Internet of Things in Libraries: A Scientometric Study

Dr. Bhalachandra S Deshpande
Faculty
Dept. of Library and Information Science
Bangalore North University
Kolar, Karnataka
e-mail: balusnd@gmail.com
(Corresponding Author)

Dr. Sajana C
Library Assistant
ISRO, Bangalore, Karnataka
e-mail: sajana.drtc@hotmail.com

Abstract - *Connecting our home computers to Internet just simply means connecting it to a large web of many other computers located at distant locations. Similarly, the emerging concept of Internet of Things (IOT) is born with the idea of connecting daily used "smart" machines and appliances to each other. As in Internet, we can tap their ability to exchange valuable information to gain productive knowledge and make our lives easier. Focusing on the role of IOT in Library, a Scientometric approach was applied to quantitatively evaluate the main interests of research trends in this field of study. To better understand the rapidly growing IOT applications in libraries, this study presents the findings of a Scientometric analysis of the related literature. Using the data from the Web of Science (WoS) database between January 2006 and July 2020, a total of 267 publications were retrieved by searching keyword- "Internet of Things (IOT) and library". The preliminary results show that the annual publications on IOT have increased steadily, since past decade. This reflects the fact that there exists absolute attraction towards this evolving concept of IOT. Other findings are related to patterns of global research collaboration, keyword frequency/subject interests to researchers, core journals, highly cited articles, citations growth etc. As observed by the authors, this article signifies the vibrant growth of research in IOT as a impending technology that has the potential to enter our daily lives and also we believe there seems to be no work in Scientometric mapping of publications related to Internet of Things in Libraries. Therefore, this current study can be considered as a fundamental work within this field.*

Keywords: Scientometrics, Internet of Things, Bibliometrics, Research output, Library

Introduction

Internet of Things (IOT) is one of the promising revolutions to radically change the way we work and live, by interconnecting the world of "*Things*". The "*Things*" in IOT refers to huge number of resources around us relating to our home, office, medical care, roads, fashions and every*thing* that can be thought of connecting to produce useful data which can help in best decisions and make our lives easier. Where the concept of IOT seems to be almost unimaginable compared to recent past, we are now witnessing rapid growth in some "smart"

devices such as wearable health monitoring systems like fitbit, automobile status update-CarlQ, SenseGiz, TeeWe, LifePlot etc.

IOT will redefine the way humans interact with their surroundings. It can be well regarded as *"Internet of Everything", Internet of All things", "Web of Things", "Internet of Smart things"* etc. These *"Smart Things"* around are expected to adapt functions as per our needs to make our lives easier and more comfortable.

Automatically, based on situations or our needs wrist band monitors our sleep, a hot cup of tea is ready in the "networked kitchen" and the music system starts buzzing our favourite songs. The complete home is automated and "Smart". Perhaps, to some extent IOT has already invaded into our lives e.g. in the form of public transport with excellent navigation applications with plethora of cab booking or sharing apps that have well defined and set system for tracking customers, processing payments, and keeping tabs on employees. The Internet of Things market is expected to experience around 28% yearly growth, rising to 5.4 bn connections across the globe by 2020. All IOT devices require a reliable cloud backend and a secure channel for communicating information captured by these devices to the backend [1]. It is also anticipated that by 2020, at least 14% of the consumers would have purchased some form of IOT. The factors that are motivating the growth of IOT include- boost in use of social media, reduced cost of sensors, high use of mobile technology, increase in connectivity etc. Gartner predicts that the IOT has great revolutionary influence on the data center related markets. Gartner estimates that by 2020 IOT product and service suppliers will create huge exponential revenue exceeding $300 billion, mostly in services.

Background

The current vision of the IOT has evolved due to a convergence of multiple technologies, ranging from wireless communication to the Internet and embedded systems to Micro-Electromechanical Systems (MEMS) [3]. In 1990, Romkey & Hackett created the world's first connected toaster powered through the Internet. It took nine years for IOT to get its name when Kevin Ashton coined the term *"Internet of Things"* and established MIT's Auto-ID Center, a global research network of academic laboratories focused on RFID and the IOT. In the same year, Andy & Arlen of Arcom introduced the first Machine-to- Machine (M2M) protocol for connected devices: MQ Telemetry Transport (MQTT).

A year later in 2000, LG announced plans for the first connected refrigerator which can identify items that are stored inside it using barcode and RFID. Then, The United Nations first mentioned IOT in an International Telecommunications Union report (2005). After Three years, the first international IOT conference was held in Zurich.

In 2010, Google introduced a self-driving vehicle project, a major milestone in the development of a connected and autonomous car. Bluetooth Low Energy (BLE) is introduced, enabling applications in the fitness, health care, security, and home entertainment industries. In 2011, IPv6 launched where it can expand the number of objects that can connect to the Internet by introducing 340 undecillion IP addresses (2128) [11]. By the end of the year 2015, it is estimated that there will be more than twenty five billion individual Internet connected devices, making our world into one common well-connected network.

Methodology

We retrieved research publications from *Web of Science database* between years January 2006 to July 2020. A total of 267 records were retrieved by searching keyword- "Internet of Things (IOT) and Library". The search strategy applied is to limit the appearance of the keyword Topic which includes Abstract, Title, Keywords Plus and Keywords. The retrieved document types included journal articles, conference proceedings and reviews. The data was analyzed using spreadsheet software to identify the research trends in the field of IOT.

Results:

Growth of Publications

The research output includes data from January 2006 to July 2020. During this fifteen years plus period, the overall trend has been a steady surge of annual output, even though the number of records in the year 2020 decreased drastically. Results also revealed that the concept of Internet of Things (IOT) was consistently the focus of researchers and has developed at an increasingly rapid rate since past few years. Starting with a single publication in 2006, the research in IOT in libraries has took-off with many studies from 2015-2018 (Figure.1).

Figure 1. Growth of publications

Document Types

Around 3 document types were identified in the total records. Most documents were proceedings papers, which accounted for 66% of the total records, indicating that these are the main mode for scientific communication in IOT research in library. Journal articles and reviews were two other important modes to publishing academic achievements in this field of research.

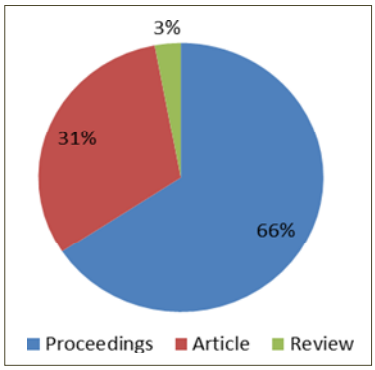

Figure 2. Document Types

Country Based Distribution of Research Output

Analysis of the country-based research in IOT, assists us to understand the scholarly output of a country and explore the variances among them. The top five countries were China, USA, India, Germany and Italy their published papers captured 77.15% of the total output. These countries, except China, India, are the developed countries striving to emerge at the technological forefront (Figure 3). However, both the developing countries have developed roadmaps to support IOT research. More specifically, in 2020, India intends to create an IOT industry of 15bn USD. It has been presumed that India would have a global share of 5-6% of IOT industry [4]. China has also steered in the standards development, forming IOT standards association and promoting Chinese-developed standards internationally [5]. The value of China's Internet of Things (IOT) industry reached 90 billion U.S. dollars in 2014 with an annual increase of 18.46% [6].

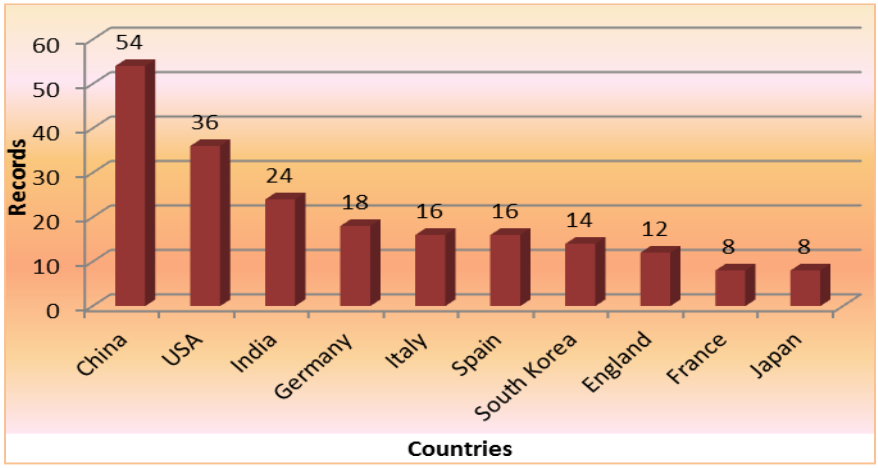

Figure 3. Country based research output

Institution Based Distribution of Research Output

Institution-based distribution of research output and activities of institutions around the world. It also can help us identify leading institutions in IOT research in libraries. As Table 1 showed, the highest institutional research output was from the Johns Hopkins University from which 6 records were found.

The next four institutions are University of Bologna, Universidad Nacional del Sur, University of Illinois and Tech University Results showed that USA contributed more to IOT research. The reason behind many countries investing in IOT research may be that, the field of Internet Of things is one of the highly promising scientific researches that requires more investigation in-order to explore ways to implement it to create tomorrow's *Connected World*.

Table-1. Institution based research output

Institution	Country	TNP
Johns Hopkins University	USA	6
University of Bologna	London	3
Universidad Nacional del Sur	Argentina	3
University of Illinois	USA	2
Tech University	Denmark	2
University of Trento	Italy	2
Centre for Automation and Robotics	Spain	2
University of Sao Paulo	Brazil	2
Le Quy Don Tech University	Vietnam	2

High-Impact Articles

High-impact articles were selected based on citation count. From Table 2 it can be seen that the top ten high-impact articles were written by authors in collaboration, of which Wang, J and Katabi, D. are among the High impact authors. The highest impact articles on IOT in libraries were published in 7 different journals and 3 conferences. The journal *ACM SIGCOMM Computer Communication Review* is in highlight as it has published the highest-impact article. Note that these articles were published after 2013, indicating that scholarly research focused IOT needed a relatively long time to achieve broader publicity and it has evolved with the technological development in modern connectivity, smart apps/objects, automation etc.

Table-2. High-impact articles

Author	Title	Journal	Year	Citations
Wang, J; Katabi, D	*Dude, Where's My Card? RFID Positioning That Works with Multipath and Non-Line of Sight*	ACM SIGCOMM Computer Communication Review	2013	171
Bilal, M (et al.)	*Big Data in the construction industry: A review of present status, opportunities, and future trends*	Advanced Engineering Informatics	2016	124
Zhao, XY; Li, H; Wang, XQ	*A High Performance Multi-standard Viterbi Decoder*	7th IEEE International Conference on Electronics Information and Emergency Communication (ICEIEC)	2017	91
Jiang, Y (et al.)	*Auxetic Mechanical Metamaterials to Enhance Sensitivity of Stretchable Strain Sensors*	Advanced Materials	2018	66
Liu, Z (et al.)	*On Emerging Family of Elliptic Curves to Secure Internet of Things: ECC Comes of Age*	IEEE Transactions on Dependable and Secure Computing	2017	56
Oztemel, E; Gursev, S	*Literature review of Industry 4.0 and related technologies*	Journal of Intelligent Manufacturing	2020	51
Kruge, CP; Hancke, GP	*Benchmarking Internet of Things devices*	12th IEEE International Conference on Industrial Informatics (INDIN)	2014	50

Carter, R; (et al.)	*22nm FDSOI Technology for Emerging Mobile, Internet-of-Things, and RF Applications*	2016 IEEE International Electron Devices Meeting (IEDM)	2016	46
Yoon, JW; Lee, JH	*Toward breath analysis on a chip for disease diagnosis using semiconductor-based chemiresistors: recent progress and future perspectives*	Lab Chip	2017	45
Bagula, A (et al.)	*On the Design of Smart Parking Networks in the Smart Cities: An Optimal Sensor Placement Model*	Sensors (Basel)	2015	40

Core Journals for IOT Research in Libraries

Around top ten core journals were identified in IOT research based on number of records published in these journals. It is evident from the Table No. 3 that most articles have been published in journals with subject coverage as Computers, Communications, IOT and Material Sciences which are in turn the very basis of Internet of Things technology. Since, IOT is a nascent research field; it holds in itself a lot of promises for the future. Lecture Notes in Computer Science (Proceedings started in year 1973) and Sensors journal, is a dedicated for IOT research saw the highest publications. This was followed by journals- IEEE access, IEEE Internet of Things journal and Future Generation Computer Systems which forms the top five core journals in IOT in libraries research.

Table-3. Core Journals

Journals/Proceedings	Publisher	Total papers	%	Rank	IF
Lecture Notes in Computer Science	Springer	11	4.1	1	1.2
Sensors	MDPI	11	4.1	1	3
IEEE Access	IEEE	9	3.4	2	4.1
IEEE Internet of Things Journal	IEEE	7	2.6	3	4.4
Future Generation Computer Systems	Elsevier	4	1.5	4	6.1
International Journal of Network Management	Wiley	4	1.5	4	1.7
Wireless Communications Mobile Computing	Wiley-Hindawi	4	1.5	4	1.8
ACSR Advances in Computer ScienceResearch	Atlantis Press	3	1.1	5	2.5
Advanced Materials Research	Trans Tech Publications Ltd	3	1.1	5	0.9
Advances in Intelligent Systems and Computing	Springer	3	1.1	5	0.6

Co-Authorship Pattern

Scientific collaboration – as measured by means of co-authorship patterns – has considerably increased during the last decades at all levels of aggregation[7].With the increase in communication network, scientific progress and interdisciplinary research the collaboration trends has seen a radical change. As represented in Figure 4, Collaboration intensity was high in two and more than two authors. Perhaps, the authorship linkage decreased relatively in single authorship and more than five authors. Thus, IOT research and development can be regarded as a joint effort of the teams.

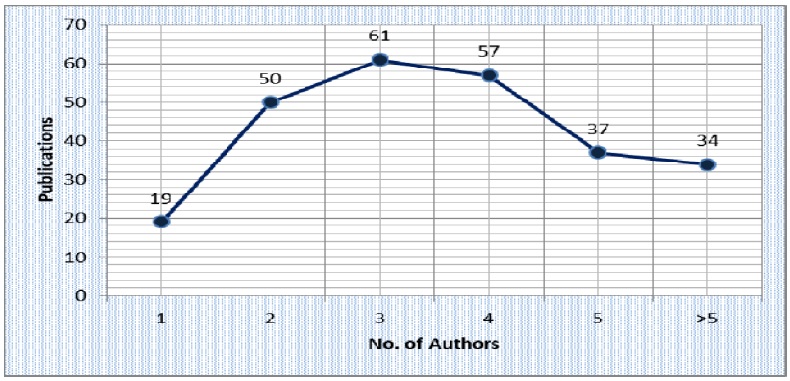

Figure 4. Author collaboration

Keyword Analysis

Results of keywords analyzed from the data is presented in Figure 5, which indicates the term "Internet Of Things" is the most extensively used keyword. It is followed by RFID, Communication systems, Wireless Sensor Networks and CoAP. These results show some logical pattern, wherein for instance Radio-frequency identification (RFID) was seen by Kevin Ashton (one who first coined the term IOT in 1999) as a prerequisite for the Internet of Things at that point. By 2014, the idea of the IOT has developed as a result of the integration of various technologies, spanning from wireless Internet connectivity and MEMS to Embeded Systems. So, this shows a linkage between each of the term represented in the documents and a direction of IOT as an emerging Inter-disciplinary research field.

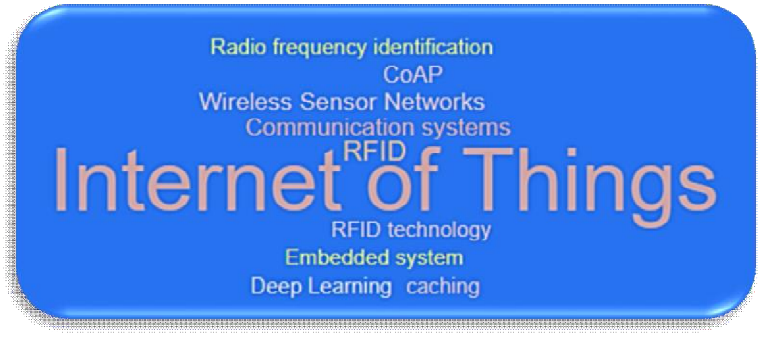

Figure 5. Top Keywords

Discussion and Findings

Even though, there is a recent growth in M2M connections and a global focus on IOT-enabled solutions there are some concerns related to IOT applications. Merely 10% of enterprises have deployed IOT technologies extensively. Various apprehensions are that the IOT is being quickly established before taking proper account of the substantial privacy concerns associated and the policy amendments that might be required [12]. Specifically, as the Internet of Things spreads widely, cyber-attacks are likely to become an increasing threat[13]. Forbes article in January 2014 mentioned list of several Internet-connected devices that can spy at home based devices like televisions, kitchen appliances, cameras, and thermostats [14]. In the current study of IOT in libraries, the research started in the year 2006 with very few annual publications. But, an exponential growth can be observed from the year 2015 onwards. It may

be identified that, there is a stable growth in research until 2019. The decline in research during 2020 can be accorded to two reasons namely, the records considered for this study is till July 2020 only and also the widespread of Covid-19 pandemic that has affected world community in general.

Majority of papers have been published in conference proceedings than in journals, which implies that most of the researches on IOT in libraries are in pre-application stages. And a very few studies have been conducted to understand the current state of this topic which are published as review papers. Further, globally the digital growth is largely uneven, with the USA accounting to 68% of the worldwide 70 major digital platforms' markets capitalization size, followed by China with 22%. The remaining of Asia accounts for about 5%, while Europe for just 3.6% [15]. Supporting to this, the current study shows that the top countries involved in this research is China, USA and India.

The involvement of majority of academic institutions i.e. the Universities, in the IOT research shows very promising growth in this field since the students are the part of it. Among the top institutions, it's very surprising to find that only one institution has contributed to this field of study and all others are Universities. Among the high impact articles, the various factors that were identified includes: (a) collaborative articles (b) most are journal articles (c) various topics like RFID, IOT, Big Data, Decoders, Sensors, Industry 4.0, Smart Cities are covered (d) all articles are published only after 2013. Moreover, the majority of papers were published by Springer, Wiley and IEEE. Among which the highest impact factor journals are Future Generation Computer Systems, IEEE Internet of Things Journal and IEEE Access. The top keywords identified in the study indicate that the IOT is a research field that accommodates many other related fields like Electronics, Computer Science, Communications and Networking.

Conclusion

Internet of Things (IOT) is the technology of future. IOT demands more research and development for its vibrant growth in-order to set its foot in all areas of society. Along with its growth, the security issues also have cropped up vast concern. So, need of the hour is to emphasize research towards increasing powers of IOT and hand in hand to decrease its security concerns.

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