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A Review of RFID Technology in Library Applications

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Abstract - Radio Frequency Identification (RFID) has become a popular technology in the implementation of library collections. RFID facilitates user-based transaction services, which is more necessary to satisfy the user needs in this information era as well as provide much security to the library collections. RFID Technology application in libraries offers better technology that can improve the circulation management, inventory, and security of library collections. This paper reviews RFID technology in some library applications.

Keywords - *RFID, Tags, Reader, Library information system, Books*

1. Introduction

Library usually contains sources of information and similar resources that are made available to a community for reference or borrowing; it is a learning centre providing information to the users; it provides useful information service to its users [1]. Over the years, efforts had been made to see library services such as book borrowing, accessing reader's information, inventory management being provided effortlessly, using barcodes, radio frequency identification, etc. The evolution of libraries has been influenced by constant changes due to information technology developments. New technologies have always been of interest to libraries, both for the potential of increasing the quality of service and for improving the efficiency of operations [2].

2. RFID and Barcode

Barcode Recognition Technology is not new to the library. But RFID technology may still be unfamiliar to most people in this field though its application in certain areas is widely used. The biggest difference between Barcode and RFID is that barcoding scans a printed label with the optical laser to identify the object, whereas RFID interrogates a tag using radio frequency signals [3], Applying RFID technology in a library, a micro-chip will be embedded into the items. Micro-chip will automatically send data such as the serial number to the scanner, which will not require as much manual scanning as in the bar code technology. In contrast, RFID can reduce production costs and improve retail efficiency. Hence more and more people think that RFID technology will be a replacement for bar code technology. More comparison of the features of RFID and Barcode can be seen in Table 1 below.

Table 1: Differences between RFID and barcode technology [4]

ISSUES	RFID	BARCODES
Data Stored	EEPROM	Paper
Line of sight requirement	Not Required	Required
Tag's Capabilities	Read/White Capable	Read-only
Number of items that can be scanned	Multiple	One
Reusable	Yes	No
Durability	High	Low
Harsh Environment	Yes	No
Event Triggering	Capable	Not Capable
Security	High	Low
ISO Standard	Incomplete	Yes
Cost of Tag	Expensive	Inexpensive

3. Radio Frequency Identification

At present, the technology of radio frequency identification (RFID) is considered to be the most promising technology in the 21st century. Radio frequency identification (RFID) is a relatively new AIDC technology that keeps track of anything, especially those assets that move. RFID is a portable memory device on a chip that acts like a Universal Product Code (UPC). This microchip can be embedded in any object that stores basic information about the item [5]. RFID employs Radio Frequency

Communications to exchange data between the memory chip and a host computer.

3.1 History of Radio Frequency Identification

The history of RFID can be traced back to World War II (the 1940s). It was used to distinguish enemy aircraft from our aircraft. People rarely speak of Radio Frequency Identification in the 40 years since World War II. Until 1991. Texas Instruments Incorporated applied RFID technology to animal husbandry. In 1999, the Massachusetts Institute of Technology began to study how to benefit wholesalers from technology. Since then, the range of RFID applications has become increasingly widespread. Radio frequency identification has been around for decades and its development can be divided into 10-year periods. RFID implementations need more planning and its compatibility related issues are some times more serious due to non-availability of international standards acknowledged by Ari and Mishra [6]. In contrast to bar code technology, RFID systems do not require line-of-sight access to the tag to retrieve the tag's data, and they are well suited to harsh environments [7]. Radio frequency identification has been around for decades and its development can be divided into 10-year periods as shown in Table 2:

Table 2: Showing RFID decades and its development within 10-year periods [8]

DECADE	EVENT
1940–1950	Radar refined and used major World War II development effort. RFID invented in 1948.
1950–1960	Early explorations of RFID technology, laboratory experiments.
1960–1970	Development of the theory of RFID. Start of applications field trials.
1970–1980	An explosion of RFID development. Tests of RFID accelerate. Very early adopter implementations of RFID.
1980–1990	Commercial applications of RFID enter the mainstream.
1990–2000	The emergence of standards. RFID widely deployed. RFID becomes a part of everyday life.
2000 – to date	RFID explosion continues

3.2 RFID Components

3.2.1 RFID has mainly four components [9]:

(a) RFID Tag: An RFID tag is a tiny radio device that is also referred to as transponder, smart tag, smart label, or radio barcode. There are two main components present in the RFID tag. Firstly, a small silicon chip or integrated circuit which contains a unique identification number (ID). Secondly, an antenna that sends and receives radio waves. The antenna consists of a flat, metallic conductive coil and the chip which is less than half a millimetre. Tags are of three basic types: Passive, Active & Semi-passive tags.
code for each branch.

(b) RFID Readers and Antenna: The second component in a basic RFID system is the interrogator or reader. RFID readers or receivers are composed of a radio frequency module, a control unit, and an antenna to interrogate electronic tags via radio frequency (RF) communication. A typical system includes several different kinds of readers, also known as sensors when installed at library exits. These are radio frequency devices designed to detect and read tags to obtain the information stored thereon. The reader powers an antenna to generate an RF field. When a tag passes through the field, the information stored on the chip in the tag is decoded by the reader and sent to the server which, in turn, communicates with the automated library system when the RFID system is interfaced with it. While there is software in each reader to facilitate communication with the server and/or with library staff, most of the software supplied by the RFID system vendor is on the server when one is included in the system.

(c) Middleware/Microcontroller: Both middleware/microcontroller and software applications are required in an RFID environment. Middleware manages the flow of information between the readers and the backend. In addition to extracting data from the RFID tags and managing data flow to the backend, middleware performs functions such as basic filtering and reader integration and control. RFID middleware assists with retrieving data from readers, filtering data feed to application software, generating inventory movement notifications, monitoring tag and reader network performance, capturing history, and analyzing tag-read events for application tuning and optimization.

(d) Server: The server is the heart of some comprehensive RFID systems. It is the communications gateway among the various components. It receives the information from one or more of the readers and checks the information against its database or exchanges information with the circulation database of the library integrated management system. Its software includes the APIs (Applications Programming Interface) necessary to interface it with the automated library system. The server typically

includes a transaction database so that reports can be produced. A server may be configured with an RFID system.

The diagrammatical representation of the components of the RFID system is shown below:

3.3 Radio Frequency Identification Frequencies

Frequency refers to the rate of the radio waves used to communicate between the RFID system's components. It can be assumed that higher frequency results in a faster data transfer rate. The frequency of transmitting information is a key factor in determining performance levels and applications for the system.

Almost, all RFID systems operate on one of four frequency bands: low frequency (LF), high frequency (HF), ultra-high frequency (UHF), and microwave (MF) [10]. See Table 3.

Table 3: RFID Frequencies Ranges and Possible Applications.

Frequency Band	Description	Operating Range	Application	Benefits	Drawbacks
125KHz to 134KHz	Low Frequency	Less than 0.5m - 1.5ft	Access control, animal point of sale application, product authentication, vehicle immobilizer, etc.	Works well around water and metal products	Short read range and slower read rate
13.56MHz	High Frequency	Less than 1m - 3ft	Smartcards, library books, airline baggage, etc.	Low cost of a tag	High read rate when compared to low frequency
860MHz to 930MHz	Ultra-high frequency	3m - 9ft	Parking lot access, electronic toll collection, etc.	EPC standard built around this frequency	Does not work well with metal content
2450MHz to 5800MHz	Microwave	1m - 3ft	Airline baggage, electronic toll collection.	Fast read rate	Expensive
3.1GHz to 10GHz	Microwave	200m	Medical assets or monitoring environmental conditions in data centres	Requires semi-active or active tags	Most expensive

4. RFID in Libraries

The objective of any RFID system is to carry data in suitable transponders, generally known as tags, and to retrieve data, by machine-readable means; at a suitable time and place and to satisfy particular application needs [2]. RFID promises to provide better control over theft, non-returns, and misfiling of a library's assets. An RFID system for library normally consists of RFID tags, a self-check-out station, a self-return system/ book drop system, a staff work station, a tagging/programming station, security gates, a shelf scanner for inventory/digital library assistant, conveyor belts and sorting systems, e.tc. Libraries are a fast-growing application of RFID as it can provide service to the user, decrease book theft, and keep constant record update more effectively without human interference. Usage of RFID in Libraries include: book charging/discharging; book drop; self-issue/return kiosk; shelve reader; security gate; theft detection; etc. Benefits of RFID in Libraries include: fast check-in/check-out of library households, increased security of library materials; long life of RFID tags in comparison to bar code; fast stock verification; save wastage of time and manpower to the library; enhances the reputation of the library and its services [6]. The use of RFID by libraries promises a solution that could make it possible to inventory hundreds of thousands of items in their collections in just a few days instead of months. Also, it allows patrons to check out and return library collection. The use of RFID saves time and it operates more efficiently and effectively than the barcode systems [11].

4.1 Advantages of RFID in Library

The main aim of today's libraries in adopting RFID is the need to increase efficiency, reduce costs, and improve service. Automation and self-service can help libraries of all sizes achieve these aims, and RFID has the added advantage that it can also provide security for the range of different media offered in libraries. The technology can also improve circulation and inventory control, which helps allocate human and

financial resources [12]. This means that libraries can relieve their employees of routine work and operational tasks. Caldwell-Stone [13] noted that radio frequency identification (RFID) technology enables the tracking and monitoring of physical items by attaching an RFID tag or transponder to an item. Each tag consists of an internal antenna and a computer chip that stores data. When the tag is scanned or interrogated by a reading device equipped with its antenna, the tag communicates its data wirelessly via radio waves to the reader. She explained that the range at which an RFID tag is read depends upon the tag design, the method of communication between the tag and the reader, and the radio frequency at which the RFID application operates. Tags are typically programmed with a unique identifier and a security bit, but can also contain other kinds of information, such as the book title, ISBN, library identifier, date and time stamps, and shelf locations. Jain et al.,[14] noted that the RFID based LMS facilitates the fast issuing, reissuing, and returning of books with the help of RFID enabled modules. It directly provides the book information and library member information to the library management system and does not need manual typing. It also provides monitoring and searching system. The monitoring module will continuously monitor the movement of books across the gates so that the books taken out without prior issuing will be traced out easily and will alarm the librarians. The searching module provides the fast searching of books using RFID handheld readers.

The physical location of the books can be easily located using this module. Utmost care has been taken to provide following features to the Library using RFID technology: to remove manual bookkeeping of records; improved utilization of resources like manpower, infrastructure, etc; less time consuming as the line of sight and manual interaction not needed for reading tag; to minimize the manual intervention; to minimize the manual errors. Yuan [15] in his case study on the Turku city Library on implementing RFID Technology in Library Systems focused on the management aspect of a library particularly the self-service support system for patrons by introducing the RFID system, it stressed on the many benefits of RFID. However, challenges are many and are pointed out as those of tracking and hot listing. Moreover, depending on the strength of the RFID reader it is possible to either greatly hinder or completely block the tag signal by wrapping an item, embedded with several layers of aluminum or tin foil. This combined with a weak gate sensor makes the risk of items getting stolen quite high. Pandey and Mahajan [2] suggested some important points based on RFID Library Management System which include: RFID tags replace both the EM security strips and barcode; simplify patron self-check-out / check-in; ability to handle material without exception for video and audio tapes; Radio Frequency anti-theft detection is innovative and safe; high-speed inventory and identify items which are out of proper order; long-term development guarantee when using an open standard. Suganthy [16] suggested that RFID technology is found to be a versatile technology in many real-time applications, especially in the library management system. This provides intelligent library management, which creates better service quality with quick and effective benefits to both library management and students this technology can be applied to a system of volume. Either it may be a small departmental library or a vast university library its effects are more obvious and applicable. This RFID technology also provides the facility of self-check for the library staff and non-returned books effectively. Lott [17] explained how RFID works noted that RFID tags are attached to an item and are then able to be ‘read’ by corresponding tag readers which communicate with a designated server to display the embedded tag data. Passive RFID tags are powered by radio frequencies transmitted from the reader. These tags are small, inexpensive, and have a long-life span. The estimated cost for each tag is between 7-10 cents depending on the brand.

Golding and Tennant [18] also suggested that the inside of the back cover is the recommended location because it is fastest for right handled tag installers to reach. Two library vendor, Verma, and Garg [19] suggested that book can be tagged at different places like on the spine of the book, top of the book, etc. but the best place to put the tag on the book according to research done is to place it any page inside book near the binding of the book, the reason for that is, it won't be visible as it would be placed close to the binding, also it's very difficult to search tag in the book for the person who wants to tamper it, as it could on any random page. Also, the tags that come for library purposes are ¼ the width of normal inlay tags, so those could be easily be placed near to the book's binding.

4.2 Some Previous Works in RFID Libraries

Research has been carried out to eliminate the old system of searching for books row by row and column by column, which is inefficient, time-wasting, and tasking using various methods including; barcodes, RFID, beacons, NFC, etc. Grover and Ahuja [20] implemented a Radio Frequency Identification Based Library Management System. Their objective was to design an RFID Based Library Management System that would allow fast transaction flow and handle the issue and return of books from the library without much intervention of manual bookkeeping. The proposed system is based on RFID readers and passive

RFID tags that can electronically store information that can be read with the help of the RFID reader.

Verma and Garg [19] implemented an automated library system that speeds up library operations. They showed how one can implement RFID into libraries using a library scenario to give a clear understanding of where the readers, tags, and antennas will be placed in a library. They also explained how best to place the tag on books; the research work focused on three modules which include; book issuing, reissuing, returning, and monitoring of books through RFID. Addepalli *et al.,* [21**]** designed an RFID Based Library Management System, that would allow fast transaction flow and will make it easy to handle the issue and return of books from the library without much intervention of manual bookkeeping which benefits by adding properties of traceability and security. Their objective was to design an RFID based LMS that helps in eliminating manual errors. They developed a system based on RFID readers and passive RFID tags. An RFID sensor is placed near the library desk wherein the user will place the tagged book near the sensor and it would get issued/reissued/returned depending on the actions required. The computer records all these data against his name.

Vimalraj *et al.,* [22] implemented RFID technology where RFID tags are embedded in the books and on the user cards and RFID readers are used to reading these tags for proper, efficient, and theft-controlled operation of libraries. The RFID tags are placed on every book and the ID card of the user. Attention is given while programming these tags as they consist of unique codes. A unique 16 digit code is programmed such that the first seven digits are the same for the users of a batch (say the first year) the next nine digits will vary from person to person. The readers are mounted on the entry and exit doors. As the tags pass through the doors they are read and communicated to the PC of the library administrator through the RS-232 cable after the computation process of the microcontroller Atmega 162. The identity of the people entering the library is displayed on the LCD. The microcontroller proposed in this system is ATmega162, It is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture.

Jain *et al.,* [14] designed an RFID based LMS that facilitates the fast issuing, reissuing, and returning of books with the help of RFID enabled modules. Each library user is provided with an RFID card that enables the user to check-in and for issuing the book containing RFID. The user's card reader allows the database of the books to be fetched and books are issued against the user's name. Library users can also check for the availability of books, at the staff work station.

Sangavi *et al.,* [23] introduced advanced technology for library management system using RFID which reduces the manpower and time consumption. The host system of the proposed project has whole details about the student of the college/school/member of the library and the books in the library. PIC microcontroller will check for the misplaced book with the help of the reader on each rack, here Zigbee acts as a media to communicate reader and PIC microcontroller. The place where the book is misplaced will be displayed in the host system. The reader placed in the door will send the entry details of the student and the book in/out details to the host system using Zigbee. RFID will be placed along with an FPGA controller in the library for identifying the authentication of students. The entire system is developed as a hardware-based system using an FPGA kit. GSM technology is used in the proposed system.

This GSM technology is used to send the message to the students and to fine if books are not returned on the given due date. The LCD will be used. Display the message card detected when the student placed the RFID card on the card reader. RS232 provides serial communication between the FPGA and display, PC or mobile, etc. Li *et al.,* [24] implemented Library Materials Management Using UHF RFID. Their motivation was that a variety of functions can be achieved by the Internet of Things, including self-borrowing and self-returning, smart inventory, intelligent query, the combination of books and information systems. To provide 24-hours self-service for borrowing and returning books, quick inventory and rapid positioning, limitations of book security. Their objective was to design an IoT system for Library Materials Management based on RFID to improve the efficiency of the librarian and satisfaction of the borrower. They proposed an Internet of Things System for Library Materials Management using passive UHF RFID tags with an Android-based UHF mobile reader (Android mobile reader) as its entry to increase the efficiency of library materials management.

Vaidya *et al.,* [25] developed an RFID tracking system using PIC microcontroller and near field RFID tags to locate the position of books. The implemented system displays the result on a graphical light crystal display screen (GLCD) by tracing the shortest path. But this technique is only useful in small libraries with a limited number of books and also GLCD screen is not suitable for very bright environments.

Patil *et al.,[2*6] designed an IoT system for library

management based on the Near-field Communication (NFC) technology using the NFC embedded tags on the books, as well as the user cards. The NFC readers are used to read the tags for operation control of libraries. But the system does not provide anti-theft protection and also the reading range for near field communication is between 4cm, which makes the reading range of the system low and therefore may not reach books unless the reader is 4cm close.

Alwadi *et al.*, [27] designed applications that can lead to significant savings in labour costs, enhance customer service, lower book theft, and provide a constant record update of new collections of books. Automating a library system with passive RFID tag infrastructure is proven to be feasible, and can be achieved with even distribution of RFID Antennas, well-designed RFID network, an appropriate middleware, and a library application with an accurate error function that minimizes the error in the detected location to an acceptable distance, for instance, 35 cm. They Implemented a Location-Aware Library RFID service employing Radio Frequency Identification as a communication technology. They presented the feasibility and applicability of adding location-aware services to the core layer (without affecting the running services). To enable the upper application layer to track and locate the smart entities. Uttarwar*et al.,[28]* uses beacons for book searching.

Xiaoyang *et al.,* [29] designed a smart bookshelf using Ultra High RFID Technology. The intelligent book positioning system is built up by the use of ultra-high frequency RFID technology [30], with book labels, bookshelf labels, readers, computers, and base stations. The key technology of the system lies in UHF RFID technology, book positioning principle, and location algorithm. The comparative result of some RFID systems is shown in Table 4.

Table 4: Showing the comparative analysis of the system.

Verma and Garg (2014)	**RFID reader and tags**	**Book issuing, re-issuing, and book returning**	**Web-based**
Vaidya *et al.*, (2017)	PIC microcontroller, near field RFID tags and reader	Book searching and monitoring	Web-based
Uttarwar*et al.*, (2017)	Beacons	Book searching	Android-based
Sangavi et al., (2016)	PIC microcontroller, Zigbee, FRGA controller, RFID card and reader	Book Searching	Android Based
Jain et Al., (2015)	RFID tags And the reader	Book issuing and returning	Web-based
Vimalraj tal., (2015)	RFID tags and reader, Atmega162 microcontroller	Book security and monitoring	Web-based
Addepalli et al., (2014)	RFID reader And passive tags	Book issuing	Web-based
Groover and Ahuja (2010)	RFID tags and reader	Book issuing and returning	Web-based
Patil et al., (2017)	NFC tags and reader	Book issuing and returning	Web-based
Alwaldi et al., (2017)	passive RFID tags and antennas	Book Searching	Web-based
Xiaoyang et al., (2017)	UHF RFID tags and reader, book positioning principle and location algorithm	Book searching	Android-based

5. Conclusion

The comparative analysis of some RFID systems was done using some performance metrics. These performance metrics include technology used ranging from the RFID reader, RFID tags, PIC microcontroller, NFC tags, NFC reader, Bluetooth and library operations performed by the system ranging from; book issuing, book re-issuing, book searching, book monitoring, anti-theft detection, and inventory management; and the platform on which the system is based either web-based system or android based.

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