MEASURING LEADERSHIP ROUNDING PERFORMANCE IN A HOSPITAL ENVIRONMENT USING REAL TIME LOCATION SYSTEMS

by

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Abstract

Among the major industries, healthcare accounts for over ten percent of jobs today and is continuing to grow per the surges of baby boomers requiring more care, rising costs in medicine and equipment, and current legislative changes on the national level. Hospitals are continually reorganizing processes to accommodate for the growth to the cumbersome employee base. As a result, hospitals must adopt lean concepts to remain competitive. It remains a challenge for management and leadership to gauge caregiver performance and discover where inefficiencies lie in the workflow.

To maintain quality of care in hospitals, nurse-rounding functions are adopted to provide comfort; pain management, safety, and an increase in overall patient satisfaction. The full rounding model also incorporates the leadership staff to participate in the process. Leadership rounding is pertinent to the rounding process, as it provides an element of upper management providing a more personable engagement with patients and acts as a facet to managing nursing staff the most effective rounding. Effectiveness of nurse rounding has been demonstrated by numerous surveys. One such survey known as the Hospital Consumer Assessment of Healthcare Providers, or HCAHPS survey acts as a performance feedback mechanism to measure the

patient's quality of care during their stay at the hospital. As the growth in healthcare has increased workloads for nurses and leadership, rounding may be overlooked, which in turn, reduces HCAHPS scores. Since these survey scores dictate certain insurance percentages; much is at stake. There needs to be a mechanism to track rounding in hospitals to confirm these job tasks are being completed (Cayer, 2014).

With the emerging technology provided by Real-Time Location Systems (RTLS), hospitals now have the ability to track assets, measure temperatures real-time, and track locations of staff. RTLS has the ability to monitor staff in the busy environment to find bottlenecks in workflow and monitor employee performance. However, the raw data sets are often hard to analyze and need to be converted into a form that is intelligible for managers and various stakeholders. .

The purpose of this study is to develop an RTLS rounding tool that ingests and processes RTLS data captured at a local Women and Children's hospital. This study discusses the outcomes of the implementation of the RTLS tool and describes the process of generating customizable reports that can be used by the management to monitor, change, and improve rounding behavior.

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CHAPTER 1: INTRODUCTION

Real Time Location System (RTLS) is beyond its infancy as an emerging technology. This technology uses Radio Frequency Identification (RFID), and in conjunction with Wi-Fi technology, records a reasonably accurate location of subjects and objects within an infrastructure. RTLS coupled with a location engine database server records and reports location-based data at any given time by providing an indoor positioning system for monitoring movement of objects and people. RTLS can be considered as an internal positioning system similar to Global Positioning System (GPS), where instead of using satellites to sense location, it uses existing wireless infrastructure and Radio Frequency (RF) based detection systems with accompanying sensors to report locations (Cacopardi et al., 2010).

RTLS has been adopted by various industries at a rapid rate. While the early adopter industries such as retail, shipping and distribution, and manufacturing for asset tracking have proven to show successful results with this emerging technology, there are still many candidate industries that have potential to benefit from RTLS. With various wireless technologies to facilitate such tracking being introduced in the last decade, enterprises have the opportunity to improve their resource management (Network, 2012).

Healthcare is one of the fastest growing industries today employing about 14.5 million people and accounts for 10.3 percent of jobs nationally in occupations that span the education, skills, and earnings continuum (Leventhal, 2013). With a cumbersome employee base, hospitals are constantly managing the ever-changing processes to appease the growth rate and have been constantly identifying, mitigating, and re-processing to maintain quality of care. In order to create a lean hospital environment, it would be economically unfeasible to add additional staff to physically monitor nurses' and other staff activities. Therefore, alternative automation-based, scalable, technological solutions need to be explored.

Rounding, which is one particular nurse process, has increased patient satisfaction in hospitals for some time. Rounding is defined as bedside visits by a physician, nurse, or other healthcare professional to evaluate treatment, assess current course of treatment and to document the patient's progress or recuperation (Segan, 2012). Within all wings of a given hospital, a healthcare professional regularly visits patients at routine times. These visits have different objectives depending on the type of professional executing the round. Doctors tend to evaluate the treatment of the patient by asking questions and observing the physical wellness in order to modify treatment. Nurses seek to carry out orders of the doctor and monitor progress on a more frequent basis. Nurses not only check vitals during these rounds, but also use script-like questions to obtain feedback in hopes to address the concerns of the patient. Leadership, such as nurse managers and department heads round less frequently by focusing not only on patients directly, but also indirectly from feedback from nurses they oversee.

Each healthcare professional sets different frequencies when carrying out a round. Doctors will round on a patient one to four times a day, depending on severity of the case. Nurses typically round hourly during daytime hours and every two hours at night. Leadership staff will round in their department to visit all patients in their wing at least once in a given workweek and one to four times per day indirectly to nurses they oversee in the department.

Since the late 1980s, the rounding process has improved the overall quality of care of patients by implementing a scripted strategy among nurses to provide more attention to the patients. Patients at the hospital have given control of their life and well-being to healthcare professionals. If they feel that all of their needs and concerns have not been met, they may feel powerless, thus causing anxiety. After discharge, the anxiety may resonate until the patient is mailed a post patient survey to rate their stay at the hospital. One particular standardized and federally generated survey called the Hospital Consumer Assessment of Healthcare Providers, or HCAHPS survey is used to measure healthcare providers. HCAHPS surveys are a hospital's feedback mechanism and are publically reported to draw comparisons among all hospitals. Not only do these surveys gauge patient satisfaction, but also depending on score percentages will dictate reimbursements rates; so they impact hospitals' revenue. Due to the positive correlation of increased satisfaction from rounding and increased reimbursements by public insurance, rounding has been feverishly adopted by hospitals large and small (HCAHPS, 2013).

Healthcare introduced object tracking of assets with the use of RTLS over ten years ago into its practices to manage and monitor expensive items of importance, including: wheelchairs, IVF pumps, and surgical equipment (Maliff, 2013). Loss of these items has decreased substantially due to the implementation of RTLS (Fosso Wamba, Anand, & Carter, 2013). Therefore, if objects can be tracked and monitored, RTLS could be adapted to track employees and in turn can prevent employee related losses in complex health-care settings.

The notion of tracking staff has only begun to be used for applications for monitoring job tasks. There has only been limited research regarding the use of RTLS technologies in surveillance activities (Clarke, 2001). Leadership of hospitals and the like can choose to use them to control people, or they can decide to take advantage of them to optimize their decision-making process (Guillemette, Fontaine, & Caron, 2008). RTLS is a technological candidate for monitoring the performance of hospital staff so management may make appropriate decisions to improve the competitiveness of the organization. This study addresses a need to remedy a problem in healthcare and describes a process to address the problem. Real RTLS data from the study location are processed to create a feasible solution.

1.1 Problem Statement and Research Questions

The problem that is addressed by this study is that there is no proven mechanism to accurately measure the rounding performance of leadership in hospitals, which has potential to impact patient quality of care.

The overall goal of this thesis is to investigate how to better integrate RTLS as an intrinsic part of quality improvement in patient care in the health care sector based on the findings of a comprehensive case study conducted in a hospital. Using this case study, the thesis seeks to explore RTLS technology as an effective mechanism for monitoring leadership rounding performance in healthcare settings. The findings of this study exhibit the tracking capabilities of RTLS to determine leadership staff location at given times. The tracking of leadership over a given period of time has the potential to provide a method to verify the effective completion of leadership's mandated tasks of leadership rounding. If rounding tasks are not completed adequately, management reports that describe the shortcomings of employee performance are delivered to the employees who need to address those identified problem areas.

The objectives of this study can be summarized as follows: (1) identify the mechanisms that can validate leadership rounding performance in the hospital setting; (2) develop a database tool to identify rounding performance; (3) create a reporting summary of rounding instances detected by the tool as meaningful reports to improve leadership behavior; and (4) identify the challenges in implementation, operation, and maintenance of an RTLS in a hospital.

Deriving from the research objectives, the research questions of this study are as follows:

1. How can leadership rounding job performance be monitored using RTLS technology in hospitals?

2. How can the output of the RTLS systems be integrated into various managerial processes in hospitals to improve care?

3. What are the issues and challenges in the implementation, operation, and maintenance of RTLS systems in hospitals?

1.2 Research Design

This study explores the use of RTLS in a hospital to identify instances of leadership rounding with a developed software tool. Real RTLS data was acquired from a hospital administrator to be processed through the software tool. Throughout this study, the hospital is referred to as “Hospital X” or simply “hospital” to maintain anonymity. The study location already has an existing RTLS system implemented for tracking numerous applications such as IV pumps, oxygen tanks, and hand-washing activity and will be extended for a new subject tracking application.

This study is devoted to the development of database tool to detect leadership rounding at a local Women and Children’s hospital using RTLS. If the tool is successful in round-detection, it will be implemented to improve patient quality of care. This tool will be an introductory tool for other subject tracking mechanisms in the hospital. Additionally, throughout the study all challenges of implementation and operation of RTLS are discussed for other future studies with use of RTLS as a subject-tracking tool.

1.3 IRB Approval and Consent

Approval from East Carolina University’s Internal Review Board for study of human subjects was required. An IRB approval was gained through the ECU IRB website to insure compliance with consents, risks, scope, confidentiality, and privacy. Since the study is collecting anonymous data with no personal identifiers, the IRB approval for Exempt status was granted.

The data collected shall be stored predominantly in the study location and the reports generated by the Information Systems (IS) department shall be stored in the researcher's laptop with username and password protection. The reports will have anonymous identifiers; the reports will not be distributed over the Internet via email or cloud storage. A sample report will be used as an appendix of the final thesis and no identifiers shall be noted on the document.

1.4 Significance of the Study

With present legislative moves by the US government and Affordable Care Act, healthcare provider spending has slowed drastically. According to the most recent projections, real per capita health care spending has grown at an estimated average annual rate of just 1.3 percent over the three years since 2010 (States, 2013). Spending reductions may be attributed to the lowering insurance reimbursement rates of clinical procedures, uncertainties of government legislation, and even more effective care where patients are discharging faster. In either sense, spending has dropped as healthcare prices have risen for hospitals. In order to keep costs low and to insure financial stability in a hospital, adoption of RTLS in healthcare milieu is a must for management in order to prepare for uncertain futures (Ruark, 2013).

RTLS has proven countless successful outcomes in tracking of assets and other human tracking, but specifically measuring length of time in a location to validate human performance is a new idea and lacks literature and research. A survey by KLAS Research showed that in late 2011, between 10% and 15% of U.S. hospitals were using RTLS (Terry, 2013), therefore more literature for the capabilities of RTLS needs exposure. Hospitals need to create more innovative uses for the technology to assist hospital leadership to assure staff duties are being carried out. By exploring this Hospital X's case, other hospitals will find this study useful for possible adoption to measure staff performance. Additionally, a future well-defined protocol or method may be established and scripted into RTLS applications for measuring performance of nursing staff or in cases where other facilities with large staff conglomeration and monitoring of staff performance is a challenge. If lean principles are applied to healthcare based on these findings, hospital survey scores may improve, and in turn provide maximum reimbursement from public insurance.

RTLS has been used in many applications, mostly with tracking assets in facilities. Other healthcare organizations are taking wireless RTLS a step further by tagging doctors, nurses, patients and equipment and then tracking the interaction of all the players and resources to build a highly-accurate profile of a patient's course of treatment (Wang et al., 2013). Even though modulating a full course of treatment with RTLS is an emerging notion, this study will assist other research in the capabilities of tracking hospital personnel as gainful for the capabilities of RTLS' ability to track human performance.

1.5 Thesis Organization

This thesis is organized into five chapters. The first chapter contains an Introduction, briefly describing the state of RTLS in healthcare and motivation of the study. Also included in the chapter: descriptions of a brief methodology, research objectives, and significance of the study. The second chapter contains a review of the literature relevant to the study. The third chapter contains the methodology where explained in full, the process of which data is collected and the detailed design of the software tool. Chapter four provides results and analysis of the processed data through the tool to exhibit outcomes of the application and reporting. Chapter five will conclude the findings of the study and include recommendations for the hospital.

CHAPTER 2: LITERATURE REVIEW

In this chapter, review of literature supporting the study will be exhibited. In section 2.1 the term rounding is described and its importance in hospital environments for patient quality of care are discussed. Section 2.2 provides in-depth analysis of the RTLS technology and its applications in hospitals together with an account of the related applications found in the literature.

2.1 Rounding

In healthcare settings, nurses endure a very stressful and dynamic workload. From answering call bells to managing routine procedures, meeting the individual needs of patients present an overwhelming workload that often needs to be completed during 12-hour shifts (Turner, 2013). Hospitals have struggled to continuously improve their patient satisfaction due to the staffs' intense and stressful workload often shown in post-outpatient satisfaction surveys. Patients require a standard fundamental care procedure to meet minimal requirements of the hospital, including: medication management, vital checks, Electronic Medical Record updates, and other caregiving. While the defined minimal care procedures are required, it is challenging to meet those standards without increasing staff or workloads and possibly reduce patients' call bells to summon nurses (Gwiazdowski & Hall, 2012).

In an attempt to improve patient care, rounding was developed to create an environment of department care staff to meet the needs of patients by periodically checking on patients using well-defined questions to assess the patient's needs. Rounding is not limited to just nurses, but also incorporates unit managers, leadership staff, and even unlicensed staff (Hutchings, 2012). By increasing frequency and attention to patients, patients tend to ring the call-bell less and patient safety increases (Davies, 2013).

2.1.1 Rounding Overview and History

The concept of rounding is not new. In the late 1980s, a medical center in Birmingham, AL, began seeking a strategy to reduce call bell instances. The lack of attention given to patients produced an increase in complaints and therefore introduced a proactive approach to address patients needs well before they asked for it (Davies, 2013). Rounding is not simply periodically walking into a room asking, "how are you doing today." Rounding relies on a script generated by leadership skilled in rounding to include more patient feedback promoting questions with these guidelines dubbed the Four P's (Woodard, 2009):

- **Pain** – asking patients to describe their pain level, typically on scale of 1-10, and completing pain mitigation tasks to help.
- **Potty** – asking patients if they have been to the restroom, or scheduling applicable times
- **Position** – assessing and assist in the physical comfort of patient
- **Presence** – assessing bed is at correct height, supplies are reachable, call light within reach.

The above 4-P's are the core parts of a nurse round, but may deviate slightly from hospital to hospital. A nurse enters a patient's room and follows a generic script such as this:

1. Introduction: "Hello Mr/Mrs/Ms (name of patient). I am (name of nurse). I will be your nurse for (time frame). I, or another member of our team, will be making rounds every hour to make sure you have what you need".
2. Positioning: "Would you like help with changing your position and are you comfortable?" NOTE: Make sure the call light, telephone, TV remote, bed light, tissues, etc are in patient's reach. Accommodate patient.
3. Potty: "Do you need help with going to the bathroom?" Accommodate patient.

4. Pain: "How is your pain on a scale of 0-10?"
5. Presence: "Is there anything else I can do for you?"

The nurse completes the above script, meets the needs of the patient, and proceeds to the next room.

In order for rounding to produce desirable outcomes, the entire nursing team must participate in the procedure by making visits to patients individually and proactively. Nurses, nurse managers, doctors, and other senior healthcare staff must adopt a rounding model that suites the hospital's mission. Many rounding models have been adopted, but the typical model requires four essential staff adherences (Hutchings, 2012):

- Education delivery to nurses
- Leadership rounding on patients
- Senior leader rounding
- Hourly rounding on patients

A nurse needs to be educated on the script and procedure to complete a round. Direct-care staff such as nurses needs to complete rounding once an hour. In addition to nurses, leadership staff and senior leaders need to participate in rounding. Otherwise, the desired outcomes may not be produced (Hutchings, 2012).

Similar to nurse rounding, leadership and senior leader rounding assists the rounding process in several ways. Firstly, leadership staff makes various patient contacts in their wing to act as an upper-level administrator to engage with patients. Patients interact with nurses all the time, but when a senior leadership takes time to be attentive to a patient, this shows genuine care from the hospital. (Hutchings, 2012). Secondly, leadership visits their governing wing to coach nurses on their performance to assist in staff development. Nurses may visit a room and complete the rounding script; then a leadership staff may evaluate and provide feedback to nurses to improve the task. Subsequently, by leadership being attentive to patients as they round, they also provide attention to the subordinate nursing staff. Baker (2010) explains, “leader rounding on staff is the single best way to raise nurse satisfaction and loyalty and, ultimately, attract and retain high-performing nurses.”

2.1.2 Outcomes to Improve Quality of Care

One important process that supports a hospitals’ mission of continuous quality improvement is to monitor patient feedback via surveys. Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) is a standardized post-admission survey, which is the first national, standardized, publicly reported survey of patients' perspectives of hospital care initiated by the Centers for Medicare and Medicaid Services (CMS) (HCAHPS, 2013). These scores provide a rudimentary gauge to measure the quality of most hospitals’ facilities and various caregiving practices. The intent of the HCAHPS initiative is to provide a standardized survey instrument and data collection methodology for measuring patients' perspectives on hospital care.

The HCAHPS survey gauges the following hospital care concerns during the patients stay (HCAHPS, 2013):

- Communication with doctors
- Communication with nurses
- Responsiveness of hospital staff
- Pain management
- Communication about medicines (side effects and options for prescription filling)
- Discharge information (follow up examinations)

- Cleanliness of the hospital environment
- Quietness of the hospital environment
- Transition of care (explanations and guidance from inpatient to outpatient services)

Continuous improvements and maintenance of scores hold many stakes. Not only does the HCAHPS score provide a feedback mechanism for rating quality of care delivered and a publicly reported documentation, but also government-paid insurance reimburses hospitals based on this score. Hospitals currently receive a baseline reimbursement of 70 percent of possible reimbursements no for all inpatient treatment. The remaining 30 percent that a hospital may be eligible for is dictated by the quarterly gross HCAHPS feedback scores received from their treated patients. These scores place a hospital in a certain tier or star rating; the higher the tier, the more reimbursement. CMS began requiring hospitals subject to the Inpatient Prospective Payment System (IPPS) annual payment provisions to report HCAHPS data publicly to receive their full IPPS annual payment update (Group, 2012). The IPPS is the plan used by CMS to provide incentives to hospitals to urge patient quality of care.

The rounding procedure has shown countless successful outcomes to improve quality of care in hospital inpatient settings. Most hospitals use HCAHPS survey scores as a practical instrument to gauge baseline and post-rounding implementation outcomes to recognize increases in percentage outcomes. As an example of how rounding improves HCAHPS, the Cleveland Clinic's Heart and Vascular Institute has seen its scores for the HCAHPS staff responsiveness composite increase from a top box score of 55 percent in the first quarter of 2009 to 68 percent in the third quarter of 2011—improving revenue by millions (Group, 2012).

Provided nursing staff are rounding effectively, with incentive-based management techniques, proper education, and accountability, the facility's HCAHPS scores should be in a desirable mean of 9 out of 10. Having such a score is considered a "top-box" score (HCAHPS, 2013).

2.1.3 Rounding Deficiencies

Although rounding has proven to be a successful procedure for increasing the overall patient's stay in a hospital, it is possible the procedure is not actually being administered correctly amongst all shift nurses in a given wing. Responsibilities of nurses can be overwhelming, with perpetual nurse care among acute patient needs. Effective rounding requires a good and caring attitude (Gould, Gelb, Housham, & Hogg, 2012). However, ineffective rounding may be attributed to several reasons. One reason is that a nurse may be apathetic and languidly checking in on patients and not completing the entire "four-P" procedure. Time demands of nurses may be another evident reason Halm explains, "Nurses extensive time demands of documentation and how the additional requirement of rounding documentation may breed resentment and wavering adherence" (Halm, 2009). Nurses may be delivering the procedure incorrectly with lack of time in the room, not asking correct questions, not responding to the needs quickly and/or not following through with patient needs, lacking integrity. Many staff members may be resistant to this program initially because they fear they will have an increase in workload (Davies, 2013). As rounding success is contingent on nurses partnering with supportive personnel who possess highly effective communication skills to prevent nurses from becoming overtaxed in hourly assessments a skill mix of healthcare personnel must be considered (Neville, Lake, LeMunyon, Paul, & Whitmore, 2012). Whatever the case may be, one ineffective nurse on the shift team may provide incorrect rounding and alter the patient's perception enough to hold all nurses accountable for the negative care (Patrick, 2013).

2.1.4 Nurse Perceptions of Rounding

Hourly rounds, defined as the intentional checking on patients at regular intervals, have re-emerged as a standard practice initiative among nurses in acute care settings. The literature is highly supportive of patient rounding as an appropriate, safe, and useful practice, yielding substantial nurse and patient benefits, yet debate among nurses remains (Neville et al., 2012). With many successes, perceptions of rounding of caregivers must not go unnoticed. Nurses do agree that the idea of rounding is applicable and an ideal way to improve patient satisfaction efforts. "A predominant theme was that rounding was perceived as an important and valued practice, as evidenced by the following statements: (1) I believe rounding is an effective way to meet patient needs in a timely manner and to reduce call bell usage; (2) Rounding is extremely important; to round on your patients should be part of every nurse's practice" (Neville et al., 2012).

All in all, rounding creates better hospital care; but with the entire complex nursing job duties, rounding be a low priority. Emerging technology, like RTLS, may provide the solution management is looking for to validate rounding performance.

2.2 Real-Time Location Systems in Healthcare

A new developing technology in healthcare to monitor and increase process improvement is the implementation of RTLS. Real-time location systems are local systems for the identification and tracking of the location of assets and/or persons in real or near real time. RTLS consists of specialized fixed receivers and readers (location sensors) reviewing wireless signals from small ID badges of tags attached to objects of interest and/or persons, to determine where the tagged entities are located within a building or some other confined indoor space (Kamel Boulos & Berry, 2012).

RTLS systems assist management with the ability to quickly locate and track objects and subjects of importance (Sutter, 2013). The tags (or badges) are based on a hybrid wireless technology, in that they receive and transmit on wireless and radio frequencies. The tag receives RF frequencies from a sensor and combines its ID number with the detected sensors ID number. The tags then transmits this data to the wireless network infrastructure with location accuracy within meters (Ekahau, 2014). The time and location data is delivered to a database and used by numerous applications for administrative use.

Real-Time Location Systems has assisted many industries to improve processes and track objects of importance. Long supply chains use RTLS to find length-of-time an object resides in a particular location in order to identifying bottlenecks, thus assisting in improving the distribution times (Yujie & Lihua, 2010). Hospitals began using this concept to begin tracking patients to identify bottlenecks in emergency rooms. The objective was to decrease patient wait times (Laskowski-Jones, 2012). As the technology has demonstrated positive outcomes, other systems and applications for RTLS have emerged. RTLS is growing in popularity in the healthcare field because of opportunities it can bring. Below are a few major uses of RTLS in healthcare today (Mattie, 2013):

- Equipment Tracking
- Continuous Monitoring
- Patient and Staff Safety
- Patient Flow and Throughput
- Infection Control

Many hospitals choosing to adopt RTLS tend to deploy scalable systems to first track objects. Once benefits are proven, projects involving tracking of human subjects soon follow (Kamel Boulos & Berry, 2012).

As stated before, RTLS was used to track objects such as wheelchairs, IV pumps and oxygen tanks. These items tend to become displaced in other areas of a hospital, causing frustration amongst staff in different departments. Staff now have the ability to quickly locate RTLS-tagged objects and retrieve them (Kamel Boulos & Berry, 2012). Wheelchairs have been a primary object of theft in hospitals and RTLS has prevented these instances of theft (Fisher & Monahan, 2012). IV pumps are among of the most expensive devices in a hospital wing, thus limiting the amount of only two or three pumps to share among numerous patients (Kamel Boulos & Berry, 2012). Being that IV pumps are difficult to locate when needed, it has been discovered nurses are "hoarding" these devices in closets so other nurses do not take them (Cameron Lawrence, 2013). These pumps may also be tagged and then easily located so caregivers can spend more time serving patient's needs instead of seeking out these missing devices.

Employees at hospitals do encounter irritated and dangerous patients; especially with mental disorders in the emergency room and mental health wards (Anonymous, 2008). Wi-Fi enabled RTLS tags offer a "panic button" feature that can be pressed during an assault or dangerous situation, thus prompting security personal with an incident alert. The exact location of the event can be observed on a real-rime map to facilitate immediate response (Malik, 2009).

Hand washing among caregivers can be neglected, either by sheer apathy or by busyness. Infection rates in hospitals are not necessarily rising, but should be improved. RTLS has been used to improve infection rates by prompting caregivers to wash their hands when going from wing to wing (Poshywak, 2013). When a nurse transitions from one wing, the RTLS badge emits a sound to prompt for a hand-washing event. The nurse proceeds to wash his/her hands at the RTLS-enabled soap dispenser near the sink, thus disabling the noise emitting from the badge. On the contrary, if the nurse is too busy he/she may opt out of a hand washing and press the button on the RTLS badge to manually stop the alert. These instances are collected in the RTLS database and used for process improvement.

2.2.1 Overview of RTLS and Equipment and Functionality

Acting as an internal infrastructure GPS, RTLS setups require an array of components to function in the locations of importance. Systems may vary with regards to frequencies and hardware, but the following components are typically required for the system to function (Malik, 2009):

- **Tags** – Small mobile devices that are attached to an object or subject for tracking. The tags may be in the form of a badge, wristband, or a chip where they are physically attached to the item of importance or carried by a subject. These tags are RFID and may be active or passive, but in most cases for RTLS, active tags are desirable. Active tags transmit location data to a server database over the existing wireless LAN. Tags may differ cosmetically depending on subjects being tracked. Figure 1 shows a staff badge and patient tag for hospital settings.

Figure 1. Staff Badge (left) and Patient Tag (right). (Centrak, 2013)

- **Location Monitors** – Devices strategically located throughout a facility to emit RF signals with location data to tags and then is relayed with the tags' ID over the WLAN to database servers. There are two types of monitors used depending on RF and spatial requirements. Monitors are omnidirectional and are typically installed in hallways and at room levels where tags only need to sense the modules and acuity is not a factor (Fig. 2). Virtual wall monitors are another form of monitor that are directional and create sensory thresholds to limit its detection range. Application of a virtual wall is useful when multiple sensory locators are in one room, (such as multiple beds in one room) and tags only need to be associated with one monitor and not conflicted by two monitors at once (Fig. 2).

Figure 2. Omnidirectional RF Location Sensor (left) and Unidirectional RF Virtual Wall Monitor (right). (Centrak, 2013)

- **Access Points** –Hardware placed throughout the facility the tags connect to wirelessly to send location data over Ethernet using IEEE 802.3at PoE. These access points can also be known as Stars, using 900MHz frequencies in lieu of 2.4GHz WLAN access points (Fig. 3).

Figure 3. Centrak Star (Access Point) (Centrak, 2013)

- **Location engine** – Software that communicates with tags to distribute location information to the WLAN.
- **Middleware** – the software that resides with the pure RTLS hardware and the business application to create the value of the technology. Applies raw data to other applications to provide meaningful data reports that the user can use for industry applications.
- **Application** – the interfacing software the works with the middleware to perform the desired job the user needs. Applications may display maps, time and location reports, triggers, and other tag interactions results.

To meet the requirements of different applications, whether they need precise location or room-level location, various RTLS solutions are available that can report tag location at different resolutions (Kamel Boulos & Berry, 2012):

- **Presence-based locating** – Locating RTLS returns tag location as to whether it is present in a given (relatively wide) area.
- **Locating at room level** – Locating RTLS returns tag location as present in a specific room, e.g., if a nurse presses the panic button to summon security assistance in the event of a physical attack on her, the location engine reports the nurse's exact room in the hospital to the security personnel.
- **Locating at sub-room level** – Locating RTLS locates tag to a specific part of the room, e.g., in hospital rooms accommodating multiple patients, such as dual-bed rooms and larger wards, if nurse is wearing tag, the location engine can report how much time the nurse has spent by each patient's bedside or cubicle.
- **Locating choke points** – Locating is returned by a specific choke point or threshold, such as a doorway to a room; it is assumed that tagged subjects or objects move from one area to another. Also, by monitoring the time a tag was detected at specific points, one can determine the direction the tag is moving.
- **Locating by associating** – Locating is returned as proximity with respect to another tag, e.g., if each patient in a hospital wears a tag and each IVF pump has a tag, the location of a given IVF pump can be returned as present next to a specific patient and how long.
- **Locating precisely** – Locating the exact tag location is pinpointed precisely on a map of the facility and reported as absolute or relative to a sensor.

2.2.3 Benefits of RTLS

There have been many successful outcomes with tracking assets in hospitals, thus saving hospitals from loss. Nurse hoarding has been improved with the use of RTLS. With use of RTLS tagged devices in hospitals, items are easily found visually on a live location map. By pinpointing locations of the equipment, the healthcare centers can make better use of supplies, reduce rental costs and improve delivery times" (Wang et al., 2013)

Patient care is the primary objective of most hospitals. RTLS creates a way to visually see workflow and patient flow in a hospital. New applications of RTLS for tracking patients, nurses, doctors, and other hospital staff are not only developing quickly, but creatively. If a milestone isn't completed or is taking longer than usual, it's tracked retrospectively. RTLS helps fix chronic workflow problems in real time, so that staff can intervene for the patient (Gardner, 2013). Patient throughput from admission to discharge is now being streamlined, but RTLS also assists hospitals and other care facilities in addressing safety concerns of patients.

Tracking Alzheimer's, dementia, and other mentally ill patients has been tested numerous times for assisting facility personnel in finding patients that may be forgetful in their location. Like an assistive technology, the system tracks all the patients instantaneously in real time and helps in analyzing patients' movement for enhancing their care management. As a general result, RTLS relieves the caregiver's burden and enhances patient's safety by close monitoring of the wandering movements of the patients in real time. Additionally, nursing homes have found RTLS useful in monitoring patients lack of movement in a reasonable amount of time as staff does not have to unnecessarily disturb the elderly in their rooms; only having to monitor the RTLS computer application for movement (Laskowski-Jones, 2012).

The overall workflow of nurses and facilities services in hospitals has been implemented at a slightly slower pace. Initial concepts were to improve processes by exposing bottlenecks. To analyze the workflow in hospitals, a number of researchers focused on developing metrics that measure the employee performance in healthcare. For example, Black (2013) analyzed the performance of a hospital's custodial staff and developed statistical means that identify the required time to clean a patient's room after discharge and furthermore, used those means as a performance measure of cleaning staff (Black, 2013).

2.2.4 Disadvantages of RTLS

With any emerging technology, there are malfunctions. RTLS technology became strengthened with thanks to numerous years of asset tracking in supply chains. The levels of accuracy, interoperability, maintenance cost, and interference all must be carefully considered when tracking staff for performance.

When considering the location accuracy of the staff, badges must be on the staff and hung externally, such as from a lanyard, for optimal accuracy. The operation frequency is 900 MHz and cannot easily be interrupted by moving assets (carts, beds, equipment) or human bodies that obstruct the path between the tags and APs (Wang et al., 2013). Staff may put badges in their pocket, decreasing reliability, however in such cases, management will easily see such issues as the item will be shown in red on the application as a live badge that has not moved for some time. Provided the correct number of sensors is implemented, the system is tested for maximum accuracy during deployment and will provide indispensable location data.

The usual method of deployment is to first select a hardware vendor. Hardware uses MSP430 MCUs from Texas Instruments and interoperates with most software vendors, as applications are built on the hardware like any IT-related platform (Instruments, 2012). The hardware standards are submitted to International Organizations for Standardization (ISO) to reduce numerous protocols and create an industry standard (Wang et al., 2013). There has to be a collaboration or interoperability strategy when choosing an RTLS system based on hardware (Tagging Highway) and software (workflow) applications (Bandi, 2011).

Cost to maintain the system is usually not an aggravating factor. Sensors' fail rates are similar to any networking equipment and may easily mitigated upon discovery. The typical maintenance issues of a badge are the batteries. Batteries are rechargeable similar to charging a mobile phone, but is a low-power consumption technology that lasts for several years (Instruments, 2012).

As with any radio frequency and or Wi-Fi technology, there is the concern for interference via signal propagation, metals, water, people, and radio signal collisions and not every environment is suitable for RF systems (Kamel Boulos & Berry, 2012). For healthcare facilities, this is a mild concern, but notifications for signal loss is collected and easily mitigated by management.

2.2.5 RTLS and Round Detection

The first study to complete a comparative analysis of RTLS and accurately detecting time in a location was conducted by Jones and Schlegel (2014) who created a simulation to test RTLS in a hospital environment by measuring validity of RTLS in measuring time in a location such as a room and using a stopwatch during the same time frame(s). Efficacy of RTLS time-use estimates was assessed in conjunction with the RTLS installation and calibration process and involved simultaneous collection of time-use data in a simulated setting with two methods: RTLS and direct continuous observation. Their comparisons demonstrated superior agreement with direct observation and RTLS with 95% accuracy. Their study also demonstrated the accuracy and capabilities of RTLS in healthcare to measure a subject's time in a location and the ability to create reports for analysis.

A patent was granted for Hill-Rom Services September 2014 for a caregiver rounding with real time locating system tracking. The patent's description discloses a tool design that successfully detects rounds in hospital environments with RTLS. Although RTLS can detect a subject at a place at a given time, the tool's design incorporates the need for a threshold of time to constitute a rounding interval; simply walking into a room for a brief time may not be considered a round (Girardeau, Walton, Davidson, & Dezelon, 2014).

Synapse Wireless, another software vendor, has been functioning as a pioneer for new applications in healthcare and RTLS. Their software complies with many RTLS hardware platforms and does not have an application to detect rounds, but does have a rounding module. The tool is a prompter of rounds with a map indicating all rooms in a wing. Initially all rooms are set to green, indicating no round is required. All rooms have a configurable round timer set to one hour. As the timer reaches fifteen minutes, the room changes to yellow. Nurses may see color change and soon thereafter complete a round with the patient. Once the nurse crosses into the room with his/her RTLS badge, the system detects it and resets the room to a one-hour countdown and indicated by green; starting the process over again (Wireless, 2013).

One study successfully piloted a rounding project with use of RTLS. This study specifically reported time intervals of physicians and their rounding habits. Using RTLS data from eight doctors for a nine week period, the study accurately provided rounding times versus other administrative time percentages in the study period (David R Ward, 2014).

More research needs to be generated as Girardeau (2014) suggests his patent description stating, "Accordingly, there is room for improvement in healthcare information technology systems from the standpoint of patient rounding." The prior research shows the importance of rounding and that there is no feasible way to measure if caregivers are completing these tasks. Nurses and doctors tend to round regardless, especially since rounding is a billable event. However, the leadership staff component is essential to the rounding model's success and to ensure quality of care. The research also shows other software tools that have the ability to detect rounds with physicians using time intervals.

The literature describes the rounding model in hospitals and emphasizes its importance. All hospitals have adopted rounding as a part of their care processes and within this model the leadership component may be neglected. Since HCAHPS survey scores could be improved if leadership did rounds, hospitals need to identify if all staff is included in the rounding process. The aforementioned tool described could be a tool to test in this study, however the vendor would not supply it for use. This study explains the design of a software tool with similar objectives in order to meet the need for the hospital--to detect leadership-rounding durations with RTLS. The next chapter provides the method of a tool design.

CHAPTER 3: METHODOLOGY

In this chapter, the hospital's implementation and functionality of its RTLS system is described and the design of a software tool that processed the RTLS output. The chapter begins with a description of the hospital's RTLS hardware and software. Next, a description of the study environment and the explanation of the method of how the data is acquired follows. Finally, the process for using the software tool for managerial purposes is explained.

3.1 Technical Functionality and Application

The hospital is currently using Centrak RTLS hardware devices of which most RTLS software vendors can utilize for their applications. The system follows the similar template of RTLS functionality where, tags, monitors (sensors), stars (access points), and an Integration Server are intricate parts of the system. Table 1 below describes the technical attributes of the Centrak RTLS Hardware deployed in the study location.

Table 1

Centrak RTLS Equipment and Specifications

Item	Dimensions	Frequency	Positioning
Tag/Badge	2" x 3" x .3"	Gen2IR & 900MHz Wi-Fi	Carried with Staff
Monitor (Sensor)	7" x 3"	Gen2IR (Omni directional)	Room Level
Monitor (Virtual Wall)	3" x 7" x 1.5"	Gen2IR (Uni directional)	Direction-specific, usually to create thresholds
Star Access Point	8" x 8" x 2"	900MHz Wi-Fi	Centered throughout hospital floor to create coverage footprint

The system requires a bridge of mediums to transfer the raw data to a server where applications may then use data for applicable uses. Among the mediums, tags are a hybrid wireless technology using Radio Frequency (RF) and Wi-Fi (IEEE 802.11) and may differ in hospital settings depending on what subject is being tracked. The tag itself is the bridge of the RF and WiFi frequencies for transmission of data. Unlike passive RFID systems, these tags are considered active RFID, where there is an actual transmission of data from the tag and not just ID detection. Once the tag senses an RF location monitor or sensor, the location monitor's ID is captured by the tag and sent with the tag's unique ID. This small data set is sent over WLAN to an access point or over a 900MHz Centrak Star to then be communicated through the LAN. The dataset is then appended to the RTLS SQL database server.

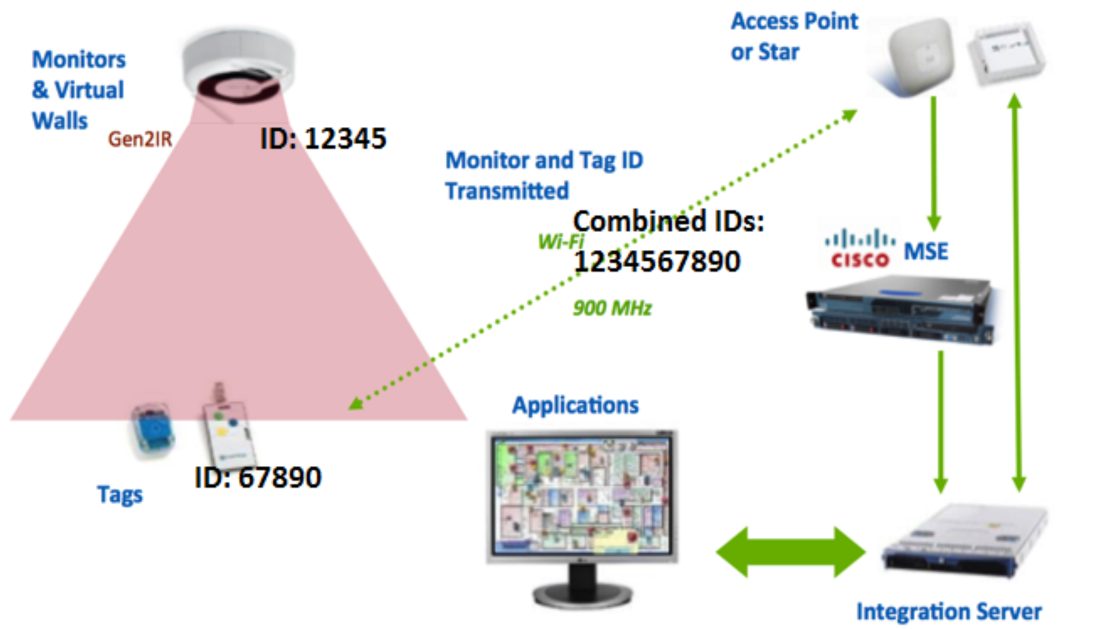


Figure 4. RTLS Flow Chart.

Figure 4 above demonstrates the flow data of a Centrak RTLS system. The Monitor ID and Tag ID are combined and communicated over the WLAN to a database server (Centrak, 2013).

The system is tested and tuned for optimal functionality. For asset and human tracking, badges (tags) are distributed and attached to the staff being tracked and converged to the network. The data set of the tag's ID and monitor's ID is sent to the location server and inserted into a table in the SQL database with timestamp along with other relevant data (Fig. 5). The table includes:

- **SNo** – Primary Entry key of database.
- **TagId** – Tag's Unique ID.
- **Count** – The number of associations the tag has made in a given time.
- **IRId** – The number of connections the Monitor has made in a given time.
- **MonitorId** – Unique ID of Monitor or Virtual Wall.
- **AStar** – Star ID the tag transmitted data to.
- **Version** – Tag version.
- **Button** – If tag's button(s) was pressed manually.
- **Rssi** – Strength of signal.
- **Time** – Timestamp of received data set.
- **WifiMacID** – 802.11 access point ID (if using instead of a Star)

SNo	TagId	Count	IRId	MonitorId	AStar	Version	Button	Rssi	Retry	Time	WifiMacId
1182	411985	1637	214	99729	136	[166]-TAG		-10...	1	12/10/2013 15:50:07	
1183	411990	1670	531	117177	264	[166]-TAG		-95.0	1	12/10/2013 15:50:40	
1184	412000	1556	928	118901	451	[166]-TAG		-88.5	1	12/10/2013 15:48:46	
1185	412011	1535	829	118491	354	[166]-TAG		-68.5	1	12/10/2013 15:48:25	

Figure 5. Raw RTLS Streaming Database Table. (Centani, 2013).

The data is collected and indexed perpetually in the location SQL database, and queried for software applications. Software applications may then utilize the time and location data and funnel it into prefabricated maps based on the floor plans of hospitals. Once the sensor and badge IDs are transmitted to the application, the generic location of the badge is displayed on these maps providing a visual representation of a caregiver. Figure 6 below shows a sample of

Awarepoint's RTLS maps depicting an icon of a caregiver in a room based on the last detected location retrieved from the SQL database.

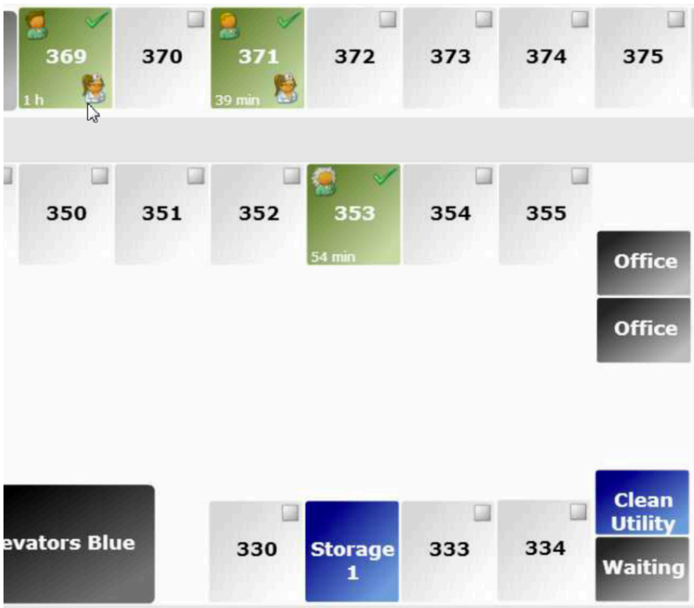


Figure 6. Awarepoint's Caregiver Location Map.

3.2 Study Environment

The hospital has an RTLS system that was in place before this study started. The system has been used to track objects of importance. The hospital has also recently begun to track caregiver staff to improve quality of care. Since the hospital has improved many processes with the use of RTLS, the hospital has begun pilot projects to use the system to its full capacity.

The specific wing of the hospital chosen for this study was the Women and Children's hospital. This particular division serves children and expecting mothers with regards to prenatal care, newborn delivery, children intensive care, and newborn care. The hospital has seen a slight decrease in HCAHPS survey scores over the last year. Since the hospital has RTLS enabled in the wing, it decided to target this wing for rounding validation of the leadership staff. If the leadership staff is in fact rounding, RTLS will be able to detect this behavior.

The hospital contains approximately 50,000 square feet and has 60 rooms. The total dedicated caregiver staff of the location is 76; including doctors, nurses, nurse managers, and administrators. Other hospital personnel cycle through the wing, but are not included in the total. The healthcare provided in this wing is deliveries of newborns, neonatal intensive care, and other specialized units for children care. RTLS areas of interest include patient rooms, hallways, elevators, offices, and nurse common areas. Because it encompasses such a large area and provides care for many patients, this location was an ideal candidate for round detection.

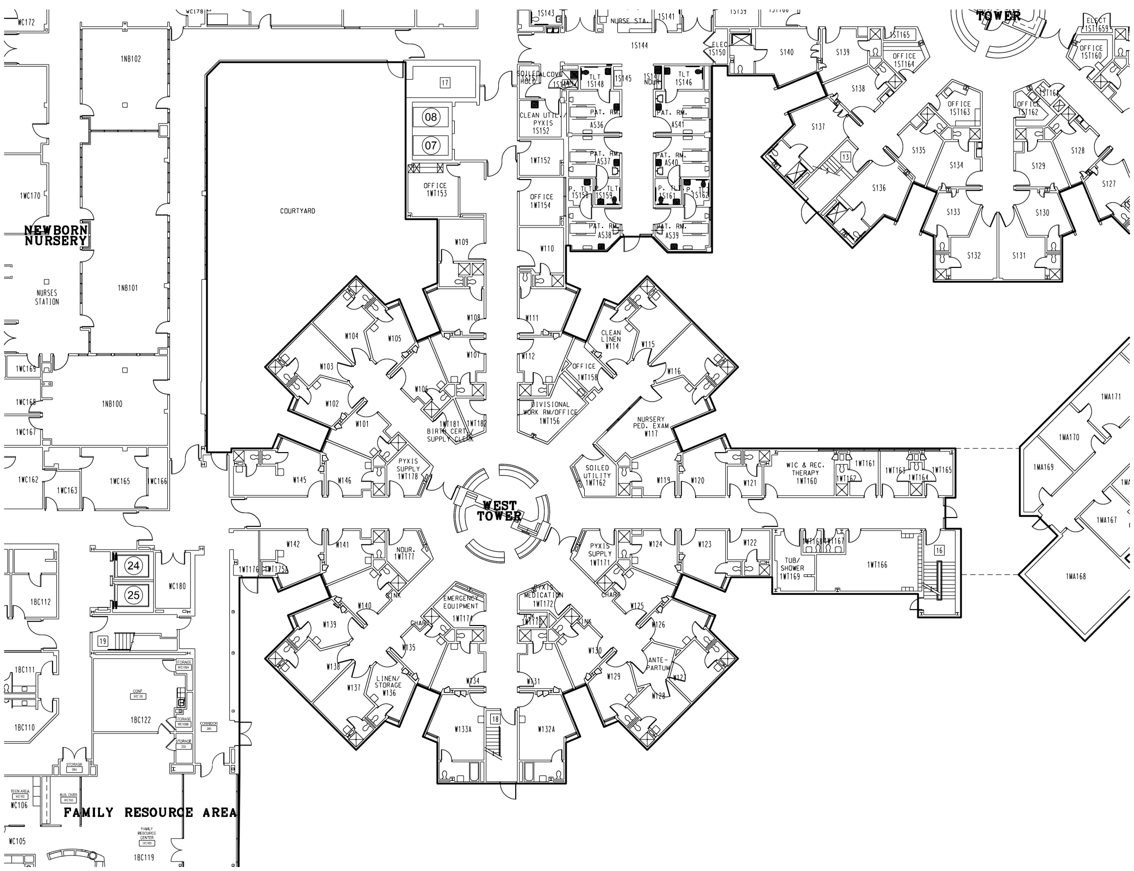


Figure 7. Women and Children's Hospital Wing Map.

Figure 7 illustrates an overview map of the Women and Children's Hospital. The stars (access points) and monitors (RF sensors) have already been deployed, configured, and tested for the project. The entire hospital is RTLS enabled with a total of 306 stars for the 900MHz wireless data transmission and a total of 243 monitors for the badges to detect locations. The study location of the Women and Children's hospital includes 12 stars and 65 RF monitors.

Figure 8. Star Locations Map with Wireless Footprints.

Although the badges have the ability to connect to the existing WLAN, the hospital chose to deploy stars solely used for the RTLS badge data transmission. Figure 8 above depicts the physical star locations in the hospital wing. The wireless footprints overlap idyllically, providing adequate signal coverage.

Monitors (sensors) must also be configured sufficiently in every room or other common area. Figure 9 below shows the location of all monitors in the study location.

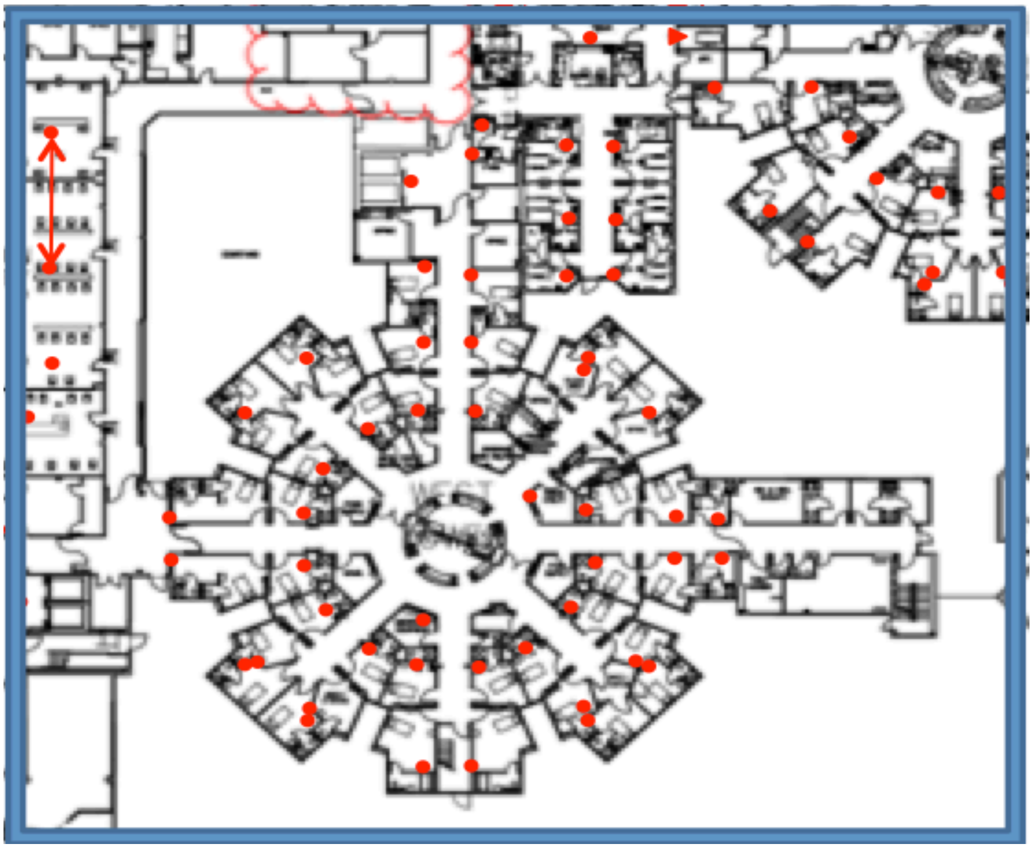


Figure 9. RF Monitor Locations at Room Level.

3.3 Data Acquisition Process

Other than doctors, the general nurse-rounding model includes nurses and the leadership. For this project, the leadership is the population that is studied and this target population includes nurse managers and vice presidents of the wing. A total of five participants wear RTLS badges identified by a six-digit tag number. As an identifier of the data, the tag number is displayed in all datasets and reports along with the subject's staffing title. Time and location datasets collected are retrospective for a period of three months, starting with May 2014 and ending July 2014.

The data for this project was collected from a local hospital and proxied from the Project Manager (PM). At the end of each month, the PM queries the RTLS database for the time and location presented in a 2-column table. The dataset was given to the researcher for analysis and later distributed back to the PM for feedback.

In order to access the 2-column dataset, administrative access to the SQL database must be obtained. The vendor Awarepoint would not allow direct administrative connection privileges to the SQL database, but Awarepoint's application generates a basic 2-column time and location report to be copied and pasted into MS Excel. Although this data was not collected directly from the database, it provided an adequate amount of detail and precision for the detection of rounding instances.

Basic RTLS data is predominantly a dualistic set of time and location. Times are in mm/dd/yyy hh:mm format in the first column, while the second column of the dataset has a labeled hospital-predefined locations. These locations were assigned to the RF Monitors by the hospital during the deployment of the system.

Tag - 235247	**Asst. Nurse Manager**
Last Location Change	**Location**
03/02/2014 01:50	z_Newborn/PACU West Hallway
03/02/2014 14:26	z_Newborn/PACU West Hallway
03/02/2014 17:22	z_Newborn/PACU West Hallway
03/03/2014 08:34	z_Newborn Nursery Hallway
03/03/2014 08:34	z_Newborn Nursery Hallway
03/03/2014 09:06	z_Newborn Nursery Hallway
03/04/2014 00:00	z_Newborn/PACU West Hallway
03/04/2014 12:18	z_Newborn Nursery ROOM1
03/04/2014 12:18	z_Newborn Nursery ROOM1
03/04/2014 12:30	z_Newborn Nursery ROOM1
03/05/2014 08:44	z_Newborn/PACU ROOM3
03/05/2014 08:59	z_Newborn/PACU ROOM3

Figure 10. Time and Location Dataset.

Figure 10 shows an example of the 2-Column Time-Location Dataset that is generated from the Awarepoint middleware report. The left column shows the time format with date and the second column shows the hospital's labeled locations. Tag identification number and staff's position are also added for identification purposes.

Before the real data was used for the study, a functioning application tool was designed with MS Excel and was tested with random data that emulated the actual input to ensure desirable functionality. The test results indicated that the tool measured rounds correctly. This ensured that the system produced reliable output when it processed the real data collected at the hospital. The rest of this chapter explains the process of how the rounding tool was designed.

3.4 Developing a Functional Tool to Track Rounds

This section describes the development of a tool to identify time durations of staff in a specific location using RTLS. If a staff member is wearing a functioning RTLS badge, time in a specific location was measured, thus aiding in the identification and determination of a rounding event.

3.4.1 Cleaning Data

As mentioned before, the data collected from the Project Manager at the hospital is considered raw data. In a full deployment scenario, raw data is ideally queried directly from the SQL database table, of which this study did not have direct access to. In order to obtain a 2-column time-location dataset from the SQL database table, a simple report had to be generated from the middleware application that did have administrative access to the time and location tables. In this case, the Awarepoint RTLS reporting agent had the capacity to generate this desired dataset. This dataset had the essential components for software tool development.

The only caveat with middleware data is that it must be copied and pasted from the Awarepoint report, into another table application such as Microsoft Excel; which interprets the time column as *Text*. Simply changing to *Text* format into *Time* format in the column did not function appropriately. The *Time* column formatted mm/dd/yyyy hh:mm as *Text* must be cleaned using simple logic statements. Two steps were required to clean the data to make it usable for calculations.

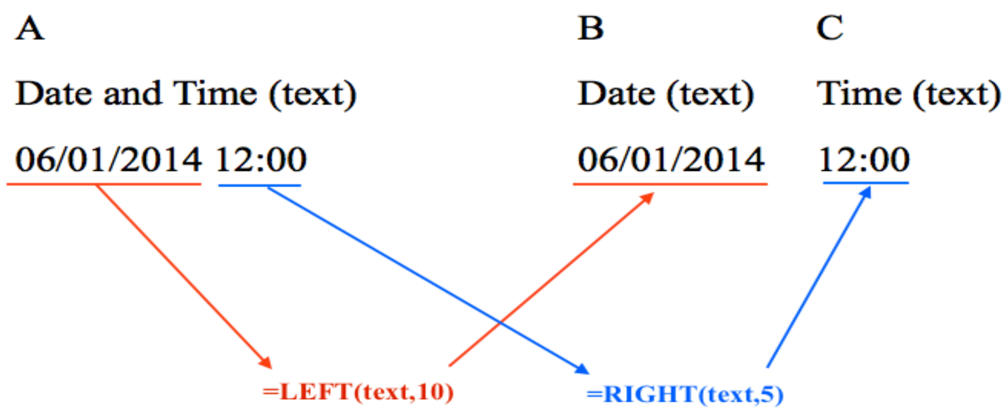


Figure 11. Data Cleaning Process. The figure shows the two formulas used to split logically the original date and time entry.

The figure above displays the first step to cleaning the data. Two essential logic statements were performed to transform the *Text* data acquired by the middleware and make it usable as *Time* for the rounding tool.

Using the *DATEVALUE* and *TIMEVALUE* functions was the second step to cleaning the data. The formula will render the data calculable in the table:

=DATEVALUE(LEFT(cell,10)) + TIMEVALUE(RIGHT(cell,5)).

From this point forth, the data was ready for use in the mathematical functions to develop the rounding tool. If future data collected was in other formats, this data provisioning process must be modified to accept the new input. Otherwise, the following sections would accept mm/dd/yyyy hh:mm format whether from a live database or copied data from other reports. If administrative privileges were given to the RTLS SQL database, the above step would not have been required.

3.4.2 Conditions for a Rounding Event

Rounding requires a caregiver to enter a room, perform a scripted dialogue to address the patient's needs for a reasonable amount of time. To discover total time rounding in a location with the RTLS system, three conditions must be met. This three-condition algorithm lays the groundwork for measuring durations in a particular location and are as follows:

1. The location detected by RTLS must have at least two sequential entries on the table to calculate duration in one place.
2. The time in the location must be within the time parameters to constitute a rounding event.
3. The labeled RTLS location detected must be considered a rounding location.

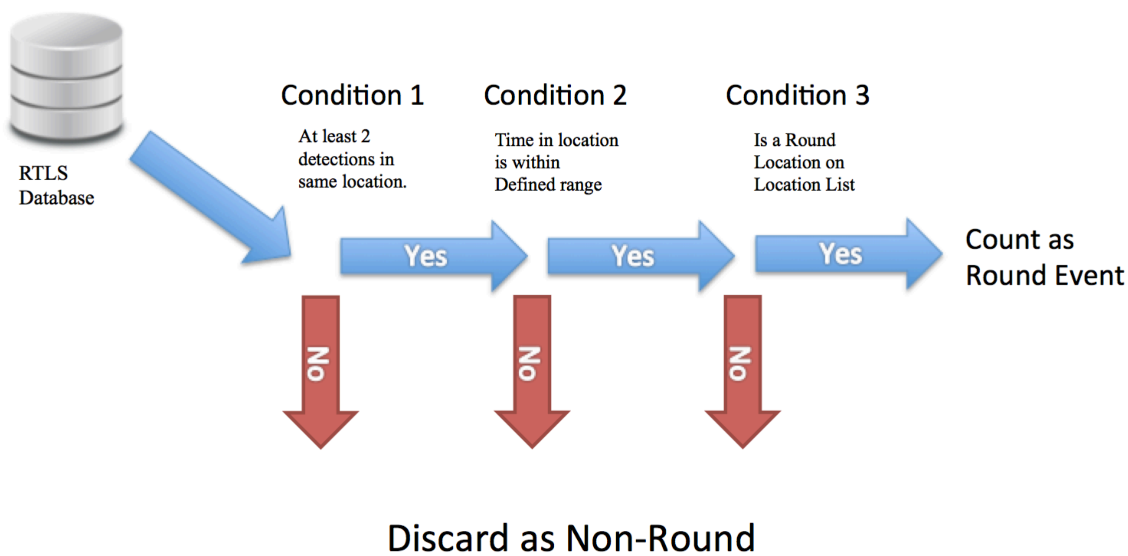


Figure 12. Conditions for a Rounding Event Flow Chart.

Figure 12 illustrates the flow from the RTLS database to be counted as a round if the three conditions are met. If at least one condition is not met, the instance is discarded and not calculated in the reports.

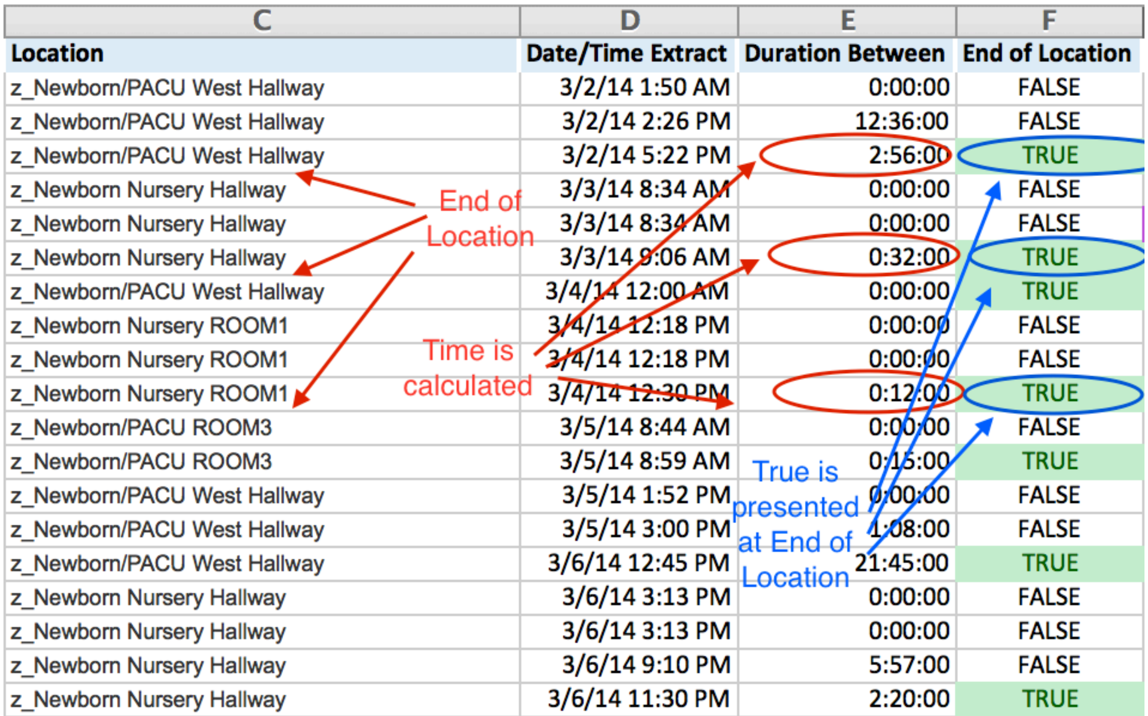
The time location tables have many location detections and for the rounding tool to function, a difference in last detected time in a location is to be subtracted from the first detected time; thus requiring at least two entries in the same place. If this condition is met, then the tool can create a total time.

C	D	E
Location	Date/Time Extract	Duration Between
z_Newborn/PACU West Hallway	3/2/14 1:50 AM	0:00:00
z_Newborn/PACU West Hallway	3/2/14 2:26 PM	12:36:00
z_Newborn/PACU West Hallway	3/2/14 5:22 PM	2:56:00
z_Newborn Nursery Hallway	3/3/14 8:34 AM	0:00:00
z_Newborn Nursery Hallway	3/3/14 8:34 AM	0:00:00
z_Newborn Nursery Hallway	3/3/14 9:06 AM	0:32:00
z_Newborn/PACU West Hallway	3/4/14 12:00 AM	0:00:00
z_Newborn Nursery ROOM1	3/4/14 12:18 PM	0:00:00
z_Newborn Nursery ROOM1	3/4/14 12:18 PM	0:00:00
z_Newborn Nursery ROOM1	3/4/14 12:30 PM	0:12:00
z_Newborn/PACU ROOM3	3/5/14 8:44 AM	0:00:00
z_Newborn/PACU ROOM3	3/5/14 8:59 AM	0:15:00
z_Newborn/PACU West Hallway	3/5/14 1:52 PM	0:00:00
z_Newborn/PACU West Hallway	3/5/14 3:00 PM	1:08:00
z_Newborn/PACU West Hallway	3/6/14 12:45 PM	21:45:00
z_Newborn Nursery Hallway	3/6/14 3:13 PM	0:00:00
z_Newborn Nursery Hallway	3/6/14 3:13 PM	0:00:00
z_Newborn Nursery Hallway	3/6/14 9:10 PM	5:57:00
z_Newborn Nursery Hallway	3/6/14 11:30 PM	2:20:00

Figure 13. View of Condition 1.

Figure 13 shows a table of the duration calculated if there are at least two sequential detections. The table shows *Newborn Nursery Hallway* detected for two instances and later differenced for a total of 32 minutes. If the two locations differ in Column C, then no time will be calculated in Column E.

The RTLS system has the ability to collect a time and location entry every few seconds, but in some cases a staff wearing a badge may enter a room where the system detects the instance and only transmits a few records. Once the last and first records in the same location are differenced, the time may only total to one minute or less. One minute may not be enough time to constitute a round; therefore certain considerations were made in the tool's design to offer the ability to modify the time parameters. For this study, intervals were set to a minimum of ten minutes and a maximum time of forty-five to establish a rounding event. If the tool detects any duration outside these parameters, the rounding instance is discarded where the second condition is not met.



C	D	E	F
Location	Date/Time Extract	Duration Between	End of Location
z_Newborn/PACU West Hallway	3/2/14 1:50 AM	0:00:00	FALSE
z_Newborn/PACU West Hallway	3/2/14 2:26 PM	12:36:00	FALSE
z_Newborn/PACU West Hallway	3/2/14 5:22 PM	2:56:00	TRUE
z_Newborn Nursery Hallway	3/3/14 8:34 AM	0:00:00	FALSE
z_Newborn Nursery Hallway	3/3/14 8:34 AM	0:00:00	FALSE
z_Newborn Nursery Hallway	3/3/14 9:06 AM	0:32:00	TRUE
z_Newborn/PACU West Hallway	3/4/14 12:00 AM	0:00:00	TRUE
z_Newborn Nursery ROOM1	3/4/14 12:18 PM	0:00:00	FALSE
z_Newborn Nursery ROOM1	3/4/14 12:18 PM	0:00:00	FALSE
z_Newborn Nursery ROOM1	3/4/14 12:30 PM	0:12:00	TRUE
z_Newborn/PACU ROOM3	3/5/14 8:44 AM	0:00:00	FALSE
z_Newborn/PACU ROOM3	3/5/14 8:59 AM	0:15:00	TRUE
z_Newborn/PACU West Hallway	3/5/14 1:52 PM	0:00:00	FALSE
z_Newborn/PACU West Hallway	3/5/14 3:00 PM	1:08:00	FALSE
z_Newborn/PACU West Hallway	3/6/14 12:45 PM	21:45:00	TRUE
z_Newborn Nursery Hallway	3/6/14 3:13 PM	0:00:00	FALSE
z_Newborn Nursery Hallway	3/6/14 3:13 PM	0:00:00	FALSE
z_Newborn Nursery Hallway	3/6/14 9:10 PM	5:57:00	FALSE
z_Newborn Nursery Hallway	3/6/14 11:30 PM	2:20:00	TRUE

Figure 14. End of Location View. Circled in blue, the figure illustrates TRUE when two sequential locations are detected from Column C.

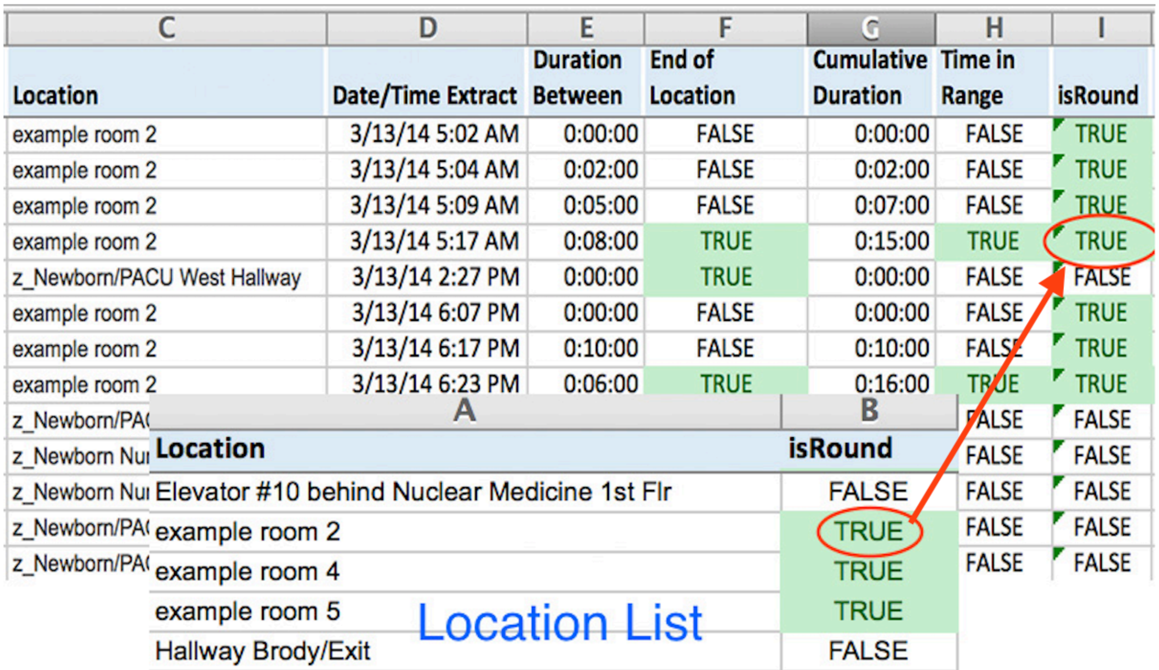
Figure 14 demonstrates an end of location detection in Column F. Boolean output is delivered as TRUE or FALSE when the location in Column C is marked has an end of the same preceding locations. As an example, the figure shows *z_Newborn/PACU ROOM1* having three detections, but the last instance before it transitions to *z_Newborn/PACU ROOM3* a *"TRUE"* is added to Column F.

C	D	E	F	G	H
Location	Date/Time Extract	Duration Between	End of Location	Cumulative Duration	Time in Range
example room 2	3/13/14 5:02 AM	0:00:00	FALSE	0:00:00	FALSE
example room 2	3/13/14 5:04 AM	0:02:00	FALSE	0:02:00	FALSE
example room 2	3/13/14 5:09 AM	0:05:00	FALSE	0:07:00	FALSE
example room 2	3/13/14 5:17 AM	0:08:00	TRUE	0:15:00	TRUE
z_Newborn/PACU West Hallway	3/13/14 2:27 PM	0:00:00	TRUE	0:00:00	FALSE
example room 2	3/13/14 6:07 PM	0:00:00	FALSE	0:00:00	FALSE
example room 2	3/13/14 6:17 PM	0:10:00	FALSE	0:10:00	FALSE
example room 2	3/13/14 6:23 PM	0:06:00	TRUE	0:16:00	TRUE
z_Newborn/PACU West Hallway	3/14/14 9:57 AM	0:00:00	TRUE	0:00:00	FALSE
z_Newborn Nursery Hallway	3/17/14 6:29 AM	0:00:00	FALSE	0:00:00	FALSE
z_Newborn Nursery Hallway	3/17/14 6:29 AM	0:00:00	TRUE	0:00:00	FALSE
z_Newborn/PACU West Hallway	3/17/14 7:30 AM	0:00:00	FALSE	0:00:00	FALSE
z_Newborn/PACU West Hallway	3/17/14 7:30 AM	0:00:00	TRUE	0:00:00	FALSE
WT 127	3/18/14 10:05 AM	0:00:00	FALSE	0:00:00	FALSE
WT 127	3/18/14 10:18 AM	0:13:00	TRUE	0:13:00	TRUE
WT 131	3/18/14 10:32 AM	0:00:00	TRUE	0:00:00	FALSE

Figure 15. Time in Range. The figure depicts TRUE in Column H when duration is within set time parameters.

Figure 15 depicts the Boolean responses of the tool where a *TRUE* or *FALSE* is delivered if the cumulative time detected is within the set range parameters. The figure shows three instances where the durations are in the 10-45 minute range.

Among the 65 RF monitors in the study location, only certain locations where patients reside may be identified as a rounding location. Typically, these locations are patient rooms and examination rooms. The developed tool has a feature to upload locations that are dedicated round locations to meet the third condition above. Conversely, any locations such as conference rooms, offices, hallways, and other common areas may have a time duration detected, but if the location is not on the Round Location List uploaded to the tool, it is discarded. When infrastructure changes occur in the hospital such as renovations, rooms may increase or decrease and the list may be easily modified accordingly.



C	D	E	F	G	H	I
Location	Date/Time Extract	Duration Between	End of Location	Cumulative Duration	Time in Range	isRound
example room 2	3/13/14 5:02 AM	0:00:00	FALSE	0:00:00	FALSE	TRUE
example room 2	3/13/14 5:04 AM	0:02:00	FALSE	0:02:00	FALSE	TRUE
example room 2	3/13/14 5:09 AM	0:05:00	FALSE	0:07:00	FALSE	TRUE
example room 2	3/13/14 5:17 AM	0:08:00	TRUE	0:15:00	TRUE	TRUE
z_Newborn/PACU West Hallway	3/13/14 2:27 PM	0:00:00	TRUE	0:00:00	FALSE	FALSE
example room 2	3/13/14 6:07 PM	0:00:00	FALSE	0:00:00	FALSE	TRUE
example room 2	3/13/14 6:17 PM	0:10:00	FALSE	0:10:00	FALSE	TRUE
example room 2	3/13/14 6:23 PM	0:06:00	TRUE	0:16:00	TRUE	TRUE
z_Newborn/PA(					FALSE	FALSE
z_Newborn Nu					FALSE	FALSE
z_Newborn Nu					FALSE	FALSE
z_Newborn/PA(					FALSE	FALSE
z_Newborn/PA(					FALSE	FALSE

Location List

A	B
Location	isRound
Elevator #10 behind Nuclear Medicine 1st Flr	FALSE
example room 2	TRUE
example room 4	TRUE
example room 5	TRUE
Hallway Brody/Exit	FALSE

Figure 16. Rounding Locations List. This figure shows a portion of the rounding locations and termed *isRound*. The cell in *Column I* seeks the *Location List* table for a legitimate rounding location indicated with a *TRUE* statement. If a *TRUE* is detected, *TRUE* is applied in the column indicating the third condition is met.

3.4.3 Reporting

Now that location-based rounds have been identified, another sheet is created within the database to provide summaries of the dataset. The report is used for distribution to management to make managerial decisions on rounding improvement. The report design applies the most basic attributes for measuring a duration detected in a location with use of RTLS. The report consists of:

1. **Badge Number**—Designated six-digit identification number
2. **Staff Name**—First and Last Name of Staff
3. **Staff Position**—Job title of staff
4. **Date Range**—Range of time queried for report

5. **Total Rounding Time**—Aggregate time rounding

6. **Average Minutes per Round**—Average time spending on rounds

7. **Round Count**—Total rounds detected

A separate table was created to present the summary of the data queried. The badge number is retrieved from another table with simple identifiers such as: First Name, Last Name, Job Title, and Badge Number. Among all tables in the database, the badge number is the primary key between tables. In a relational database, there must be at least one and only one primary key and is the unique identifier in every table for data to be queried appropriately (Fig 17).

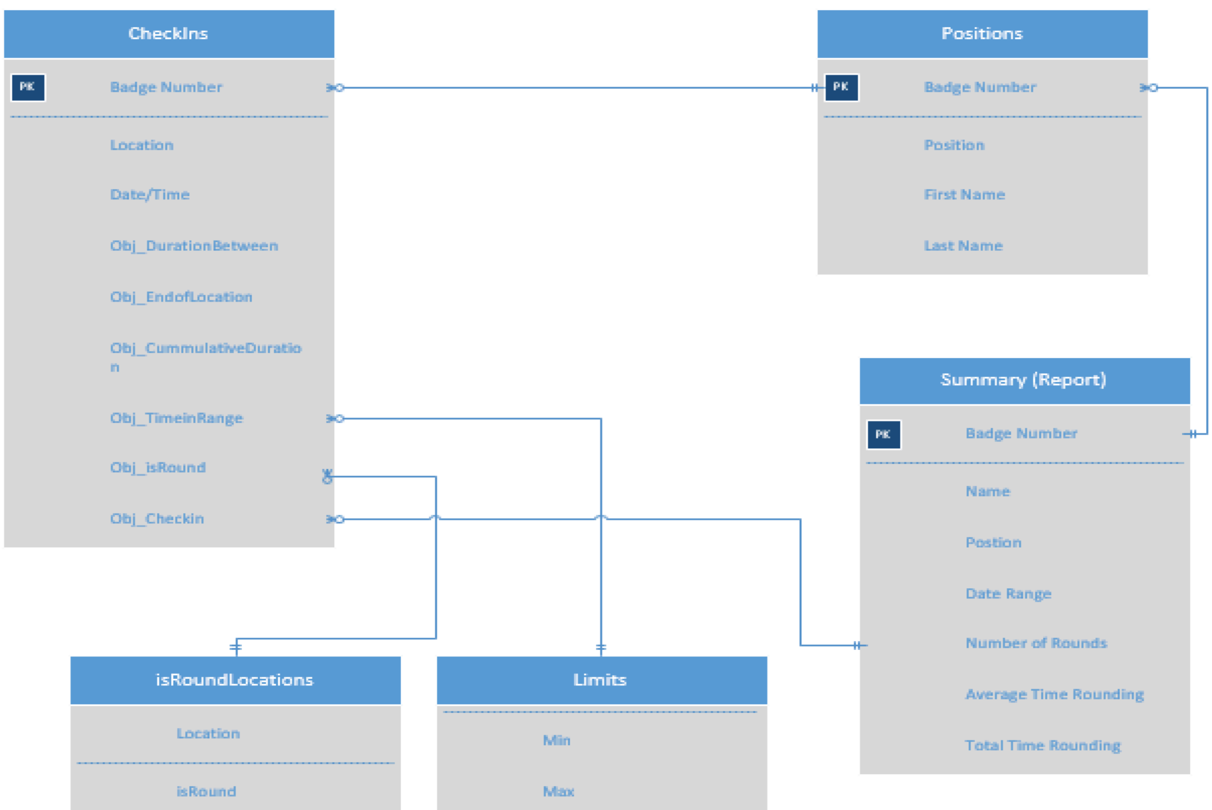


Figure 17. Relational Database Design. The figure illustrates the relationships of the Rounding Tool's design.

The first step to generate a rounding report is to type a legitimate six-digit badge number in cell B2 of the *Rounding Report* table. The name is extracted from another table entitled *Positions* using the *CONCATENATE* function. Figure 18 displays the Rounding Report used as the output mechanism that will be used by the hospital for managerial evaluations and other functions.

A	B
Rounding Report	
Badge Number	235247
Name	Jane Doe
Position	Asst. Nurse Manager
Date Range Begin	3/2/14
Date Range End	6/13/14
Number of Rounds	7
Average Time Spent On Rounds	0:19:51
Total Time Rounding in Date Range	2:19:00

Figure 18. Rounding Report Summary.

The position of the associated badge number is called from the *Positions* table with an *IFERROR* function. The function seeks the name in the cell and calls the position from *Positions* table as well. If the name is not found in the cell, "*Unknown*" is displayed on the report.

The data range is simply the detected range of dates in the queried date range on *Checkins* table. The function *SMALL* and *LARGE* are applied to provide these results; *SMALL* simply finds the lowest date in the column and *LARGE* finds highest date in the range.

To average the number of rounds in the dataset, the instances of *TRUE* residing in Round detection of the *Checkins* table must be counted. Next the summation of the total minutes rounded in the range and divided by the total rounds. To obtain the average, the following string is entered:

=IFERROR(SUMIFS(CheckIns!G:G,CheckIns!J:J,TRUE,CheckIns!A:A,Summary!B1)/COUNTIFS(CheckIns!J:J,TRUE,CheckIns!A:A,B1), 0).

Finally, to extract the total minutes rounded in the provided date range, the *SUMIFS* function is inserted. The time will be generated from the column, but another contingency is added; only the sum of times with value of *TRUE* in the column is summated.

As stated before, the aforementioned design model did not use real data from the study location. RTLS data from the five badges is processed through the model and analyzed later in Chapter 4. The rounding tools calculations and a manual review of the raw data were compared for consistency.

3.5 Methodology Review

The objectives of this thesis are to find any mechanisms through technology that can detect leadership rounding durations with RTLS in a hospital setting. If successful in detection, reports are created for use by the hospital to assist management for healthcare improvement. In this chapter, a methodology that develops a tool that processes the output of the hospital's RTLS system was explained and it was demonstrated that the tool facilitates the measurement of the length of time a staff member resides in a particular location in the hospital. The tool also reports the necessary elements to act as a feedback mechanism for the hospital management to begin taking measures to improve the rounding behavior. The next chapter will discuss the findings of the tool in numerous scenarios.

CHAPTER 4: DATA ANALYSIS AND RESULTS

This chapter describes the results and findings by providing and analyzing the time-location data gathered by the badges employed in the study using the developed rounding tool. The badge datasets span from May 1, 2014 to July 30, 2014. The data is graphically presented to evaluate the validity and effectiveness of the tool in detecting leadership rounding in the study environment. Additionally, the challenges in implementation, operation, and maintenance of the RTLS system are observed during these trials.

It is important to note that data acquired was collected in three different intervals. Collection was at the end of each month for the purpose of reviewing and reporting errors back to the hospital for the following month's data. For the each batch of data, time and location information is imported into the rounding tool. The rounding time parameters for this first trial are set to a minimum time of 10 minutes and a maximum time of 45 minutes. The hospital agrees at least 10 minutes in a given location constitutes a round. All five badges are processed for analysis to determine if the tool functions correctly. They are followed by an analysis of the rounding performance of the tracked staff. Table 2 provides a list of the key identifiers of all five badges. Names are fictitious and job titles are not important for this study, but they demonstrate capabilities of tool for reporting purposes.

Table 2

RTLS Badge Numbers and Other Identifying Data

Badge Number	**Job Title**	**First Name**	**Last Name**
296247	Nurse Manager #1	Jane	Doe
293711	Nurse Manager #2	John	Doe
296830	Asst. Nurse Manager #1	Dean	Winchester
296872	Administrator	Tiger	Woods
296909	Asst. Nurse Manager #2	Michael	Jordan

Note: Names are fictitious to provide anonymity of the study subjects.

Once the records were processed through the tool, the date was manually reviewed to detect any possible peculiarities in the reports. All comparative reports were manually generated and not part of the rounding tool application. The following table defines the attributes listed on the comparative reports.

Table 3

Rounding Report Attributes

Attribute	Description
Staff Badge Number	Six digit badge number
Detected Rounding Count in Date Range	Rounds detected with the set date range parameters
Average Rounding Time	The average time spent rounding for given badge
Total Time Rounding in Date Range	Total time spent rounding within set date range parameters
Dataset Total Records in Date Range	Count of time and location records detected within the set date range parameters

All of the above attributes are already reported in the rounding tool with exception to the Data Total Records in the set date range. The record count is another variable to validate an efficient round count. In other words, a low record count may be attributed to numerous reasons such as: badge left stationary in staff's office, staff taking the badge home for the day, or end of battery life of the badge. To preserve battery life, if the badge does not detect a sensor location-to-location transition, no data will be sent to WLAN and the RTLS database. As a result, the system produces a small number of records, which is not sufficient to generate round counts. Moreover, if the badge is taken from the study environment, no records will be appended to the database. Therefore, round count is essential in reporting.

4.1 First Month Rounding Trial

Findings from first month's trial had promising results as it is evident the rounding tool is reporting sufficient numerical totals. Analysis of the report shows three of the five badges detect a total seven rounding events using the 10-45 minute time limits. Table 4 shows the summation of the first month's data indicating the badge number and all rounding events detected.

Table 4

May 2014 Round Event Comparison (10-45 minute limits)

Badge Number	Position	Rounding Events	Average Rounding Time in hh:mm:ss	Total Rounding Time in hh:mm:ss	Record Count
296247	Nurse Manager #1	0	00:00:00	00:00:00	*0
293711	Nurse Manager #2	4	00:17:00	01:08:00	423
296830	Asst. Nurse Manager #1	1	00:14:00	00:14:00	1328
296872	Administrator (VP)	0	00:00:00	00:00:00	692
296909	Asst. Nurse Manager #2	1	00:14:00	01:14:00	705

*Record Count is 0, alluding to non-compliance of staff or hardware malfunctions.

Badges 296830, 293711, and 296909 have successfully revealed rounding behavior, based on the time parameters of 10 and 45 minutes. Since this is a pilot study and the tool is in a testing phase, a manual review of the raw time and location table was required to validate the rounds detected were in fact legitimate. The manual review did show the rounds were completely valid providing cogency of the tool's functionality. This exhibits great promise for the tool as an instrument for the hospital to detect staff in a location for duration of time. Figure 19 below illustrates a detected rounding event for badge from the manual review of raw data. The figure presents a rounding location of 14 minutes being within the range parameters and is at the end of location.

C	D	E	F	G	H	I	J
Location	Date/Time Extra	Duration Between	End of Location	Cumulative	Time in Range	isRound	End of Location & isRound & Time
z_Newborn Nursery Hallway	05/07/2014 16:53	0:00:00	TRUE	0:00:00	FALSE	FALSE	FALSE
z_LD OR/LD PACU	05/07/2014 16:53	0:00:00	FALSE	0:00:00	FALSE	TRUE	FALSE
z_LD OR/LD PACU	05/07/2014 16:54	0:01:00	FALSE	0:01:00	FALSE	TRUE	FALSE
z_LD OR/LD PACU	05/07/2014 17:07	0:13:00	TRUE	0:14:00	TRUE	TRUE	TRUE
z_LDA/ On-call Rooms	05/07/2014 17:07	0:00:00	FALSE	0:00:00	FALSE	TRUE	FALSE
z_LDA/ On-call Rooms	05/07/2014 17:09	0:02:00	TRUE	0:02:00	FALSE	TRUE	FALSE
z_LD OR/LD PACU	05/07/2014 17:10	0:00:00	TRUE	0:00:00	FALSE	TRUE	FALSE

Figure 19. Detected Rounding Event in Database.

Another observation from the report indicates badge 296247 has no rounding events and no counted records, which indicates that the badge is not being detected. A brief manual review of the raw data also confirmed that no round count was recorded for this particular badge. This could be attributed to the badge's low battery life, the badge not within the hospital wireless infrastructure, or other operational issue. When contacting the hospital, the identified badge (296247) was found and was active and operating correctly. However, the staff member was non-compliant and forgot to wear the badge. The badge was in an office enclosed in a drawer where it could not contact the WLAN for location reporting. The zero record count exposed the compliance concern, however the tool may still expose these instances to prompt management to remind the particular badge holder to become compliant.

Badge 296872 also had a zero round count, yet had 692 records counted. Even though the badge was communicating with the WLAN, another manual review of the data was required. The records show for the first two weeks some location changes occurred however only one location was detected for the remainder of the month. Again, this portrays another compliance issue with staff leaving their badge in their office. However, it was learned if a badge does not detect a transition of locations it would send a location update every 70 minutes—which will assist in tuning the tool for future trials. Moreover, after running these reports management may again contact staff to follow compliance wearing their assigned badges.

In summation, the new rounding tool reports effectively as the manual review of the data coincides with the report totals. Observations of the lack of records counts by two of the badges also indicates the tool is reporting effectively and also will assist hospital management to increase compliance among staff.

4.2 Second Month Rounding Trial

After the first month's data was collected and deficiencies were observed with non-compliance of two badges, a follow-up request was made to the hospital PM for all participants to begin and/or continue wearing the badges. At the end of the second study period of June 2014, the same report is generated to collect results and is analyzed. Again, the range of 10 to 45 minutes was used to define a round for the second month trial.

Overall, rounding events improved with a total of six defined rounds occurred. Focus is given to badge 296909, as this badge produced seven rounds with an average of twenty-seven minutes and a total more than three hours of rounding in the month. After reviewing the data manually to validate the instances were true, the tool functioned as predicted, as all locations were non-common locations such as patients rooms and other clinical areas. Furthermore, time durations did meet limit requirements falling within the 10 to 45 minute parameters.

Table 5

June 2014 Round Event Comparison (10-45 minute limits)

Badge Number	Position	Rounding Events	Average Rounding Time in hh:mm:ss	Total Rounding Time in hh:mm:ss	Record Count
296247	Nurse Manager #1	1	00:22:00	00:22:00	1765
293711	Nurse Manager #2	0	00:00:00	00:00:00	769
296830	Asst. Nurse Manager #1	1	00:21:00	00:21:00	1573
296872	Administrator (VP)	0	00:00:00	00:00:00	3297
296909	Asst. Nurse Manager #2	7	00:12:32	01:28:00	1252

Two of the badges did not record any rounding instances, but did have a several hundred record count; with exception to badge 293711 only having only 769 records counted. Another manual review of the raw data was required to justify no identification of rounds. The comparison of the report and manual review indicated the tool is functioning correctly. Badge 293711 has incomplete records, where after June 16 no records were appended to the data.

Again, this may attribute to non-compliance or an operational issue. The hospital was notified of this deficiency and the response eluded that the *Nurse Manager #2* chose not to continue participating in the RTLS study.

Badge 296872 had similar results as the month before. The badge exhibited a several thousand record count, but location change did not occur. The WLAN and RTLS database was receiving valid records, however the tool discovered an exceptional amount of records. Since the record count was more than double the other badges it seems the badge requires tuning to send time and location at faster intervals. This concept will assist future study considerations to possibly configure the badges to send more frequent location records for more precise location duration measurement.

The second month trial is demonstrating a positive performance for the rounding tool. Lessons learned from this trial show the tool can detect a badge not moving when it remains in an office. Certain algorithms may be developed in the future to possibly send alerts to management to remind staff to wear their badge. Additionally, some of the badges are sending faster intervals of time and location. The RTLS system may provide more conclusive results if the transmission interval is turned up on all the badges.

4.3 Third Month Rounding Trial

The third and final month of the study is presented in this section. July's data of all five badges is compared and evaluated for any rounding events along with raw data idiosyncrasies. The parametric range remains the same of 10-45 minute round definitions.

Table 6

July 2014 Round Event Comparison (10-45 minute limits)

Badge Number	Position	Rounding Events	Average Rounding Time in hh:mm:ss	Total Rounding Time in hh:mm:ss	Record Count

296247	Nurse Manager #1	2	00:11:00	00:22:00	1307
293711	Nurse Manager #2	0	00:00:00	00:00:00	*0
296830	Asst. Nurse Manager #1	0	00:00:00	00:00:00	937
296872	Administrator (VP)	0	00:00:00	00:00:00	*2678
296909	Asst. Nurse Manager #2	2	00:30:00	01:00:00	697

*Staff members chose not to participate in the study this month.

The final month reports show little change in rounding behavior from the previous two trials. Two of the five badges indicate four total rounds detected. Once again, the raw data will be manually reviewed for consistency of the report. Specifically, badge 296909 exhibits three rounds with an average round-rate of 26 minutes and 1 hour round time in the month. The raw data also shows record count of 697, but does stop reporting on the 18^{th} of the month. The next data record starts back on August 1, 2014, which provides the assumption the staff, may have taking a vacation during this time. With this discovery, an entirely different application may be designed around actual work-hour job activity. There could be no need for “clocking in” as RTLS could detect when a staff member comes to work, performs job tasks, and leaves for the day.

4.4 Cumulative Analysis of the Three Month Period of Data Collection

The trails offered significant findings for the rounding tool. The tool quantifies a badge length of time in a rounding location with the time range. For this trial the time range parameters were set to a minimum of 10 minutes and a maximum of 45 minutes. The transmission of location intervals may have been set too low to gather a legitimate round. It is quite possible leadership staff that were compliant during the study may have completed more rounds than the system RTLS detected location. In other words, a staff member may have rounded in a patient room for 20 minutes, but the badge transmitted only one location detection while the staff was in the room; thus not providing duration to establish a round event. One of the logic statements of the rounding tool is to detect at least two instances of the same locations sequentially to difference the last time recorded and the first time. Needless-to-say, if the badge was sending more locations to the database more rounds may have been detected. These uncertainties merited another trial of the last three months reports. The data is retrospective, and the time range parameters can be modified easily to produce another set of results.

4.5 Three Month Retrials with New Time Parameters

This section is another comparison of the five badges and the previous three months of May, June, and July 2014. The original parameters set for the round detection was a 10-minute minimum and a 45-minute maximum. The new parameters for the retrial are set to a 0-minute minimum and a 45-minute maximum. With these new parameters, any staff that actually enters a patient room and RTLS detects the location in that room; the tool will define this event as a round. These reports will be compared with the original trial reports and evaluated for improvements in round count.

The reports show an increase in rounding events with the new parameters. Many of the badges that only detected one to three rounding events with the old parameters are now exhibiting fifteen or more events. Depending how the hospital chooses to proceed with the rounding tool, the new parameters now present more rounding instances.

Table 7

Time Parametrical Comparison of 10-45 minute vs. 0-45 minutes for May-July. This table exhibits the increases in detected round instances by reducing the minimum detection threshold to 0 minutes for the three-month study period.

May 2014 Round Range Comparison (10-45 minutes vs. 0-45 minutes)

	10-45 minute range			0-45 minute range			
Badge Number	Rounding Events (10-45 minutes)	Average Rounding Time in hh:mm:ss	Total Rounding Time in hh:mm:ss	Rounding Events (0-45 minutes)	Average Rounding Time in hh:mm:ss	Total Rounding Time in hh:mm:ss	Record Count
296247	0	00:00:00	00:00:00	0	00:00:00	00:00:00	612
293711	4	00:17:00	1:08:00	12	00:11:30	02:18:00	423
296830	1	00:14:00	00:14:00	3	00:05:20	00:16:00	1329
296872	0	00:00:00	00:00:00	1	00:05:00	00:05:00	692
296909	1	00:14:00	00:14:00	10	00:04:24	00:44:00	705

June 2014 Round Range Comparison (10-45 minutes vs. 0-45 minutes)

	10-45 minute range			0-45 minute range			
Badge Number	Rounding Events (10-45 minutes)	Average Rounding Time in hh:mm:ss	Total Rounding Time in hh:mm:ss	Rounding Events (0-45 minutes)	Average Rounding Time in hh:mm:ss	Total Rounding Time in hh:mm:ss	Record Count
296247	1	00:22:00	00:22:00	10	00:05:42	00:57:00	1765
293711	0	00:00:00	00:00:00	2	00:02:00	00:02:00	769
296830	1	00:21:00	00:21:00	9	00:06:07	00:55:00	1573
296872	0	00:00:00	00:00:00	0	00:05:00	00:05:00	3297
296909	4	00:22:00	01:28:00	21	00:06:45	00:02:20	1252

July 2014 Round Range Comparison (10-45 minutes vs. 0-45 minutes)

	10-45 minute range			0-45 minute range			
Badge Number	Rounding Events (10-45 minutes)	Average Rounding Time in hh:mm:ss	Total Rounding Time in hh:mm:ss	Rounding Events (0-45 minutes)	Average Rounding Time in hh:mm:ss	Total Rounding Time in hh:mm:ss	Record Count
296247	1	00:10:00	00:10:00	3	00:11:20	00:34:00	0
293711	0	00:00:00	00:00:00	0	00:00:00	00:00:00	423
296830	0	00:00:00	00:00:00	0	00:00:00	00:00:00	1328
296872	0	00:00:00	00:00:00	0	00:00:00	00:00:00	719
296909	2	00:21:40	01:05:00	9	00:08:53	01:20:00	705

Overall, these new parameters show a drastic increase in the detected rounds by the five badges for the 3-month study period. At least four of the badges detected an increase of more than 150% rounds detected. Badge 296909 (Asst. Nurse Manager #2) had a considerable increase of rounds detected when changing to these new parameters. The original parameters detected only 7 rounding events, but changing to the new time parameters has detected 36 events. Figure 20 below charts both datasets with the 10-45 minute and 0-45 minute comparison of the entire 3-month study period showing the increase of detected rounds.

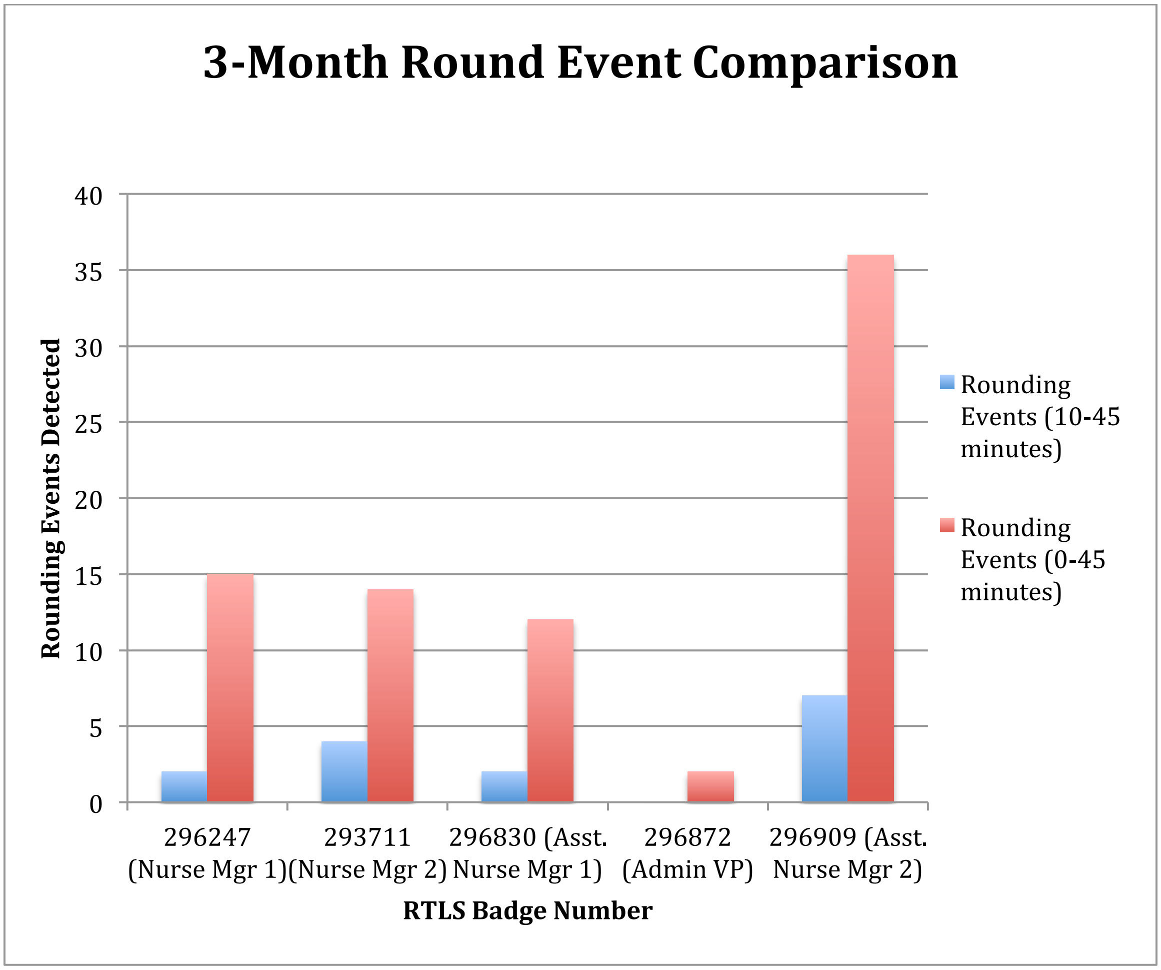


Figure 20. 3-Month Round Event Detection Comparison. The figure illustrates a relative increase in round detections when the minimum time is set lower to zero minutes.

The second trial using the new time parameters not only has provided an increase of detected rounds, but also has provided better averages of rounding events. Since the hospital has not indicated a clear definition of how much time justifies a round. The rounding tool can offer management the necessary time to dignify a round. When reducing the minimum time range from 10 minutes to 0 minutes, the tool was able to gather the rounding events under 10 minutes.

Table 8

Mean Time Spent Rounding for 3-Month Study

Badge Number	Rounding Events (0-45 minutes)	Total Time Rounding	Mean Time spent per Round (in hh:mm:ss)
296247	15	01:28:00	00:05:52
293711	14	02:20:00	00:10:00
296830	12	01:11:00	00:05:55
296872	2	00:10:00	00:05:00
296909	36	01:29:20	00:02:29
TOTALS	79	06:38:20	00:05:03

Note: The table represents the five badges and the average round times in minutes using the 0-45 minute range.

The mean time of the five badges has indicated the hospital leadership staff rounds approximately 5 minutes. This is an extremely useful observation to dictate how much time is required to complete a round (Tab. 8). The hospital may use these averages to increase quality of care by modifying the rounding script to apply more time to the rounding event duration. Future studies may compare the rounding duration with the patient stay post satisfaction surveys (HCAHPS); where the hospital may increase rounding averages for a period of time and then measure the patient satisfaction surveys against the increases for a positive correlation.

4.6 Summary of Results

The rounding detection tool has proven to function with the chosen parameters for detecting a staff member in an RTLS-enabled hospital. The tool will detect the staff's time duration in rounding location; delivering the amount of detected rounds, total time rounding within the defined date range, and the average time spent rounding. The reported data will assist the hospital in making changes to policy by setting benchmarks for leadership to accomplish and to increase quality of care in the particular wing. Additionally, the tool is scalable for when new rooms are added to the hospital and are RTLS enabled, the list of round-friendly rooms may be appended prior to running the report. Once the hospital creates statistical means to constitute a rounding event, the minimum and maximum time limits may be changed with tool so short durations may be discarded and not be considered a rounding event.

After the study was completed, many challenges were observed to also aid the hospital in creating a more accurate system. Among these observations was staff compliance. Some staff did have compliance issues wearing the badges, but the tool did detect such instances. These detections by the tool may be observed by administration, and then used to manage staff to wear their badges. Moreover, one staff member went on vacation during the study and was also observed by the rounding tool, where her badge was not moving for a period of time. This observation merits the idea of the RTLS system to measure staff start and end of working hours--similar to a time clock. Since the tool can already measure duration, it may also measure durations that last too long in one location, and therefore send alerts to hospital management.

The data gleaned from the hospital's Project Manager during this project was simply copied and pasted from a middleware reporting software from the Awarepoint database. The data acquisition from the middleware source caused many limitations to easily manipulate and filter data. With the current setup, data must be cleaned every time a report is to be generated. Moreover, there was no direct live connection to the server to write more enriched SQL queries. MS Excel does have the capabilities to connect to SQL servers; however, the Awarepoint vendor did not offer administrative access to the database. The tool designed for this project is not easily scalable to larger environments and has limitations for the amount of data that may be generated for large reports. A recommendation is to aggressively seek administrative privileges to the database that would provide real-time access for more efficient report generation.

There were some operational abnormalities learned during the study. The RTLS badge has the capability to send a detection frequency of every 3 seconds. However, much of the data had intervals of more than ten minutes between detections and in some cases every 24 hours depending if the badge was stationary. When the badge is moving from place to place it was observed that they send more frequent location detections. The researcher recommends tuning of the RTLS badge interval settings. An ideal interval value would no less than 15 seconds. To render the most accurate rounding durations, the badge must send its location more frequently, especially if the hospital desires the most accurate times. The only caveat to increasing transmission intervals with the badge is that battery-life decreases significantly, but is a reasonable sacrifice to allow the rounding tool to function with more valid results.

CHAPTER 5: CONCLUSIONS AND FUTURE WORK

The objectives of this research project were to identify a mechanism that could detect rounding amongst leadership in a hospital, describe the function of administration in the hospital to distribute meaningful reports for management to improve rounding performance, and identify any obstacles during implantation, operation, and maintenance of the RTLS tool. This chapter provides conclusions to the research by addressing the research objectives above. A future work section discusses the possible new features that can be added to the next versions of the tool developed in this research. It also describes a number of potential application areas for RTLS tool development.

The RTLS rounding tool developed in this study was created as groundwork for future initiatives. The tool does detect instances of a round in the hospital's RTLS-ready environment, which addressing the first objective question. The hospital may now utilize this tool to begin monitoring leadership and to possibly set rounding benchmarks for staff.

The tool developed during this study produced reports that provide significant insight to the management by identifying and monitoring rounding instances for each badge. The hospital plans to use those reports to improve rounding instances by leadership staff in the Women and Children's Hospital.

As stated before, in order for the rounding process to be a successful protocol in a hospital, the administration must deliver Rounding Reports to the leadership staff to provide feedback on their performance. At the time of the study, the hospital had no requirements or definition for leadership rounding with regards to frequency or weekly duration. Therefore the initial objective of the hospital was to seek only to identify if leadership was rounding at all. The tool identified some amount of rounding by leadership. Now with use of the reports generated will be used as a catalyst for setting benchmark requirements in the studied department with hopes to improve quality of care.

5.1 Observations on Implementation, Operation, and Maintenance

Overall, the system functions well with tracking of objects such as IV pumps and oxygen tanks. On the other hand, human subjects have posed certain challenges for the RTLS setup used in this study. Compliance of the participating employees was found to be below the expectations as the recorded data showed that some subjects were leaving their badges in their offices or placing the badges in their pockets causing insufficient tracking data.

Reliability of the system was observed during the study. The findings of this study show the importance of the database receiving a time and location record at least every minute. As mentioned before, the frequency at which the badges transmitted time and location data were found to be longer than one minute. This resulted in a skewing the guaranteed duration a staff member may have been in a patient’s room. The study determined that this attribute is significant and requires proper tuning since it is closely linked with the validity of the data produced. In addition, all leadership staff electing to participate in the project were required to wear the RTLS badge under their hospital ID badge in the portrait orientation. During implementation, the study determined that wearing badges in landscape versus portrait orientation affected the reliability of the data collected. The portrait orientation resulted in better data collection performance. Even though these findings challenge the validity of the reliability of the RTLS system in this hospital, it does not invalidate the integrity of the rounding tool software developed in this project. More research of the RTLS system’s reliability is recommended.

Maintenance of the RTLS system is of little or no concern. Once the system has been deployed and configured, the system is scalable where more star access points may be added throughout the hospital to begin new projects. RTLS badges have a battery life of approximately 1 year and can easily be replaced. Alerts may be configured in the system to notify administration when batteries do become low. Moreover, the badges send data over existing hospital Wi-Fi equipment, so as long as the wireless network is functioning reliably; RTLS operates well. The RTLS SQL database is located on-site and is backed up daily via cloud, and if goes down only provides missing RTLS data. These observations will provide other researchers the confidence to pursue the same or similar studies with RTLS for detecting time duration in location applications.

Lessons learned from this study are to have a reliable and dependable relationship with the study location. As a researcher, RTLS data may not be directly accessible and must be gleaned from a contact from the study location. This may slow the rate of which the study may be undertaken. It is advised to obtain direct access to data if possible.

5.2 Future Work

The hospital is in continuous pursuit to improve patient care. The tool has potential to measure other hospital staff and their job performance. For instance, nurses are required to round every hour within their department. This tool can be used to monitor their movements inside the hospital and produce scorecards of their performance. Those scorecards can be disseminated to managers to identify any deficiencies in job performance. The tool is not limited to care staff. It can also be adapted to monitor the performance of other staff, such as custodial staff. Custodians are required to clean patient rooms efficiently to make ready for incoming patients. Some staff may be under-performing in this area. Mean times may be established with use of this tool to find ideal cleaning times of rooms. For the slowest custodians, this tool may identify them and allow management the opportunity to increase performance of these employees.

One of the future objectives of the Women and Children's Hospital is to describe how RTLS has the potential to improve quality of care for patients. From prior research in Chapter 2, rounding has proven to be an intrinsic part of increasing patient satisfaction, however, rounding on the nurse level by itself is not an effective way to improve quality of care—rounding by department leadership is pertinent. The rounding tool used in this project has successfully detected rounding behavior of leadership employees in the hospital. With such a tool, reports may be administered to department leadership to shape rounding behavior according to administration's needs. A future statistical hypothesis test should be pursued to actually measure a correlation by using this tool to discover a baseline of leader rounding. Once a baseline is created, the current HCAHPS survey scores for this period should be observed. It is recommended to increase the rounding frequency by leadership to a higher percentage, and observe any positive correlation in increased HCAHPS scores.

The results from this study offer great promise to the healthcare industry at large. The need was to find a mechanism to measure staff work duty performance. The outcome of this study addresses the problem and offers a simple application tool to measure time duration of a subject in a given location. Knowing where and what staff is doing in a busy work environment can create awareness and also aid management to create efficiency. Tools like this may improve all organizations' staff workflow for establishment of optimal performance of employees.

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APPENDIX

APPENDIX A: INSTITUTIONAL REVIEW BOARD APPROVAL

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board Office
4N-70 Brody Medical Sciences Building· Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284** · **www.ecu.edu/irb**

Notification of Exempt Certification

From: Social/Behavioral IRB
To: Charles Hopkins
CC: Erol Ozan
Date: 5/30/2014
Re: UMCIRB 14-000094
RTLS CASE STUDY: MEASURING LEADERSHIP ROUNDING PERFORMANCE IN HOSPITAL ENVIRONMENTS

I am pleased to inform you that your research submission has been certified as exempt on 5/29/2014 . This study is eligible for Exempt Certification under category #4.

It is your responsibility to ensure that this research is conducted in the manner reported in your application and/or protocol, as well as being consistent with the ethical principles of the Belmont Report and your profession.

This research study does not require any additional interaction with the UMCIRB unless there are proposed changes to this study. Any change, prior to implementing that change, must be submitted to the UMCIRB for review and approval. The UMCIRB will determine if the change impacts the eligibility of the research for exempt status. If more substantive review is required, you will be notified within five business days.

The UMCIRB office will hold your exemption application for a period of five years from the date of this letter. If you wish to continue this protocol beyond this period, you will need to submit an Exemption Certification request at least 30 days before the end of the five year period.

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

IRB00000705 East Carolina U IRB #1 (Biomedical) IORG0000418
IRB00003781 East Carolina U IRB #2 (Behavioral/SS) IORG0000418

APPENDIX B: ROUNDING ALGORITHIM (VERBAL)

```
sort date of checkins chronologically
if (dateofcheckin is between date limits){
    if (position checked in is a rounding position){
        if (checkin is last checkin is location){
            if (time spent in position is between rounding limit){
                count checkin as round
            }
        }
    }
}
```

APPENDIX C: ROUNDING ALGORITHIM (LOGICAL Using C-Sharp)

```
using System;
using System.Collections.Generic;
using System.ComponentModel;
using System.Data;
using System.Drawing;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using System.Windows.Forms;
using System.IO;
using System.Collections;


namespace ProcessCheckins
{
    public partial class Form1 : Form
    {
        public List<List<string>> data = new List<List<string>>();


        public List<List<string>> filteredDate = new List<List<string>>();
        public List<List<string>> filteredLocationsAndDate = new List<List<string>>();
        public List<List<string>> timeInLocations = new List<List<string>>();
        public List<List<string>> rounds = new List<List<string>>();
```

```
public List<string> roundLocations = new List<string>();

public Form1()
{
    InitializeComponent();

}

private void btnImportData_Click(object sender, EventArgs e)
{
    // Show the dialog and get result.
    DialogResult result = ofdImportData.ShowDialog();
    if (result == DialogResult.OK) {
        try
        {
            System.IO.Stream fileStream = ofdImportData.OpenFile();
            System.IO.StreamReader sr = new System.IO.StreamReader(fileStream);

            //For Progress Bar
            int numOfLines = File.ReadLines(ofdImportData.FileName).Count();
            pgbLoadingFile.Visible = true;
            pgbLoadingFile.Minimum = 1;
```

```
pgbLoadingFile.Maximum = numOfLines;
pgbLoadingFile.Value = 1;
pgbLoadingFile.Step = 1;

int row = 0;
while (!sr.EndOfStream)
{
    List<string> line = new List<string>();
    line = sr.ReadLine().Split(',').ToList();
    if (line[0].ToString().Length != 0)
    {
        if (row != 0)
        {
            data.Add(line);
        }
    }
    row++;
    pgbLoadingFile.PerformStep();

    Console.WriteLine(row);
}
pgbLoadingFile.Value = 1;
fileStream.Close();
```

```
        }
        catch (IOException ex)
        {
            MessageBox.Show(ex.Message.ToString());
        }
    }
    else
    {
        MessageBox.Show("There was an error selecting a file.");
    }
    MessageBox.Show("Data Imported Successfully.");
}

private void btnProcessData_Click(object sender, EventArgs e)
{
    if (data != null)
    {
        //Set Textbox to total events
        txtTotalCheckins.Text = data.Count().ToString();

        //Filter Out Events Not Within Date Range
        filteredDate.Clear();
```

```
for (int i = 0; i < data.Count(); i++)
{
    if ((Convert.ToDateTime(data[i][1]) > Convert.ToDateTime(dtpStartDate.Text)) && (Convert.ToDateTime(data[i][1]) < Convert.ToDateTime(dtpEndDate.Text)))
    {
        filteredDate.Add(data[i]);
    }
}

txtCheckinsInRange.Text = filteredDate.Count().ToString();



//Search For Rounds
double timeInRound = 0;
double totalTime = 0;
timeInLocations.Clear();
for (int i = 1; i < filteredDate.Count(); i++)
{
    if (filteredDate[i][0] == filteredDate[i - 1][0])
    {
        timeInRound = timeInRound + (Convert.ToDateTime(filteredDate[i][1]) - Convert.ToDateTime(filteredDate[i - 1][1])).TotalMinutes;
        totalTime = totalTime + timeInRound;
    }
```

```
    else
    {
        //Add to array of total time in locations
        List<string> timeInLocation = new List<string>();
        timeInLocation.Add(filteredDate[i][0]);
        timeInLocation.Add(timeInRound.ToString());
        timeInLocations.Add(timeInLocation);
        timeInRound = 0;
    }
}
txtTimeAtAllLocations.Text = totalTime.ToString();



//Filter out non rounding locations
filteredLocationsAndDate.Clear();
for (int i = 0; i < timeInLocations.Count(); i++)
{
    if (roundLocations.Contains(timeInLocations[i][0]))
    {
        filteredLocationsAndDate.Add(timeInLocations[i]);
    }
}
txtRoundsNoTime.Text = filteredLocationsAndDate.Count().ToString();
```

```
            //Filter out Rounds not in time constraint

            rounds.Clear();

            for (int i = 0; i < filteredLocationsAndDate.Count(); i++)

            {

                if ((Convert.ToInt16(filteredLocationsAndDate[i][1]) >
Convert.ToInt16(txtMinRoundTime.Text)) &&
(Convert.ToInt16(filteredLocationsAndDate[i][1]) <
Convert.ToInt16(txtMaxRoundTime.Text)))

                {

                    rounds.Add(filteredLocationsAndDate[i]);

                }

            }

            txtRounds.Text = rounds.Count().ToString();



            //Find total time rounding

            int totalTimeRounding = 0;

            for (int i = 0; i < rounds.Count(); i++)

            {

                totalTimeRounding = totalTimeRounding + Convert.ToInt16(rounds[i][1]);

            }

            txtTotalTimeRounding.Text = totalTimeRounding.ToString();

        }

        else

        {
```

```
        MessageBox.Show("Please Select Data");
    }
}

private void btnImportLocations_Click(object sender, EventArgs e)
{
    // Show the dialog and get result.
    DialogResult result = ofdImportLocations.ShowDialog();
    if (result == DialogResult.OK) {
        try
        {
            System.IO.Stream fileStream = ofdImportLocations.OpenFile();
            System.IO.StreamReader sr = new System.IO.StreamReader(fileStream);

            //For Progress Bar
            int numOfLines = File.ReadLines(ofdImportLocations.FileName).Count();
            pgbLoadingFile.Visible = true;
            pgbLoadingFile.Minimum = 1;
            pgbLoadingFile.Maximum = numOfLines;
            pgbLoadingFile.Value = 1;
            pgbLoadingFile.Step = 1;

            int Row = 0;
```

```
        while (!sr.EndOfStream)
        {
            string line = sr.ReadLine();
            if (line.Length > 0)
            {
                roundLocations.Add(line.Trim());
            }

            Row++;
            pgbLoadingFile.PerformStep();

            Console.WriteLine(Row);
        }

        pgbLoadingFile.Value = 1;
        fileStream.Close();
        txtRoundableLocations.Text = roundLocations.Count().ToString();
    }
    catch (IOException ex)
    {
        MessageBox.Show(ex.Message.ToString());
    }
}
```

```
        else
        {
            MessageBox.Show("There was an error selecting a file.");
        }
    }
}
class DataComparer : IComparer
{
    public int Compare(object x, object y)
    {
        // x and y are arrays of strings
        // sort on the 2nd item in each array
        string[] a1 = (string[])x;
        string[] a2 = (string[])y;

        try
        {
            DateTime date1 = Convert.ToDateTime(a1[1]);
            DateTime date2 = Convert.ToDateTime(a2[1]);
            return (date1.CompareTo(date2));
        }
        catch (Exception ex)
        {
```

```
                MessageBox.Show("There appears to be commas in your location data. " +
ex.Message);

                return 0;

            }

        }

    }

}
```