Research Article

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Radio Frequency Identification (RFID) Implementation in an IoT Smart Library

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ARTICLE INFO	ABSTRACT
	The Internet of Things (IoT) could be described with the help of its basic concept—a network of sensors, which constantly produce data for numerous smart applications. The development of the Radio Frequency Identification (RFID) application in IoT frameworks is the subject of this research, with emphasis on library systems. The objective is to evaluate the effectiveness of the RFID system in the improvement of the library management systems. In our experiment, we had a clear method, illustrated by specific examples of the enhancement RFID introduces to the operation of a library. Some of the emerging discoveries as per the study are enhanced managerial control, mechanisms of book circulation and decreased manual work. Future research directions are the expansion of IoT applications for increasing environmental awareness in library systems. **Keywords:** Internet of Things, RFID, Library Systems, Wireless Sensor Network, Near-field Communication.

INTRODUCTION

The Internet of Things (IoT) can be regarded as a revolutionary step in the evolution of technology as it consists of a set of sensors that produce enormous volumes of data perpetually. This technology makes it possible to develop many smart applications that alter several facets of life. Another contributory factor in IoT is the incorporation of Wireless Sensor Networks (WSNs) and Radio Frequency Identification (RFID) that greatly improve data acquisition and analysis.

In contrast to printed sources, digital information is characterized by such features as dynamicity and numericity. It enables the digital data to survive the software and hardware changes because it has the back-end support, which is a major boon under the Information Management and Information Access. Digital information is in hyper-structures, which are more sound and elastic than the structures of printed matters flat (Ferguson, Thornley, & Gibb, 2015).

The internet has also played a role in enhancing the flow of information across the world making the world a global village. However, this kind of fast pace in the digital transformation comes with some drawbacks specifically in the aspect of the quality and credibility of information posted online. Given that quality control mechanisms are less enforced on digital platforms, the credibility of digital data tends to come under question.

In the case of libraries, the use of IoT especially through the RFID technology has numerous advantages. The RFID tags and sensors provide an instantaneous method of interaction as well as a constant inventory of library resources to boost the effectiveness of library services. The integration of this helps in developing libraries that are intelligent and can handle large volumes of information within the shortest time possible so as to enable users to have easy access to the resources they need (Chelliah, Sood, & Scholfield, 2015).

This technology also helps improve security in the library systems since tracking and monitoring of books and other materials are made easier. Such automation helps in easing the burden of work on the library staff and utilizing their time in more important tasks while at the same enhancing user satisfaction. Further, self-service operations through RFID is a feature that also increases efficiency in terms of user operations.

Also, it is important to note that Internet of Things in library applications goes beyond the firm's operational uses. They also enrich environmental awareness as they minimize the usage of resources and do not require physical artifacts. Smart libraries use IoT to make the environment more sustainable and reduce resource consumption which is a part of the overall goal to be sustainable and use resources responsibly (Parashar, Khan, & Neha, 2016).

Therefore, the adoption of IoT and RFID in library systems is one of the advancements in information management. They not only help improve operations and security in the institution but also help in the development of smart libraries. There are promising implications for the use of IoT applications in libraries that should be investigated in subsequent studies with further integration of technology tools and enhancement of patrons' experience.

Research Problem

The advancement of IoT stems from the idea of linking physical objects to the internet to have a ground for interaction with the physical environment. It is this vision that forms the basis of emerging uses like online monitoring, smart houses, smart libraries, and green transport. It is estimated that by the year 2020, there will be approximately 50 billion internet connected devices, and hence, dealing with a large amount of data from sensors to gain insight into the environment. Identifying an ever-widening application area for IoT means that organizations can improve service delivery and meet clients' requirements.

The present research paper will seek to give a comprehensive analysis of the efficiency of RFID technology when integrated into library systems. As concluded in literature, RFID when combined with IoT can greatly improve management effectiveness, which is vital for organizations whose operations are based on efficient information management systems (Pujar & Satyanarayana, 2015). This paper focuses on the effect of IoT on technology, processes, and people to build a proper theoretical framework that can explain the interaction of these factors in the context of smart library systems.

The essence of this study is based on how one of IoT sub-systems, namely RFID, can help eliminate mistakes and slow processes that are characteristic of manual work in libraries. In this case, this study aims to explore the different ways through which RFID has been implemented and the results achieved in relation to the efficiency of book tracking, checkout, and return processes. Furthermore, the study aims to explore the privacy and security risks that come with the implementation of RFID and IoT technologies in libraries and how these risks can be managed for the best outcomes to be achieved.

Furthermore, the research problem relates to the practical issue of how IoT and RFID solutions can be implemented in various libraries of different sizes and with different levels of capacity. Thus, based on the case study of the given work and the analysis of the existing literature, the study sheds light on the application of such technologies in a variety of library contexts ranging from the small public library to the large academic library. This exploration is very important in establishing the best practice and formulation of the guidelines for the implementation and integration of IoT based solutions in library management.

Thus, this research problem focuses on the innovative possibilities that IoT and RFID technologies can bring to the improvement of the library's systems. To that effect, by methodically analyzing the effects of smart library systems on technology, processes, and people, the study encompasses an important discovery toward the understanding of the field of library science, with a view to improving on the future integration of such systems.

Research Questions

1. How do IoT based library services eliminate errors from human operations and promote effective RFID Implementation for searching, querying, and indexing in relation to information retrieval?

2. In what ways are IoT systems preferable because the technology creates scenarios where advanced connectivity of devices proceeds without human involvement?

LITERATURE REVIEW

Information Technology (IT) can be said to have led to the enhancement of human life through coming up

with secure ways of communicating and through the provision of ways of automating activities. The IoT is at the center of this phenomenon, which has a substantial influence on the daily experience through concepts such as the WSN and RFID. IoT is a continuum of growth in many dimensions such as in conventional library management systems (Chelliah et al., 2015).

Education sector stakeholders are gradually integrating online library schemes that synchronize tangible things like books and typologies of texts for real-time interaction and constant monitoring. This integration would need RFID tags and sensors and offer flexibility and security in creating an efficient online supply chain (Bayani, Segura, Alvarado, & Loaiza, 2018).

These ideas of boundless computing introduced by Mark Weiser resulted in the development of WSNs in the year 1988. This innovation was later used to inspire Kevin Ashton to introduce the concept of IoT at the Lab Auto-ID centers. RFID employs actuators, tags and sensors to identify the events and interactions, which captured data are transmitted for analysis, assessment, monitoring and control (Parashar et al., 2016). It consists of functions of security tagging, self-servicing, registration, control and tracking; therefore, user information is required for identification of book holders. However, issues regarding the privacy of users have remained an issue of debate although RFID has proved to be efficient in management especially when used in Near-field Communication like library management as noted by Ahmad (2019).

The implementation of RFID in 2014 was another major innovation which assisted in self-service solutions enhancing the operation of the library system. RFID tags, the users and books are both labelled and the information about them is processed and transmitted to the administrators of the databases (Chelliah et al., 2015). The first objective is to assess the effectiveness of data gathering and review customers' satisfaction levels. Studious by different scholars confirm that RFID is vital in tracking commodities where it has a faster rate of execution than manual procedures.

IoT applications in libraries also make people environmentally conscious through the use of smart technologies. The use of RFID systems affects librarians, students, administrators and teachers in a positive way through the improvement of library functions and technologies. In the Unitec University of Technology Sydney case, there was a show of enhanced process efficiency by RFID, which encourages the formation of new approaches to enhance processes and supply chain management.

The use of IoT in the management of libraries is intended to interconnect libraries internationally with real time communication capability in knowledge dissemination and information management. This way, the flow of information is easy and the network makes the growth and development of the linked firms possible (Abbasy & Quesada, 2017). The advantages of such systems include flexibility, efficiency, security and subsequently, the satisfaction of users, thus can be considered as a bonus to contemporary libraries.

In conclusion, the literature has presented the possibilities of change through IoT and RFID in library systems. Such advancements help to provide safe, fast, and automated functioning of libraries as well as to solve numerous issues related to the traditional organization. Besides the improvement of management functions, IoT integration into libraries reflects general trends in technological development, which allows libraries to remain popular and progressive.

METHODOLOGY

Content Analysis

The approach used in this study is a qualitative research method, and hence the use of content analysis to determine the effects of IoT and RFID in library operations in relation to searching, servicing, querying and indexing. This approach entailed the analysis of fifteen research articles obtained from peer reviewed journals within the period of 2014-2019. These sources were obtained from the following database search engines EBSCOHOST, Semantic Scholar, Academia, ResearchGate, and Science Direct. The search terms employed in the articles' retrieval were "IoT smart library" and "RFID for IoT Libraries".

To conduct an effective comparison, the selected articles were classified according to their title, abstract, keywords, and suggestions for future research. This was followed by the schema coding for the identification of the major themes which were then analyzed and discussed. Coding was useful in narrowing down the data into topics because it ensured that the collected information was categorized in a manner that was relevant to the research question within the context of library management and IoT and RFID technologies.

One of the main themes that were identified was the improvement of business operations' effectiveness due

to IoT and RFID adoption. These technologies enable the tracking and monitoring of the assets of the library in real-time thus enhancing the efficiency and speed of information acquisition. For example, the integration of RFID tags and sensors into books and other materials means that users and librarians can easily trace the whereabouts of the items. The real-time tracking capacity greatly minimizes the time and energy that can be wasted in keeping tabs on inventories, hence adding to the general improvement of operations (Chelliah et al., 2015).

The second important theme was about the use of IoT in the automation of library processes. It has been observed that RFID systems have the potential to increase some functions in libraries such as self-service check-in/check-out, automated management of stocks, and security. These automated processes not only save the time of staff members in libraries but also enhance the satisfaction level of users as the services are faster. This literature reveals that the integration of IoT and RFID within the libraries enhances service delivery processes as operations become more user-friendly (Abbasy & Quesada, 2017).

The study also focused on the effects of IoT and RFID on data control and the ability of data analysis. As data creating and collecting tools, these technologies offer a lot of information about users' activity, resources, and the libraries' performance. It provides the library with a way of making decisions based on facts efficiently allocating resources and enhancing on the services it delivers. In addition, the integration of IoT with other smart technologies like the cloud, big data and analytics improves the functionality of library management systems through improved data collection, analysis, and presentation (Dewi, Gunawan, & Winoto, 2014).

Moreover, it was noted that the research focused on the issue of privacy and security risks of IoT and RFID technologies. Although these technologies present many advantages, they present major privacy concerns, especially regarding the gathering and storage of customers' information. The study advises for strong security measures to be put in place and privacy policies to be adhered to in order to protect the data of the users and to be in compliance with the data protection laws. These issues must be addressed to ensure the effective deployment of IoT based solutions in the library environment (Ahmad, 2019).

Additionally, the content analysis of the articles unveiled the fact that the flexibility and business growth potential of IoT and RFID options are critical to achieving the desired results in libraries of different sizes and capacities. Thus, analyzing case studies and the literature, the research revealed the most effective strategies for the use of these technologies in different libraries. It is also important for the formulation of policies to be adopted by the different libraries in order to enable them to harness the benefits of IoT and RFID technologies as noted by Abbasy and Quesada (2017).

Therefore, the content analysis used as a method in this study offered rich insights into how IoT and RFID affected the operations of the library. The identified themes show how these technologies provide a lot of value in improving operations, automating tasks, managing data, and handling privacy. This qualitative approach also reveals the potential of IoT and RFID in enhancing library systems and delivering better services. Through the systematic analysis of the impacts of the mentioned technologies, this study offers the body of knowledge to the field of library science and the future development of smart library systems.

RESULTS

This paper shows that the introduction of RFID technology profoundly affects library functions and enhances the relationship between people, processes, and technology. The main motive behind integrating IoT in libraries is to improve the management aspects and this research clearly depicts the same. The use of RFID technology solves many issues associated with the search and analysis of information (**Table 1**).

Table 1. Research Results from Reviewed Scholarly Sources

Study Title	Study Year and Name of Researchers	Major Findings
IoT based library automation and monitoring system: Developing a framework of implementation	Bayani et al. (2018)	1. ICT and related topics like IoT are linked to elements of human life. 2. IoT transforms information retrieval through smart features of Radio Frequency Identification and Wireless Sensor Network. 3. It improves many contexts of society, such as the traditional library and research processes. 4. IoT enables connectivity of physical objects or continuous monitoring of books in real-time and tracking objects. 5. IoT also permits online library supply chain implementation. 6. It integrates seamlessly with other technologies.
RFID technology in libraries: A case study of Allama Iqbal Library, University of Kashmir	Ahmad (2019)	1. The research demonstrated the usage and effectiveness of RFID technologies at a University library 2. Benefits and risks of RFID have been highlighted. 3. RFID technology implemented at a University library reduced waiting time and increased books borrowed per transaction. 4. A majority of the users, around 80.70% used self-check-in and check-out. 5. A small percentage relied on manual issues and returns. 6. It serves to modernize library services.
Internet of Things: A route to smart libraries	Kaladhar and Rao (2018)	1. IoT is a ubiquitous technology in the current scenario. 2. Connecting various objects in the library without human interference is possible through embedded technologies. 3. The concept of IoT is applicable to library housekeeping activities. 4. RFID and WSN technologies have paved the way for smart libraries.
An IoT based secured smart library system with NFC based book tracking	Brian, Arokiam, and Malarchelvi (2014)	1. IoT impacts everything from smart homes to libraries. 2. Through RFID library management systems, technology can be applied in issuing and returning books seamlessly. 3. IoT based libraries can provide interconnected systems using Wi-FI based LPS and NFC tags for effective searching, sourcing, and information retrieval.
Predictable Influence of IoT (Internet of Things) in the higher education	Abbasy and Queseda (2017)	1. This research shows the impact of IoT on higher education using statistical analysis. 2. Managing factors like hypoconnectivity, research opportunities, and collaboration create a significant effect. 3. Emergent technologies like IoT are transforming the digital world. 4. IoT meets the educational needs of the students.
Internet of Things and libraries	Pujar and Satyanarayana (2015)	1. The Internet has taken a leap forward for IoT, making it possible to connect objects and transfer data with or without human interventions. 2. Much like other service industries, it betters library services. 3. The technology and growth examples from service industries and potential areas where implementation is possible are widespread.

Study Title	Study Year and Name of Researchers	Major Findings
The adoption and implementation of RFID: A literature survey	Yusof and Saman (2016)	1. A formal innovation, decision centered framework was used to analyze RFID and IoT in libraries. 2. Early adopters in libraries found RFID to be useful and functional in asserting tracking and item identification.
Internet of Things: Architectures, protocols, and applications	Sethi and Sarangi (2017)	1. IoT is a paradigm in which objects equipped with sensors, actuators, and processors communicate to serve a meaningful aim. 2. Methods, protocols, and applications were used to propose a novel taxonomy for IoT technologies, especially for the differently-abled and elderly.
Risk assessment in Securing Radio Frequency Identification (RFID) systems: A case study on Petra Christian University Library	Dewi et al. (2014)	1. Present barcode systems in libraries lack security features. 2. Petra Christian University Library implements RFID for collection security, as per this research study. 3. RFID implementation requires analysis to assess risk factors and provide a response to risks. 4. Risk assessments are based on NIST SP800-98 and SP800-30 Guides. 5. Risk intelligence process and process risk are the two aspects considered in this study.
How do libraries manage the ethical and privacy issues of RFID implementation? A qualitative investigation into the decision-making processes of ten libraries	Ferguson et al. (2015)	1. Research methods used were a literature review, theme identification, interview analysis, interview scheduling, and a sample of 10 libraries and library networks, and 18 participants formed the span of the study. 2. The main drivers of RFID development, perceived benefits, data security, and levels of ethical concerns were identified.
Internet of Things applications in academic libraries	Nag and Nikam (2016)	1. The researchers consider cloud computing, pressure pad sensors, and magic mirrors using WSN technologies. 2. Such systems are a step towards a smart library.
The Internet of Things and its impact on the library	Massis (2016)	Transparency is essential for addressing privacy and security vulnerabilities in IoT libraries.
Realizing the strategic value of RFID in academic libraries: A case study of the University of Technology Sydney	Chelliah et al. (2015)	In this study, the strategic value of IoT and RFID technologies in smart libraries is identified.
RFID and it's use in libraries: A literature review	Singh and Mahajan (2014)	IoT provides increased productivity, user satisfaction, and security within library systems.
Application of Radio Frequency Identification technology to study library user's information-seeking behavior	Sugie (2013)	RFID tags influence information-seeking behavior that adds value to the speed of information processing and retrieval.

The integration of RFID technology cuts down on the initial highly time-consuming process that is performed manually where several tasks used to be done manually (Chang, 2016). This automation helps library staff to attend to other important tasks, hence improving the general operations of a library. The result of the study showed that RFID technology was beneficial for increasing customer satisfaction, as students and teachers can garner the required information faster than using conventional techniques.

In addition, RFID technology greatly enhances the protection of library resources since the problems of barcodes—their inaccuracies and distractions—are effectively solved. For instance, when students and teachers borrow books, RFID sensors read user specific information on the user's ID cards and match it with the books, which helps in accurate data collection as the users open gate control systems (Sugie, 2013). This makes the checkouts, returns, and item search faster than the traditional techniques while at the same time improving the level of security.

The results also indicate that in an RFID-enabled system, queries are turned into machine-readable text where fast gathering of documents relevant to the queries can be done due to the index structure built in them (Abbasy & Quesada, 2017). This efficient querying process that is illustrated in **Figure 1** enables users to get the search results as fast as possible depending on the system.
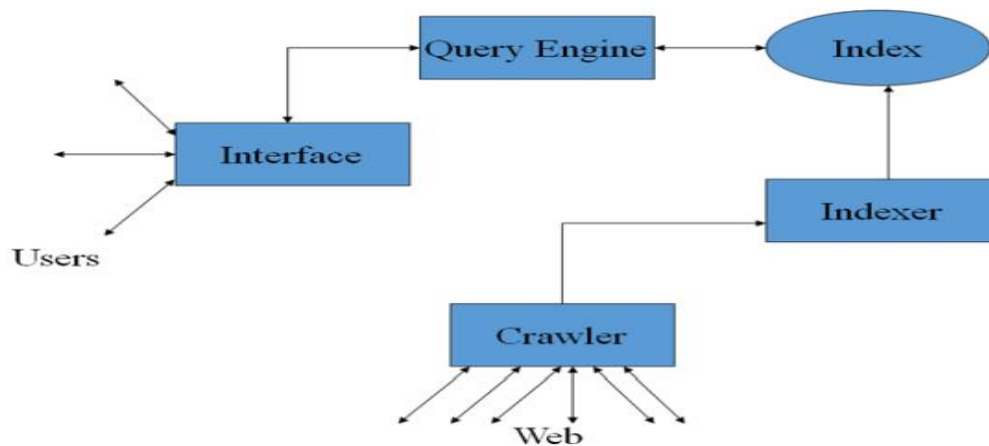

Figure 1. Efficient Query Process

It becomes almost impossible to quantify the number of lost books due to handling when RFID is not used to automate the process. Periodical updating of such records may create errors that make the manual book records inaccurate (Singh & Mahajan, 2014). A system that does not involve IoT heavily depends on tracking the book using the help of the library staff, which is often time-consuming and error-prone. In this regard, it is possible that students take resources but do not return them appropriately, thus affecting the effectiveness of conventional library administrative arrangements (Chelliah et al., 2015).

The study also discusses the need to achieve the research objectives in line with the chosen research method to ensure that they are relevant. The information, which was obtained from different sources, was incorporated into the dialogue to give a detailed picture of the utilization of RFID technology in the library setting. The results of the reviewed scholarly sources are presented in **Table 1** to show the general positive impacts of RFID on the improvement of library operations and security.

Therefore, the findings suggest that RFID technology, combined with IoT, helps in the improvement of library systems' functionality and protection levels. This improvement is accomplished by automating business activities, gathering reliable data, and quickly obtaining information. The study also shows the possibilities of RFID and IoT in the process of libraries' modernization and may be useful for further implementations.

DISCUSSION

Radio Frequency Identification (RFID) devices that use radio waves for identification purposes are widely used in smart library environments for the identification of people or items. The general functions of RFID assist several processes of the smart libraries such as circulation of the materials among the staff members and security against theft with the aid of sophisticated detection equipment (Butters, 2018). Further, on a general note, RFID systems save time as it has been noted that time wastage is likely to be eradicated for instance through the non-requirement of bar code scanning during check-in and check-out (Ahmad, 2019). Smart libraries can also utilize applications that store, process and distribute information from environmental resources in order for the students to access them using their smart mobile phones. These devices associated with RFID technology have the capability to identify the users and provide information as per the search results (Sethi & Sarangi, 2017). Through these tools, library management can poll whether the smart library is meeting or not meeting the users' needs. As much as it is costly to maintain RFID systems they are very efficient in the day-to-day running of libraries.

The design of a smart library system involves two main components: software development and system architecture of the hardware. The hardware architecture assists the software and the general IoT structure encompassing IPv6, WSNs, cloud systems, RFID, and the Internet to connect sensing devices (Ahmad, 2019). Internet connection is essential as it helps the physical objects such as the actuators and controllers to perform

smartly within the library context as the authors pointed out in their study by Bayani et al. (2018). These devices monitor events and activities, transmit the appropriate message to the administrators and save the data which has been gathered to the cloud systems with the help of identification numbers. Thus, RFID is the primary identification tool to track books borrowed from the learners and teaching staff.

The IoT architecture consists of three layers: perception, network, and application of the specified construct. The perception layer, WSN and RFID sensors identify events and object's existence such as books. The objects in the network layer are connected wirelessly or through cables to analyze and send data that is collected by the perception layer. This layer comprises of gateway components that get data sensed and stored on the cloud system (Ahmad, 2019). The application layer deals with services and applications for both human and machine users for a number of programs and processes necessary for efficient smart library management (**Figure 2**).
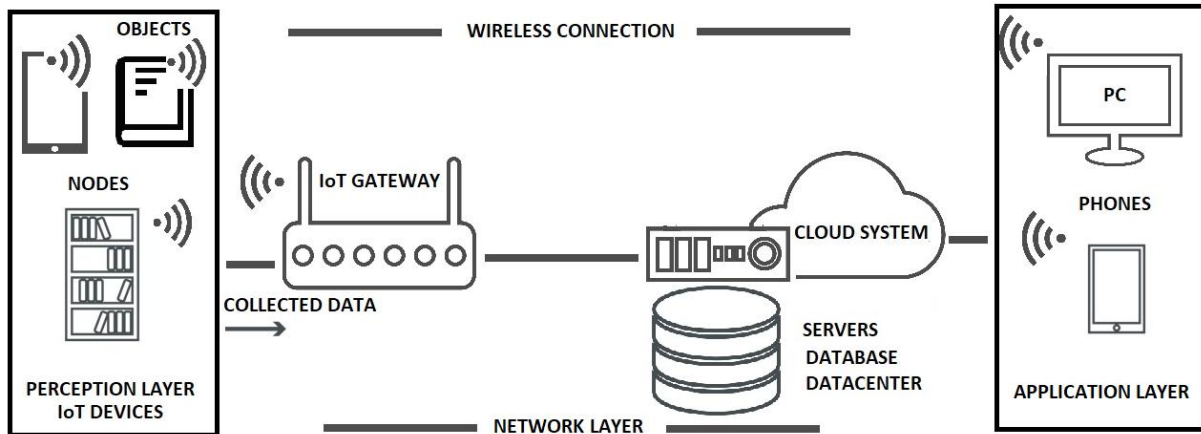

Figure 2. Diagram Illustrating the Three IoT Layers [Source: Bayani et al. (2018)]

The complexity of the RFID platform is quite low and it mainly comprises Smartphones and other portable equipment that capture the RFID signals and transfer the data to the storage (**Figure 3**). Electric cables cost a lot of money to install during the development of the smart library system, researchers tried using Wireless Sensor Networks (WSNs) in place of cables. WSNs which are small electronic sensors working in the field recognize events and acquire information necessary for assessment and analysis (Abbasy & Quesada, 2017). This process checks whether or not sensor nodes can establish a non-centralized network structure with the necessary data collection and processing ability (**Figure 4**).
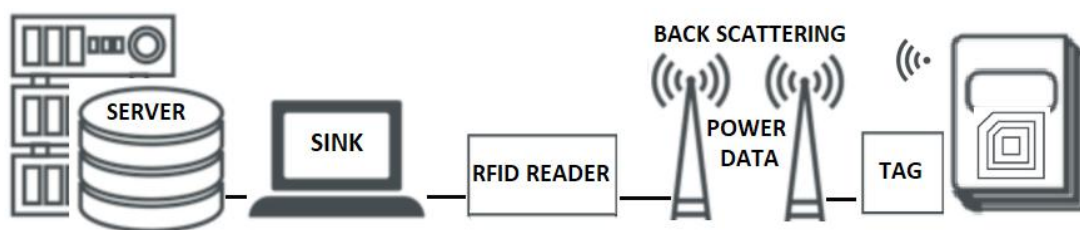

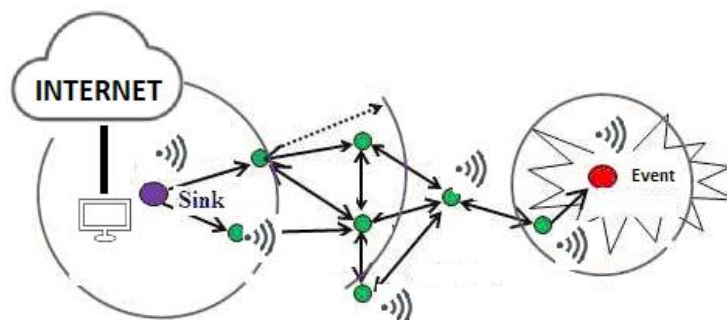**Figure 3.** Simple Architecture of RFID [Source: Bayani et al. (2018)]

Figure 4. Non-centralized Network Architecture [Source: Bayani et al. (2018)]

When establishing an IoT-based library system, there are specific administrative areas that should be developed. Technologically, the proposed IoT based library system has two parts; the first one shows the RFID network and the second part shows the WSN network. This setup demonstrates the full motion of a book from tagging to the users' interactions (**Figure 5**). First, new books are introduced to the tagging section where they are given RFID tags. Users use RFID cards to borrow books that are tagged for identification. Thus, the embedded labels and ID cards in the electronic access gate control make signals to the IoT system to recognize the user and the borrowed book. This information is then passed to the Cloud storage thus ensuring it is available anytime for the monitoring system.
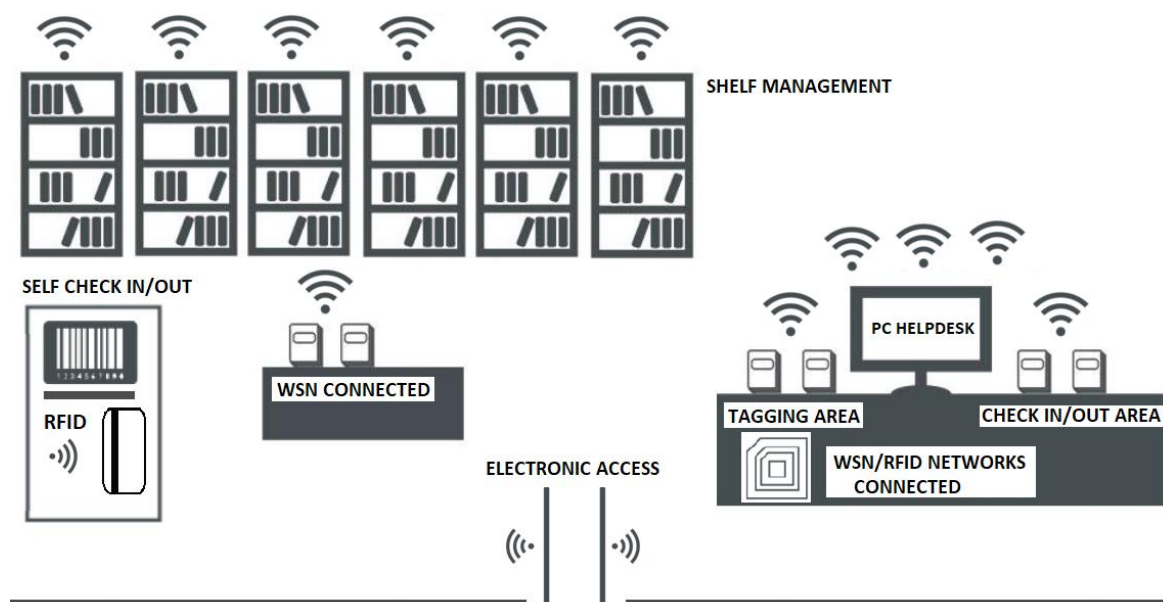

Figure 5. The WSN Network [Source: Bayani et al. (2018)]

Accordingly, the discussion underlines the prospects of RFID and IoT technologies in improving the functioning of the library. Smart technologies introduced in this chapter show that greater efficiency, security, and user satisfaction are possible in libraries, thus opening the prospects for the future of smart library systems. As it has been done in this discussion with the aid of clear diagrams, the steps and structures of the architecture of an IoT-based library system will be understood in detail.

CONCLUSION

The use of information technology especially the IoTs and RFID technology has the possibility of revolutionalizing almost all aspects of human existence as seen in the smart library systems. These systems help solve the issues of handling large volumes of information and enhancing customer service productivity. Students and teachers get to apply organized systems that enable them to access information within a short span of time hence addressing their academic needs appropriately.

The use of IoT in libraries helps to eliminate most of the activities that in the past were done manually like issuing books and returning books. These are the objectives that are achieved by automating the processes, thus minimizing the mistakes and improving the overall functioning of a library. The various IoT technologies like RFID, WSNs, and cloud systems are useful for the execution of an online library supply chain. It is not only a system for improving the tracking and managing of books but also a system that makes users content and gets quick and accurate information.

Additionally, the conclusion contains the outlook with respect to the further development of IoT in libraries. It also describes the advantages that can be obtained by integrating the library system with IoT, for example, the minimization of the workload, greater protection, and better data handling. Thus, based on the capabilities of IoT, libraries can devise a more effective, safe, and comfortable space. Therefore, future research should focus on the improvement of integrating more new technologies in order to enrich the features and benefits of smart library

systems. Such a vision helps to maintain libraries' relevance and develop them as organizations that constantly adapt to new technologies to better suit the users' needs.

CONFLICT OF INTEREST

The author has no conflicts of interest to declare. As for the contents of the manuscript, there is no financial interest to report. I certify that the submission is original work and is not under review at any other publication.

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