A Comparative Study of RFID Technology Measuring Efficiency and Acceptance when Capturing Attendance

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Abstract

The use of Barcodes and Radio Frequency Identification (RFID) technology has become a ubiquitous means of inventory and asset tracking. When considering the application of monitoring people in an enclosed environment, for example in a classroom or an examination setting, previously employed RFID-enabled solutions have yielded high costs and poor user acceptance. Previous studies have also shown that an important factor which has impacted adoption is privacy issues surrounding Ultra High Frequency (UHF) systems. In this paper, we compare attendance recording techniques and technologies to determine the optimum method focusing on the price, efficiency and user acceptance. The three approaches we have examined include manual recording, barcode scanning and Low-Frequency RFID capturing over a fixed period conducted as a technology integration pilot study. From our initial results, we have found that a low cost RFID reader and tags approach is most favoured for user acceptance, drastically reduced the recording time compared to manual methods and is comparative to the cost of barcode systems.

Keywords: RFID, User Acceptance, Efficiency.

1 Introduction

The process of capturing attendance has in the past been a manual process of calling out names and awaiting a response which resulted in unacceptable consumption of time. To more efficiently address the process, both Barcode and Radio Frequency Identification (RFID) technologies have been employed to manage the task. Barcode technology uses a printed series of lines in conjunction with an optical reader to determine an items unique identifier while RFID uses wireless technology between a reader and the tag being interrogated. While barcode systems have have the potential to be more efficient than a manual roll call, however in past studies concerns that have been raised included the technologies requirement for line-of-sight, if a card is partially covered, angled or worn it can often result in misreads. RFID systems that have been deployed have often opted for long range Ultra-High Frequency (UHF) devices

which have not only been costly but raised concerns around privacy as the technology continually makes readings, effectively tracking participants (Pateriya & Sharma 2011).

In this paper we will compare and analyse three methods and technologies used for attendance recording to identify the optimum method in consideration of speed, user acceptance and cost. The three methods trialled were Manual Roll Call, Barcode reading and RFID scanning. The architecture was made up of a database driven web application, client machines with a web browser and the Barcode and RFID readers. Readers were attached via usb to the client computer which was logged into the application, upon receiving a valid read the application would record the attendees identification and current time stamp in the data base for later review and analysis.

At the conclusion of the trial our results showed the RFID technology was most favoured for user acceptance, was the most speed efficient method and was comparative to the cost of the Barcode system.

The remainder of this paper is organised in the following sequence: Section 2 provides the required background information for both the methods previously used for attendance tracking, as well as information about the technologies deployed which include Barcode and RFID technologies. Section 3 delivers a succinct account of related work previously studied which then leads to our methodology outlined in Section 4. The results and analysis of the technology integration pilot study are delivered in Section 5. Finally Section 6 discusses our conclusions on which method provided the optimum solution and the future work we intend to study following on from this research.

2 Background

Recording attendance has traditionally been a manual procedure where by either participants sign in or a process of announcing names and recording the response is undertaken during the attendance period. The time required for manual attendance monitoring procedures can be significant, particularly for large groups. Various means of speeding up the process have been suggested such as recording only a random 10% of attendees when roll taking is used as an incentive to increase attendance (Shimoff 2001). When the full data is required however, such is the case for statistical analysis, electronic means of recording have been utilised to reduce not only the time required for recording attendance, but also to streamline or even eliminate post recording work such as data entry. The technologies we will be examining in this research are Barcode and RFID technologies.

2.1 Barcode Technology

Barcode Technology incorporates a printed series of solid lines and spaces which are interpreted by a reader into a string of alphanumeric values to identify an object. The Barcode Reader is most often a laser scanner where the light reflected back off the printed Barcode is interpreted by the reader. The solid lines reflect less light, while the spaces reflect more light (Woodland et al. n.d.), (Sriram et al. 1996).

Barcode Technology is a familiar and accepted technology largely due to its almost universal use in supermarkets and retail in general. Barcode technology is used across a vast number of applications from personal identification tags to inventory management to tracking items in transit.

2.2 RFID Technology

Radio Frequency Identification (RFID) incorporates the wireless transfer of data between a reader and one or more identifying tags (Want 2006). When entering the range of a reader, a tags Electronic Product Code (EPC) is reported back to the reader to identify the tag (Chawathe et al. 2004). RFID Technology can be divided into short and long range systems. Low Frequency (LF, 125-134 KHz) and High Frequency (HF, 13.56 MHz) systems are short range, whereas Ultra-high frequency (UHF, 860-960 MHz) is long range (Nikitin et al. 2007). The range of the RFID interrogation zone spans 3 meters to 100 meters depending on the type of tag and reader employed (Chawathe et al. 2004).

The primary purpose of RFID Technology is to accurately and efficiently identify an object using its associated tag. RFID is employed across a wide range of industries and use cases such as Stock Management in the Retail sector, Smart Cards for Financial transactions and Human Identification items such as passports (Ilie-Zudor et al. 2011).

2.3 Related Work

Systems have been implemented and evaluated using Barcode or RFID to automate attendance tracking with the goal of increasing efficiency. Barcode systems use statically located readers or (often several) portable hand-held units, in both cases it is typically the subjects themselves handling the scanning. It has been observed that statically located readers have caused bottlenecks when there are many attendees all attempting to register a scan, this is exasperated by failed reads due to the Barcode systems line-of-sight requirement, where any covering of or incorrectly aligned Barcode would result in a misread. Portable units raised concerns such as possible theft, absentees providing their Barcode to attendees to scan, and misuse of a reader for scanning unrelated Barcodes (Casey & Kille 2011). The bottleneck problem could be reduced by increasing the number of available readers, this would however reduce the ability to monitor the scanning to eliminate false scans as well as increase the expense of deployment.

RFID Technology has been deployed using short and long range systems for use in automated attendance tracking, though long range systems are preferred as they can scan large numbers of tags autonomously (Chang 2011).

Long range UHF systems have a number of problems which has discouraged wide scale adoption. Some of these problems include the high cost of equipment, possible signal interference, reading collisions and multiple reads of the same tag. (Wu et al. 2006)

Long range systems also have greater Privacy Concerns than short range. UHF Long range systems would have readings of attendees for their duration within the read area, and thus act to track an attendee rather than the approach of a Short range system which simply takes a snapshot at a given time (Silva et al. 2008).

A Short Range RFID system coupled with secure communication and strict server security does not suffer the same privacy concerns as a Long Range system.

2.4 Motivation

It is often desirable to collect attendance data for an event, class or exam, whether for further analysis, reflection and planning or to encourage greater attendance. Collecting this data for large groups can be tedious and can cause unacceptable disruption and consumption of precious time. The goal of our technology integration pilot study is to identify the optimum method for capturing attendance, balancing efficiency to address the time constraint, user acceptance of the technology to encourage participation and to keep the cost of deployment to a minimum. Our pilot study concentrated on three methods which met some basic constraints of the environment and which could be deployed simply, cheaply and immediately.

3 Methodology

In this paper we will compare the results of our technology integration pilot study to determine the optimum method by which to record attendance. The recording methods analysed are Manual Roll Call, Barcode scanning and Low-Frequency short range RFID capturing. To determine the optimum, each method is analysed on the basis of three key measurements, efficiency, user acceptance and cost. The following section outlines the motivation of our analysis, after which the systems architecture and requirements are described.

3.0.1 Manual Roll Taking

The traditional method of manual roll taking met all environmental and cost constraints, however the disruption and time consuming nature of this approach has often meant that it has been unpopular for both the attendees and the coordinator. Regardless of its short comings, Manual Roll Taking was included in the study to provide a base line for comparison. Any alternative method must at minimum have a greater efficiency and user acceptance to be considered viable.

3.0.2 Barcode Technology

The use of Barcode Technology for the study was a natural choice due to the low cost of the scanning equipment coupled with the existing Barcodes allocated to each student that appear on their student identification cards. Although a single scanning unit can cause bottlenecks with larger classes, the requirement of supervision to prevent problems discussed earlier, such as absentees providing their barcode to attendees to register attendance, resulted in the use of a single scanning point at a very low cost and reduced the likelihood of mistreatment or breakage of the equipment.

User acceptance of Barcode Technology was expected to be high as the identification cards Barcodes were already in use by the students and so would be

familiar. It was expected that the rate of scanning would be more efficient than traditional roll call.

3.0.3 Short range RFID Technology

The use of RFID Technology was trialled primarily on the basis of efficiency. As RFID does not require line of site to obtain a reading, it was thought that overall read time would be shorter as attendees would be less likely to encounter read issues. Short range Low Frequency equipment was selected over Long range Ultra High Frequency due to cost, potential privacy issues and possible user acceptance problems as previously discussed.

The cost of an RFID reader was comparable to the cost of the Barcode scanner, however tags had to be purchased and distributed to all the students. While the tags supplied were low cost, it may not be necessary in future to supply tags as students cards may be distributed with RFID chips to be used for security access. As is the case with the Barcode system, if the student cards are issued with the required technology then there will not be an extra expense to provide tags for the purpose of tracking attendance.

It was not clear what level of user acceptance would be attained with RFID compared to a bar code system, and so this Technology was of particular interest in the trial.
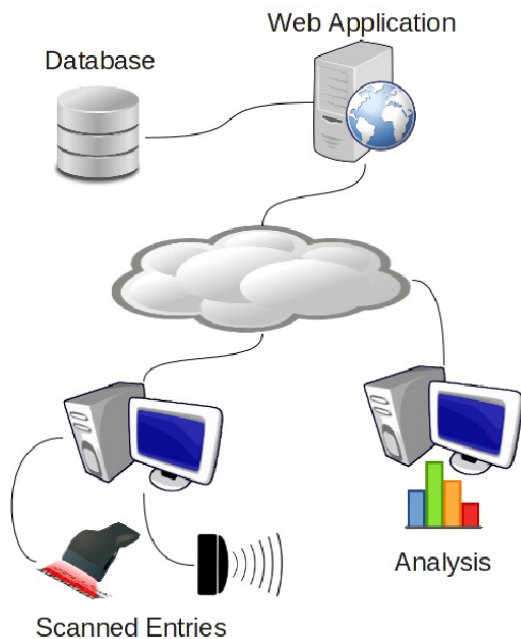
3.1 Architecture

Figure 1: Architecture overview

As shown in Figure 1, the system architecture is made up of client machines connecting via a network to a web based application. In the classroom the client machine reads the attendees identification through either Barcode code or RFID technologies, the reading is then sent to the web application which in turn writes the record to the database including both the attendee and the current time. Out side of the class room, a client machine is used to access the web application to retrieve real time reports and analysis on the attendance data. To ensure secure communication between the clients and the server, the application is password protected and runs over a Secure Socket Layer (SSL).

Figure 2: Barcode reader

Figure 3: RFID scanner and tag

3.2 Assumptions

We have made three assumptions regarding the trial processes. The first assumption is that each attendee will have with them their student identification card or assigned RFID tag as required in class. The second assumption is that the organiser will have in their possession either the Barcode Reader or the RFID Scanner as needed. The last assumption is that there is access to a network connected computer with a web browser at the venue so that it is possible to connect with the web application.

4 Experimental Results and Analysis

The following section describes the framework we assembled to undertake the technology pilot study as well as the methodology followed. To begin with we look at the environment in which the Technologies operated, next we detail the results of each method in the context of efficiency, user acceptance and cost.

4.1 Environment

Our web based application was coded using a Linux, Apache, MySql and Php (LAMP) stack. The server Operating System is the Debian GNU/Linux distribution Release 6 "Wheezy". The Operating System for the client machines was Windows XP with Service Pack 3 installed. Both the Barcode Code Scanner and the RFID Reader operated as standard input devices running over USB. The RFID Reader and tags operate at 125Khz. The web browsers used to access the web application were Firefox and Chrome.

4.2 Efficiency

A key measurement for determining the optimum method for attendance recording is undoubtedly speed efficiency. For a technology to be considered for adoption it must at minimum have a far greater time

efficiency than manual attendance recording. Each method trialled had its capture duration recorded for two lectures with a class of approximately 60 students, the averaged results of which are represented in Figure 4.
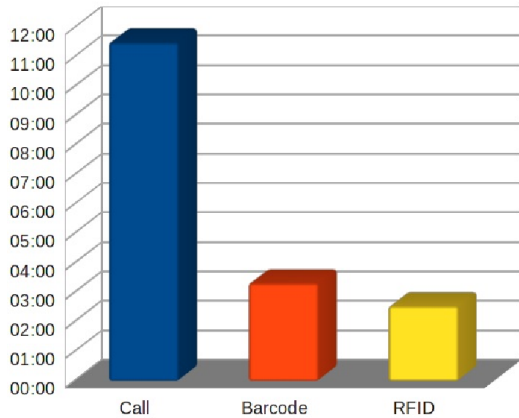

Figure 4: The aggregated results of the recording duration of each method

4.2.1 Manual Roll Call

The duration of Roll Call was determined by manually recording the time of commencement and of completion. The times were recorded by a second person so as not to interfere with or allow bias by the roll taker. It is important to note that while the average time taken to record attendance using this method came to 11 Minutes 30 Seconds, an extra task of data entry was performed after each class, and while this did not effect the class, it had the impact of effectively doubling the attendance tracking effort. The results show that the time needed for manual roll call has a significant impact on the time remaining for the class and as such is rarely adopted for large audiences.

4.2.2 Barcode Technology

The results show a vast improvement in time efficiency over Manual Roll Call with an average recording duration of 3:19 Seconds. The duration of Barcode approach was retrieved by database queries calculating the difference between the time stamps of the first and last reads, the scanning required students to approach the the reader at the front of the room and present their barcode. The capture time for each record was fairly consistent for Barcodes, while Manual Roll Call varied greatly. The varying times for Manual Roll Call can be attributed to slow responding attendees and absentees. A call is repeated a number of times when there is no response to ensure that the person is absent rather than having not heard the call. Also the callers often encounter names they find difficult to pronounce, and this also causes delays which the bar code system is immune from.

4.2.3 RFID Technology

RFID claimed the greatest time efficiency with an average recording duration of Two Minutes Thirty Two Seconds. Like the barcode system, students were required to approach the reader at the front of the room, this time however they passed their tag over the reader. The performance increase over Barcode reading is a result of not requiring line of sight and hence encountering less misreads.

4.3 Technology Adoption

As part of the technology integration pilot study a survey was conducted to measure the level of user acceptance for each method. The survey used a Likert-type approach with a scale of 1 to 5 where 1 is strongly disagree and 5 is strongly agree. There were twelve questions used for evaluation, the aggregated results of which are shown in Figure 5. The survey questions were divided into four areas, Perceived Usefulness, Perceived Ease of Use, Intention to Use and Attitude Towards Usage. The survey includes questions such as "Using ... enables me to get my attendance checked quicker" and "Overall, I find ... very useful" for each of the approaches given a grade between 1 and 5. Additionally, a space was provided at the end for any additional comments regarding the technology.

The survey showed a significant bias in all categories in favour of RFID, even though in this trial it required attendees to manage an extra item (the rfid tag). Interestingly attendees still rated RFID higher for ease of use than Barcode Technology which they were already familiar with from existing use. As part of the survey, space was provided for general feedback, of those that responded the majority reported that it was primarily the speed of RFID that was appealing. A number of participants also commented that there would be increased convenience if the RFID tag was integrated into the student card so they only had one item to manage.
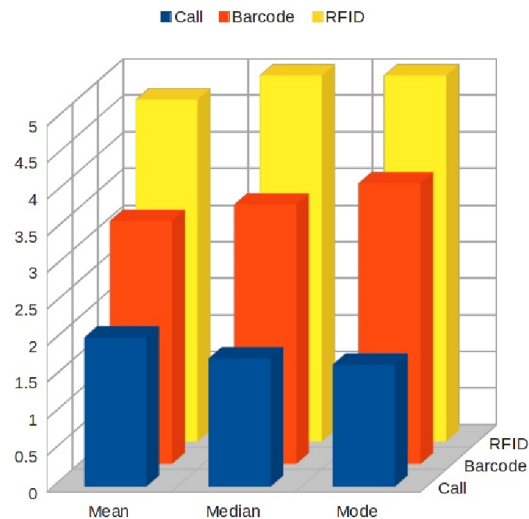

Figure 5: The aggregated results of the Likert-style survey for user acceptance of attendance recording methods

4.4 Cost

4.4.1 Barcode Technology

The only purchase required to trial the Barcode Technology was a Scanner as students had already been supplied with a unique bar code by way of their student cards. We purchased the 80mm USB Barcode Scanner shown in Figure 2 for AUD$24.92

4.4.2 RFID Technology

To trial the RFID Technology we purchased both a reader and a sufficient number of tags. The reader as shown in Figure 3 is a 125Khz EM4100 RFID USB Proximity ID Card Chip Reader purchased

for AUD\$9.60. The RFID tags were purchased for AUD\$0.27 each (\$26.90 per pack of 100).

5 Conclusion

In this paper we have carried out a comparative analyses on three methods of attendance capturing, Manual roll call, Barcode and RFID technologies. The focus for comparison was based on three key indicators, speed efficiency, user acceptance and cost (including equipment and deployment costs). Our results have shown RFID Technology performed greatest for both speed efficiency as well as user acceptance while remaining affordable with a cost of deployment comparative to that of Barcode technology.

To further leverage the benefits of an optimal attendance capturing technology, it would be interesting in future work to analyse the captured data for useful applications such as attendance prediction for class planning, and recognising attendance patterns to aid content delivery planning.

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