DOCUMENT MANAGEMENT SYSTEM USING WIRELESS RFID TECHNOLOGY FOR INTELLIGENT HEALTHCARE OPERATIONS

Saisakul Chernbumroong, Anthony S. Atkins and Hongnian Yu
Faculty of Computing, Engineering, and Technology, Staffordshire University, Beaconside, Stafford, United Kingdom

ABSTRACT
It has been estimated that in the UK National Health Service (NHS) 33% of nurses spend at least an hour in a shift on non-productive activities, equals 40 hours a month and costs the NHS approximately £900 million per year. This includes searching for equipment and patient records, a situation which will become more acute as the ageing population is expected to rise to 18.5% in the UK by 2020. The paper presents the use of emerging Radio Frequency Identification (RFID) technology for application in tracking and tracing document such as patient records in a hospital environment. The system developed uses low-cost passive tags to provide real time non intervention information using a TCP/IP protocol allow monitored across the organisation to track and trace and reduce un-productive time and prevent loss of documentation. This information can be linked to intelligent systems such as work flow management, simulation and data mining techniques etc. to provide intelligent decision making and what-if analysis. The paper discusses the development of Electronic Patient Record (EPR) and its issues and what our proposed system can offer and enhance EPR system.

KEYWORDS

1. INTRODUCTION

Over the last decade there has been a significant worldwide increase in the elderly population. According to the United Nations online database (2008), the ageing population (≥65 years) is currently 7.6% and this is expected to increase to 16.2% by 2050. Normally, the health of older people deteriorates with increasing age, resulting in an increased demand for long-term care. The implication is that the number of hospital admissions will rise dramatically. At the moment, hospitals already have difficulty with long waiting times and lists. According to the UK Department of Health hospital waiting list statistics for the second quarter of 2008/2009, there were 556,015 patients waiting, and the longest period that a patient has to wait is over 30 weeks. With the growth of the ageing population, waiting times and waiting lists will undoubtedly increase further. In order to prepare for this, hospitals must have effective management systems to ensure unproductive time is not wasted and that patients receive prompt and efficient care.

A research survey by GS1 UK and Nursing Times (2009) indicates that nurses still waste time on non-productive activities. More than 33% of nurses spend at least an hour trying to locate items of equipment during an average hospital shift. This equals 40 hours a month and costs the NHS nearly £900 million a year. It is vital that nurses spend time with patients delivering high quality care rather than searching for equipment that should be readily available for use. Many hospitals have employed barcode technology to solve the problem of tracking the location of medical equipment. The disadvantage of this method is that the equipment needs to be scanned every time it moves in or out of a room. This is prone to human error and also affects the working flow of the system.

With advancements in wireless technology, other solutions such as Radio Frequency Identification (RFID) can be used to monitor and track the location of equipment. RFID is an emerging technology which offers advantages over bar-coding systems: with its non-line of sight and non interference properties etc. the location of equipment can be automatically recorded and real-time track and tracing is possible. The use of RFID would allow nursing staff to spend more time on other professional activities.
2. RFID TECHNOLOGY

RFID is a means of storing and retrieving data through electromagnetic transmission to an RF compatible integrated circuit (Liu et al, 2007) and is now being used as a means of enhancing data handling processes, comprising of three main components: RFID tags, RFID reader and a middleware respectively.

An RFID tag consists of a microchip attached to a radio antenna mounted on a substrate. The tags come in various designs allowing them to be used in different commercial applications. The purpose of the tag is to store data which can be altered or retrieved via a radio frequency. There are three types of tags: passive tags, semi-passive tags and active tags. The passive RFID tags have no battery and require an external source to invoke a signal transmission. Semi-passive tags also require an external source to activate them, but have a significantly higher forward link capability providing a greater read range. An active RFID tag contains a battery and can transmit signals autonomously. The passive tag is small and inexpensive (1 pence) but the coverage range is short while the active tag offers larger coverage and is normally more expensive (£5 to £60) depending on the quantity procured.

The RFID reader is usually a handheld or fixed unit that can interrogate RFID tags that are in the reading range using radio communication. Some RFID readers have antennas residing in the package while some require external antennas. The RFID reader works with the antenna emitting a radio wave to activate the tag and to read or write data to the tag. The antenna can send the signal over an area from a few centimetres to 100 metres or more, depending on the frequency used and output power. Once the tag passes the electromagnetic field, it detects the activation signal and modulates it. The reader decodes the data stored in the tag and sends it to the middleware for further data processing.

RFID is fundamentally based on wireless communication, exploiting radio waves, which form part of the electromagnetic spectrum (Ward et al., 2006). It operates in an unlicensed space and the operating frequency is different in each country depending on the regulations. These frequencies are normally categorized into four groups, Low Frequency (LF), High Frequency (HF), Ultra High Frequency (UHF) and Microwave. Table 1 shows the operating frequency, reading range, and application for each RFID band.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Read range</th>
<th>Application</th>
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<tbody>
<tr>
<td>LF (125 kHz)</td>
<td>&lt; 50 cm</td>
<td>access control, animal and livestock identification, ticketing, laundry, supply-chain management, vehicle identification, container tracking, asset management, waste management, product identification, process automation, stored value</td>
</tr>
<tr>
<td>HF (13.56 MHz)</td>
<td>&lt; 100 cm.</td>
<td>access control, ticketing, library management, laundry management, supply-chain management, vehicle identification, container tracking, asset management, waste management, animal and livestock identification, product authentication, process automation, stored value, pharmaceutical counterfeit</td>
</tr>
<tr>
<td>UHF (433 MHz, 868-915 MHz)</td>
<td>Passive: &lt; 10 m. Active: &lt; 100 m.</td>
<td>supply-chain management and distribution logistics, express parcel delivery, airline baggage handling, asset tracking, vehicle identification, container tracking, access control, waste management, product authentication, process automation, stored value</td>
</tr>
<tr>
<td>Microwave (2.45 GHz, 5.8 GHz)</td>
<td>Passive: &lt; 3 m. Active: &gt; 100 m.</td>
<td>ETC(Electronic Toll Collection) and RTLS(Real-Time Locating System)</td>
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An RFID read range is affected by many factors such as operation frequency, reader output power, tag antenna size, reader antenna size, tag type (passive/active), reader position, object interference, and other RF device interference etc.
Middleware is used for data processing, routing and managing the RFID reader. Middleware combines the RFID data with application logic and generates appropriate application events. Examples of middleware tasks are data dissemination, data filtering and aggregation, RFID reader operation controls i.e. reading/writing from/to tags, data privacy management and integration of RFID readers in IT service management (Floerkemeier and Lampe, 2005).

3. PROPOSED DOCUMENT MANAGEMENT SYSTEM

To improve hospital document management and work flow, a Document Management System (DMS) that applies RFID technology to monitor and track documents in hospitals is proposed. RFID has advantages over barcodes: automated data collection allowing real-time document tracking and is non intervention system, allow more information other than the unique item ID to be stored, reprogrammable tags and etc.

3.1 Document Management System (DMS)

The document management system chose an UHF passive RFID system as it provides many benefits and is appropriate for this application. EPC Class 1 UHF RFID tags will be used which have no batteries onboard, reducing maintenance. The passive tags are powered solely by the RF energy transmitted by an RFID reader. The tags do not transmit any RF energy, but communicate with the reader through backscatter modulation, changing reflective characteristics and reflecting RF energy back to the reader. The cost of a passive tag is relatively cheap which is suitable for tracking large amount of documents and equipment, whereas active tags are more expensive and also carry the additional cost of battery maintenance. Active tags are more appropriate for applications that require long range coverage while DMS only needs to record documents that move from room to room: only room level coverage is required. The system uses UHF system which allows multiple tags to be read at once and longer ranges can be achieved. Recent developments in UHF tag technology have enabled them to work in metal and liquid environments. The DMS consists of 3 main parts, an RFID system, a database system, and an intelligent system respectively as depicted in Figure 2.

3.1.1 RFID System

This system composes of many ‘gateways’ or ‘choke points’ incorporating antennas and readers usually located at the different rooms in the system flow. The passive RFID tag is used for storing information about the document such as document unique ID (tag UID), document type, security level etc. Since RFID tags can store only a limited amount of data, only important information should be stored. Other information such as document name, location, and date and time should be stored in the database. Each RFID tag is attached directly to a document. An RFID reader is installed at each ‘gateway or choke point’ as required, for instance, at the door of a room. Each time a person moves, documents pass the door; the reader receives data from the RFID tags and sends it over a wired or wireless network to the database and application system for data storing and processing.

3.1.2 Database and Application System

The database and application system is used for data processing, routing and controlling the RFID readers. This system contains a web server for storing web applications and a database server for managing received data. The purpose of the web server is to store a web application allowing users to access the document.
management application over both wired and wireless devices across the organisation. The administrator can use the web application to control the operation of RFID readers i.e. read, write, change setting, and manage information about RFID tags, documents, locations and etc. The web application is linked with the database server over a TCP/IP protocol. The database server is used for storing data received from RFID tags, information about documents, staff, location, readers, tags etc.

3.1.3 Intelligent System

The Intelligent system is used to analyse data in the database system with the aim of highlighting useful information, allowing ‘what-if’ scenarios and supporting decision making. The analysed data can be used for patterns of document flow allowing a hospital to design the document system to optimise the flow of documents in relation to patient scheduling. The Intelligent system will enhance the document management in the hospital.

3.2 System Benefits

Keeping track of documents manually is labour-intensive and subject to error. DMS offers many benefits to hospital management. It allows staff to track and manage documents efficiently, so that quality time can be spent on other productive activities. The system will also enhance safety and security for confidential documents.

3.2.1 Automatic Data Collection

RFID does not require line of sight to read or write data to tags, unlike barcodes. The data can be collected automatically without wasting time scanning, allowing data to be collected accurately and objectively. Staff can carry on with their work while the document tracking information is captured effortlessly and automatically to the database server.

3.2.2 Real-time Tracking

As an RFID system allows data to be updated instantly as a tag passes the reader, the system can then track the location of a document in real-time. When a tagged document enters or leaves a particular area, the new location will be immediately updated in the system. Staff can use the Document Management System to identify the location of documents, resulting in reduced search time.

3.2.3 Multiple Readability

A hospital usually contains a large amount of documents, from patient health records to financial contracts. It is essential that several documents can be tracked in a short period of time. The Document Management System employs UHF RFID technology that allows multiple tags to be read in an instant. Furthermore, due to the use of improved passive UHF tags, data can be captured even when folders are stacked with tags closely packed together.

3.2.4 Security and Safety

Scanning documents and staff ID tags at the same time automatically establishes responsibility. With an RFID reader fitted at each choke point, hospitals can maintain precise location information of documents as well as accurate records of the chain of responsibility. For confidential documents, the reader can detect whether those files leave a certain room or area without an authorized staff member. The RFID system ensures documents are kept safe and ensures only permitted persons can access the files.

3.3 RFID Effect on Medical Devices

Since the Document Management System will be used in a hospital filled with critical care equipment and devices as well as patients and staff members, it is vital to ensure safe and effective use of both tracking technology and the patient care devices. RFID emissions must not affect health or interfere with medical devices. A study on the effects of passive UHF RFID system on medical equipments (Christe et al., 2008) did not detect any problems with electromagnetic interference (EMI). The study tested RFID EMI effects on
medical devices such as infusion pumps, EKG monitors, blood pressure monitors, and other equipment in a patient room. Overall, 1,600 performance assessments were carried out and it was found that an RFID system does not interfere with the medical devices. Another research study (Togt et al., 2008) tested two RFID systems, active and passive, and 34 out of 123 EMI incidents were found. The research suggested that RFID can cause potentially hazardous incidents in medical devices. However, the research used 2-4 Watts of a passive RFID system which is much more powerful than interrogators typically found in existing hospital RFID deployments (Payne, 2008). However, it is essential that EMI tests are carried out on the actual site before deployment of an RFID-related system.

4. EXPERIMENT

The RFID experiment was carried out using an Alien UHF passive RFID system. The selected Alien RFID reader model, ALR-8800, is fully compliant to the European Telecommunications Standards Institute (ETSI) EN 302-208 specification. The reader operates at 865.7 MHz to 867.5 MHz and is able to emit RF up to 2 Watts ERP. For RFID tags, Alien ALN-9640 Squiggle was selected. It is compliant with EPC class 1 Generation 2 and ISO/IEC 18000-6C standards.

The experiment was set up to replicate the scenario of documents moving from room to room. The experiment used a reader and four antennas to represent two doors or ‘gateways’. Each door was located 4.5 metres apart. Each pair of antennas was placed at the door at 0.87 metres apart. Four antennas were connected to the RFID reader using coaxial cables. The reader was connected to the access point via a LAN cable and the RFID data was sent over a TCP/IP protocol. Each RFID tag was attached to a document folder. The experiment was performed by a participant carrying a document passing from one door to another. The data regarding readability, signal strength, date, time, antenna UID, and tag UID were recorded. Experiments were used to test multiple reads in a short time. A participant passed the door carrying ten documents at a time. The same variables were observed and recorded by the system. The participant also carried a box containing 50 documents, of which only 10 were attached with RFID tags and these could also be recorded on the system.

The prototype application has been developed as shown in Figure 4. The application allows new documents to be added and associated with respective RFID tags. The security level of the documents i.e. low, medium, high or confidential can also be set, thus in future applications, documents with a high security level could trigger an alarm when they leave a certain area. The user can monitor the information on each document such as description, security level, RFID tag, current location and etc. and also search for a specific document. Other information on the RFID tags and RFID reader can be easily retrieved from toolbar buttons. The application performs document tracking, continuously recording which antenna reads the tags, discovery time, last seen time, and the location of the antenna and also updates the current location of that document.

The result of the experiment showed that the document can be tracked using a passive UHF RFID system. A large number of documents can be tracked in a very short period of time. The tag data is collected instantly and automatically. The tag can be read even when it does not face the antenna directly. There are issues that need further experiments such as where and how the antenna and RFID tag should be placed to get the best tracking result, reading time interval and the EMI test of RFID and hospital equipment.
Overall, using a passive UHF RFID system for a document tracking system provides an automated solution. A document management system using passive UHF RFID has the benefit of using low cost RFID tags enabling thousands of documents to be tagged at an economic cost. Using an RFID system allows automatic and objective data capturing and real-time document tracking. Staff can work more efficiently to provide better care to patients.

5. ELECTRONIC PATIENT RECORD AND THE USE OF DMS

The UK NHS is changing the way it stores and manages medical records by converting them into an electronic format. An Electronic Health Record (EHR) collects the health information of an individual patient. The NHS Care Records Service (CRS) is currently under development and has been implemented throughout the NHS in England since May 2006; to date 1.25 million records have been digitalised and this is expected to rise to 50 million by 2014 (BBC, 2010). The purpose of the CRS is to enable patient information to be accessed quickly and reduce the use of paper and film records. These electronic records will be kept separately in two locations: local and national. The information kept nationally records important information about patient health i.e. allergies, current prescriptions, and adverse medical reactions, while more detailed records will be kept locally by GPs or hospitals and all electronic records will be linked together (NHS Care Record Service, 2010). Although CRS appears to bring many benefits to healthcare services, several issues concerning the use of electronic patient records have been raised. The cost of adopting EHR is expensive, not only the cost of system implementation on which £12.7 billion has already been spent, but also the costs of IT systems, such as hiring competent IT staffs to maintain the system, IT training for staff and IT resources i.e. computers, laptops and PDA.

Currently, the electronic health record project has been suspended, as the British Medical Association (BMA) protested that patients were not given sufficient information and awareness of the system (Timmins, 2010). The Document Management System can enhance the NHS CRS system. While the CRS is being developed, the DMS can help manage the documents efficiently and prevent loss of documents. When the development of CRS is complete, a patient who wishes to opt out of CRS can continue to keep their paper-based records. However, there are issues regarding different IT infrastructures across UK hospitals. Different Trusts use different IT systems which are not integrated, sometimes even within hospitals. Moreover, other organisations i.e. social services and also other types of medical records i.e. mental records use different record systems. Many people have concerns about security and patient confidentiality and the possibility of unauthorized access to these records. Computerization of medical records diminishes patient privacy and increases the potential of misuse, especially in non-consensual secondary use of individually identifiable records (Baumer, Earp and Payton, 2000). Unsecured system could easily be accessed by unauthorized persons. Obtained information could be misused, abused, exposed causing damage and threat to both organizations and patients.

There is also a difference between acute medical records and primary care medical records. Although held on the same patient, these are entirely separate entities held in entirely separate systems, some electronic, some in paper form. Healthcare is split by providers into primary care i.e. GP surgeries, and acute care i.e. hospitals and NHS trusts and each provider historically have their own systems.

- General Practice (GPs)

Used to keep their own paper notes which were shared with no-one and remained within the practice. These held the details and histories of practice visits, test results etc. Most GPs now have their own electronic stand-alone systems for the practice. These systems are provided by various companies, i.e. in one
sector in the West Midlands where there are 67 separate GP practices, 30% use an EMIS PCS system, 65% use an EMIS LV system and 5% use an ISOFT system.

- Hospitals

Historically keep their own paper ‘Medical Notes’, ‘Health Records’ etc and these keep records of all in-patient and out-patient stays throughout the patient’s history of visits to the hospital. These also contain all specialist visits to the hospital.

In the case of one NHS Trust regarding acute tracking of patients’ documents, all clinical documents are held within patient health record folders which use RFID tagging. The folders are manually scanned in and out of the various locations and this allows records to be tracked centrally; however it completely relies on the physical act of passing the individual record over a scanner. If this is not done the record is thought to be at its last tracked location. This has improved the tracking and locating of records but is not 100% reliable.

Some trusts have similar systems and some have none at all. An aspiration of the NPfIT (National Programme for Information Technology, also known as CfH Connecting for Health) is that all medical records would be electronic by 2014. However, in reality this will not be realised, mainly due to the costs of back scanning and the fact that the national programme is so far behind schedule. Again, some acute trusts have gone ahead independently and started scanning records but the costs run into millions of pounds. Most primary care providers already have electronic records and the aspiration is that elements of these could be shared with other health care agencies via the summary care record processes over the national spine. It is in this that some GPs have concerns over privacy and security issues. Patients have the right to opt out of the sharing of this information, but as this is already electronic, RFID tracking would not come into the scenario. In acute trusts this would be an intermediate step until all patient medical records are digitalised, and in many cases this would be far beyond 2014.

Document storage and indexing are highly competitive in developing expertise in high-tech asset management to provide added value to customers, and the use of RFID and other sensors would give a more efficient and cost effective process for locating and monitoring paper records or other assets both in the National Health Service (NHS), Ministry of Defense (MOD) and local government etc. In some hospitals they may employ up to seven staff to manage and locate medical files during daily inter-departmental movement costing around £100,000/year. With the use of RFID document tracking this cost will be greatly reduced and provide cheaper document storage together with the use of scan on demand, where a hospital only pays to have documents scanned when they need them. Lost notes in hospitals can delay treatment or have other clinical implications, and RFID tracking of notes will enable hospital staff to find patient folders quickly. Some of this Healthcare Trust has expressed interest in a system that would deliver greater real-time visibility of high value assets such as medical records using RFID technology. The technology would provide a pervasive system that will deliver real time visibility and tracking of the files associated with daily operations within a hospital and traceability without disruption or re-engineering of current processes.

6. CONCLUSION

The paper outlines the issue of the non-productive time spent by healthcare workers searching for documents relating to patient care and proposes a document management system using RFID technology to provide a tracking and tracing system in real time. A tracking and monitoring system prototype was developed using an SQL server and visual basic.net to monitor document tracking which can be accessed wirelessly anywhere in the organisation based on a NHS Health Trust study. The system uses low cost UHF (865.7 MHz to 867.5 MHz) passive tags with RF emission up to 2 Watts ERP and complies to EPC class 1 Generation 2 and ISO/IEC 18000-6C standards. As the system has been specifically designed to use low cost passive tags this allows the system to operate on room level ranges for practical application and eliminates issues of interference and battery duration which are an inherent problem of an active tag system. There have been a number of research studies which are ambiguous regarding the potential hazards of using RFID near medical devices. However, the researchers appeared to use a 2-4 Watt passive RFID system which is more powerful than interrogators typically found in existing hospital RFID deployments. Nevertheless, an EMI test needs to be conducted in a real environment to check before the deployment of any RFID-related system.

The system developed simplifies the conventional manual system which is labour-intensive and subject to errors. The RFID document management system provides automatic real time information on the location
and time stamping of documents within the organisation, eliminating unproductive staff time spent locating documents such as patient records and X-rays etc. The sensors (i.e. readers) which need to be linked to various gateways (depending on whether for partial or fully integrated systems) can be configured into the existing wireless system operating in the hospital environment. This allows access to information anywhere in the organisation providing valuable management information for resource allocation. This information can be linked to intelligent systems such as work flow management or simulation-linked to Witness Quick 3D and data mining techniques etc to provide intelligent decision making and what-if analysis.

Even though the NHS is pushing to use Electronic Patient Record (EPR) system, there are still many issues such as differences in each hospital IT systems, costs related to using EPR system i.e. IT training, system maintenance, scanning, etc, different type of medical record e.g. physical, mental records that needs to be realised in order to develop the system successfully. Importantly, the security and privacy issues needs to be resolved prior the development as confidential information of patient and would cause harm and threat if being accessed by unauthorised person. Awareness must be raised to make sure the patient understand every aspects of the system and that they have a choice whether to have the electronic records or not. The proposed Document Management System can be used while issues of EPR system are being resolved providing automated real-time document tracking. At the end of the day what we need is the system that will allow professional staffs to work promptly and efficiently in order to deliver the best care to the patients.

REFERENCES