, the research problem of this study is to explore the R&D capacity in 5G and 6G TIS concerning the applicability of Remote Surgery worldwide and, consequently, in Germany. The general objective is to improve the industrial relevance of Remote Surgery through quantifying publications and patents and the collaborative networks in these domains. According to publications and patent data, the results reveal a crucial R&D map of Germany until 2021.
Keywords: 5G/6G; Technological innovation systems; Remote surgery.

Resumo
Este artigo aborda o tema 5G e 6G como Sistema de Inovação Tecnológica (TIS) juntamente com a aplicação industrial da Cirurgia Remota como caso empírico, explorando três contribuições principais. Em primeiro lugar, esta investigação contribui para a ligação da perspectiva dos Sistemas de Inovação Tecnológica e das redes 5G e 6G numa perspectiva quantitativa a nível nacional e internacional. Em segundo lugar, contribui para estudos de Produção (F2) e Difusão de Conhecimento (F3) por meio de Bibliometria e uso de softwares. Terceiro, contribui para os estudos de conexão em redes 5G e 6G na aplicação do caso empírico de Cirurgia Remota na base analítica do TIS. Metodologicamente, o problema de pesquisa deste estudo é explorar a capacidade de P&D em TIS 5G e 6G no que diz respeito à aplicabilidade da Cirurgia Remota em todo o mundo e, consequentemente, na Alemanha. O objetivo geral é melhorar a relevância industrial da Cirurgia Remota através da quantificação de publicações e patentes e das redes colaborativas nestes domínios. De acordo com publicações e dados de patentes, os resultados revelam um mapa crucial de P&D da Alemanha até 2021.
Palavras-chave: 5G/6G; Sistemas de inovação tecnológica; Cirurgia remota.

Resumen
Este artículo aborda el tema del 5G y 6G como Sistema de Innovación Tecnológica (STI) junto con la aplicación industrial de la Cirugía Remota como caso empírico, explorando tres contribuciones principales. En primer

lugar, esta investigación contribuye a conectar la perspectiva de los Sistemas de Innovación Tecnológica y las redes 5G y 6G desde un punto de vista cuantitativo a nivel nacional e internacional. En segundo lugar, contribuye a los estudios de Producción de Conocimiento (F2) y Difusión (F3) a través de la Bibliometría y el uso de software. En tercer lugar, contribuye a los estudios de una conexión en redes 5G y 6G en la aplicación del caso empírico de Cirugía Remota sobre los antecedentes analíticos de TIS. Metodológicamente, el problema de investigación de este estudio es explorar la capacidad de I+D en 5G y 6G TIS en relación con la aplicabilidad de la Cirugía Remota a nivel mundial y, en consecuencia, en Alemania. El objetivo general es mejorar la relevancia industrial de la Cirugía Remota mediante la cuantificación de publicaciones y patentes y las redes de colaboración en estos dominios. Según publicaciones y datos de patentes, los resultados revelan un mapa crucial de I+D en Alemania hasta 2021.
Palabras clave: 5G/6G; Sistemas de innovación tecnológica; Cirurgia remota.

1. Introduction

Firstly, it is crucial to highlight that the evolution of telecommunications technologies has propelled society from the 5G era, which is fast Internet with low latency, to the nascent horizons of 6G, ultra-fast Internet with ultra-low latency. A deliberate exploration of 5G technology requires, by extension, a forward-looking observation of its successor, 6G. Following this rapid technological advancement, 5G must inherently encompass a proactive consideration of its future manifestations in the form of 6G. Furthermore, standardization in 6G is already underway for advanced reflection on technological change, which is occurring in increasingly shorter periods (Porter & Kramer, 2018; Louçã, 2023; Freeman & Louçã, 2001).

Therefore, the 5G and 6G networks are key technologies to critical geopolitical disputes, such as those in the semiconductor industry, transistors and integrated systems that lead to software and hardware construction - main components of cutting-edge networks (5G and 6G) (Rikap & Lundvall, 2021; Moldicz, 2021). According to this article's data, 5G and 6G technologies applied to Remote Surgery represent a crucial advantage in the geopolitics scenario, as seen in the Results and Discussion (Rikap & Lundvall, 2021; Moldicz, 2021; Liu et al., 2018; Liefner et al., 2019) because of Remote Surgery.

According to this, remote surgery is a crucial application for 5G and 6G, including in the ongoing COVID-19 Pandemic. According to Tataria and colleagues (2021), the essential applications for tactical and haptic Internet are Remote Surgery, according to Graphic 2 of this research, Telediagnosis and Telerehabilitation. Remote and Robotic surgery is vital for situations of distance necessity and viability of latency (5G) or ultra-latency (6G), which means 10 to 1 millisecond of time response in operation. In practice, it represents a revolution in medicine with connectivity. In contrast, one of the best industrial applicability in terms of productive forms of a technological system or a sector is the mixed reality (MX), which means a conjunction of all worlds: physical, virtual and both of them - augmented reality (AR), virtual reality (VR) and mixed reality (MR). It can be tested precisely in remote surgery. After all, according to Islam and colleagues (2023), especially MR is possible through the metaverse - which in medical domain revenue is expected to reach $640 Billion by 2027 (Tataria et al., 2021; Islam et al., 2023).

Therefore, the research problem of this study is to explore the Research and Development (R&D) in 5G and 6G TIS concerning the applicability of Remote Surgery worldwide and, consequently, in Germany. The general objective is to investigate the industrial relevance of Remote Surgery through quantifying publications and patents and the collaborative networks in these domains.

This way, this article is organized in two phases: (i) in a conceptual and methodological discussion and (ii) in a discussion of the conceptual-empirical case through software, exposing the essential data. Following gaps, a theoretical discussion based on the TIS conceptual elements is analyzed in a 5G to 6G use case in remote surgery. As an evolution, 6G will enhance the 5G mobile communication system through innovations that will benefit that system. After all, the 5G and 6G networks will be seen as a conjunction of the 5G-6G evolving, according to the correspondent term "5G and 6G", which comprises both innovative forms of internet wireless communication.

1.1 5G and 6G in Remote Surgery

The interconnection of 5G technology has given rise to several other applications in the health sector. Virtual patient consultations, augmented reality (AR), and virtual reality (VR)-based simulated surgeries (García-Magariño et al., 2019) have become viable options, enhancing medical training and offering innovative approaches to medical procedures. Moreover, artificial intelligence (AI) supports robotic surgeries, enabling precise and minimally invasive procedures that improve patient outcomes (Dananjayan & Raj, 2020).

Silva and Guerreiro (2020) have provided an overview of the fifth generation of cellular communications and its potential advancements (5G and 6G). The transmission techniques of current 5G communications and expected future developments are explored, with a brief study of non-orthogonal multiple access (NOMA) using the single carrier with frequency domain equalization (SC-FDE) block transmission technique, highlighting its contribution to spectral efficiency.

The sixth generation of cellular communications (6G) presents, according to many authors, such as Silva and Guerreiro (2020), Abdel et al. (2022), Banafaa et al. (2023), Muhammad et al. (2022) and Muhammad et al. (2020), as an ultra-fast and ultra-low latency Internet, fundamental for Remote Surgery. Incorporating 5G and 6G within the framework of the Fourth Industrial Revolution (Industry 4.0) has been discussed. 5G represents a paradigm shift from previous generations, enabling a wide range of services based on the Internet of Things (IoT) and vehicle-to-vehicle (V2V) communications, supporting technologies like autonomous driving, smart cities, and Remote Surgery in ambulances.

Novel techniques, including millimetre waves (mm-wave) and massive multiple-input multiple-output (massive-MIMO) technology, are employed to support these services, distinguishing 5G from the fourth generation (4G) of cellular communications in a technological evolution (Silva & Guerreiro, 2020; Abdel et al., 2022; Banafaa et al., 2023; Muhammad et al., 2022).

While 5G plays a vital role in the initial implementation of the Fourth Industrial Revolution, 6G anticipates addressing a host of new services, including virtual reality (VR), augmented reality (AR), holographic services, advanced IoT, AI-integrated applications, wireless brain-computer interaction (BCI), and high-speed mobility. Ongoing research on 5G and 6G systems indicates that new MIMO techniques will support these applications and utilize Terahertz (THz) bands (Silva & Guerreiro, 2020; Ananya et al., 2023).

According to Rajat et al. (2019), in surgical intervention procedures, the Internet of Things (IoT) has produced a considerable volume of data processing exploring big data through the application of artificial intelligence (AI) algorithms. This dynamic is employed considering extracting significant insights and knowledge from extensive datasets. Specifically, the amassed data has laid the groundwork for facilitating human decision-making processes (Rajat et al., 2019).

As healthcare systems become entirely AI-driven and reliant on 6G communication technology, our outlook on lifestyle will transform. Presently, time and distance present significant obstacles to accessing healthcare, but with 6G, these challenges can be surmounted. Additionally, 6G is set to revolutionize healthcare as a game-changing technology. The current cutting-edge healthcare system is incapable of offering telesurgery due to communication difficulties. Moreover, the ambulance service is to be replaced (Ahammed, et al., 2023).

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2. Conceptual Background

Carlsson et al. (2002), aligned with Freeman and Perez (1988), have suggested that an Innovation System is a systemic perspective of innovation in order to a conjunction of actors, organizations (public and private), networks and technologies with the same objective of directing and intensifying the speed of innovation (Carlsson et al., 2002; Markard, 2020). In other words, the systems perspective, assumed from an Engineering viewpoint, is made of components, attributes, and relationships, which link all these concepts in an interactive approach. It is about a framework for the substantial relations of the Innovation process, according to an economic or a techno-economic perspective of organizational, integrative or coordinated ability. According to Hekkert et al. (2007), this approach in TIS terms may direct the speed and intensity of innovation, proposing "indicators" for the Innovation Policies according to a specific technological system, whatever it is (Hekkert et al., 2007).

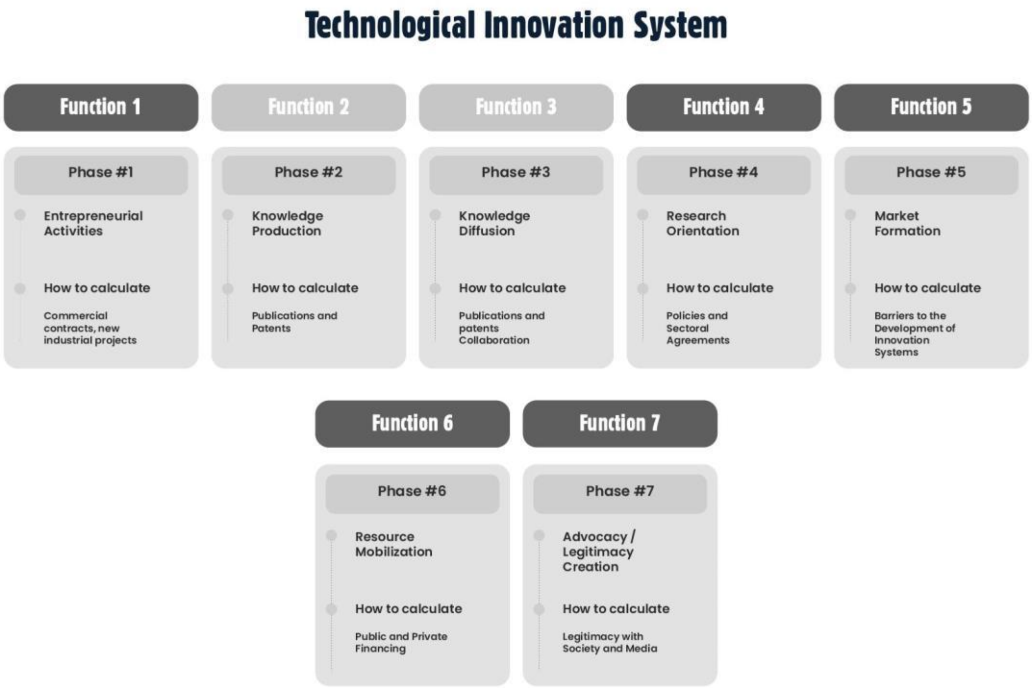
Regarding this, according to Furtado et al. (2020), De Oliveira et al. (2020), Ashari et al. (2022), Bergek (2015) and Markard et al. (2015), the crucial fragility of the Technological Innovation System (TIS) conceptual background is the problem of geographical contexts. Part of the worldwide literature has tried to resolve (Van Der Loos et al., 2021; Walrave & Raven, 2016; Huang et al., 2016 and Edsand, 2019, for example) this problem with the micro and meso spheres in its analytical perspectives, which means regionally and nationally, but not always in a multilevel perspective. Binz and Truffer (2017, 2011) and Bergek et al. (Bergek et al., 2015) are crucial papers for comprehending the problem of contexts in Technological Innovation Systems, especially in connection to decision-making and political perspectives in a policy mixes approach.

Contrastingly, exponents such as Knut Koschatzky, R. A. A. Suurs and Knut Blind adopt a lens that centres more decisively on the structural dynamics and developmental pathways ingrained within innovation systems. Their focus consists of structural *motors* or *drivers* that transpire within innovation systems over time, delineating trajectories that technological evolution traverses. Beyond structural modifications, their purview encompasses intricate metamorphosis and reconfiguration that TIS undergoes over technological trajectories. Via technological paths, TIS grasps technologies' directional evolution and maturation throughout the technological life cycles. It explicates the mechanisms that culminate in certain technologies asserting dominion within the TIS framework. Consequently, they underscore the pertinence of *disruptive innovations*, heralding transformative shifts in the innovation industrial configuration (Ashari et al., 2023; Blind & Niebel, 2022; Buggenhagen & Blind, 2022).

Hekkert et al. (2007), Furtado et al. (2020), Johnson and Jacobson (2001), Negro (2009), and Binz and Truffer (2017) have each added unique contributions to this framework, emphasising the profound influence of TIS functions in guiding the trajectory of technological change. Conversely, the perspectives achieved by Bergek et al. (2015) and Weber and Truffer (2017) underscore the significance of TIS mechanisms, especially those related to blocking, in shaping innovation contours.

In this sense, this investigation proposes working with TIS Functions 2 and 3, which correspond to Functions 2 and 3. These functions can sign precisely how technology transfer and spillover are produced concerning 5G technology. This structural focus of analysis can be understood in the figure below:

Figure 1 - TIS Working Functions (See Hekkert et al., 2007; Furtado et al., 2020; Martinelli & Mazoni, 2024).



Source: Authors.

This article has focused on Function 2 and Function 3. Henceforth, the focus is on publications, patents and network scientific collaborations, which have, for instance, a crucial role in the speed and direction of the innovation process. Publications and patents have relevant elements that reinforce 5G and 6G development (Buggenhagen & Blind, 2022) and sustain efforts in medical applications worldwide. In telecommunications, Research and Development (R&D) has been established as a cornerstone of innovation, diffusing via channels of knowledge and technology transfer encompassing principally publications and patents (Ashari et al., 2023; OECD & Eurostat, 2018). These endeavours have amplified the possibilities of research becoming an accepted application in the market. Nevertheless, recently, there has been a long journey for technologies to gain reliability in the market (Ashari et al., 2023, Markard, 2020).

2.1 Empirical Case of 5G And 6G for Remote Surgery

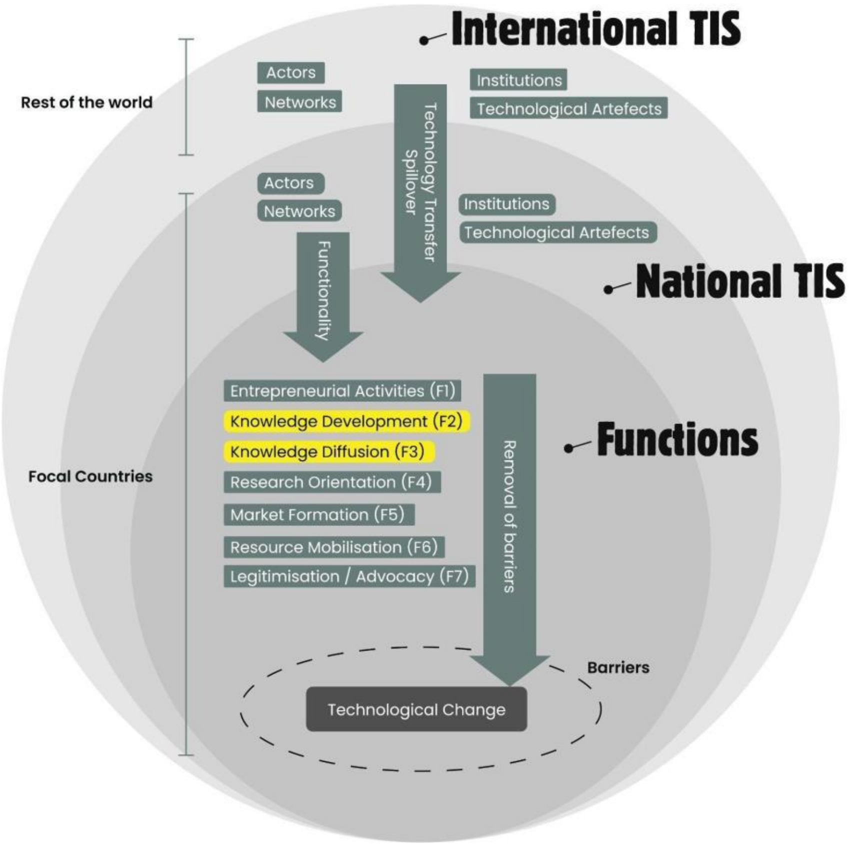
This study is based on a theoretical-empirical case focused on Remote Surgery. The Healthcare TIS is interplayed with the 5G TIS and 6G subTIS through publications, patents and networks, elucidated by research on clustering and collaborations. In this way, the case of Remote Surgery empirically retraces the conceptual framework of TIS through its primary functions for a nascent technology: knowledge production and network formation.

It would be one of the bases for the dynamics of technological overflow - *spillover* - and technology transfer, based on the knowledge produced in publications and patents terms and their collaboration through the formation of networks. Innovation cycles need this dynamic and feed on these learning curves, through inputs of route corrections of innovation actors in 5G and 6G (Rodríguez-Pose & Crescenzi, 2008; Preobrazhenskiy & Firsova, 2020; Lundvall, 2016; Rikap & Lundvall, 2021; Ashari et al., 2023).

The dynamics of institutions in 5G and 6G in interconnection with the Healthcare System, given its best industrial application, the Medical Internet of Things (medical-IoT, m-health, IoMT), has the best way to be patentable and to build arguments in article publications in Remote Surgery. It maps entrepreneur activity (Dwivedi et al., 2022; UNCTAD, 2021).

At the same time, this research analyzes the national level in patent terms in Germany because of the networks' publications graphics worldwide. It has been disclosed that network graphics worldwide are in Germany and China nodes, which means R&D networks in those countries. This systemic orientation can be seen in the figure below:

Figure 2 - TIS Levels and Work Functions (Schmidt & Dabur, 2014 adapted).



Source: Authors.

The publications, both internationally and nationally in Germany, are the same regarding public and private organizations involved with the topics. Therefore, we maintained a graphic for both national and international TIS levels. Internationally, the publication's result is equal to 130 articles published. Nationally, the publication's result is equal to 8 articles published, according to (Eq - A1). This result demonstrates the collaboration in Germany amongst these eight articles.

The empirical results of specific industrial applications research, such as Medical Industrial Internet of Things (MIIoT) in remote surgery cases, make possible the route correction of the TIS context problem proposed by the current literature (Bergek et al., 2015; Furtado et al., 2020; De Oliveira et al., 2020; Edsand, 2019). According to publications and patents, using the industrial application to the national contexts suggests macro and meso-economic contexts, which may complement the TIS conceptual background in a more specific approach than the worldwide context.

2.2 Working Formulas

EQ. (A1)

Table 1 - Systematic Research Publications Formula.

Publications – Scopus (2005-2021)
(5g technology) OR (5g mobile communication system*) OR (fifth generation mobile communication system*) OR (5g wireless) OR (5g network*) OR (6g technology) OR (next generation wireless network*) OR (future wireless communication solution) OR (cutting-edge wireless network* technolog*) OR (advancement* in wireless communication) AND (Remote Surgery) OR (minimally invasive surgery) OR (medical robotics) OR (robot-assisted) teleneurosurgery) OR (Remote Surgery) OR (teleoperated robotic) OR (robot-assisted minimally invasive surgery) OR (remote clinical stereo tactic neurosurgery)

Source: Authors.

EQ. (A2)

Table 2 - Systematic Research Patent Formula.

Patents – Orbit Intelligence and Insight (2005-2021)
(EPD <= 2021) AND REMOTE SURGERY OR MINIMALLY INVASIVE SURGERY OR MEDICAL ROBOTICS OR ROBOT ASSISTED OR TELENEUROSURGERY OR REMOTE SURGERY OR TELE OPERATED ROBOTIC OR ROBOT ASSISTED MINIMALLY INVASIVE SURGERY OR REMOTE CLINICAL STEREO TACTIC NEUROSURGERY AND (((5G OR FIFTH GENERATION OR 5TH GENERATION)/BI/SA/TX/KEYW AND H04W/IPC/CPC AND (5G OR FIFTH GENERATION OR 5TH GENERATION)/BI/SA/TX/KEYW) OR ((5G TECHNOLOGY OR 5G MOBILE COMMUNICATION SYSTEM+ OR FIFTH GENERATION MOBILE COMMUNICATION SYSTEM+ OR 5G WIRELESS OR 5G NETWORK+ OR 5G)/TI/AB/OBJ/ADB/ICLM) OR (6G TECHNOLOGY OR 6G NETWORK+ OR NEXT GENERATION WIRELESS NETWORK+ OR FUTURE WIRELESS COMMUNICATION SOLUTION OR CUTTING EDGE WIRELESS NETWORK+ TECHNOLOG+ OR ADVANCEMENT+ IN WIRELESS COMMUNICATION OR 6G))

Source: Authors.

2.3 Conceptualising Publications, Patents, and Networks

The subsequent section presents visual representations generated using the VOSviewer software, which illustrates the interconnections between publications related to 5G, 6G and Remote Surgery from Scopus (Elsevier, 2023; Zhu & Liu, 2020), specifically in the context of medical-industrial applications for Remote Surgery, as illustrated in Figure 2. In the Publications section, this paper develops a quantitative analysis of publications through statistical tables and network analyses based on keywords, countries, and organizations using Publication Bibliometrics.

This approach allows for a comprehensive examination of this process, serving as a quantitative metric of publications that enables comparisons amongst various variables within the graphs. For instance, it facilitates comparisons amongst authors, keywords, countries, and organizations (Ashari et al., 2023). After all, it has been used by VantagePoint to form quantitative and scientific indicators, according to the achievement of suggested data performance. Scientific Indicators and Scientific Metrics are statistical data used for the intangible measurement, which may illustrate a multifaceted reality (Maurya, 2021; López-Pernas et al., 2022; Mingers & Leydesdorff, 2015).

PATSTAT has been recognised as a system primarily reliant on data from the European Patent Office. This partnership between the US Patent and Trademark Office (USPTO) and the European Patent Office (EPO) forms a component of contemporary research methodologies, particularly in patent analysis. It facilitates a nuanced comprehension of the intricate interplay between patents, innovation, and industrial evolution (European Patent Office, 2023; European Environment Agency, 2020; Oecd.org, 2022). The patent graphics were generated using Python on *granted* patents. The universe of covered patents, as pointed out by the EPO and USPTO (European Patent Office, 2023; Office, U., 2023), are patents from the West, that is, from the countries of North America and Western Europe, that is, members of the UN, NATO, OECD and European Union.

In contrast, the platform Orbit Intelligence and Insight have essential data from East Patent Offices such as from China and Japan, which means that it is crucial to cross those databases. Regarding this, it is also primarily important the codification of SEPs (Standard Essential Patents), especially to understand the evolving of 5G to 6G networks, technologies linked with essential patents and standards (Buggenhagen & Blind, 2022).

3. Results

3.1 Publications and Patents Quantifying

As a result of our methodological demonstration, this section provides raw data on publications and patents resulting from the formulas in question. To quantify publications and patents, we sought to develop Function 2 of the Technological Innovation System: knowledge production in 5G or 6G and remote surgery.

Table 3 - Publications and Patents (Elsevier, Nov 2023; Orbit Intelligence, Feb 2024).

Publications (2005-2021)	**Patents (2005-2021)**
International TIS - 130 scientific papers	**International TIS –** 35 patent families - 2 SEPs
National TIS (Germany) - 8 scientific papers	**National TIS (Germany) –** 3 patent families

Source: Authors.

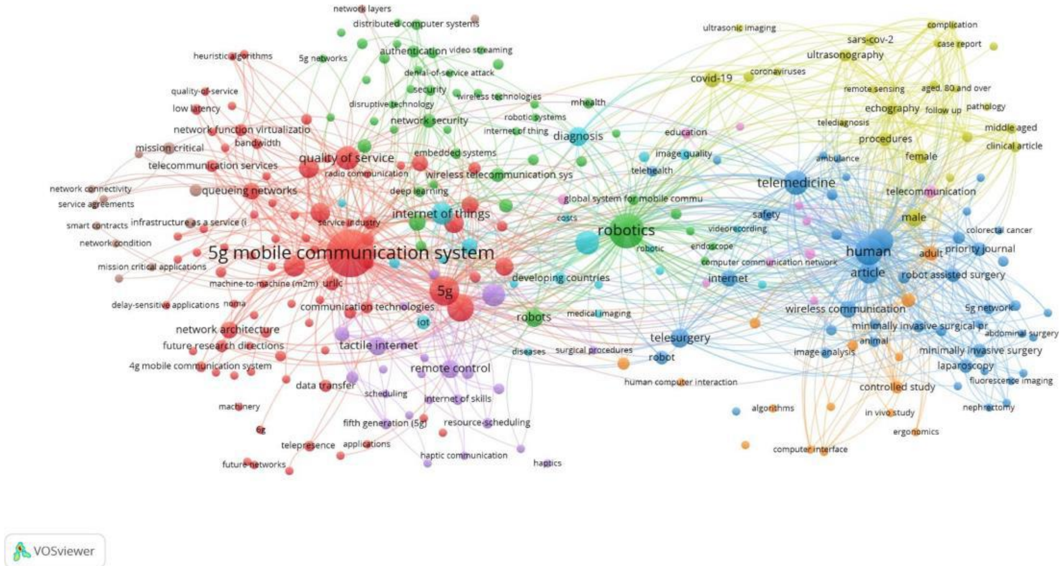
Especially in Scopus, the number of publications regarding the patent market oscillation may vary according to the selected time frame. Thus, in a month, you can have a discrepancy in publications and patent terms. Because of this, we crossed the databases and Patent Offices. Crucial issues that emerged from the patents subject for 5G are the correspondence of SEPs (Standard Essential Patents) to the correlated standards for 5G and then for 6G, according to the international debate. Buggenhagen and Blind (2022) arise on the subject; however, they do not have an in-depth viewpoint because of a lack of standardization focus by the Releases. In contrast, their perspective is the most closely related to this article.

3.2 Publications Graphics

The following section provides graphics (maps) generated by VOSviewer software, creating article couplings to collaborate in 5G and 6G from Scopus with the medical-industrial application for Remote Surgery, according to Eq. (A1) and Eq. (A2). This article explores publication networks by keywords, countries, and organizations through Publication Bibliometrics, which makes it possible to obtain an analysis of this process. It is a quantitative indicator of publications, which can establish comparisons between the variables in the graphics, according to Scientific Indicators Worldwide (Ashari et al., 2023).

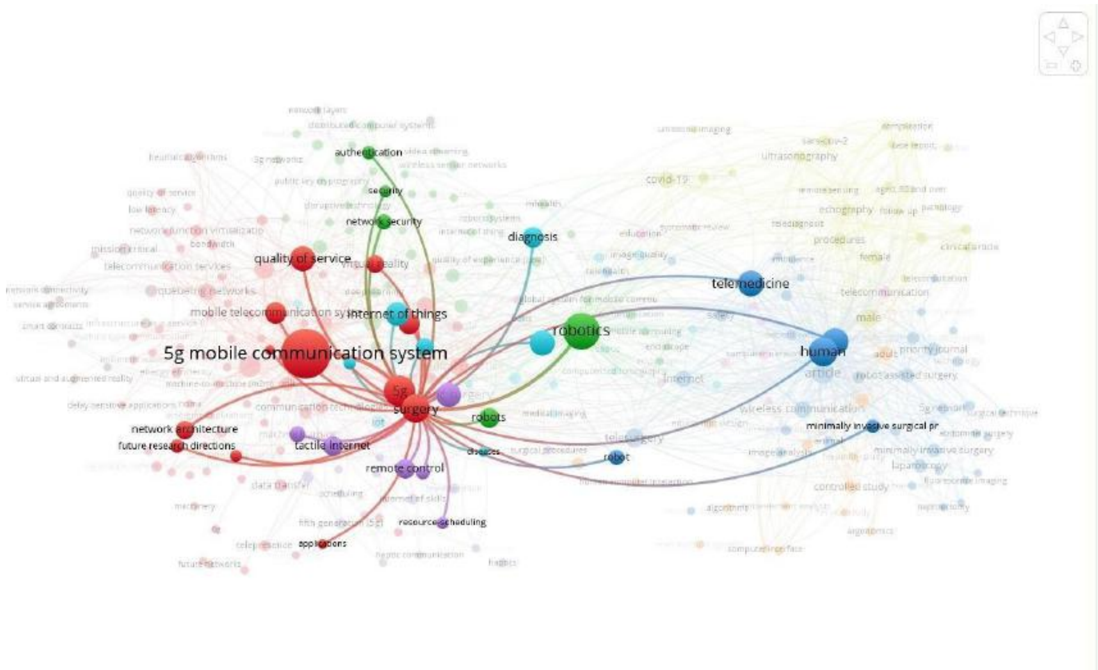
3.2.1 Sample I - Publications at International TIS

Graphic 1 - Scientific Indicators at International TIS by Keywords.



Source: Authors.

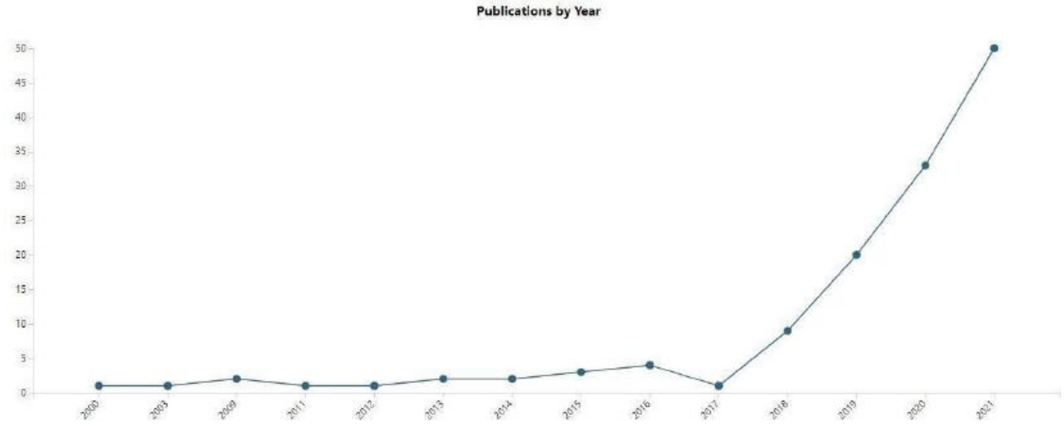
Graphic 2 - Zooming in Surgery Keyword.



Source: Authors.

Surgery is also directly linked to the topic of 5G, although there are already indicators of future research directions, possibly concerning 6G. On the one hand, there is a strong relationship between the topic and 5G and network architecture structures; however, special attention is paid to possible applications for 5G, 6G, and Remote Surgery. The quality of service is also something that draws attention. Through the visualization of the purple cluster, the theme is also linked to the tactile Internet and remote control: Remote Surgery, Robotics and Telemedicine. Consequently, the researchers - in other terms, the scientific actors of innovation - discuss and research these related issues.

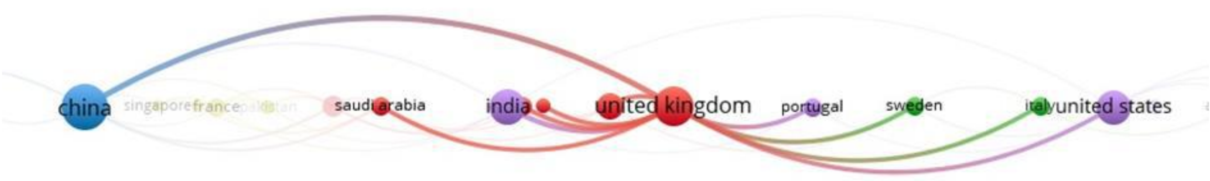
Graphic 3 - Scientific Indicators at International TIS by Timeline.



Source: Authors.

In Graphic 3 above, an upward curve can be seen, especially from 2015 onwards. According to Mendonça et al. (2022), there was a boost in publications around the topic of 5G in 2015. Therefore, this is possibly the reason for the take-off in Graph 3. On the other hand, 2017 was also a record year when conflicts between China and the USA intensified over interests in the dominance of semiconductors, including the technological race (Rikap & Lundvall, 2021).

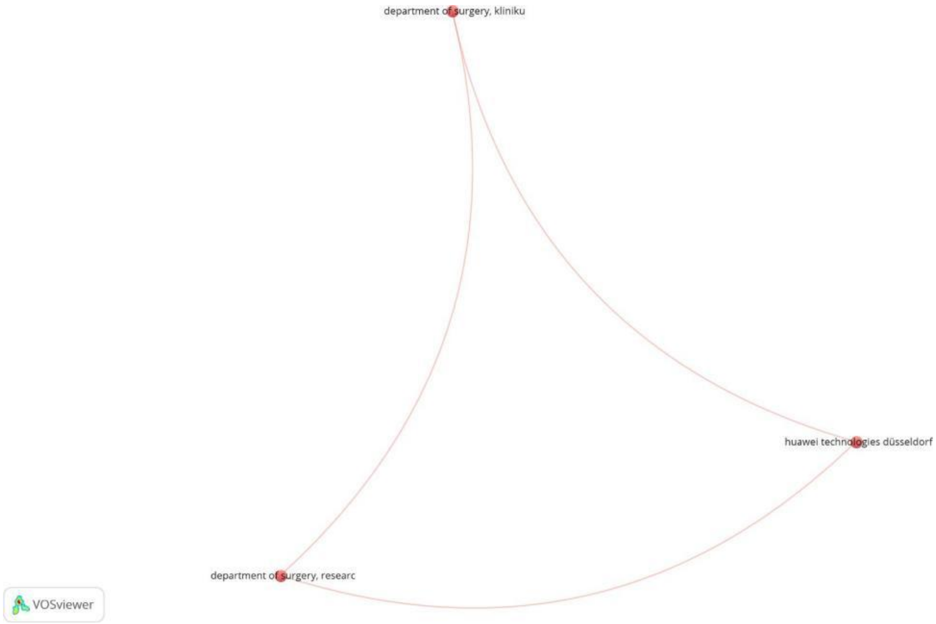
Graphic 4 - Scientific Indicators at International TIS by Countries.



Source: Authors.

In that order, China and the United Kingdom stand out in the number of publications. These countries have a strong connection in terms of academic cooperation, although China also cooperates with France, South Korea, Spain and Japan. The United Kingdom, in turn, cooperates with India, Portugal, Sweden and the USA, being, until 2021, the *link* (Graphic 5) between the United States and China. The USA also had many publications and cooperated with Australia, Sweden, Canada, Finland, Sweden, Portugal and the United Kingdom.

Graphic 5 - Scientific Indicators at International TIS by Organisations.



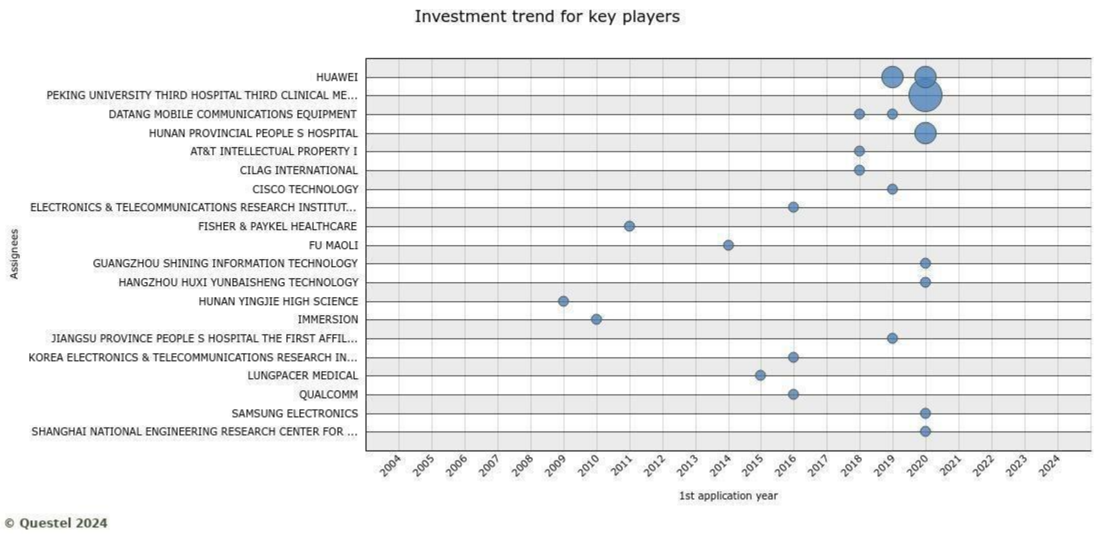
Source: Authors.

The Graphic 5 and this Zooming show that Huawei Technologies from Düsseldorf had until 2021, collaborated on publications with the other two Institutions: the Department of Surgery in Klinikum, Germany and a Department of Surgical Research that cannot be identified. It means that Germany and China have ordinary research until 2021 at least and that Germany cooperates nationally in publications. It means that until 2021, Huawei's R&D departments were in Germany, and these countries carried out R&D activities.

3.3 Patent Graphics

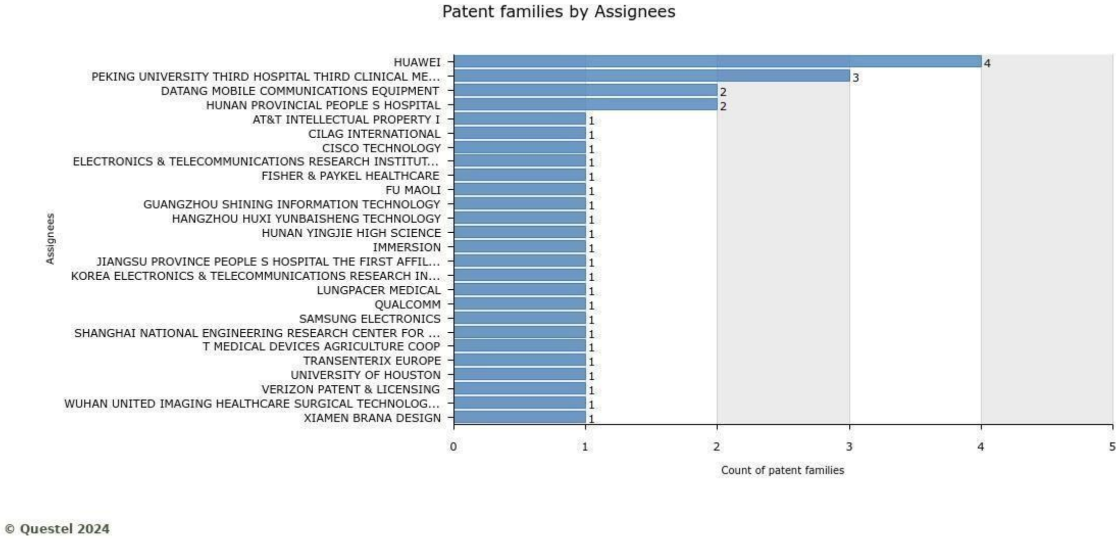
3.3.1 Sample II - Patents at International TIS

Graphic 6 - Innovation Indicators at International TIS by Investment for Key Players.



Source: Authors.

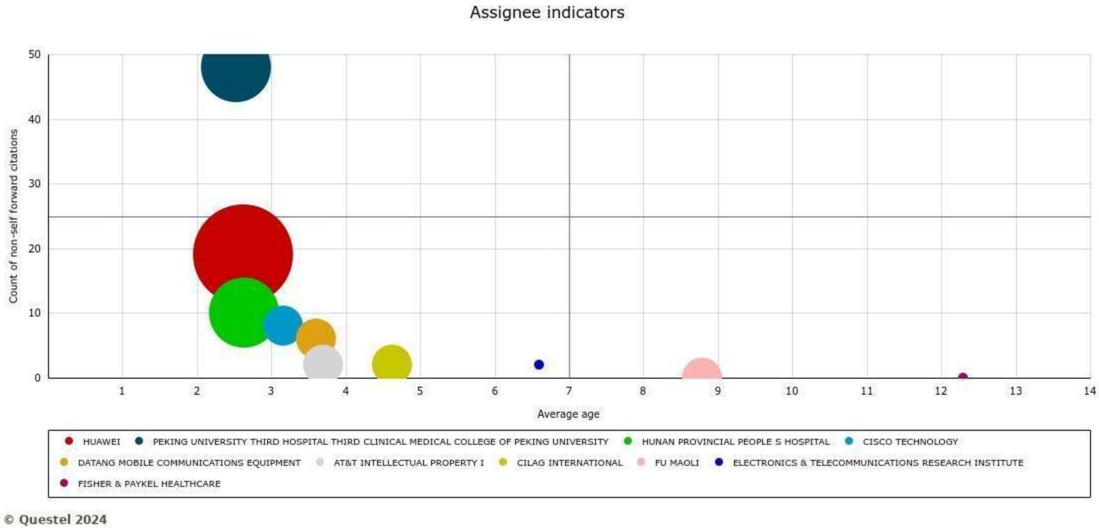
Graphic 7 - Innovation Indicators at International TIS by Patent Families by Assignees.



Source: Authors.

Similar to publications, the expansion in patents worldwide increased correspondingly in 2020, the year in which conflicts between China and the United States intensified over semiconductors, the main insulators of electricity and used in the manufacture of all types of electronic components, from transistors to integrated circuits - essential materials for connectivity and the functioning of the Internet (Rikap & Lundvall, 2021). At the same time, the year in which OMS accepted the Pandemic situation internationally.

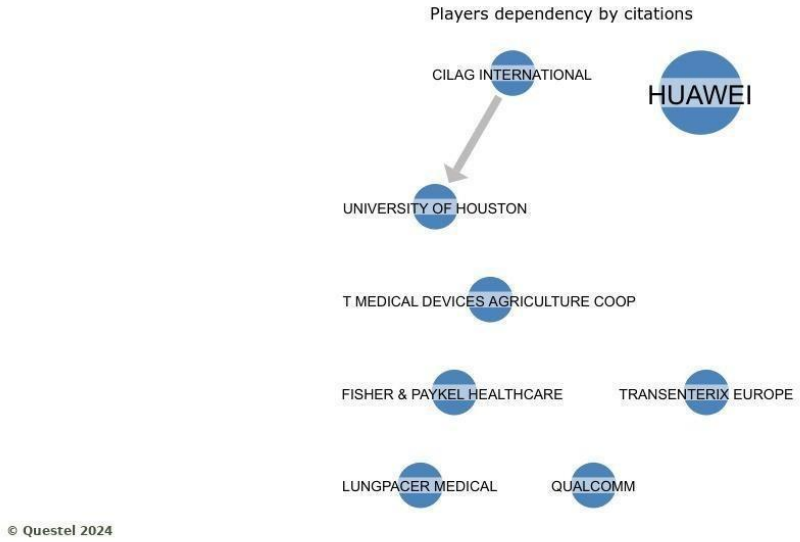
Graphic 8 - Innovation Indicators at International TIS by Assignee Indicators.



Source: Authors.

The legend itself shows the relationship between players through designated indicators. Thus, Huawei precedes the others, followed by Peking University Third Clinical Medical College of Peking University and Hunan Provincial People's Hospital. Consequently, it is also possible to observe the leading role of Cisco Technology, Datang Mobile Communications Equipment and AT&T Intellectual Property. Cilag International and Fu Maoli also play a leading role, while Electronics & Telecommunications Research Institute and Fisher & Paykel Healthcare are entering the market through inclusion in the patent universe.

Graphic 9 - Innovation Indicators at International TIS by Players Dependency by Citations.



Source: Authors.

As of 2021, there is only one patent-level collaboration worldwide: Cilag International and the University of Houston. All other companies operate on an individual level and are highly competitive. The absence of further collaborations indicates an extremely truncated market and, probably, by the year 2021, with geopolitical and military disputes in terms of dominance over patents in 5G, 6G and Remote Surgery.

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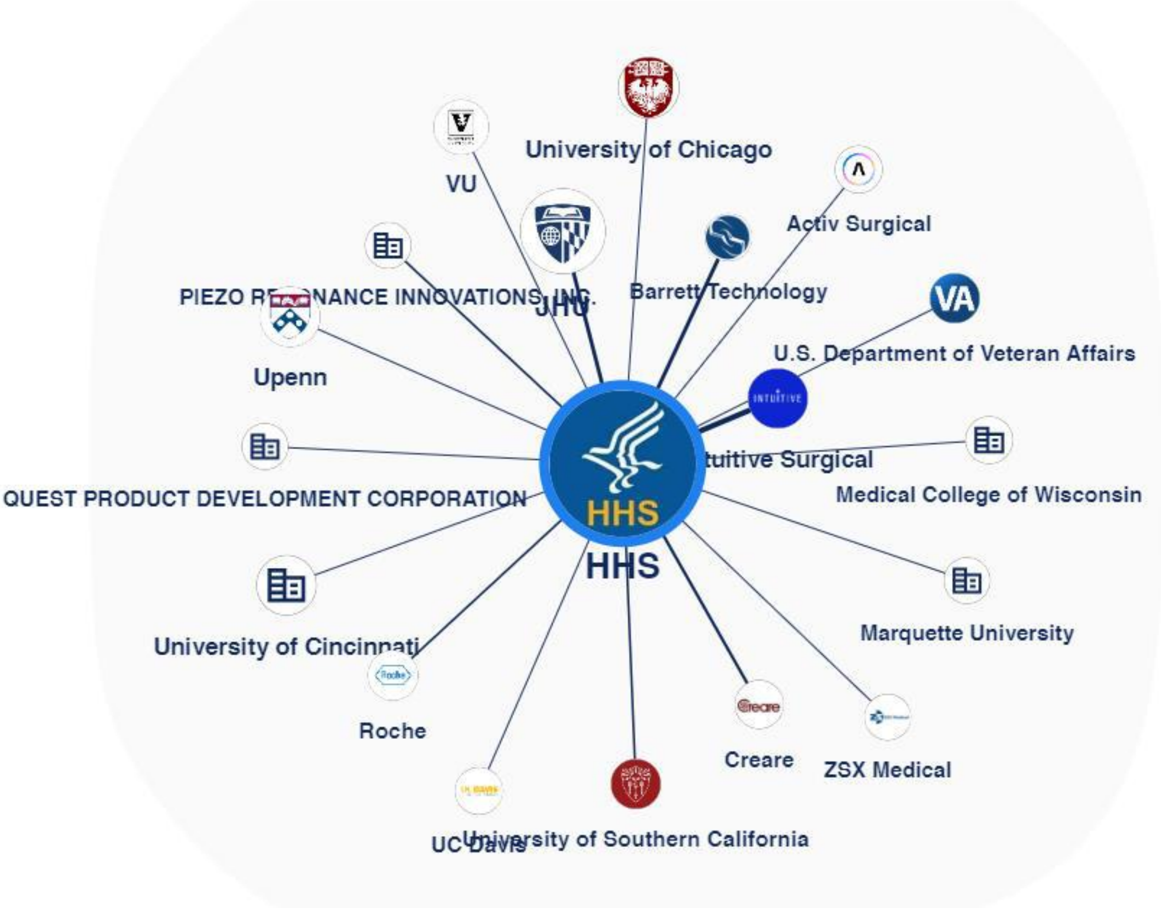
Graphic 10 - Innovation Indicators at International TIS - Focus in the Mapping Node.

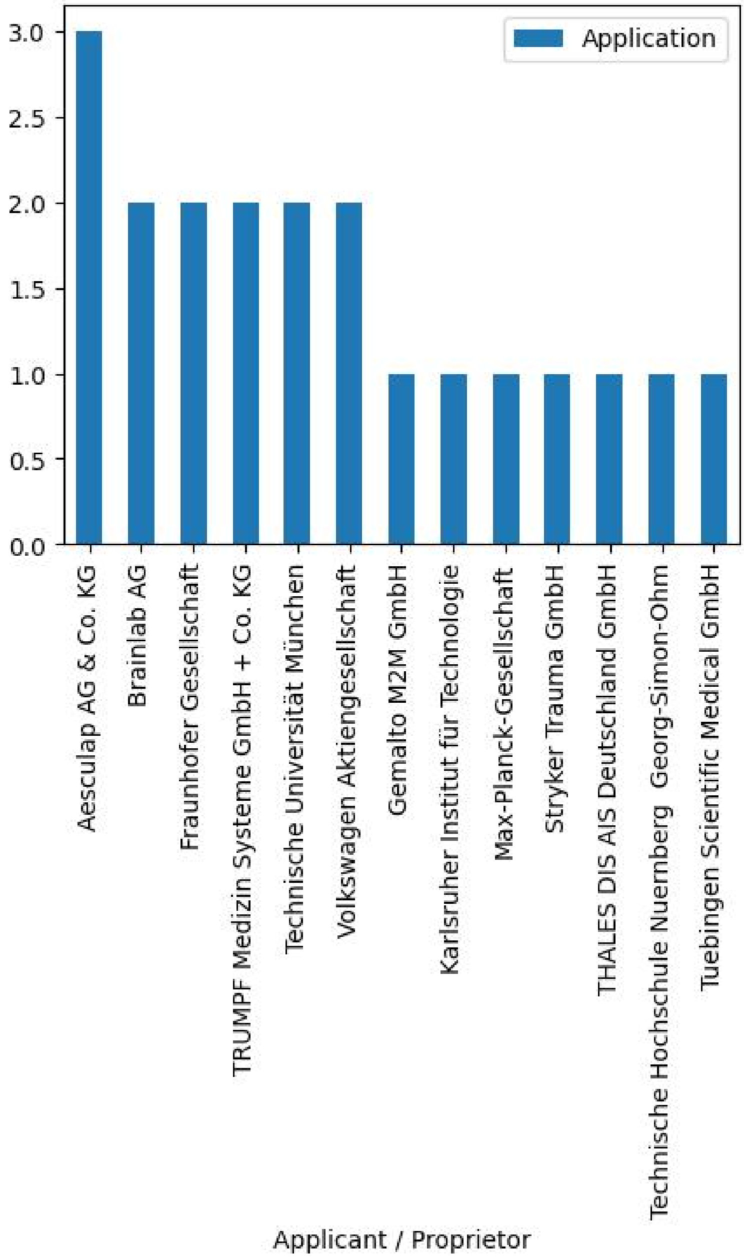


Source: Authors.

The interpretation of chart 10 shows that the United States department of health and human services (HHS) represents the central node on the international patent map, indicating its prominent position in the healthcare innovation landscape. This prominence suggests that HHS and a network of public and private organizations play a crucial role in generating and developing new health-related technologies and discoveries. The presence of multiple public and private organizations connected to HHS indicates significant collaboration between different sectors and technological systems to drive innovation in healthcare. It may include government agencies, research institutions, pharmaceutical companies, hospitals, and other healthcare-related entities. With its central role in the patent map, this interpretation suggests that HHS promotes scientific and technological advancement in healthcare, facilitating collaboration and knowledge exchange between diverse entities. it could have important implications for public policy, investments in research and development, and innovation strategies in the healthcare sector, both in the united states and internationally.

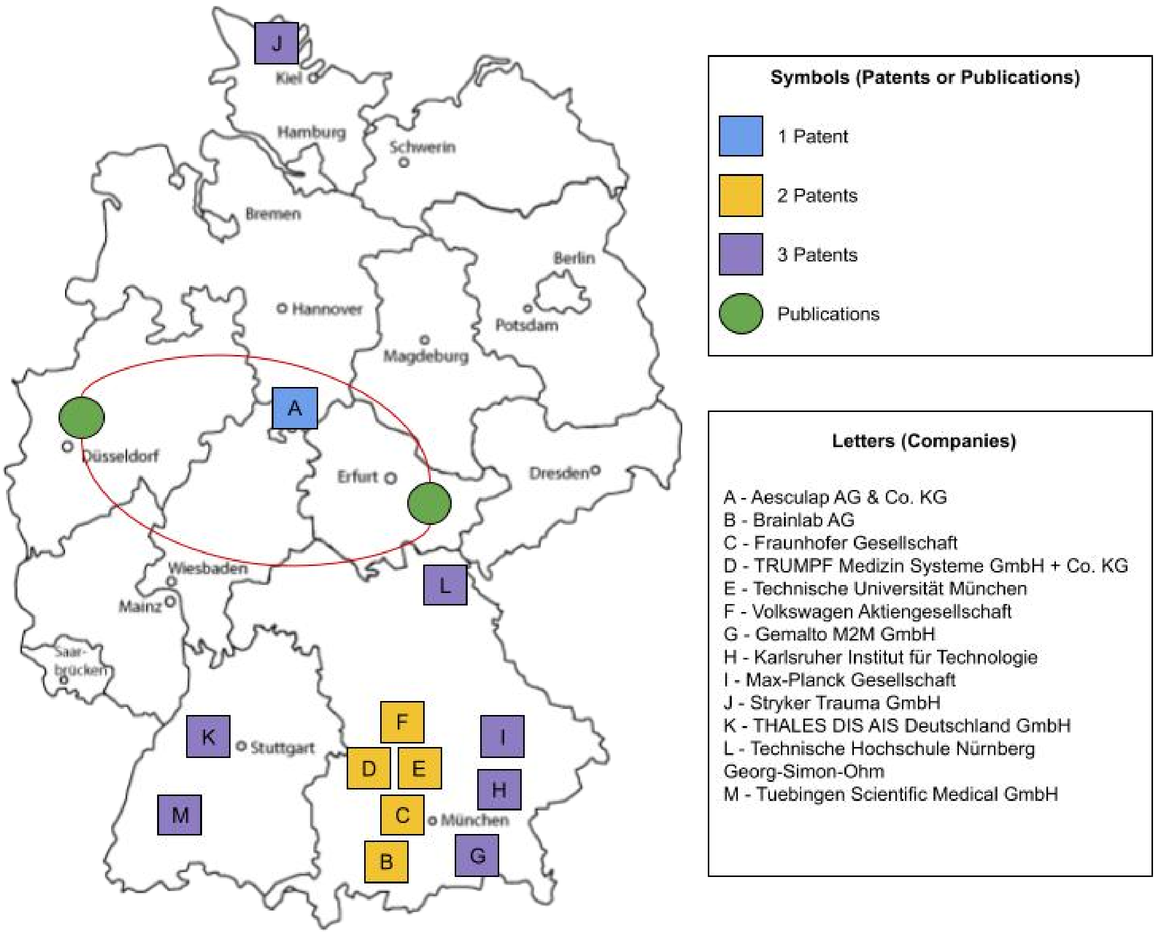
3.3.2 Sample III - Patents at National TIS

Graphic 11 - Innovation Indicators at National TIS by Enterprises.



Source: Authors.

Figure 3 - Germany Research and Development Mapping until 2021.



Source: Our Elaboration, based on Liefner et al. (2019).

4. Analysis

According to Lin et al. (2018), Innovation is an essential factor that drives economic globalization. The global innovation chain is a new development through which China may implement open innovation and utilize the world's knowledge, technology, information and other advanced resources to improve its innovation capabilities, promote industrial modernization and enhance its protagonism in global value chains (Lin et al., 2018).

Lin et al. (2018) make a precious contribution in their article "*Industrial Upgrading Based on Global Innovation Chains: A Case Study of Huawei Technologies Co., Ltd. Shenzhen*". Through a detailed case study, Lin et al. (2018) describe how China introduced talent, attracting foreign investment, expanding trade in intellectual property, and developing outsourcing and international strategic alliance research and development to build a global innovation chain. Besides that, China is, according to the authors, at the lower end of the global value chain (Lin et al., 2018). On the other hand, it is logically strategic for Chinese researchers to retract the power of China economy's strength to avoid entry barriers in foreign economies.

Nevertheless, until 2019, according to Liefner et al. (2019), in an article on the study case of Huawei in Germany, this case was significant, as it progressed more than most other companies in China and other industrializing countries. Studying Huawei's approach is, therefore, potentially relevant for other newcomers countries. German universities and research institutes have examined that collaboration partners are much less distinctive amongst Western countries than other countries, which means that, according to these authors, Germany is a collaborative country at a global level. While they collaborated voluntarily and continued a tradition of openness to industry needs, they maintained strong ties with basic research (Liefner et al., 2019).

Something that draws attention in the article by Liefner et al. (2019) is that the authors deal entirely with Huawei's collaborations in Germany. Interestingly, the R&D center in Germany is in Munich rather than Düsseldorf. Their article is based on patent information. In contrast, Lin, Li and Chen (2018), who deal with Huawei's international cooperation, mention Huawei in Düsseldorf. The article displays that this global strategy of the Chinese company covers other countries (Liefner et al., 2019; Lin et al., 2018).

Munich is a hub in Research and Development, even though it is still behind the United States and China. Their government may mirror Chinese and North American Innovation and Science and Technology Policies to encourage more publications and patents in remote surgery with 5G and 6G. Furthermore, Germany is the only one to establish scientific collaborations.

Finally, Graphic 4 is crucial in discussing the Bibliometrics maps of countries. The data shows that until 2021, all the countries exposed were involved in this strategic synergy of those countries. Besides the link between the West and the West, the United Kingdom proved that it was possible to build some bridges along this terrain of conflict. After all, most countries are directly and indirectly, strongly and weakly, in collaboration regarding publications. It makes scientific advancement and technological spillover possible. In patent terms, the technology transfer.

5. Final Considerations

In conceptual terms, this paper has investigated publications and patents considering identifying the global and national (Germany) 5G TIS and 6G subTIS and their respective life cycle phases for Remote Surgery. The pioneering advancements of 5G and 6G technologies are prominent within spheres of commercialization and market dimensions. 5G and 6G still encompasses a nascent TIS stage, which demands further exploration by research productions (Buggenhagen & Blind, 2022). However, with solid market penetration through soft powers (Moldicz, 2021), and according to this data analytics, it is not so in the nascent stage, but starting to have its maturity in TIS.

Finally, Public Policies connecting Innovation and Telecommunications Policies at the national level depend on new 3rd Generation Partnership Project (3GPP), the Institute of Electrical and Electronic Engineers (IEEE), and International Telecommunication Union (ITU) standards, which may be subject to regulation until 2030 at the international level guiding the national level. At the same time, it means that looking at 5G requires forward-looking observations about 6G, including from a political viewpoint at the national level in co-operation with NIST, European Union, OECD and with China (UIT, 2023; 3gpp.com, 2023; NIST, 2023; IEEE Standards Association, 2023).

Future studies on TIS, 5G and 6G and Remote Surgery may analyse the other functions of TIS more extensively, nevertheless, without failing to correlate them with standardization at an international level. Furthermore, there could be studies correlating the international and national levels with appropriate empirical studies through case studies, with a composition of software use and interviews. These future studies could overcome many limitations of the present article, such as analysing the Healthcare TIS context through patient monitoring by new technologies (5G and 6G) with an in-depth discussion about standardization.

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