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Exploring the Development and Progression of 5G: A Bibliometric Analysis of Scholarly Production

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Abstract

5G (5th Generation) and the related technologies implementation are expected in 2020. The 5G is considered to be a breakthrough of IoT devices in terms of enhanced bandwidth, efficiency, reliability and energy consumption. This study focuses on quantitative and qualitative progression of research in the field of 5G. It also provides the publishing trend, most productive and cited countries, organizations, and authors on 5G. In addition, it identifies the most frequently used keywords, authorship pattern and preferred journals. The research is based on 5G related research from Scopus database, which includes all relevant keywords of the field limiting it to conference papers, articles, book chapters, editorial and books. The outcome of the study revealed that 5G related research is on the rise worldwide. The number of yearly published articles has increased from one to 2222 during the period between 2003 and 2020. China, United States and United-Kingdom are most productive countries. Beijing University of Posts and Telecommunications have taken lead in publishing 5G research. Furthermore, it is noteworthy that 19 out of these 20 most productive organizations in the world, seven belong to China. Majority of top 10 preferred journals are Q1 and published by IEEE (Institute of Electrical and Electronics Engineers). The most popular authorship pattern is three-authors. In subcategories of wireless networks, 5G communication gets a lot of attention.

Keywords: 5G; wireless networks; bibliometric analysis; citation analysis

Introduction

The proliferation and advancement in the handheld multimedia enabled technologies and low-cost storage has created a challenge in the communication realm. These advancement in the technology has created completely portable gadgets embedded with the features from telecommunication to entertainment. Health monitoring sensors and now to the internet of things (IoT). However, to cope with these advancements there is a rapid development in the telecommunication technologies. The evolution of wireless technologies from 1G to 5G is beyond the speed enhancement and also provide the support for the integrated new evolution like 3D gaming, IoT and huge number of sensors for health monitoring. Nowadays, the mode of communication between the people is completely changed. The availability of advanced gadgets along with the high speed and improved connectivity has shrink the whole world into the cellphone.

Presently, the 4G networks are in use from a few years providing the huge number of facilities. Wireless networks play an indispensable role to cope with the dynamic and fast sectors developments worldwide (Wang et al., 2014). Due to huge number of embedded sensors in the electronic devices, mobile devices, portable noninvasive health monitoring devices huge number of data is created continuously. There is a need for the widespread access to the data. The emergence and prevalence of 5G will likely open new business breaks through and also leads to the mobilization of different industries (Hansen, 2017).

In the beginning the communication link was developed via physical link also known as 0G (0 Generation) a pre-mobile phone technology like PTT (Push to Talk), MTS (Mobile Telephone System) and IMTS (Improved MTS). The cellular technology has changed the way of communication and can send the voice, multimedia data, internet, gaming etc. without any physical link barrier. Due to the increasing number mobile users there is a tremendous increase in the development of the mobile communication technologies. In addition to the mobile device usage the integration of internet in the individual's is inevitable. According to International Telecommunication Union (ITU) the number of internet users will be 4.1 billion at the end of 2019 (*ITU-Committed to Connecting the World*, n.d.). The increase in the number of users increases the network traffic and demand enhanced network services with the increased bandwidth. As per ITU statistics during 2020 and 2030 the network traffic will be increased between 10-100 times and the number of internet devices will reach to approximately 50 billion.

Several studies have been done regarding the requirements, challenges and the benefits of 5G. Some of the challenges were data rate, latency, huge number of connections, cost and quality of services (Gupta & Jha, 2015). A study has been made to explore the innovation progression, certainty and uncertainty in innovation for the mobile technologies (Yeo et al., 2015). Another bibliometric mapping study has been to explore the advancement and development and analyze the patent portfolios in 4G by leading companies (Han, 2015). As per our literature survey no bibliometric study has been found to explore the trends and recent development in 5G. Bibliometric review can provide the opportunity to the researchers to explore the current breakthrough in the research domains and can identify the gap. It can serve as one of the tools to ensure the progression and the degree of innovation of the technology. Bibliometric studies can be used to explore the number of research output country, region and university wise. It can also serve as a tool for the new researchers to identify the most appropriate journals to publish their contribution.

The purpose of our study is to provide a quantitative and qualitative progression of research in the field of 5G. The study contains the number of publications each year along with the number of citations. Moreover, it provides the top 20 countries and organizations producing

high number of publications from the period of 2003-2020, number of publications, number of citation along with the impact. In addition, the study also identifies top 10 articles, journals and the authors with the highest number of citations. Our study will help the future researchers to identify the most prolific authors and identify the journals. Similarly, it will help the research community to easily identify the research gap by referring to the most preferred articles.

The remainder of the paper is as follows: the progression of the cellular mobile generation is discussed in the next section. Section 3 contains the methodology, while section 4 covers the data analysis. Results and discussion are presented in section 6 and finally, the paper concludes with the conclusion and recommendation section.

Bibliometrics and Technology Road Map

Bibliometrics is quantitative analysis of research publications in a certain domain based on quantitative indicators such research productivity, most prolific authors, countries, organizations, topical trends and collaboration patterns etc. The literature searching reveals a good number of bibliometric studies conducted in computer science domain but lack of bibliometric literature on 5G.

(Admaja, 2018) explored the 5G technology research between 2013-2017 using Scopus database. The article was written in Chinese language and mainly focused on research collaboration and keyword analysis and excluded all scholarly publications before 2013 and thus limited the scope of the study

Few bibliometric publications found related to the communication, cellular data, network technologies, IoT, Device-to-Device communication, green technologies and cloud computing. A comprehensive bibliometric review of device-to-device communication and pros and cons of the D2D communications was reported in (Mukhlif et al., 2018). It is expected that there will be huge human and machine communication soon after the adaptation of 5G technologies, more than 50 billion devices are expected to be connected by 2020 (Fehske et al., 2011) and revaluation for 5G is to build a linked community with sensors, wearables, medical devices, drones and vehicles (Hwang et al., 2013). These technological devices need energy, which will be the next bottleneck ahead for the 5G. The (Mukhlif et al., 2018) presents bibliometric study on green communication for the next era. Furthermore some studies (Buzzi et al., 2016), (Yeo et al., 2015), (Wang et al., 2014) present survey about the green computing and wireless communication energy consumption. Similarly, a bibliometric study was made on Big-data and their network infra-structure (López-Robles J.R., et al. 2018). Literature review reveals several journals that publish bibliometric and scientometric papers. Mention could be made of “Scientometrics”, “COLLNET Journal of Scientometrics and Information Management” , “Journal of Scientometric Research” , “Journal of the American Society for information science and technology”, “informetrics”, “Research evaluation”, and “Social studies of science”.

Similarly, big data will be generated by all the communication devices with 5G, the (López-Robles J.R., et al. 2018) discussed a bibliometric study was made on the network analysis and big data research. Another bibliometric study was conduct about cloud computing (Yu et al., 2018). Moreover the author discussed about the 5G technologies and their applications for the smart cities (Minoli & Occhiogrosso, 2019).

1. Technology Road Map of Cellular Mobile Generations

Formerly the cellular communication was based on base station (BS) and making them as network centric, but with the help of Device-to-Device (D2D) communication. The 5G are

expected to bring new dimensions in communication (David Astely et al., 2013). The 5G will improve reliability of link, boost ethereal efficiency and system capacity, improve performance and will minimize the issues of delay and inactivity in the network (Chai et al., 2013).

Cellular technologies can be categorized into various generations (G) in terms of frequency, bandwidth, compatible transmission technology and the data rates as shown in the Table 01. The section below contains the generations from 1G to 5G for the mobile communication.

First Generation(1G)

First Generation of the wireless cellular technology was introduced in 1970's. Analog signals were used for transmitting the voice services. 1G was specifically designed for voice communication and used Frequency Division Multiple Access (FDMA), Nordic Mobile Telephone (NMT) and Advanced Mobile Phone System (AMPS) as a technology. The speed of 1G technology was 2.4kbps with a poor voice quality. The size of the mobile phones was big with the limited battery life. There was no data security in 1G mobile technology. Moreover 1G technology reliability is less due to call dropped problem faced by the user's sometimes.

Second Generation (2G)

The second-generation cellular technology introduced the digital signals for voice communication for the first-time using Global System for Mobile communications (GSM) technology. 2G technology was introduced in late 1980's. In comparison with 1G, 2G can deliver the text and small size images at the low speed along with the voice data. The data speed of 2G was up to 64kbps with the text and multimedia data sending feature. The data transmission speed was better as compared to 1G. Due to digital signals the power consumption was reduced and better voice quality and was less susceptible to noise as compared with the analog signals.

Another variation of the 2G technology was 2.5G. In 2.5G the General Packet Radio Service (GPRS) technology was integrated into 2G. The speed was extended from 64kbps-144 kbps with the integration of web browsing, emails and fast upload and data download speed along with the better data safety.

The emergence of Enhanced Data rates for GSM Evolution (EDGE) technology leads to 2.75G results in better data services along with fast and better data speed. The data speed was extended to 384kbps.

Third Generation (3G)

The 3G cellular technology was also based on GSM with the data speed of 144kbps to 2mbps and was introduced in 1990's. 3G provides better web browsing and other applications like video conferencing, large size emails with the integrated multimedia support, mobile TV support and the fast audio and video data transmission. 3G technology also provide the support for the 3D gaming. The concept of smart phone was introduced after the 3G. The mobile phones were expensive with the huge infrastructure cost like licensing fees, mobile towers. The 3G cellular phones were also named as Universal Mobile Telecommunication system (UMTS).

Fourth Generation (4G)

4G technology was first introduced in 2000 with speed of 100Mbps to 1Gbps. 4G uses WiMax LTE and Wi-Fi technology. 4G provide better mobile web access along with high

definition mobile TV. 4G provide the services of cloud computing along with IP telephony. 4G cellular technology provide high security with the better battery life. The drawback of 4G technology is it needs the complex hardware and is not easy to implement.

Fifth Generation (5G)

The discussion about 5G technology was started from late 2010. The main motivation of 5G technology is wireless world wide web (WWW) with the better capacity and speed. 5G will provides the data broadcast speed in Gbps. It will support the huge memory smart phones with the support of fast high definition quality video data transmission and with interactive multimedia support 5G technology are expected to provide support for Internet of thing (IoT) a huge data generated from sensor every second, smart sustainable homes and cities. Moreover, it should support virtual and augmented reality, 3D gaming with less delay. Nowadays there are huge trend of machine to machine communication in various domains like different types of robots, weather forecasting, NASA, 3D surgical planning, diagnosis, automated vehicles, remote sensing, and various other industry computerizations. Nevertheless, 5G technology will face huge challenges to support the huge number of devices, tremendous number of mobile internet user’s along with the colossal number of data generated from several machines. 5G is expected to provide more “connected World” with less data delay and full fill the user’s expectation.

Table 1. Different Generation of Cellular Technology.

Generations	1G	2G	3G	4G	5G
Deployment	1970	1980	1990	2000	2020-
Bandwidth	2kbps	14-144kbps	144kbps-2Mbps	1Gbps	More than 1Gbps
Technology	Analog cellular Technology	Digital cellular technology, GPRS, EDGE	GSM	WiMAX, LTE, WiFi	WWW
Service	Voice	Voice, SMS, MMS	High Quality audio and video data	Cloud computing, wearable devices	Dynamic Information Access, Wearable Devices, Machine to machine communication
Multiplexing	FDMA	TDMA, CDMA	CDMA	CDMA	CDMA

The literature review reveals that 7419 publications published in Scopus on various aspect of 5G technology. There were good number of review articles. No comprehensive bibliometric study is specifically conducted on latest research trends, highly productive countries, organization and authors. What are the core research journals, authorship and collaboration patterns, frequently used keywords? So current study is an attempt to fill the gap in 5G literature.

Research questions

1. What are publication and citation trend of 5G research
2. What are the most productive authors, countries and organizations?
3. What are the most preferred journals in which 5G researchers would like to publish their work?
4. What is the authorship pattern of 5G researchers?
5. What are the most frequently used keyword for 5G research?

Research Methodology

Bibliometric analysis was applied to know about the research productivity of 5G in the world. The selection of appropriate database is very important. The authors compare the two leading and largest bibliographic database Scopus and Web of Science. Scopus database was selected as it is one of the largest and core bibliometric databases in science and technology and have maximum coverage of the scholarly publications than Web of Science in the topic (Falagas et al., 2008). Scopus was used at Imam Abdulrahman Bin Faisal University (IAU), Dammam, Saudi Arabia on December 14, 2019. In the search box, the following query has been run in the title and keyword field.

“Title (5g OR “fifth-generation cellular wireless” OR “fifth generation cellular wireless” OR “5TH generation cellular wireless” AND (network* OR mobile OR wireless OR smart OR autonomous OR vehicle* OR qos OR *phone* OR robot* OR security OR cyber* OR *generation* OR device* OR digital OR tele* OR bandwidth)) OR AUTHKEY (5g OR *fifth-generation cellular wireless* OR *fifth-generation cellular wireless* OR *fifth-generation cellular wireless* AND (network* OR mobile OR wireless OR smart OR autonomous OR vehicle* OR qos OR *phone* OR robot* OR security OR cyber* OR *generation* OR device* OR digital OR tele* OR bandwidth).

Inclusion and exclusion criteria

The bibliographic information of relevant studies was downloaded and imported in MS Excel. No filter related to language and date of publication was applied. The note, short Survey, erratum, conference review, letter, data paper, retracted and undefined type of documents were excluded.

There were total 7634 results appeared. The following irrelevant record i.e. “Note (14), Short Survey (14), Erratum (6), Conference Review (4), Letter (3), Data Paper (1), Retracted (1), Undefined (26)” were excluded. Finally, the bibliographic details of 7565 records were downloaded and imported in MS excel format for further refining. The bibliographical detail of each record was checked one by one to ensure the transparency and validity of the data. The irrelevant (81) and duplicated (65) records were removed and finally 7419 relevant records were considered for data analysis. These records contain 4194 conference paper, 2781 article, 166 review articles, 152 book chapter, 104 editorials and 22 books. The whole process was once again repeated to ensure the accuracy of the data (see figure 2)

Data Analysis

A year-wise publication between 2003 and 2020 is presented at Figure 3. It shows that 2003 was the starting year for research publication on 5G. In this year, one publication received 40 citations. The years 2004, 2005, 2007 and 2010 were disappointing years as there were no publications in those periods. The significant growth has been observed from 2013. The years 2018 and 2019 were marvelous as in that year’s total 4294 research publications were produced. The year 2018 is excellent as in that year 2222 publications produced.

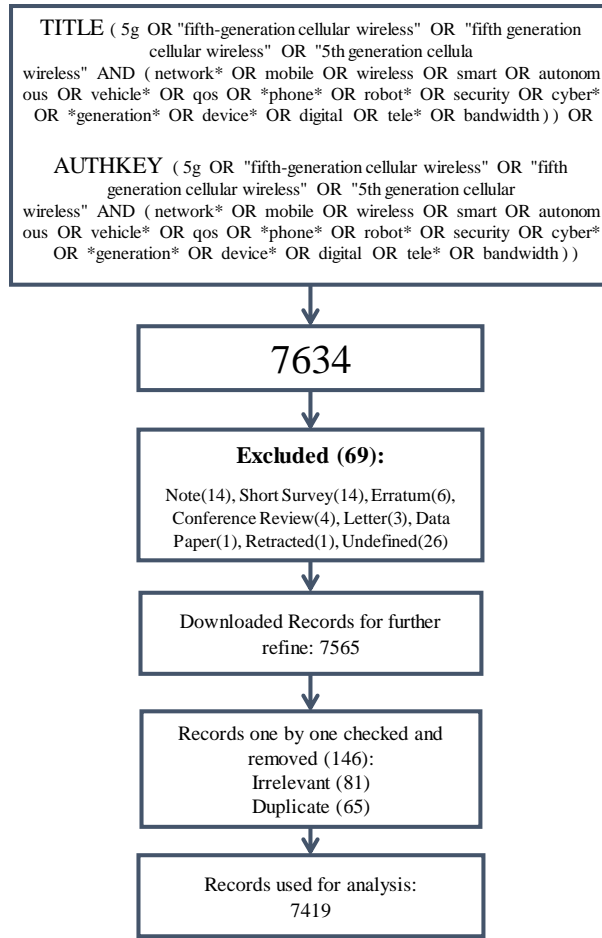


Figure 2. Literature Searching Process.

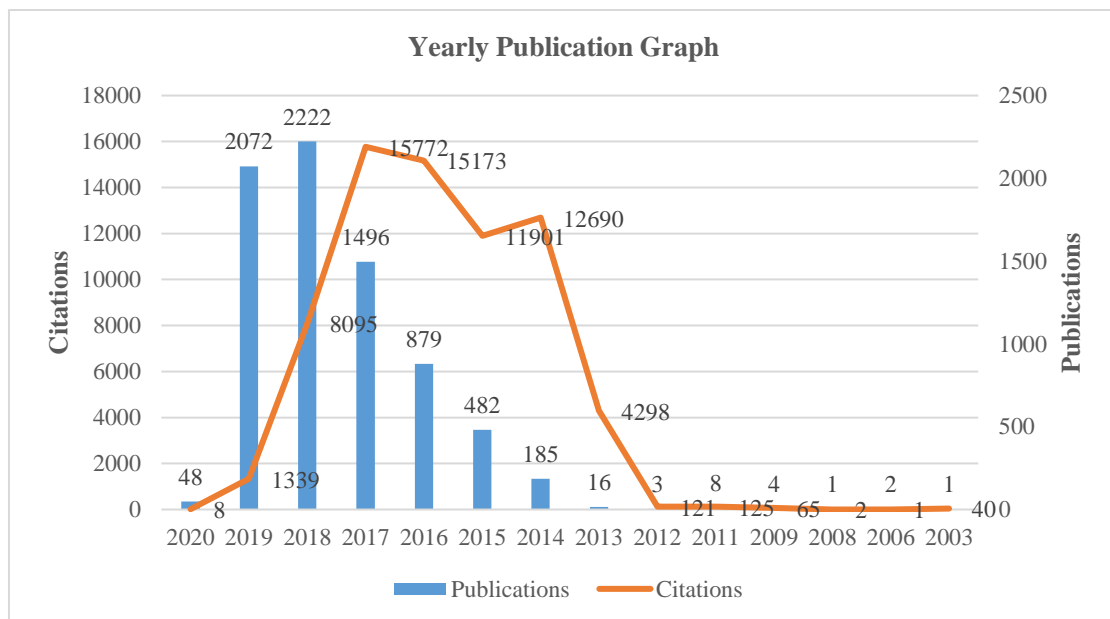


Figure 3. Year Wise Publications.

Table 2. Top 20 Productive countries

Rank	Country	2003-2013	2014	2015	2016	2017	2018	2019	2020	TP*	TC**	Citation Impact
1	China	1	32	95	186	271	432	414	6	1437	19586	13.63
2	United States	8	36	69	124	235	347	308	6	1133	19404	17.13
3	United Kingdom	3	25	56	122	147	223	182	3	761	12493	16.42
4	Germany	1	23	50	69	129	172	119	1	564	9025	16.00
5	Italy	1	11	28	58	114	144	136	3	495	5668	11.45
6	Spain	0	5	27	65	114	139	137	3	490	4105	8.38
7	South Korea	1	13	25	44	87	138	126	4	438	4837	11.04
8	India	1	3	19	45	56	127	153	9	413	2055	4.98
9	Canada	0	11	45	61	70	136	85	3	411	7082	17.23
10	France	0	10	32	54	81	137	90	2	406	4764	11.73
11	Finland	1	18	39	67	87	91	90		393	6052	15.40
12	Japan	0	8	29	46	68	88	88	1	328	3210	9.79
13	Greece	1	10	19	38	83	77	70	3	301	2928	9.73
14	Sweden	2	6	35	47	70	63	62	2	287	5264	18.34
15	Taiwan	1	1	13	20	40	62	69	3	209	1220	5.84
16	Pakistan	1		4	12	37	62	53	1	170	702	4.13
17	Malaysia	4	1	7	19	32	49	42	1	155	744	4.80
18	Denmark	3	12	9	28	31	38	30		151	1589	10.52
19	Saudi Arabia	0	5	16	20	25	48	29	2	145	1241	8.56
20	Australia	0		7	18	33	46	36		140	2605	18.61

*TP=total publications; ** TC=total citation

Top 20 Highly Productive Countries

The top 20 countries producing publications on 5G is presented in Table 2. There are only two countries that produced over one thousand publications i.e. China and United States. It shows that China is the top of the list in top 20 most productive countries producing 1437 total publications, 19586 citations against these publications and citation impact 13.63. China also remains a top country comparatively by producing maximum publications from 2014 to 2019. United States is obviously the 2nd on the most productive countries list followed by United Kingdom with 761 publications, German with 564 publications, Italy with 495 publications and others. It is surprising that though Australia is the least in the list with total 140 publications, however, the impact of these publications is 18.61, the maximum of all countries.

Highly Productive Organizations

Major contributing organizations (top 20) in 5G are given at Table 3. There are four outstanding organizations that have over 100 publications from which Beijing University of Posts and Telecommunications, China, is apparently on the top of the list with notable 212 publications, 2406 citations of those publications and overall 11.35 citation impact, followed by Nokia Bell Labs, USA, with 199 publications, Ericsson Research, Sweden, with 139 publications and other organizations (Table 3). Furthermore, it is noteworthy that out of these 20 organizations in the world, seven organizations belong to China. Furthermore, Huazhong University of Science and Technology, China, at 12th rank in that list with only 54

publications but it is distinguishable that its publications have maximum citation impact i.e. 38.72%.

Table 3: Top 20 Most Productive Organization

S#	Organization/Year	2003-2013	2014	2015	2016	2017	2018	2019	2020	TP	TC	Citation Impact
1	Beijing University of Posts and Telecommunications, China	0	4	17	26	40	74	51		212	2406	11.35
2	Nokia Bell Labs, USA	0	9	18	33	57	37	43	2	199	2357	11.84
3	Ericsson Research, Sweden	6	4	26	31	19	24	29		139	1658	11.93
4	University of Oulu, Finland	0	3	6	18	23	31	24		105	1644	15.66
5	Aalborg University, Denmark	2	10	9	23	19	18	18		99	1313	13.26
6	Aalto University, Finland	1	1	14	16	19	17	15		83	1577	19.00
7	University of Electronic Science and Technology of China, China	0	2	7	10	22	19	21		81	1037	12.80
8	Xidian University, China	0	1	7	13	13	25	20	1	80	947	11.84
9	University of Surrey, UK	0	3	9	18	7	21	11		69	1160	16.81
10	Tampere University of Technology, Finland	0	4	3	9	18	14	18		66	527	7.98
11	Universitat Politècnica de Catalunya (UPC), Spain	0		2	7	15	15	17		56	252	4.50
12	Huazhong University of Science and Technology, China	0	5	4	8	13	14	10		54	2091	38.72
13	Tsinghua University, China	0		5	13	10	11	13		52	1948	37.46
14	University of California, USA	0	1	3	6	11	17	13		51	409	8.02
15	Georgia Institute of Technology, USA	1	1	2	5	4	15	22		50	434	8.68
16	Beijing Jiaotong University, China	0		4	2	7	20	16		49	521	10.63
17	Instituto de Telecomunicações, University of Aveiro, Portugal	0	2	5	2	9	12	18		48	290	6.04
18	Southeast University, China	0	3	2	6	6	13	18		48	1548	32.25

19	National University of Sciences and Technology (NUST), Pakistan	0			6	13	19	9		47	305	6.49
20	Concordia University, Canada	0	2	5	11	8	12	6		44	710	16.14

Table 4. Top 10 most Preferred periodicals.

Source title	Cite Score	TP*	TC**	Citation Impact
IEEE Access	4.96(Q1)	334	8019	24.01
IEEE Communications Magazine	11.27(Q1)	149	14585	97.89
IEEE Wireless Communications	11.8(Q1)	94	3846	40.91
IEEE Transactions on Antennas and Propagation	5.47(Q1)	81	1807	22.31
IEEE Transactions on Vehicular Technology	6.29(Q1)	84	1186	14.12
IEEE Journal on Selected Areas in Communications	10.91(Q1)	76	2740	36.05
IEEE Transactions on Wireless Communications	7.79(Q1)	73	1077	14.75
Transactions on Emerging Telecommunications Technologies	1.56(Q2)	63	423	6.71
IEEE Network	8.98(Q1)	62	2271	36.63
Wireless Personal Communications	1.28(Q2)	54	403	7.46

*TP=total publications; ** TC=total citation citation impact = TC/TP

Most Preferred Periodicals

The top 10 most preferred periodicals are presented in Table 4. It is notable that most of the periodicals are belonged to IEEE family. IEEE Access is on the top of the list with remarkable 334 publications, 8019 citations against these publications and 24.01 citation impacts. IEEE Communication Magazine is on the second rank on this list with 149 publications and amazingly 14585 citations with 97.89 citations impact. Rest of the periodicals though most preferred periodicals in the said list, however, have less than 100 publications. There are only two periodicals of Quartile 2 and rest of them is Q1 periodicals.

Authorship Pattern

Authorship pattern is shown in the Figure 4. The entire authorship pattern has over 100 publications. The key authorship patterns are two, three, four and five authors. The most popular number of authors is 3-authors with 1612 publications

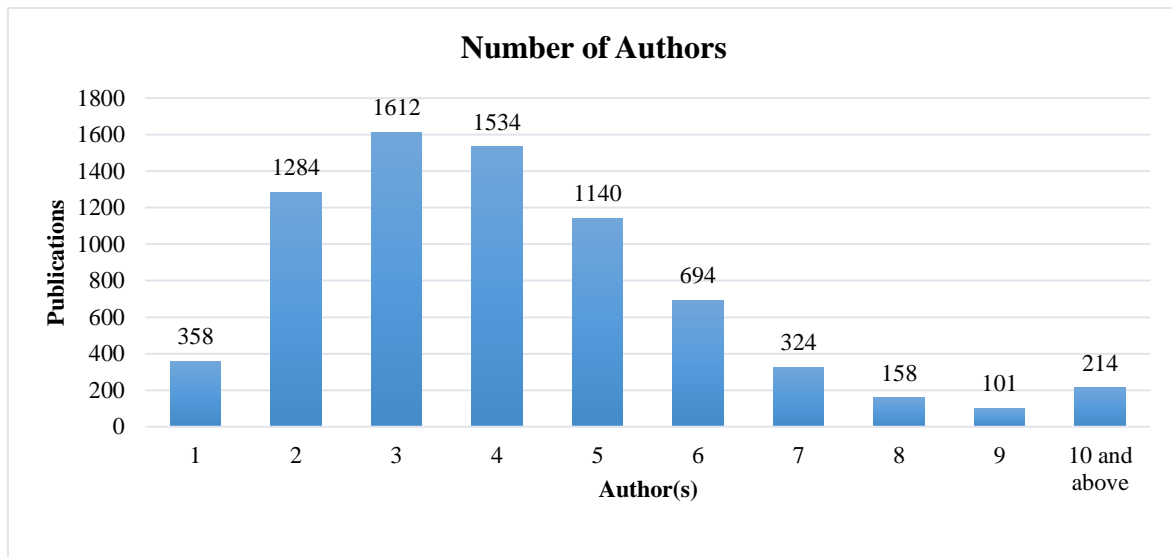


Figure 4. Number of authors.

Most Prolific Authors

There are twelve authors that have over 50 publications (table 5). The list of most prolific authors shows that Zhang X. is the most productive authors with 94 publications, 653 total citations and 6.95 citation impacts, followed by Li Y. with 92 publications, Wang X. and Zhang J. with equally 86 publications each and so on. It is noted that Wang L. is almost on the bottom of this list with 37 publications, however, the impact of these publications is remarkable i.e. 23.43 the maximum from all the authors in this list.

Table 5. Top 20 Most Prolific Authors.

Author/Year	2003-2013	2014	2015	2016	2017	2018	2019	2020	TP	TC	Citation Impact
Zhang X.	0	2	5	14	15	28	30		94	653	6.95
Li Y.	1	1	9	6	22	28	25		92	1412	15.35
Wang X.	0	1	10	12	18	29	16		86	816	9.49
Zhang J.	0	1	7	15	21	21	21		86	920	10.70
Liu Y.	0	1	6	9	14	16	26		72	1172	16.28
Zhang Y.	0		3	7	15	18	27		70	1084	15.49
Wang J.	0	1	3	9	15	24	17		69	673	9.75
Wang Y.	0	2	4	5	11	19	27		68	433	6.37
Li X.	3		4	7	14	24	14		66	533	8.08
Li J.	0	2	5	6	14	20	14	1	62	1283	20.69
Zhang H.	0	1	8	10	10	20	12		61	1068	17.51
Wang H.	0	2	4	3	8	13	21		51	562	11.02
Zhang S.	0	2		1	12	15	18		48	487	10.15
Imran M.A.	0	2	4	11	5	10	10		42	1019	24.26
Chen Y.	0	2	2	5	6	12	13		40	671	16.78
Chen X.	0			3	8	12	16		39	224	5.74
Liu X.	0		2	3	9	14	11		39	387	9.92
Valkama M.	0	3	1	6	9	9	11		39	273	7.00
Li S.	0		2	1	11	10	13		37	467	12.62
Li Z.	0	5	2	4	8	6	12		37	344	9.30
Wang L.	0		3	5	7	12	10		37	867	23.43

Pedersen G.F.	0			10	7	8	11		36	306	8.50
Wang Q.	0		1	3	5	17	10		36	175	4.86

Frequently Used Keywords

Forty Frequently used keywords for 5G research is highlighted in Figure 5. The top five keywords appear more than 300 times. '5G' is the most used keyword that firstly appear in 2008. This keyword '5G' is the most representative as it appears 2893 times followed by 'mmWave' that appear 533 times, '5G networks' that appears in 478 publications, 'IoT' appears in 397 times and '5G mobile communications' that appears 314 times. Rest of followed by 4-authors with 1534 publications, 2-authors with 1284 publications and 5-authors with 1140 authors. Rest of the keywords though important but appears less than 300 times.

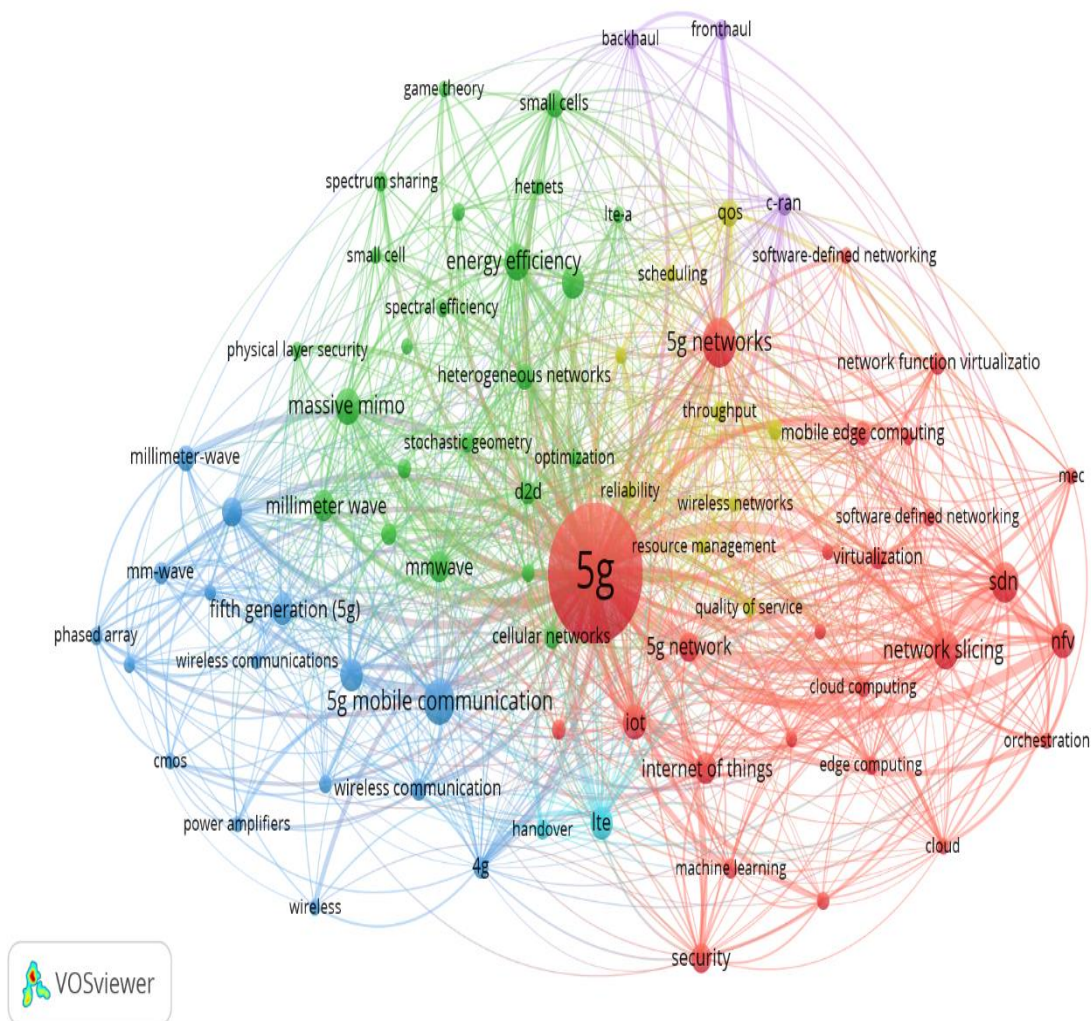


Figure 5. Frequently used keywords for 5G research.

Three factor Analysis (Keywords, organization, and Authors)

Figure 6 shows the relationship among subject areas (keywords), organizations, and Authors on 5G literature. The top 5 subject areas of 5G (5G, 5G Mobile communication, 5G networks, and mmWav) have a relationship with 5 research organizations (Beijing University of Posts and Telecommunications, Nokia Bell Labs, Ericsson Research, University of Oulu, Aalborg University, Denmark, and Aalto University) and these have a strong relationship with top 5 authors (Zhang X, Li Y, Wang X., Zhang J, Liu Y., Zhang Y.).

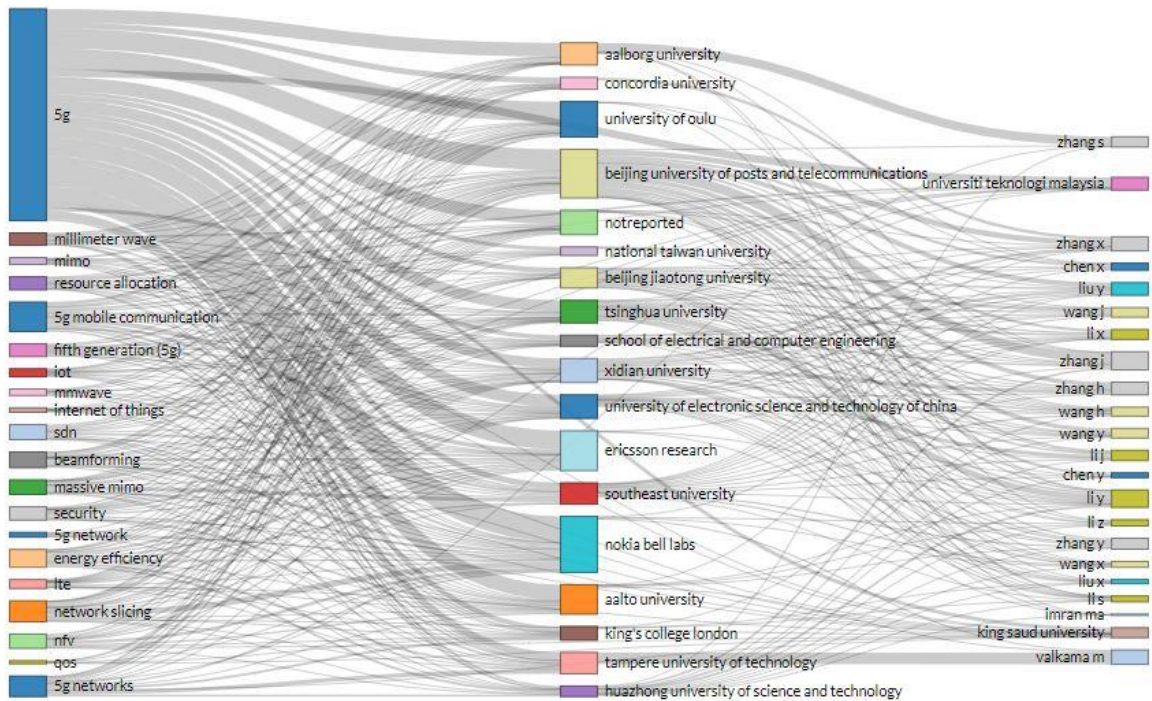


Figure 6: Three Factor Analysis (Keywords, Organizations, Countries)

Global collaboration map on 5G literature

Figure 7 shows the country collaboration map on 5G research. The China emerged as a top collaborator with USA (197 publications), UK (119 publications each) and Canada (103), followed by Germany with UK (99 publications) and Spain (94 publications), and others. The least collaborator countries among 10 collaborators were Germany and Italy with 74 publications.

Country Collaboration Map

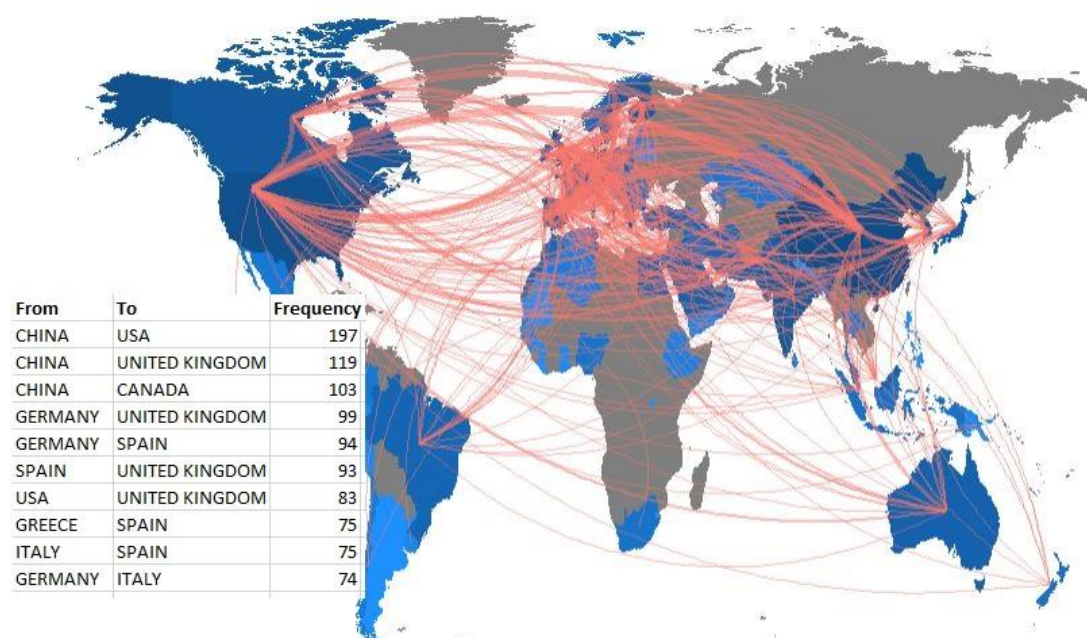


Figure 7: Global Collaboration Map on 5G Research

Discussion

Based on the result in the Table 1, the increase in the rate of publication in 5G domain is significant during the era of 2014-2019. During that time period the standard were defining for 5G and there was a great exhort for the exploration of the technologies that will provide support for this emerging technology (Woon Hau Chin, Zhong Fan, 2014), (Mockel & Makala, 2019). Approximately similar number of publications were found in 2018 and 2019. Another plausible rationale for these findings is that due to the emerging technology the number of citation most likely increases. Furthermore, the duration from 2014-2019 was the formation of standards for the 5G and their related technologies and most of the research publish their work directly or indirectly related to 5G (Wang et al., 2014), (Hansen, 2017), (Han, 2015), (Hwang et al., 2013), (Of et al., 2004), (Minoli & Occhiogrosso, 2019), (Mockel & Makala, 2019). Perhaps in 2020 5G technology are expected to be implemented and will be available. More likely after the implementation of 5G the number of publications might increase, and the research community will publish the outcomes, challenges, and implication of the implemented technology.

The leading country in 5G technology based on the analysis provided in Table-2 is China. The history of telecom and communication reveal that European were the pioneers in adopting 2G technology in 1990 (Dunnewijk & Hultén, 2007). In early 2000, Japan adopted 3G technology, while US led to launch 4G technology in 2011 (*Technology Review*, n.d.) and lead the world in the respective technology. In case of 5G technology China is leading. There are couple of government-based and non-government-based research institute in China targeting the 5G technology. CAICT (China Academy of Information and Communications Technology) estimates that by 2030 huge amount of investments will be made by major industries or 5G hardware and services. To achieve this breakthrough China government granted the license to top three Chinese telecom companies (1) China Mobile Communications Group Co., (2) China Telecommunications Group Corp., and (3) China United Network Communications Group Co.,(Shan Li & Woo, 2019). Ultimately China is now considered the principal in rolling-out 5G technologies and applications. Additionally,

huge investment is expected from the Chinese government in the research and development of 5G technologies. Due to that huge number of research is going on in China in the field of 5G become a leading country in 5G publication and research. Likewise, the Chinese government initiate number of projects for the researcher to support them in the 5G technology.

Similarly, the Table-3 presents the topmost productive organization in the field of 5G, again the Chinese university, i.e., the Beijing University of Posts and Telecommunications, China is on the top, while it is on 42 number according to the top chine's university list. But in the field of 5G technology research and publication its stands number one (*University Ranking*, n.d.). The key reason is the university pledge number of degree program at Undergraduate, Graduate and post graduate level in communications and Engineering like Electronic communication, Communication Engineering, Information Engineering, Electronic Information Science and Technologies, Computer Science and Technology, Network Engineering and Telecommunications Engineering with Management etc. Beside these, the university has numerous research institutes for communication technologies which promote the 5G technology and their research. With 100 years of history in research and innovations, with 17 Global Research Centers and 9 Nobel Prize Awards, the Nokia Bell Labs, USA stand on second highest position in the most productive organization in 5G and their related technologies around the global. Nokia Bell Labs are conducting prospective and active research in the development of basic technologies for 5G (Series, n.d.). The Figure-1 presents the country wise analysis of the most productive organization in 5G sector, where China again hit the top position, while US and Finland are the followers. The rest of the countries from where the top-20 most productive organization hits the list are Pakistan, Sweden, Denmark, UK, Spain, Portugal, and Canada, which make them first followers in the 5G technology.

We observed that mostly research articles on 5G technology published in IEEE journals or conferences. From the Table-4, in journal list, IEEE Access score top position in the Preferred list of periodicals due to the Multi-disciplinary nature which is and indexing of IEEE Access. The multi-disciplinary domain covers vast domains and provides more opportunities to the researchers for article submission. In addition, IEEE Access have huge number of special issues related to the 5G technologies, which also contribute to the ranking among the Top 10 periodicals. Moreover, another additional factor is the average publication time i.e. 4-6 weeks. The IEEE have an edge in publishing articles related to advanced technology, that is why we can see Table-4 is having 8 journals from IEEE.

Limitation of Study and Future Research Directions

This study was limited to Scopus publications indexed on the subject area of 5G, during 2003 - 2020. It was out of scope from our study to determine whether the incorporated research work was conducted in relevant countries or not. Other databases like Web of Science, IEEE and Google Scholar will give other set of records on searching, which is out of scope in this analysis; future work in this domain may verify the present findings with the data from these sources. Furthermore, the research work presented is a quantitative study, and quality of publication were not analyzed, which can be a potential future work.

Conclusion:

The bibliometric studies related to 5G technology shows a noticeable increase in research community. The substantial amount of publications and citations received in this field; hence it is anticipated that the research on 5G and its related technologies will sprout in the future.

This article discussed a complete view of the publishing trend, most productive and cited countries, organization, and author from 2003 to 2020. The discussion also covers the reasons of achieving the top position by countries and organizations. The 5G technology is the opportunity for achieving the smart cities, automatic vehicle drawing, improve performance of navigating and assistive devices. All these, applications require high bandwidth which will be successfully implemented via 5G.

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