Current Research Trends Machine Learning in 5G: A Bibliometric Analysis

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Researchers are attracted to emerging field 5G with machine learning. Many review articles have been carried out to analyze in a different direction of 5G with machine learning. However, no researcher presented bibliometric analysis on machine learning in the 5G research field to a detailed analysis of research status and future trend network in this research area. A bibliometric analysis was done in the current study using the bibliometric R tool and VOS viewer software. The relevant literature was collected period 2001 to 2021 from the Web of Science (WoS) Core Collection and Scopus database. The quantitative analysis was done in terms of a yearly published article, most trend research topic, and future direction in ML in 5G technology. Finally, the result indicated that China, the U.S.A., and India are the top countries to publish this field because China, the U.S.A., and the U.K. are the most cited countries. Beijing University of Posts and Telecommunications is the most relevant organization, Wang most appropriate and most influential author in this research area (5G in AI/ML). IEEE Access, IEEE transactions on vehicular technology, and Sensor are the most relevant journal. The main challenges in this field are low latency communication, resource allocation, resource management spectral efficiency, millimeter wave, 5G with the Internet of things (IoT), a device to device communication, power control, and massive MIMO. Deep learning, machine learning, cognitive radio, and reinforcement learning are artificial intelligence techniques used in 5G.

Keywords: First 5G, Machine learning, Artificial Intelligence, wireless communication, Internet of things.

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1 Introduction

The International telecommunication union -radio communication (ITU-R) is responsible for 5Gstandardisation of 5G requirements. Major Telcom vendors and operator is associated with third-generation (3Gpp) consortium for technical requirements such as modulation scheme, radio protocol, data protocol, etc. The 5G is mapped to different use case scenarios such as enhanced mobile broadband (eMBB), Massive ma-chine type communication (mMTC) and ultra-reliable low latency communication (uRLLC). IoT, Smart city, Smart building, 3D video, UHD screens, Augmented reality (A.R.), Industrial automation, and self-driving car applications are using 5G networks [1]. In 5G architecture, there is three leading components user equipment (U.E.), a Next-generation radio access network (5G New Radio (N.R.), next-generation node b (gNB)), and a 5G core network. The main key features of 5G N.R. are small cell, dual connectivity, cloud R.A.N., Beamforming and stirring radio enhancement, and increased spectrum. OFDM, flexible numerology, resource block, Network function virtualisation (N.F.V.), network slicing, handover in 5G characteristics make an efficient 5G network [2]. IoT is developed very fast still spectrum is limited resources. Non-orthogonal multiple access (NOMA) technology is used in 5G still have spectral efficiency, energy efficiency problem [3] Deep learning (DL) can improve wireless network efficiency [4]. Increasing the cellular network and its complexity suggested that machine learning provides the right solution for future networks. In VNET, millimeter-wave and MIMO improve the fast data rate; however, they efficiently require beamforming to connect device to device. In this context, band measurement and device position information can reduce to find the beam pair. Beam selection is a problem due to actuation, mobility, and other issues. IEEE 802.11 and 5G train the beam for standardisations. DL and ML efficiently provide beam selection [5]. Due to many users and coordination between them in the 5G network, IEEE 802.11 Channel allocation capacity leads to sub-optimal performance. DL is used for dynamic Channel allocation with optimized spectrum selection [6]. Delay, jitter, loss performance predicts the accurate network model. Analytical models are fast but not accurate, while the packet-level simulator is costly. Graph neural network (G.N.N.), a machine learning algorithm, provides a promising solution to build a distinct network to control and manage networks [7]. Internet Traffic increases the problem of network bandwidth, computing, and storage. ML and DL are used for radio network traffic prediction, which is more accurate, mainly demand prediction [8]. Sensors, control systems, safety analysis, congestion detection, lane changing, etc., are implemented in autonomous smart transportation. ML and DL can improve for these types of applications in the wireless network. Dynamic spectrum access is the solution to utilize the inefficient spectrum way. Cognitive approaches with machine learning are used in 5G wireless networks [9].

Therefore, it is essential to a comprehensive analysis of AI/ML in 5G to explore the research trend, key technology, and future trend of the research topic. In this study, bibliometric analysis in AI/ML in 5G is helpful for research scholars and industry practitioners to gain deep insight knowledge of published research articles in 5G with machine learning. Much bibliometric analysis is done in research areas5G and 5G with security, and it has been used widely to understand the corpus knowledge, identify the scientific area [10-14].

This paper contains three sections. Section 2 details the research methodology and research question, section 3 discuss the data analysis, and section 4 discusses the conclusion.

2 Research Methodology

Bibliometric analysis is one way to review a large number of articles in a particular research area to know the importance of literature. Web of Science (WoS) and Scopus are some of the extensive peer-

review research articles databases. We selected Scopus and Web of a science research article in a particular area 5G with Machine learning in this study. In phase one, we decide the topic. Later on, we search the web of science and the Scopus database for data collection. Finally, we refined the datasets using some criteria [15-19]. Figure 1 is a graphical representation of methodology.

2.1 5G and ML Research questions for study

1. The trend of publication and citation of 5G and machine learning research
2. Find the Topmost organisations, contributed authors for publication, contributed countries
3. Find the Topmost journals in which 5G with machine learning researchers published their work.
4. Find the 5G with machine learning (5G/ML) authorship pattern.
5. Find the most used keyword in 5G with ML research.

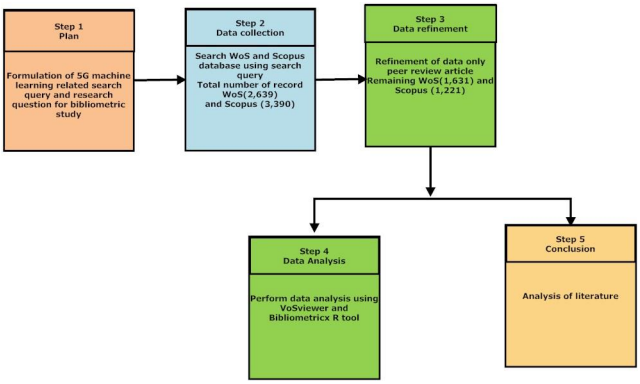


Fig. 1. The proposed method for 5G with ML bibliometric study

3 Data analysis (5G with ML)

To interpret the data in a bibliometric study involved various phases. First data collection from Scopus and web of science. Second refinement of data. We have finally used comprehensive software to visualise the result. For the current study, we used VOS viewer [20] and Bibliometrix (R Tools) software [21] to analyse the bibliometric data. We performed keyword analysis, analysis of scientific production year-wise, country scientific production, the Most cited country of scientific output, Most cited country in terms of citation year-wise, top 10 relevant organisation, top 10 authors publication wise, top 10 authors H-index wise, most trend topic year-wise within 5G and ML, top 10 relevant journals, keyword clustering, WordCloud, country collaboration map and finally we did factor analysis to find the top highest contributing papers and cited articles [22].

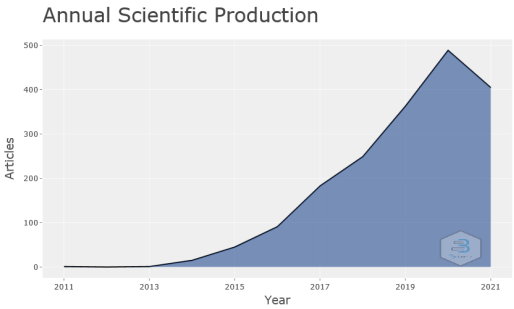
Table 1. Different search queries and results in WoS and Scopus.

S. No.	Queries 5G within ML	No. of results (WoS) with 5G within ML	No. of results (Scopus) 5G within ML
1	("5G" AND "Machine learning") (Topic) or ("5G" AND "cognitive radio")	2,639	3,390

	(Topic) or ("5G" AND "device to device") (Topic) and 2003-2021 (Year)		
2	("5G" AND "Machine learning") (Topic) or ("5G" AND "cognitive radio") (Topic) or ("5G" AND "device to device") (Topic) and 2003-2021 (Year) Refined By: Document Types: Articles or Review	1,631	1,221

3.1 Scientific production year-wise (5G and ML)

In the current study, we have taken the publication from Scopus and web of science database. We consider only peer-review journals so that they will be more authentic. In this respect, published article is taken for the study period from 2001-2021 as tabulated in Table 1. The graph of scientific publication is shown in Figure 2 (annual scientific production), highlighting the publication trend year-wise. The year-wise publication shows the variation of publication over a particular time. The analysis represents that publications related to 5G and machine learning (device to device communication) peaked from 2019 to 2021. researchers have been active for the last nine years. The most productive year is 2020, with 489 publications, whereas 2011 is starting publication related to 5G and ML topics. From the data, we can predict 2021 (405 publications) will be the most paper related to 5G and machine learning Top 10.



Year	Articles
2011	1
2013	1
2014	15
2015	45
2016	91
2017	183
2018	249
2019	363
2020	489
2021	405

Fig. 2. Yearly publications within 5G Machine learning

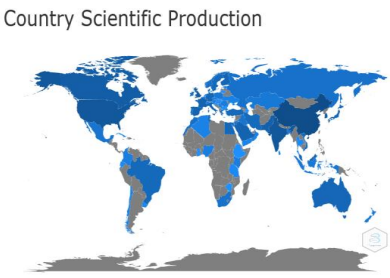
3.2 Productivity analysis (5G and ML)

In terms of productivity analysis within 5G and machine learning, our aim is to focus on most scientific publications in terms of countries, most relevant organisation, the relationship between the organisation, country, and keywords in a specific topic, most contributed authors, year-wise trend topics, most relevant journals, keyword analysis and global collaboration within the 5G and ML. The research is presented in the following section.

3.2.1 Countries

Figure 3 represents country-wise scientific publication of the top 20 countries in the 5G Machine learning (ML) research area. Figure 4 represent the Top 20 country contribution in term of total

citation, and Figure 5 Top 20 country contribution in term of several citations per year. In current analysis indicated that the highest number of research publications is from china, the most cited country. In contrast, Israel has the highest average citations per year in the research area of 5G and machine learning (5G and ML) with 1214, 7370, and 111.5, respectively. Regarding publication and citation, the U.S.A. is the second country with a value of 395 and 5301. Similarly, in terms of publication and citation, India is the third country with a value of 387 article publications and 2169 total citations, the U.K. with 247 publications, and South Korea (S.K.) with 239 publications and 1021citation. Israel, the number of citations per year is highest at 111.5.



region	Freq
CHINA	1214
USA	395
INDIA	387
UK	247
SOUTH KOREA	239
CANADA	201
PAKISTAN	149
MALAYSIA	108
SAUDI ARABIA	107
FRANCE	99
ITALY	99
SPAIN	95
FINLAND	81
GERMANY	77
AUSTRALIA	72
JAPAN	71
EGYPT	62
BRAZIL	57
TURKEY	56
SWEDEN	55

Fig. 3. Country specific publication within 5G Machine learning

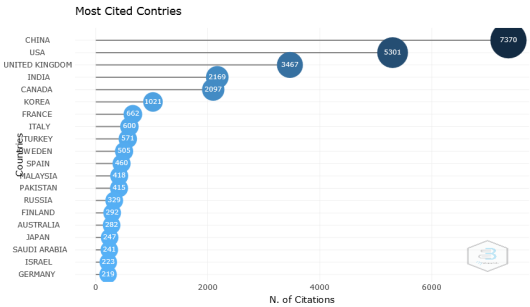


Fig. 4. The top 20 countries were contributing total citation within 5G Machine learning

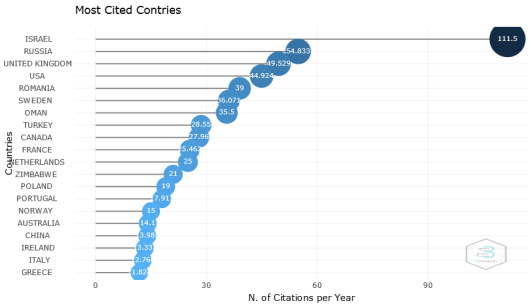


Fig. 5. Top 20 average number of citations per year within 5G Machine learning

3.2.2 Top 10 Most Relevant organisation

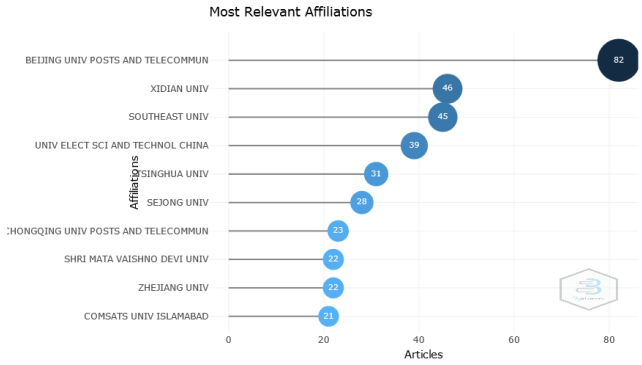


Fig. 6. Top 10 most relevant organisations within 5G Machine learning

3.2.3 Three-Fields Plot (Organization country and keywords)

Figure 7 shows the relationship among subject areas (keywords), organisations, and countries on 5G machine learning literature. The top 9 subject areas of 5G (5G ma-chine learning, 5G, 5G mobile communication, resource allocation, a device to device communication, cognitive radio, resource management, energy efficiency, and Internet of things) have a relationship with five research organisations (Beijing University of Posts and Telecommunications, Southeast univ, xidianuni, tsingghua univ, univ elect sci and technol china, Sejong univ, chongqing univ posts and telecommun, comsats univ Islamabad and Zhejiang univ). These are from these countries (China, U.S.A., France, UK, Canada, Korea, Pakistan, Saudi Arabia, Malesia, and India).

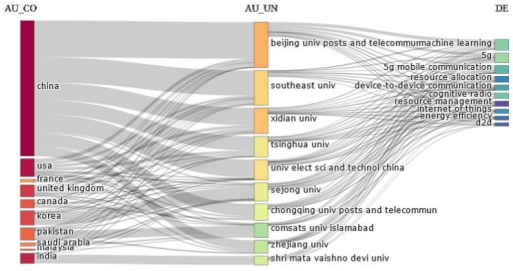


Fig. 7. Three-Fields Plot (Organization country and keywords)

3.2.4 Authors (5G and ML)

This author's section related to 5G and machine learning represents the top ten most relevant authors who contributed most in this area, as shown in Figure 8. Similarly, Figure 9 and Figure 10 highlight the top ten authors whose H-index is high and the top ten authors whose total citation is increased concerning publications. As mentioned in the figure, Wang X from the National University of Defense

Technology has the most publications (39), followed by Liu. Y from the Queen Mary University of London, London, UK, and Wang Y, from the Guangdong University of Technology with 32 and 30 publications, respectively. However, Wang X has the highest publication in terms of the publication. Still, the total citation is the highest of author Ding (2811), which indicates that it is not necessary who has more publications has top citation as well.

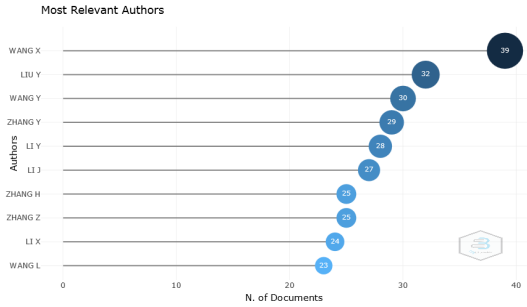


Fig. 8. Top 10 author-publication wise within 5G machine learning

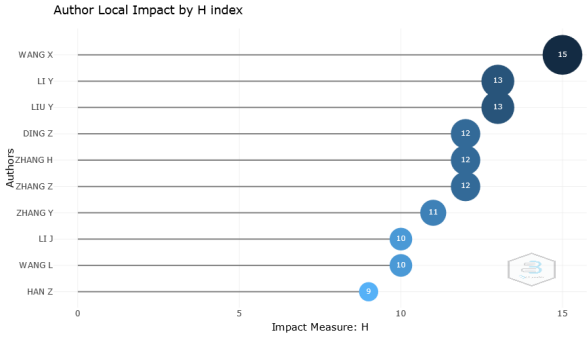


Fig. 9. Top 10 author H index wise within 5G machine learning

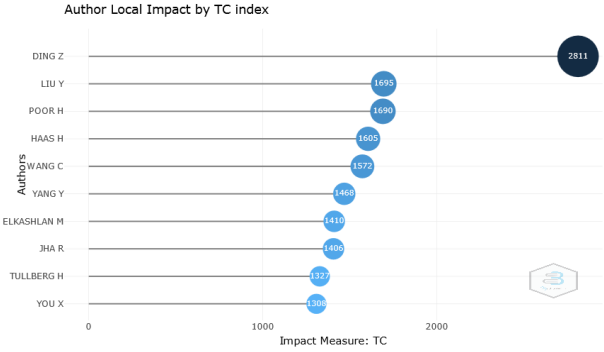


Fig. 10. Top 10 author total citation wise within 5G machine learning

3.2.5 Most trend Topics year-wise within 5G

This section highlights the most trend topics year-wise concerning5G and machine learning, as shown in Figure 11. Millimeter-wave, low latency communication, spectral efficiency, Internet of things (IoT) are the most trendy topics in 2021. from 2019 researchers are published the research article on different issues such as wireless and network challenges, 5G Performance, non-orthogonal multiple access of 5G, resource allocation of 5G, Internet of things, spectral efficiency.

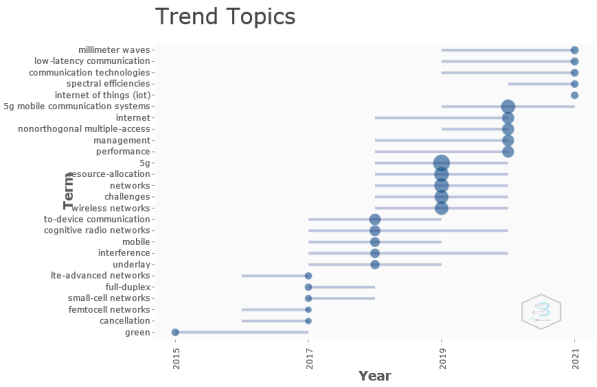


Fig. 11. Top 5 trend topic year-wise within 5G machine learning

3.2.6 Top 10 Most Relevant Journal for 5G Machine learning

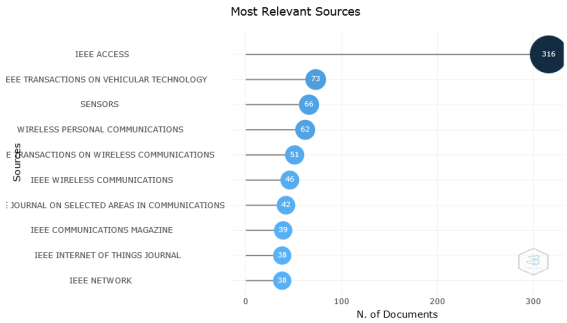


Fig. 12. Top 10 most relevant journals within 5G machine learning

This section highlights the top ten journals concerning topic 5G and machine learning. In addition, we highlight the source clustering through Bradford's Law, as shown in Figure 12 and Figure 13, respectively. Figure 12 highlights the top 10 journals concerning the number of publications related to 5G machine learning (5G/ML) research. In this context, the IEEE Access journal is the most relevant source venue, with 316 research articles published. Similarly, IEEE Transaction on vehicular technology (73 publications) and Sensors (66 research publications) and Wireless personal communication Journal (62 research publications) are the fourth choices. IEEE Access has the most publications because it fast peer-review journal, so the number of publications is more. In addition, we

did Source clustering through Bradford's Law to find the pattern on the source on the particular topic in this study. We found IEEE ACCESS, IEEE Transaction of vehicular technology, sensors, wireless personal communication wireless communication are core sources.

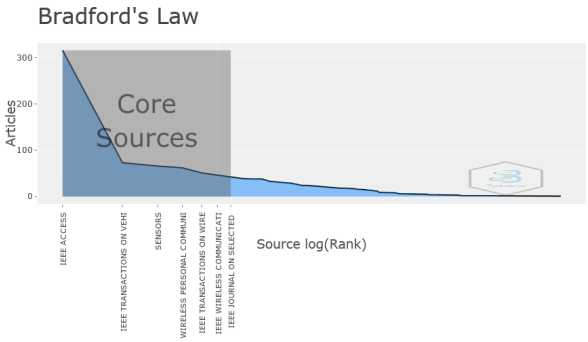


Fig. 13. Source clustering through Bradford's Law within 5G machine learning

3.2.7 Keyword analysis

This section analyses the keywords used in research articles (author keyword and keyword plus). We use VOSviewer to analyse the keyword's co-occurrences. Results are shown in Figure 14—the bigger node size, as the number of occurrences, is the largest.

In figure 14 shows 5G, Machine learning (ML), Cognitive Radio (C.R.), Internet of things (IoT), wireless network, and device-to-device connection (d2d) are frequently used keywords. In addition, the weight of edge connecting nodes shows how frequently used together keywords such as 5G with massive MIMO, 5G with security, 5G with resource allocation, 5 G with machine learning, 5G with cognitive radios, etc.

Figure 15 shows the density visualisation graph, and it indicates the cluster's colour with the default colour blue and green. There are two types of forces, attractive and repulsive, which show the association between the nodes. If two nodes are nearby, they have an attractive power with the highest association. However, if two nodes are apart, it means repulsive force in nature they have less association. Figure 14 shows that 5G, machine learning, and cognitive radio are attractive in nature and suggesta high association. In contrast, device-to-device communication and the queueing network have a high association.

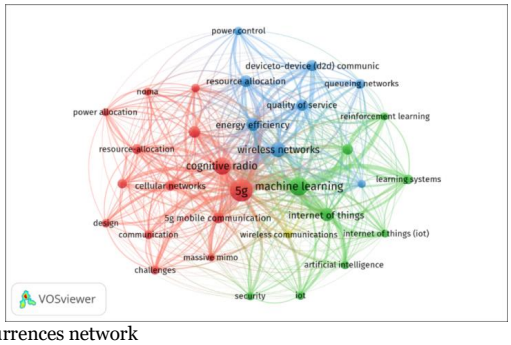


Fig. 14. Keyword co-occurrences network

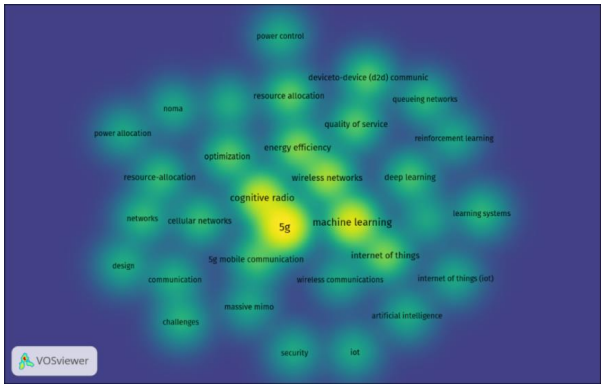


Fig. 15. Keyword co-occurrences density

Table 2 indicates four clusters that we get from keywords co-occurrences analysis through VOSviewer software. In terms of use in literature, keyword divides concerning research topic 5G and machine learning (5G/ML).In figure 14, the giant cluster, namely Cluster 1, has 14 keywords shown in red. The second biggest cluster, namely Cluster 2, has eight keywords, as shown in green. The third biggest cluster, Cluster 3, has eight keywords as shown in blue colour, and the fourth cluster, namely Cluster 4, has one keyword as shown in yellow colour. In cluster 1 most frequently used keywords in literature are about 5G mobile communication challenges, cellular networks, cognitive radio (C.R.), resource management, resource-allocation, Massive MIMO, NOMA, and optimisation in 5G.In Cluster 2 most frequently used keywords in literature are about the field of artificial intelligence, deep learning (DL), machine learning (ML), reinforcement learning, security, and the Internet of things (IoT). Cluster 3 shows most of the research publications discussed device-to-device communication, energy efficiency, network architecture, power control, quality of service, queueing networks and, resource allocation. Finally, in cluster 4, most of the research articles discuss wireless communications.

Table 2. Different search queries and results in WoS and Scopus.

Cluster #	Colour	# Of keywords	Cluster keywords
1	Red	14	5G, 5G mobile communication, cellular networks, challenges, cognitive radio, communication, design massive Mimo, networks, noma, optimisation, power allocation, resource management, resource allocation
2	Green	8	artificial intelligence, deep learning, Internet of things (IoT), learning systems, machine learning, reinforcement learning, security
3	Blue	8	Device-to-device (d2d) communication, energy efficiency, network architecture, power control, quality of service, queueing networks, resource allocation wireless networks
4	Yellow	1	wireless communications

Figure 15 shows that 5G, machine learning, and cognitive radio are attractive in nature and mean high association, whereas device-to-device communication and the queueing network have a high association.

3.2.8 Most Frequent Words

Figure 16 and Figure 17 highlights the top keywords with most occurrence in published literature 5G (371) followed by Machine learning (307), cognitive radio (186), 5G mobile communication (184), the device to device communication (127), Internet of things (111), resource allocation (105), energy efficiency (102) and resource allocation (84) times respectively. Figure 17 shows that WordCloud, a more important word, is primarily used in5G and Machine learning research literature.

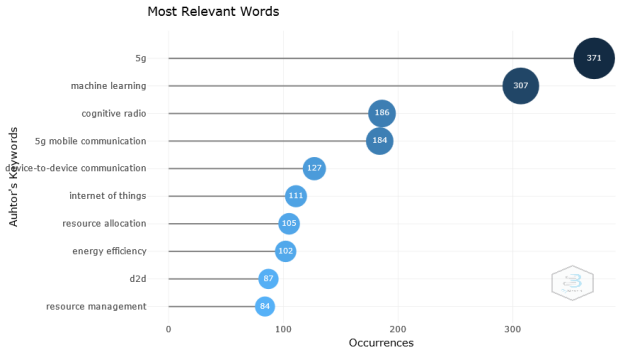


Fig. 16. Top 15 keywords within 5G machine learning research

Fig. 17. WordCloud within 5G machine learning research

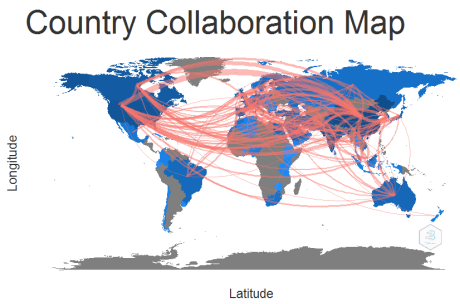


Fig. 18. Global collaboration map within 5G machine learning research

Figure 18 represents the global collaboration between the countries regarding research publication. Teamwork is essential for the research community to progress in research areas. At least one author should be another country indicating that international collaboration. Individual research is less productive concerning global production. To conduct this study, we used bibliometric R tools to view how authors collaborate with other country research areas5G and machine learning. Figure 18 represents. The country collaboration network map Indicating that the two countries with the highest collaboration are China and Australia. China– Australia, Canada–Saudi Arabia, Canada –Pakistan, Brazil–Portugal, and Canada –U.A.E. are the top five collaborating pairs countries. In addition, Canada is connected with Saudi Arabia, U.A.E., Pakistan, Bangladesh, and France are the top 5 collaborating countries.

3.2.9 Factorial Analysis

A popular exploratory data analysis tool is multidimensional scaling, which illustrates the connections between the studied topics [23]. The keywords used in the multidimensional scaling analysis were found to be dispersed across the coordinate plane in the resulting graph. Because the keywords move closer, their relative positions represent their convergence. In the context of our discussion, more convergent words create a set. They provide a foundation for relevant literature to the extent that a term is situated toward the middle of the cluster (Hoffman & De Leeuw, 1992). In the end, a factorial map of the clusters can be calculated as a result of the research. Figure 19 demonstrates the multidimensional scaling methodology used to generate the factorial map.

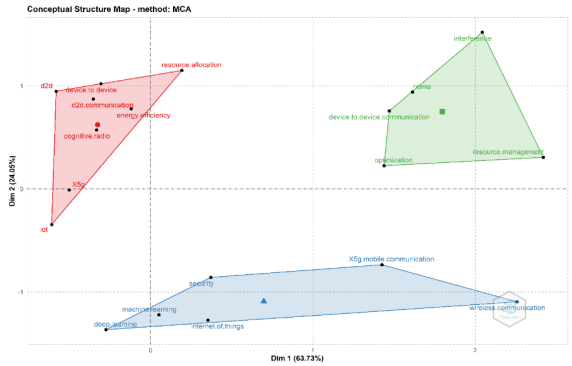


Fig. 19. Multidimensional Scaling Analysis of Keywords

The first cluster includes the concepts of IoT, device-to-device communication, resource allocation, energy efficiency, cognitive radio, and 5G. The factorial map shows that the idea of cognitive radio occupies a more central position. It can be interpreted as the importance of cognitive radio for d2d communication in a 5G environment so energy efficiency and resource allocation will improve in the IoT environment.

Cluster 2 includes machine learning, deep learning, 5 g wireless communication, security and IoT, and the Internet of Things close to the centre. It can be represented as machine learning, and deep learning is used for IoT,5G, and wireless communication security.

The third cluster includes d2d communication, NOMA, resource management, and Optimisation. In this cluster, the idea of NOMA is more central, and it shows that NOMA is used for d2d communication.Figure 20 shows that cluster wise top 2 publications. Similarly, Figure 21 shows thatcluster wise top two most cited research articles.

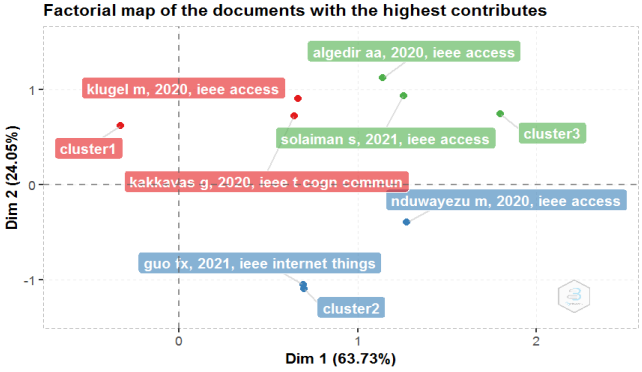


Fig. 20. Top 2 cluster wise publications with highest contribute

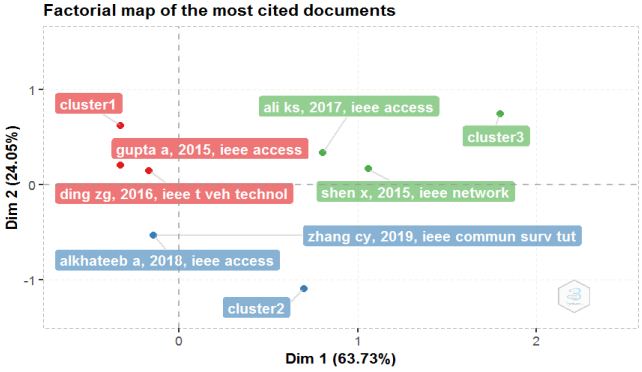


Fig. 21. Top 2 cluster wise most cited publication with highest contributes

4 Conclusion

This study performed bibliometric analysis on 5G and machine learning topics. We present a comprehensive analysis of existing research. In this research, We performed keyword analysis, analysis of scientific production year-wise, country scientific production, the Most cited country of scientific output; Most cited country in terms of citation year-wise, top 10 relevant organisations, top 10 authors publication wise, top 10 authors H-index wise, most trend topic year-wise within 5G and ML, top 10 relevant journals, keyword clustering, WordCloud, country collaboration map and finally we did factor analysis to find the top highest contributing papers and cited articles. The 5G technology is increasing the scope of the device to device communication, Internet of things. In addition, we need to optimise the resource used in 5G infrastructure using cognitive radio, deep learning, machine learning. The implementation of IoT needs 5G in an efficient way, such as power management or control using machine learning, resource allocation in an efficient manner using deep learning. Bibliometric analysis is a popular method for a new researcher to identify the research area in a particular field.

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