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An RFID-Based Library Management System

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ABSTRACT

This paper looks into the viability of Radio Frequency Identification and Detection (RFID) technology as a base technology for developing a library management system. The successful outcome of a project implemented using the technology will lead to an enhancement in the use of library services within the case study area, being the Central Library, Auchi Polytechnic, Auchi. The developed system uses RFID for book information tracking and also in ascertaining the number of people who access the library. The major components of the library management solution include an RFID reader, a Bluetooth module, a micro controller, together with an RFID transponder for tracking the library items. Each item is assigned a unique ID stored into a desktop application alongside its other related information. By this measure of operation, relevant data on library users, books, associated RFID tags and issuing processes can be help facilitate adequate cataloging in the library. A device was built, and its operability was tested using several data that yielded efficient result in its usage as a library management system.

Keywords: radio frequency identification (RFID), visual basic, microcontrollers, RFID tag, tag reader

1. INTRODUCTION

RFID is a potential automatic identification technology that uses radio waves to communicate data. RFID uses today span from security, manufacturing, logistics, animal tagging, trash management, postal monitoring, and airline baggage and road toll management to name a few. Numerous attempts have been devoted to ensure that library services such as book borrowing, user information tracking, and so on are as made simple as possible. Library Management Systems (LMS) are computer-based systems that automate one or all of the functions of a typical library. They have a long history dating back to the mid-1950s. In some related literatures, LMS has been termed as Integrated Library Systems (ILS) owing to the fact that its processes are being executed from a central database. Some LMSs according to Jones, (1993) were known to have connections to conventional tools like Microsoft's Excel for the presenting of statistical data by the end of the 1990s. RFID technology advancements have resulted in benefits such as resource optimization, better efficiency, security, visibility, and accuracy in processes. In recent

years, this technology has gotten a lot of interest for library information management systems. With particular respect to libraries, institutions now have access to new types of enterprise applications, and there is a demand for improved LMS connection with these systems (Haravu, 2009). Furthermore, with the continuous rapid development in library system management being driven by information technology, the digital transformation in mundane library operations towards computerized automated processes can also be made possible using RFID solutions. RFID has been employed in a variety of applications, including inventory management and building access (Zhu, Mukhopadhyay and Kurata 2021). The working principle behind the RFID can be equated to that of electronic barcodes for the identification, tracking, as well as detection of library materials. In this system, short RFID tags (labels), embedded hardware and developed software together form the library management system. Similar to its usage in this project, RFID has equally been utilized in implementing class attendance systems, for monitoring school assets such as computers electronic equipment, and mechanical tools as well in the area of access control for student hostels (Rong, Hui and Weiping, 2012).

With the introduction of radio technology, RFID was born. In 1935, the Germans, British, Americans, and Japanese all used radar systems to detect oncoming planes. Scottish physicist Sir Robert Alexander Watson-Watt demonstrated how his invention of radar might use radio waves to locate physical objects in a research report written at "VU University Amsterdam." A library management system can use these technologies to maintain track of the lending, borrowing, and shelving status of objects like books, audio or video tapes, CDs, DVDs, and other media. Barcodes and security strips, on the other hand, have significant limits. They take a long time to read and are easily taken. All of this resulted in an irreversible loss of a library's precious inventory supply. This is where RFID technology can help library administrators (Singh, Brah and Fong, 2006).

Srujana et. al, (2013) in their work demonstrate the design of a an RFID system using MATLAB. However, in this work we develop an RFID system for the Auchi Polytechnic, Auchi as a pilot Library management project. This is done in order to digitize the experience in using, lending, borrowing and processing library of materials albeit to enhance the concerned library services.

THE ESSENTIAL ELEMENTS OF THE RFID SYSTEM

As indicated in Figure 1, an RFID system is always made up of two components. The transponder is attached to the object to be identified, the detector or reader, which can be a read or write/read device depending on the design and technology utilized. The transponder, which is made up of a coupling element and an electronic microchip, is the actual data-carrying component in an RFID system.

A reader usually includes a high frequency module (transmitter and receiver), a control unit, and a transponder coupling device. Many readers also have an additional interface (RS 232, RS 485,

etc.) that allows them to send the data they receive to another system (PC, robot control system, etc.).

RFID tags are classed as low frequency (LF), high frequency (HF), ultrahigh frequency (UHF), and microwave based on their frequency. For book tracking and access management, HF passive tags are routinely employed in libraries and bookshops; however, UHF passive tags have lately been deployed in library applications. UHF has a faster reading speed and a greater reading range than HF. This allows for faster identification of multiple items as well as inventory checking.

When it comes to the self-service environment in libraries, however, UHF RFID waves must be properly managed so that untargeted items nearby are not misread, resulting in check-in and check-out mistakes (Ching and Tai, 2009).

2. METHODOLOGY

To develop the application interface we used C programming language, Visual Basic. Details of all the components and modules that make up the full Library Information System (LIS) are captured in the system design and analysis sections that follow.

3. CONSTRUCTION AND DESIGN OF SYSTEMS

The RFID Library Management System consists of both hardware and software components. Microcontroller, computer system, RFID reader, liquid crystal display (LCD), and Bluetooth module are the hardware requirements. Microsoft Windows 7, Visual Basic, SQL server drivers installed, database (SQL, MS Access, or SQLite) as back end, and Windows Presentation Foundation (WPF) as front end are the software prerequisites.

An RFID enabled library for book cataloging, Bluetooth enabled for easy mobility, flexibility in searching information, centralized database, user identification through RFID tags, and security features that include a login procedure with password protection for both the librarian and members are among the system's features.

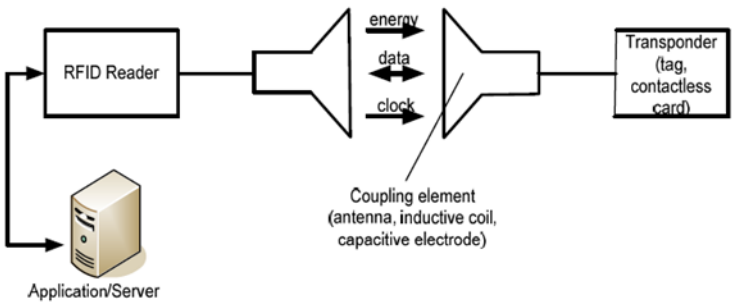

Figure 1. RFID system components (Finkelzeller,2010)

THE COMPONENTS

The following are the individual components that make up the RFID system:

THE PIC CONTROLLER

The PIC18F4520 is in charge of the device's principal activities. The crystal oscillator provides an external clock frequency of 8 MHz to the PIC microcontroller. It has all of the embedded peripherals (modules) required for the device's functionality. The Enhanced Universal Synchronous Asynchronous Receiver Transmitter EUART and Serial Peripheral Interface (SPI) modules are examples of such peripherals.

THE BLUETOOTH MODULE

Bluetooth has evolved into the industry standard for short-range communication. Because of its lower power utilization, lower costs, and improved signal functionality, the technology is favoured over its shorter-ranged wireless transmission technology counterparts (Waseem, 2009). The RN-41 Bluetooth module served as a communication route between the system components and the personal computer in this configuration. The RN-41 was housed on a board dubbed "Easy Bluetooth" by Mikroelektronika. The Bluetooth board has been connected to the microcontroller and is in "cable replacement mode."

THE RFID READER

The RFID reader module (EM4095) with on-board transceiver serves the purpose of reading identification cards (RFID cards) utilizing radio waves, and the RFID reader's antenna continuously sends a 125 KHz carrier signal. The carrier signal turns on the passive RFID tag, which is often inserted in an ID card. When the tag is turned on, it sends an FSK encoded signal to the reader, which contains the data saved on the card.

The reader transmits a 125 kHz sinusoidal signal constantly using the antenna, obtains and filters the returned signal from the tag, extracts the digitized data obtained via the processed signal, and further validates the data on the tag with the help of stored records.

3.1 THE LIBRARY INFORMATION SYSTEM ARCHITECTURE

The architectural overview of the library information system (LIS) is presented in detail in this section. Figure 2 shows the five cross-sectional levels of the architectural framework created and constructed utilizing RFID technology. The individual layers and their functioning concepts are explained in the subsections that follow.

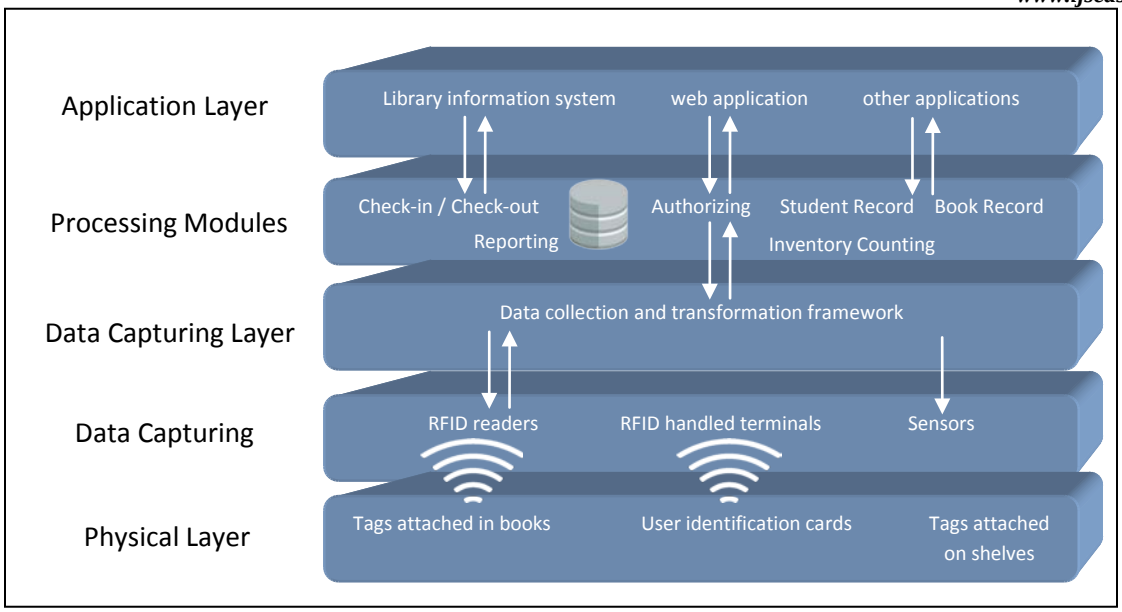

Figure 2. Architectural framework of the LIS

3.1.1 LAYER 1: PHYSICAL

The physical layer precedes all the others, and it includes UHF RFID tags affixed to books, CD/DVD cases, shelves, and student identity cards. For book tracking and access management, high frequency (HF) passive tags are frequently employed in libraries and bookstores; however, ultra-high frequency (UHF) passive tags are used in the proposed RLIS. These UHF passive tags have a frequency range of 860 to 960 MHz and can communicate with RFID scanners over long distances using antennas.

3.1.2 LAYER 2: FRONT END DATA CAPTURE

In the second layer, also known as the data-capturing front-end system, RFID readers are utilized. The goal of the data capturing front-end layer is to give the system with exact real-time data. To connect with UHF tags, handheld terminals and readers with fixed antennas are employed. Fixed antennae can be found at the library's entrance, service desk, and check-in/check-out desks. A handheld reader can equally be employed for the purpose of counting the collective book numbers on a shelf by scanning the tags attached to the volumes.

3.1.3 LAYER 3: LAYER FOR CAPTURING DATA

This layer acts as a middleware and it does the job of aggregating, routing and RFID data filtering. The data from the previous layer can be viewed as a stream of RFID observations of the form (tag id, reader id, timestamp), where tag id and reader id refer to the unique identification codes of the tagged item and the RFID reader (as well as their location), and the timestamp refers to the time when the reading occurred. In order to correct collected readings and deliver clean

and useful data to application logic, RFID middleware solutions are often implemented between the readers and the applications.

3.1.4 LAYER 4: MODULES FOR PROCESSING

The components in this layer are in charge of storing RFID data in a relational database system, retrieving it using Structured Query Language (SQL), and processing it using integrated processing modules. Check-in/Check-out, Reporting, Authorizing, Inventory Counting, User Record, and Book Record are the components that make up this system. They can communicate with the middleware system by sending simple queries or by setting up standing queries that produce a stream of matching data.

3.1.5 LAYER 5: APPLICATION LAYER

This layer sits above the processing components of the system, and it's responsible for coordinating and integrating the processing modules as well as managing transfer of data throughout the developed library information management system the respective system applications. This layer provides the library staff with an easy-to-use computer interface for using the modules, as well as supporting different enterprise and web applications.

4. THE LIS SYSTEM ANALYSIS AND DESIGN

We intended to inculcate the existing procedures and operations within the library at this level, as well as develop system architecture. As a result, we conducted interviews with the library's employees while simultaneously observing their operations. We examined operational demands and functional key requirements for LIS after learning about the library's functional processes and operational environment. Following our system analysis, we created a system architecture that serves as a baseline for the system development phase. We take careful consideration of the subsystems and identify them in the system overview. In so doing, we establish a framework for controling and monitoring the subsystems.

Our developed LIS system has six subsystems: New User Record, Tagging, Check-in/Check-out, Anti-theft Detection, Inventory Control, and Administration. All of these subsystems are connected to the main server through a wired or wireless network. The individual functionalities which make up the major subsystems are outlined in detail below.

4.1 Creating user record.

Users of the library would be required to have an RFID-enabled member identification card on them. This subsystem is used to register new users and allows staff to print fresh UHF tags. At the information desk, there is a PC, an RFID reader with antenna, and an RFID printer.

4.2 Administrative Functionality.

The library manager can use this subsystem to keep track of check-in/check-out records, stock verification, and tagging process information. The manager can also get business intelligence reports from the subsystem.

4.3 Check-in/Check-out.

Staff at the service desk can use this subsystem to handle check-in and check-out procedures. For this operation, a reader with a permanent antenna is also deployed at the service desk.

4.4 Inventory management.

In large libraries, taking inventory at regular intervals is a vital role. This subsystem allows employees to swiftly verify stock levels. A hand reader can scan hundreds of books/CDs on shelves without having to pick up a single book. This device can also be used to organize shelves and find specific goods.

4.5 Theft detection.

This subsystem is in charge of detecting theft, which is a significant difficulty for libraries. Theft detecting pedestals have been erected at the library's entrance and exit gates. As it travels past the pedestal, any item that has not been checked out is detected. This subsystem also detects those who come into the library without a membership card.

5. RESULTS AND TESTING

The system was tested under various operating conditions after completion of the design and construction, including different input power supplies, obstruction between RFID tag and reader, RFID card angle of interrogation, PC and device response to data transfer, and the maximum distance between device and PC for reliable communication.

5.1 MICROCONTROLLER TEST

The PIC18F4520 40 pin IC was examined for any possible internal I/O pin damage. To guarantee that the pins were not damaged, a simple C program was built that simply turns on and off all 35 I/O pins once every second. The array of LEDs linked to the PIC I/O pins on the development board demonstrated this. Each pin voltage was measured using a digital multimeter, and the average value for all pins was 4.21V for logic HIGH and 0.02V for logic Low.

5.2 BLUETOOTH TEST

The RN-41 was placed on the simple Bluetooth board to facilitate optimal communication with the PC and ensure proper Bluetooth operation. The data transfer was only tested for about

7 meters during the test, which is sufficient for its applicability in the design. It's safe to state that the distance it can transmit is determined by the transmitter's total power input at 2.4GHz.

5.3 TEST OF RFID MODULE

RFID was tested on the development board, and the RFID card performed admirably. Cards were brought close to the reader and read at a distance of 3 centimetres for interrogation. When it was finished, the space between interrogations was decreased to roughly 2 centimetres or less when it was powered by a battery.

6. CONCLUSION

Libraries have been looking for technological tools to help them improve customer service and manage the different services they provide (Bansode and Desale, 2009). RFID is an automatic identifying technology that has a lot more potential than barcodes, which are often used in libraries. UHF RFID technology allows for no-line-of-sight item identification and rapid batch scanning, resulting in reduced manual labor. Under the conditions of its rated power, the designed system performs admirably, although the design remains a prototype. We want to improve on this idea by utilizing more sophisticated RFID scanners with an operating frequency of around 13.56MHz that can interrogate cards from a distance of up to five feet.

7. ACKNOWLEDGEMENTS

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