RADIO FREQUENCY OPTIMIZATION FOR 802.15.4 ISM WIRELESS SENSOR AMBIENT ASSISTED CARE NETWORK (WSAACN)

A Dissertation Presented in Partial Fulfillment of the Requirements for the Degree of Doctor of Computer Science

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Abstract

Wireless sensor networks have the capacity to record physiological boundaries from multiple patient bodies or environments. Physiological monitoring is performed by fault tolerant wireless devices on the patient. Fault tolerant wireless devices can broadcast to local storage media, or directly to a medical professional. Not all wireless technologies are terrestrial in nature. The body sensor network is a whole body solution to be carried around by a patient in what can be called a personal broadcast area. The relationship between the body sensor network and the wireless sensor network is the foundation of this research. Body sensor networks arrangement design is a biomedical engineering method. While wireless sensor networks have been designed to gather environmental information and movement vectors. In this research the association between the two networks creates a whole solution a wireless sensor ambient assisted care network.
Dedication

This research and the attainment of my goals in life would not be possible without the support and love of my family. My Wife Eva, whom I love dearly gave me the inspiration to go back to school, my boys put up with dad working at school every day and most nights for 10 years. I believe I owe my family a vacation. Without School work.
Acknowledgements

I would like to thank my Mentor Dr. Myles Vogel, who had been very patient with me and my rewrites. His encouragement and knowledge has helped me hugely. I would be remise, if I did not thank Dr. Bruce Harmon, for the challenges he presented me during defense of my proposal. I could always count on Dr. Carol Howard to come up with great ideas on improving work. I thank all my professors.
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CHAPTER ONE

Recent advances in wireless communications has enabled developing low-cost sensors for the 802.15.4 standard. Wireless sensors are no longer researched in the Wi-Fi standard; it is now in the Industrial Science Medical band (ISM) used by sensors in body area networks. (Benny P.L. Lo) Possible use of body area networks in medical care is presenting an added delivery for secure tracking of patient health at home. This tracking method can be a boon for the current state of home health care tracking and its future designs. Recent research is showing the elderly experiencing longer lives. Longer lives for elderly may represent an improvement in healthy living conditions and healthy behaviors of the elderly.

In the early 90’s, a rapid rise in the use of home health care contributed to a shift away from institutional care. Continued improvement in healthy behaviors requires continued physical monitoring. The wireless sensor network can be a pervasive monitoring system that does not rely on patient Journaling. Sensor networks can monitor vital signs, patient medical thresholds, and rate of change from previous health values gathered by the health care professional. If needed, additional patient monitoring can be performed with this sensor network; such as reactions to prescribed medicines.

Sensor information could record sweat, palpitations, intensity of breath, movement and posture including if a patient is lying down, sitting up, or walking. Within the base station, which is a server, patient information will include medical history and a set of instructions to aid medical professionals to decide medical care.
A phone over IP, built into the base station can dial emergency services when patient life signs have stopped or have lessened in vitality. Continuous information exchange is the key to a successful model for pervasive patient health care tracking, from the time the sensors come online to the time the patient statistics read by a medical professional. In this chapter, this research covers the current state of patient care tracking and the achievable home health care tracking. Patient health tracking is growing in interest; however the interest in health care tracking has been slow in coming and focused on the limited use of cellular phone technology. Current wireless topologies have been obstructive in nature; however patient health tracking on the application layer on the sensor may prove to advance home health care nursing. Achieving radio transmission reliability requires the use of several different stochastic processes, to control sensors, routers, energy use.

**Topic Overview/Background**

The pursuit of a pervasive wireless home health patient care tracking is in the earliest research stage. Delivery of patient medical data to the medical professional has become the hottest research topic in patient tracking. Presently in the home health care, the time a patient spends outside the hospital has not been tracked effectively. Many early studies have found that early release from hospital care to a home health care environment promotes a rapid recovery for the patient. However, the patient in a home setting is the key to a successful transition from care in a hospital to the home environment. Health tracking from the health care professional needs to be on the same level of patient monitoring as it was in the hospital.. It is in the after hours of home care, when the patient
is at home alone, and after the caretaker has left, that disparity in patient care occurs. Pervasive patient health tracking may fill that gap effectively. This research lays that groundwork for a pervasive patient health tracking.

Problem Opportunity Statement

The variety and potential applications of home health tracking networks are fast becoming a research interest globally. However, 802.15.4 sensor networks are off to a shaky start, due in part to the wireless sensor transmission and the unreliability of battery energy retention. Combine just these two issues to understand why the ISM model, is not a choice for indoor tracking. (Brownfield, 2006)

Many causes contribute to the success and failure of wireless sensors, for example, the success of a wireless sensor network is dependent on the control of the power release to the sensors. The power depletion issues are prominent in a single sensor battery; the battery life of the sensor is dependent on the broadcast cycle and distance vector. Preventing network failure in a sensor network can be as simple as topology design. Currently used sensor topology designs in wireless networks rely on the basic wireless sensor network architectures of mesh, grid and star topology as an example. However, all network topologies suffer from a single point of failure it is how the network will recover from the single point of failure which will discover a successful sensor placement. Currently in the Research field of (BSN) Body Sensor Networks researchers have been trying to overcome the unrecoverable single failure rate in the network designs. An example of data transmission point of failure found in many single
hop wireless architecture models. I.e., Sensors in transmissions on the same network branch, the immediate neighbor to the broadcasting hop, fails, and the data has no alternate route through the network. In effect, the sensor failure will cancel that branch. One resolution to single failure event has been to multicast while leveraging a multihop broadcast. This solution brings back to the forefront the weakness of the wireless sensor networks and network energy conservation.

Purpose Statement

The purpose of this research is to discover a pervasive home health tracking model using the 802.15.4 ISM wireless sensor networks. Despite the remarkable theoretical developments in wireless sensor networks transmission models, scientific understanding of transmission models for these networks, are developing. Key areas of concern in wireless sensor networks is the power consumption and data transfer. This research design is in the architecture of a wireless sensor network and the computational execution of data within the health tracking network. This research will aid in the research of sensor energy decrease in wireless sensor networks, by using current methods in computational math and network and sensor design within the 802.15.4 ISM model.

Research Question

Large wild game reserves currently use wireless sensor networks to track movement of wildlife and identify the migration patterns. In several military campaigns, the use of sensors to track troop movement in the battlefield have shown limited success. (Sang Hyuk lee, 2012)  The Chinese have spent time researching a sensor network to
track coal miners as they work deep in the mines (Jianghai Li, 2009). Much of current research in sensor networks involve large dense sensor architectures.

This research paper is exploring the possibility of applying similar tracking technologies to track patients in a sparse sensor placement in a home health environment. As early as the 1980’s the medical community realized the need to track patients at home through available technology. (R tribes, 2011) Today’s wireless technology offers the possibility to design and manufacture effective low-cost patient managed devices, handling biomedical signals and data in an electronic wireless environment.

In the electronic tracking of patients, a wireless sensor network (WSN) can be an integral part of treatment. No single network tracking solution currently meets a reliable datum handling for treatment. (Hongzhou Yu, 2011)

No single patient tracking model is more effective than another, continuous research discussion drives developing differing technological for patient tracking. Currently, cellular networks are used to track patients (many of which are heart patients) through small sensors on medical devices that broadcast the signals for patient data collection on cellular frequencies. (Netanel Avisdris, 2009) The wireless approach has many advantages over wired medical device networks. Mobility clearly being the most important advantage and effortlessness of use the other advantage. (Victor Shnayder, 2005)

So what decides a successful application of a patient medical tracking wireless sensor network? First it must be able to support different communication protocols on medical devices such as in-vivo implants and surface patient tracking and supporting equipment. Sensor placement, in past research, has shown that confined spaces have
brought about new challenges to positioning wireless sensors. Successful sensor placement considers wireless sensor placement indoors will have different transmission problems found in larger outdoor sensor placements, therefore, a successful sensor placement will address obstacle effects and lessen sensor failure from energy depletion during retransmission.

Wireless sensor ambient assisted care network (WSAACN) model optimization designed for indoor wearable medical mobile devices with a focus in part to low power throughput and low complexity in design and implementation. WSAACN, a wireless model is a clustered novel design controlled by probability algorithms. The communication protocol between the sensors and the wearable medical mobile device amplifies the transmission within a restricted range. Unlike other tracking models, it does not rely on the current network topologies i.e. (star, mesh etc.) between transceivers. Due to the random sensor placement and the sensors transmission algorithms.

In this research, the design of a pervasive home health care tracking network simulated within the ISM model. A question persist, can wireless field sensors adapt to random network design, with a sparse sensor deployment reacting as a cluster topology? Can sensors continue with a higher than usual computational requirement on the routers while experiencing minimal network power consumption?

Experimental Hypotheses

$H_1$: Leveraging different algorithms in a restricted novel sparse topology will control shadowing effect and energy consumption.
$H_1$: An ideal antenna sizing on the gateway device will not create increased shadowing effect on all sensors within the topology.

$H_1$: Creating a sparse sensor placement will lessen energy consumption on the sensors.

**Null Hypotheses**

$H_0$: levering different algorithms, will not change the effectiveness of a restricted novel clustered topology to which the sizing will have no effect in controlling shadowing effect and energy consumption.

$H_0$: Sizing of the antenna on the gateway device will create increased shadowing effect on all sensors within the topology.

$H_0$: Creating a sparse sensor placement will not lessen energy consumption on the sensors.

**Theoretical Perspectives and Conceptual Framework**

Gupta and Kumar (Shirish Karande, 2008) proposed to study the simpler wireless sensor placement. The features of the research needed all the sensors in the network to broadcast at the same bit rate. For testing broadcast conformity. Then Gupta and Kumar would review the scaling limit of the transmission rate, increase the number of sensors in the network until the capacity region of the network transmission falls to a single point of failure. They would then verify the results on the network behavior. Gupta and
Kumar’s derived some additional assumptions on the physics of signal propagation and the underlying basis in network restrictions.

Based on Gupta and Kumar mathematical assumption a wireless network composed of "n" normalized wavelength. Which is a pair of sensors equal to their sources and radio destinations, each source sensor can communicate to its intended destination at the rate of $O((\log n)^2 / \sqrt{n})$ bits per second. It is likely that Gupta and Kumar’s limit is due in part to limits of the spatial degrees of freedom found within a network brought on by the location of environmental objects.

The objective of the random cluster test network is to identify a control range of radio signals. If the signals can fully exploit the number of degrees of freedom available for signal propagation, even with a line of sight loss from interior obstacles. Further, as the topology was being tested with a random clustered design, the sensors will be tested in part for their critical transmission range and signal collisions. The research will control the wake-sleep function of the field sensors and routers to control collisions and reduce the effects of loss of line sight.

The research on indoor patient tracking, must take into account the critical transmission range (CTR) of the sensors network. Critical transmission range calculates the transmission range for all individual sensors in the network, to maintain connectivity. Previous research has shown that wireless signals propagate in the wireless network, through line of sight, reflection, diffraction and scattering. These propagation models can pose a fundamental limit on the achievable growth in a home tracking network without adding multiple transmitters. (Massimo Franceschetti, 2009)
Assumptions

The research supposition in the health care field by moving towards patient home care and the reduction of patient stay at hospitals added to the need in health care research in remote tracking of patients. Research in patient care has brought about many novel communication methodologies and sensor topologies. Leveraging the use of the body of knowledge in tracking sensors. Successful use of a home health monitoring system will require very little to no interaction by the patient. A pervasive tracking model brings about an autonomous patient care system.

There are plenty of transmission algorithms for communication that can ignore interference and many that may prevent or resolve collisions in known communication transmission models. To the best of this researcher’s knowledge, no potential solution to patient tracking sensor networks addresses collisions and energy conservation in one model, combining patient sensor control.

Significance of the Study

The health care professionals have understood for a long time, the anytime-anywhere access to patients real-time medical information, can be, sometimes the difference between life-and-death for the patients. Health care professionals would like to expand a pervasive patient tracking system to support patient’s long term healthcare needs out of the hospital. Long term health care support will require an extensive health tracking model for all levels of care. (Upkar 2006) Using low-cost high availability
wireless sensor that could monitor physiological parameters from multiple patients or just a single patient at home or in a hospice, could help lessen the cost of expensive health care monitoring. Research of wireless sensors has been moving towards the use of a hybrid signal processing with a built in robust performance and fault-tolerant wireless sensors transmission. These wireless sensors should be able to perform interoperability for the signal from electrocardiogram (ECG) and blood pressure devices, through the use of 802.15.4 ISM band.

The complications in sensor technology have increased proportionally with the advances in patient health monitoring sensors and small medical body sensors. An example of the complications in differing sensors has been the interoperability issue between several sensor manufacturers on medical implant devices and body sensor networks which suffer from the-ever present signal conflict and sensor power depletion. (Miller and Derse 2002).

Even with interoperability issue, research continues in the field of patient care, such as total parental nutrition or intravenous antibiotics, which may be delivered via sensor networks. (Pilling and Walley 1996) Since 2006, there has been a rise in home based vital sign monitoring; referred to as Tele-medicine. An implementation of several Tele-medicine patient care programs, including pacemaker monitoring and adjustments, started around the early 2000’s. Telemetry medicine program approached its patient monitoring model from a simple cellular communications. Telemetry medicine program had used regular phone lines or cellular phones to link the patient to the medical office while the patient in telemetry medicine care would have access to a patient station that would provide a blood pressure cuff and pulse oximetry. The medical data from the
patient station would then transmit the results to a central database at the hospital. (Shore, 2006) Hospitals used different monitoring processes to track the sick and the elderly at home. A large gap of knowledge on patient telemetry exist when it comes to accurate and reliable information concerning the physical activity levels of the elderly at home. The medical professionals are constantly seeking ways to monitor the recovery of their patients. Typically information relating to a patients activity at home is gathered by interviews of the patient by the visiting health care professional many times the health care professional will have the patient keep journals of their daily activity. Too many variables exist in patient tracking their own activity. If the patient is recovering from head trauma, or mentally challenged patients. However, a solution may exist in having systems capable of remotely measuring and logging data and presenting it to the medical professional in a meaningful collective manner.

Moreover, monitoring patient’s vital statistics metrics electronically with sensors will prove to be quite useful in the case of elderly subjects, who are prone to falling or suffer from memory or cognitive degeneration. Researchers currently are developing a way to monitor a patient’s movement by the use of a smart phone application with an application that could be used to track and monitor movement with an accelerometer. (Martin Hynes, 2011) in 2010 The research moved from cellular phones to hand held portable medical terminals relying on wireless frequencies to deliver the medical data for management of the health of the patients at home with Diabetes. Medical terminal monitoring becomes more of a support system for a diabetic patient which is especially useful for the patient who is recently diagnosed. With the most current model of monitoring, the use of a PDA the patient inputs into the device all daily life information,
i.e., the patient information on exercise and diet. The patient information is sent to the medical professional using the PDA, once reviewed the patient can receive health instructions. The Medical professional can receive the results of the analysis by using a PC. The medical professional can then send the resulting analysis in an email to the patient. (Shoko Tani, 2008). However, the use of the cellular phone or PDA is proving problematic because of data loss and lack of redundancy to the medical data and a reliance on the patient manually entering the necessary information. (Bart Braem, 2008)

Network and sensor reliability is the key to a successful application of home health care monitoring; Technological advances in wireless sensor networks have made it possible for sensors to enter pervasive computing. These sensors typically run off an onboard battery power, and when the sensors are used sparingly, they can operate in excess of a year.

(See figure 1) However, when field requirements call for a higher usage, battery monitoring and replacement becomes a major deployment issue. (Dwivedi & O.P.Vyas, 2011) Recent research has found that energy consumption and the computing strength of the sensors depends entirely on the network architecture, and the ability for the sensors to wake, compute, transmit, receive and deactivate. The transmission filtering of ambient signal noise is necessary to increase battery life. (Katenka, Michailidis, & Levina, 2008) As the research in the field of wireless sensor networks, the data has shown clearly wireless sensor energy retention and recovery are central to the success of the implementation of a wireless sensor health monitoring network. Ongoing research and
continual defining of industry transmission standards in Home Health Care system will bring it into the 21st century.

Figure 1 Basic design of a wireless sensor

Delimitations

This study will not cover the structural designs of the sensors rather the wireless sensor architecture and radio signal propagation and optimization. The delimitations within this study fall within covering the design of the body sensor networks that encompasses a patient and their personal operating space. Though this would be future work to fully realizing a complete monitoring personal operating space.
Limitations

This research is based entirely indoor and not outdoor sensor monitoring. Outdoor signal processing can create additional application constraints to sensor monitoring. A weakness in this research that must be noted is that there are different types of materials that are used in a wall in a home that can affect the diffraction of the signal. In this research, I will not define the wall type or design or objects in the environment. The simulation will recognize a wall as an obstruction, which affects both lines of site and signal diffraction. Within the context of the research, this researcher cannot control the mathematical models built into the simulation software. This research can only give a probability of sensors success based in theoretical models, and not actual success.

Definition of Terms

Symbol Period (also known as a Modulation rate) is the amount of frequency changes made to the radio signal. Calculate time $T_s$, $F_s$ is the symbol rate. $T_s = \frac{1}{F_s}$

Quadrature Phase Shift; Quadrature comes from the use of four quadrants within a signal space. Quadrature phase shift has a direct correlation to power usage in transmissions and reception for the modulating digital signals onto a radio-frequency. Quadrants improve throughput performance even with signal interference from power panels or fluorescent lighting systems. The Quadrature phase shift is used extensively in
modem technology or this case within sensor routers. However, extensive modulation will consume sensor power as much as constant transmissions.

OSI model; Open systems interconnection is a conceptual model that characterizes and standardizes the internal functions of a communications system portioning it into abstraction layers.

PHY layer; Physical layer is usually a combination of software and hardware programming within a sensor or router.

MAC Layer; Media access layer is a sublayer of the data link layer of the OSI model this is the layer that moves data.

CCA; Clear channel assessment is a carrier sense mechanisms in WLAN or Wi-Fi part of the 802.11 and 802.15.4 standard.

CFS; Channel frequency selection is a listening period followed by back-off timers to determine when the air is free for wireless sensors to send packets.

LQI; Link quality indication is used in wireless networks to indicate the strength of the communications link Between sensors.

16 (QOM) 16-array quasi-orthogonal modulation; is a data symbol duration period consisting of four information bits within one of the 16 orthogonal pseudo-random noise sequences in the modulation.

(PRN) Pseudo-random noise sequence; Random noise signal that meets the qualifications of a test for statistical randomness.

(POS) Personal operating space is a spherical area that surrounds a portable or digital wireless device.

Concatenated; linked together in a chain or sequence.
Contention free period (CFP) used in wireless signal broadcasts, it is a standard to define a period during which access to the wireless sensor is free of contention. Piezoelectricity; Piezoelectricity is an electrical charge that builds up in certain solid materials i.e., crystals, certain ceramics, and bone DNA and proteins when mechanical stress is applied.

General Overview of the Research Design

This research is a computer simulation based entirely on a low-density population deployment of sensors in an enclosed area. The obvious conjecture here is that with a reduced sensor density deployment, the sensor network will experience a lower interference and reduced signal contentions. Running simulations from the sensor level, the network level, may give a descriptive example of a pervasive monitoring system through the probabilistic sensing model within the network routing protocols. MatLab will perform the metrics simulation on success rates and the baseline communication examination. Based on a leach particle swarm optimization protocol.

Summary of Chapter One

Wireless sensor networks are moving fast to fill the technological void in the delivery and monitoring of the health of a patient at home. While this research touches on just one area in wireless sensor networks, it is by far the most important issue in a wireless sensor network. The life of a battery a sensor is dependent on the transmission cycles and the computational response. Many standards were considered. However, this
research settles on three standards, two of which will be used in this research model. This research lays the groundwork on what sensors will calculate and when sensor will relay. This research will delineate the signal processing barriers for the success of a WSN deployment.

Organization of Dissertation (or Proposal)

The dissertation begins with a brief background on wireless sensors and the challenges that are placed on wireless sensor networks by their environments. A brief description of the current wireless standards closes chapter one. In Chapter two, this research investigates the possible use of wireless sensor networks in conjunction with medical body sensor network to provide a pervasive home health monitoring system. The evaluation of different transmission metrics explains the possible use of novel routing methods while leveraging stochastic algorithms and swarm optimization for sensor activation and deactivation. While a theoretical topology is discussed, that same theoretical frameworks have possible limitations, are examined. Chapter three Methodology; It is the hope that this research will provide a possible supposition to constructing a successful pervasive home health tracking wireless sensor network. The tools used will be simulating the topology, using asynchronous simulators such as MatLab, and Atalaya, these simulators will provide response times and sensor behavior while leveraging network protocols.
Chapter Two

Chapter 2 was written to cover the current studies in wireless sensor networks from past attempts to monitoring wireless networks and the future advances. The structure of this chapter first addressed the application of a wireless sensor monitoring network for the home. Only three standards discussed. One of which is the 802.15.4 ISM standard. The current network architecture designs employed in the tracking field. Chapter two wraps up with research in the theoretical and radio collision and scaling laws of wireless sensor networks. The place where people devote the large amount of time is in creating a personal environment in the home. The home is the place we wish to recover from illness or injury. Researchers are trying to determine which method can best deliver optimal outpatient care. The two health care delivery models considered is Home health care versus Hospital supervised inpatient care. (Irene j Higginson, Vera p Sarmento, Calanzani, & Gomes, 2013)

Home Health care can be as safe as hospital care. With fewer complications and fewer medical caretakers’ interventions. It is apparent in this research that both patients and the medical community would prefer a health care delivery and monitoring system which reduces health care costs; hospital acquired infections and hospital stays. While health care monitoring research continues, the caretaking process for the critically ill, remains the same. Options are hospital stay until the end of life or transfer to a hospice, although patients would prefer to be cared for, at home, home care has not been fully supported by the medical industry. Recovery preference is restricted by the technological design restrictions and the cost of deployment. Some critical care studies have shown
critically ill patients prefer passing at home over passing within a hospital environment. Within a study performed in 2013, up to 87% of the terminal patients favor passing at home. The study further suggests the next highest preference to passing away in an inpatient hospice care rather than a hospital environment. (Higginson, et al., p. 7)

As a result of home health care studies like this one, the medical care at end of life for patients will have to be rethought. Even with the recent development and medical improvements to extend the life of terminal patients the current patient health tracking model is inadequate. Further studies have shown the critical ill patients will incur a quarter of health care expenditure in patient care in the last moments of life.

As the discussion about caring for terminal patients continues, many health care professionals attempt to address the increased cost of terminal diseases monitoring. Even with the increased focused on terminal patient care. Monitoring fatal diseases from a patient at homes it is predicted to continue to rise in the United States (Mullner, Jewell et al. 1999). Caring for patients with advanced terminal diseases has increased. US medical system is expecting this care by as much as 1.27 trillion dollars in 2009 and by 2019, the potential in healthcare cost will rise to 4.5 trillion dollars in caring for advanced terminal disease. (Truffer, keen ET al.2010) Electronic health care monitoring is at the top of public research dollars. Research has found a growing acceptance by the public for a home health care monitoring solution aimed at patients for long-term health care maintenance and disabilities.

This patient health tracking solution must have comprehensive health solution for the patients’ homes, hospices, and hospital care. Advancement of patient health tracking
systems will have to address how to collect data 24 hours and seven days a week while providing a reliable data transmission model. (Upkar, 2006).

Elder and Home Health Care Monitoring

Recent estimation has US residents 65 and over increased significantly, in fact, by 2050; it is expected that a quarter of the United States population will be elderly. The belief that population of postwar babies are reaching (Baby Boomers), retirement age and an increase in life expectancy for people over 65 also have increased. Creating an older population that is living longer. (Loraine West, 2014) CDC research on life expectancy has shown the longer life span aging does not correlate to reduced health care cost. In fact, health care has been enduring the continuous rise in cost for care. In part to the aging population and the associated changes in health of the aging population and severe health conditions of the elderly. This severe health conditions in the elderly has led to limits of elderly patient mobility and medical dependencies in their day-to-day lives. Despite the increased limits in movement, the elderly in the United States have increasingly expressed a wish to live and heal in their homes. This trend for the elderly to stay in their homes may lessen the cost, and hospital stays may even someday lead to a better quality of life in the elderly. A pervasive home health patient tracking model that could be reliable and easy to use would likely ensure a safe homestay for the elderly. In 1991
home deaths had credited to 9,600 falls in the home, 80% of the falls involved people over the age of 65. And in the same year of 1999, 2.6 million nonfatal related injuries treated totaling just over 19 billion dollars to care for the injured. Elderly falling while at home has become a serious public health issue among older US residents (Stevens, 2006). To meet this growing concern, the use of an electronic patient home health monitoring system would be able respond quickly when a monitored elderly person falls in the home.

Patient condition monitoring and mobile evaluation system will require:

- Continual sensor communication to the patient body sensors with and monitoring of patients vitals.
- Sensor network reliability would have to reassure patients and their families of the viability of the system in their homes.
- Successful patient health tracking can lead to the development of increased independent living through tracking and evaluation.
- Educating the patient in the health benefit of tracking and the likelihood that they will be limiting their exposure of hospital acquired infections (Mann, Marchant, Tomita, Fraas, & Stanton, 2002).

The study by (Mann, Marchant, Tomita, Fraas, & Stanton, 2002) developed a questionnaire entitled home care monitoring devices this questionnaire consisted of questions that addressed user functions such as:

- Types of devices used and the need of health monitoring.
- Wireless sensor network potential may provide to the user.
- How often the health monitoring will take place, 24-hour frequency or less.
• Preference of the patient's desire to use at the home and the option of an emergency alert system only.

The data from the study offered descriptive statistics on five prototype home monitoring devices that were presented to the 70 study participants. The 70 individuals in the study had a mean age average of 73.5 with the global age range of 60 to 90. The study had shown statistically with a favorable response of 89.9% of the participants would use monitoring devices while at home. Of those 70 respondents of this study, the features that they would like to see on the monitoring system was to make the monitoring system smaller less elaborate and simplified to use. (Than the current bulky patient monitoring devices)

A (95.7%) overall perception of the participants had expressed in the study that they would not mind having the device in their home. A modest amount of the participants of this 1999 CDC study stated that they were willing to pay out of pocket for efficient non-intrusive monitoring device. However, not all the participants wanted to be tracked,

97.2% of respondents stated that they would rather use a home health monitoring system as an emergency alert system then be monitored for health care needs twenty-four hours a day and seven days a week.

Current Standards used in Wireless sensor networks

The most widely used and currently commercially available existing wireless sensor network standard is Zigbee. The standard has been the most popular among all the
short-range benchmarks for sensor monitoring because of its low broadcasting power. Zigbee can be an ad hoc wireless network; it is a terrestrial wireless standard for short-range communication. Zigbee is designed for small low-cost devices with low power expenditure with a low computational overhead. The 802.15.4 wireless protocol 802.11b (Wi-Fi) will play an important role in the delivery of the home health care data to the health care professional.

RFID and Zigbee protocol

This section introduces the RFID operational frequency and Zigbee standard which corresponds with the 802.15.4 respectively. 902-928 MHz (North America) UHF based on a short-range wireless frequency with a divided network: wireless local area networks (WLANS) and wireless personal area networks (WPANs). RFID range is up to 1 - 12 meters with a reader attached to the device. And in this research the patient with the passive tag walks within the magnetic field of the reader, and the programmed chip in the gateway field sensor will activate the device.

RFID

Radio Frequency Identification (RFID) considered as one of preferable ways for the position estimation in indoor environments. (Patrick Seeling, 2013) In this research, the RFID reader will be on the coordinator and wake-sleep router to wake the system and
initiate distance calculation protocols. The tag reader in turn will have to be programmed with the mac address of all field devices for the identification of the sensors.

802.15.4 ISM (Industrial Science Medical) transmission standard

Transmission over wireless protocol 802.15.4 is a lower data rate transfer. The signal transmission is varied between 868 MHz and 2.4 GHz. While various bands can technically be used by 802.15.4 is more popular as it is open in most of the countries worldwide.

There are bands in the United States, Canada and a few other countries that accept FCC regulations. 802.15.4 Standard communication. Communication in 5 MHz channels ranging from 2.40-2.480 GHz in the 2.4 GHz band the basic framework of 802.15.4 ISM protocol. The central identifying feature of 802.15.4 wireless personal area network is the ability to achieve an extremely low manufacturing and operational cost. One feature available to 802.15.4 is the inclusion of reservation guaranteed time slots and collision avoidance through CSMA/CA. Much like cellular networks.

Zigbee Protocol

The Zigbee protocol is built on the IEEE 802.15.4, the protocol a low power and low rate wireless communication device which operates on the network layer and application layer. The physical layer provides 16 channels for Zigbee control. (Mu & Liu, 2010, pp. 405-409). The physical layer provides Link Quality Indicator (LQI) in order
verify the connections between sensors. The Zigbee identifies three kinds of devices in a typical Zigbee network. There is a coordinator, which organizes the network. Routers, controls the communication routes and transmits to multiple types of devices, and the end device, which can talk to routers and the coordinator but not to one another. Its parent sensor assigns the address of each device in a Zigbee network following a tree structure. Every potential parent is assigned a sub-block of address space; which is used to assign network addresses to the sensors that it supports. The tree routing algorithm supports device destination addressing. (See figure 3) however, each device manages its descendant if the destination address is in the address space that a sensor is managing.

The sensor forwards the packet to one of its child sensors. Otherwise, it forwards the packet to its parent sensor. The parent or child sensor which receives the packet selects the next sensor hop according to the destination address in the same manner. The body sensor network frequency Radio spectrum for medical implant communications service, (216-217 MHz) well within the range of the Industrial Scientific and Medical Radio Bands, which makes the 802.15.4 ISM the ideal vehicle for medical monitoring a patient in a home health care environment.
Figure 2 Zigbee tree structure

Figure 3 Comparison of wireless standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Bandwidth</th>
<th>Power consumption</th>
<th>Stack size</th>
<th>Strengths</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wi-Fi</td>
<td>54 Mbps</td>
<td>400+mA standby 20mA</td>
<td>100 KB</td>
<td>High data transfer threshold</td>
<td>High data transfer rate for file transfers</td>
</tr>
<tr>
<td>RFID</td>
<td>UHF</td>
<td>9 dB/µA/m</td>
<td></td>
<td>interoperability</td>
<td>High frequency EAS only</td>
</tr>
<tr>
<td>Zigbee</td>
<td>250 kbs</td>
<td>30 mA. Standby 3uA</td>
<td>less than 32 kb</td>
<td>long battery life low cost</td>
<td>Remote control battery operated products, sensors.</td>
</tr>
</tbody>
</table>
Wireless Body area Network

Wireless body area networks have a promising future because of recent advances in Micro-Electro-Mechanical systems (MEMS) technology, integrated circuits, and wireless communications. (Sana, Pervez et al. 2009) Wireless body area networks could reduce the workload of hospital staff and improve the recovery rate of patients.

Monitoring can be done by Medical implant communication Services (MICS) in many wireless sensor networks. A body area network is a wireless network of biomedical sensors attached either in the patient or on the outside of the patient.

Recent technological advances in low power integrated circuits, wireless short range communication, and physiological sensing allow miniature, lightweight, ultra-low power intelligent monitoring devices. The key point to remember is that the role of general purpose wireless sensor networks is to monitor the target area and report the data acquired from the area to the end system efficiently with little resource use.

The body sensor networks have emerged as a natural byproduct of existing WSN technology and bio-medical engineering. Medical monitoring will leverage the two networks, the Wireless body Network, and the Body sensor network to become commonly known as a wireless body sensor network. The WBSN is a sequence of small sensor actuators, implanted, or located on the surface of the patient’s body. (R.Ashok, 2003, p. 13) Each actuator has its energy supply, and storage area and energy harvesting devices. Each actuator has enough memory to implement the task assigned to it. Each actuator can communicate with other sensor actuators, or with a gateway controller worn
on the body. (Bogue, 2009) The gateway controller collects and stores the data for recall and or immediate transmission when called by the medical professional. (Prem Chand Jain, 2011, p. 362)

Body Sensor Network

Body sensor networks (BSN) consist of miniature wireless sensors. These wireless sensors transmit the collected data to an aggregator device such as a gateway device which can store and transmit the data through a (WBN) Wireless Body Network and transmit out over wireless 802.15.4 to a central gateway control device which transmits 802.11 to a wireless router and out into the internet. Wireless body networks depend heavily on industry advances in signal processing, microelectromechanical system (MEMS) (see Figure 4) and Nanoelectromechanical systems (NEMS). Sensors in development are; biosensors, which measure blood pressure (BP), continuous blood sugar, core body temperature, blood oxygen, respiratory rate, ECG, EEG, and EMG and bio kinetic, which measures the acceleration and angular rate of rotation from human movement.

The development of new wearable sensor technology brings benefit to the medical professional and health enthusiast, the small wearable sensors meet most of the technical aspects of the ECG (Electrocardiogram). The continuous development of smaller powerful ECG devices could in the future increase onboard memory. The smaller sensor design has helped to push the current trends in ambulatory measurements to
anytime anywhere remote access, to online, real-time data for immediate diagnosis by the medical professional. Thus, the development of wearable sensors can fully be integrated into any telemedicine project. (Jose A Gneechi, Antonio d Herrejon, Patino, & Espinoza, 2012)

Figure 4 MEMS pump Implant size (E Meng, 2014)

Environmental sensors can measure conditions the patient is experiencing. The body sensor network allows remote care, continuous long-term monitoring, and low cost accurate medical measurements. Preliminary designs of BSN and WBN Systems are now available due to the advancement of MEMS, there is a basic design structure that must be met. The sensors must be inconspicuous, small and non-restrictive. The battery life should extend for more than a year and recharge itself. The sensor must also provide data transmission reliability and low maintenance cost. All of this will equate to a quality of service that the medical industry’s demands in a Body Sensor Network from health care professionals and first responders.
Low Rate Wireless Personal Area Network

802.15.4 is a low data rate protocol. This standard is based on low-rate WPAN or LR-WPAN. This standard is used for supporting simple devices that consume minimal power and typically operate within (POS) the personal operating space. Zigbee can provide a self-organized multi-hop mesh network to which the personal operating space can attach. The Zigbee wireless networking protocol layer is based on an open system interconnect (OSI) model. The bottom two networking layers define 802.15.4; this standard has defined the PHY and MAC layers as part of the Zigbee networking protocol. The 802.15.4, ISM standard was developed independently of the Zigbee standard. The Zigbee standard currently is used in industrial monitoring space and the home hobbyist. What the Zigbee protocol can bring to patient home health tracking is a possible interoperability with other medical device vendors and wireless solutions. (Farahani, 2010)

Transmitting Metrics

Proximity of sensors is a common challenge in the operation of indoor and short range wireless sensor networks. One solution that was researched was the use of received signal strength (RSS) across the wireless channel since mathematical propagation models of indoor RSS are still considered complex and inconsistent in accuracy. Most RSS algorithms use non-parametric approaches that pre-sample the RSS in the environment.
(Chernoy, Shalom et al. 2010) RSS pre-sampling could reduce the energy available for computational and transmission. In the network design of a wireless sensor ambient assisted care network (WSAACN), pre-sampling will not be required. The focus of Chernoy research had been in designing network oriented position based routing protocols. The protocol routing research has resulted in a large number of varying research algorithms differing in approach and performance. (Popescu, Tudorache, Peng, & Kemp, 2012) Research performed on routing metrics has been on geographic and non-geographic routing procedures and each share a network design issue. Geographic routing characterizes the algorithmic process of shaping the paths on which to send traffic within a network. Topographical routing is what this research is partly based. The determination of paths on which to send traffic within a network. Using sensor position information and geographic location (detailed on the routing schema) to the nearest router.

This geolocation topology based path definition is considered to be substantially better from an energy conservation point of view than that of the beacon broadcasting approach. Wireless networks have two kinds of network architectures; an ad-hoc network and an infrastructure network. Infrastructure networks have fixed wired gateways. Ad-hoc sensor networks maintain routes to neighboring sensors as the network evolves.

The research in WSAACN is within that of an ad-hoc network. The maintenance of the sensors wireless routing will be performed by the use of a table routing protocols. Each sensor will maintain routing information in one or more tables within the sensor. The sensor information will be updated with each pass of the patient and updated accordingly as sensors fail or come online.
Two routing protocols that will be used in the WSAACN, destination sequencing, and distance vector routing, each TED sensor will have a routing table containing possible destinations and the number of hops to each destination. This table will be continuously updated by the sensor routing network device. The SRN or sensor routing node will act as a sensor cluster gateway switch. As part of the routing protocol, the SRN will act as an identification operation signal broadcast, implementation and connection point for a group of sensors in the WSAACN. The SRN will connect two clusters, i.e., (the living room and bedroom) the SRN will act as a gateway node and will maintain a cluster member table. Which will store the nearest destination cluster head for each sensor node?

Because this network will be wireless, each node will maintain four tables, the distance table, the routing table, the link cost table and the message retransmission list table. Each entry in the retransmission list contains a sequence number of the update message, a retransmission counter, an acknowledgment required flag indicator and a list of past updates that were sent in the update message. Using the list for all updates and retransmissions will record the transmission acknowledgment. A majority of the sensor activities are to perform location and maintenance routes to the determined destination sensors. (Sawant, 2006)

Possible Routing algorithm

Part of the routing protocols needed estimations will be determining the needed minimal hops within a network, from field sensor to routers. Particle swarm optimization
models can be used for energy aware sensor clustering. Economic power usage is a critical issue within any wireless sensor networks. The transmission of signals within a WSN varies exponential with the increase or decrease of sensor placement, with that placement consideration a reduced distances for transmissions will conserve sensor energy. A WSN’s lifetime depends on how efficiently it carries datagrams from the source to the receiver. Routing the packet via a novel clustered sensor network topology can make a significant difference to energy consumption.

One novel clustered sensor network topology that is being researched heavily is referenced as a Low energy aware clustering hierarchy (LEACH) particle swarm optimization. PSO Clustering has many different operational variants, everything from time-varying inertia weight to time-varying acceleration constants, (Raghavendra V Kulkarni, 2011) PSO can be used in many different location finding applications.

Particle Swarm optimization? PSO Is a population-based search algorithm that gained a lot of attention in the early eighties Particle swarm optimization is based in the natural world. For an example of PSO, take, for example, the imaginary retired biologist Harry. Harry gets up early in the morning at a lake house with a coffee cup in hand and walks to the end of the splintered gray dock. As he sips his coffee, he sees a school of fish moving in the lake in a fast ballet. As they twist and turn in the pursuit of the water bugs, he observes the synchronistic movement in which none collide. The morning sparrows fly by, exhibiting the same agility and synchronized group behaviors as the school of fish, flying in formation without colliding. A flock of birds exhibits many contrasts. It is made up of separate birds yet the overall motion seems fluid; this is
nature’s position optimization. Or what is referred to as particle swarm optimization algorithm.

Routing metrics for the PSO algorithm requires selecting a non-interfering particle swarm optimization transmission route. Therefore, designing an energy aware PSO algorithm becomes an important factor to extending the life of the sensors. Part of this life extension will require clustering of the sensors within a home, and the distribution of the clusters can be done; room by room. Each room forms a single cluster. This clustering reduces the routing table size and complexity of each node and all the while reducing the bandwidth. (M Natarajan, 2013) Another location identification algorithm is the Dijkstra’s shortest path.

If Dijkstra’s shortest path algorithm is used applying this algorithm during the deployment stage assists in the creation of an optimal transmission route. (Estrin, Govindan, Heidermann, & Kumar, 1999) Clustering the sensor sensors will assist in addressing the latency and energy consumption issues found in wireless sensor networks. (Varaprasad 2011) Latency is an important factor for system reliability, such as in the case of medical monitoring, as well as the accuracy of data reporting in circumstances of high-frequency periodical data updates. Another key factor is energy consumption; energy consumption is essential to ensure survivability of sensor and the lifetime operation of the system.

Wireless sensor traffic is aggregated and forwarded by intermediate sensor towards the Central gateway device will ensure the sensors share the transmission packets. As the patient body sensor network moves through the wireless sensor field (Yunjun Gao, 2008) the sensors activate in passing the wake-sleep router.
The transmission is then carried forward of the body sensor network to the central most center. The following sensors will distribute the packets until the patient body sensor network approaches the central gateway device for final transmission and storage of that data. An important query for the field sensors upon placement is to calculate a three dimensional analysis. This three dimensional analysis will locate the nearest possible trajectories of a moving patient device in relation to the closest sensor in its data acquisition space.

Upon sensor location the PSO algorithm and the K nearest neighbor (k NN) algorithm will search for the moving target within a predefined spatial geometry established by the three dimensional analysis established earlier.

The k \((\geq 1)\) trajectories that are closest to a given query object). K nearest Neighbor in the use of localization of sensors is a common challenge in the operation of indoor and short range sensors. (Aaron Ault, 2012)

![Diagram](image)

**Figure 5** *k nn* sensor location calculation
Sensors

Sensors are made up of four basic components; a sensing unit, a processing unit, a transceiver unit and a power unit. (See figure 1) sensors may have have application dependent components. The sensing units may be composed of two subunits: sensors and analog to digital converters (ADCs). The analog signals produced by the sensors based on the observed target, are converted to digital signals by the ADC and then the data is fed into the processing unit. The processing unit, which is the small storage unit, manages the procedures that make the sensors collaborate with the other sensors to carry out the assigned tasks. A transceiver unit connects the sensor to the network. One of the most important piece of the sensor is the power unit. power scavenging device can be used to power sensors. There are also other subunits, which are application dependent. All of these subunits must fit within a matchbox sized module, however, the sensors do have limitations on them: the sensors must utilize extremely low power. Research has indicated that one area to consider for making the sensors more reliable is the technique of duty cycling. Duty Cycling is the act of a sensor turning on and off when it isn’t needed. Duty cycling power to a subsystem to reduce its average power draw is a promising technique. Duty cycling and hierarchical sensing are commonly used to lower the power consumption of sensors. The duty cycling when applied to sensing; will follow a sleep-wake up-sample-compute-communicate cycle however any given node will spend the majority of their time sleeping. (Dutta, 2005) Duty cycling leads to more complex
communication patterns that include polling and scheduling. The complexity of duty cycling sensors mechanically makes the cost almost prohibitive. The Duty cycle networks should have a low production cost and be easily dispensable; it would be best if they were autonomous while adaptive to the environment. Due to the architecture space available on a sensor a micro electronic device, a limited power supply is available for transmissions. Sensor lifetime shows a strong dependence on battery life. (Akyildiz & W., 2002)

Sensor Acceptance and Balance

The use of body worn wireless sensors for physiological monitoring is nothing new, in hospitals. However, it does promise to revolutionize the approach to health care for our aging baby boomer population at home, by enabling a low cost, remote and continuous patient monitoring tool. In order for the health care community to accept the use of the body sensor networks in a pervasive home health care environment.

Researchers need to lessen the sensor energy consumption thus producing a longer battery life. (Nabar, 2010) when sensors are set in the field, the sensor is extremely constrained in terms of hardware due to factors such as maximizing lifetime of the sensor while minimizing physical size and overall cost.

Since large numbers of sensors are typically deployed in dense topological designs, neighboring sensors may end up being close to another sensor. This neighboring sensor proximity can attribute to the multi-hop communication in sensor networks. While this closely packed deployment of wireless sensors in the field helps in the delivery of the
data by having many sensors beaconing and the sensors remaining active. This continual beaconing and active state drains the onboard battery to the point of failure.

In a smaller topological designed sensor deployments, the reliability of the data and the successful transmission of that data are reduced. And the sensor power consumption is decreased for the substitute of data packet loss, in the network. This designed failure can draw a sensor network designer to choose from increased power consumption and over cached data to reduced power and minimal data caching. Striking a balance can be very challenging.

Sensor energy harvesting

In recent studies on wireless sensor transmissions, signal transmission consumes energy by more than two orders of magnitude in comparison to the computation energy used. Energy usage for the sensors in the field is part of the problem of an effective healthcare delivery system. Sensors that are deployed in the field are designed to be used until the battery expires and many times they are left in the field and are not retrieved.

Research is underway to develop alternative power sources for sensors by scavenging or harvesting energy from the sensors environment. Obtaining power from
the environment is not a new concept. One of the best known examples of exploiting mechanical energy is the self-powered wrist watch and ambient light (i.e. solar energy).

Obtaining energy from ambient sources, such as solar, vibration, thermal gradient, and electromagnetic signals, is an attractive prospect as the solution for developing methods of energy harvesting. Recharging batteries with harvested energy could extend the sensors battery life and the life in the field. Simplifying the sensor network topological can extend the battery life.

Research challenges in sensor networks are formidable because of potential line of sight issues and energy availability uncertainty and what does the exposure to low level RF frequency’s do to the sensor network user? Energy harvesting sources can vary widely in practice and efficiency. Still, the inclusion of an efficiently designed hybrid network that combines energy generation and energy storage in the sensors. While including a customized network topology, may lead to a successful deployment of a sensor network. This efficient network will have to integrate seamlessly, and utilizes common off the shelf sensor components.(Prem 2011)

Scavenging Energy

Research in the application of Nano-energy generators Has fast become a large field of interest in microelectronics. The newest research is the Low frequency vibration and friction energy conversion. Has led to the study of piezoelectric Nano generators. Nano generators look like sandwich circuit boards that have material grown outward around the zinc oxide Nanowires. The energy generation consists of entanglement of two
fibrous wires rubbing against one another. Mechanical energy from the touching of the nanowires is converted into electricity by combination of piezoelectric and a semiconductor process.

This particular research approach to energy generation can be used for scavenging wind energy and or body movement. (Yong, Xudong et al. 2008) Georgia institute of technology is working on a parallel research in energy generation on the microscopic scale working with piezoelectric properties of nanoscopic arrays, the arrays are vertically-aligned zinc oxide (ZON) nanowires. (Yong, Xudong et al. 2008).

The early building stage involves growing an array of nanowires, about a half micron apart, on gallium arsenide, sapphire or a malleable polymer substrate. The layer of ZON is then grown on top of the substrate (gelatinous in nature) to collect the energy current combined with silicon to collect the power from the electrodes. (The electrodes contain thousands of nanometre scale tips made of a malleable metal coating), the tips are then lowered onto the nanowire grouping, leaving just enough space so that a significant number of nanowires are free to move.

With the movement of the equally spaced metal tips, this oscillates the nanowires intermittently, causing the tips to make contact with the fibers, this contact transfers an electrical charge through the hundreds of nanowires. The considered value of this particular design of a Nano generators is that of the non-toxicity and the potential compatibility with the human body.
The Nano generators can be integrated into the implanted biomedical devices, leveraged by the Body sensor network. (Bogue, 2009) However, for the wireless body sensors or vivo sensors the most promising research in energy generation, is in the electrical charge of a single DNA molecule. DNA research is showing possible support in engineering applications because of its appealing features for use in nanotechnology.

The nature to which DNA is self-assembly, employing DNA as building blocks in electrical circuits has been the guiding influence behind the current research DNA energy scavenging. However, one of the biggest challenges to overcome in this field of DNA
energy research is individually connecting a single DNA molecule to an electrode for a reliable measurement of conductivity of the circuit. (Guangyong Li, 2007)

Figure 8 Nano Generator

Advance Nano Sensors

The smallest unit of technological design is Nanotechnology. As researchers are looking to make the sensors miniature, nanotechnology is being considered for the application of body sensors. The combination of recent technological advances in electronics, wireless communications, computing, and networking. These advances have accelerated the development of MEMS wireless sensor networks technology. Recent developments in Micro Electromechanical System devices (MEMS) and wireless technology together will enable remote sensing of a network by using a significant number of miniaturized wireless sensor sensors. (A. & J, 2002, p. 291) The development toward miniaturization, greater performance, and better functionality for the sensors are possible by the success of solid state microelectronics technology. Nanotechnology has enabled the realization of possible low power devices such as MEMS for body sensors.
The base station coordinator and its placement has a significant impact on sensor network performance. Part of a successful implementation of a wireless sensor network depends on the base station and its placement within the wireless sensor network. The energy expenditure to transmit data from one sensor to another sensor depends on the data bit rate and the physical distance between the two sensors and the base station.

The development of a placement algorithm is one of the issues that must be addressed. (Shi, Hou et al. 2009) Recently an algorithm has been deployed by researchers (Weiping, Pengjun et al. 2010) it is an approximation algorithm for location placement of a central gateway device within the network.

In research, the design of the network determines the type and number of router sensors. This research of a fixed deployment of the router sensors within the clustered network topology, this topology gives a moderate to high throughput depending on the size and location of the network. The smaller the networks had a higher than average data
throughput. (Kim, 2010) This research demonstrated optimizing sensors transmissions throughput can be found in the placement of a router sensor. Some research has shown that developing an algorithm based on a linear programming can achieve an interference free link scheduling between the sensors. (Fan Li, 2008)

Sensor Deployment Architecture

Many architectures rely on large numbers of distribution points in their topology. In order to capture the trajectory of a mobile sensor and the sensor movement, it is wise to consider the different type of sensor dispersal models if only to reduce an RF exposed terminal problem. Controlling the exposed terminal problem in smaller topologies will require a reduction of the transmission power. Striking a balance between power and sensor distance. As you can see, this all becomes an equalizing act between throughput and signal collisions. Sensor topology dispersals occur in three commonly used sensor network configurations.

Grid dispersals: sensors are arranged using a grid constructed fashion, and the separation of the sensors can be spaced at equal distance to each point within the grid. The grid layout seems a natural structure to the sensor placement in larger fields.

Random dispersal: cell sensors are randomly and independently distributed in the field of coverage. An initial distribution will not have prior information to the possible field of coverage.

Clustered dispersal: mobile sensors are placed in random sensor clustered deployment (i.e. Cluster tree network Peer to Peer). The cluster tree network is a special...
case of a peer to peer network in which most devices are full-function devices. (FFD)

This research project will utilize a novel clustered network topology.

PSO Routing

A new method for the optimization of continual nonlinear signal processing was introduced in the late 90’s particle swarm optimization (PSO). Particle swarm optimization has its roots in two algorithm methodologies. The obvious connection is Genetic Algorithms (GA) its secondary algorithmic relationship is evolutionary computation. PSO has proven to be effective for global optimization of (non-polynomial –time hard) NP-Hard Problems in network engineering because of the ease of implementation and resource lite computational model.

Various wireless routing protocols are designed for efficient data management within a sensor network to maximize energy efficiency and to reduce packet drops between sensors. Stochastic algorithms have been developed that replicates behaviors of swarming in nature. (Panda, 2011, p. 48). Particle Swarm optimization (PSO) search algorithm that gained a lot of attention in the early eighties. It is designed after the natural world of swarming, birds and fish.

Many models have been suggested, and Reynolds behavioral model is just one. (Reynolds 1987) Reynolds model suggest three parts to Particle swarm optimization:

Separation: Each agent tries to move away from its neighbors if they are too close.
Alignment: Each agent steers towards the average heading of its neighbors. Cohesion: Each agent tries to go towards the average position of its neighbors. The advantage of particle swarm optimization is that it is scalable because the same control architecture is used for both a few and for thousands of sensors. Using PSO in the body sensor, or the field sensor, provides robustness in the communication string that relies on unit redundancy and a minimalist sensor design. It is noted that the use of PSO will increase autonomy and self-sufficiency within a sensor network, thus increasing the topology flexibility. (Amanda 2006)

Connectivity

Connectivity is a crucial property in wireless networks. If the connectivity is achieved, any pair of sensors in the network can communicate with each other. Network connectivity is tightly coupled with the transmission power of each sensor. If this energy discharge is too low, the network will fail, sooner rather than later. While a sensor may use very high transmitting power to make the network connection. The same time a higher energy discharge will cause interference and shorten the sensors’ life. In a typical sensor networks, the range is reduced by walls and floors and with an increased packet error rate in comparison to an external. This research proposes the use of clustered ad hoc topology to address these transmission and interference issues.
Sensor Low Noise Filter

With the use of an external low-noise filter added to a Zigbee sensor, the Zigbee sensors have shown an increased radio range with little impact to packet error. Compared to 472 packet errors without the low-noise amplifier for point to point connection. (Farahani, 2008) Some research had found that by increasing the sensitivity in the sensors, the radio range can be increased without increasing the radio power output. (Meng Shiuian Pan, 2004) Using low-noise filters helps to reduce the power consumption to a minimum and extends the battery lifetime. Constrained application protocol (CoAP) approaches the IPv6 protocol and the Zigbee protocol with a unique transfer procedure. CoAP is a light HTTP that uses the industrial, scientific and medical radio bands (ISM). This radio frequency in the past was reserved for microwave ovens and medical diathermy machines which used the 40 GHZ range. The connectivity of CoAP is in its reduced complexity, instead of using TCP, it uses UDP, and it defines a very simple message (PK, 2009) layer for transmitting within the UDP packets. This standard is tiny and well designed and a possible functional stand in for the HTTP, which can connect with the 802.15.4 and the 802.11. A connectivity issue that will have to be addressed is the beaoning cycles of the sensors within the 802.15.4; 802.15.4 provides a number of packet features to help conserve power in sensors during beaoning cycles. Power conservation is accomplished with the use of longer super-frame cycles and guaranteed time slots with power efficient idle modes established in the sensors.
Power consumption

Part of the Power consumption issue within a wireless sensor network is the signal processing capabilities of the sensors. Signal processing is performed in the field sensors to extract relevant information from the BSN of the patient during transmission. Recent research has shown the benefits of performing signal processing at the full functioning device itself, rather than transmitting raw data within the data link. In FFD sensor, processing reduces the amount of communication performed by the full functioning device, by sending preprocessed data of a smaller size through the routers and end device. However, this does affect the full function device (FFD) sensors power consumption due to onboard calculations.

A key question in the efficient operation within an energy constrained network is how sensors should be activated and deactivated to maximize the number of events they can monitor.

To understand the energy consumption within a topology model you must know at what point is the energy level optimal and is sensor efficiency equal through out the network topology, to find this a calculation of the sum total of all sensors, and of the energy discharge during sensor communication, including idling, activation and deactivation. (Mrutyunjaya 2011)
Operating system and Available memory

The onboard memory of the sensor is an important factor in determining its processing and data storage capabilities. At the processing level, an operating system must support a low power operation if possible. The operating system can use an event-driven execution model in which all computation occurs in response to internal or external events. A robust memory module and Operating system could be contained in the gateway (wake-sleep router). A smaller basic functioning operating system within the field sensors can power down the onboard processors on the sensors reducing wasted energy in the sensors which are being held in awake state. Additional sensor access to energy efficient storage techniques can be acquired through RAM, EEPROM, and Flash; Ram buffers may be able to provide energy efficient data manipulation which can be persisted onto the EEPROM.
Procedure

The main focus of this research will be in the network topology and transmissions of sensors and controlling energy discharge through routing calls. The protocol that this research will use is built on 802.15.4 ISM protocol. Within this research the wireless sensors and the potential use of a combination of stochastic algorithms and a non-parametric method for classifying objects, based on closest training examples. These algorithms will run on field sensors that will act as autonomous components in the network.

Each wake-sleep sensor will perform multiple calculations, PSO, and Knn and Dijkstra single shortest path algorithms. Not at the same time but, in sequence. Each field sensor will calculate location identification for routing. Dijkstra introduced the single shortest path, his algorithm brought about a set of processors, each running a program with an “If” condition and a “then” statement. If the requirements are satisfied, the processors is termed privileged.

The scheduler chooses any privileged processor. The processor chosen will then execute its statement. If there are several privileged processors, the scheduler (the Sleep router Node) or (SRN) chooses any of the processors in this design by implementing Dijkstra self-stabilizing algorithms.

The processors will be the Transceivers End devices (TED). Additionally, the calculation of K-NN in relation to the location of the base station will be calculated by the TED. The SRN chooses any subset of the privileged TEDs. Changes to the instructions to sensors are simultaneously distributed to begin from any initial
configuration. As movement is detected by the router the field sensors will be classified as accepted for receiving or not. The sensors will be designated the simultaneous instructions provide information for a sequence of probable moves of the patient sensor as it is recording data to be sent over to the base station coordinator. In conjunction to the calculations being performed by the scheduler, another scheduler will be reacting to the RFID chip contained on or in the medical device by wakening SRN. (Yang, 2009)

Particle swarm optimization is an algorithm modeled on swarm intelligence, which will find a solution to an optimization problem in the search space. The use in this research will be stochastic, population-based computer algorithm modeled on swarm intelligence. Swarm intelligence is based on a social psychological principle. The research procedure will follow a novel random placement scenario.

The transmission end device (TED) will be placed randomly in a network simulation. Once the sensors are placed, this research will leverage Dijkstra’s algorithm that will calculate the locations and placement of the sensors (TED) in relation to the placement of the sleep-wake routers. The routers will then mark locations within routing tables. The sleep-wake routers will act as typical gateway devices in the clusters. After deployment the RFID chip worn by the patient, attached to whatever medical device, will walk by the sleep-wake router. The RFID will then call to the RFID reader which will be attached to the sleep router node (SRN). The router will wake sensors as the RFID chip leaves the personal operation space. The SRN will calculate nearest neighbor to the TED just adjacent to the RFID chip. Once that sensor wakes it will begin receiving data from the patient device. The sensor with the data will then calculate the nearest RN to the base station. The calculation will use an optimization algorithm to make as few hops as
possible to the base station coordinator from its location. Once the data packet from the patient device has left the device. That data packet will then be received by the router node nearest the base station coordinator to which it will then send the data packet to the base station for storage. (See figure 14)

The following node communication procedure using Dijkstra’s algorithm is in the following diagrams below.

- Testing simulations
- Dijkstra single shortest path within a sensor network
- $Knn$ Calculations against the sensor sensors and a moving RFID signal
- PSO algorithm response within a wireless network
- Triggering Criteria, failure based.

The core research will not be just the network design; it will be throughput, energy usage, energy savings, coverage, and reliability.

Sensor communication after placement

With the use of Dijkstra’s single shortest path on deployment and a novel random placement of wireless sensors, the single shortest path calculation, should help to solve the path problems in the wireless sensor networks from a source Vertex “v” to all other vertices.
Figure 10 Initialize Dijkstra’s routing algorithm

Figure 11 call 2 Dijkstra’s node location routing algorithm
Figure 12 Sensor C next calculation

Figure 13 Selection E sensor

Q: A B C D E
0 = = = =
10 3 = = =
7 11 5 = = =
Figure 14 Sensor E searches next point

Figure 15 Sensor B searches
In this research K Nearest Neighbor ($Knn$) will be leveraged once the sensors are deployed and the patient begins to enter the WSAACN topology. The first sensor that receives the transmission from the patient device performs a calculation to locate the nearest neighbor to the patient body sensor device. This basic $Knn$ algorithm. Function $knn$ Input: A finite set $D$ of points to be classified. Finite set $T$ of points, function $c$: $T \rightarrow \{1, \ldots, m\}$. The natural number $k$ Output: A function $r: D \rightarrow \{1, \ldots, m\}$

Begin for each $t$ in $T$ add the pair $(d(x, T), c(t))$ to $U$. Sort the pairs in using the first components. Count the class labels from the first $k$ elements from $U$. Let $r(x)$ be the class with the highest number of occurrences. End for each Return $r$

End
The leveraging of the K Nearest Neighbor ($Knn$) algorithm by the sensors during transmission provides the location of the patient device and then the following stochastic PSO algorithm will begin its transmission localization protocol.

**Particle Swarm Optimization**

Particle Swarm Optimization (PSO) optimization solution for solving a distribution problem by iteratively attempting to improve a location solution with regard to a given measure of quality. PSO will optimize a problem by having a population of location solution with a pBest particle best solution or gBest global best solution these are measurements of the quality of its location. (Russell Eberhart, 1995) elements movement is affected by its local best-known position and is also guided toward the best known positions in the search space position is updated by better positions found by other particles.
In WSAACN topology, the sensors in the field will calculate the best sensor for receiving data by using the PSO algorithm and the sensor K-NN calculation to the nearest neighbor sensor to the patient.

Upon determination that the best sensor position and delivery of data the receiving sensor will calculate on the fly the minimal hop to the base station from its point of origin. Particle swarm optimization is showing great promise for optimization of continuous nonlinear functions.

Particle swarm optimization simulates a genetic algorithm, while acting as an AI algorithm with each possible solution there is assigned a randomized velocity of particles, and the possible solutions, the particles then move through space. Each particle will track its coordinates in hyperspace which will have an association with the best solution or fitness at that point in time.

The valued fitness of the particle is stored and called pBest. All the while another best value is tracked. It will be the global version of the particle swarm optimized to the best value, and this position is called gBest. As you can see the actual PSO in action begins on ()
Figure 18 Patient walks by SRN and activates search
Figure 19 First pBest determined KNN begins calculation relational to patient.

Figure 20 pBest continues, Knn continues search for patient/Base station coordinator vector.
Figure 21 gBest established, pBest continues

Figure 22 New gBest established, pBest continues Knn finds nn
Wi-Fi (or 802.11), is the generic name of the family of standards for wireless networking. The communication network for Wi-Fi is WLAN, which provides an extension to existing Wired Local Area Network designs. The industry standard for Wi-Fi is 802.11. It utilizes an unregulated signal frequency, such as the Bluetooth standard with the 2.4 GHz and the bandwidth of 54 Mbps. Wi-Fi allows a beacon to lie anywhere within a 1000 foot range of a Wi-Fi router (without obstructions).
The basic operation of a Wi-Fi station requires it to initiate scanning for available channels to discover active networks where beacons (such as laptops, cell phones, tablets) are being transmitted. It will then choose a network either in ad hoc mode or an equipment determined infrastructure mode. Infrastructure mode authenticates itself with the access point and then associates with a WPA security established in the network router if implemented.

This association and re-association of networks is common when searching for stronger beacons. This roaming between networks is a shared and common distribution system. Wi-Fi is based on a cellular architecture; each cell is a basic service set (BSS). A BSS is a mobile or fixed Wi-Fi Station architecture. (Erina Ferro, 2004)

The link layer handles link configuration, authentication protocols, security, and quality of service (QoS) in addition; it controls power consumption and transmission scheduling. The Control layer supplies a command interface to the link manager and the lower band levels of the layers, thus providing a clear interface to Bluetooth hardware such as cellular phones, Mp3 players, and Laptops. The logical link control adaption protocol (L2CAP) layer supplies a correlated connection and connectionless services to the upper layers.

Zigbee

Zigbee is a set of specifications on top of the 802.15.4 ISM standard; the Zigbee standard is formed of OSI layers. Each layer provides services to the above layer. For example 802.15.4 defines the physical (layer PHY) and the media access control (MAC)
at the sub layer. Zigbee standard builds the foundation for the network layer and the application layer on the 802.15.4 ISM standard.

The Zigbee network will consist of the coordinator, Router, and end device. There is a single coordinator in a Zigbee network that will act as a router to other networks. The router can extend the network topology by using different network designs. (Meng Shiuan pan., 2004)
Theoretical framework

The design of a Wireless Sensor Ambient Assisted Care Network (WSAACN) is a wireless sensor network which has different operational constraints when compared to wired or cellular networks. Wireless network applications differ from internet like applications.

Four different types of devices are defined in wireless sensor ambient assisted care network. The Sleep router node (SRN) which is a fully functioning device (FFD) and the transceiver end device (TED), which is a reduced functioning device (RFD), a router node (RN) which is a (FFD) and the base station coordinator (BSC).

The BSC can communicate to RN, and SRN. While the TED device can only communicate to the Patient medical device and other TED devices as well as the RN the RN can act as a PAN (personal area network) coordinator in conjunction with the RFID chip on the medical device. The interaction of the sensors is defined by the OSI layers. The 802.15.4 can leverage a single hop on a star network topology configuration or even a self-configuring multi-hop network.

A sensor in the 802.15.4 network can either be a 64 bit address or 16 bit addresses. This research will use a 16 bit address. The PHY layer delivers the interface between the MAC layer and the radio channel. The PHY layer provides two services accessed through two service access points (SAPs) this is the data service structure. And the PHY management service. (Lee, 2013)

The PHY layer is responsible for the following tasks: Activation and the deactivation of the radio transceivers manipulating them into one of the three states:
Transmitting. Receiving or off/Sleep according to the request from the Mac sub-layer. Energy detection (ED) happens within the channel established. It is an estimate of the received signal power within the bandwidth of an 802.15.4 channel. The standard assessment for detection time of the energy should be eight symbol period in accordance with CCA.

The energy detection can be used by the network layer as part of the channel selection algorithm or to be used as a clear channel assessment (CCA). Within a Zigbee wireless network, the sensors will determine the Link quality indication (LQI) for received packets: Link quality indication measurement is performed for each received packet. The PHY layer uses receiver energy detection, a signal to noise ratio to measure the strength and or quality of a link from which the packet is received. However, the use of LQI results by the network or application layers is not specified in the standard.

Clear channel assessment (CCA) for carrier sense multiple accesses with collision avoidance (CSMA-CA): The PHY layer is required to perform CCA using energy detection, carrier sense or a combination of these two.

In energy detection mode, the medium is considered busy if a signal modulation and spreading characteristics of 802.15.4 is detected. Within the combination, both conditions are determined to be met if an energy threshold above a predefined threshold is met and is achieved through signal modulation.

Clear channel frequency selection: Wireless links under the ISM model can operate in 27 channels (however any single network can choose to authenticate all or part of the channels). The PHY layer should be able to tune its transceiver into a certain channel after receiving the request from the MAC sublayer.
The MAC sublayer provides an interface between the service specific convergence sublayer and the PHY layer. The PHY layer and the MAC sublayer provide two services, the MAC data service and the MAC management service.

The MAC sublayer is responsible for generating network beacons for the network sleep router node. Sleep router node (SRN): a sleep router node can determine whether to work in a beacon enabled mode or sleep mode, this determination could be performed in a super frame structure. The super frame is bounded by network beacons and divided into a number super frame slots. Value of 16 equally sized slots. (See figure 23)

The SRN sends out beacons when called upon, by proximity to the patient RFID chip which is attached to the medical device. As the patient moves through the network synchronizing of the RFID chipped patient device and the sensor begins.

On the initializing of the wake cycle on the sleep router node, the wake cycle will create a cascading wake timing in response to the RFID chipped patient device movement. The SRN sends out the synchronizing call for data polling; energy saving and detection of node orphaning is initiated. (Al-obaidy, Ayesh, & Sheta, 2008) support for self-configuration 802.15.4 embeds association and disassociation functions in its MAC sublayer. This disassociation helps in the creation of single to many topologies.

The MAC layer employs the carrier sense multiple accesses with collision avoidance (CSMA-CA) mechanism for channel access, within 802.15.4. For energy saving and lower data rate, this sensor design does not include a request to send (RTS) and clear to send. (CTS) These mechanisms are abandoned in consideration of the lower data rate.
When working in a beacon enabled mode an SRN can allocate predesigned percentages within the active super frame to any device in the network. These percentages will comprise the contention free period (CFP) of the super frame.

The MAC sub layer employs various mechanisms to enhance the reliability of the connection. Among them are the frame acknowledgment, retransmission, and data verification by using the CSMA-CA.

802.15.4 Allows the use of a super-frame structure. The format of the super frame is defined by the SRN (coordinator) the full use of the Super frame will require the reduction of collisions. The active portion of the super frame is divided into 16 slots (0-15) one device will be allocated one full slot.

![Figure 25 Example of super frame structure](image)

The format of the super frame is defined by the WSR. The super frame comprises an active part which is defined with the CAP and CFP and an inactive part, which is bounded by network sensor beacons. The beginning Beacon enabled mode is to the left of the GTS Scheme super frame structure. The structure is delimited by two consecutive beacons. (The Begin and the End) (Afonso, Silva, Macedo, & Rocha, 2011)
The interval and the length are defined as:

- $\text{BI} = \text{aBaseSuperframeDuration} \times 2 \times \text{BO}$,
- $\text{SD} = \text{a BaseSuperframe Duration} \times 2 \times \text{SO}$
- “$\text{aBaseSuperframeDuration}$” = 960 symbols \( \text{BO} = \text{Beacon Order}, \text{SO} = \text{Super frame order} $\

The values of BO and SO are determined by the (WsR) wake-sleep router. The active part of the super frame is divided into “$\text{aNumSuperframeSlots}$” (default of a value of 16) equally sized slots. The beacon frame is transmitted in the first slot of each super frame. The active part of the super frame can be broken down into two periods, a contention access period (CAP) and an optional contention free period (CFP). The CFP may accommodate up to seven guaranteed time slots (GTSs), and a GTS may occupy more than one time slot period. A part of the CAP will remain for contention-based access for the transmitter on the patient body sensor or medical device itself. A slotted CSMA-CA mechanism is used for channel access. All contention based transactions shall be complete before the CFP begins. The transactions using GTS will be completed before the time of the next GTS or at the end of the CFP.
Antenna Orientation

Antenna orientation can play an important part on the performance of signal propagation within a wireless sensor networks. Sensor networks have many factors affecting the transmission and reception of a wireless sensor in the network. One of the key network design issues not covered in depth, in many of the research network topology designs, how can an antenna orientation effect the signal propagation indoors. Research performed by Manish on WSNs found a decrease in the accuracy of the WSNs due in part to the lack of antenna orientation.

The researcher had hoped to draw attention to the impact of wireless sensor networks and antenna orientation. (Manish Wadhwa, 2009) This research continues with studying the behavior of wireless sensor networks and the maximum range of the
antennas. The range of the antennas depends upon the power output from the node. The power output increase will decrease the life of the wireless sensor node. The power output will provide noticeable change in signal strength couple that with a varied antenna orientation, the orientation of the antenna is a major component in the determination of the performance of a sensor network outdoors.

Sensor networks in a restricted distance

In a random placement, restricted distance scenario, \( n \) sensors are randomly located in either a two dimensional space or three-dimensional space. For this research paper the assumption of the wireless network will be that sensors are homogeneous i.e. all transmissions employ the same nominal range or power input of 0.5 joules.

Throughput of \( \lambda \) \((n)\) bits per second for each node utilizing a spatial and temporal scheme built with Novel algorithm, vertex shortest path sensor group optimization (VSPSG) for scheduling transmissions. Short term buffering is predetermined by the sensors and established by the wake sleep router. Every node can send \( \lambda \) \((n)\) bits per second to the chosen router as determined with the routing protocol. Thus \( T < \infty \) within every time step \([(i - 1)T, iT] \) determines every node can send \( T \lambda \) \((n)\) to the next destination node.

All sensors will share a restricted range \( r \) within the network from the Wake sleep Routers, (WSR) when node \( x_i \) transmits to WSR \( x_j \) over the \( m \) the wireless channel; the transmission is successfully received by \( x_j \) if The distance between \( x_i \) and \( x_j \) is no more
than $r \ |x_i - x_j| \leq r$ for each WSR that will simultaneously transmit over the same channel as the sensors to the server $|x_k - x_j| \geq (1 + \Delta)r$ the throughput is defined by time average of the number of bits per second that can be transmitted by each node to its WSR. The above throughput will use that calculation to determine the scheduling algorithm which will have the determined location of all sensors and the succeeding traffic demands and location within the temporally and spatially coordinates.

Summary of Literature Review

Wireless sensors can be very simple in design. Due to technical reasons most available field wireless sensor devices are constrained in terms of a sensors computational abilities and energy consumption. Main reason most of the wireless sensor network research has focused on the energy conservation and computationally efficiency of sensors.

The resurgence in wireless sensor research has gained ground because of the development of the smaller size of sensors and the potential use in our everyday lives. Sensor Networks can be equipped with single or multiple sensors according to the monitoring needed. Wireless sensor networks have seen use in domains of agriculture, military, manufacturing, transportation, environmental and engineering but not in the monitoring of patient health at home.

The deployment of a home health care monitoring system, has its challenges and will need continued research. Some of these challenges are based in the nature of wireless frequencies and consequence of the constrained transmissions and the availability of resources in the networks.
The hope is this research will contribute to the ongoing development of indoor wireless sensor tracking. Signal propagation within a home health care monitoring network. The importance of reliable health monitoring for the future of health care cannot be overstated. There will be hurdles to overcome due to the sensitivity of wireless networks and potential network failures.

The scalability of sensor deployments has shown promise. Some wireless sensor applications have used hundreds or even thousands of wireless sensor devices in the network. Wireless sensors can easily run well known proactive or reactive routing protocols. Wireless sensors must maintain an interconnectivity so that data reaches the destination for storage and analysis.

New protocols and mechanisms need to be designed to achieve interconnectedness and allow the transfer of data reliably. The current nature of wireless sensors has shown a high failure rate due to a lack of availability of energy. Future design of wireless sensor networks will require heterogeneity, with embedded sensors in development for the marketplace with different capabilities and functions which will require new transmission algorithms.

With the continued growth in the use of wireless sensor networks, privacy and security have moved from the shadows of obscurity in the considerations of network designs. Security protocols will have to be designed, so they are less demanding of resources. Wireless sensor networks, no matter the design, share the same failure points; energy consumption and energy retention.

This research will look at ascertaining the general regularities of sensor sets in clustered topology within a constrained sparse network and their cause and the effect and
relationship to the delivery of datagrams. Proving a clustered topological network design can provide a reliable, effective pervasive home health monitoring system. It is the hope of this research to add new knowledge by proving a novel topological transmission design, validating the research testing of the theories that focus on the design of an effective wireless sensor ambient assisted care network. In chapter three, the research on a spatial statistics methodology on determining the random placement for sensor deployment.

CHAPTER THREE

This research covers low density randomly dispersed wireless field sensors. Within this research, an attempt to address signal contentions RF interferences and quality of service is covered directly in this chapter. The hypothesis is simulated. Will a reduced sensor density deployment within a constrained sensor network experience a lower interference and the reduction of signal contentions?

Research Tradition(s)

The research is based in quantitative research and uses empirical evidence as a means to determine the value of the simulation evidence. This research will look at establishing the general regularities of sensor sets within a constrained network and their cause and effect relationship to the delivery of datagrams. The research will leverage some secondary data including sensor data type and frequency signal. It is the hope of this research to add new knowledge through proving a novel clustered proximity sensor network with a controlled energy discharge on need to broadcast model will validate the
research testing of the theories that focus on the design of an effective wireless sensor ambient assisted care network.

Research Questions

This research will leverage a spatial statistics approach on determining the effectual placement process for sensor deployment. This research will attempt to define key characteristics of the structure of an energy conservative wireless network topology. The modeling of a spatial structure of wireless sensor network will enable a complex analysis of the simulated environment.

Research Design

Wireless sensor networks have serious challenges that will require additional research it is possible that the challenges faced in WSN, has a direct correlation to the constraints of a network design as well as the resource distribution within the network. The challenges that this research will focus on will be the network lifetime: WSN’s are battery powered and because of this the network viability has a direct correlation to the how wisely will the sensors use energy. Beyond the network viability, sensor networks rely on interconnectivity: WSN’s need to experience interconnectivity to ensure the deliverability of the data. Normally network connectivity in WSN is handled by gateways such as sinks and differing protocols. Though Homogenous WSN sensors design remain a constant. They have developed differing capabilities; this research will look at a Hybrid-interconnectivity from a WSN device to the Wireless sensor network with a
leverage of stochastic algorithms. This research will be quantitative in nature. This research simulation will be based entirely on low-density population of sensors.

Additionally, this research will address basic implementation questions for the resource deployment cost of wireless sensor networks within the constraint of providing a minimum level of quality of service (QoS). The QoS is measured by the coverage and the average bandwidth provided by each sensor. The mathematical calculation to define the metrics of the QoS is the Poisson process; the theory of the Poisson process is closely related to stochastic geometry. The Poisson process can be a collection of points that are localized in space or time. Stochastic geometry can allow the representation of the spatial interactions between sensors and routers and the network sink.

Random Deployment

Usually, sensors cannot be deployed in a standard wired network architecture due to physical constraints within the environment. Randomness on the actual sensor locations will need to be accounted for the design in a wireless network architecture. Additionally the assumption is that the sensors transmit power equally. A wireless sensor model is built on the realization of a random Poisson process and more precisely of some homogeneous Poisson process in the Euclidian plane.

The Poisson assumption can be restated by asserting that the amount and the location of the sensors are independent and non-overlapping. Denotation done by $\theta_{\alpha} = \{x_1, x_2, ..., x_k, ...\}$ for the sensors $\theta_{\alpha}$ Poisson process intensity $\lambda_{\alpha}$ the assumption is that the patient walking within the environment will move within a random passage in accordance to the homogeneous Poisson point process $\lambda_{u}$. 

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Radio Transmission Model

The math model used in this research will perform a Radio transmission analysis based on a model of a radio channel. The radio channel model is calculated by the power received at a point $y$ from the (TED) Transmitter end device located at point $x$ designated by $P(x, y)$, is given by $P(x, y) = P \cdot S_y^x \cdot \gamma(x, y)$, where:

- $P$ is the Transmission power;
- $\gamma(x, y)$ is the path loss between $x$ and $y$;
- $S_y^x$ is a random variable representing the fading and shadowing effects between these two locations.

$$
\gamma(x, y) = \begin{cases} 
A \cdot d(x, y) - \alpha & \text{if } d(x, y) > r_0 \\
A \cdot r_0 - \alpha & \text{if } d(x, y) < r_0 
\end{cases}
$$

$d(x, y)$ is the Euclidean distance between $x$ and $y$ to replicate the positive real numbers $r$, $\gamma(r) = A \min (R, r_0) - \alpha$. The path loss exponent $\alpha > 2$ has a variable on the indoor environment versus outdoor environment. For all $y$ and all sensors located at $x$, the random variables $\{s_y^{x1}, s_y^{x2} \ldots \}$ with this assumption they are independent, identically distributed and they are exponentially scattered with the parameter $\mu$. The gain and phase elements of the channels distortion are represented by the assumption of the complex number.
CSMA/CA Location Paradigm

This research will measure the transmit time and back off time by CSMA/CA (See figure 28) which will consider chosen sensor transmission at the given time established by the wake router. Roughly sensors $x$ and $y$ cannot transmit at the same time. Specifically if the sensors do not belong to the same domain of each other, for example if $P(x,y)$ and $P(y,x)$ are under the same domain, then they can transmit at the same time.

Each CSMA/CA transmitter have a timer that indicates its back-off time. This action will define the random number of slots. If the sensor detects another sensor in its domain, the timer will stop until the transmitter becomes free. The CSMA/CA design is will not allow transmission in the domain if another transmitter is transmitting. Notation on representation $\Phi = \{x_1,x_2,\ldots,x_k\ldots\} \Phi(t)$ the set of sensors that have been determined to transmit at the time established $t$. The set $\Phi$ plays a part in the role of network performances of the 802.15.4 ISM network.
Non Conflicting channel allocation probability

Here we will consider the probability of non-conflicting channel allocation when 802.15.4 and 802.11b (sharing the same space) $P_{good}$, for the sake of discussion, the assumption of non-conflicting channel $n$, within the 802.15.4 standard. (See figure 29)

The random variable $R$ will be representative of a number of conflicting channels in the selected 16 channels and $K$ as the number of conflicting channels in the selected multihop channel sequence out of the $R$ conflicted segment. The random variable $S$ denotes the channel status (0) no channel conflict (1) channel allocation conflict occurred defined $P_{good} = P[S = 0]$ for the study of the coexistence issues.

The simulation software uses a similar coexistence calculation the Chen uses here in the following example: Sensor deployment 1: $n=1$. Single coexistence between 802.15
network and 802.11, needs to be established that $P(R = r)$ with the probability that $r$ conflicting channels in a selected segment of the qualifying adjacent 16 channels. (Chen, pp. 1-6)

$$P[R=r] = \begin{cases} \begin{align*}
\binom{49}{r} \cdot r = 16 \\
\binom{79}{r} \cdot 1 \leq r \leq 15
\end{align*}
\end{cases}$$

With $r$ conflicted channels in the adjacent channels, the probability of $k$ channel conflict out of the selected multi hop sequence ($k \leq r$)

$$P[K = k]R = r = \binom{32,32}{16} = \binom{32^r}{k} \binom{32-r}{k}$$

Given $k$ channel conflict in the selected 20 hop sequence, the probability of channel conflict while selecting one channel from the 20 hop sequence is defined as:

$$P[S = 1|K = k, R = r] = \frac{k}{20}$$

To build on all conditions of possible $r$ and $k$ values shown above displays that you can get $P_{good}$ the probability of no channel conflicts. Here is the proof

$$P[S = 1|R = r] = \sum_{k=1}^{64} (P[S = 1|K = k, R = r]P[K = k|R = r])$$

$$P[S = 1] = \sum_{r=1}^{64} (P[S = 1|R = r]P[R = r])$$

$$\approx 0.202532$$

$$P_{good} = 1 - P[S = 1] \approx 0.797468$$

Possible conclusion, a coexistence issue between IEEE 802.15.4 based Wireless personal area network topology and other wireless or cellular networks. Within a home health care network may increases in probability of channel conflicts, thus causing conflict within the WSAACN not unlike other wireless signal transmissions with the variable of energy throughput.
Proofing research design

Wireless sensor networks (WSNs) typically employ a large number of disposable autonomous sensors. The typical deployment of a wireless sensor network is in a remote area for monitoring animal migration. Deploying in a home health care system is the next logical step for a wireless sensor deployment.

This research paper will leverage simulators that imitates selected behavior attributes of sensors and topological design.

This ability to imitate real sensor networks makes software simulation a valuable research tool. The types of network simulators either run in asynchronous mode, event
triggered mode or in a synchronous mode with events happening within fixed time periods.

Synchronous simulation: The synchronous simulation is cyclic. At the beginning of the cycle the simulator moves the global set time by one unit, then it will move the sensors according to their topology design and subsequently update corrections as needed. Synchronization is a common issue in WSN, how to wake up sleeping sensors?

One way to wake up all sensors at the appropriate time is to have a synchronized network, upon the initial deployment.

Asynchronous simulation: will be an event based simulation. In this style of simulation, the simulator will hold a list of message events and time events, which are correlated by the time the events should happen. Additionally this research will leverage an algorithm level simulator to focus on the logic and data transmission structure. The packet level simulator will be used to simulate the implementation of the data link and physical layers in a typical OSI network stack. The research tools this investigation the Ataraya simulator for topology construction and MATLAB.

Simulation proofing

Over the past few year’s sensor networks with different types of antennas, notably within large sensor deployments, has been a well-researched topic. In this research, the examination of the use of multiple antennas at the SRN or RN is hoped to achieve considerable transmission energy savings compared to a single antenna on the field sensors.
Network simulations will run for 60 seconds. Data clarification will be achieved through the operation of the PSO routing within an indoor wireless sensor network. Radio connectivity will be tested from different routing protocols and radio channels.

Sensor simulation parameters for data collection

The simulation of a wireless sensor network, in which a sensor deployment is uniform and the transmission is random in a square area. Sensors will be chosen at opposite ends of the wireless sensor network. (Cooperative and non-cooperative routes from $s$ to destination $d$ will be determined).

The computation of the total amount of energy consumed on each route using different routing algorithms, including Dijkstra’s path loss algorithm. Finding the path loss exponent $\alpha = 2$ noise power $P_n = 1$ and the (SNR) signal to noise ratio threshold $\beta = 0.65$, the numbers used, can be obtained by averaging multiple simulation runs with different wireless sensor locations. Utilizing the max sensor power $P_{max}$ set at the initial connection without router cooperation, the sensor network model is 50 sensors uniformly distributed (later performing the same simulation with randomized placement of sensors) for a non-constrained optimization sensor relations are subject to a probability of a given power outage of any one of the sensors. (Mostafa Dehghan, 2011)
Multiple Aerial Receivers in wireless sensor networks

The broadcast of the radio frequency signal in an indoor environment is subject to fading prompted by a shadowing effect. This increase in propagation by the use of multiple antennas may reduce the shadowing effect and signal fading. Received signal strength measurements in indoor applications are affected by the broadcast environment. I.e., interior walls, this author’s research found that spatial diversity can be achieved by employing multiple antennas within the home.

This deployment may improve the reliability and the quality of the wireless link considerably. (Safa Hamdoun, 2013). Manish Research found a decrease in the accuracy of the WSNs due in part to the Antenna orientation. The researchers of this paper hope to draw attention to the impact of wireless sensor networks and antenna orientation. (Manish Wadhwa, 2009) This study continues the behavior of wireless sensor networks and the maximum range of the antennas. The range of the antennas further depends upon the power output from the sensor for the antenna to operate.

Instrumentation

In a WSN, sensors are capable of sensing their environments, processing the information locally and sending it to one or more collection points through wireless links. These sensors need operational statistics about the network architecture under design or
in use. The sensors must be able to gather systems and protocols data and application calls. (Dwivedi A.K., 2011)

The emergence of wireless sensor network simulators brought about new ways for network engineers to test topologies; the development of simulations saves hours of testing. The simulations that this research will be leveraging is Asynchronous simulation since WSAACN is an event driven architecture.

Asynchronous Simulators for wireless sensor networks

1. MatLab (MathWorks, 2014) statistical leverage PSO leach simulator
2. Atarraya Topological simulator

Validity and reliability

Using multiple antennas at the receiver achieves considerable transmission energy savings compared to a single antenna thanks to the spatial diversity inherent to random sensor networks. (Bellanger, 1984)

The simulators will summarize and log sensor activities by calculating averages. And probabilities model statistics. The statistics are gathered only from complete simulations. Under the probabilistic sensing models the simulators will determine the defined areas by the inner area being the distance \( r - r_u \) which in the simulation will determine that the sensor will detect event \( e \) with the probability of 1, where \( r_u \) is known as the uncertainty of the distance of the next sensor. However the range outside the uncertainty region will reflect an opposite probability of the sensing event, the probability of sensing event \( e \) is zero. More directly \( d(s, p) \) is greater than \( r + r_u \). Within the
uncertainty region of a sensing model the sensor will detect event e with certain probability that decays exponentially with the distance. While sensor s can be expressed

\[
C(s) = \begin{cases} 
1, & \text{if } r - r_u \geq d(s, p) \\
\exp(-\lambda \alpha \theta), & \text{if } r - r_u < d(s, p) \leq r + r_u \\
0, & \text{if } r + r_u < d(s, p) 
\end{cases}
\]

\(\alpha = d(s, p) - (r - r_u)\) & \(\beta\) and \(\lambda\) represent the differing parameters that yield diverse detection probabilities, while modeling different types of physical sensors such as the RFID and field sensors.

The simulator will proof the direction based protocol in the signal transmissions during or before identification of the next nearest neighbor. The distributed relative neighbor graph protocol (DistRNG) all sensors start by using the minimum transmission power. During the calculation of the next nearest neighbor, the schema will be updated within a relative neighbor graph for determination of a single transmission area of coverage for each sensor. Upon the determination of the neighbor, if sensor \(v\) is not in the covered region, the edge \((u, v)\) will be added to the relative neighbor graph on the table schema in the sensors, if more than one sensor is found to be uncovered, the uncovered sensor will be added to the schema. The angle of the new sensor \(\theta_v\) will determine the updated covered area by implementing, \(\theta \cup cone_v\).

The (DistRNG) will be calculated until \(\theta = 2\pi\) is at maximum transmission range. The parameters proposed for the homogenous sensor cluster deployment are: Number of sensors, communication radius, sensing radius, size of the area deployment (interior setting) Position distribution based on Normal with center sink in \((x, y)\) this position distribution will require mean and standard deviation of the location.
The hierarchical protocol for clustered topology will determine what each node a stochastic algorithm PSO is used at each simulation round with the sensors to determine the cluster sink. The sink determination will be used once a derivative of the samples will depict the sensor head in a wireless sensor topology. The Griewank function was used for the study of PSO algorithm as a benchmark function.

Antenna attenuation will determine which antenna model will perform the best; it is this researcher’s belief that a quarter length monopole antenna placed on router sensors and sleep-wake routers. Because the operation of the monopole antenna is half the wavelength of dipoles, and the simulation is in a restricted space for an antenna with half the wavelength, shadowing should be at a minimal. (Mostafa Dehghan, 2011)

Summary of Chapter Three

Wireless sensor research looks at the behavior of wireless sensor networks in an interior environment within a pervasive sensor monitoring. The leveraging of simulations for wireless sensor networks, deployment, and signal processing will prove out the effectiveness of the topology. All the while examining the energy saving attribute of the sensors in random deployments. The next chapter will demonstrate the results of the simulations and discussion of the validity of the simulated conclusions.
Chapter Four

There are different approaches to evaluation of WSN implementation models. The first is a mathematical model for evaluating and analyzing different algorithms within the environment, and the second is via simulation. As this research is presented in both forms in this experiment, all specifications of the wireless network protocol and algorithms are tested and defined in the simulator. This approach is not without its faults many simulators have a limited capability to run full operational simulations. Many simulators will differ in design; the Atarraya and MatLab simulator both share limitations, they will supply a different measurements.

It may not be feasible to validate with simulators the many differing monitoring scenarios discussed earlier. However, it is this researchers hope to draw enough results for the reader to see the viability in the deployment of a home health care wireless network. This research will test the possibility of a deployment of an ad-hoc wireless sensor network in a sparse topological design. Much of the information gathered includes the topological design constraints in a typical WSN.

The data gathered is from a single sensor response in ad-hoc topology, with the inclusion of energy variables and sensor optimization in communication algorithms (including a stochastic algorithm and greedy algorithms). The design of the topological control is a theoretical model. Covering two dimensions, this research has been able to control many attributes of the physical design and topology control; within the statistical and graphical dissemination of data. Running simultaneous sensor optimization
benchmarks on the WSAACN topology while using PSO leach algorithm for sensor responses. Results will be comparatively examined from the sensor deployment benchmarks, and a determination on the effectiveness of the network both in its design and communication effectiveness.

Presentation of the Data

In order to review the probability of success with the use of a swarm routing algorithm PSO LEACH, (The routing protocol is the mechanism that the sensors will use to exchange the network information) algorithm usage in this research design is split into two instances. The first is initiated by the deployment of the sensors using Dijkstra’s shortest path. Dijkstra's shortest path protocol is used to identify location and shortest path to the base station and as a location identification method, each wake sleep router and router sensor keeps track of episode links (link is up or down, and the cost of the
link) each sensor transmits their operating state that gives each router the complete view of the graph edge. Each router and wake-sleep router will compute the shortest paths to the base station and construct the forwarding table accordingly.

```
Begin:
Initialize
% create a set to new field i where sDist[i] is solved %
create empty priority queue to New field:
sDist[1]<0; %distance to the source%
forall vertices w in V-{1} do % edges have not been explored%
sDist[w]< infinite
end for;
fill new field vertices w in V arranged by priorities sDist[w];
endintilize;
repeat
vc deleteMin(new field); % vis the new closest; sDist[v] is correct%
forall of the neighbors w in Adj[v]do
if sDist[w]>sDist[v]+edgeCost(v,w)then
    sDist[w]<sDist[v]+edgeCost(v,w)
    update w in New Field %with priority sDist[w]%
end if
endfor
until new field is empty
end
```

Figure 14 Dijkstra’s shortest path pseudo code

This routing algorithm finds the best possible path from the originating source to its destination in a location-based routing simulation. Packets are routed based on the location of the set of chosen sensors and the location of the final destination. As the result of the method of the next routing, sensors do not need to make complex computations find the next hop. This dynamic location/routing algorithm is the first part within a routing table to determine:

1) The location of all sensors and routers

2) Map location by predetermined assigned MAC address of the gateways (WSR) and default gateways (SRN). Each routing table in all the sensors and base station will build a default route as determined during deployment. The routing protocol is the
mechanism for the exchange of network information that the sensors use. The network information is then sent through the network, network layer packets are generated by the routing protocol local or globally through the network and it will contain the location variables of each sensor. After Dijkstra’s shortest distances is run on the wake-sleep router the same processes will be run on the other sensors until all sensors have mapped the locations in their routing table.

Figure 15 Shortest destination is calculated, and sensors locations are identified.

After determining the location of the sensors in a network, the next step is to determine the amount of controlling transmission energy of the sensors to connect to all
sensors in the network. The sensor simulation will include 10, 20, 50, 100, sensors, with five trials.

Energy models for this research will have built in assumptions about energy discharge. For example Using (Chandrakazan Heinzelman, 2000) energy algorithm:

\[ E_{TXbit} = E_{elec} + (E_{amp} \times (\pi r^2)) \]

\[ E_{RXbit} = E_{elec} \]

In the simulations, the objective was to model a physical layer on the sensor while experiencing path loss and shadowing effects as part of the Quality of Service attribute for delivery assurance.

The simulation at the PHY level determines the probability of a clear signal to noise ratio and modulation parameters needed for deployment. The input of the simulations included a number of sensor positioning as well as testing minimum back off time on the PHY layer.

The measurement parameters that had been used had been measured in wavelength and tested in meters. This measurement was accomplished by the quantity and intensity of back off occurrences within a predetermined time interval. (As typically modeled in the Poisson distribution in network transmissions) This similar measurement was used to determine the standard deviation in shadowing and path loss within the simulations.

A review of the expected failure vectors and energy displacement of typical wireless sensor networks had to be considered within the distributed leach swarm optimization model. These failure vectors included the standard deviation in shadowing
including minimum range and maximum range failure points. Channel availability was calculated by the probability of finding the channel busy (receiving sensor) during the initial transmission in the state designated as Alpha. The Atarraya simulator had built in the parameters on the amount of the sensors placed in the topology.

An additional usage estimate was undertaken and expressed by the expressed state Beta built on the probability of finding a channel busy during the re-transmission (after receiver failure) of the initial signal after a failure. Both the alpha and beta state was measured for the availability of the network sensors as dispersed in a random topology (built on a single sensor reaction). In this simulation the utilization of 10 sensor nodes, 20, 50, 100 sensors, had shown a remarkable stabilization at .05 joules while finding restricted channel access increased with the growth of sensors to the count 100 sensors. (See figure 16) The simulation was run to reflect the scenario of "N" Stations trying to communicate with the wake sleep router on initial deployment. The estimation of the packet collision was determined with the probability of collision assumed in both the alpha and beta test. The initial notable differences between 10 sensors and 20 sensors network capacity showed very little variation. With the 50 to 100 sensor we see an initial retransmission failure increasing in occurrence. This initial retransmission failure eventually leads to sensor signal degradation and sensor failure.
Sensor failure in the network is just one area of concern when dealing with delivering medical data efficiently in a WSN. As part of the reliability and availability delivery model of data aggregation, a sensor network must retain enough operational sensors for the delivery of that data, as part of the wireless sensor ambient assisted care network. The deployment of a minimum amount of working sensor needed to be determined. In this next part of the research a comparison was drawn on the deployment size 10, 20, 50, 100 sensors and transmission packets sequences using Poisson energy distribution model with $\lambda_e$. In this part of the simulation 10 sensors deployed in a 100 x100 m area had been optimal with the delivery of over 1500 transmission packets without shadowing or signal collision interrupting the transmission time. (See figure 17)
As the network added sensors, the reduction of successful transmissions began to fall off. In this simulation shadowing was appended to test the sensor failure rate.

Figure 17 transmission test sensor failure

The next part of a WSN analysis was an energy component burn time, for a home health care model. Since the energy in this model was based on a finite energy source the determination of sensors failing due to the lack of power at the transmitting sensor.
Dead sensor test in the cluster topology controlled energy model

Energy model values in joules initial energy 0.5

2 sensors

- Packet length 6400 at 5217 transmission one sensor failed.
- Packet length 6400 at 5708 transmissions all failed.

5 sensors

- Packet length 6400 at 792 transmissions; one sensor node failed.
- Packet length 6400 at 1880 transmissions, 2 sensors failed.
- Packet length 6400 at 2543 transmissions; three sensors failed.
- Packet length 6400 at 2610 transmissions four sensors failed.
- Packet length 6400 at 3451 transmissions four sensors failed did not have a complete failure.

10 sensors

- Packet length 6400 at 511 transmission 1 sensor node failed.
- Packet length 6400 at 1098 transmissions 3 sensors failed.
- Packet length 6400 at 1200 transmissions five sensors failed over half of the sensors in this deployment have failed.
- Packet length 6400 at 1356 transmissions eight sensors failed.
- Packet length 6400 at 1567 transmissions nine sensors failed.
- Packet length 6400 at 2284 transmissions nine sensors failed.
20 sensors

- Packet length 6400 at 492 transmissions one sensor failed.
- Packet length 6400 at 1098 transmissions 18 sensors failed.
- Packet length 6400 at 1200 transmissions 18 sensors failed.
- Packet length 6400 at 1356 transmissions 18 sensors failed.
- Packet length 6400 at 1363 transmissions 19 sensors failed.
- Packet length 6400 at 1370 transmissions all sensors failed.

50 sensors

- Packet length 6400 at 423 transmissions 1 sensor node failed.
- Packet length 6400 at 1060 transmissions 49 sensors failed.
- Packet length 6400 at 1061 transmissions all sensors failed.

100 sensors

- Packet length 6400 at 393 transmissions one sensor node failed.
- Packet length 6400 at 986 transmissions 99 sensors failed.
- Packet length 6400 at 987 transmissions all sensors failed.

Initially I had begun the simulation at 10 sensors within the network topology however after running the simulations, I had found that the terminal failure rate of the sensors earlier in the research simulations happened faster, as the numbers of sensors increased. Proportionately speaking the simulation running at two sensors was added at the beginning to find the failing point of the network.

This simulation was designed to find the life of the cluster topology per sensor transmission.
Due to the finding of packet collision and shadowing, and the higher the number of sensors deployed, the expectation that the sensors in the cluster will experience a catastrophic failure from sensors failing. (Catastrophic failure is determined by the entire deployment of sensors having the inability to continuing transmission.)

With the current knowledge of the failure rate at .05 joules the next step to determine the energy output needed for this type of sensor deployment. To extend the life of the network for the sensors while preventing excessive signal collisions meant to increase the energy availability to determine the failure of the sensors in a WSN in home health care network.

Energy model values in joules initial energy 1.5

- At a higher joule's rate of 1.5, it had taken two sensors to fail at 10000 transmissions
- At a higher joule’s rate of 1.5, it had taken five sensors to fail at 9936 transmissions
- At a higher joule’s rate of 1.5, it had taken ten sensors to fail at 6078 transmissions
- At a higher Joule’s rate of 1.5, it had taken 20 sensors to fail at 4556 transmissions
- At a higher Joule’s rate of 1.5, it had taken 50 sensors to fail at 2731 transmissions
- At a higher Joule’s rate of 1.5, it had taken 100 sensors to fail at 3059 transmissions
The single sensor response is important to determine the viability of the sensor deployment when sensors are told to sleep and wake by the router by approximation of the patient RFID chip, a single sensor must respond.

During the running of the current simulations, it was found that a noticeable performance hit was demonstrated by the sensors. Causing an accelerated weakening of the ratio average of throughput versus the proposed payload. The cause of this reduced ratio average can be directly correlated to the maximum back-off stage of each sensor.

The low data rate transmission by the nature of this topology design brought about interesting data. The leveraging of stochastic algorithms introduced longer channel activity which consumed energy at the individual sensor within the network. Computational activity on the field sensor shows that the network failure is increased in time at each sensor during its computations.

The exponential sensor failure with a sum of the energy source of 1.5 joules leads to the catastrophic network failure in most transmissions by 9126 transmissions. (See figure 18) The minimal energy level point of failure within the sensors appears to be at 0.02. Any sensor below that threshold will not operate. To have an optimal sensor deployment, the energy of the sensor must not fall below 0.01785 after which catastrophic sensor failure occurs. (See figure 19) With the sum of 1.5 joules, this research had shown that a higher amount of transmissions occurred with a residual energy source left in the sensors. (See figure 20 and 21) after transmission.
Figure 18 Sensor Transmission failure proportional to energy output

Figure 19 sensor trend failure without increase of energy output (.05)
Figure 20 higher rate successful transmissions with higher energy source

Figure 21 Higher successful transmissions with lower residual energy
Figure 22 Energy output and transmissions including differential sensor failure

The noticeable difference of transmission between 1.05 joules and 0.05 is the nearly doubled transmission rates at two sensors. And the final failure rate at 1.05 is 2073 transmissions increase over the 0.05. (See figure 22 and 23)
Topology randomization

The next part of this research is in the topology deployment. The parameters include the number of sensors 10, 20, 50, 100 deployed randomly with a normal position distribution. The communication radius $r_{comm}$ as an integer value of 100 and the sensing radius is at the default of $r_{sens}$ 20. The cluster deployment had been random in design just as it would with a patient distributing the sensor at home. The initial deployment example at 100 sensors is shown in (figure 24), for research purposes on the performance of the network simulation, the assessment of the topology construction and the sensor distribution included the number of active sensors and their connectivity in the deployment and the number of messages received. A single sink was used in these simulations.
Of the 100 sensors deployed seven sensors had not been reached. (Failed) The average number of sensor neighbors was 7.8707. From the sink (which would be the wireless sink router) messages sent had been 59577, and received 497486 within the algorithms used 93 sensors were not connected. 16 sensors had failed. 15 sensors had not been covered on the initial deployment.

Figure 24 Sensor deployment random topology
Using the same metrics found in the 100 sensor deployment. 50 sensors with one sink. 26 of the 50 sensors had not been reached 26058 messages sent, 110202 messages received 45 sensors had not been connected. Six dead sensors, with the average neighbors at 3.67067

Again using the same metrics 20 sensors with one sink all sensors covered an average number of neighbors 63 messages sent 21 received (Four sensors dead). All sensors connected. Dead sensors had been calculated by a probability equation, for realistic wireless sensor network simulation. The simulation failed at ten sensors. The qualifier in the process with a probability of failure 0.52 the network is no longer functional.
Figure 25. 100 sensors CRT excessive signal collision within the topology parameters
Figure 26. 100 sensor sensing radius with multiple signal over rides
Figure 27. Failed topology at ten sensors

Topology manipulation

The sensitivity analysis performed on the topology tested the influence of the energy threshold in the lifetime of the sensors in the network. The simulation was
deployed with a dynamic energy topology model. Using two different thresholds, one at five percent, and the other at 50% when the energy threshold was met, the simulation would reconstruct, using the energy model mentioned. This determination of the energy threshold had been very useful to fully understand the failure rate of wireless sensors (per individual sensor) when building the sensor network, for a reliable, available wireless sensor ambient assisted care network.

Antenna design

Since wireless sensors use, 2.4 GHz band antenna design is key to implementation. Antenna design is a function of frequency, application area, range and overall costs. The common method to evaluate an antenna would be to view the antenna gain pattern; the antenna gain pattern is a measurement of the directionality of the antenna. Within the internal sensor structure, the transmission lines will take on an inverted F-antenna. This form of microstrip (patch) antenna will assist in determining the parameters to define characteristic of the antenna’s impedance. Wireless sensors for 802.15.4 are differential; the RF impedance at the radio will be in the range of 100 Ohms. Some of the low-cost radios will characteristicly have an impedance of 50 Ohms so by design the antenna should have the same Ohm feed. The antenna structure within the sensor should be comparatively matched in size to the wavelength of the RF field (half the wavelength) about six cm in the air within the 2.4 GHz ISM band. When matching the radio to antenna, some applications will require a substrate with a different layer substrate thickness. The goal is to have an antenna on the printed circuit board (PCB)
within the sensors that has matching impedance 50+J/Ohms. The antenna will have a 50 Ohm load to the output of the radio. I have designed what the antenna radiation will look like, on the sensors and what will work with the WSAACN in a restricted space. The process includes possibly fabricating a patch antenna on a high dielectric constant substrate. This design should help in reducing the typical signal interference within a smaller topology. The expression used for the dialectic constant

\[ \varepsilon_{ref} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left[ 1 + \frac{12 h}{w} \right] \left( \frac{1}{2} + \Delta L \right) \]

the length of the patch is extended on each end by \( \Delta L \).

The function of a dialectic constant \( \varepsilon_{ref} \) the width to height ratio (W/h) \( \Delta L \) is calculated to an approximation in relation to the normalized extension of the length. (Ali Elrashidi, 2014) The antenna design is good theoretical design for small sensors on the 802.15.4.

**Controlling Antenna Gain to overcome NLOS**

The gain is the ratio of the output power for an antenna, equal to the total input power the input power to the antenna is the total power including, radiated power and the overall losses of power. Gain can be calculated by

\[ G = \frac{P_{out} \text{(output power)}}{P_{total} \text{(input)}} \]

controlling antenna gain will help to pick up wave diffraction due to furnishings and walls.
The addition of the antenna on a sensor is to reduce the shadowing factor created by a no line of sight. This research has estimated the use of an IFA (Inverted F-Antenna) (Sinai, 2006) due to the size of the sensors an IFA PCB antenna was measured using the radiation pattern by plane in orientation of the antenna. The model I use in this research is a random half dipole of infinite length, and the model assumes a sinusoidal current distribution symmetrical about a central feed point. The center frequency of operation of the IFA antenna $f_c \approx \frac{c}{2L\sqrt{\varepsilon_r}} = \frac{c}{2L\sqrt{\varepsilon_0 \mu_0}}$ has the basic determination by the length $L$.

How effective an antenna will receive the power of radio waves? The aperture in this research will be designated as the area, orientated perpendicular to the direction of an incoming radio wave (Z coordinates).

Due to exchange, an antenna’s gain in receiving and transmitting will be identical. The power output of the antenna in watts is equal to the power density of the radio waves in watts per square meter, multiplied by its aperture in square meters. The polarization of the incoming waves must match the polarization of the antenna, with an impedance match. 10, 20, 50, 100 randomly distributed in the cluster topology and distributed sparsely. This research model had studied the effect (Sinai, 2006) the following simulation was run for antenna reflected and transmitted power as would be experienced in a clear space for waves propagating in the z direction.

WSAACN sensor antenna design

An antenna radiation pattern was drawn up with the use of a dialectic constant for plastic at 3.4 the board being two mil at a frequency of 300 GHz the length of the antenna
Presentation and Discussion of Findings

In this research, a wireless network had been broken down to basic components, the sensors and the topology the responses of the sensors to different network constraints. Wireless sensors by design can be a challenge to adapt to a clustered indoor topology. In the process of this research it had been learned that a sensor network could deploy several different algorithms in the network. However, computational energy usage does become a prevalent issue.
Likewise, if a sensor begins its transmission with a higher energy rating, the residual energy may help in computational issues. The issues in this research that ended up receiving more attention than expected had been how the energy is used on the sensor during its transmissions and how the network topology efficiently utilizes the sensors.

Summary of Chapter four

As this research has examined the possibility of a deployment of an ad-hoc wireless sensor network in a sparse topological design, much of the information gathered includes the topological design constraints in a typical WSN. The leverage of several tools to benchmark a WSN topology has been used Atarraya and MatLab. The data gathered was extensive, from the sensor mobility parameters, energy variables, and sensor communication algorithms including a stochastic algorithm. By design of the topological control in a theoretical model, (covering two dimensions), this researcher has been able to control many attributes of the physical design and topology control. Still, within the statistical and graphical dissemination of data, a solid benchmark on a standard wireless network had been established.

As the research progressed, it was discovered that actually to address the antenna issue a radiation model had to be considered for the sensors energy usage. The final results had been comparatively examined and determination on the effectiveness of the network both in its design and sensor communication effectiveness.
CHAPTER FIVE

Within this chapter will be a review of the findings of the research and the recommendations of the future research in a home health care wireless sensor network.

Findings and Conclusions

Wireless sensor networks for home health care is gaining interest, hospitals are becoming overwhelmed by the additional people that now have health care in the United States. Our population is aging, and many who need care prefer to stay home as much as they can while being treated. This research purpose was to find a way to allow people to stay at home to heal and to give care givers 24/7 access to the patient’s vitals. The core of this delivery method is the sensor network topology and the sensors. This researcher began developing the concept of using a stochastic algorithm to assist on identifying the sensors in the network and their location in proximity to the base station. The initial thought by this researcher; was to be able to provide a low cost solution to home health monitoring that would be pervasive in nature, and requiring no interaction from the patients other than initially placing the sensors throughout their homes.

In order to ascertain the probability of success, a particle swarm optimization algorithm had been used, (which in this case was the LEACH optimization). This routing algorithm is the mechanism to which the sensors will communicate within a network. The deployment of the sensors relied on the use of Dijkstra’s shortest path algorithm to identify the sensors location and the closest neighbor to the base station. In this case it was number three sensor. Each sensor had been assumed to have its own Mac address
and number assignment. After running the algorithm on several different topologies’, the
shortest path had been found to the base station
(As determined by Knn). The k- nearest neighbor search on determining the location may
also be useful on determining moving object trajectories within a predetermined spatial
target.

This knn implementation was relatively straightforward to accomplish, however,
from observations the Dijkstra’s algorithm will have to be reimagined to perform the task
with fewer failed trials. By far the single most important issue facing the wireless sensors
is energy. The initial design idea was to have the sensors plugged in of course that idea
was soon put to rest since you could not guarantee enough outlets for the sensors, and
then you had shielding issues and rising cost to build and supply. (The sensors will still
need backup power, in the event of power failure).

In the energy simulations, the objective was to model the physical layer of the
sensors. As the failure vectors were examined in the simulations interesting changes
occurred. Many of the current wireless sensor kits require .05 joules to operate. The
delivery of the transmission packets has several requirements one of which is the channel
availability. CSMA/CA was covered in the example. Through the simulations, it had
been found that ten sensor responses at .05 joules experienced a rather steep sensor
failure.

While leveraging probability statements in the energy distribution model of 10
sensors, one single sensor in a 100 by 100 meter space delivered 1500 transmission
packets, while higher count sensors delivered less. It was during this finding that it
became necessary to determine the network response to the current energy and higher
joules energy. After five trials of thousands of transmission in the .05, joules range packet transmission failure was very quick. The next step was to run the same trials with a substantially higher joules, to which 1.5 joules was tested. Here again, the sensor failure at a higher transmission rate led to a full catastrophic failure of the sensor in the network. When two sensors had been simulated, at 1.5 joules, the failure did not happen until the transmission was in the tens of thousands. The conclusion drawn from this is that sensor simulation has provided insight as to what a higher energy distribution can produce. It results in a higher packet transmission with only two sensors. Using identical energy models one can extrapolate the power metrics in the network topology would share the same failure numbers, to visualize the sensor communication activity in a topology is to determine the threshold in the life of a network. The next step in determining the viability of a wireless sensor home health care model, was to determine antenna attenuation for the sensors to reduce signal collision and shadowing while controlling energy displacement from the transmission. The conclusion was to use an inverted “F” antenna and to determine the antenna radiation for the sensors. With a design in this research, it meets all the basic parameters for antenna design for an interior antenna. As the research was reviewed a successful deployment of a WSAACN consisted of one sensor one router to a room with an IFA based on a higher energy distribution model on the sensors. However in following this format the elimination of the use of Knn calculation would be overkill, to which Knn would have to be eliminated.
Limitations of the Study

During the search for simulators to perform the needed simulations, it was discovered that a limited amount of RFID simulators had been available. Most simulators required a hook up to the actual reader and tag. Because of this a full simulation was not possible. This study did not cover the patient BSN device and it's subsequent communication to the field sensors. This research main design was to determine the effectiveness of having optimization algorithms operate in a home wireless sensor network.

Implications of Study and Recommendations for Future Research

When a company or hospital is dealing with regulated data with a high availability need packet loss and or sensor failure is not an option. This small piece of research has shown that wireless sensors can be built to be pervasive in the home. The topology will require only two sensors remain before it is considered to be a catastrophic failure, a field sensor and a wireless sensor router for each room, and the base station will be needed. The direct correlation drawn here is more sensors deployed equals’ higher sensor failure and higher energy discharge on battery power alone. The research direction as of next should focus on the sensor design themselves to solve the power and catastrophic failure issues.

The possible future research introducing a constant power source to the sensors may very well reduce the catastrophic sensor failure. Possibly deploying the batteries as an emergency backup process may prove beneficial on deploying a pervasive home health monitoring network. In the future, I will try to improve battery discharge by
controlling the energy draw from the sensor by addressing this within the sensor through the operating system. Ideally sensor OS construction should be built with a Linux kernel and have a synchronous dynamic random access memory within the sensor. Additional research in stochastic algorithms may be used between the battery and the sensor module. The battery may help to control that discharge by addressing the charging and discharging of the energy from the battery an additional component to energy control is controlling the battery temperature; this could be significant for predicting the terminal state of the sensor. This study could be expanded to include the behavior of wireless sensor networks and the maximum range of the antennas. With a varied antenna orientation an increase in signal strength is possible the observation from this change is that the orientation of the antenna is a major component in the determination of the performance of a sensor network.

This research focused on a limited subset of antenna orientations with varying degrees ranging from 0 degrees to 180 degrees. This research paper considered mostly inside and not outside environments. A consideration for future research would be the differing types of antennas (e.g. Dipole, Omni…) and RFID chip design,

My original RFID sensor interaction design, leveraged the use of an RFID chip outside the medical device, instead design the RFID chip into the bio-medical sensor and in-vivo to the patient. The in-vivo bio-medical sensors can be implanted by the physicians to monitor the patient leveraging micro-miniature fiber optic sensors. Design the sensors to transmit to or monitor differing medical devices and medical parameters:
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*N/A

Figure 29 Sensor Parameters

Biomedical sensors present unique design challenges and particular problems related to their interface with humans. A properly designed sensor for implant must be safe, reliable, highly stable, biocompatible, responsive to device sterilization, will not be susceptible to implant rejection and not require continual calibration during use. The biomedical sensor must be small and as simplistic as possible in operations. This sensor should be designed for the network and patient needs specific to their ailments. For example, will it be inside the body or outside the body. Much of the current efforts in miniaturization of pressures and optical sensor can be provided by leveraging micro-fiber optic pressure sensors. Micro biomedical sensors can be built so that it can sense body temperature, or pressure on the lungs. Maybe even observational imagery. Keeping in
mind that sensors with fiber optics keeping can be transmitted to a biomedical receiver attached outside the body. This external transmitter can be the heavy lifter in the monitoring of the patient. This external transmitter can also leverage a VPN tunnel through the internet via cellular or Wi-Fi if available directly to the hospital, giving additional coverage of the patient outside the home making the health care monitoring life pervasive. This biomedical processing can be intricately connected to the sensor computer processing. However, ideally moving the transmitter and sensor combination inside the body could lead to a vast application in human and computer interface. Imagine a patient going home and the physician will be able to monitor all vital signs and visually see real time imagery of the heart or ocular input of the patient, all through fiber optic biomedical transmitting sensors. (E. udd, 1988)

Conclusion

The success of sensor networks outdoors has more to do with the amount of sensors in the field and where they are placed. In an African Savanah, for example, there is a greater line of site then there is within a home or even a treed forest. Collision problems are reduced with line of site and increased amount of sensors deployed allow for a larger amount of sensor failure. (I.e.at a 1000 sensors). However, this researcher
believes the solution to an efficient wireless sensor network lies in the antenna design and the computational design of a sensor. With the correct antenna design a sensor could deliver the patient data to the base station. Even with a LOS issue, increasing the computational power and controlling the battery discharge will increase the efficiency of and availability of the data to the medical professionals. Designing an efficient biomedical body sensing body area network will expand medical monitoring.

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