

EXPLORING WIRELESS TECHNOLOGY APPLICATIONS IN CLINICAL STAFF
RESPONSE TIME REDUCTION IN HEALTHCARE FACILITIES

A Thesis

Presented to

The Faculty of the College of Business and Technology

Morehead State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Chase R. Johnson

November 13, 2017

ProQuest Number:10642994

All rights reserved

INFORMATION TO ALL USERS

The quality of this reproduction is dependent upon the quality of the copy submitted.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if material had to be removed, a note will indicate the deletion.



ProQuest 10642994

Published by ProQuest LLC (2017). Copyright of the Dissertation is held by the Author.

All rights reserved.

This work is protected against unauthorized copying under Title 17, United States Code
Microform Edition © ProQuest LLC.

ProQuest LLC.
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106 – 1346

Accepted by the faculty of the College of Business and Technology, Morehead State University,
in partial fulfillment of the requirements for the Master of Science.

Dr. Nilesh Joshi
Director of Thesis

Master's Committee: _____, Chair
Dr. Ahmad Zargari

Dr. Nilesh Joshi

Dr. Sam Nataraj

Date

EXPLORING WIRELESS TECHNOLOGY APPLICATIONS IN CLINICAL STAFF RESPONSE TIME REDUCTION IN HEALTHCARE FACILITIES

Chase R. Johnson
Morehead State University, 2017

Director of Thesis: _____
Dr. Nilesh Joshi

Healthcare is met with an increasing burden to mend patient safety and the quality of patient care. This has led to a mounting interest in the use of mobile technology to address concerns about mistakes or oversights in patient care coming from failures in information exchange amongst healthcare authorities. The literature enforces the use of mobile technology as a way to improve efficiency within healthcare organizations. To achieve outstanding patient satisfaction in a healthcare setting it demands an intricate process. In that process, teamwork and consistent open dialogue with clinical staff, doctors, ancillary departments and most importantly, patients are essential. There is a continuous problem in healthcare that goes unnoticed; the response time to patient alarms. In an effort to address the inefficiencies of these response times, the solution is implementing wireless technologies applications that use the wireless network. Multiple communication systems can be integrated with other applications to achieve this result. This study proposes a basic technology architecture, which can be used to integrate various

commercially available wireless technology applications. The study also examines and compares the various applications limitations to quantify the impact of the wireless communications system on response times to nurse alarms. The data yields that wireless technology proposed in this study can have a significant impact on improving response time to patient triggered alarms.

Accepted by: _____, Chair

Dr. Ahmad Zargari

Dr. Nilesh Joshi

Dr. Sam Nataraj

Acknowledgement

I would first like to thank my thesis advisor Dr. Nilesh Joshi of the Morehead State University. The door to Dr. Joshi's office was always open whenever I ran into a trouble spot or had a question about my research or writing. He consistently allowed this paper to be my own work, but steered me in the right the direction whenever he thought I needed it.

I would also like to acknowledge the assistant dean of the college Dr. Zargari for always being their push and challenge me to be a better person. I am gratefully indebted to him for his very valuable advice, lectures, and comments on this thesis.

Finally, I must express my very profound gratitude to my mother and to the first lady for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them. Thank you.

Table of Contents

Contents

1	Introduction	1
1.1	Scope of Thesis	1
1.2	Issues with Mobile Communication Use	2
1.3	History of Communication in Healthcare	3
1.4	Purpose of the Investigation.....	4
1.5	Significance of the Investigation.....	5
1.6	Research Questions	6
1.7	Thesis Summary.....	7
2	Literature Review	8
2.1	Literature Overview	8
2.2	Wireless Alarm System History.....	9
2.3	Technology Application.....	12
2.4	Summary	12
3	Design of Technology	13
3.1	Existing Architecture.....	13
3.2	New Architecture	15
3.3	Investigating Current Technologies	16
3.4	Prototype Implementation.....	19

3.5	HIPAA Compliance	23
3.6	Expected Outcome	24
4	Data Analysis and Findings.....	25
4.1	Data Collection.....	25
4.2	Pre and Post Implementation Analysis	28
5	Conclusion.....	35
5.1	Statistical Evidence	35
5.2	Healthcare Impact	36
5.3	Recommendations and Future Research	37
6	References	39

Table of Figures

<i>Figure 3-1 – Existing Architecture</i> _____	15
<i>Figure 3-2 – New Architecture</i> _____	16
<i>Figure 3-3 – GRS 5 Beside Patient Bed</i> _____	17
<i>Figure 3-4 - GRS5 At The Patient Beside</i> _____	19
<i>Figure 3-5 - GRS10 at Nurse Station</i> _____	20
<i>Figure 3-6 - Existing Architecture</i> _____	21
<i>Figure 3-7- Diagram of Proposed Architecture expanded</i> _____	22
<i>Figure 4-1 – Bed Exit Alarm Duration Without and With Wireless Technologies</i> _____	28
<i>Figure 4-2- Boxplot of Bed Exit Alarms Without and With Wireless Technologies</i> _____	29
<i>Figure 4-3 – Normal Alarms Plot Of Duration Without and With Wireless Technologies</i> _____	30
<i>Figure 4-4 – Boxplot Of Normal Alarms Without and With Wireless Technologies</i> _____	31
<i>Table 4.1 – Alarm Response Without Wireless Technologies</i> _____	26
<i>Table 4.2 – Alarm Response With Wireless Technology Similar To Proposed</i> _____	27
<i>Table 4.3 – Response Times without Wireless Technologies</i> _____	32
<i>Table 4.4 – Response Times with Wireless</i> _____	32
<i>Table 4.5 – Two-Sample T-Test and CI: Duration for Normal Alarms Without Wireless and Duration With Wireless Technology</i> _____	33
<i>Table 4.6 – Two-Sample T-Test and CI: Bed Exit Alarm Duration Without Wireless and With Wireless Technologies</i> _____	34

1 Introduction

1.1 Scope of Thesis

The healthcare industry invests a significant amount of money and resources to improve the efficiency of all processes. The objective is to optimize the budget, schedule, and space while providing the most effective patient service possible. There are a variety of tools that can be used to help optimize the processes to achieve satisfactory results. Today's technology has revolutionized the way people communicate and commit to their daily processes and job duties. In healthcare, wireless technologies are starting to influence workflow, clinical decision making, and communication. A byproduct is patient satisfaction, because of the impact of wireless technologies (Igbokwe, 2004).

To maximize efficiency in healthcare, the wireless technologies that are available have great potential. The technologies that are available range from patient monitoring devices such as vitals that are connecting wirelessly, virtual walls, used for tracking staff, and wireless nurse call notifications to name a few. This investigation will focus on the wireless nurse call and the notifications. The nurse call system will be integrated with other services to provide wireless notifications on mobile devices of the clinical staff. By plunging into this process to identify the problem, who is affected, what can be done to improve or fix the problem and what the results are. Specifically, this will focus on improving patient care and improving clarity and unity for communication.

1.2 Issues with Mobile Communication Use

Progressively, mobile technology is being renowned as a vital tool for improving information flow and organizational effectiveness in healthcare systems. Clinical Staff is consistently in close proximity to the patient and plays an essential role in the handover of information and the synchronization of patient care to the specialty teams. Clinical Staff spends a significant amount of their time charting on patients and assembling those charts for use by interdisciplinary teams, such as attending physician, auxiliary services in the likes of dietary, radiology, and many more. The clinical staff, nurses are extremely versatile in their day-to-day actions no day is ever the same, moving recurrently between the patient's bedside, the nurse's post, the medication area, and helping with nutritional services. In a multifaceted and often changing settings, the clinical staff's information and communication needs are problematic to meet from virtually any location on the nursing unit, at all times of the day, and in a range of situational perspectives.

The majority of major healthcare organizations have answered these issues by quickly employing mobile wireless technology with the goal of refining opportunities for communication among healthcare specialists, enabling care management, and decreasing the response time for patient alarms for care (Altimier, 2002). The reinforcement of improving patient care is the driving factor in these healthcare facilities that are striving to be up to standard.

1.3 History of Communication in Healthcare

In healthcare, clinical staff is unable to be at the patient's bedside 24/7. The theory of having 24/7 bedside assistance would eliminate patient dissatisfaction and achieve one hundred percent patient satisfaction, no falls, and no risk. In this instance, if a 950-bed facility that operates with a scheme of one nurse and one technician per bed that's roughly 1900 nurses and technicians, this is not practical, for many reasons. There is not enough space for 1900 nurses divided up across all the nurse stations, they would be shoulder to shoulder, this is not practical. Instead, for instance, some patients are only recovering from a minor surgery that only requires a nurse checkup every few hours, for a two-day stay. On the other hand, there could be someone in an intensive care unit after a heart transplant that requires attention almost every thirty minutes. The ideal practice is that the nurses/techs are assigned multiple rooms. Doing so creates a vacuum for nurse calls being addressed in a timely manner due to staffing limitations.

With this comes the burden of addressing alarms which cause a delay in patient care that could have severe effects on patient health and negative patient care consequences. For example, the patient alarms inside their bathroom alarm goes off (they have fallen and requesting help) and only people in proximity of nurse stations can hear the alarm (device at nurse station like a computer only displays which room and type of alarm going off), but if they are not at the station and cannot see the above the patient door light, they can't visually see which room is alarming to address that alarm, they have to go to the nurse station and then address it and then walk to the patient room. This creates the chance that patient care is being neglected because of inefficient technologies in place.

1.4 Purpose of the Investigation

In flight, the objective of a Heads Up Display is to provide critical data to the viewer while not distracting them from the crucial task for which the data is needed. A “HUD” notifies a fighter pilot of altitude, speed, and heading, among other data, which diminishes the need for the pilot to gaze down at the instrument on the console for levels. A communications application will be implemented to improve team communication and facilitate wonderful patient care using current technologies while looking at instruments are important they don’t have to be engaged in one thing because the communication application will act as a HUD. The goal is to improve the medical staff awareness and response to an alarm through making the facility a connected hospital via wireless technology and applications to support patient satisfaction. The following are the research objectives of this study:

- Study the existing technology architectures and their limitations
- Propose a new architecture that integrates the commercially available technology
- Collect and Analyze Data of Pre and Post Implementation of the new technology architecture

With the arrival of alarm automation and mobile devices, the clinical team can, for the first time, have a mobile platform rather than having to depend on the overhead or monitoring of the nurse station alarm system. This permits clinical staff to achieve higher efficiency ratings and improve patient care from a multi-disciplinary team perspective.

As nurses play a crucial part in the direction of care and management of information for healthcare, a superior understanding of the issues that affect how they integrate a wireless nurse call structure into their day to day practices will clarify how people and teams working in organizations interrelate with skill and make sense of mobile technology. The drive of this

investigation is to discover the circumstances that form expectations about wireless nurse call phone use and the unintended costs rising from these expectations to deliver understanding into the insinuations of mobile technologies for people and groups. This thesis presents an investigation dealing with the use of mobile technology, a wireless nurse call system, to support the clinical actions of nurses and deliver a timely response to requests for care of different large hospitals.

Even though the drive of this investigation is not to frame conclusive answers regarding which direction the expansion of mobile technology should take, some recommendations pertinent to this subject and based on the findings of this investigation are presented in Chapter Five. Implementation of these recommendations is anticipated to assist executives, technologists, and engineers in implementing similar mobile technology in the healthcare setting.

1.5 Significance of the Investigation

The importance and objective of this investigation are to provide faster, efficient patient care. With the implementation of these systems healthcare providers can easily connect to each other from anywhere in the facility no matter the location. This permits medical staff to focus more time on essential functions. With the integration of this solution, there will be a huge decrease in overhead paging, which provides a more comfortable and quiet environment which would promote healing and improve patient satisfaction. With the availability to be connected anywhere, this could put the tools in the hands for medical staff to gather specialty teams in an even faster manner. This will permit clinical staff to address and act quicker in critical care situations.

Investigation set in the real-life situation of the healthcare setting is essential to help understand how the circumstances that form expectations about mobile technology use and the

unintended costs arising from these expectations contribute to the opportunities and challenges clinical staff face in interrelating with technology. It is the goal of this investigation to aid integration; how clinical staff interacts with mobile technology during the delivery of patient care. This information will contribute in the strategy, application and assessment of communication systems that withstand both the mobile workflow and communication necessities of clinical staff and in the operative distribution of clinical information across spatial, time-based and relative limitations to provision the continuum of care.

1.6 Research Questions

Differences in work practices and communication patterns may arise for numerous different motives: clinical staff varies their activities and interactions in order to answer to the deteriorating of a patient's health standing or the admission of an unsteady post-operative patient. This leads to the universal issues that will be brought to the table in this thesis set out in the overall research question:

“How to improve nurse's response time with wireless technology in their daily clinical practices?”

To answer the question, this reading investigates the experience of clinical staff with incorporating a wireless nurse call system into their day to day clinical practice in a healthcare environment as they interrelate with each other. The expansion of recommendations founded on the investigation findings can deliver direction to endorse mobile technology use through modifications of product design and staff education. Wireless technology has already impacted healthcare with something that is taken for granted every time visiting a hospital, Guest Wi-Fi. Guest Wi-Fi is an amenity that is offered to all its guests and can improve patient and family satisfaction and has now been provided for some years. However, this has also provided the

opportunity for wireless devices connected to the secure network through the same wireless access points that the guest network is provided on is now an instrument to promote the nurse call notifications forwarded to the wireless devices regardless of location pertaining to anywhere with the wireless signal.

1.7 Thesis Summary

The following sections have illuminated the subject and content for the research described in the coming chapters. Chapter two starts literature review which references articles and published documents that engage both sides of the implementation of wireless technology. The design of technology explained in chapter three will reveal the standard and infrastructure for the current and the new standard of wireless communication applications in healthcare.

The data collection, chapter four will expand on the data analysis side of implementation of the design of technology. How data gathered from various facilities either supports or condemns the implementation of wireless technology in a clinical setting.

The chapters forthcoming will feature a more in-depth description of the methods and results that will address the research question.

“How to improve nurse’s response time with wireless technology in their daily clinical practices?”

2 Literature Review

Patients rely on the nurse call infrastructure when in need of clinical staff assistance, while clinical staff rely on the nurse call system to organize day to day work activities. The focus of the literature review is to investigate the poor response times to patient-initiated alarms, to explore the initiatives that other hospitals are implementing to address the issues with response times, and study the state of the art technology that is supporting clinical staff by improving efficiency and decreasing response time to requests for help from patients. Literature overview in the first section details implementation and how it could benefit the clinical staff. After examining the benefits of a wireless integration, the next section maneuvers into the history of the wireless implementation and how the results have yielded in regards to decreasing response time. The final section of this chapter will reveal the summary of all of the literature and how the limitations moving forward will impact the implementation of a prototype design.

2.1 Literature Overview

With the advances in mobile technology in the workforce, it is implied that the opportunity to change and make our method of communication more efficient is now (Davis, 2002). With the implementation of wireless technology, the nurses are now capable of having a connection to other clinical staff without having to be face to face or connected to a cord into the wall. Team collaboration is essential for the team to achieve excellent patient satisfaction and for the continuity of care. The implementation of wireless technology into the clinical setting may develop unexpected changes in social exchanges and day to day work activities that are harmful for the healthcare environment through the disruption of everyday routines and patterns of communicating.

Though mobile technology use in the healthcare environment has picked up speed, a thorough review of the literature exposes that mobile technology overall has been severely under-investigated. There is a gap in developing a theoretical understanding of mobile technology appropriation (Alpay, 2004), with a huge quantity of studies examining performance results. With this gap, there has been a need to reexamine the research approaches used to observe mobile technologies in the settings in which they are used.

2.2 Wireless Alarm System History

A study was conducted to evaluate the impact on workflow and communications of clinical staff using a wireless communication structure. The researchers investigated two medical-surgical in-patient units in a mid-sized Hospital in the US (Breslin, 2004). A post interpolation examination was used to gauge the efficiency of the clinical staff. The information assembly period for the post-intervention phase was the entire month of December, in 2003. This data concluded that there are significant advantages and disadvantages in regards to the impact of wireless technology being integrated with wireless nurse call. The advantages were decreasing response time to triggered alarms and a disadvantage was alarm fatigue to clinical staff.

A study conducted in Baltimore, Maryland investigated the impact of wireless communication technology developed by a vendor similar to Voalte, which is a wireless communication application known as Vocera Communications. The focus was on the impact of the Vocera Messaging Interface, which permitted connectivity between unlike systems, the nurse call system. The results of the study of the nurse call integration affirmed that the use of the integrated communication system condensed overall time for finalizing a patient request by nearly 50% across all studies when governing for observation type. Additionally, examination of clinicians' usage of the structure for different types of patient requests exposed that it enables the

clinician to have additional control in prioritizing and answering to requests according to the importance of the occurrence (Kuruzovich, 2008).

A medical-surgical unit in a Texas hospital observed the results of adding wireless communication technology to support nurses in identifying patient bed status changes and enhancing team communication. In order to obtain this data, a group of nurses was shadowed for 8 hours before and after the introduction of the wireless devices. Data was collected concerning patient room visits, a number of patient calls, bed status calls, response time to calls, and the initiator of the communication incidents.

After implementation, a follow-up study showed that response time to calls had significantly decreased. Clinical staff responded to bed calls in less than 1 minute—nearly 60% of the 37 calls. Communication outcomes specified a significant shift in clinical staff-initiated communications, suggesting an enhanced ability to communicate with team members and to assist in monitoring patient status. Patient falls trended downhill for a six-month period of wireless technology use linked to the same period the previous year (Guarascio-Howard, 2011).

Robin Digby and colleagues studied the effects of raising awareness of call bell response on how promptly staff address patient falls. Their study compared call bell response times in two units before and after the introduction of a suite of interventions designed for decreasing patient falls. The data on call bell response times were gathered over two periods, once before the implementation and once after the implementation. Data were collected from the call system that captured in detail the time taken to answer every call activation. Another period of data gathering was directed half a year after the execution of the initiatives. The conclusion of Digby's results was prioritizing call answer and raising staff cognizance enhanced response to patient calls. There was a minor reduction in falls, though call activations did not fall. The study implies that

strong management is necessary from nurse leaders to stress the significance of quick call response (Digby, 2011).

There is great literature to support the implementation of hourly rounding, this requires a vast amount of resources to be applied every hour. The studies conducted by Mitchell et. Al. (2014) proved that hourly rounding significantly improves patient's perspective of clinical staff responsiveness in areas that may have had problems with falls and nurse call alarms, which in turn improves patient satisfaction scores (Mitchell, 2014). The hourly rounding will require the staff to invest time in rounding which is a great activity for healthcare but with the implementation of wireless technologies, this permits the staff to be more efficient with their day to day activities.

Clinical Staff addressing patient alarms is absolutely vital. "In healthcare, a call alarm is a lifeline for hospitalized patients" (Meade, 2016). Meade highlights that a patient's rating of satisfaction with clinical care relies on how the patient views how they have been treated in response to their needs. Although, other issues such as alarm fatigue and patient load, these are the reasons clinical staff cannot address the call-in time (Meade, 2006).

Health-care providers in other countries are discovering the use of wireless technology to expand patient care delivery. A focus group discussion was aided by nearly ten senior management staff in health care in Australia. This led to a set of challenges, which were used to request opinions from clinical staff in Queensland. Roughly 30 interviews were directed. The investigation yielded a set of almost 60 outlying themes, which were assembled. These consortiums echoed the challenges as lack of user-friendly, inferior testing, scarcity of staff, anxieties for security, dependence on technology, existing glitches, work schedule, education/training, coverage of wireless access points, and privacy. The discussions clearly

specified the need for training and attentiveness measures. The present study delivers some of the information essential to understand an enterprise-wide execution of wireless technology (Gururajan, 2005).

2.3 Technology Application

A research study led by Ruland (Ruland, 2002) to examine clinical staff use of a mobile device documentation structure to gather patient preferences concerning care preparation. This investigation similarly explored the similarity between patients' preferences and clinical staff care priorities. The investigation took place on at a medical facility for geriatrics and a rehabilitation facility in Europe. The investigators determined that the use of the hand-held computers to gather patients' preferences at the point of care could very well be an operative approach for refining clinical staff care. This investigation was significant since it confirmed the nurses had a positive experience with regard to the benefits of wireless technology.

In a unit clinical model, communication is vital for the organization of healthcare and the effectiveness of response to patient situations. In an analysis of roughly 150 fatal events, the Joint Commission (Joint Commission on Accreditation of Healthcare Organizations., 2008) grades deficiency of communication as the second leading cause of falls. The objective of technology is to help reduce the ambulatory time and increase the effectiveness of healthcare services.

2.4 Summary

The review of the literature conducted has implied that mobile technologies may affect organizational procedures in unexpected behaviors (Hn Tjora, 2002). The practice of mobile technology in a clinical setting has boundless potential to resolve some of the difficulties with communication breaks and information interruptions that burden patient care in healthcare.

3 Design of Technology

Conventional nurse call systems involve the push knobs situated near the bed of the patient room. When triggered by the patient, it notifies the nurse station by emitting a distinct tone or illuminating a light panel that flashes outside each room. The multi-color indicator fixture is stationed outside the patient room composed with a control to cancel the previously recorded call. When a light is lit, it designates that the patient needs care. On the other hand, a different color light when lit designates that the call has been recognized by the clinical staff. This prevents the same patient from being attended by more than one member of the clinical staff. These alarm indications are turned off only if the request is attended by the clinical staff. In case of an interruption caused for the clinical staff to address the call registered by the patient, the light flash frequency and the pager sound intensifies (Usman, 2011). The design of this structure will focus on two-way voice communications and send alarms to mobile devices where only the clinical staff can invoke the voice communication.

This chapter first explains current outdated standard architecture that has been in use by many healthcare organizations. After examining the current technologies and their infrastructure, the text discusses the state of the art technology and architecture design that improves on the limitations discussed in the first section of the chapter. Thus, achieving the new standard for implementing wireless technology in a clinical setting.

3.1 Existing Architecture

Different facilities will have different scales of applicability. Smaller facilities will rely on the traditional setup which is pictured below in Figure 3.1. This is the standard across healthcare. In the traditional method below, a computer requires someone to be at the desk 24/7 to acknowledge alarms and then notify the clinical staff. There are numerous drawbacks to this

schematic. The requirement for a 24/7 clinical person to be at the desk. The nurse in the next room has to come back to the nursing station in order to actually know about an alarm that was in the patient room next to them, this creates a significant amount of unneeded work.

Additionally, nurse call systems implemented from the early 2000s do not have the voice over IP function integrated which permits clinical staff to answer calls as soon as a call is raised to see what the request for help was pertaining to. In those instances, it could be regarding more pain medicine or other medications. This enables the clinical staff to answer the call, and stop by the medication room on the way to the patient's room to get the medicine request. Another example would be pertaining to an extra pillow, or need help getting out of bed, which would require more than one person to help in some instances, all of these justifications are quite relevant and help save time for clinical staff. Below in figure 3.1 shows the existing architecture.

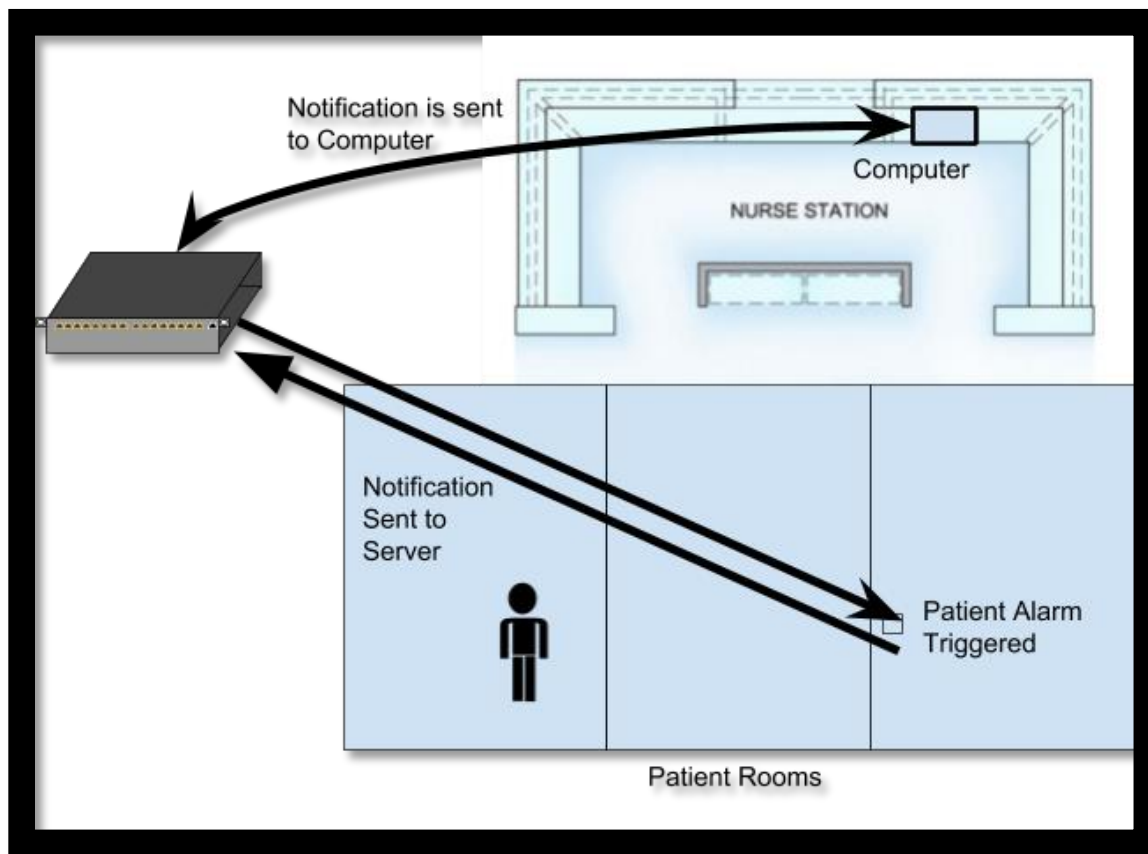


Figure 3-1 – Existing Architecture

3.2 New Architecture

Today, with the advances in technology, the architecture shown in figure 3.1 above is becoming more and more outdated. The new and rising status quo is implementing wireless technologies to improve efficiency. Below is figure 3.2 showing what the new process flow is for lowering response times. This process will also increase productivity. This is essentially replacing the nurse station primary role in notifying clinical staff of requests for patient help.

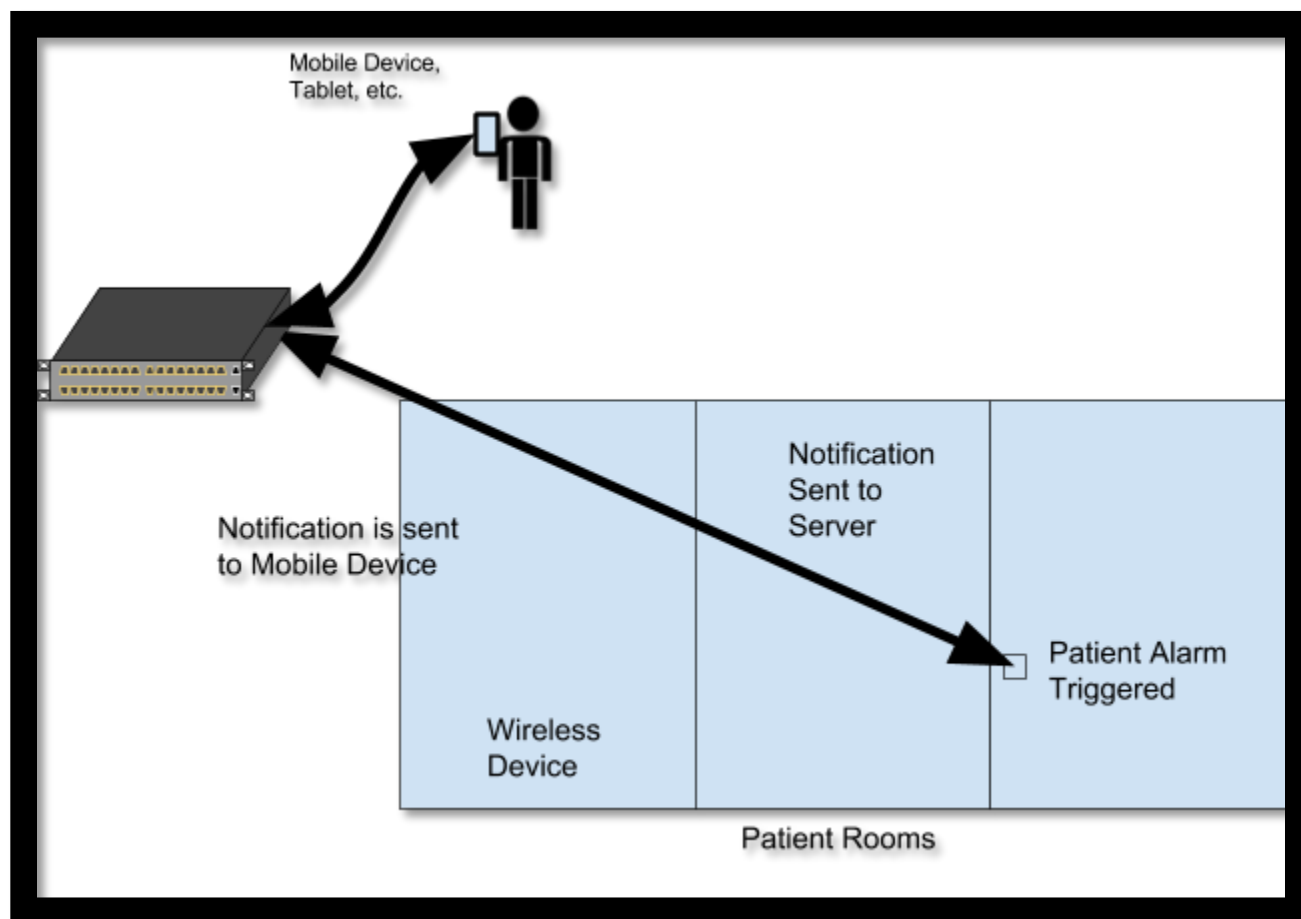


Figure 3-2 – New Architecture

3.3 Investigating Current Technologies

To achieve the desired result of wireless technology integration it demands cross-platform communication. There are a wide variety of applications that can help achieve this goal and make the effort of decreasing alarm response times seamless. First, a nurse call system must be in place. There are two nurse call systems that are being observed; Hill-Rom and Critical Alert.

Nurse call systems will be almost the same product with different names, logos and color schemes. There are two middleware applications being examined, Bernoulli and Connexall, both of which will provide the monitoring applications to notify the communication application of which will be either Voalte or Vocera, that there is a patient alarm triggered.

Nurse Call Applications:

- Hill-Rom (NaviCare) can initiate alerts about the patient and alarm to be sent directly to caregivers, through nurse call or wireless devices with the integration of a middleware. An additional perk of Hill-Roms product Bi-directional digital data integration between nurse call, electronic medical record systems, and wireless devices. Below in figure 3.3 illustrates a nurse addressing a Hill-Rom alarm at the bedside.



Figure 3-3 – GRS 5 Beside Patient Bed

- Critical Alert is essentially the same product as Hill-Rom. Critical Alert offers its own middleware, Common Path Wireless Integration which connects cross-platform applications, permitting them to communicate. An additional perk of critical alert is real-time location system which permits the management of clinical staff via virtual walls, to improve efficiency and productivity.

Integration applications (middleware):

- Bernoulli is an application that permits cross-platform connectivity from a nurse call system into a communication application that is automated.
- Connexall is an application that permits cross-platform connectivity from a nurse call system and the potential for other health care items such as IV Pumps out of fluid, and vitals bottoming out, for example, to be transmitted to a wireless device.

Communication Applications:

- Vocera is a Secure HIPAA-compliant text messaging that is encrypted and secure. This application allows communication and alerts virtually anywhere with mobile device and desktop based applications.
- Voalte is a HIPAA compliant messaging application that permits care teams inside and outside the hospital access and exchange information securely via text, calls, and alarms. This is an application that is installed on mobile devices to permit communications and alarms.

3.4 Prototype Implementation

For this investigation, the products chosen will be Hill-Rom, Voalte and Connexall. Hill-Rom will provide the instrument for connection for the nurse calls alarms to the Connexall server. The Hill-Rom products will be a GRS5 (patient rooms) shown in Figure 3.4 and GRS10 (outside patient rooms) shown in Figure 3.5.



Figure 3-4 - GRS5 At The Patient Beside

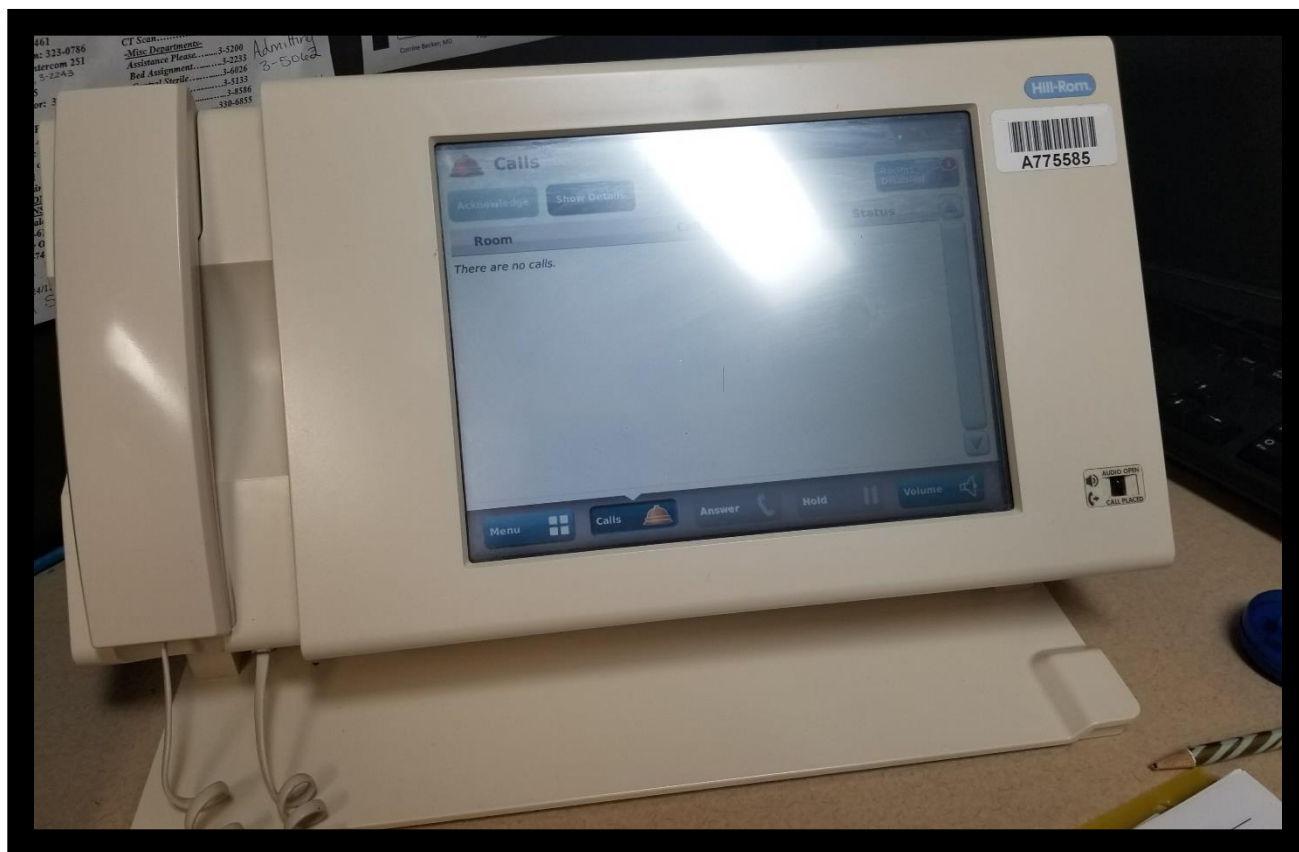


Figure 3-5 - GRS10 at Nurse Station

The Connexall server will send a task of the triggered alarms to the Voalte server, these alarms include any alarms that are integrated into the Hill-Rom nurse call. From there, the Voalte server will send the alarm as a notification to the clinical staff via the mobile device they are carrying with them. This mobile device will be more sophisticated than a normal pager which, the medical staff is prominently wearing instead a cell phone like device that permits two-way voice and has the functionality of a smartphone with access to applications. Of the applications would be the Voalte Communication application that the clinical staff can log into and begin communication regardless of location. A limitation described in the literature review was expressing grief about clinical staff having too many devices to juggle on any given day, the advantage to implementing the mobile phone like devices permits the staff to access the mobile

version of the electronic health record system. While the mobile application would be limited, it could still interface with the system. Another advantage of the mobile devices is the options for the clinical staff to take pictures on the devices and send to other specialty teams, which would alleviate the burden of those teams traversing across the facility to look at one patient.

Therefore, increasing productivity for the specific specialty teams. The overall outcome desired for this investigation is to decrease response time to patient triggered nurse calls. There will be a learning curve, as with any new product or device implementation. Below is a figure 3.6 that aligns with what the generic standards across the nation's healthcare facilities.

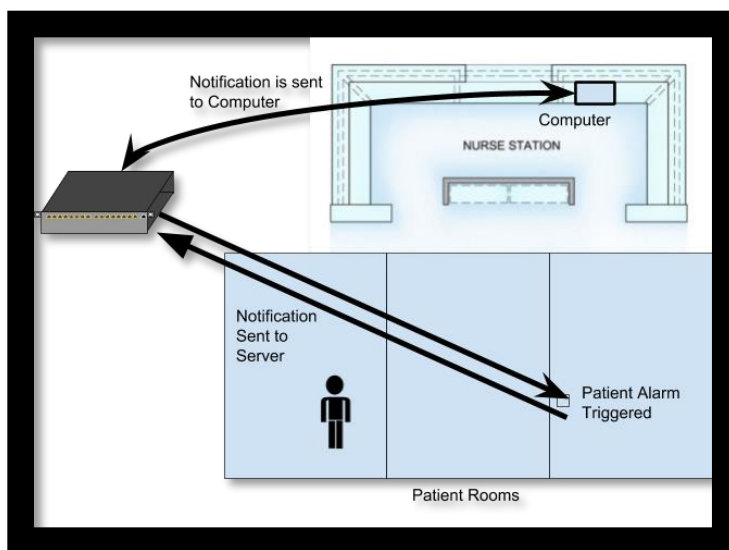


Figure 3-6 - Existing Architecture

Not depicted above in figure 3.6 would be the option for the clinical staff to connect to the pillow speaker in the room of the patients when the alarm is triggered via voice over IP function, which is described as a limitation in some of the literature referenced in the investigation. This function could be integrated with the wireless devices, which permits clinical staff to answer calls as soon as a call is triggered from a patient room. The clinical staff could have the option to determine what the call was initiated for. This enables the clinical staff to

answer the call, and stop by the medication room on the way to the patient's room to get the medications request. On the other side of this perspective is the nurse would address the alarm, navigate to the bedside and seek what the request was, for example, medications, so the nurse then needs to navigate back the way they just walked and collects the meds to distribute to the patient. This implementation of voice over IP within the nurse call system has some significant advantages that promote total quality improvement. Figure 3.7 below shows the proposed architecture diagram.

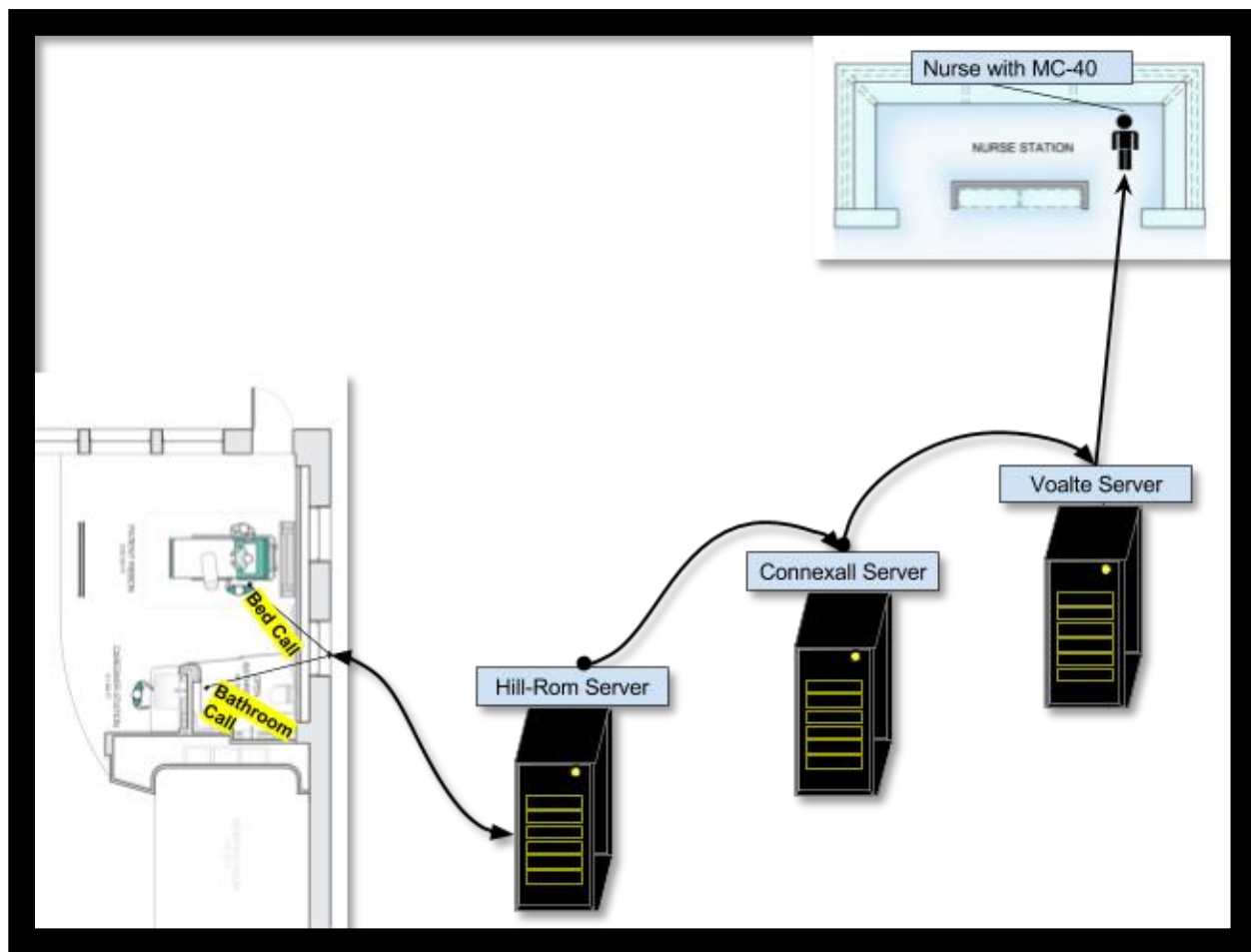


Figure 3-7- Diagram of Proposed Architecture expanded
(Metropolis Magazine) (Behind The Design - Patient Rooms)

3.5 HIPAA Compliance

HIPAA, the Health Insurance Portability and Accountability Act, sets the standard for protecting patient data. Any organization that deals with protected health information or PHI, they must ensure that all the mandatory physical, network, and process security measures are in place and operated by.

This contains covered entities, someone who conducts treatment, payment, and operations in healthcare. The other entity is business associates, someone with access to PHI and provides support for treatment, payment, or operations.

In order for the Communications application, Voalte or any for that matter to be compliant with HIPAA must be able to remotely delete text messages if they are sent to the wrong individual or when an enrolled user's mobile device is stolen. The applications must also secure against the unauthorized interception of messages that are transmitted over an open Wi-Fi (Wang, 2013).

The communication applications modeled will have most of the following:

- Unique User identification for auditing control.
- Emergency Access Procedure for obtaining necessary PHI during an emergency event.
- Automatic log off that terminates a secure connection after a set time.
- Encryption and Decryption, to encrypt the hard drive and or decrypt.
- Authentication, procedures set to verify the person requesting access to PHI is the person who is claimed.

3.6 Expected Outcome

With all of the steps illuminated above, the correct process flow once all the technological components are integrated into the unified architecture should reflect in an efficient manner.

Depicted below, shows the step by step process flow from the alarm being triggered to the nurse acknowledging it.

- Hill-Rom Nurse call triggered in the patient room
- Hill-Rom Server detects an alarm has been triggered
- The Connexall Server is monitoring the Hill-Rom Server for any active alarms
- The Connexall application sees the triggered alarm
- The Connexall application invokes a task to send the notification to voalte server
- Notification is received on a voalte server and forwarded to mobile device
- Nurse with the mobile device can acknowledge the alarm to attend to the patient

While doing so the Voalte server then notifies all the stakeholder servers that the alarm has been sent to the user. The nurse has the option to acknowledge the call or acknowledge and call the patient. By sending the acknowledgment of the nurse back to the server permits clinical staff to monitor the quality of patient care that their staff is delivering, this essentially holds the staff accountable.

To support the expected outcome, the next chapter introduces the data analysis which supports and illuminates the setbacks of the implementation or wireless technologies in general.

4 Data Analysis and Findings

In this chapter, the results of the data analysis are presented. The data was collected from two facilities and then processed in response to the problem cited in chapter one. The ultimate goal that propelled the gathering of the data and the succeeding data analysis was to develop a base of knowledge about the response times in clinical care settings, without wireless technology and after the wireless technology has been implemented. A study was performed in a hospital that has a rudimentary wireless technology and the objective of data analysis is to compare the results to see if the yields are beneficial from the new age wireless technology perspective.

The data analysis determines if the proposed technology architecture and utilization are dependable with the basic goals or principles of improving response times to patient triggered alarms. The data analysis objectives were accomplished. The findings presented in this chapter validate the proposed new architecture for improving response time for clinical staff to patient alarms. The expected outcomes of the proposed wireless technology are going to be better than what was observed.

The first section of this chapter discusses the data collection process. The second section documents the Pre and Post-implementation data analysis. The final section of the chapter concludes the findings.

4.1 Data Collection

The data that has been collected is from two facilities within the united states. This data was observed first hand and recorded. Table 4.1 shows an observation of 27 calls over different floors of a hospital and the clinical staff response time to acknowledge a call and attend to a patient request for help. The table below shows the results without wireless technology. The results are organized so that normal calls and bed alarms are separate.

Table 4.1 – Alarm Response Without Wireless Technologies

Alarm Type	Duration before Response - Seconds
Bed Exit	92
Bed Exit	150
Bed Exit	77
Bed Exit	32
Bed Exit	52
Bed Exit	55
Bed Exit	44
Alarm Type	Duration before Response - Seconds
Normal Call	155
Normal Call	318
Normal Call	482
Normal Call	34
Normal Call	290
Normal Call	181
Normal Call	333
Normal Call	62
Normal Call	113
Normal Call	119
Normal Call	100
Normal Call	171
Normal Call	140
Normal Call	316
Normal Call	434
Normal Call	334
Normal Call	281
Normal Call	194
Normal Call	100
Normal Call	127
Bed Exit Average Response Time - Seconds	71.71428571
Normal Call Average Response Time - Seconds	214.2

Table 4.2 shows the results of 27 calls over different floors of a hospital and their response times to acknowledge a call. The results are with the rudimentary wireless technology implemented. The data is divided into normal calls and bed exit calls.

Table 4.2 – Alarm Response With Wireless Technology Similar To Proposed

Alarm Type	Duration before Response - Seconds
Bed Exit	21
Bed Exit	34
Bed Exit	36
Bed Exit	40
Bed Exit	9
Bed Exit	2
Bed Exit	11
Alarm Type	Duration before Response - Seconds
Normal Call	47
Normal Call	49
Normal Call	61
Normal Call	64
Normal Call	74
Normal Call	83
Normal Call	22
Normal Call	37
Normal Call	40
Normal Call	43
Normal Call	51
Normal Call	55
Normal Call	59
Normal Call	63
Normal Call	4
Normal Call	6
Normal Call	21
Normal Call	29
Normal Call	34
Normal Call	41
Bed Exit Average Response Time - Seconds	21.85714286
Normal Call Average Response Time - Seconds	44.15

4.2 Pre and Post Implementation Analysis

Data from Table 4.1 is graphically represented in figure 4.1 and shows the average response time to bed exit alarms. The joint commission addressed this as a huge target for improving patient care. Figure 4.1 depicts the results of response times to alarms without wireless technology. Without wireless technologies, the units are utilizing extra staff to attend to the calls and dispatch the appropriate staff. The response time is roughly over one minute to respond to bed exit alarms. With the data from the hospital that has wireless technologies, one can see the time to address the call is nearly 85 percent faster. This is 50 seconds faster than the average without wireless technologies.

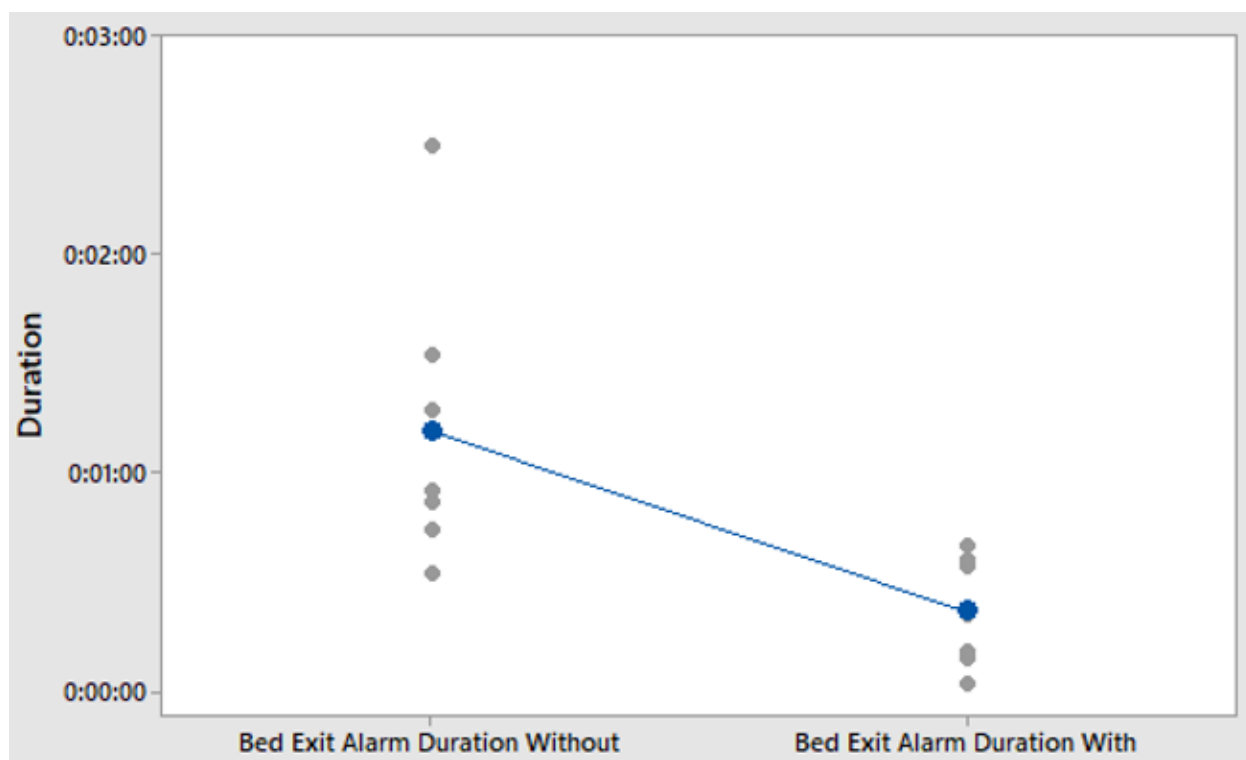


Figure 4-1 – Bed Exit Alarm Duration Without and With Wireless Technologies

In figure 4.2 we see the display of boxplots of bed exit alarms without and with wireless technologies implementation. The boxplots below indicates the degree of variation in the data which is shown in the bed exit alarms without wireless to be more significant. In the bed exit alarms with wireless, they yield a comparatively smaller variation.

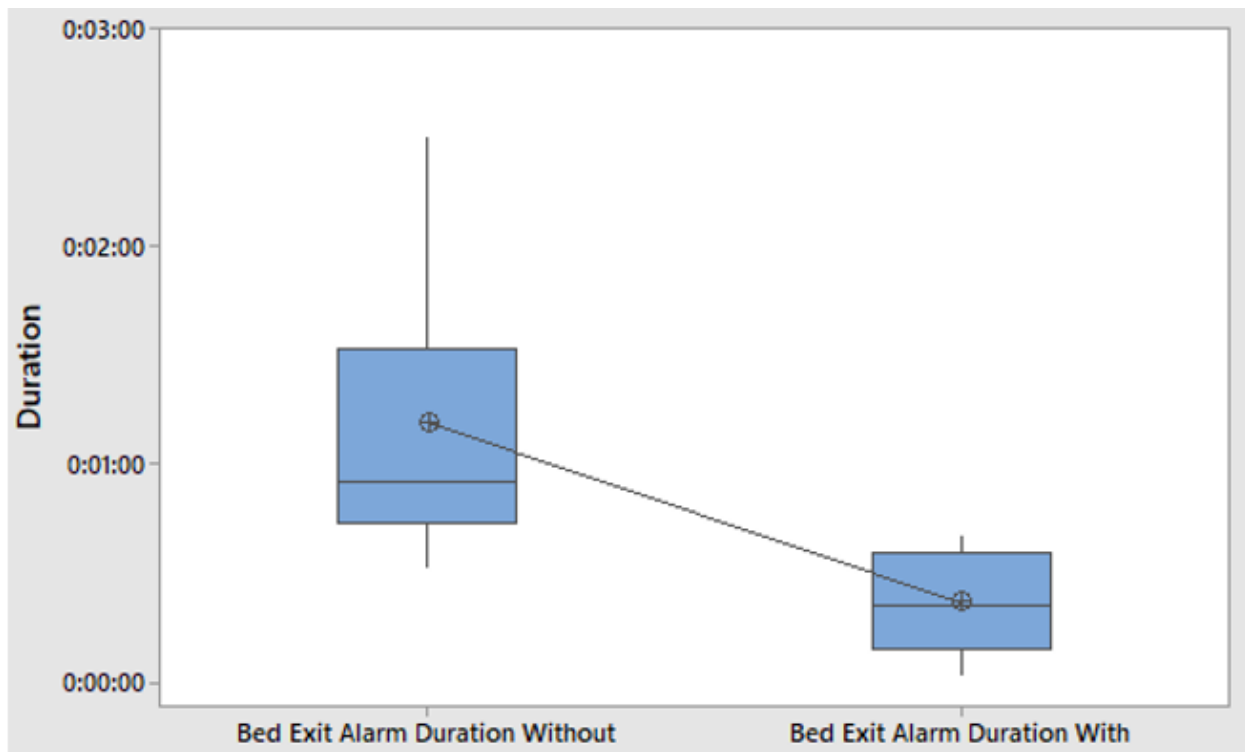


Figure 4-2- Boxplot of Bed Exit Alarms Without and With Wireless Technologies

In figure 4.3, the data is graphically representing the average response time at the hospital without wireless technologies is roughly 4 minutes. The data observed at a facility that has wireless technology proved to be very helpful in responding to normal patient alarms. The data yields that 440 percent increase in average response times to normal alarms. The improvement in average time is 3 minutes and 13 seconds.

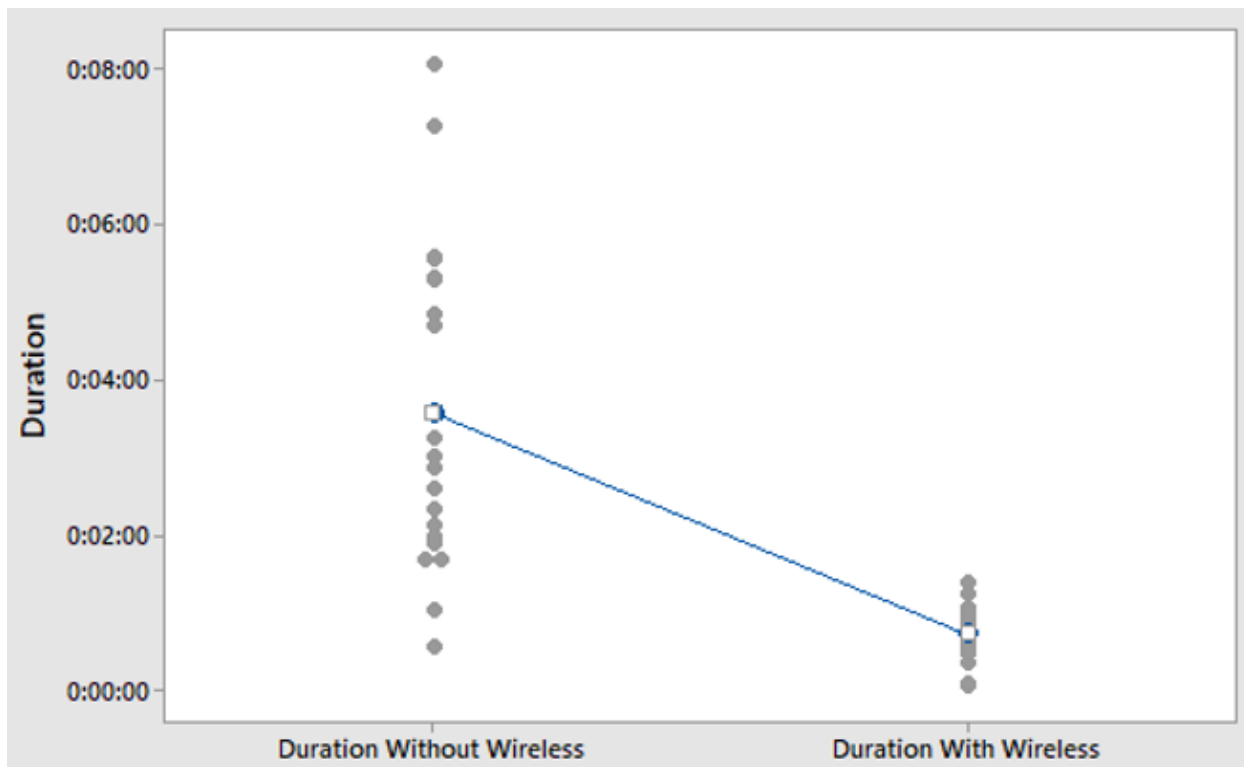


Figure 4-3 – Normal Alarms Plot Of Duration Without and With Wireless Technologies

Figure 4.4 shows the variation in the normal alarms response times. The respective boxplots show that the degree of variation is quite radical for the duration of alarms without wireless technologies when compared to the more concise and expected outcome of the normal calls with wireless technologies implemented.

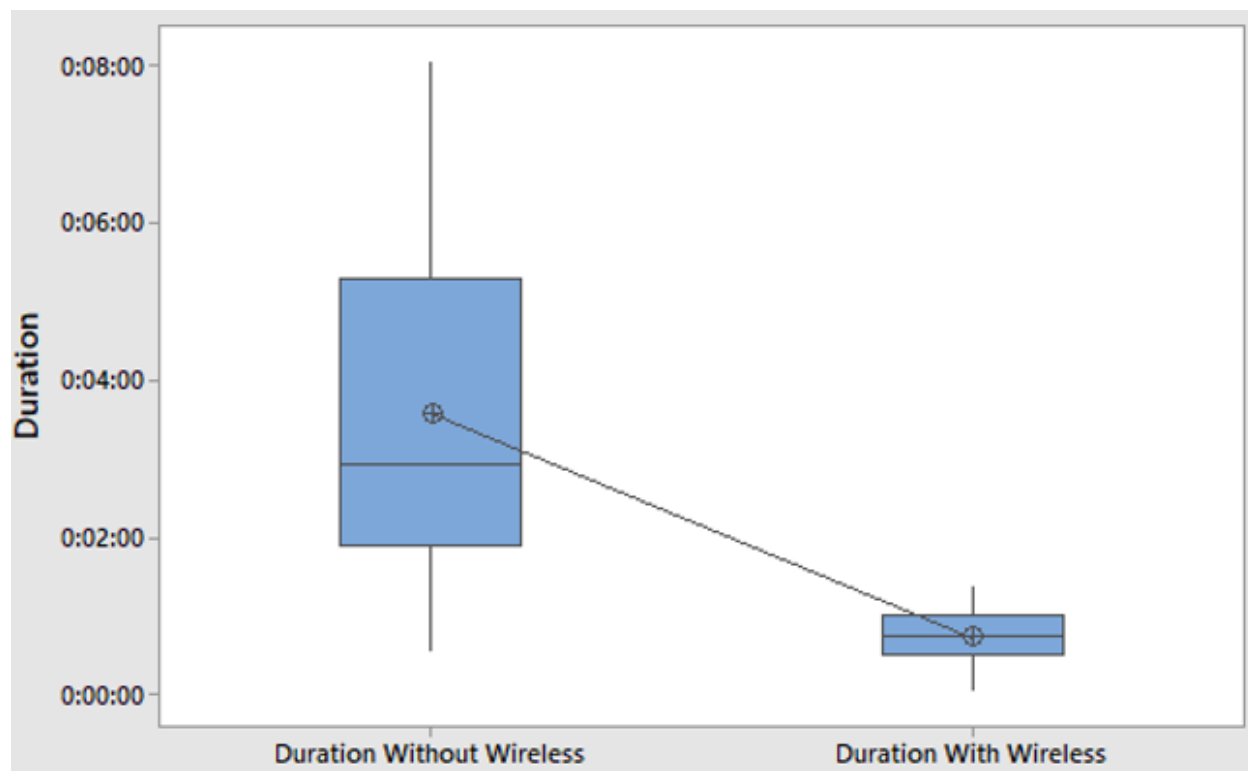


Figure 4-4 – Boxplot Of Normal Alarms Without and With Wireless Technologies

In table 4.3, the standard deviation shows the bed exit alarm response rates deviating 40 seconds over the alarms observed. In reference to the normal alarms, they have over two minutes of standard deviation.

Table 4.3 – Response Times without Wireless Technologies

Alarm Response Rates Without Wireless	
Standard Deviation of Bed Exit	40 Seconds
Standard Deviation of Normal Alarms	2 Minutes and 3 Seconds

Table 4.4 illustrates that with the wireless integration, it has significantly decreased alarm response rates on both bed exit and normal calls. The results yield very positive results when compared with facilities that do not have wireless technologies.

Table 4.4 – Response Times with Wireless

Alarm Response Rates With Wireless	
Standard Deviation of Bed Exit	15 Seconds
Standard Deviation of Normal Alarms	20 Seconds

The results were supported by respective two-sample T-tests. In table 4.5 we see that the Low P value and high T value support the claim that the inclusion of wireless technology brings a statistically significant reduction in response times.

Table 4.5 – Two-Sample T-Test and CI: Duration for Normal Alarms Without Wireless and Duration With Wireless Technology

Method

μ_1 : mean of Duration Without Wireless

μ_2 : mean of Duration With Wireless

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
Duration Without Wireless	20	214	126	28
Duration With Wireless	20	44.1	21.0	4.7

Estimation for Difference

Difference	95% Lower Bound for Difference
170.0	120.9

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 > 0$

T-Value	DF	P-Value
5.96	20	0.000

In table 4.6 we can see the similar results as in table 4.5. The P-Value of close to zero and the T value of 3.09 once again indicates that the decrease in response time for the bed exit alarms is statistically significant with the inclusion of the wireless technologies.

Table 4.6 – Two-Sample T-Test and CI: Bed Exit Alarm Duration Without Wireless and With Wireless Technologies

Method

μ_1 : mean of Bed Exit Alarm Duration Without

μ_2 : mean of Bed Exit Alarm Duration With

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
Bed Exit Alarm Duration Without	7	71.7	40.0	15
Bed Exit Alarm Duration With	7	21.9	15.0	5.7

Estimation for Difference

Difference	95% Lower Bound for Difference
49.9	19.3

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$

Alternative hypothesis $H_1: \mu_1 - \mu_2 > 0$

T-Value	DF	P-Value
3.09	7	0.009

The overall outcome from the graphical and the statistical analysis perspective yielded that the implementation of a wireless technology would significantly help in lowering patient response rates. The technology that was studied yielded this data and the proposed technology is more invasive and poised to decrease response times lower than recorded data from this rudimentary technology that was observed.

5 Conclusion

From the data gathered and analyzed in the previous chapter, all findings yield significantly strong support of implementing wireless technology, specifically the proposed architecture.

Literature from the joint commission addresses that bed exit as one of the leading processes to be improved in healthcare (Joint Commission on Accreditation of Healthcare Organizations., 2008).

5.1 Statistical Evidence

The data recorded and analyzed illustrated that the average time to respond to a bed exit alarms was roughly one minute and ten seconds. This is not a good practice in healthcare with the response times to alarms, with any healthcare facility they will want to improve on this and the proposed technology architecture does. With the implementation of the wireless technology, we can see that twenty-two seconds is significantly faster and more attentive to response time and response rate the issue brought up by the joint commission. The wireless technology improved response time to bed exits by roughly 80 percent. The standard deviation of the bed exit alarm without wireless technology was 40 seconds, this is very inconsistent. With the implementation of wireless technology, the standard deviation came down to 15 seconds, which is a much better improvement for clinical staff attending to those alarms.

The most shocking data collected is that the average time to respond to normal calls was almost four minutes. The standard deviation of this dataset was almost two and half minutes without wireless technologies. After observing a facility that has the wireless technology, the response time is roughly 40 seconds with a standard deviation of 21 seconds, the wireless technology architecture is supported by these findings that resulted in a 428 percent increase in response to normal alarms. The T tests proved very helpful in support of implementing wireless

technologies, signifying that the wireless technology we observed was successful in decreasing response time to patient triggered alarms.

5.2 Healthcare Impact

The data gathered supports the benefits of the proposed technology architecture and the objective is that the other healthcare facilities should use should consider using this architecture in future. The proposed architecture was discussed at length in Chapter 3. The other facilities considering adopting similar wireless architectures can get insights from the data analysis regarding the extent of positive results that can be expected. The wireless technology architecture can impact healthcare from all facets, from clinical management to patient care.

A study from hospital serving the Baltimore/DC metro area yielded that using a wireless technology over out-of-date communication methods on one nursing unit rewarded a time savings of more than 3000 hours a year or the equivalent of 1.5 full-time clinical staff personnel. Typical communication time when using the wireless technology was more than five times faster than when using out of date methods. In addition, the clinical staff reported that wireless technology had an affirmative impact on workflow and the clinical staff's capacity to deliver superior patient care (Breslin, 2004).

5.3 Recommendations and Future Research

With the proposed architecture, the recommendations would come from the perspective of major limitations of user education, and user-friendliness aspects of the technology. The clinical staff fully adopting the technology will have a learning curve and require education of staff for all applications. The devices becoming more user-friendly will progress over time, this will stream from the publisher of the middleware, nurse call and communication applications that are chosen. The feedback from healthcare facilities to these developers will change the tide of which direction they take to make their applications widely accepted. The objective should align with making their product more streamline and easier to adopt.

Future Research would involve adding additional alarms outside of the nurse call such as IV Pumps notifications, patient vitals, and patient motion tied into the application on the phone that receives the alarms. Permitting vitals, IV pumps and patient motion to be implemented into the communication application would give the virtual meaning of 24/7 bedside assistance. The IV Pumps being monitored wirelessly for notification is halted due to the literature supporting a patent that is blocking other developers from adopting this outcome (United States of America Patent No. U.S. Patent No. 5,569,187, 1996) .

There is no limit to what impact future wireless technologies could have in healthcare. The research is steadfast and ever changing to continually improve healthcare. The traditional pager that most healthcare facilities still use has its days numbered.

As a conclusion, with the help of wireless technologies in healthcare environment, clinical staff are able to respond to patient alarms faster, more consistently, and improve patient care, which in turn help with the patient's recovery and wellness. While the proposal of using wireless technologies to reduce healthcare response time to patient triggered alarms seem logical and practical, it is still largely unproven due to the lack of large-scale trials. Therefore, future work should include the analysis of large-scale deployment of wireless technology solutions. The security aspect of encryption of devices will require much further research to ensure these devices are HIPAA compliant as new technology is evolved and created. The current technology is HIPAA compliant with the ability to remote wipe, secure data and delete it. The results of using these proposed solutions should be well documented for comparison of implementing wireless technology versus the cost of not implementing the wireless architecture.

6 References

- Alpay, L. T.-S. (2004, June). Supporting healthcare communication enabled by information and communication technology. *Proceedings of the Conference on Dutch Directions in HCI*, p. 12.
- Altimier, L. B. (2002). Go wireless to spark productivity. *Nursing management*, 33(7), 43-44.
- Behind The Design - Patient Rooms*. (n.d.). Retrieved from Getting Started With A Hand Hygiene Cad Layer Outsmarting Outbreaks: http://www.swawou.org/medium/getting-started-with-a-hand-hygiene-cad-layer-outsmarting-outbreaks-hospital-room-plan_1502185885_420x460_25b65e2315fedd4b.jpg
- Breslin, S. G. (2004). Wireless technology improves nursing workflow and communications. *CIN: Computers, Informatics, Nursing*, 275-281.
- Davis, G. B. (2002). Anytime/anyplace computing and the future of knowledge work. . *Communications of the ACM*, 67-63.
- Digby, R. B. (2011). Improving call bell response times: Robin Digby and colleagues studied the effects of raising awareness of call bell response on how promptly staff attend, patient falls and satisfaction. *Nursing older people*, 23(6), pp. 22-27.
- Guarascio-Howard, L. (2011). Examination of wireless technology to improve nurse communication, response time to bed alarms, and patient safety. *Health Environ Res Des J*. 2011, pp. 109-120.
- Gururajan, R. M. (2005). Challenges for implementing wireless hand-held technology in health care: views from selected Queensland nurses. *Journal of telemedicine and telecare*, 37-38.

- Hill-Rom. (n.d.). Retrieved from Hill-Rom Products: <http://www.hill-rom.com/contentassets/05e33e4c64804db5b94bcb347ae8077c/navicare-new.jpg>
- Hn Tjora, A. (2002). The technological mediation of the nursing-medical boundary. *Sociology of Health & Illness*, 721-741.
- Igbokwe, O. (2004). Wireless technology and healthcare.
- Joint Commission on Accreditation of Healthcare Organizations. (2008). Retrieved from National patient safety goals: <http://www.jointcommission.org/PatientSafety/NationalPatientSafetyGoals/>
- Kaiser, U. (1996). *United States of America Patent No. U.S. Patent No. 5,569,187*.
- Kuruzovich, J. A. (2008, May-June). Wireless communication role in patient response time: a study of vocera integration with a nurse call system. *CIN: Computers, Informatics, Nursing*, pp. 159-166.
- Meade, C. M. (2006). Effects of nursing rounds: on patients' call light use, satisfaction, and safety. *AJN The American Journal of Nursing*, pp. 58-70.
- Medical Expo. (n.d.). Retrieved from http://img.medicalexpo.com/images_me/photo-g/68741-4400377
- Metropolis Magazine. (n.d.). Retrieved from <http://www.metropolismag.com/wp-content/uploads/data-import/7c/7c366f69f9c1b1303cb0fb4c0a878242-NXTPR20DiagramsCS511.jpg>
- Mitchell, M. D. (2014). Hourly rounding to improve nursing responsiveness: a systematic review. *The Journal of nursing administration*, p. 462.

- Ruland, C. M. (2002). Handheld technology to improve patient care: evaluating a support system for preference-based care planning at the bedside. *Journal of the American Medical Informatics Association*, 192-201.
- Usman, M. A. (2011). Design of a wireless footswitch for medical applications. *SOUTHEASTCON 2014, IEEE*, 1-7.
- Wang, J. (2013, October 30). *How do I become HIPAA compliant? (a checklist)*. Retrieved from True Vault: <https://www.truevault.com/blog/how-do-i-become-hipaa-compliant.html>