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A Bibliometric Analysis on Optimization of Application Layer Protocols in the Internet of Things

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ABSTRACT

Internet of Things (IoT), getting popular day by day, thanks to the every object that has been made intelligent and started communicated among themselves with ease. These objects are equipped with sensors and capable of connecting and exchanging the application data over the Internet. While the application data is getting exchanged among these intelligent objects smoothly, there are various concerns with these intelligent objects like they are constrained when it comes to resources like memory, processing capability, power consumption etc. In this regard many attempts are made to enhance or to optimize existing messaging protocols so that we can get best out of these objects. Along with this there are some serious issues need to be addressed to achieve the growth of IoT systems globally, to name a few are security, standardization, privacy, government regulations and politics and civic engagement.

In this article, we present the previous research contributions in the area of optimization related work in application layer protocols in IoT, especially Message Queuing Telemetry Transport (MQTT) Protocol and Constrained Application Protocol (CoAP) by the help of detail bibliometric analysis. For this analysis, we have referred to the Scopus database and for pictorial depiction of the data we have used the tools like VOSviewer, iMapBuilder. We have selected last 10 years duration for this analysis considering the significant evolvement in the IoT and its allied areas. In this period, a total of 1106 research articles are published by various researchers. We have observed the significant rise in the research in IoT related areas in last 4 years, where the total of 862 articles are published & in the year of 2019, it was having the maximum count of 287 articles published. The detailed analysis study revealed that a maximum of published articles are conference papers followed by journal articles and book chapters. According to the analysis, India is the torch bearer in the IoT related research areas & is followed by countries like South Korea and Italy.

Keywords: Internet of Things, Message Queuing Telemetry Transport Protocol, Constrained Application Protocol, Bibliometric Analysis, Application Layer Protocols

1. INTRODUCTION

Internet of Things (IoT) is a next big thing which can accommodate variety of applications generating tremendous amount of data. A typical IoT application consists of large number of intelligent objects equipped with sensors, which are generally interconnected with each other and the broker. These objects gather the data and forward it to broker, which aggregates it and sends it to interested receivers / clients. To integrate these objects seamlessly over the Internet requires protocols which

are efficient with respect to bandwidth utilization, energy consumption and capable to work in resource constrained environment. In this regard, several IoT messaging protocols have been developed but there performance is not well evaluated.

[Paridhika Kayal and Harry Perros] evaluated and compared four different communication protocols, namely, CoAP, MQTT, XMPP, and WebSocket by implementing a smart parking application to measured their response time by varying the traffic load over the network. According to the study MQTT & CoA stands more suitable where broker utilization is more & less respectively.

[Lavinia NĂSTASE, et. al] carried out experimental evaluation in eHeatlh system for six different protocols MQTT, CoAP, HTTP RESTful services, WebSocket, AMQP and XMPP. Average RTT, total data bytes and total bytes were the few criteria's that were considered for evaluation. As per the study, CoAP & MQTT has shown satisfactory performance as compared to other protocols.

Comparisons are also made for IoT application layer protocols with standard internet protocols like HTTP, but HTTP is more suitable for web based heavy traffic and it has significant overhead as compared to MQTT & CoAP, thus makes it not favorable for IoT applications. After comparing HTTP with IoT application layer protocol, especially MQTT and CoAP over the parameters like response time, throughput and delay, it was observed that HTTP is not suitable for IoT applications [S. Sasirekha et. al]. Also, the payload size, the type of data that are carried by HTTP is different as compared to data generated by intelligent objects, so it is not preferable for IoT applications.

In IoT selecting the best suited protocol solely depends upon application constraints, network conditions and data to be exchanged, quality of service and security and privacy concerns. CoAP is suitable for peer to peer data exchange between client and broker and it has reduced communication overhead as it runs on UDP while, MQTT is suitable for battery operated devices, and appropriate for many to many communication. It is preferred for application which sends frequent data updates as it has less overhead in generating the payload and transferring it as compared to CoAP [Stefan Mijovic et. al]. [I. Heđi et. al] investigated MQTT, CoAP and WebSocket via experimentation over simple IoT devices and in controlled network environment. As per the results the protocol performance doesn't change by changing the network environments though it has significant impact of application needs. The energy consumed is dependent on various states of devices. MQTT & CoAP are more energy conservative compared to XMPP and other protocols. They are very lightweight and have less overhead in transferring the data which makes them to save on energy consumption. [Aleksandar Velinov et. al]

Among the various IoT application layer protocols, MQTT stands as the most popular one and is having an upper hand as compared to CoAP. Still there is a need to enhance these protocols as per the application needs and constraints. Besides this, there are other concerns in IoT systems that need to be addressed like interoperability standards, traditional governance, security, privacy and autonomy. IoT has a very promising future for sustainable communication practices among intelligent objects, though it has a very long way to go unless all the concerns needed to be eliminated to prosper the growth in this area.

This bibliometric analysis is aimed to study the research contributions in the area on IoT and its allied areas over the period of last 10 years. This analysis gives detailed information about global research and is classified area wise, source wise, country wise etc. and will serve as path finder for the research aspirants in the area of IoT with necessary comprehensions for future work.

2. PRIMARY DATA COLLECTION

For this bibliometric analysis we have considered Scopus database which is largest database of peer reviewed literature which gives the complete insights to scientific global research in different fields. The keywords used to search the database are listed below.

Table 1: Keywords used for analyzing Scopus Database

Master Keywords	"MQTT" OR "CoAP" AND "IoT"
Primary Keywords	"Optimization" OR "Application layer protocols" OR "Messaging protocols" OR "Message framework" OR "Throughput" OR "Reliability"

"MQTT" OR "CoAP" AND "IoT" are used as master keywords for searching through the database which results with about 10,000 plus publications but it has been filtered to 1106 search results by using few primary keywords *(Data access till June 10th, 2021)*. Figure 1 shows the word cloud of all the keywords considered for doing this bibliometric analysis.

The cluster analysis of authors with the publication through past 10 years is done via "VOSviewer" software tool. Figure 2 depicts the cluster analysis of authors as below. One can easily highlight the growth of research in the IoT allied areas over the period of last 10 years using cluster analysis.

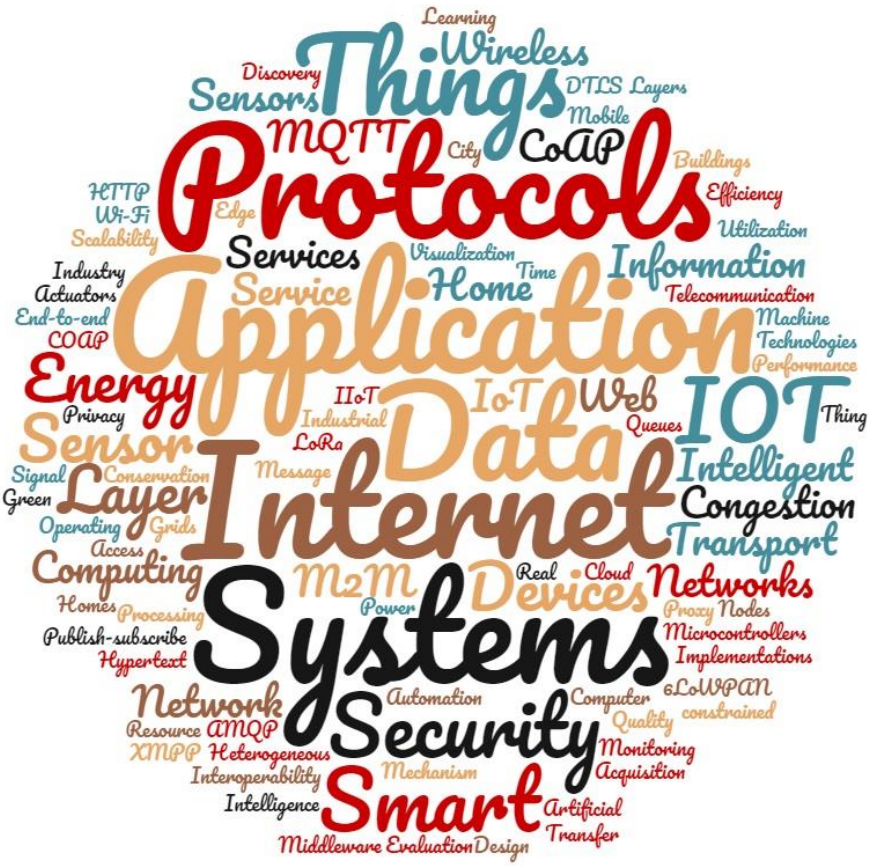

Figure 1: Word Cloud of Keywords (Data access till June 10th, 2021)

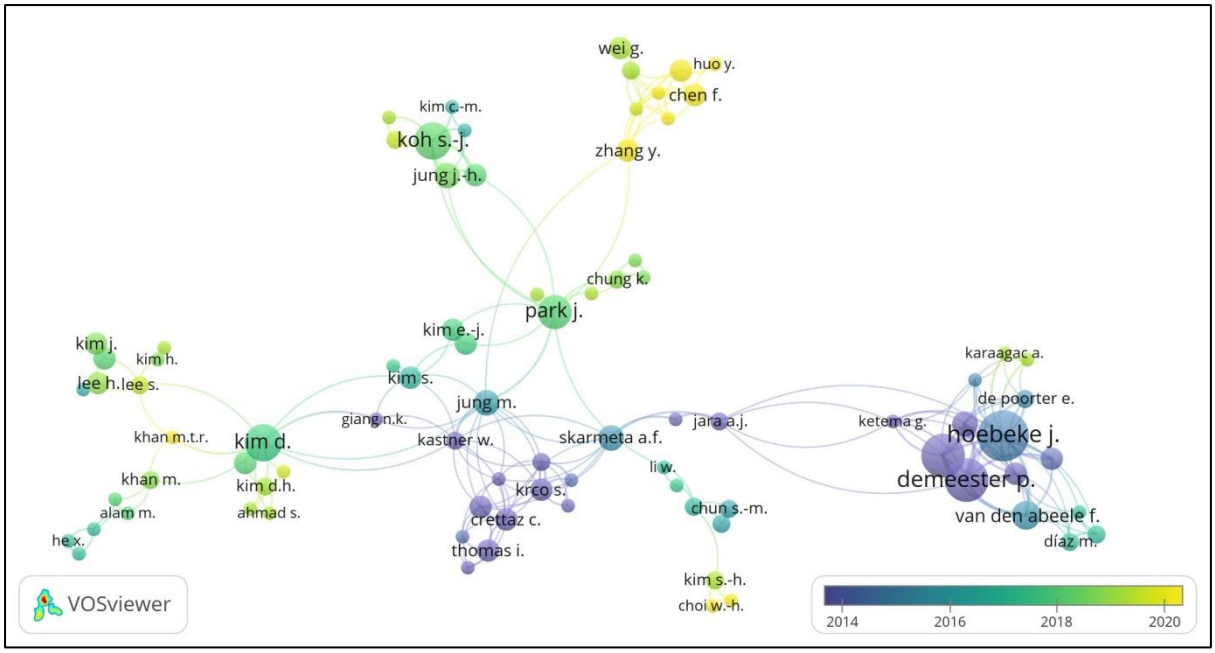

Figure 2: Cluster Analysis of Authors (Data access till June 10th, 2021)

3. DATA ANALYSIS AND INTERPRETATION

As the Scopus database is the most popular scientific database; the data collected from there to perform literature review with different concerns like affiliation, authors, country wise, subject area, access type, publication year etc. and it is presented in this section.

3.1 Analysis by Affiliation, Author, and Language of Publication

As per the data gathered; Kyungpook National University, South Korea is at the helm with 29 publications followed by Universiteit Gent, Belgium with 16 publications among top 10 affiliations that are considered for this analysis. A total of 118 publications are noted for the top 10 affiliations in the current study of bibliometric analysis

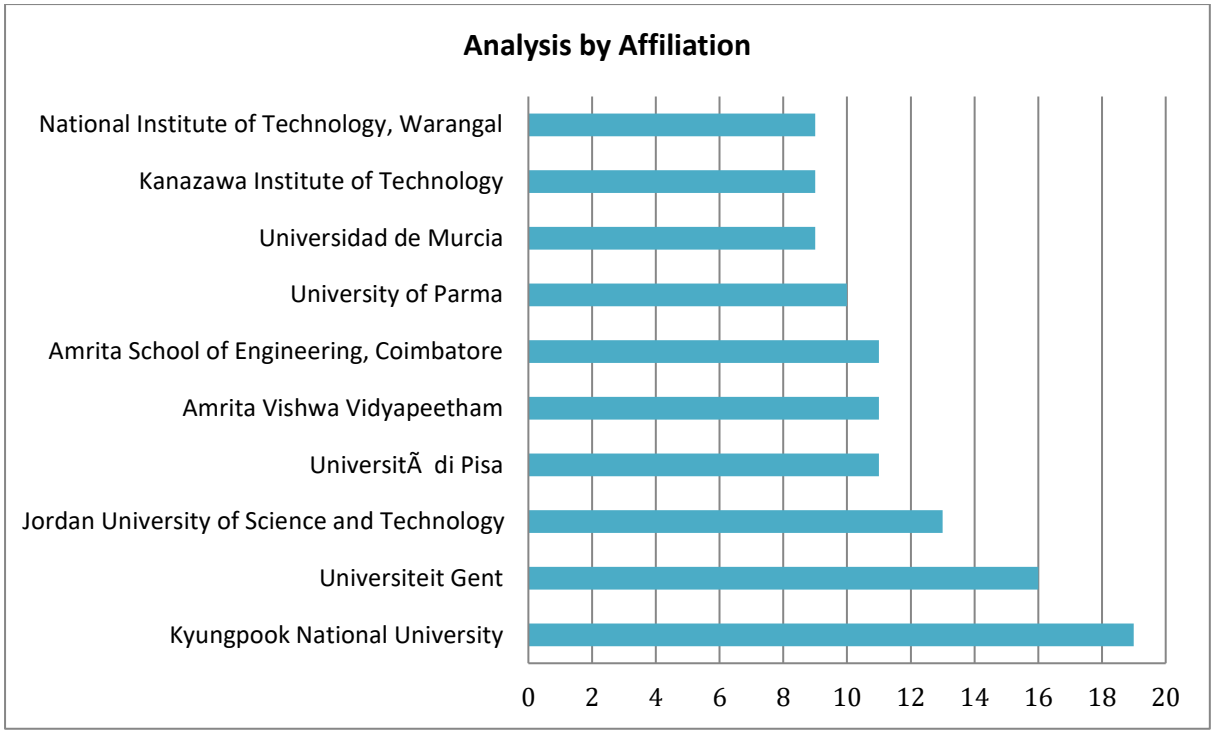

Figure 3: Analysis by Affiliation (Data access till June 10th, 2021)

As indicated in Figure 4, a total of 128 research articles are published by top 10 global authors. As far as the referred data; most of the authors having affiliation with Kyungpook National University, Universiteit Gent and Jordan University of Science and Technology while from India, Amrita Vishwa Vidyapeetham and Amrita School of Engineering are in top 10 affiliations.

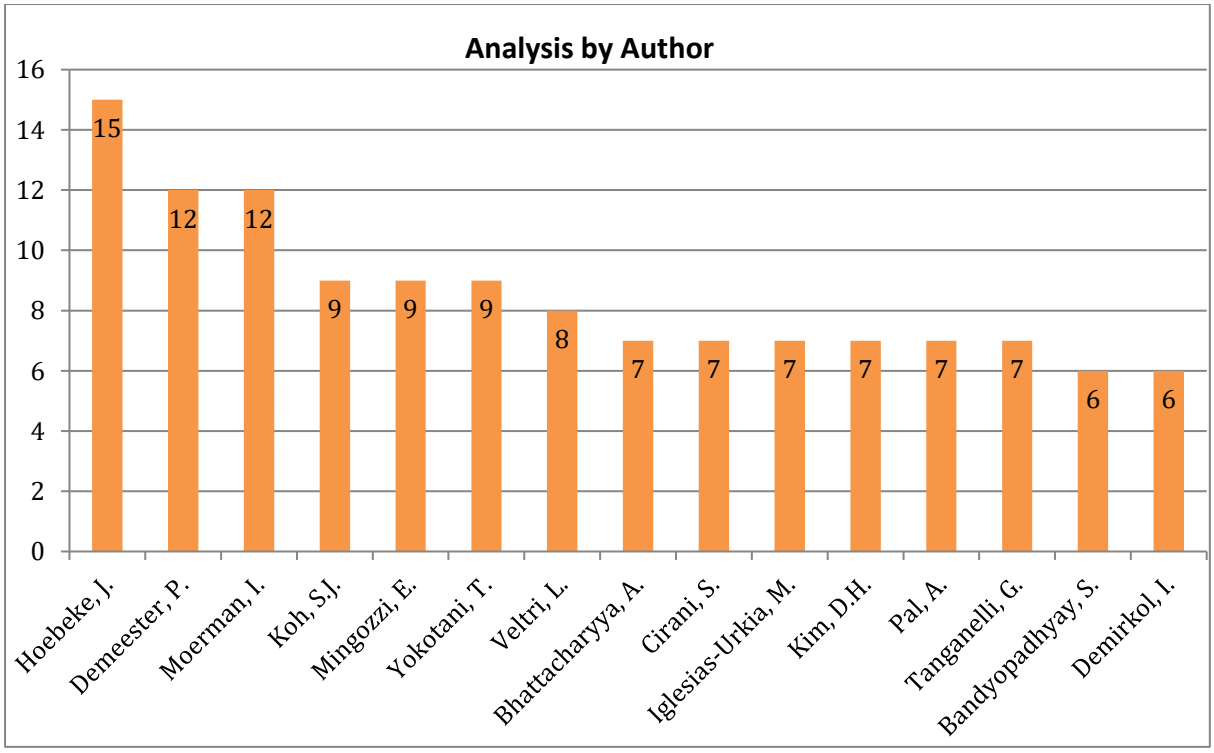

Figure 4: Analysis by Author (Data access till June 10th, 2021)

Regarding the language of publication; a total of 1094 articles are published in an English language while other languages like Spanish, Portuguese, Turkish, Chinese, Croatian, Korean and Russian all are in single digits. About 98% of research work is published in English language to have a global reach.

Table 2: Language wise Publication details

Sr. No.	Publication Language	No. of Publications in Scopus
1	English	1094
2	Spanish	4
3	Portuguese	3
4	Turkish	2
5	Chinese	1
6	Croatian	1
7	Korean	1
8	Russian	1

3.2 Analysis by Access and Document Type

This kind of analysis is used to identify different articles based on their access type and the document type. Referring to the selected data for this particular analysis, the maximum research articles are open access and rest are classified into different categories wiz Gold, Hybrid Gold, Bronze and Green. As indicated in Figure 5, a total of 224 articles are open access followed by Green category consisting of 128 articles.

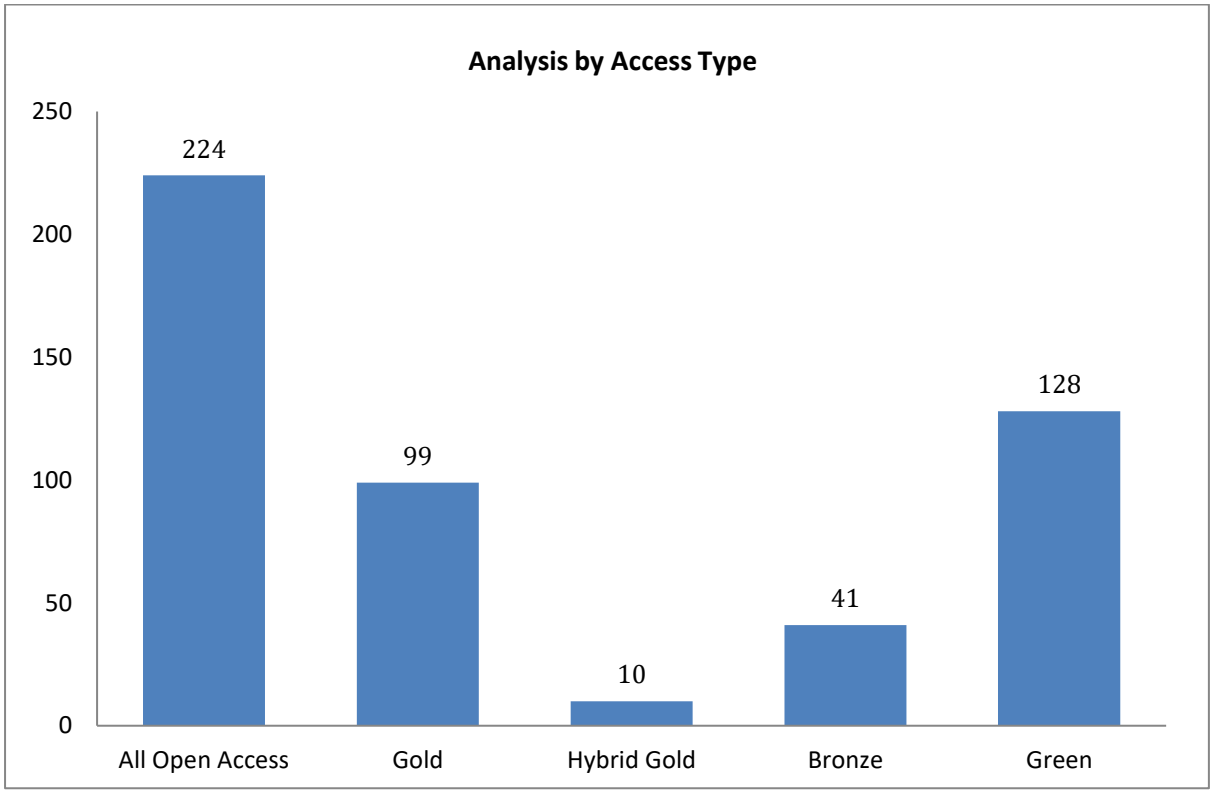

Figure 5: Analysis by Access Type (Data access till June 10th, 2021)

Table 3: Summary of Data based on Document Type (Data access till June 10th, 2021)

Sr. No.	Document Type	No. of Publications in Scopus
1	Conference Paper	793
2	Article	285
3	Book Chapter	24
4	Review	2
5	Short Survey	1

Table 3 shows the summary of data collected for this study. It clearly indicates that the maximum numbers of publications are in the form of Conference papers trailed by research articles. Few of the publications are also made as a part of book chapters.

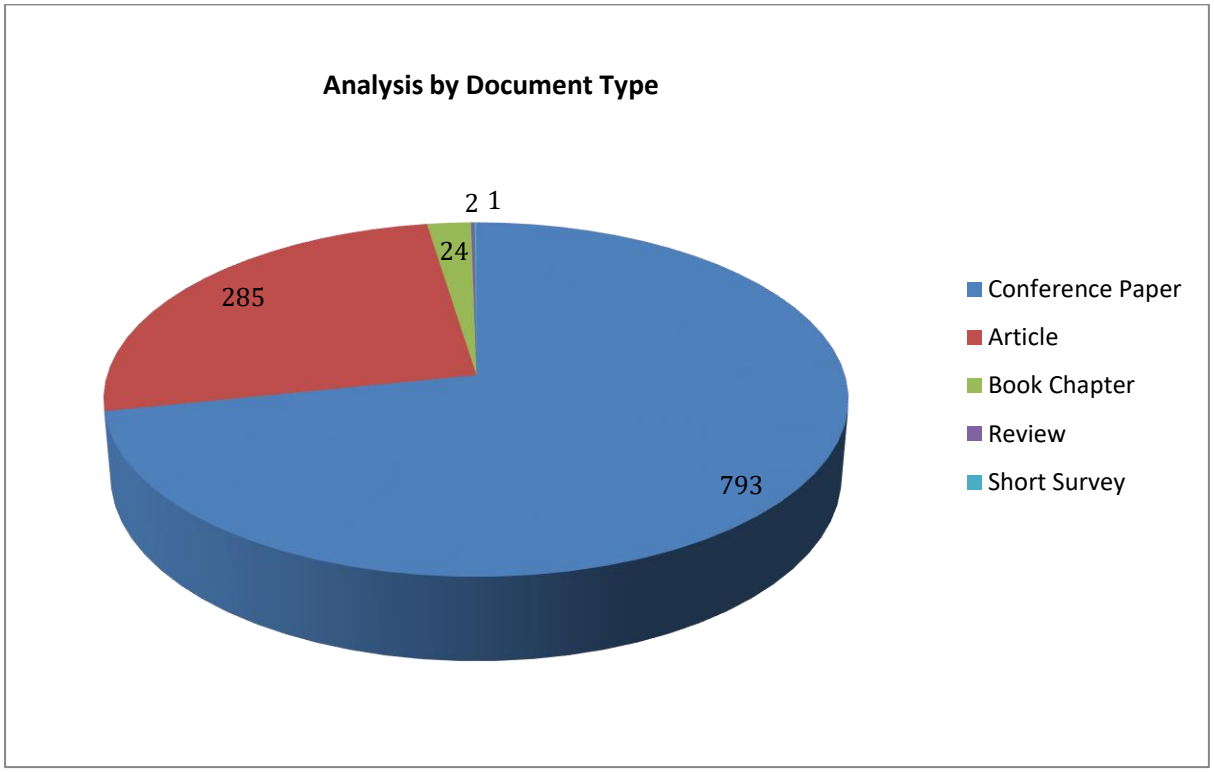

Figure 6: Analysis by Document Type (Data access till June 10th, 2021)

Figure 6 depicts graphical representation of analysis based on document type where conference papers are 793 and tops the list preceded by 285 research articles. The contribution of book chapter is 24. This is an indication of quality contribution done by the researchers in the IoT and its allied areas.

3.3 Analysis by Year

In this section, the precise summary of publications done on year to year basis is represented with a comprehensive analysis. The publications from 2011 to 2021, i.e. past 10 years are considered for present study. The analysis shows that the maximum numbers of publications are made in the year 2019 making the threshold of 287 publications, which was the highest in last 10 years. By observing

Figure 7, it is evident that the research trend in IoT application layer protocols especially MQTT and CoAP is growing considerably and it will continue its trend in the upcoming years too. Given the latest development in the field of IoT, it is forecasted that the coming decade will be of intelligent objects communicating and exchanging data to make life easier for human being.

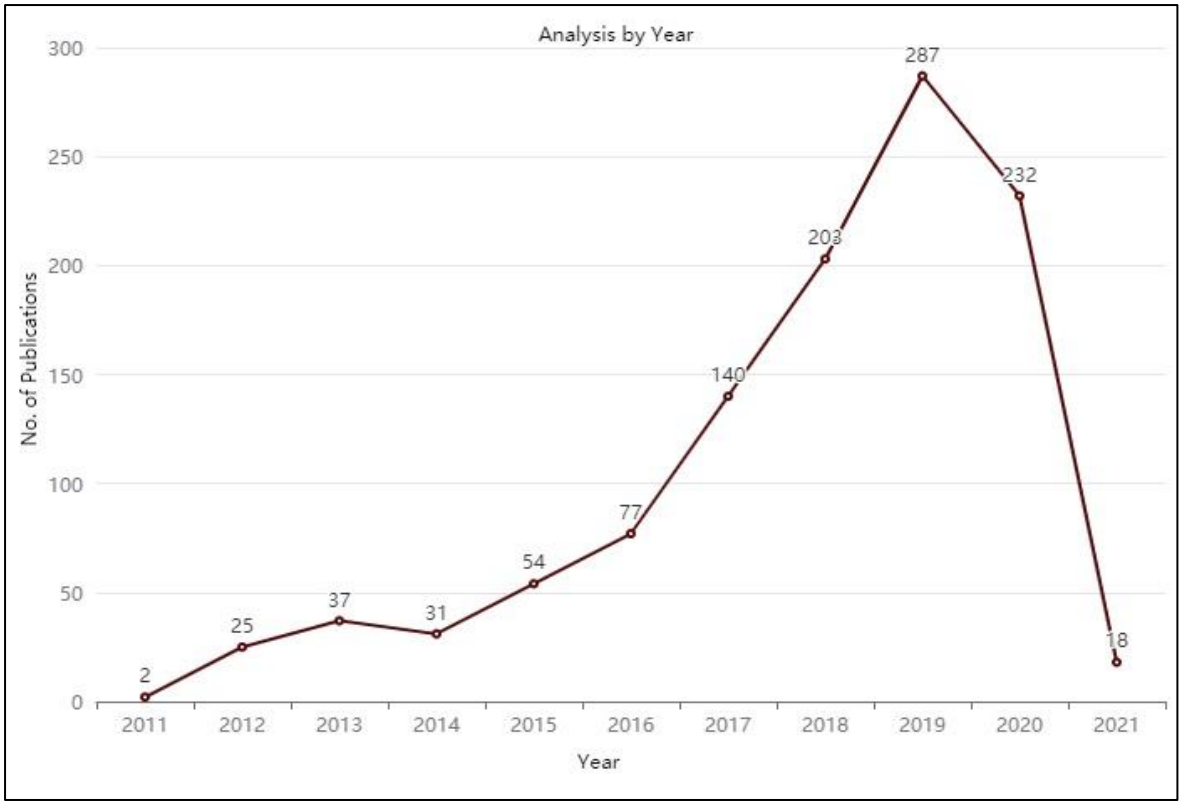

Figure 7: Analysis by Year (Data access till June 10th, 2021)

3.4 Analysis by Subject Area

The subject area analysis assists in recognizing key concentration areas for the present study. As shown in Figure 8, a maximum of 935 publications are made in the area of Computer Science followed by 510 in the Engineering area. The maximum contribution is identified in Computer Science areas are endorsed to the core communication protocols between intelligent objects in IoT. A lot of research work is underway in this area citing to improve these communication protocols. To be more precise most of the existing protocols are examined to be used with IoT but later found that they are not suitable for IoT applications. The more promising protocols like MQTT and CoAP are on the radar of past researchers. Though they are suitable for different IoT applications, there is considerable improvement is needed and this potentially could be the area of interest for many of the researchers and will be the driving force for the worldwide growth of IoT. Second most publications are in the Engineering area exclusively due to significant rise in the use of IoT towards industrial IoT or Industry 4.0.

Significant contributions are also noted in the area of Mathematics, Physics and Astronomy and Decision Sciences. By observing the analysis trends, it is apparent that the contributions are made into different areas by making union of them to make IoT truly interdisciplinary research area. Despite of this, areas like Arts and Humanities, Earth and Planetary Sciences, Health Professions and Pharmacology, Toxicology and Pharmaceutics can be taken ahead in upcoming days.

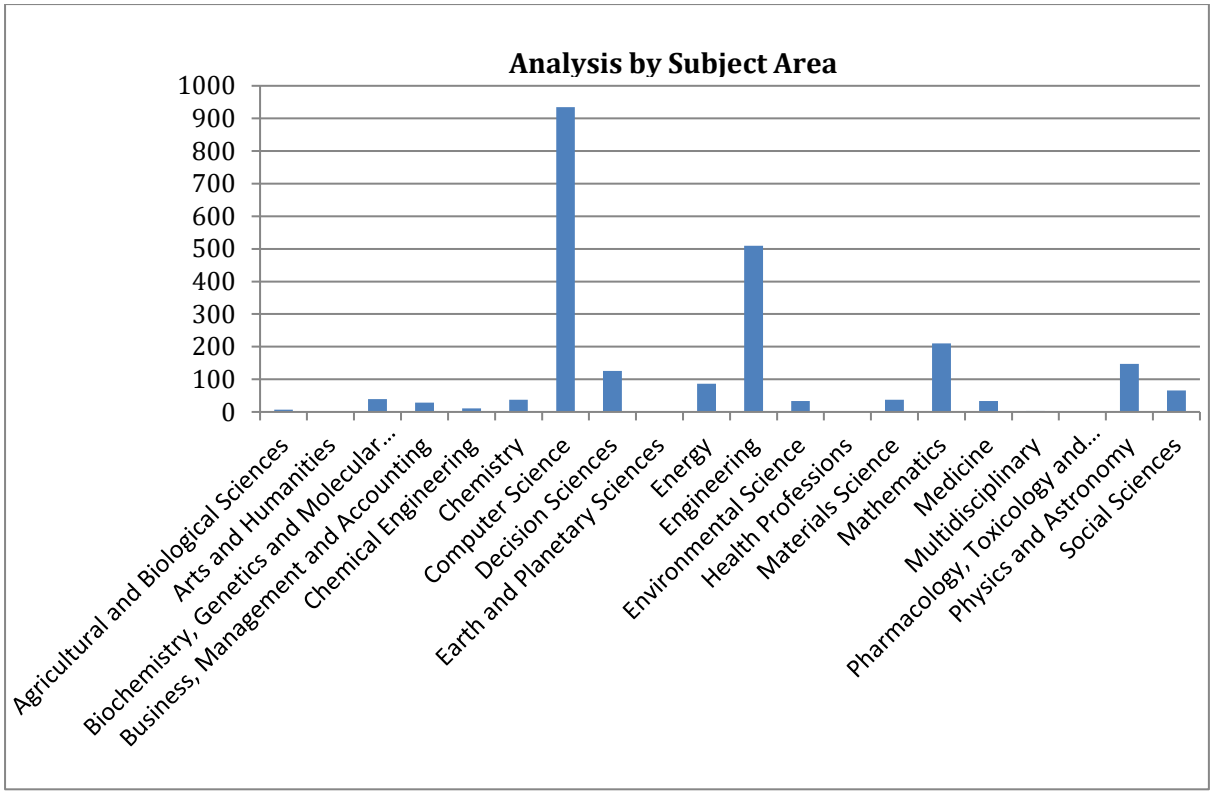

Figure 8: Analysis by Subject Area (Data access till June 10th, 2021)

3.5 Analysis by Source

This section summarizes about the research contributions made from different sources of publications identified with the help of Scopus database. A maximum of 34 publications are noted from the ACM International Conference Proceeding Series and Sensors Switzerland each, followed by 30 in the Lecture Notes in Computer Science Including Artificial Intelligence & Bioinformatics. Below Table 4 shows the swift summary of data regarding the analysis from top 10 sources. Figure 9 shows the analysis based on source for the Scopus database under review.

Table 4: Summary of Data based on Source (Data access till June 10th, 2021)

Sr. No.	Source Title	No. of Publications in Scopus
1	ACM International Conference Proceeding Series	34
2	Sensors Switzerland	34
3	Lecture Notes In Computer Science Including Artificial Intelligence & Bioinformatics	30
4	Advances In Intelligent Systems And Computing	23
5	IEEE Internet Of Things Journal	18
6	Communications In Computer And Information Science	16
7	Procedia Computer Science	14
8	IEEE Access	11
9	International Journal Of Innovative Technology And Exploring Engineering	11
10	Lecture Notes In Electrical Engineering	10

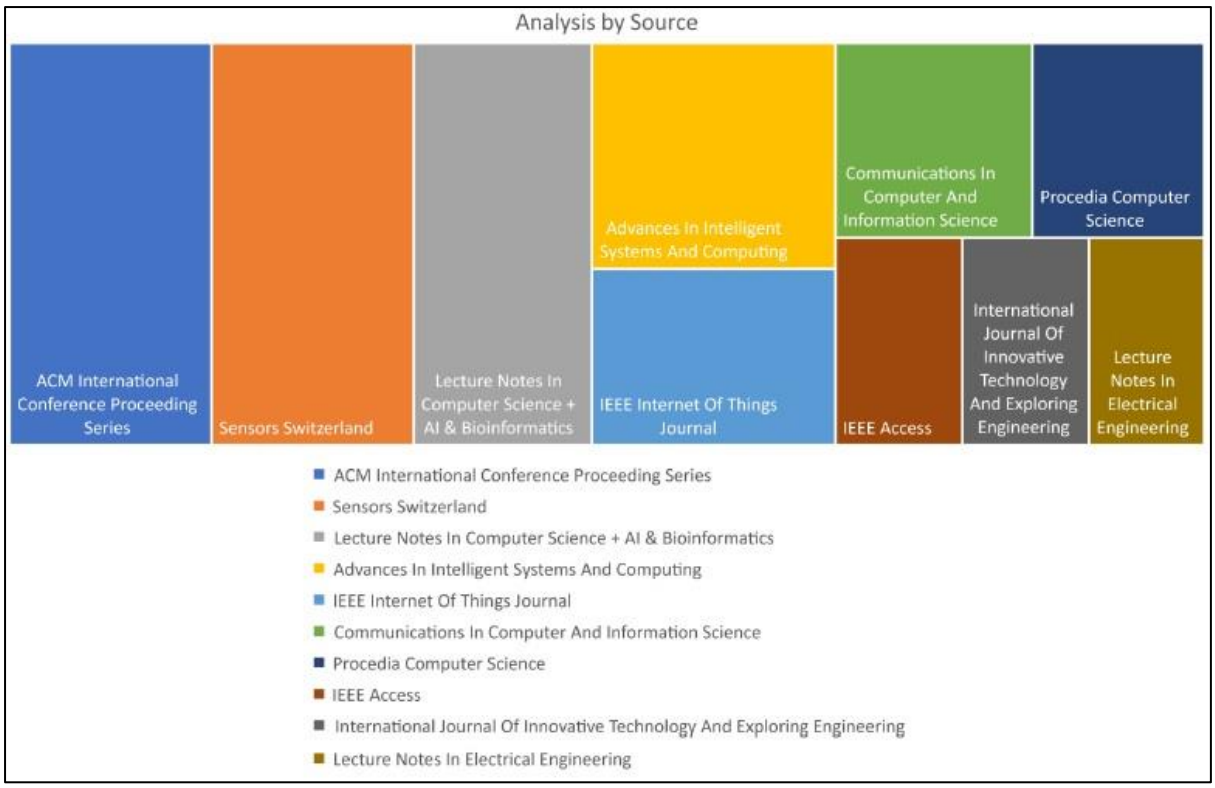

Figure 9: Analysis by Source (Data access till June 10th, 2021)

3.6 Analysis by Country

Country wise analysis is offered to comprehend the deliberations in the underlying research area. Based on the selected Scopus database over the period of past 10 years, it is evident that India is a leader in IoT related research contributions with a maximum of 247 publications.

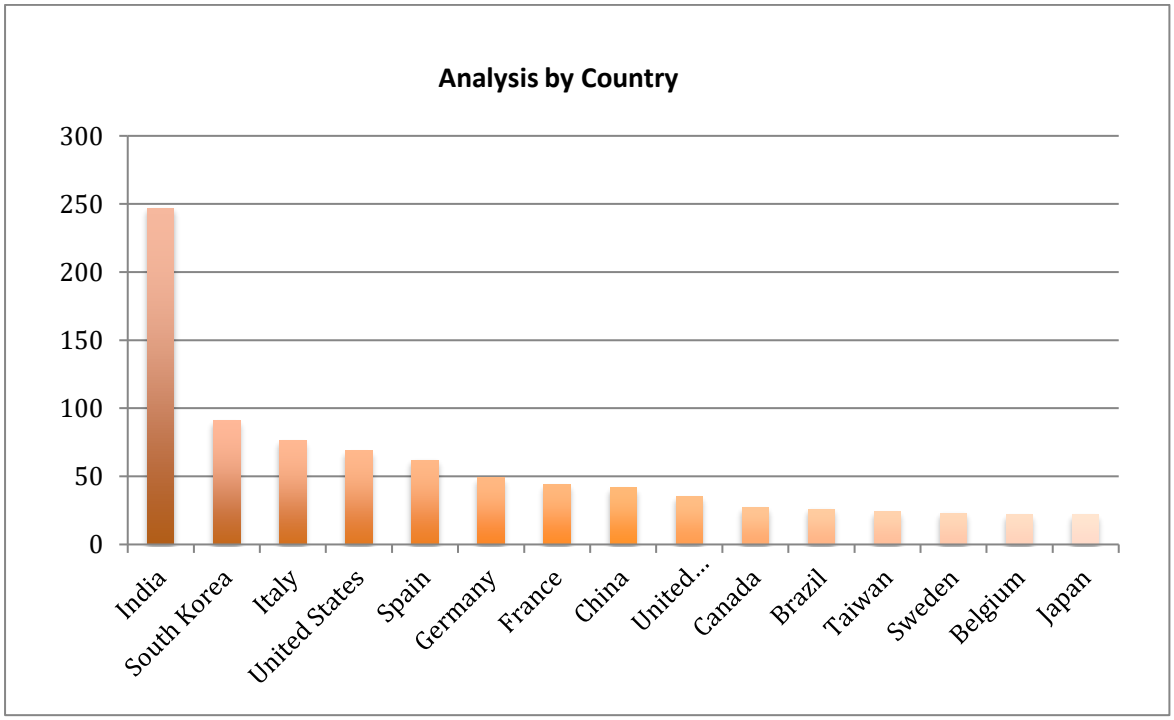

Figure 10: Analysis by Country (Data access till June 10th, 2021)

South Korea, Italy, United States and Spain are also made significant contributions in research publications in the concerned area. Figure 10 illustrates the country wise analysis based on the Scopus database under consideration. The top 15 countries are taken into account to represent this analysis. In addition to this, topographical locations map representing countries contributing to publications in the concerned area is presented in Figure 11. The below map is prepared using Imap builder software and can clearly denote the worldwide growth in IoT related research contributions.

Figure 11: Topographical Locations of the Country (Data access till June 10th, 2021)

3.6 Analysis by Funding Sponsor

This section focuses of the funding analysis as research funding is critical for any research work and it promotes the contributions in the concerned area by highly motivated and focused researchers. It acts as a catalyst to boost up the research process and in recent time many funding agencies have come forward in this regard to promote research and innovation. Figure 12 depicts the analysis for the top 10 funding sponsors worldwide in the concerned research area.

Table 5: Summary of Data based on Funding Sponsor (Data access till June 10th, 2021)

Sr. No.	Source Title	No. of Publications in Scopus
1	National Research Foundation of Korea	29
2	Institute for Information and Communications Technology Promotion	18
3	Seventh Framework Programme	16
4	European Commission	14
5	Horizon 2020 Framework Programme	13
6	European Regional Development Fund	12
7	National Natural Science Foundation of China	12
8	Ministry of Science and ICT, South Korea	10
9	Ministry of Science, ICT and Future Planning	10
10	Ministry of Science and Technology, Taiwan	8

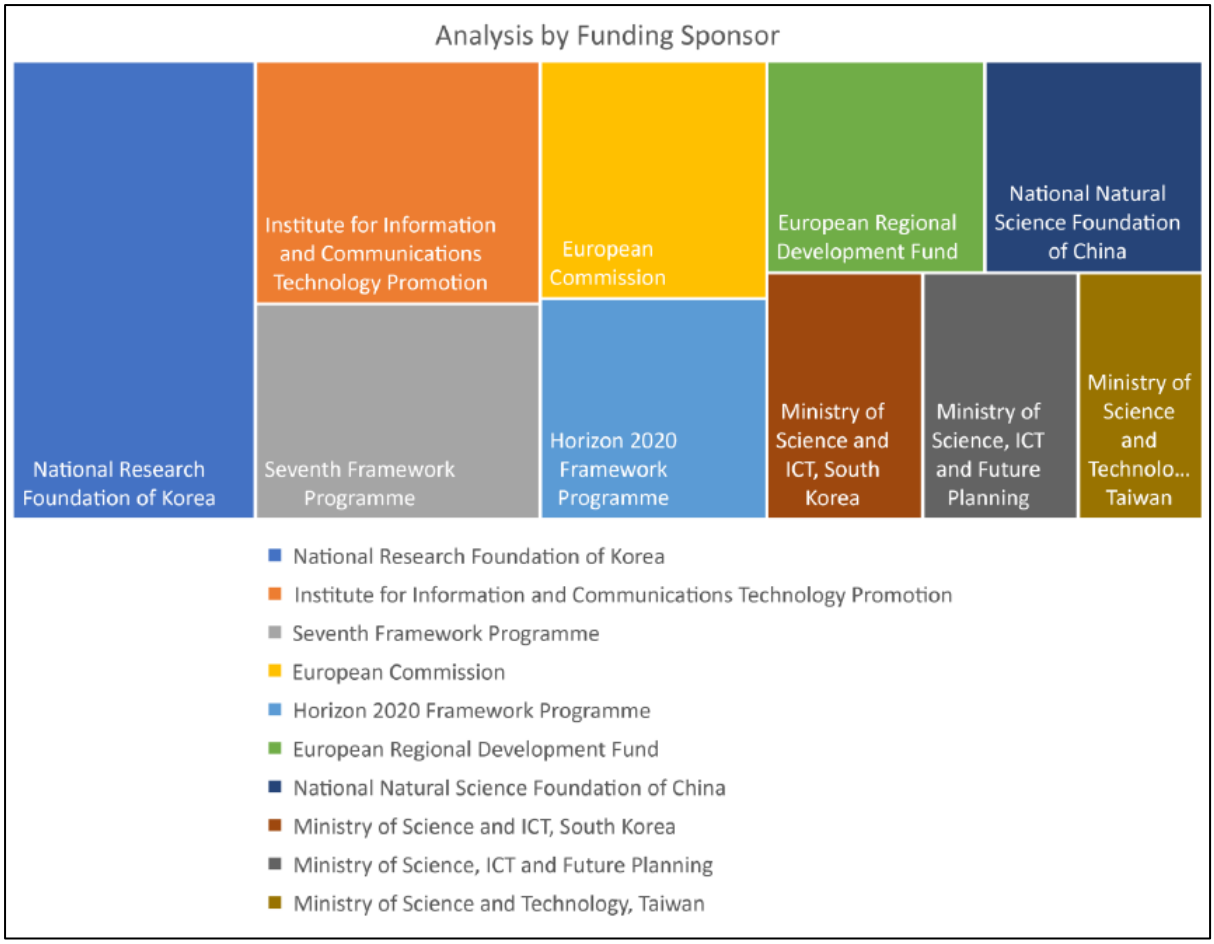

Figure 12: Analysis by Funding Sponsor (Data access till June 10th, 2021)

As mentioned in Table 5, National Research Foundation of Korea is the top funding agency contributing with 29 publications followed by Institute for Information and Communication Technology Promotion. Figure 12 represents analysis by funding sponsor based on data collected from Scopus database for this bibliometric analysis.

4. CONCLUSIONS

Sustainable development is larger construct and reaching to each absolute best facet of Engineering, Society and Environment is a key aspect of it. Over the past decade research contributions are well documented to signify the importance of the need to choose best suitable messaging protocols for IoT applications. The need of the hour is not only to select appropriate protocol but also to optimize the performance of it to get better from the constrained intelligent objects communicating in constrained IoT environment. Major challenges like getting maximum throughput, minimum energy consumption, reliable message delivery and high network time is utmost important for any IoT application and these requirements can be very well satisfied by protocols like MQTT and CoAP. Past researchers discussed the suitability of existing protocols for IoT applications and compared them with few of the IoT messaging protocols which clearly depicts the edge MQTT and CoAP is having over their counterparts. This bibliometric analysis is a comprehensive study based on data collected from the Scopus database over the past 10 years. As far as the research contributions are concerned in the said area, significant contributions are noted in 2019 and 2020 and well endorsed to the exponential rise over the past decade. This clearly indicates the focus of the past researchers to optimize the IoT application layer protocols and will continue in the upcoming future time.

Hopefully, India, the torch bearer in the research area of IoT and its allied areas will continue to hold its flagship by contributing to the further development for sustainable IoT applications. As optimum resource utilization is very important in IoT environment, optimization work in the IoT application layer protocols will continue to grow. The current bibliometric analysis can be extended to a comprehensive study in future to specific IoT messaging protocols like MQTT and CoAP along with the performance evaluation case studies. This would guide the researchers to design and develop sustainable IoT applications using best suitable messaging protocols giving optimum performance.

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