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IoT and Its Application in Library: A Review of Emerging Trends

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ABSTRACT

The library activities are always oriented towards offering the best possible resources and services to its users. From time to time, technological advancements have benefited them in accomplishing their objectives effectively. The internet of things (IoT) has recently been predicted to be a technology that will benefit librarians in their endeavours. The purpose of this article is to review selected scholarly papers on IoT applications in libraries in order to demonstrate the potential of IoT applications in library activities, particularly in the academic environment. The paper discusses several elements of IoT applications in libraries and cautions readers about possible consequences. The study is exploratory in nature, and national and international articles were culled from a variety of sources. Articles that recommended or advocated the use of IoT technology in libraries are included in the study. The study offers an in-depth analysis of IoT technologies for library use in five sections: introduction, concept of IoT, application of IoT in libraries, advantages and challenges in adopting IoT. Our review reveals that while several IoT applications have been developed for library usage, only a few libraries in western nations have implemented them, and the technology has not been extensively accepted, particularly in Indian libraries. Finally, concludes that, despite the cyber security concerns and hurdles, the introduction of IoT technology in libraries is critical for providing current services alongside traditional services to a vast mass of techno dexterous users at their chosen location.

Keywords – Internet of Things, RFID, Wireless sensor network, academic library, IoT

1. INTRODUCTION

The internet has been transformed by technological advances during the past decade. Numerous new technologies have emerged as a consequence of the massive internet transformation including machine learning, cloud computing, big data and the Internet of things (IoT). IoT is regarded as the most comprehensive and important phenomena today, since it connects many things through the internet. It enables digital or physical objects/devices which are embedded with software, electronics, sensors and other forms of hardware to behave smart and provides the capability to collect and exchange data to make independent decisions with or without human intervention with the help of internet connectivity¹. Due to its versatility,

incredible features, and potential impact on society, the environment, and the economy the IoT is gaining popularity among academics, businesses, industries and government². Several industrial sectors, like automotive, logistics, transport and manufacturing have adopted IoT technology and are now delivering remarkable services to their clients. The government of USA, China, South Korea, Singapore and Germany are funding many IoT initiatives to boost the economic status, build smart cities, develop smart infrastructures, etc.

Numerous studies have been conducted and are still being conducted in the field of LIS in order to implement the potential technology. Several researchers have developed different models and identified many areas in libraries where IoT can be implemented. Implementation of IoT in libraries is essential for optimizing library operations, activities and for interconnecting available resources and systems in order to redefine services and to render interactive and innovative services to large number of users wherever they are most needed³. Few librarians have made significant attempts to adopt IoT and even taken proactive steps in educating users on how IoT technology works, how it may be used and its ramifications for our community⁴. This article examines scholarly publications on IoT with the intention of showing prospects for IoT applications in libraries, particularly in the academic environment. The article discusses many aspects of IoT applications in libraries, demonstrates the various attempts made to incorporate IoT applications into library activities, and cautions about the challenges.

2. METHODOLOGY

The study conducted exploratory research as it aims to provide greater familiarity with the theme of the IoT in libraries. In relation to its purpose, it is descriptive research, as it aims to analyze the scientific publications produced on the application of IoT technology in libraries. Literature search was conducted using the key term "IoT+Librar*" in Scopus, ProQuest and Google Scholar databases and retrieved many articles pertaining to IoT technology without applying the delimitation of the year of publication, as the theme is a recent concept for libraries.

Titles that were outside the scope of the research (primarily dealing with the term library with reference to database/software) were excluded, and articles with the theme "smart/intelligent library" that did not address the application of IoT as well as titles that briefly mentioned the application of IoT without delving into the subject were excluded. Finally, forty-six publications published in the English language were considered for review.

3. REVIEW OF LITERATURE

In libraries, especially in academic libraries, there are many research works on IoT applications. This section summarizes IoT and its use in libraries, as well as its advantages and challenges.

3.1 Concept of IoT

The term "internet of things" was introduced by Kevin Ashton to represent the interconnection of the real world and objects using sensors through internet⁵⁶. Though the term was coined in 1999, it was not used until 2005⁷. Since 2005 many descriptions have been given to

IoT. Magdalena Wojcik described IoT as "everyday objects equipped with appropriate sensors and network access that can communicate to fulfill certain tasks"⁸. According to Anton Purnik, "IoT is a complex of things (or mechanisms) connected with each other over the Internet. They can communicate with each other and act without people's intervention"⁹. According to Kevin Aston, IoT "empowers computers with their own means of gathering information, so they can see, hear and smell the world for themselves, in all its random glory using RFID and sensor technology to enable computers to observe, identify, and understand the world - without the limitations of human-entered data". In summary, IoT is a technology that uses sensors and the internet to interconnect two or more objects (things) without human interaction. However, Kaba& Ramaiah argue that IoT technology needs a user interface along with sensors, devices, and the internet¹⁰. Shen also argues that IoT "transforms the academic library into a living-learning lab that senses and studies human dynamics, human computer interactions, and human-building interactions"¹¹. It suggests that sometimes human interaction is necessary to apply IoT for different purposes. Kevin Aston, who is widely recognized as the father of IoT, believes that IoT is a necessary tool for comprehending the real world¹². Whereas Liang² believes that the IoT will have a significant impact on the community and every little thing. Peter Fernandez¹³ perceived that libraries have already demonstrated IoT, as libraries include numerous things such as books, journals, reports, that can be searched and located easily using many applications like the library management system, which allows us to communicate internally and transform the library into an ideal object that is interconnected. Nevertheless implementation of IoT in libraries is necessary to connect both physical things (print resources), digital things (digital resources) and many other things (objects) like space, equipment, lighting, seating, etc¹⁴. Adoption of IoT in libraries showed a mixed reaction from librarians. Many librarians consider IoT as an eminent technology that must be adopted immediately to assist them in providing better services¹⁵⁶¹² while, others want to follow the wait and watch policy. The study by OCLC shows that, several librarians do not know about IoT and related technology. The study further reveals that librarians doubt whether IoT is a hype or reality. Their study also reveals that librarians intend to delay in spending time, effort, and money on establishing IoT services until the technology is more generally adopted.

3.2 Application of IoT in Libraries

Implementing IoT technology in libraries is critical for demonstrating the value and relevance of libraries in a technologically oriented world, as well as for providing the best services to user community¹⁶. Similarly it is important to enhance personalized services and to build a comfortable learning environment¹⁷. Several authors such as Maceli¹⁸; Kaba and Ramaiah¹⁰; Fleisch²⁰; Mohammadi and Yegane²¹; Sheeja and Susan²² have made attempts to demonstrate, IoT application in library Whereas, Qin¹⁹ demonstrated the relevance of IoT in library activities and services, highlighting the successful implementation of the BluuBeam IoT technology at the Orlando public library and implementation of the caper technology at the Somerset County library and the Half Hollow Hills community library.

Potential Areas

In order to educate librarians and encourage them to adopt IoT applications, many eminent authors have discussed a wide range of IoT applications that can be used in libraries. Evidently, a few attempts have been undertaken to evaluate the importance of the IoT technology for the library system especially in the below mentioned areas

Collection Management: RFID enabled collection management; collection development and providing access to traditional and online collections.

Infrastructure management: Tracking equipments like printer, scanner, photocopiers to display the availability; tracking room utilization to display the availability of seating; monitoring temperature and humidity for special collections, monitoring and effective functioning of items like fire alarms, lights, fans; monitoring users' activities for theft control.

Facilities: Providing facilities like catalogue, library guides, shelve guides, virtual tour, self-check in and checkout of documents; storing and sharing information with peers; flexible learning environment; safety systems like evacuation system, fire alarms.

Services: Providing highly interactive OPAC with detailed information, awareness services, alerting services, notification services, consultancy and training services, location-based services

Other applications like online fine payment, taking feedback from users, information storage, information analysis and information management, marketing and promotion of library resources and services were discussed by Gardiner¹⁶; Gupta and Singh¹⁴; Sheeja and Susan²²; Xie et.al.¹⁵; Xie²³. All these potential IoT applications for libraries, help in transforming the library into a smart library²⁴ and the library building into a smart building. Many authors, on the other hand, voiced their concerns about the adoption of IoT technologies in libraries.

IoT Models for Library

The model allows librarians to handle a greater number of options and challenges than would be feasible without the model. IoT models serve as prerequisite for librarians and guide them in right direction, while incorporating IoT technology into all operations and services. Due to the complex distribution of IoT, general library management models as well as service-oriented models are necessary for libraries to implement IoT. In this direction broad and extended general library management IoT model was proposed by Tawalbeh et al.²⁵ who built an IoT model focusing on providing security and privacy, that was supported by a cloud/edge infrastructure and included “virtual machine (sensors), an edge node (Raspberry Pi), and cloud services (AWS)”. To supplement the existing library systems using intelligent scientific systems, Du and Liu¹⁷ presented a five-layered system architecture that integrates IoT with traditional library systems. To manage the library collection Bayani et al.²⁶ provided three layered hardware architecture and software architecture using RFID and wireless sensor networks. Similarly Ozeer and Nagowah²⁷ provided a near field communication based IoT architecture to reduce human error.

Service oriented models brings together various techniques in a coherent and practical way, aiding in providing effective services, thus to provide IoT based services, a model was proposed and verified by Qin¹⁹, which was further compared with that of commercial services and found that the IoT may be effectively adopted in libraries as in the case of commercial sector. Five-phase process for integrating IoT into library services, ranging from factual information exchange to consulting and training was proposed by Wójcik⁸. In addition, he presented the theoretical model for IoT based library services. Special service model that showcases workflow from the kind of service to, delivery and promotion is demonstrated by Mohammadi and Yegane²¹ who provided a model for a smart reference room that connects reference books to users hand-held devices. Further for the purpose of transforming authenticated message to different sections of the library Mohammadi and Yegane²¹ showcased the IoT platform for internal communication and revealed that, the efficiency of the library can be enhanced by

implementing the proposed platform. Showcasing the model for emergency materials supply in library during disasters Yang et.al.²⁸ provided principles, delivery sequences and loading sequences and proved that their model is efficient in supplying emergency material to different parts of library.

IoT Application in Library Management System

The majority of IoT systems uses wireless networks and RFID technology, which are regarded as foundational technologies of IoT²⁹. They are widely used in library management systems, just as they are in any other system. NFC based IoT library management is more efficient and effective among other IoT based library management system²⁷ that demonstrates the M2M communication mode of IoT using sensing devices, processing units, cloud services, and network connectivity¹⁶. Several authors such as Pandey et al.³⁰; Muhamad and Darwesh³¹; Ramkumar et al.³² and Vandana; Bhattacharjee and Gupta³³ have designed an efficient library management software using RFID to resolve the difficulties of traditional system. RFID based IoT system makes libraries smarter by providing self-service kiosks, offering semantic information retrieval system and discovery tool¹⁶. It also assures secured and efficient system that does multiple job without disturbing the other operations and guarantees efficient information access and makes way for global research in real time³³.

In addition to the library management system, IoT technology can be effectively employed for searching and locating documents in library stacks as demonstrated by Kolhe et al., who designed, microcontrollers and infrared sensors based IoT technology, which also has the potential to detect missing or stolen documents³⁴. Similarly, robot based IoT was designated to locate documents by Gupta et al.³⁵, which works on a text command sent through Wi-Fi and a prerecorded voice command by library staff. They equipped the robot with a camera and sensor system, to recognize documents and record/monitor all activities. However, their system showed inefficiency in terms of time, therefore machine learning techniques were recommended as a way to boost the efficiency.

IoT Applications during Emergencies in Libraries

An IoT-based evacuation system for libraries has been suggested by Xie et al.¹⁵, following a comprehensive study of the causes for user gathering and the existing emergency procedures. In order to create evacuation routes, they presented a framework based on Dempster-Shafer evidence theory and Panther find software program. As part of their testing, they evacuated five hundred library patrons in fifty-five seconds, demonstrating the framework's actual use in safety management. Similarly, Mei³⁶ also proposed library crowd evacuation system, which was not explained in detail or tested. Chang³⁷ showed a graphical depiction of a smart building that may be used in a library to offer emergency services in the case of an accident or natural catastrophe. Combining IoT technologies with fuzzy algorithms to safe guard library staff, users, and construction workers, Xie et al.³⁸ designed a four-layered danger alert system. Their risk management system allows users to monitor the equipment, materials and personnel in the construction site in real-time. However, their application was not put to test to evaluate the efficiency.

IoT Applications in Other Areas of Library

Librarians and technologists have made few attempts to integrate IoT into library operations, either as a means of offering better services or for more efficient services. Among

few attempts Sabanci et al.³⁹ used IoT technology to record the number of users in the Inonu university library by using Arduino-Raspberry-pi and Thing speak cloud but encountered a problem in dealing with the shadows, thus strongly suggested to use the human recognition algorithm such as face detection within the system to improve the accuracy of the system. To help specially abled library users in reading document Kumar et al.⁴⁰ upsurge characteristic of wheelchair using IoT technology in a wheel chair embedded with mobility-control software, a speech recognition system and enabled with a translator feature that allowed users to choose the required language along with the audio output. IoT is also been implemented to manage facilities like archival collections by Maceli¹⁸, who designed an environmental monitoring system using open source IoT and found that, the system is easy to use, effective and improved over the existing system. Ramkumar et al.³² also proposed a system that controls the lights and fans using voice command and text command using Adafruit IO MQTT for voice command, Google assistant for text command and IFTTT for interface. Further to conserve energy in library buildings Patel and Thacker⁴¹ proposed an energy conserving system that relied on two main sensors to detect human presence and the amount of light in the environment. When electrical equipment was not in use, the technology successfully regulated its use. To send auto messages to users Muhamad and Darwesh³¹ used GSM along with RFID technologies, to notify availability of documents, overdue documents etc.

Awareness and Implementation of IoT in Library

Although few models and certain library operations are integrated with IoT, the implementation of IoT in libraries is still in its infancy. Thus to record the awareness or familiarity of the term IoT among librarians OCLC³ surveyed 100 librarians and found that librarians are more acquainted with the term 'smart' like smart homes, smart watch, smart city, self-drive cars etc. than the term IoT, with RFID being the most familiar IoT technology. Research by Gupta and Singh showed that the majority of the Indian librarians have learnt about IoT through conferences, seminars, and discussion forums¹⁴. On the other hand research by Kaushik⁴² shows that the majority of library professionals learnt the concept of IoT through online resources and did not use or publish articles on IoT. Additionally, he found that most librarians are willing to participate in IoT training programme to integrate library operations and offer better service. A favorable attitude towards IoT implementation is also necessary for IoT adoption. Whereas study by Asnafi; Razavi and Moradi⁴³ revealed that despite the unfavorable attitude of higher authority and a lack of awareness among library staff in Iranian libraries, librarians were prepared to implement IoT to provide easy access to resources and quality services. Further research by Makori⁶ showed that majority of library professionals has positive attitude towards IoT along with few negative attitude and observed that the revolution in internet influenced librarians to adopt IoT. The study by Alagumalai and Natarajan¹ reported that the many librarians in UAE implemented IoT in video conferencing and delivering library tutorial, which influenced users to utilize library resources. Further showed that librarians were highly satisfied with IoT based modern facilities and services. Research by Gupta and Singh showed that, a higher number of librarians used IoT in collection development and felt its importance in faster and easier communication.

3.3 Advantages in IoT Application

Advances in IoT has provided multiple benefits to libraries. Descriptive analysis by Asnafi, Razavi, and Moradi⁴³ showed that implementing efficient IoT can address incidents like fire

accidents, accidents due to old infrastructure, natural disasters and theft of the resources. IoT can also be used to create apps to assist users in making appropriate use of limited resources like water and electricity²⁰. It also helps libraries in optimizing use of space, enhancing the users experience, preserving valuable collections through smart room management, in providing self-guided, virtual tour of the library²¹. Additionally IoT allows librarians to manage facilities and equipment in better way¹⁰. Further IoT reduces the staff requirement for doing odd tasks, as majority of the tasks would be carried out by machine³⁰, which allows the staff to work intensively to address user problems⁹ and provides opportunities for staff to spur the uptake of the service, that allow staff to relish the new experience offered by the new system and enables better way to manage the resources⁴⁴. Resources may be managed by automating library management system, which enables librarians to provide comprehensive information on available resources and offer effective services including alerting messages³⁴. Thus it assist in saving time, controlling and monitoring the systems for better results and provides opportunity to review the operations which results in better performance of the system²⁶. It also help in streamlining back offices process and in providing user orientation and in promoting library resources and services⁸. It also aid libraries in delivering location-based services, as well as the provision of information literacy¹⁵.

3.4 Challenges in IoT Application

IoT offers many opportunities along with variety of associated challenges like negative perceptions of information professionals and technologist⁶, a declining trend in use of library resources³, training staff in efficient use of the technology, creating awareness among users¹⁶, technical issues, lack of manpower, infrastructural problems and financial constraint¹⁴. There is huge financial implication in migrating from traditional library management system to IoT based system which demands for switching over of special infrastructure facilities^{6,26}. However, the financial challenges can be addressed using open sources IoT technologies that minimizes the initial investment cost and referring to the huge benefits of IoT in saving time of staff, the investment may be justified.

Security risk due to the complex environment of IoT^{26,178,2116}; decentralized nature of IoT technology; variety of data; no standard to integration across IoT devices; malware⁶; large data production without the user knowing where that data finally resides⁴⁵ and possibility of data theft due to exchange of data between many devices²⁶ are the major challenges in IoT implementation. To overcome these challenges, need for comprehensive security and control practices to protect data and information resources are identified. As a solution to these challenges NIST's cyber security department has provided guidelines and suggested the use of digital certificate and cryptographic algorithms to secure IoT⁴⁶. Further Muhamad and Darwesh³¹ found that use of "3-DES and MD5 algorithm to encrypt the input data and decrypt all stored data, avoids the risk of data theft".

Along with security challenges other challenges like electrical power supply to sensor nodes that are placed in hard to reach location³⁷, lack of appropriate management, inaccuracy due to disruptions in the system and failure in the system¹⁰, technical complexity and rapid pace of IoT evolution, which demands for regular upgradation¹⁸ and need for hardware, software and the availability of internet network as limitations during emergencies like accidents and disasters³⁸ are the practical challenges in the implementation of IoT in libraries.

4 CONCLUSION

This paper presents a comprehensive analysis of 46 published research studies pertaining to the concept and implementation of Internet of Things (IoT) technology in library settings. The findings of a scholarly investigation indicate that despite attempts to integrate the Internet of Things (IoT) into libraries, its utilization remains limited. Notably, there is a dearth of evidence of IoT implementation in Indian libraries. The reception of IoT-based technology among librarians is characterized by a heterogeneous set of opinions, encompassing both positive and negative perspectives, as well as varying degrees of consensus and dissent regarding its benefits. The present exploratory review highlights the persistent endeavors of librarians to incorporate technology into various library activities. The employment of IoT technology in libraries has been observed since 2014, despite its prior establishment. The increasing prevalence of research in this domain is indicative of the manifold endeavors undertaken by librarians to integrate IoT technology within libraries, with a particular focus on converting them into smart libraries. Smart libraries offer librarians an opportunity to make informed decisions and deliver top-notch services. Several studies have put forth theoretical frameworks and practical implementations for libraries utilizing the Internet of Things (IoT); however, the adoption of such models remains limited, particularly in Western nations. Furthermore, it has been noticed that a significant proportion of librarians have adopted an Internet of Things (IoT) based system for managing their libraries, despite the potential for implementing IoT in various other library domains that were previously identified. The integration of IoT technology has the potential to enhance library services by automating various activities such as self-check-in and check-out, stock verification, monitoring of user activities, access control, theft control, and information analysis and management. Additionally, IoT can be utilized to improve the overall user experience by offering a range of services. Real-time monitoring of various aspects such as space, lighting, ventilation, and equipment such as printers, photocopiers, and computer systems, as well as facilitating evacuations during emergencies, are among the important roles played by it, in addition to providing various opportunities. The Internet of Things (IoT) is commonly linked with a limited number of challenges, particularly in the areas of data security and financial implications. It is imperative for librarians to embrace Internet of Things (IoT) technologies in order to remain current with the constantly evolving technological landscape. By leveraging advancements in technology, librarians can establish a cutting-edge, smart library that caters to the needs of its users.

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