



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

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ABSTRACT

This article aims to examine selected scholarly publications on different aspects of the Internet of Things (IoT) in libraries to demonstrate prospects for IoT applications in libraries, particularly in the academic environment. The study is exploratory, and national and international articles were culled from various sources. Articles that recommended or advocated using IoT technology in libraries are included in the study. However, this article did not include IoT applications that might be used in libraries. The study offers an in-depth analysis of IoT technologies for library use in five sections: introduction, the concept of IoT, application of IoT in libraries, and advantages and challenges of adopting IoT. Finally, it concluded that implementing IoT technology in libraries is essential to offering contemporary and conventional services to many techno-dexterous people at their preferred location despite the cybersecurity risks and challenges.

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

1. Introduction

Technological advances have transformed the internet during the past decade. Numerous new technologies have emerged due to the massive Internet transformation, including machine learning, cloud computing, big data and the Internet of Things (IoT). IoT is the most comprehensive and important phenomenon today since it connects many things through the internet. It enables

digital or physical objects/devices embedded with software, electronics, sensors and other forms of hardware to behave smartly. It 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 client services. The governments of the USA, China, South Korea, Singapore, and Germany are funding many IoT initiatives to boost economic status, build smart cities, develop smart infrastructures, etc.

Numerous studies have been conducted and are still being conducted in the field of LIS to implement the potential technology. Several researchers have developed different models and identified many library areas where IoT can be implemented. Implementation of IoT in libraries is essential for optimizing library operations activities and interconnecting available resources and systems to redefine services and render interactive and innovative services to many users wherever they are most needed.³. 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 community.⁴ This article examines scholarly publications on IoT to show prospects for IoT applications in libraries, particularly in the academic environment. It mainly introduces different aspects of IoT applications in libraries and cautions about the challenges.

2. Methodology

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

Titles 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

Many research works exist on IoT applications in libraries, especially in academic libraries. This section summarises IoT, its use in libraries, and 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 the Internet^{5 6}. 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 fulfil certain tasks"⁸. Anton Purnik states, "IoT is a complex of things (or mechanisms) connected 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 significantly impact the community and everything. Peter Fernandez¹³ perceived that libraries have already demonstrated IoT, as libraries include numerous things, such as books, journals, and 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, etc.¹⁴. 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 services^{15 6 12}, 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 hype or reality. Their study also reveals that librarians intend to delay 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 their value and relevance in a technologically oriented world and for providing the best services to the user community.¹⁶. Similarly, enhancing personalised services and building a comfortable learning environment is important.¹⁷. Several authors, such as Maceli¹⁸; Kaba and Ramaiah¹⁰; Fleisch²⁰; Mohammadi and Yegane²¹; Sheeja and Susan²² have made attempts to demonstrate IoT applications in the 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 the caper technology at the Somerset County Library and the Half Hollow Hills community library.

Potential Areas

Many eminent authors have discussed a wide range of IoT applications that can be used in libraries to educate librarians and encourage them to adopt IoT applications. A few attempts have been undertaken to evaluate the importance of 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 equipment like printers, scanners, and photocopiers to display availability; tracking room utilization to display seating availability; monitoring temperature and humidity for special collections; monitoring and effective functioning of items like fire alarms, lights, and fans; monitoring users’ activities for theft control.

Facilities: Providing facilities like catalogues, library guides, shelf guides, virtual tours, self-check-in and check-out documents; storing and sharing information with peers; flexible learning environment; safety systems like evacuation systems, and 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, 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 information analysis and information management, and marketing and promotion of library resources and services were discussed. 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 library.²⁴ 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 a prerequisite for librarians and guide them in the 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, a 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 and software architectures 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 coherently and practically combine various techniques, aiding in providing effective services. Thus, to provide IoT-based services, a model was proposed and verified by Qin.¹⁹, 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 the 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. Mohammadi and Yegane demonstrated a special service model that showcases workflow from the kind of service to delivery and promotion²¹ who provided a model for a smart reference room that connects reference books to users' hand-held devices. Further, to transform authenticated messages 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 the library during disasters Yang et al.²⁸ They provided principles, delivery sequences, and loading sequences and proved that their model is efficient in supplying emergency material to different parts of the library.

IoT Application in Library Management System

The majority of IoT systems use wireless networks and RFID technology, which are regarded as foundational technologies of IoT²⁹. They are widely used in library management systems, just like in any other system. NFC-based IoT library management is more efficient and effective than other systems.²⁷ 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 systems. RFID-based IoT system makes libraries smarter by providing self-service kiosks, offering semantic information retrieval systems and discovery tool¹⁶It also assures a secure and efficient system that does multiple jobs without disturbing the other operations, guarantees efficient information access, and allows global research in real-time.³³.

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. This technology also has the potential to detect missing or stolen documents.³⁴. 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 recognise 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 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 of user gathering and the existing emergency procedures. In order to create evacuation routes, they presented a framework based on the Dempster-Shafer evidence theory and the Patherfind 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 a 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 safeguard 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 tested to evaluate their 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 a 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 Thingspeak cloud but encountered a problem in dealing with the shadows; they strongly suggested using 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 documents, Kumar et al.⁴⁰ upsurge characteristics of a wheelchair using IoT technology in a wheelchair embedded with mobility-control software, a speech recognition system and enabled with a translator feature that allows users to choose the required language along with the audio output. IoT is also 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 commands and text commands, using Adafruit IO MQTT for voice commands, Google Assistant for text commands, 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 used, 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, the goal is to record the awareness or familiarity of the term IoT among librarians of OCLC.³ surveyed 100 librarians and found that librarians are more acquainted with the term 'smart', like smart homes, smart watches, smart cities, self-drive cars, etc., than the term IoT, with RFID being the most familiar IoT technology. Research by Gupta and Singh showed that most Indian librarians have learnt about IoT through conferences, seminars, and discussion forums.¹⁴. On the other hand, research by Kaushik⁴² shows that most 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 programmes to integrate library operations and offer better service. A favourable attitude towards IoT implementation is also necessary for IoT adoption. Whereas studies by Asnafi; Razavi, and Moradi⁴³ revealed that despite the unfavourable 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 The study showed that the majority of library professionals have a positive attitude towards IoT, along with a few who have a negative attitude. It also observed that the revolution in the internet influenced librarians to adopt IoT. The study by Alagumalai and Natarajan¹ reported that many librarians in UAE implemented IoT in videoconferencing and delivering library tutorials, which influenced users to utilise library resources. Further, it 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.

Advantages in IoT Application

Advances in IoT have 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 resources. IoT can also be used to create apps to assist users in appropriately using limited resources like water and electricity²⁰. It also helps libraries in optimising the use of space, enhancing the user's experience, preserving valuable collections through smart room management, and providing a self-guided, virtual tour of the library²¹. Additionally, IoT allows librarians to manage facilities and equipment in a better way¹⁰. Further, IoT reduces the staff requirement for doing odd tasks, as the 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 allows staff to relish the new experience offered by the new system and enables a better way to manage the resources⁴⁴. Resources may be managed by automating a library management system, which enables librarians to provide comprehensive information on available resources and offers effective services, including alerting messages³⁴. Thus, it saves time, controls and monitors the systems for better results, and provides an opportunity to review the operations, which results in better performance of the system²⁶. It also helps in streamlining back office processes in providing user orientation, and in promoting library resources and services⁸. It also aids libraries in delivering location-based services, as well as the provision of information literacy.¹⁵

Challenges in IoT Application

IoT offers many opportunities along with a variety of associated challenges like negative perceptions of information professionals and technologists⁶, a declining trend in the use of library resources³, training staff on inefficient use of the technology, creating awareness among users¹⁶, technical issues, lack of manpower, infrastructural problems and financial constraint¹⁴. Migrating from a traditional library management system to an IoT-based system has huge financial implications, requiring switching over special infrastructure facilities.^{6, 26} However, the financial challenges can be addressed using open-source IoT technologies that minimise the initial investment cost. Given the huge benefits of IoT in saving time for staff, the investment may be justified.

Security risk due to the complex environment of IoT^{26 17 8 21 16}; 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 the possibility of data theft due to the exchange of data between many devices²⁶ are the major challenges in IoT implementation. To overcome these challenges, the need for comprehensive security and control practices to protect data and information resources is identified. As a solution to these challenges, NIST's cybersecurity department has provided guidelines and suggested the use of digital certificates and cryptographic algorithms to secure IoT⁴⁶. Further, Muhamad and Darwesh³¹ found that the 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 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 article extensively reviews forty-six published research works on IoT technology concepts and library applications. Our review reveals that, though efforts have been made to implement IoT in libraries, it is not widely used, especially since there are no traces of implementation of IoT in Indian libraries, which should be taken seriously.

There is a mix of favourable and unfavourable opinions on IoT-based technology and agreement and disagreement on the advantages among librarians. Our exploratory review

reveals that IoT may be adopted in integrating library collections and offering the best services and also in automating library activities, which facilitates self-check-in and check-out, stock verification, monitoring users' activities, feedback of users, access control, theft control, information analysis and information management.

It also plays an important role in real-time monitoring of space, lighting, ventilation, equipment like printers, photocopiers, computer systems, evacuation during emergencies, etc. Along with these opportunities, IoT is associated with a few challenges, especially in data security and financial implications. However, librarians need to adopt IoT technologies to keep up with ever-changing technology and make use of technological advances to build a hi-tech/smart library and to serve users at their place.

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