DENSITY ADAPTIVE

MONITORING WIRELESS SENSOR NETWORKS IN CANCER MONITORING AMONG ELDERLY PATIENTS

BY

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DECLARATION

I declare that this research Project is my original work and has not been previously published or submitted elsewhere for award a degree. I also declare that this Research project contains no material written or published by other people except where due reference is made and author duly acknowledged

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ABSTRACT

In this research I propose system architecture for wireless smart healthcare based on an advanced Wireless Body sensor Networks. It also aims assisted-living residents and others who may benefit from continuous, remote health monitoring. An experimental living space has been constructed at the Department of Computer Science at

University of Virginia (UVA) for evaluation. Early research suggest strong potential for Wireless Sensor Nodes to open new research perspectives for low-cost, ad hoc deployment of multimodal wireless sensors networks for an improved quality of Health care. However the simple continuous sending of data mechanism causes lots of duplicated packets and consumes a lot of power and its resources. In view of these challenges, the transmission network nodes should reduce repeated sending of data such that power conservation is obtained since the devices within a wireless sensor network have limited battery power. In order for wireless body area networks to ensure widespread use and adoption, some of the design constraints should be solved to promote uptake and meet social expectations. Since it is not necessary for each wireless sensor node to be active all the time a more sophisticated method might be introduced to flood an entire network and the other side is more efficient. In this work, an asynchronous sleep scheduling is proposed by an adapted duty cycle for each wireless sensor where the duty cycle is based on the RSS based density estimation for each wireless sensor node. Broadcasting by flooding is one of the most fundamental services for both wired and wireless networks. This also includes several wireless sensor network applications that use broad-casting to spread information from one wireless sensor node to the other wireless sensor nodes in the entire wireless sensor network. These wireless sensor networks have certain characteristics such as limited power and battery driven. By using the proposed duty cycle the reachability is compared with that of the fixed duty cycle and the adapted duty cycle by using neighborhood discovery density estimation model.

Wireless body area networks (WBANs) give plenty of application opportunities in the area of medical care. In the past previous developments in wireless sensors and radio communication, advanced technologies have motivated many researchers to design Wireless Body Area Network systems for application in the elderly medical and health provision and monitoring. Energy consumption is still a limiting factor in realizing a Wireless Body Area Network with a very long lifetime.

As a result, design of energy efficient Wireless Body Area Networks is required to enhance battery life at the same time ensure that wireless sensor nodes are small enough to be conveniently worn or implanted in the body. Power consumption in Wireless Body Area Networks happens during sensing, processing and communication.

Key Words: Wireless Body Area Network (WBAN), Energy efficiency, Wireless sensor, MATLAB, Relay.

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DEDICATION

To my family Doreen, Anthony, Oliver and Eric. You are my Inspiration.

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LIST OF ACRONYMS

WBAN	Wireless Body Area Networks
MAC	Media Access Control
SNR	Signal to Noise Ratio
BER	Bit Error Rate
OQPSK	Offset Quadrature Phase Shift Keying
AWGN	Additive White Gaussian Noise
QOS	Quality of Service
MICS	Medical Implant Communication System
UWB	Ultra Wide Band
ISM	Industrial Scientific and Medical
FFD	Fully Function Device
RFD	Reduced Function Device
FFD	Fast Fourier Transform
LOS	Line of Sight
NLOS	Non Line of Sight
MATLAB	Matrix Laboratory
WSN	Wireless sensor Network
WBSN	Wireless Body Wireless sensor Network
BASN	Body Area Wireless sensor Networks

CHAPTER 1: INTRODUCTION

A wireless sensor network (WSN) consists of a large number of tiny and inexpensive devices, mostly wireless sensors, which send their data wireless within a network. In general the tasks that these devices perform are the following: on board data processing, communication between wireless sensors, sensing capabilities and actuation explicabilities. These devices share data obtained from measurements taken by the device or to redirect their data to a central collection point. The advantage of this wireless network in health monitoring is that the communication between the devices is performed wireless and there is no need for any additional network infrastructure. Hence these kinds of networks are very easy and flexible which makes them portable and easy to use in health monitoring environments. (Otto, Aleksandar, Sanders, & Jovanov, 2005)

A wearable Body Wireless sensor system for continuous medical monitoring is a key concept in helping the transition to more proactive and affordable healthcare. They allow an individual to keenly monitor changes in his or her vital signs and provide feedback to help maintain an optimal health status. If integrated into a telemedical system, these wireless systems can even alert medical personnel when life-threatening changes occur. In addition, the wearable wireless systems can be used for health monitoring of patients in critical settings. For example, they can be used as part of a diagnostic procedure, a supervised recovery from an acute event or surgical procedure, to monitor adherence to treatment guidelines (e.g., regular cardiovascular exercise), or to monitor effects of drug therapy. (IEEE, 2013)

There has been an increase in the number and variety of wireless wearable health monitoring devices, ranging from simple wireless pulse monitors, wireless activity monitors, and portable Holter monitors, to sophisticated and expensive implantable wireless sensors. However, wider acceptance of the existing systems is still limited by the number of important restrictions. Traditionally, personal medical monitoring systems, such as Holter monitors, have been used only to collect data. Data processing and analysis are performed offline, making such devices impractical for continual monitoring and early detection and prevention of medical disorders. Systems with multiple wireless sensors for physical rehabilitation often feature unwieldy wires between the wireless sensors and the monitoring system. These wires limit the patient's activity, navigability and level of comfort and thus negatively influence the measured results. In addition, individual wireless sensors often operate as stand-alone systems and usually do not offer flexibility and integration with third-party devices.

One of the approaches in building wearable health monitoring systems utilizes emerging wireless body area networks (WBAN). A Wireless Body Area Network consists of multiple wireless sensor nodes, each capable of sampling, processing, and communicating one or more vital signs (heart rate, blood pressure, oxygen saturation, activity) or environmental parameters (location, temperature, humidity, light). The wireless sensors are placed strategically on the human body as tiny patches or hidden in users' clothes allowing ubiquitous health monitoring in their native environment for extended periods of time. (Reusens, 2009)

1.1 BACKGROUND

Embedded electronic network systems are widespread and many in nature; from alarm clocks to Personal Digital Assistants, from mobile phones to cars, nearly all the wireless gadgets we use on a daily basis are controlled by wireless embedded or internal electronics. In relation with the recent advances in technology more of the wireless microprocessors produced today are used in such embedded systems, and recently the number of embedded systems in use has developed and increased. The concept of ambient wireless device intelligence reflects the vision that wireless technology will not only develop but be embedded, invisible, and fully hidden in our natural surroundings, but present whenever we require it, enabled by simple and easy interactions. Ambient intelligence has been defined by the Advisory Group to the EU Information Society Technology Program (ISTAG, 2000) as "the convergence of three major key technologies: ubiquitous computing, ubiquitous communication, and interfaces adapting to the user". In the near future wireless computing and communication will attract more interest and research. Wireless body wireless sensor networks are usually considered one of the technological foundations of ambient intelligence. Agility, low-costing, ultra-low power networks of wireless sensors collects a huge amount of important information from the surrounding environment. Using a biological analogy, Body wireless sensor networks can be viewed as the wireless sensory system of the intelligent environment of the human body. Body Wireless sensor Networks are irregular clusters of communicating wireless sensor nodes, which collect and process information from onboard wireless sensors, and they can share some of this information with neighboring or surrounding nodes or even with nearby data collection stations. (Darwish & Aboul, 2011)

Current Wireless Body wireless sensor network applications in ambient intelligence range from the monitoring a deficiency, monitoring diseases, environmental monitoring of ecosystems and industrial processes for tracking assets and people, etc. In addition, each application, they also have different requirements and restrictions based on the nature of the problem. In this review, I will focus on one specific driver application, namely monitoring of humans based on wearable wireless sensors and human body implantable wireless Body wireless sensors to expand the role of such technologies in medical healthcare and to overcome new challenges from Nature on human health. There are several reasons for this choice. First, human monitoring is an extremely important field and important for all of us. Second, the scope of human monitoring application poses new challenges such as requisites for unobtrusiveness, security and low energy consumption, etc. Finally, this is one of the ambient intelligence application fields where research and development are the most active areas.

(Aceros & Nurmikko, April 2013) According to Grace Peng, Ph.D., who oversees the Rehabilitation Engineering Program of the National Institute of Biomedical Imaging and Bioengineering (NIBIB), part of NIH, For people who have sustained paralysis or limb amputation, rehabilitation can be slow and frustrating because they have to learn a new way of doing things that the rest of us do without actively thinking about it, Brain-computer interfaces harness existing brain circuitry, which may offer a more intuitive rehab experience, and extremely and ultimately, a better quality of life for people who have already faced serious challenges. Recent advances in brain-computer interfaces (BCI) have shown that it is possible for a person to control brain tumors and cancer by detecting them earlier and also taking action against preventing further growth of tumors or further spread of cancer. However, such devices have relied on wired connections and wired wireless sensors, which pose infection risks and restrict movement, or were wireless but had very limited computing power. Building on this line of research, David Borton, Ph.D., and Ming Yin, Ph.D., of Brown University, Providence, R.I., and colleagues surmounted several major barriers in developing their wireless sensor. To be fully implantable within the brain, the device needed to be very small and completely sealed off to protect the delicate machinery inside the device and the even more delicate tissue surrounding it. At the same time, it had to be powerful enough to convert the brain's subtle electrical activity into digital signals that could be used by a computer, and then boost those signals to a level that could be detected by a wireless receiver located some distance outside the body. (Aceros & Nurmikko, April 2013)

Like all cordless machines, the device had to be power enabled hence rechargeable, but in the case of an implanted brain wireless sensor, recharging must also be done wirelessly. The researchers consulted with brain surgeons on the shape and size of the wireless sensor, which they built out of titanium, commonly used in joint replacements and other medical implants. They fitted the device with a window made of sapphire, which electromagnetic signals pass through more easily than other materials, to assist with wireless transmission and inductive charging, a method of recharging also used in electronic toothbrushes. Inside, the device was densely packed with the electronics specifically designed to function on low power to reduce the amount of heat generated by the device and to extend the time it could work on battery power. Testing the device in animal models -- two pigs and two rhesus macaques -- the researchers received and record data from the implanted wireless sensors in real time over a broadband wireless connection. The wireless sensors could transmit signals more than three feet and have continued to perform for over a year with little degradation in quality or performance. The ability to remotely record brain activity data as an animal interacts naturally with its environment will help inform studies on muscle control and the movement-related brain circuits, the researchers say. While testing of the current devices continues, the researchers plan to refine the wireless sensor for better heat management and data transmission, with use in human medical care as the goal. According to Borton, Clinical applications will include thought-controlled prostheses for severely neurologically impaired patients, wireless access to motorized wheelchairs or other assistive technologies, and diagnostic monitoring such as in epilepsy, brain tumors, and cancer monitoring where patients currently are tethered to the bedside during assessment. (Aceros & Nurmikko, April 2013)

The design, implementation, and deployment of Wireless Body Sensor Networks requires contribution from the fields such as medicine, engineering, and computing, as mentioned earlier in the research, to consideration of the numerous application-specific challenges. In the last five years, significant progress has been made in the development of Wireless Body Sensor Networks, and some WBSN-based commercial products have already appeared on the market.

A wireless sensor network consists of a big number of wireless sensor nodes, which are installed either inside the subject of study to be monitored or very close to it. Wireless sensor networks represent a significant improvement over traditional wireless sensor networks, which are deployed in the following two ways: (ISTAG, 2000)

(i) Wireless sensors situated far from the actual subject of study to be monitored. With this perspective, large wireless sensors that use some of these methods to distinguish the targets from environmental noise of study are required.

(ii) Wireless sensors that perform detecting are deployed. The locations of the wireless sensors and communications network topology are steadily designed. They transmit the data about the subject of study to central nodes where computations are performed and data are fused.

The unique feature of wireless sensors are that the cooperative effort of wireless sensor nodes. Wireless sensor Networks are equipped with an on-board data processor. Instead of transmitting information to other nodes responsible for the infusion, wireless sensor nodes process to locally perform simple computations and transmit only the needed and partially processed data. (Darwish & Aboul, 2011)

1.1.2 CHALLENGES IN CANCER MONITORING

The challenges involved in cancer monitoring includes the below:

i. Identifying the optimal imaging modality for surveillance imaging remains a significant challenge in cancer monitoring.

ii. Imaging surveillance identifies appropriately the algorithm and modality for surveillance in the post-mastectomy population. There are no definitive guidelines for surveillance in patients treated by mastectomy with or without reconstruction.

iii. To determine accurately and repeatable means for evaluating response to therapy remains a challenge. An objective assessment of responsiveness of the primary tumor and any metastatic lesions is necessary to measure the therapeutic effect.

iv. The most primary challenge in the neoadjuvant setting also where it includes the accurate assessment of early response to therapy and discovering a non-invasive means of accurate predicting pathologic complete responsiveness to therapy. Both of the areas are still under active investigation and will be discussed in the accompanying manuscript addressing future directions.

v. With the goal of therapy focusing on improving quality of life and overall survival, the challenge has been to find a test that is concentrating on the very safety, non-invasiveness and reliability to assess response from cancer patients.

vi. Improvement of early detection and more importantly, how to translate early detection of cancer into increased survival.

vii. When determining which cancer patients are at a higher risk of relapse, it may aid in this challenge. In order to help identify high risk cancer patients there has been a national shift towards treating more women prone to cancer with neo-adjuvant therapy. With the use of new microarray and DNA based cancer assays, the ability to obtain tissue to assess for cancer predictive and prognostic markers before and after neo-adjuvant therapy may help us determine which woman may benefit from enhanced cancer surveillance.

viii. The fight against metastatic disease is to provide safe, inexpensive and accurate tumor markers assessment for our tested cancer patients. Only through well-designed and standardized clinical trials will we be able to move the field forward.

1.2 PROBLEM STATEMENT

1) Limitation of amount of energy in Wireless sensor Nodes

2) Lack of sleep scheduling time during idle time in Wireless sensor Nodes

3) Lack of clock synchronization in Wireless sensor Nodes

The Wireless sensor nodes in a Wireless Sensor Node have a very limited amount of energy and if all the wireless sensor nodes are active all the time the whole network may collapse in a short time. This is due to the high power sustainability consumption of the wireless sensor nodes. However it is not necessary for all the wireless sensor nodes to be active all the time, they only need to become active when there is a need to transmit data or receive data. Therefore, sleep scheduling can prolong the lifetime of a Wireless sensor Network significantly because this would conserve energy. Wireless sensor Network Sleep scheduling works by activation of wireless sensor nodes when there is a need to transmit or receive data the remainder of the time the wireless sensor node sleeps. Wireless Sleep scheduling belongs to the category of power management protocols which is one of the main energy conservation techniques used for Wireless Body Wireless sensor Nodes.

One of the most used sleep scheduling patterns is the scheduled rendezvous protocol which belongs to the category of synchronous wireless pattern protocols. The main advantage of this protocol is that when a wireless sensor node is awake it is guaranteed that all its neighboring wireless sensor nodes are awake well. In this way the scheduled rendezvous protocol will allow to wireless broadcast transmission of messages very anciently to all the neighboring wireless sensor nodes. The disadvantage of this protocol is that it is a synchronized wireless protocol which requires that all the wireless sensor nodes need to have their internal clocks synchronized; this requires an extra exchange of additional information. The synchronization of the internal clock of the wireless sensor nodes causes more communication overhead and more energy consumption.

To avoid the problems described above for synchronous protocols an asynchronous protocol on the wireless sensor nodes can be used. One of the advantages of an asynchronous protocol is that a wireless sensor node can wake up whenever it wants to communicate with its neighbors. In contrast with the scheduled wireless sensor rendezvous protocol, it is not possible to broadcast a message to all neighbors, though each wireless sensor node is able to contact any of its neighboring wireless sensor nodes in a finite amount of time. In an asynchronous protocol it is improbable that all neighboring nodes are simultaneously active unlike in the scheduled rendezvous protocol, so wireless sensor nodes need to wake up more frequently in order to reach their respective neighbors.

Asynchronous sleep scheduling is more suitable for a Wireless sensor Network since it requires no knowledge of the network, it can be done locally without any additional communication overhead and it makes wireless sensor nodes wake up independently and wirelessly. But the most important benefit is that it solves the clock synchronization problem, there is a lot research ongoing about asynchronous protocols. In this dissertation an analysis is made for asynchronous protocols for Wireless sensor Networks and an analysis is made under which circumstances the reachability is maximized. Always before a source node wants to transmit a packet, a preamble of a certain length is sent. Only when the preamble time overlaps with the active period of a wireless sensor node the source node shall start transmitting the packet. Several factors may influence on how many neighbors are reached in this case such as what is the best ratio between active times of wireless sensor compared to the time of one period, this is also known as the duty cycle, the node density within a Wireless sensor Network, the maximum transmission range and the preamble length. These factors should all be observed in order to obtain maximum energy conversation in combination with a maximum network coverage which is the desired situation for a Wireless sensor Network. This depends on the size of the area where the wireless sensors deployed and the wireless sensor density within an area however the characteristics of the area in which the wireless sensor nodes are deployed is not easy to change. The goal in this report is to adapt the duty cycle based on the node density and a given preamble length so that maximum reachability is attained during transmission or relay of messages. In this way a simple and asynchronous sleep scheduling is implemented for a Wireless sensor Network. Wireless Body Area Network is a wireless network which enables communication among wireless sensor nodes operating on the body surface or inside the human body.

Wireless Body Area Network is a wireless network which enables communication among wireless sensor nodes operating on the body surface or inside the human body to collect information on various body parameters and even motions. In the deployment of Wireless Body Area Networks, communication between the wireless sensor devices is of the critical design consideration. Communication between wireless sensor nodes needs to consume minimal power and offer high reliability. In the recent past, a lot of the research in the area of Wireless Body Area Networks has been directed to areas like wireless sensor circuitry, minute wireless sensor design, processing of signals by the wireless sensors protocols in Wireless Body Area Network implantation and other related issues, (Min Chen. et al, 2010).

Star topology is associated with high power consumption in relaying data over long range single-hop point-to-point links. The issue of on-body wireless sensor movement, wireless connection links which are unreliable and changing from time to time and the importance of reliability and fast data signal transmission at minimal energy use are some challenges facing deployment of Wireless Body Area Networks (Wount J et al, 2011).

Recent developments in reduced power wireless transmission, communication and signal processing have triggered enormous attention in the deployment and design of wireless technology in healthcare and biomedical research, as well as Wireless Body Area Networks. Among the issues of utmost importance in Wireless Body Area Networks is low power consumed by the circuitry of the wireless sensor, signal processing and transmission of the data. The wireless sensor nodes implanted in and worn on the body have small battery capacity or can get little energy from their surroundings. Thus to prolong the life of the network, mechanisms to conserve energy has to be adopted. As such efforts towards the design of wireless sensors which used less power is alive among many researchers. Protocol design and network set up can be optimized to reduce energy used.

The use of wireless transceiver which consumes less and low power to minimize the amount energy required normally will lead to a small coverage area in signal transmission. This implies that a multi-hop topology is one of the best design choices for implementing Wireless Body Area Networks, (Majid & Ee., 2010)

A lot of research has been conducted towards developing power efficient Wireless Body Area Networks. The focus has been on protocol design, energy efficient bit-map-assisted (BMA) MAC schemes used of wake up radio concept where the wireless sensor goes to sleep when it is not communicating and wake up only when it has data to send (al, 2012).

(Wout J et al, 2012) The investigation of energy consumption in star and multi-hop topologies and find that multi-hop topology is associated with lower power consumption but the wireless sensors closer to the coordinator use a lot of energy to transmit signal from wireless sensor nodes further away.

This research proposes a multi-hop topology model which uses a relay between the coordinator and distant wireless sensor nodes. The relay is dedicated to transmit signals from distant nodes only while wireless sensors closer to coordinator transmit directly to the coordinator.

1.3 Objectives

1.3.1 Main Objective

The main objective of this research is to develop a wireless energy efficient model for deploying Wireless Body Area Networks using multi-hop network topology.

1.3.2 Specific Objectives

The specific objectives of this research are:

i. Identify factors affecting energy consumption in Wireless Body Area Networks

ii. Design an energy efficient model for deploying Wireless Body Area Networks using multi- hop network topology

iii. Test and validate the model.

1.4 Justification of Study

The World Health Organization (WHO) observes that caring for the elderly people is becoming a significant challenge, at the same time a sizeable group of people suffer from lifestyle related diseases such as obesity and other chronic diseases because of their inactive and non interactive lifestyles in their day to day life. This situation continues to worsen the declining quality of services offered by the near overwhelmed health care systems, (Min Chen. et al 2010). Wireless Body Area Networks will play a very big role in monitoring the elderly, the environments they stay in and other parameters of interest. The information collected is used to trigger an action like insulin injection for diabetic people or transmitted to the relevant people who are responsible for monitoring them.

To enhance Wireless Body Area Networks adoption the wireless devices are supposed to be small enough as not to interfere with the wearer. This research will compliment other efforts towards reducing power consumption in Wireless Body Area Networks considering that energy efficiency is one of the main challenges in deploying Wireless Body Area Networks. In Wireless Body Area Network technology, researches have been carried out and various models proposed which seeks to reduce power consumption.

Several design issues are considered in Wireless Body Area Network deployment including wireless scheduling, wireless topology control, node placement in relation to other devices, and node localization. The other critical areas of concern are; energy consumption during signal relay and sensing, network duration for transmission, and the distance the signal can cover. These issues are important because it is quite cumbersome to keep changing batteries on thousands of micro wireless sensors after they are deployed and they consume all the power. These are the main critical issues attracting much research work by various researchers and enthusiasts alike. (Navid, 2011).

(Reusens, 2009) In this book by Reusens about Wireless Body area networks published in 2009, it underscores the importance of energy efficient topologies in

Wireless Body Area Network. They observe that radios used in the design and deployment of Wireless Body Area Networks are miniaturized thus does not allow use of large batteries which could otherwise prolong the network duration.

(Emil Jovanov & Aleksandar Milenkovic, 2011), identifies very low power operation, wireless sensor integration, system integration and user localization and identification as four technical issues which influence the uptake of ubiquitous health monitoring applications. Low power operation allows design of smaller batteries for power storage, which enhance wear-ability and ease of use eliminating the need for frequent battery changes/recharging.

1.5 Significance of the study

It is possible that in a Wireless Sensor Node the energy consumption of wireless sensor nodes may vary unevenly. It was shown in about 30% of the wireless sensor nodes consume 95% of their battery power while about 60% of wireless sensor nodes only consume 10%-20% of their battery power. Therefore, it is necessary to make adaptations to the network protocols in order to adapt to the density. Because the density can influence the performance of a Wireless Sensor Node it is of interest how to estimate this density. There are deferent approaches that have been studied using density control techniques for Wireless Sensor Nodes and also for ad hoc networks.

The use of density control techniques means that wireless nodes in the network are scheduled to sleep and wake up in order to save energy and where the density of the wireless network is used to select the time between a sleep and an awake period. In a sparse wireless network the active period needs to be longer in order to achieve the same reach-ability and for a dense network the active periods can be shorter for the same reach-ability.

Previous work done using density control techniques is proposed where an optimized routing protocol for the nodes is introduced. The optimized routing protocol combines an energy efficient wireless routing algorithm with the shortest distance routing algorithm to reduce the energy consumption and to optimize the distance between source and destination. An adaptive control of duty cycle mechanism by using the node density is proposed. This approach allows a wireless sensor node to operate at a lower duty cycle, by leveraging the presence of its neighbors. This mechanism shows that the adaptive duty cycle based on density can reduce the energy consumption and extend the net-work lifetime. In a network with a higher wireless sensor node density the network lifetime is longer when an adaptive duty cycle based on the wireless sensor density is enabled. When these measured densities are not implemented the network lifetime cannot be extended by increasing the node density. (Qutaiba, September 9, 2012)

A wireless routing mechanism is proposed by taking into account the wireless node density to select a power conservation route and keeping energy consumed evenly among the Wireless Sensor Nodes in order to extend the network lifetime. The wireless sensor nodes are unevenly distributed, namely one part of the Wireless Sensor Node has a high wireless sensor node density area and the other part has a low wireless sensor node density area. In a cluster allocation algorithm is proposed based on the node density to preserve a high coverage ratio to prolong the network lifetime. It assumes that the Wireless Sensor Node stops its operation if the coverage ratio goes below 80%, and the number of rounds in is defined as the lifetime of the Wireless Sensor Node. Then in the wireless node density near the base station was increased without increasing the total number of wireless sensor nodes, since the wireless sensor nodes close to the base station consume more energy. It also finds a better density proportion for usage in the deployment stage to extend the Wireless Sensor Node lifetime. These above mentioned papers show certain ways so that the wireless sensor nodes consume their energy evenly and more efficiently by combining with the density control of the wireless network. In summary, by using density control techniques the energy consumption can be reduced and the network lifetime can be extended. For a Wireless Sensor Node with a local high wireless sensor node density the duty cycle can be lowered for wireless sensor nodes in that specific area. Since all the wireless sensor nodes do not need be active for all time, only certain wireless sensor nodes need to be active for a given period of time based on the proposed wireless protocol. Hence there is larger chance to reach at least a few neighboring wireless sensor nodes for the same duty cycle. By using sleep scheduling in combination with density control the network traffic can be reduced, and the routing job can also be facilitated. Thus adaptive sleep scheduling based on the network density increases the lifetime of Wireless Sensor Nodes.

As described in the previous section, an asynchronous protocol is simple to implement and that is why density adaptive sleep scheduling with asynchronous wireless protocol is implemented in this work.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

More implementations of Wireless Body Area Networks used for body wireless sensor communication have recently been reported in the study. Some of the researches focus mainly on on-body MAC layer issues. The Sensor network implemented uses a slotted multi-point-to-point mechanism in which the data from many on-body wireless sensors are sent to a central node in a collision free environment for further analysis. The sending slots are synchronized using beacon signals periodically sent out by a pre-designated wireless node. The mechanisms reported in involve the use of an on-body adaptation of the standard IEEE 802.15.4/ZigBee based MAC (IEEE, 2013). The work reported in investigated on-body of the subject of study wireless MAC-routing cross-layer issues via wireless distributed transmission coordination in the presence of the routing structures. The owner also presented an energy-efficient slotted MAC in the presence of a Wireless Autonomous Spanning tree Protocol (WASP) that is used for on-body packet routing of the subject of study.

This research aims to investigate the energy efficiency in multi-hop wireless body area networks. Some research has been carried out in Wireless Body Area Network architecture and energy consumption both in star and multi-hop topologies.

Wireless Body Area Network connects independent nodes (e.g., wireless sensors and actuators) that are deployed around the body like in the clothes worn by persons, placed on the skin or deployed a few millimeters below the skin. The network typically covers a few centimeters around the body and the network nodes are connected through a wireless communication link. The deployment normally is implemented using multi-hop or a star, (Wout J. etal 2011). Wireless Body Area Network has attracted applications in various such as electronics for consumer applications and other wireless network innovations which enhances ubiquitous healthcare. The general wireless network topology used in wireless body area networks is the star topology with wireless sensor nodes relaying data to a central processing node for data fusion. Generally, multi-hop communication is used in regular senor wireless sensor networks with network connection being guarantee by use of router between the nodes. Implementations of involve signals being transmitted in one hop to the network coordinator/sink, (Min Chen. et al, 2010)

Some issues have been highlighted as regards Wireless Body Area Network design and deployment. Among the critical considerations are issues like scheduling, topology control, node placement in relation to other network devices, and node localization. Other important concern which has attracted much interest from researchers includes energy consumption of the network devices, lifetime of the nodes and the entire network, and range of signal strength. All these issues are considered as the most critical since replace batteries on thousands of micro wireless sensors could be impossible after these networks are deployed. Much work has been done to try and address these issues, many works exist that take these issues into account in designing communication protocols used deployment of Wireless Body Area Network, media access control (MAC) protocols and physical layer, (Meenakshi Bansal and Navroop Kaur 2011).

The deployment and adoption of Wireless Body Area Network depends on how the design constraints are addressed. Some of the issues are highlighted by (Min Chen. et al 2010);

“Several design issues must be addressed in order to enable the deployment and adoption of Wireless Body Area Networks. At the hardware level, body wireless sensors must be small l, thin, non-invasive, wireless-enabled, and must be able to operate at a low power level. From the communications perspective, it is imperative to design appropriate medium access control (MAC) protocols to ensure higher network capacity, energy efficiency, and adequate quality of service (QOS). At the application level, innovative architectures should be implemented for the corresponding applications”.

Energy consumption is a very key parameter in deployment of Wireless Body Area Networks, it is therefore imperative that energy demands of Wireless Body Area Networks should be as small as possible. Wireless Body Area Network consumes energy during sensing, communication and data processing. A lot of energy is consumed during communication of between the wireless nodes. In the last few years a few researchers have been looking at various techniques for realizing energy efficient design and assembly. Some ways have been proposed to minimize power consumption in wireless nodes including addressing architecture challenges, assembling, operating system schemes and efficient integrated circuit designs. (Robert, 2013)

The wireless protocol resembles a tree-based cross-layer approach, but is constructed for reducing packet delivery delays over an on-body distance. This wireless sensor node works on body navigability by absorbing and steady maintan the spanning tree used for packet routing.

From the on-body routing standpoint, most of the existing Wireless Body Area Networks systems adopt star topology on a connected graph; meaning a physically connected end-to-end path between any pair of on-body wireless sensors is assumed at any given point in time. However, these wireless models do not apply for the targeted

Direct Transmission Node/network routing paradigm in this research, which handles topology partitioning leading to scenarios in which end-to-end physical connectivity between node pairs may not be present at times. Such partitioning is mainly due to the ultra short range Radio Frequency transceivers used.

The knowledge based strategies are typically for single copy forwarding and they make use of information about connectivity dynamics to make efficient forwarding decisions. The hybrid approaches combine replication and knowledge based strategies. The general principle behind these approaches is as follows: when a node with a packet to be forwarded encounters another node, the forwarding rule should determine if the packet (or a copy of the packet) should be transferred to that node or it should continue to be buffered. The rule is based on the estimate whether the encountered node is more likely than the forwarding node to visit the destination.

The above mechanisms are all applied to networks spanning across local to wide areas, with a few extending all the way up to the inter-planetary scale. The objective of the work described is to apply the key DTN routing concepts, as identified above, in an ultra short-range body area environment. The challenge is to develop mechanisms for capturing the locality of on-body node movements caused by human postural mobility.

Wireless Body Area Networks provide efficient communication solutions to ubiquitous healthcare systems. Health monitoring, telemedicine, military, interactive entertainment, and portable audio/video systems are some of the applications where Wireless Body Area Networks can be used. (Darwish & Aboul, 2011) have presented a comprehensive work on the applications of Wireless Body Area Networks in smart healthcare applications, including epileptic seizure warning, glucose monitoring, and cancer detection. In this paper, I am highlighting a number of projects that enable Wireless Body Area Networks to provide unobtrusive long-term healthcare monitoring with real-time updates to a health center. Mark et al presented BASNs as systems enabling human-centric sensing for a variety of intriguing applications in healthcare, fitness, and entertainment, but such networks must demonstrate enough value for users to overcome inhibitions related to inconvenience, invasiveness, and general discomfort. Authors described wearable technologies that will “silently monitor” heart rhythm, detect irregularities, and alert emergency personnel in the event of a heart attack. This vision, not far removed from current research efforts, illustrates the promise of Wireless Body Area Networks in this important area.

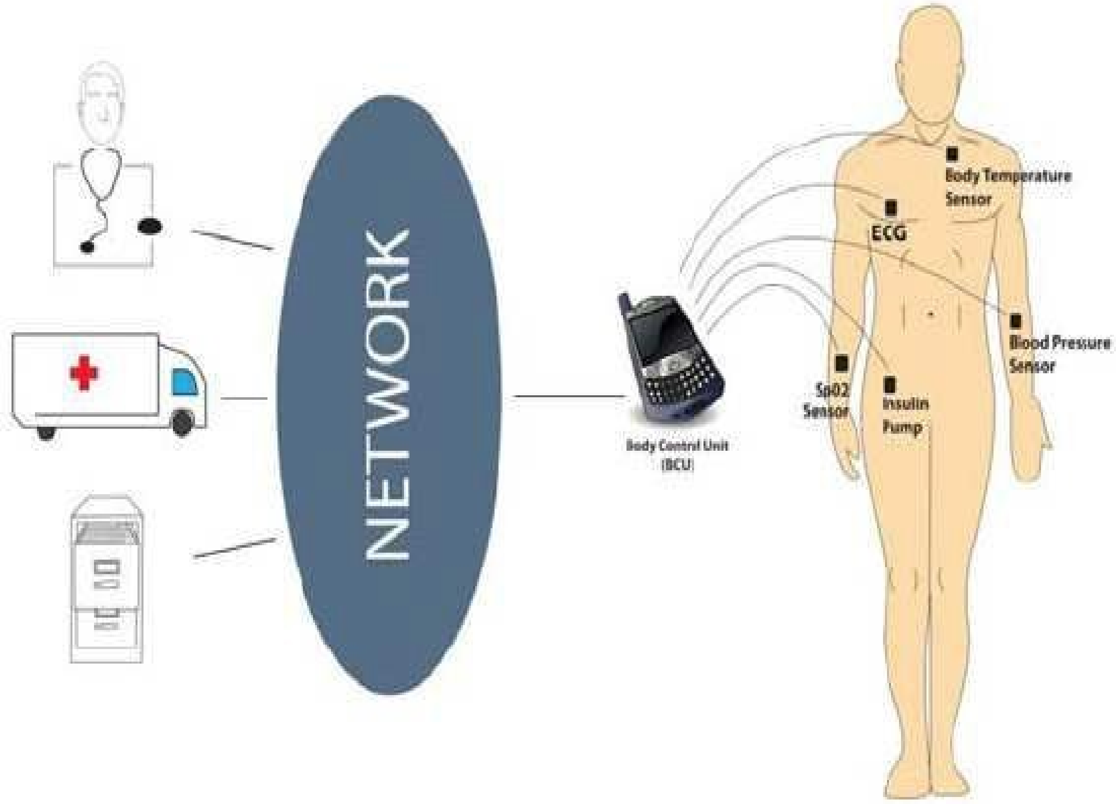
2.1.1 Wireless sensors

A wireless sensor is a device that used to measure a physical quantity and convert it into an electronic signal which can be observed by an observer or measured by an instrument. It is also a device that produces a measurable response to a change in some physical condition such as temperature or to a chemical condition such as concentration. A possible application for wireless sensors is to use them in wireless networks where the wireless sensors sense, processes this data and communicate the measured values to one another. Wireless sensor networks may consists of different types of wireless sensors such as seismic, thermal, visual, infrared, acoustic and radar. It is also possible that wireless sensors transmit their measured values wirelessly to one or several sinks. Unfortunately a wireless sensor is limited in power, computational capacities and memory. This is because wireless sensor nodes in wireless networks are wireless and henceforth rely on battery power. The current situation is that wireless sensor nodes in wireless networks carry limited amount of battery power. The current technology for batteries has not yet reached the stage that wireless sensor nodes can operate for a long time without recharging or energy harvesting. Hence one of the most important limitations of wireless sensor nodes is power consumption. When a wireless sensor node has drained out of its battery, it directly affects network usefulness because it may break the entire network.

Wireless Body Area Network Architecture

Figure : Wireless Body Area Network

Architecture

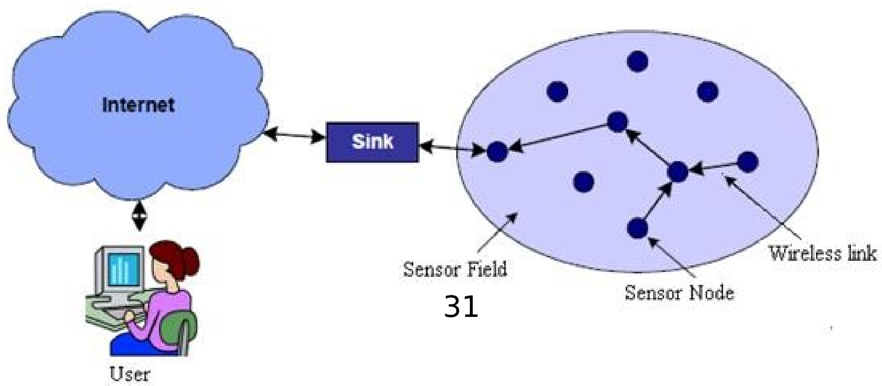


Source: ((Laurie, 2012)

2.1.2 Wireless sensor Networks

Wireless sensor networks consist of a large number of small, battery-powered, inexpensive and wireless sensors which send their data wirelessly. More specifically, a Wireless Sensor Node consists of spatially distributed autonomous wireless sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. Typically, data packets are generated by each node and are sent to a Base Station (BS) or a sink.

Figure : Basic Architecture of a wireless sensor Network (Fengju, 2013)



Here the data is aggregated and forwarded to the user. In Figure 2-1 it shows the basic architecture of a Wireless Sensor Node using wireless sensors to monitor the physical conditions. From the above a Wireless Sensor Node has peculiarities such as limited processing power, limited memory, low power, low rate, limited range radio and battery driven.

2.1.3 Applications

Wireless Sensor Nodes are widely used in various kinds of applications, such as Health monitoring applications, health applications, and environmental applications. For example, in military applications Wireless Sensor Nodes can be an integral part of military command, control, communications, computing, intelligence, surveillance, reconnaissance and targeting systems, can be used for target detection, to monitor forces and equipment, to detect nuclear, biological or chemical attacks and for the surveillance of battlefields. Another example is using Wireless Sensor Node for health applications, which are providing interfaces for the disabled, integrated patient monitoring, diagnostics and hospital drugs administration. Wireless Sensor Node are also used in environmental monitoring where Wireless Sensor Node can be used for tracking the movements of the small animals, detecting forest fires, flood detection and environmental monitoring in marine and soil environments. One of the applications is the use of Wireless Sensor Node in homes such as home automation. In recent years Wireless Sensor Nodes are widely used in more fields such as wireless factory, smart (intelligent) buildings and implantable medical wireless sensors which are used for medical applications. (Fengju, 2013)

2.1.4 Issues

An important limitation for Wireless Sensor Nodes is that wireless sensor nodes carry a limited amount of batteries and hence have a limited amount of energy. In a Wireless Sensor Node it is possible that the wireless sensor nodes are deployed in large numbers over a wide area and it can be difficult to replace or recharge the batteries of all the wireless sensors. A wireless sensor node may be impossible to reach physically, for example in environmental monitoring where wireless sensor nodes are attached to animals or lowered on the ocean floor, or it is economically too expensive, the operation of changing the battery may cost more than the entire wireless sensor node. Therefore the lifetime of a Wireless Sensor Node is dependent on the battery power of the wireless sensor nodes. If a certain percentage of the wireless sensor nodes in a

Wireless Sensor Node die because they have no more power the whole network may collapse. However, for many applications it is desirable that a Wireless Sensor Node has a long network lifetime. In order to prolong the network lifetime of a Wireless Sensor Node there are two possible directions, the first one is energy conservation which is the current focus of a lot of research groups in Wireless Sensor Node. Energy conservation makes sure that the lifetime of the network is maximized. The second option is energy harvesting or recharging the batteries; this approach becomes more a research topic recently and got more attention. In a Wireless Sensor Node, the communication of wireless sensor nodes consumes more energy than the data processing of the received information. Hence the primary focus in energy conservation is that communication between wireless sensor nodes needs to be minimized. Additionally, all the wireless sensor nodes in a Wireless Sensor Node do not necessarily need to sense continually hence turning off some wireless sensor nodes or having a alternative sleeping schedule for a certain percentage of the wireless sensor nodes does not necessarily affect the network as long as there are enough functioning wireless sensor nodes with enough energy to sense and communicate.

2.1.5 The Power Management Protocol for Wireless Sensor Nodes

The power management protocol for Wireless Sensor Nodes is one of the main energy conservation techniques available for a Wireless Sensor Node. The power management protocol can be classified into two categories depending on the location of the power saving within the network layering. Each category of these power management protocols is best suited for a certain type of network topology .The two power management protocols are independent sleep-/wakeup protocols running at the network or application layer and integrated with the MAC protocol itself. Based on the specific sleep scheduling, the MAC protocol then optimizes the medium access functions which are used for power management. Independent sleep/wakeup protocols can be used in combination with any MAC protocol in order to reduce the energy consumption. Within these kinds of sleep/wakeup protocols a classification can be made into three main categories: on-demand scheduled rendezvous and asynchronous protocols. Each of these specific sleep/wakeup protocols has advantages and disadvantages. In the following section these three sleep/wakeup protocols are presented with their respective disadvantages and advantages.

2.1.6 The On-demand Protocol

First of the power management protocol that is introduced is the on-demand protocol. This protocol is based on the idea that a wireless sensor node should be in the sleep mode or off when there is no data packet to transmit and/or receive. As soon as there is a data packet that needs to be transmitted and/or received the wireless sensor node shall become active. In this way wireless sensor nodes alternate between active and sleep periods depending on network activity. The consequence is that the energy consumption is minimized since wireless sensors do not waste energy by unnecessary transmissions and unnecessary sensing. But the main disadvantage of this protocol is that it is difficult to inform the sleeping wireless sensor nodes if another wireless sensor node wants to communicate with them.

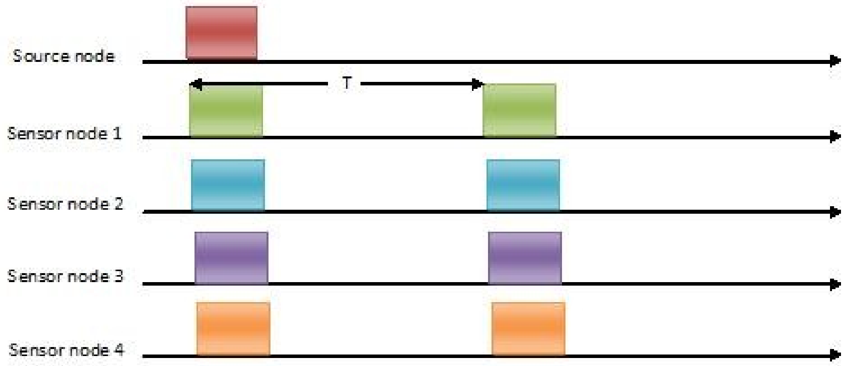
In order to combat this disadvantage the use of multiple radios is required. This requires two channels to work corporately, namely a data channel and a wakeup channel, the former one is used for normal data communication and the other one is for awaking neighboring wireless sensor nodes when needed. Implement the on-demand wakeup schemes in combination with two deferent channels, one for normal data communication and the second channel for awaking neighboring wireless sensor nodes when needed. In the energy quality of on demand sleep /wakeup protocol is presented with the purpose of providing high performance energy efficient local monitoring for Wireless Sensor Nodes.

Therefore, although the approaches mentioned above can be optimal both latency and energy efficiency, they are not very practical due to the additional cost of the second radio.

2.1.7 The Scheduled Rendezvous Protocol

The second power management protocol is called scheduled rendezvous protocol which belongs to the synchronous protocols since it requires all neighboring wireless sensor nodes to wake up at the same time. In Figure 2-2 the sleep scheduling of wireless sensor nodes using a scheduled rendezvous protocol is shown. In this approach wireless sensor nodes wake up according to a wakeup schedule and remain active for a short time interval to communicate with their neighbors. After the transmission of the data the senor nodes will go to sleep until the next rendezvous time. The main advantage of this protocol is that it is guaranteed that if a wireless sensor node is awake that all its neighboring wireless sensor nodes are awake as well. It is very convenient for data aggregation and allows sending broadcast messages to all neighbors.

Figure The sleep scheduling for a synchronous Protocol (Fengju, 2013)



The disadvantage is that this protocol is a synchronized protocol which requires all the neighboring nodes exchange the synchronization information so that their clocks are synchronized. Because a synchronous protocol in a Wireless Sensor Node aims at equalizing the local times for all the wireless sensor nodes in that Wireless Sensor Node. Some of the applications require time synchronization for all wireless sensor nodes at all time and this is the most energy consuming protocol. It is expensive and in some cases it is difficult to achieve in a Wireless Sensor Node. Some other applications require only time synchronization of few wireless sensor nodes at a time. Synchronization algorithms are presented and compared, the three time synchronization algorithms are the following: Reference Broadcast Synchronization (RBS), Timing-Sync Protocol for Wireless sensor Networks (TPSN) and Tree-based Synchronization Algorithms. In terms of accuracy, the RBS and TPSN algorithm perform very well and their accuracy is in order of few micro seconds. In TPSN the need for sending and receiving extra packets makes it less energy efficient than the RBS algorithm. The Tree-based Synchronization Algorithms are flexible and based on the given precision, complexity might be high or low. The root node plays a main role in this type of algorithms.

In order to reduce the energy consumption the wireless sensor-MAC(S-MAC) algorithm has been proposed. It is a fully synchronized protocol specifically designed for Wireless Sensor Nodes. In this case, all the wireless sensor nodes within the network cope with idle listening by repeatedly putting nodes in active and sleep periods. The wireless sensor nodes are synchronized to a common wakeup scheme with a slotted structure. At the beginning of a slot the synchronized packets are regularly broadcasted, the neighboring nodes can adjust their clocks to the latest synchronized packet. By applying this method the relative clock drifts are corrected.

The result shows that this protocol achieves low duty cycle operation of each node by periodic sleeping and reduces energy consumption caused by idle listening.

There also exist some drawbacks for this protocol such as it is difficult to determine an optimal size of active periods and it must be based on idle listening and collisions. For example, if the active periods are too short they increase contention and thus collision rates even if the idle listening period was reduced. On the other side if the active periods become too long the contention is reduce but the idle listening period was increased.

A contention-based MAC protocol for Wireless Sensor Nodes, the so called T-MAC algorithm is pro-posed in this paper. The T-MAC algorithm uses an adaptive duty cycle by dynamically ending an activation event interval when there is no activation event for a given time. Although in this method nodes often go to sleep too early, this reduces the amount of energy consumption on idle listening and maintains a reasonable throughput.

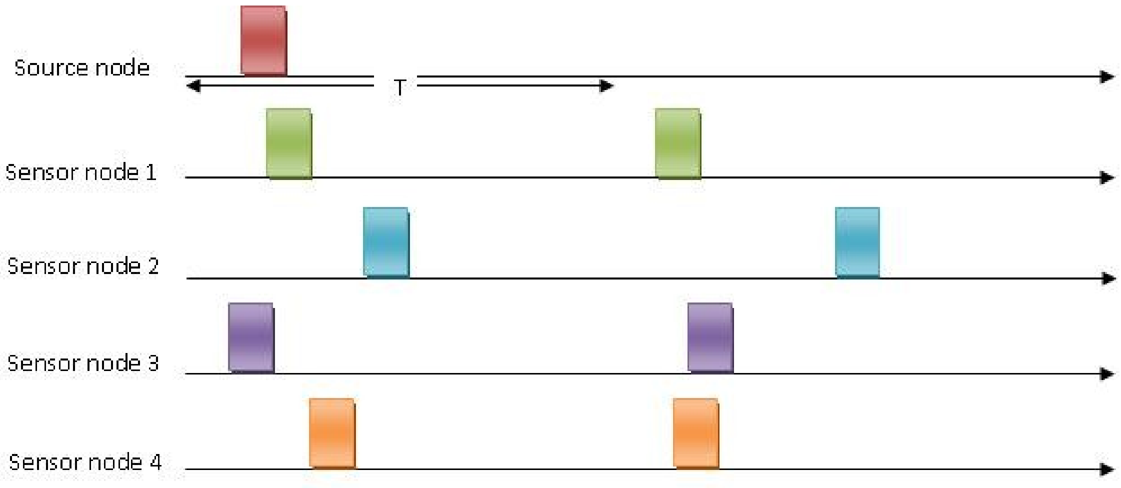
2.1.8 The Asynchronous Protocol

The last algorithm that can be used is the asynchronous protocol. The basic idea is that each node is allowed to wake up independently of the others by guaranteeing that neighboring wireless sensor nodes always have overlapped active periods of time within a specified number of cycles. Figure 4 shows the sleep scheduling of an asynchronous protocol. According to this figure only wireless sensor node 1 and wireless sensor node 3 can receive the transmitted packet. Since the active period of the wireless sensor nodes partially overlap with the active period of the source node.

One of the advantages of this protocol is that a wireless sensor node can wake up at anytime when it wants to communicate with its neighboring wireless sensor nodes. Therefore, in asynchronous protocols there is no need to exchange extra synchronization information unlike in the synchronous protocols so that the energy efficiency is improved. In contrast with the scheduled rendezvous protocol, it is not possible to broadcast a message to all neighboring wireless sensor nodes in one period of time. Though each wireless sensor node is able to contact any of its neighboring wireless sensor nodes in a finite amount of time, it almost never happens that all neighbors are simultaneously active. In contrast to scheduled rendezvous protocols, wireless sensor nodes need to wake up more frequently.

The asynchronous scheme B-MAC has been proposed to reduce the energy consumption within a Wireless Sensor Node. In this approach a long preamble is used before the data packet to reduce the duty cycle and minimize idle listening. It shifts the cost of coping with idle listening from the receiver to the transmitter. This paper also compared the B-MAC algorithm with the S-MAC algorithm mentioned above. The conclusion was that the B-MAC algorithm performed much better than the S-MAC algorithm in packet delivery rates, throughput, latency, and energy consumption. In order to reduce the end-to-end latency with energy efficient data transmission proposed an Asynchronous Wakeup Schedule (AWS) in Wireless Sensor Nodes. Each node was assigned a particular color and maintains a forwarding table which contains the color information of the neighboring nodes. The result shows that the end-to end latency was reduced by using the forwarding table which helps to find out the neighboring node that becomes active sooner.

Figure : The Sleep Scheduling for an Asynchronous Protocol (Fengju, 2013)

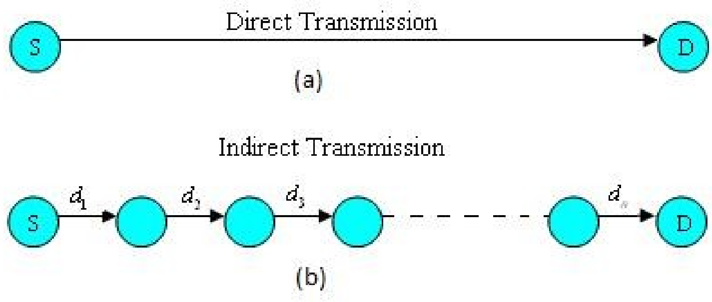


Two advanced MAC protocols in Wireless Sensor Nodes are proposed, namely the Adaptive Duty Cycling Synchronous MAC (AD-MAC) and the Asynchronous-MAC (AS-MAC) for a synchronous and a asynchronous approach, respectively. AD-MAC improves the energy efficiency by using Preoccupancy Request to send technique which can avoid overhearing and diminish the long delay. AS-MAC also reduces the energy consumption caused by idle listening and overhearing by using a preload message which contains the address of the receiver and the remaining time until data transmission is finished.

2.1.9 Data Transmission

Data transmission is an important topic of Wireless Sensor Nodes, as the distance between each wireless sensor nodes is different; the energy consumed by each wireless sensor node is different. When the distance between a wireless sensor node and the base station is large the data transmission from wireless sensor node to base stations consumes more energy than in the case when the distance is small. Hence the distance between wireless sensor nodes among another and the distance from wireless sensor nodes to the base station impacts the lifetime of the Wireless Sensor Nodes.

Figure : Data Transmission (Fengju, 2013)



Data transmissions can be classified into two categories, namely direct transmissions and indirect transmissions. Figure 5 (a) shows a data transmission from source to destination directly without any intermediate nodes; however, in Figure 5 (b) data packet was transmitted from source to destination via the intermediate nodes, the distance d_i can either be equal to each other or different from each other.

2.1.10 Direct Transmission

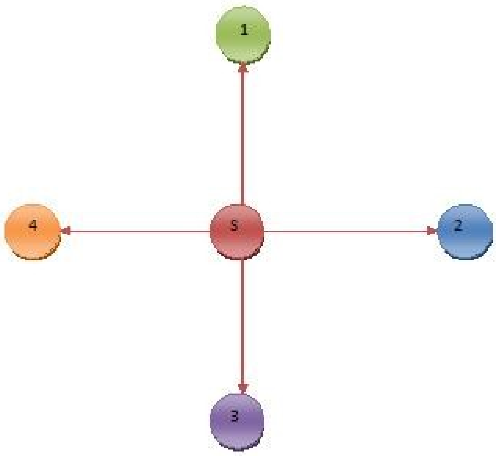
In a direct data transmission, each wireless sensor node collects and transmits the data to the base station directly, there do not exist any intermediate nodes for transmission, the path which from wireless sensor node to the BS can also be called single-hop path. The advantage of direct transmissions is that the data rate is higher and the implementation is easier. WNS using these kinds of transmissions are suitable for local scale applications. In large scale applications, especially if the wireless sensor node is far away from the BS, the battery power can drain quickly due to the long distance which needs to be covered for the data transmission. Another disadvantage is that the data may not be sent to the BS because the wireless sensor node is too far away.

2.1.11 Indirect Transmission

Indirect transmission means that wireless sensor nodes send their collected data to intermediate nodes also called relay nodes that are in the proximity of themselves. This relay node will then forward the aggregated data to the BS, the path from the wireless sensor node to the BS is also called multi-hop path. The advantage of this kind of transmission is that the high energy consumption problem in long distance transmission has been solved. The drawback is that the wireless sensor nodes closest to the BS may consume more energy to forwarding data for other nodes, thus it will also impact the lifetime of Wireless Sensor Nodes. The indirect transmission is more energy efficient than the direct transmission only when the distance from source to destination is longer so that it cannot be reached with the direct transmitting power. (Fengju, 2013)

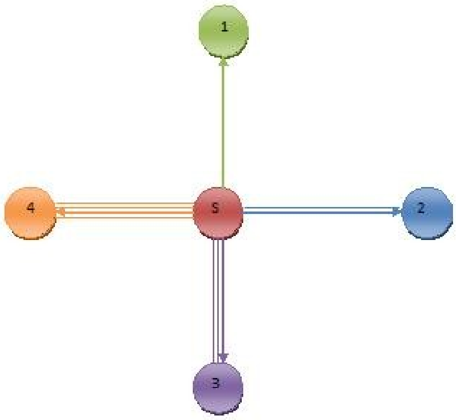
2.1.12 Broadcasting

In both wired and wireless networks broadcasting is one of the most fundamental ser-vices in order to reach every node in a network. More specifically broadcasting is the principle that one wireless sensor nodes want to transmit data to every other wireless sensor nodes. Since broadcasting ensures a maximum number of delivered packets among the en-tire network. Broadcasting works that if a wireless sensor node wants to transmit data it will broadcast the data to all its neighboring nodes. The wireless sensor nodes that received the packet from the source node shall further rebroadcast the packet to their respective neighboring wireless sensor nodes which the source node could not reach. In this way in a short time the entire network is reached. Although broadcasting has many advantages such as it is simple to implement, fast and robust, it also has some disadvantages. The disadvantages are lots of contention, collision, duplicated packets and it is not energy efficient. Especially this last disadvantage is important for a Wireless Sensor Node since in a Wireless Sensor Node each wireless sensor node carries limited amount of energy. (Robert, 2013)
When the source node transmits its packets to its neighboring nodes in a synchronous
Figure : Synchronous Broadcasting (Fengju, 2013)



Wireless Sensor Node, then all the neighboring wireless sensor nodes receives these packets due to the synchronized active periods. This is the best case; the source node waits until all other neighboring wireless sensor nodes to be active and then broadcasts the packet as shown in Figure 2-5, after one period of time the entire network with each of the wireless sensor node is reached and hence maximum reach-ability. In this way the waste of energy is also limited. However most WNS are asynchronous and the wireless sensor nodes do not have the same sleep scheduling as the synchronous protocol and the wakeup period of one wireless sensor node does necessarily overlap with the source node, then the waiting time becomes infinite. The worst case is that all the wireless sensor nodes have a different sleep scheduling as shown

Figure Asynchronous Broadcasting (Fengju, 2013)



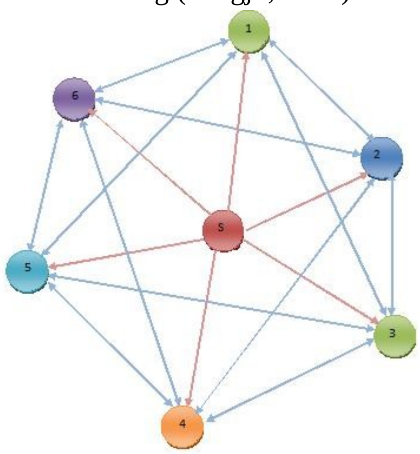
in Figure 7, in this figure if there is overlap between the source node and just one wireless sensor node it will lead to broadcast 4 times to the number of 4 wireless sensor nodes . Since this requires much more energy consumption then in the synchronized Wireless Sensor Node. In asynchronous Wireless Sensor Node it is important that the active periods of each node overlaps each other in the case of a broadcast. However, large active periods also mean high energy consumption. Hence there is a tradeoff for duty cycle and the attained reach-ability in a broadcast and the energy consumption otherwise. In this work an attempt is made to find an optimal way of choosing the duty cycle so that the energy consumption is minimized but the network reach-ability is optimized. There are various approaches for broadcasting in Wireless Sensor Nodes that have been explored; broad-casting techniques can be classified into four categories: simple flooding, probability-based, area-based and neighbor knowledge-based scheme.

2.1.13 Flooding

Flooding is a technique to update the topology databases for each node. It is one of the fundamental broadcasting mechanisms in both wired and wireless networks. In simple flooding each incoming packet is sent out on every outgoing link or interface except for the interface it entered. Figure 8 shows the structure of the simple flooding. The source node broadcasts packet to every node, they can all receiver the packet; afterwards each node broadcasts the packet to the neighboring nodes except the source node. This process generates lots of duplicated packets repeatedly and it does not stop by itself unless some measures are used to limit the number of the duplicates such as Time To Live (TTL) and sequence number techniques. Simple flooding consumes most of the network resources and May also cause too high overhead.

Due to the high cost of flooding in WIRELESS SENSOR NODEs, energy conservation is achieved by selecting parents with the highest link quality in a flooding tree based design. Unlike this traditional selection, proposed correlated flooding that nodes with high correlation are assigned to a common sender and a single acknowledge message is used for receiving the broadcasting packets. The result shows that the energy consumption can be reduced by letting higher correlation nodes receive packets simultaneously.

Figure : Flooding (Fengju, 2013)



2.1.14 Gossiping

Gossiping is a probabilistic broadcast method that tries to improve the flooding algorithm. This approach works in the following way: the nodes in the network have a pre-specified probability Pgossip61 which is needed in order to broadcast packets. With the probability of 1- Pgossip, the received packet is discarded. In order to achieve the desired application requirements and minimize the overhead, a probability Pgossip is chosen. There are no synchronization requirements for gossiping. Although gossiping is a simple solution and it is capable to achieve better reliability and load balancing, choosing the correct probability is a difficult problem. However, when the probability is chosen correctly, the broadcast message is received with a very high probability among the entire network. Thus, a correctly chosen Pgossip may extend the network lifetime.

2.1.15 Duty Cycle Awareness

Various approaches have been studied for reducing unnecessary power consumption in Wireless Sensor Nodes. One of these approaches is to let wireless sensor nodes use a low duty cycle, such as in B-MAC, in order to prolong the network lifetime. An asynchronous duty cycle broadcasting (ADB) [30] has been proposed, it is a new protocol for efficient multihop broadcast in Wireless Sensor Nodes using a asynchronous duty cycle. Unlike the traditional multihop broadcast, this protocol is integrated with the MAC layer in order to use the information which is only available at this layer. As this is an asynchronous protocol each wireless sensor node has a individual sleep scheduling. This method optimizes the broadcast transmission from a node to its each neighbor individually. The final result shows that the energy consumption was reduced.

2.1.16: Preamble Awareness

Before a transmitter sends a data packet a preamble of certain length is sent before the data packet. In Wireless Sensor Nodes with high wireless sensor node density a small preamble will be sent before the data transmission. This preamble is received by a number of neighboring wireless sensor nodes which are present within the transmission range of a wireless sensor node. The neighboring wireless sensor nodes that received the data packet will rebroadcast the packet in the next period of time and will still use the same preamble length. If the preamble is large, the transmission cost at the transmitter increases. Figure2-8 shows that a preamble before the data packet is sent by the source node where only wireless sensor node1 and wireless sensor node 3 can receive the transmitted packet in this scenario.
Figure 2-9 shows that flooding with preamble of the transmitter and duty cycle of the cycle of node 1 and node 3. After node 1 and node 3 receive the packet, they will receiver technique in the network. In this figure it can be seen that the source node transmits packets to node 1 and node 3 because the preamble of the source node over-laps the duty broadcast the packet to their neighboring node which is node 6 and node 2. Finally node 6 reaches node 4 and node 5. In this technique there is no duplicated packets.

Figure : Data packet transmission with preamble (Fengju, 2013)

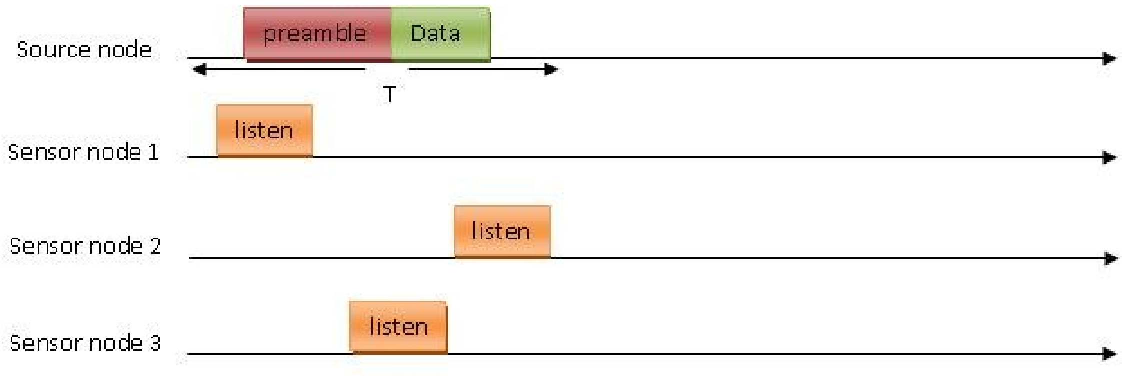
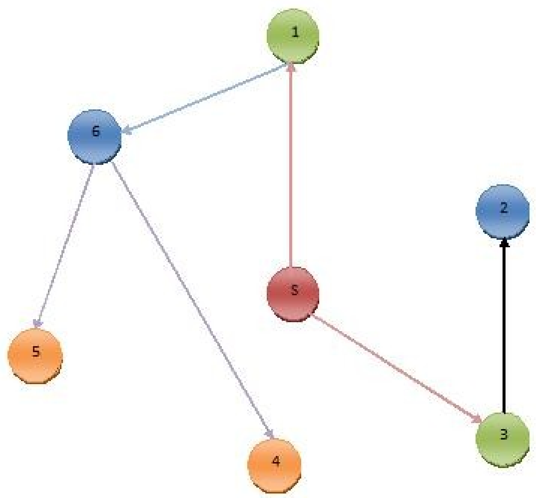


Figure Flooding with preamble technique



2.2 Simulation Phase

This includes as below;

2-2-1 Problem Formulation

This phase entails understanding the problem of interest, organizing the system into objects and activities into a form which can be executed experimentally. Getting the solution to the problem requires one to choose the way to achieve it from the potential solutions. At this stage inputs, outputs and processes are identified to enable building of the conceptual model in the next phase.

2.2.2 Conceptual Model

At this stage, the structure and layout of the objects and attributes are built to reflect all the features of the system. The output should give a picture of how the components interact and critical areas of the system.

2.2.3 Collection and Analysis of Input/output Data

This step involves studying the attributes identified in the preceding phase to enable one to obtain input/output data of the system. The attributes are classified as either stochastic or deterministic.

2.2.4 Modeling

In this phase, the conceptual model and the data collected for output/input are used to develop an elaborate representation of the system. The structure and behavior of the system is defined using the attributes, interfaces and methods already identified in the previous phases.

A model is developed showing how the attributes and variables relate and any assumptions made are highlighted.

2.2.5 Simulation

At this stage the model developed in the previous phase is implemented using a chosen simulation tool. There are various programs and tools which can be used to achieve this. Algorithms are developed and translated to specific programming language or model for simulation.

2.2.6 Verification and Validation

Verification and validation is done in almost all the phases of simulation. Verification checks the consistency among the conceptual model, system model and simulation model while validation involves comparison of the model and system reality.

2.2.7 Experimentation

This includes:

2.2.8 Output Analysis

During this phase a number of tools are used to analyze and visualize the outputs. The process allows better understanding of the system and deep communication therefore no loss of data.

2.2.9 Advantages of Simulation

- It enables simulation of complexity
- It eradicates the complexities of analyzing difficult data
- It also allows foreseeing of data by using sensitivity analysis and varying model parameters.
- It eases system changes thus leading to system improvements
- It provides greater understanding of analytical problems

2.2.10 Disadvantages of Simulation

- It lacks accuracy, the model is usually not an exact system replica of the real-world systems
- It does not allow study of several parameters at once

2.2.11 Simulation Phases Chart

Problem Of Study

Figure : Simulation Phases Chart

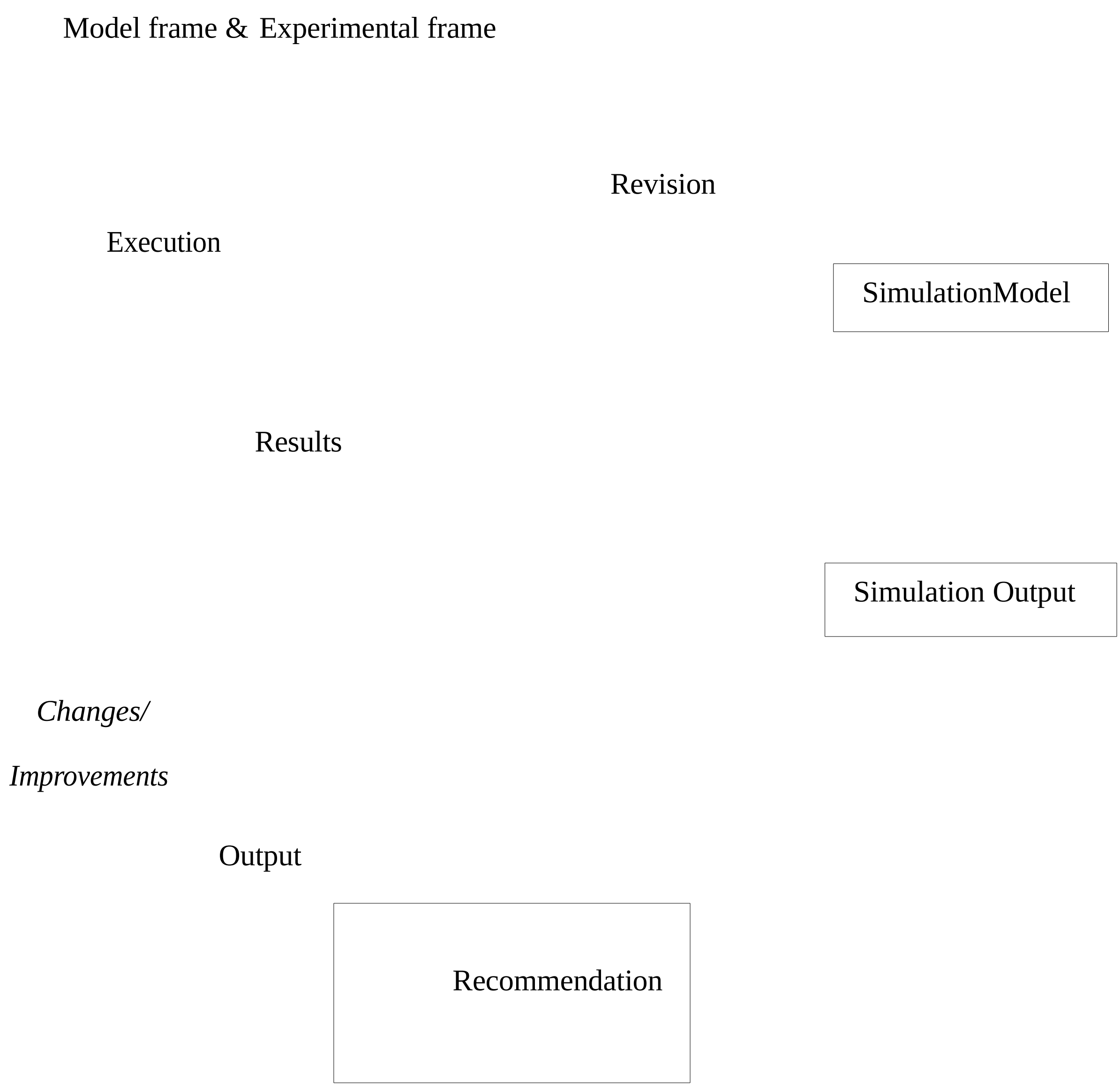
Validation

Entities & Relationships

Verification

Implementation

Conceptual Model


Model frame & Experimental frame
Revision
Execution
SimulationModel
Results
Simulation Output
Changes/
Improvements
Output
Recommendation

2.2.12 Case Study

This hypothetical case study to illustrate the usefulness of our proposed system. The patient presented is fictitious, but representative of common issues a recovering heart attack patient would face. We discuss the issues and describe the system can be used to both address the problem and provide advantages over typical present day solutions. Juan Lopez is recovering from a heart attack. After the release from the hospital he attended supervised physical rehabilitation for several weeks. His physicians prescribed an exercise regime at home. During the physical rehabilitation it was easy to monitor Juan and verify he completed his exercises. Sadly, when left to his own self-discipline, he does not rigorously follow the exercise as prescribed. He exercises, but is not honest to himself (or his physician) as to the intensity and duration of the exercise. As a result, Juan's recovery is slower than expected which raises concerns about his health prognosis, and his physician has no quantitative way to verify Juan's adherence to the program. (Fengju, 2013)

Our health monitoring system offers a solution for Juan. Equipped with a Wireless Body Area Network, tiny wireless sensors provide constant observation of vital statistics, estimate induced energy expenditure, and assist Juan's exercise. Tiny electronic inertial wireless sensors measure movement while electrodes on the chest can measure Juan's heart activity. The time, duration, and level of intensity of the exercise can be determined by calculating an estimate of energy expenditure from the motion wireless sensors. Through the Internet, his physician can collect and review data, verify Juan is exercising regularly, issue new prescribed exercises, adjust data threshold values, and schedule office visits. Juan's physician need not rely on Juan's testament, but can quantify his level and duration of exercise. In addition, Juan's parameters of heart rate variability provide a direct measure of his physiological response to the exercise serving as an in-home stress test. Substituting these remote stress tests and data collection for in-office tests, Juan's physician reduces the number of office visits. This cuts healthcare costs and makes better use of the physician's time. In urgent cases, however, the personal server can directly contact Emergency Medical Services (EMS) if the user subscribes to this service.

2.3 Wireless Sensor Node Applications

The characteristics described in the previous section provide a wide range of applications for wireless sensor networks. WSN can be used in the armed forces/army applications, home monitoring, machine medical monitoring and medical guidance, wireless traffic pattern monitoring and navigation, wireless plant monitoring in farming, and wireless infrastructure monitoring.

2.3.1 Military Applications

Wireless sensor networks can be a part of military command, control, communications, computing, intelligence, surveillance, reconnaissance and targeting systems. The rapid deployment, self-organization and fault tolerance characteristics of wireless sensor networks make them a very promising sensing technique for military applications. Some of the military applications of wireless sensor networks are monitoring friendly forces, equipment and ammunition; battlefield surveillance; reconnaissance of opposing forces and terrain; targeting; battle damage assessment; and nuclear, biological and chemical attack detection (recently is considered as one of the critical types of attacks) and reconnaissance.

2.3.2 Environmental Applications

Another important area of wireless wireless sensor networks are environmental applications which include smart homes, tracking the movements of birds, small animals and insects; monitoring environmental conditions that affect crops and livestock; irrigation; macro instruments for large-scale earth monitoring and planetary exploration; chemical/biological detection; precision agriculture; biological, earth, and environmental monitoring in marine, soil, and atmospheric contexts; forest fire detection; meteorological or geophysical research; flood detection; bio-complexity mapping of the environment; and pollution study.

2.3.3 Home Applications

Home automation: as technology advances, smart wireless sensor nodes and actuators can be incorporated into appliances, such as vacuum cleaners, micro-wave ovens, and refrigerators. These wireless sensor nodes inside the devices can communicate with each other and with the external network via the Internet or satellite. They allow end users to control home devices locally and remotely more easily and can be used as alarms for disasters at homes.

2.3.4 Commercial Applications

Some of the commercial applications are monitoring material fatigue; building virtual keyboards; managing inventory; monitoring product quality; constructing smart office spaces; environmental control in office buildings; robot control and guidance in automatic manufacturing environments such as interactive toys; interactive museums; factory process control and automation; monitoring disaster area; smart structures with wireless sensor nodes embedded inside; machine diagnosis; transportation; factory instrumentation; local control of actuators; detecting and monitoring car thefts; vehicle tracking and detection; as well as instrumentation of semiconductor processing chambers, rotating machinery, and wind tunnels.

2.3.5 Healthcare Applications

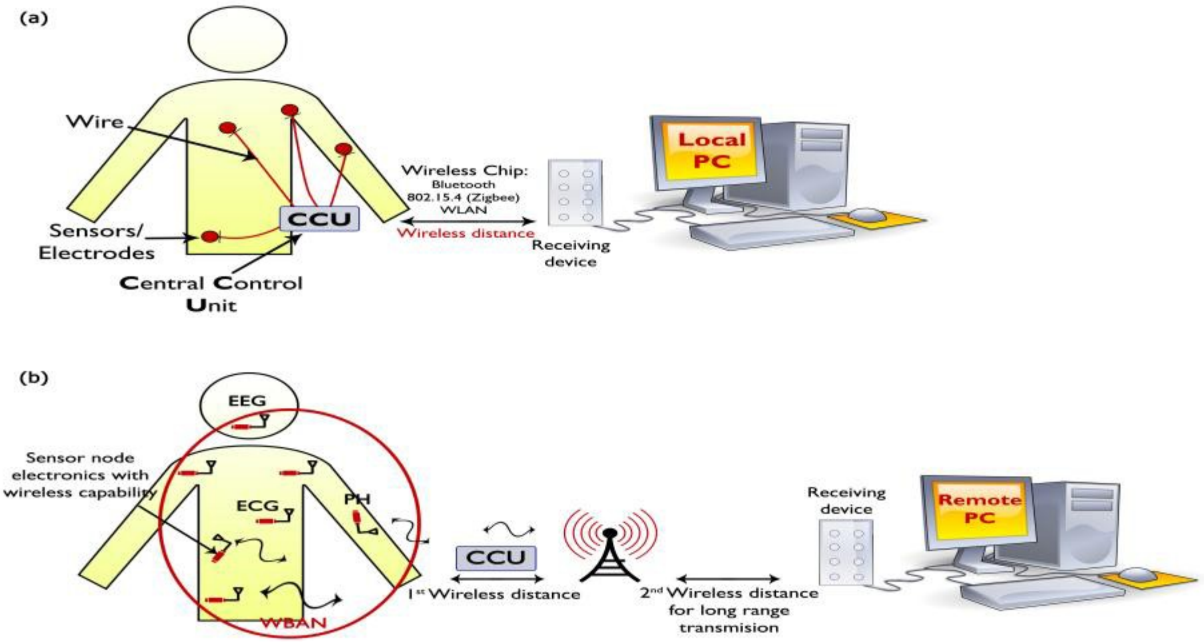
Some of the health applications of wireless sensor networks involve providing interfaces for the disabled, integrated patient monitoring, diagnostics, drug administration in hospitals, telemonitoring of human physiological data, and tracking and monitoring doctors and/or patients inside a hospital. I will briefly explore some capabilities of WIRELESS SENSOR NODE for healthcare monitoring as I focus in this paper on wearable and implantable body area networks.

i. Telemonitoring of Human Physiological Data: The physiological data collected by wireless sensor networks may be stored for a long period of time, and can be used for medical investigations when needed. In addition, the installed wireless sensors can also monitor and detect the behavior of elderly people. As an example, a health smart home was designed by the Faculty of Medicine in Grenoble-France to check the feasibility of such systems.

ii. Tracking and Monitoring Doctors and Patients inside a Hospital: Each patient has a small wireless sensor node attached to them. Wireless sensors vary based on their functions and each wireless sensor node has its own specific task to perform. For example, one wireless sensor node may be detecting the heart rate while another is detecting the blood pressure. Doctors can also carry a wireless sensor node, which allows other doctors to locate them within the hospital.

iii. Drug Administration in Hospitals: If wireless sensor nodes can be attached to medication, the chance of getting and prescribing the wrong medication to patients can be minimized. Thus, patients will have wireless sensor nodes that identify their allergies and required medication. Computerized systems as described in have shown that they can help minimize the side effect of drugs.

Figure : Typical Wireless Sensor Node system for detecting and transmitting signals from a human body: (a) current application of health and medical wireless sensor network and (b) future application of healthcare and medical wireless sensor network targeted by wireless body area network.



2.4 CONCLUSION

In this study I have provided a survey of this promising field through a survey of pioneer WBASNs Research projects and enabling technologies, including, sensing and preprocessing, communication environments of Wireless Body Area Networks, data analysis and feedback that have feature extraction, detections and classifications. In particular, for life-saving applications, thorough studies and tests should be conducted before Wireless Body Area Networks can be widely applied to humans. Compression is used to reduce the amount of physical data traffic that the wireless sensor send in a small size to improve and utilize bandwidth communication, power consumption and memory space. Wireless sensor supply chain and communication technologies used within the system depend largely on the use case and the characteristics of the application. On other hand, the feature extraction, detection and classification, play a vital role in diagnosing most of the cardiac diseases and they provide efficient tools for enhancing the diagnosis of illnesses in various clinical and life settings.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This is the systematic, theoretical analysis of the methods applied to a field of study. It comprises the theoretical analysis of the body of methods and principles associated with a branch of knowledge. Typically, it encompasses concepts such as paradigm, theoretical model, phases and quantitative or qualitative techniques.

A methodology does not set out to provide solutions - it is, therefore, not the same thing as a method. Instead, it offers the theoretical underpinning for understanding which method, set of methods or so called “best practices” can be applied to specific case, for example, to calculate a specific result.

It has been defined also as follows:

1. The analysis of the principles of methods, rules, and postulates employed by a discipline
2. The systematic study of methods that are, can be, or have been applied within a discipline.

3.2 Current Methods

3.2.1 Actual Design

The design entails the combination of components required to develop a real world wireless product. This method is time consuming in terms of designing, sourcing of components and actual development of the product. The method provides actual parameters when used allowing the developer to vary various parameters during experiments be able appraise the design in the actual application. (Robert, 2013)

The cost, availability of materials and time taken is the main limitation of this method.

3.2.2 Analytical Approach

The method involves breaking down a problem of focus into small portions to enhance easy solving. It entails application of various formulas, equipments and tools to achieve the solution. Each part of the problem becomes a smaller and easier to handle. This involves

1. **Exploratory research**, this identifies a problem and further elaborates a problem.
2. **Constructive research**, this research tests the research and proposes solutions to a problem or question.
3. **Empirical research**, this tests the research feasibility of solution using verifiable evidence.

There are two major types of research design: qualitative research and quantitative research. Researchers choose qualitative or quantitative methods according to the nature of the research topic they want to investigate and the research questions they aim to answer:

Qualitative research

is a method of inquiry employed in many different academic disciplines, traditionally in the social sciences, but also in market research and further contexts. Qualitative researchers aim to gather an in-depth understanding of human behavior and the reasons that govern such behavior. The qualitative method investigates the why and how of decision making, not just what, where, when. Hence, smaller but focused samples are more often used than large samples.

Quantitative research

This refers to the systematic empirical investigation of social phenomena via statistical, mathematical or numerical data or computational techniques. The objective of quantitative research is to develop and employ mathematical models, theories and/or hypotheses pertaining to phenomena. The process of measurement is central to quantitative research because it provides the fundamental connection between empirical observation and mathematical expression of quantitative relationships. Quantitative data is any data that is in numerical form such as statistics, percentages, etc

3.2.3 Simulation

Simulation is the imitation of the operation of a real-world process or system over time. The act of simulating something first requires that a model be developed; this model represents the key characteristics or behaviors/functions of the selected physical or abstract system or process. The model represents the system itself, whereas the simulation represents the operation of the system over time.

Simulation is used in many contexts, such as simulation of technology for performance optimization, safety engineering, testing, training, education, and video games. Often, computer experiments are used to study simulation models. Simulation is also used with scientific modeling of natural systems or human systems to gain insight into their functioning. Simulation can be used to show the eventual real effects of alternative conditions and courses of action. Simulation is also used when the real system cannot be engaged, because it may not be accessible, or it may be dangerous or unacceptable to engage, or it is being designed but not yet built, or it may simply not exist. (Leinonen, 2007)

Key issues in simulation include acquisition of valid source information about the relevant selection of key characteristics and behaviors, the use of simplifying approximations and assumptions within the simulation, and fidelity and validity of the simulation outcomes.

Difference between the Analytical approach and Simulation in Research Methodology.

In any system (or model), you have parameters and other conditions (e.g. initial conditions) with make results different. In simulation, values of these effective parameters must be specified and result will be true just for that value of parameter. But analytical result, give a general description of system for any value of parameters. For example, suppose that we want to solve a simple linear ode: dx/dt=a*x, which a is parameter. In numerical result, we choose an initial condition and a value for "a" and find solution, but we can't deduce general result for any initial condition and any value of "a", while analytical result (if can be derived) gives result for any initial condition and any value of "a".

A computer simulation, a computer model, or a computational model is a computer program, run on a single computer, or a network of computers, that attempts to simulate an abstract model of a particular system. Computer simulations have become a useful part of mathematical modeling of many natural systems in physics (computational physics), astrophysics, chemistry and biology, human systems in economics, psychology, social science, and engineering. Simulation of a system is represented as the running of the system's model. It can be used to explore and gain new insights into new technology, and to estimate the performance of systems too complex for analytical solutions.

3.3 Proposed methodology

3.3.1 Introduction

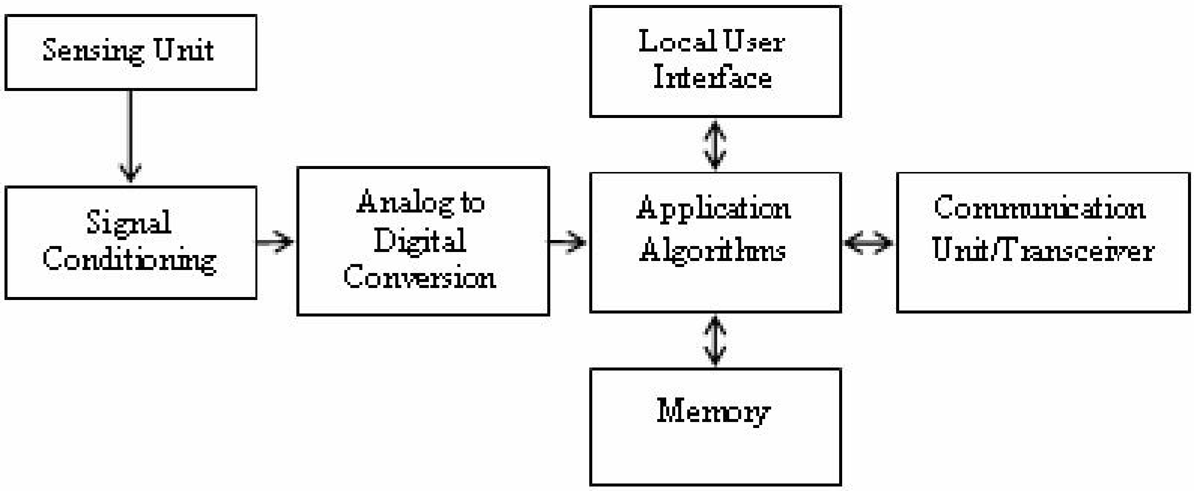
In this research, simulation was chosen as the primary method to do the work. Simulation provided the required scope, convenience, time and cheaper alternative to realize the aims of this research and obtain the results.

Simulation is a widely used technique for representing the actual systems, normally dynamic. The model acts as a real system allowing use of simulation tools and emulators running on computers to study various systems as they were real. There are a number of simulation tools which can be used to simulate various scenarios in Wireless Body Area Networks studies as described in the previous sections. Simulation is used in this research to enable the study of effects of various factors on signal transmission in Wireless Body Area Network. (Robert, 2013)

3.3.2 Characteristics of Proposed Methodology

MATLAB R2009a and Simulink simulation program is used for this research to be able to capture how wireless and radio signals are affected by various factors in multi-hop topologies. This simulator can represent various wireless network processes including wireless routing, wireless protocol clustering and provide statistical information of the various network devices such as the residual energy devices and show the transmission channels.

Simulink is a graphical user interface application which enhances the use of MATLAB to model and simulate various systems as they were real systems. Simulink offers various blocks for building different simulation models. The systems are developed on screen using components from various blocks. During model development, Simulink and MATLAB can be used together allowing data transfer between the two interfaces without any limitation to the real world system. (Ayon, Subhajit, & Kaushik, June 2010)



1) **The transmitter**

This system is based on wireless technology that is considered as the backbone of transmission operation.

Wireless sensor signal stage: This is where is wireless sensors put up to send and receive data signals.

Table : The ratio of the number of reached neighbors over the total number of neighbors for a Wireless Sensor Node with 50 wireless sensor nodes

duty cycle	percentage of the number of reached neighbors over the total number of neighbors
10%	18%
20%	36%
30%	50%
40%	63%
50%	72%
60%	81%
70%	86%
80%	95%
90%	100%
100 %	100%

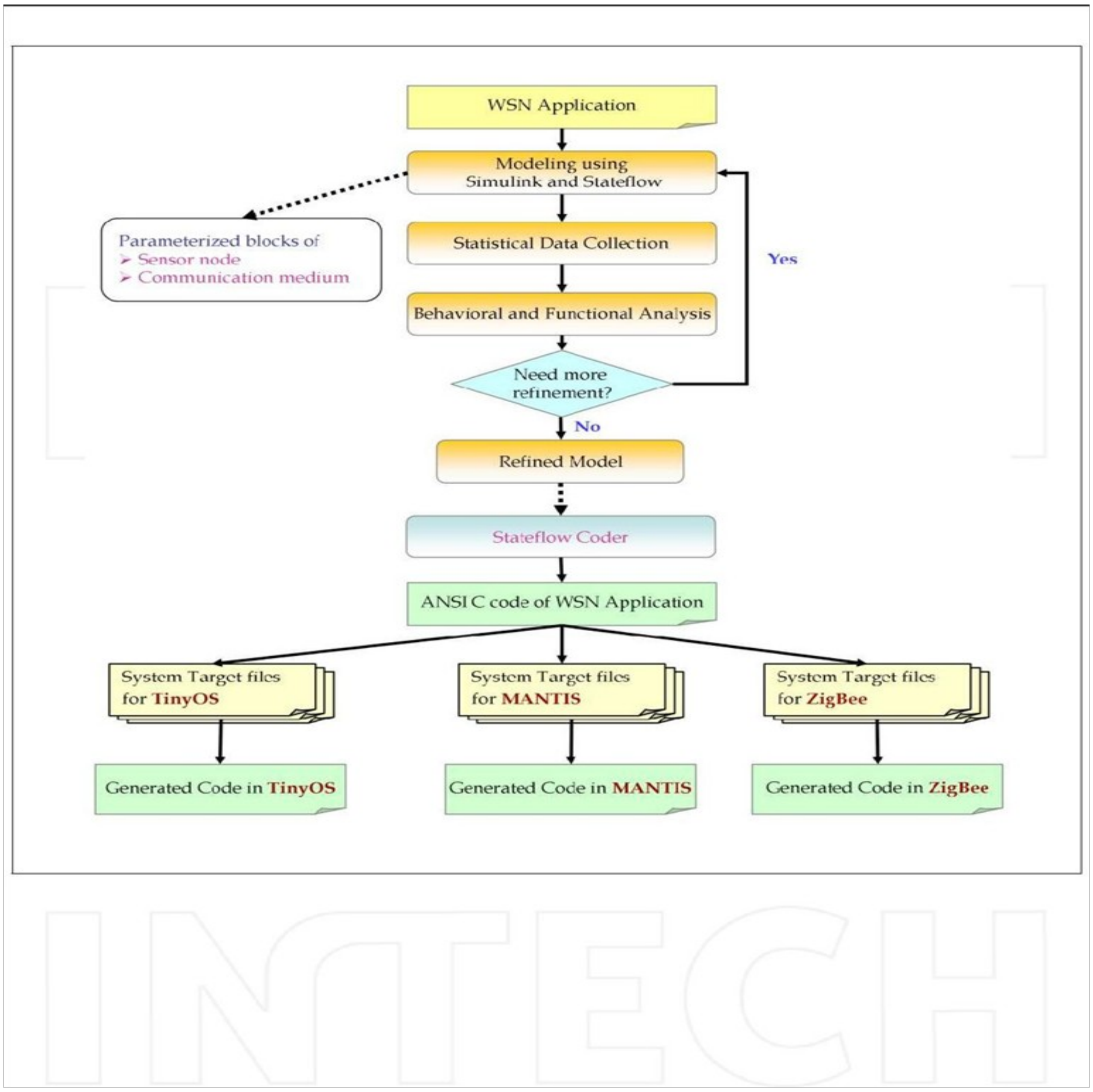
Table : The ratio of the number of reached neighbors over the total number of neighbors for a Wireless Sensor Node with 100 wireless sensor nodes

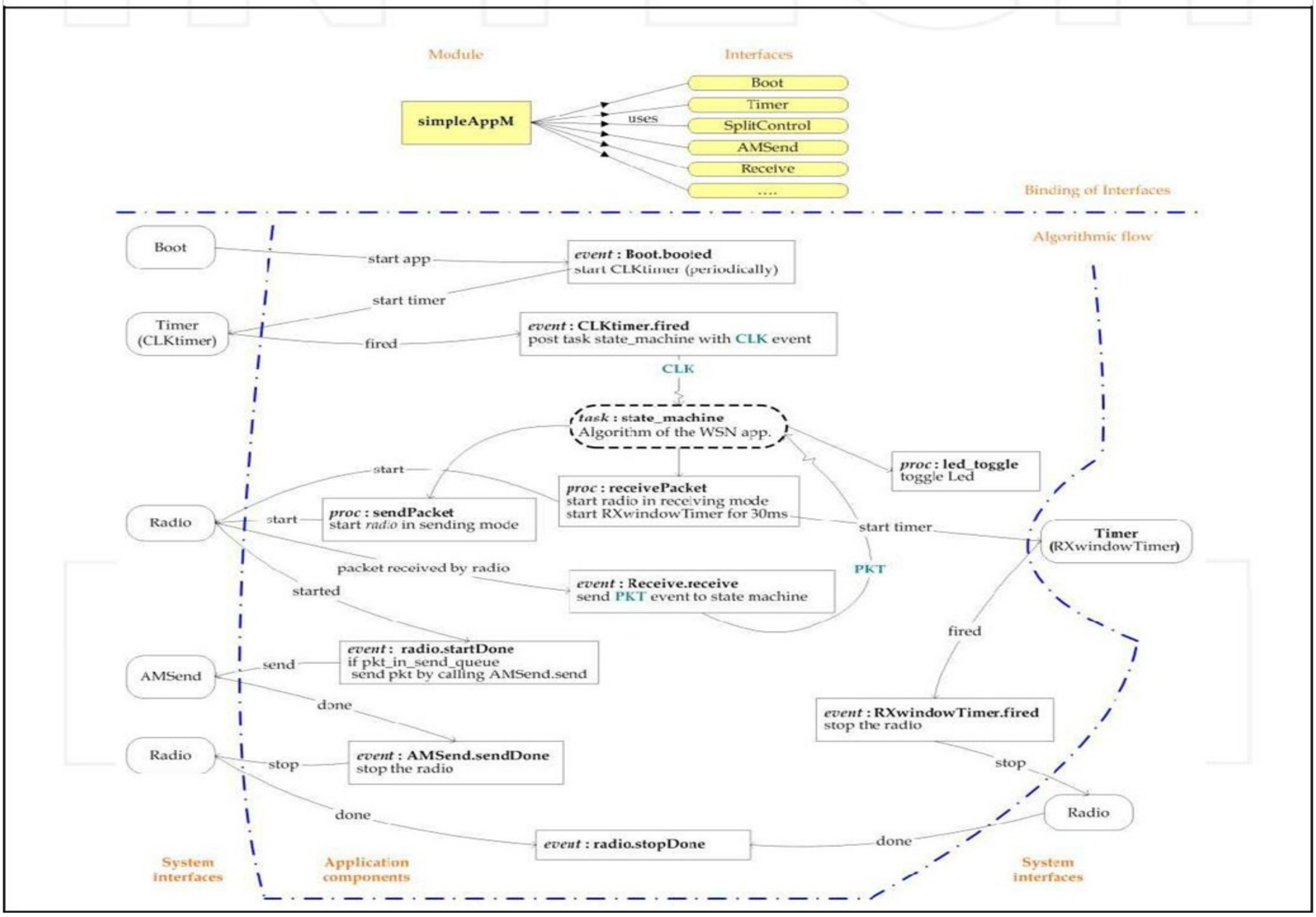
duty Cycle	percentage of the number of reached neighbors over the total number of neighbors
10%	20%
20%	34%
30%	51%
40%	62%
50%	75%
60%	82%
70%	88%
80%	94%
90%	100%
100%	100%

Table : The ratio of the number of reached neighbors over the total number of neighbors for a Wireless Sensor Node with 200 wireless sensor nodes

duty Cycle	percentage of the number of reached neighbors over the total number of neighbors
10%	19%
20%	35%
30%	51%
40%	61%
50%	75%
60%	81%
70%	89%
80%	95%
90%	100%
100%	100%

CHAPTER 4: CONCEPTUAL MODEL





4-1 The Density Estimation

Previous work about density estimation has been done by sharing the received power measurements from the neighboring nodes in [20]. Based on these collected measurements from the neighboring nodes, the maximum likelihood estimate (MLE) of the density _ *nodes/m*2 is computed. In this previous work two models are proposed, namely the individual density estimation and the cooperative density estimation. The result of [20] shows that cooperative density estimation has better a accuracy with less variance than individual estimation. When nodes share received power measurements from neighboring nodes further away, the density estimation has a even much better accuracy because of the further reduced variance. In this thesis work only the individual density estimation is used to adapt the duty cycle.

In the individual density estimation model, for each node the received power from *kthj* neighboring nodes is collected to compute the estimate for j=1, 2, 3, ..., n. For a homogeneous network, each wireless sensor node has the same following assumed parameter and it is listed in table 4-1. The antenna gains of the transmitting and receiving are equal to 1.

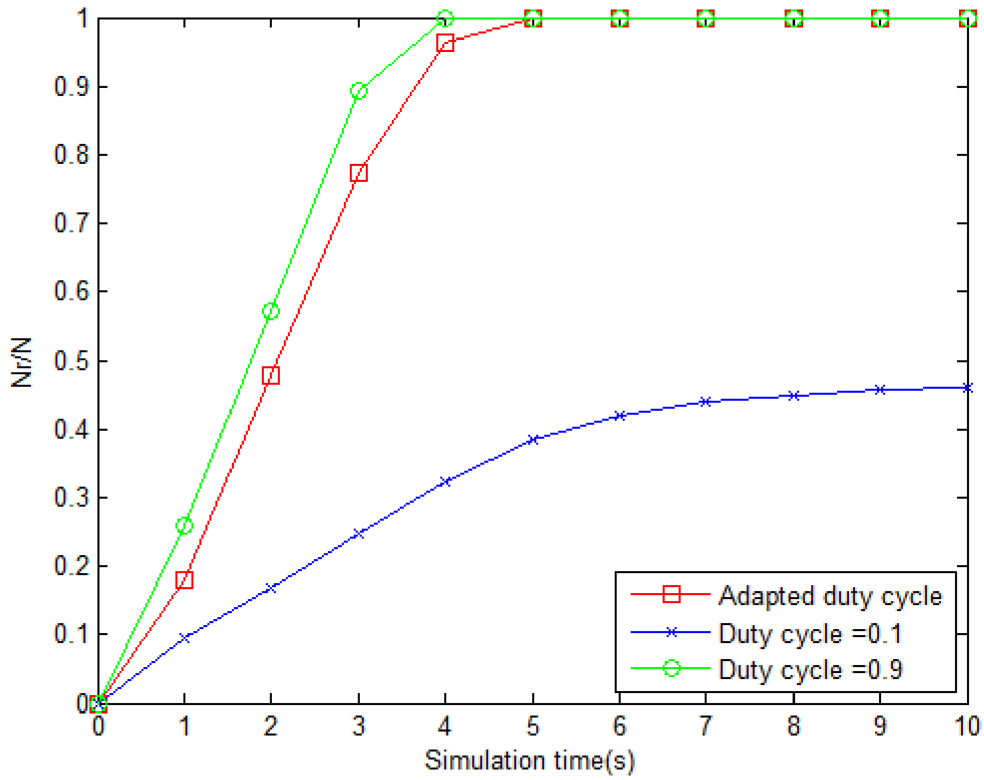
4-2 Comparing with the fixed duty cycle

4-2-1 The Reach-ability

In this section the adapted duty cycle for each wireless sensor node is calculated based on the individual estimated density. Instead of fixed duty cycle for all the wireless sensor nodes, the adapted duty cycle for each wireless sensor node is used. The preamble length assumed to be 0.1 s and for this scenario there are 9 neighbors can be reached.

Figure The averaged reachability of 50 wireless sensor nodes with various duty cycle, where preamble length=0.1s,9 neighbors can be reached

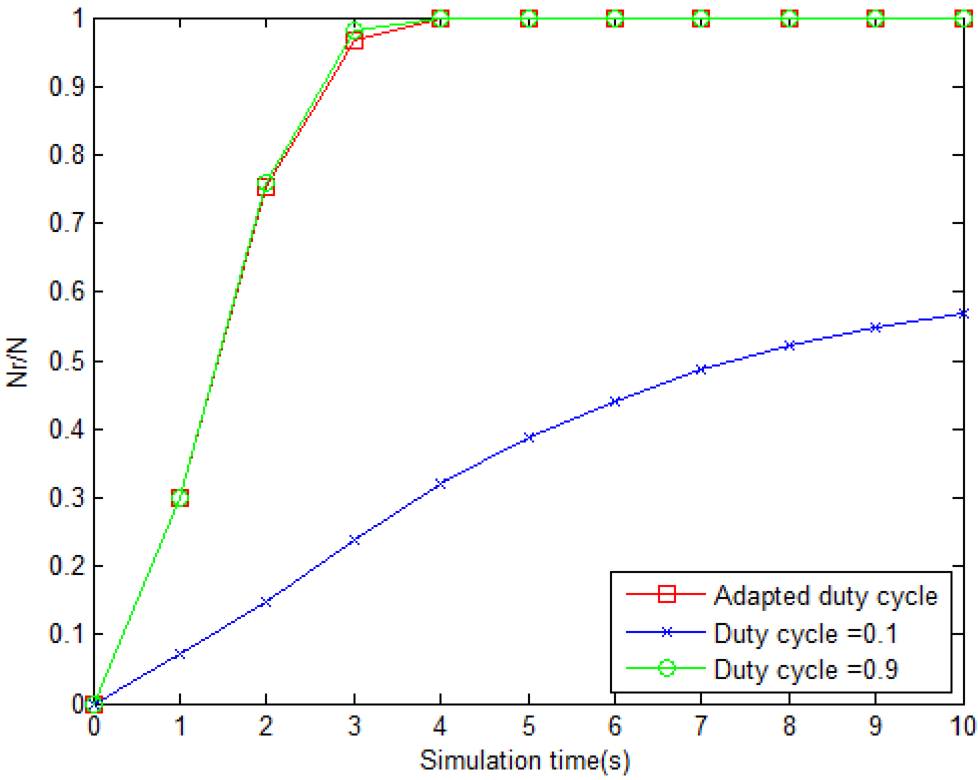
(Fengju, 2013)



In Figure 13 the reachability for 50 wireless sensor nodes is plotted versus simulation time by using the adapted duty cycle, a low fixed duty cycle of 0.1 and a high fixed duty cycle of 0.9. This figure shows that the adapted duty cycle has almost the same reachability with the fixed duty cycle which equals to 0.9, both of them reached maximal reachability at the same time.

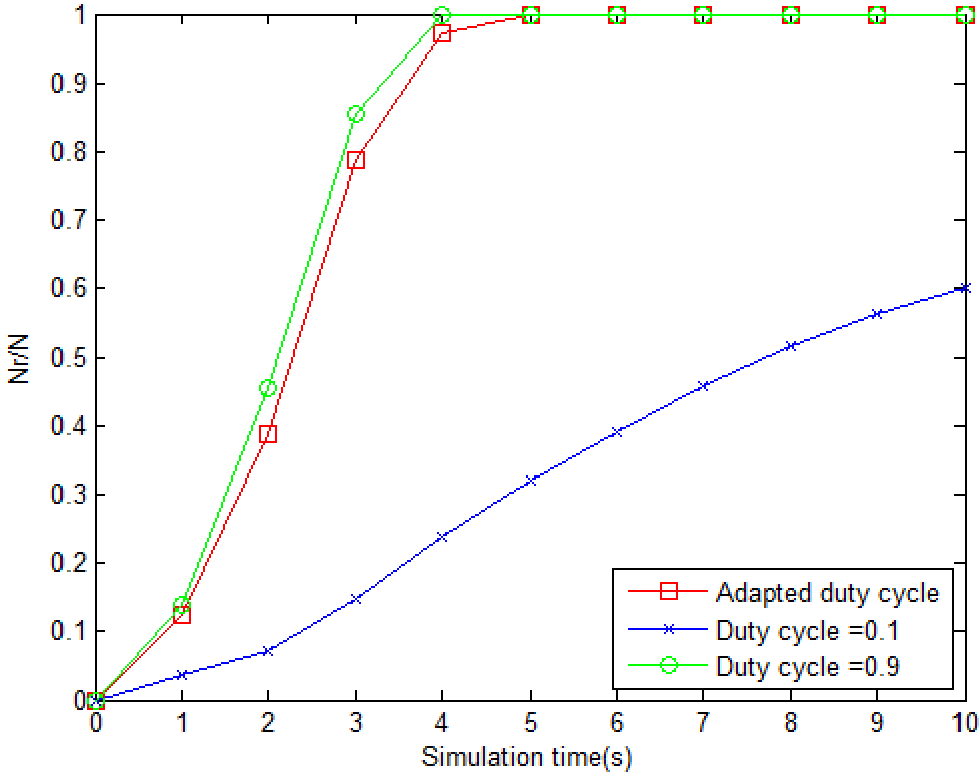
However, the averaged adapted duty cycle is only 0.35. The reachability of a fixed duty cycle which is equal to 0.1 has the lowest reachability and at T= 10 seconds it reaches its maximum reachability of 46% of the whole network. But for the adapted duty cycle and a fixed duty cycle equals to 0.9 the reachability reaches 96% at T=4 seconds.

Figure The averaged reachability of 50 wireless sensor nodes for various duty cycles, where preamble length=0.1s, 15 neighbors can be reached (Fengju, 2013)



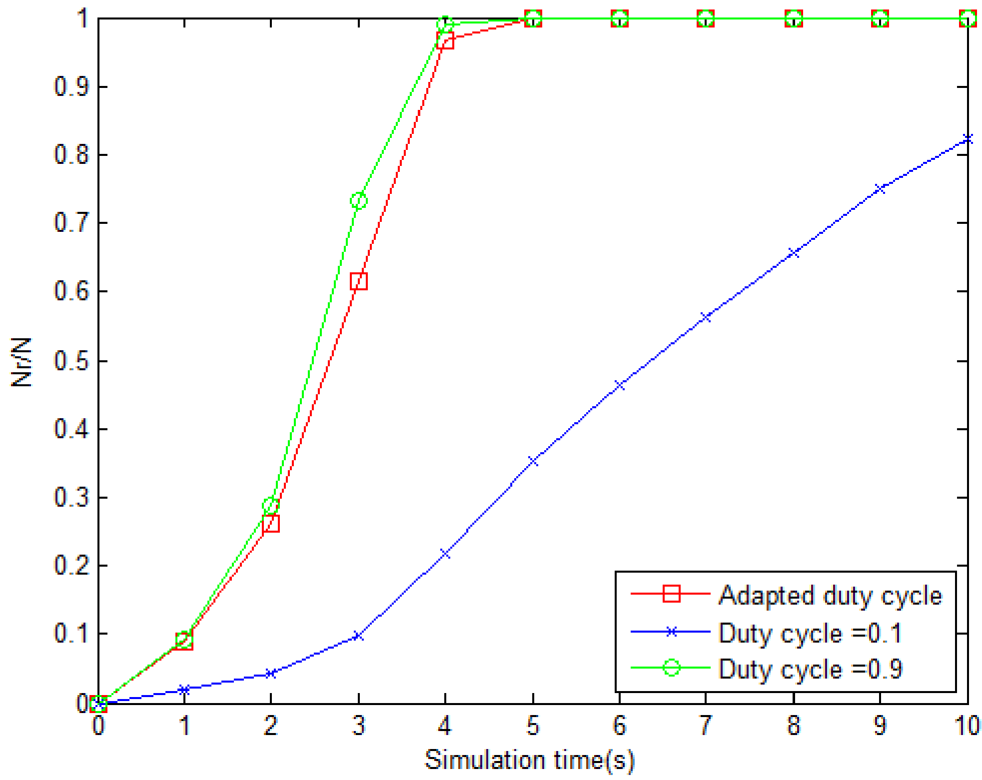
In Figure 14 the reachability is plotted versus the simulation time, in this figure it is assumed that there are 16 neighbors are reached. The other simulation parameters are all the same as in the previous simulation. In this case the averaged adapted duty cycle equals to 0.76 which almost overlaps with the fixed duty cycle of 0.9. This shows that with a higher number of desirable received node, a higher duty cycle is needed.

Figure The averaged reachability of 100 wireless sensor nodes for various duty cycles, where preamble length=0.1s,16 neighbors can be reached (Fengju, 2013)



In Figure 15 the reachability for various duty cycles versus the simulation time in combination with 100 wireless sensor nodes is plotted. It is assumed that there are 16 neighbors are reached and the preamble length equals to 0.1s. The averaged adapted duty cycle equals to 0.32 which has the same reachability as the fixed 0.9 duty cycle.In a dense network for the same amount of expected received nodes a smaller preamble is needed and has almost the same reachability as in the sparse network.

Figure The averaged reachability of 200 wireless sensor nodes for various duty cycles, where preamble length=0.1s,32 neighbors can be reached (Fengju, 2013)



For the simulation plotted in Figure 16 the preamble length equals to 0.1s and there are 200 wireless sensor nodes are deployed in the field. It is assumed that there are 32 neighbors can be reached. Therefore, the averaged adapted duty cycle is 0.31, but the reachability is almost the same as with a 0.9 duty cycle. This shows that with a denser network, a higher node density, there are more nodes reachable.

This shows that the adapted duty cycle reaches the same reachability as with a fixed 90% duty cycle at the same time, for a dense network the number of reached node are increased for each wireless sensor node. The node density estimation has an important role in the network, the optimal attainable reachability can be achieved by using an density adaptive sleep scheduling.

4-2-2 The Energy Consumption

In the previous section the reachability of various duty cycles was plotted versus the simulation time and it was shown that the adapted duty cycle has almost the same reachability as in the case of a fixed duty cycle of 0.9, which means that the wireless sensor node is almost active all the time. Nevertheless this consumes too much energy so in this section the energy consumption difference of the active period between the adapted duty cycle and a fixed 0.9 duty cycle is compared. Since both of the protocols have almost the same reachability this means that the total number of transmitting nodes is almost the same. The receiving nodes with a larger duty cycle which have a even greater chance to receive the packets consume even more energy. Thus the energy for transmitting and receiving/processing of the transmitted data is not considered in this section. The energy consumption in sleeping is very small, so it is neglected in this scenario. Only the energy consumption when a node is active was taken into account which is 12 mW (Fengju, 2013)

Figure : The energy consumption of 50 wireless sensor nodes with various duty cycle to reach 8 desirable neighbors (Fengju, 2013)

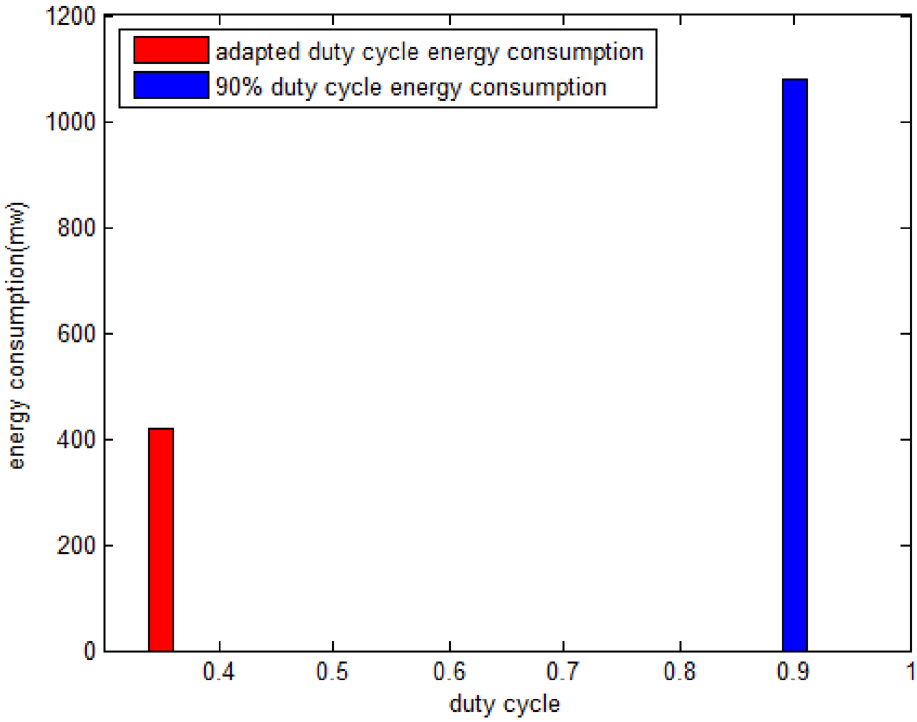


Figure 17 shows the activated energy consumption difference between the adapted duty cycle and the fixed 90% duty cycle for 50 wireless sensor nodes in order to reach 8 desirable nodes for each node. This figure only compares the energy consumption difference for these two mentioned duty cycles. Because both of them achieved almost the same amount of reachability at the same time although a fixed duty cycle of 10% uses even less energy, the obtained reachability is not the same compared to the 90% duty cycle. Thus only the energy consumption of the adapted duty cycle and the 90% duty cycle is compared. The result shows that the adapted duty cycle reduces the activated energy consumption by 61%. Since the adapted duty cycle is smaller than the 90% duty cycle, so the receiving power consumption is also smaller than that of the 90% duty cycle.

Figure : The energy consumption of 50 wireless sensor nodes with various duty cycles to reach 12 desirable neighbors (Fengju, 2013)

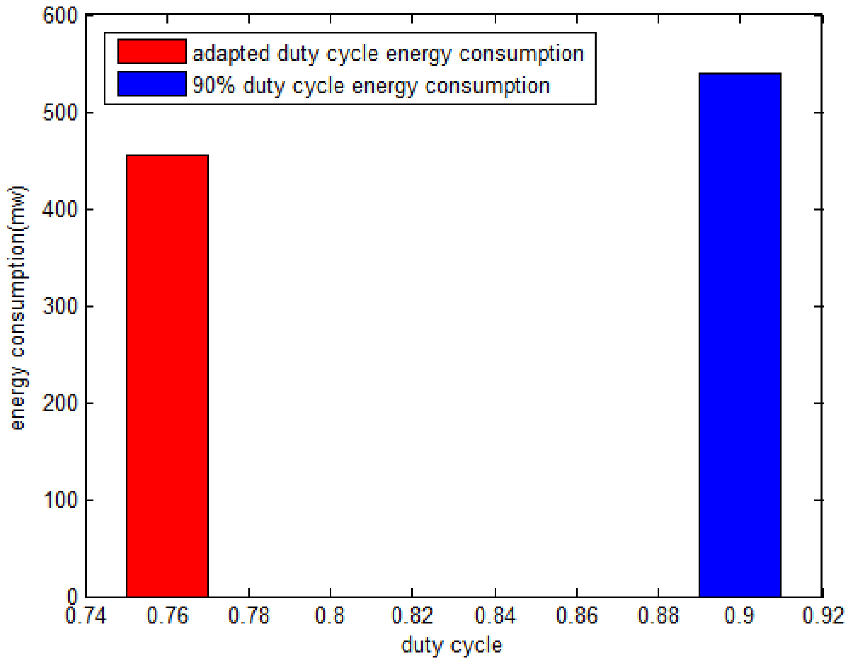


Figure 18 shows the activated energy consumption difference between the adapted duty cycle and a fixed 90% duty cycle for 50 wireless sensor nodes in order to reach 12 desirable received nodes for each wireless sensor node. This shows that the activated energy consumption is reduced by 15%. Figure shows the energy consumption difference between the adapted duty cycle and a fixed 90% duty cycle for 100 wireless sensor nodes in order to reach 12 desirable nodes for each node. The activated energy consumption is reduced by 61% . It can be seen that for a dense network and for the same number of desirable received nodes for each wireless sensor node that in the denser network the energy consumption for each node is less than that of the sparser network. It can be concluded that for the same amount of reachability a WIRELESS SENSOR NODE with a high density network the and a fixed 90% duty cycle for 200 wireless sensor nodes in order to reach 60 desirable nodes for each node. The activated energy consumption is reduced by 61%. In summary, by using the density adaptive sleep scheduling for the same amount of reachability, the energy consumption can be reduced. The energy consumption for each node can also be reduced by increasing the node density in the network. These two ways can both extend the network lifetime. (Fengju, 2013)

Figure : The energy consumption of 100 wireless sensor nodes with various duty cycles (Fengju, 2013)

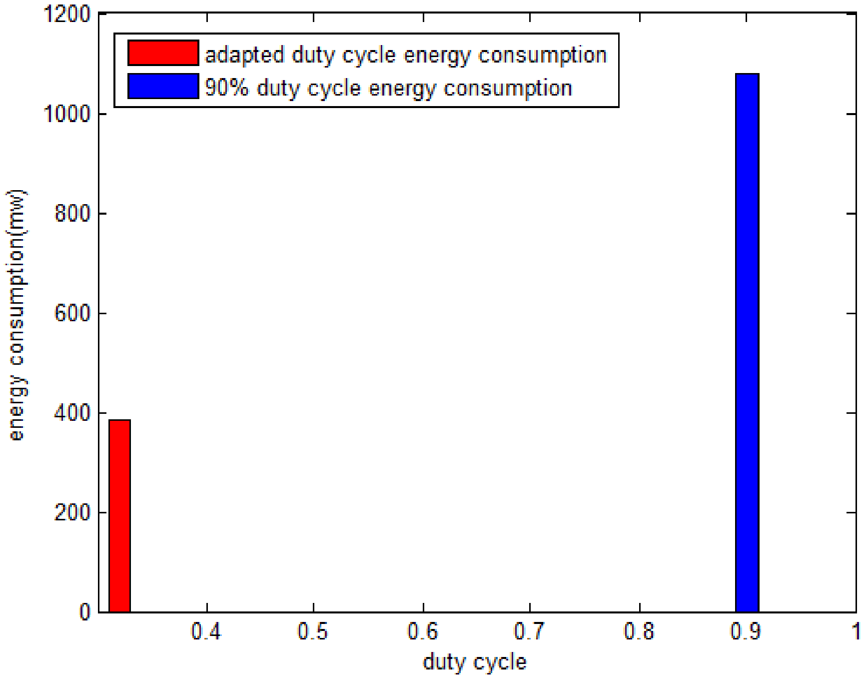
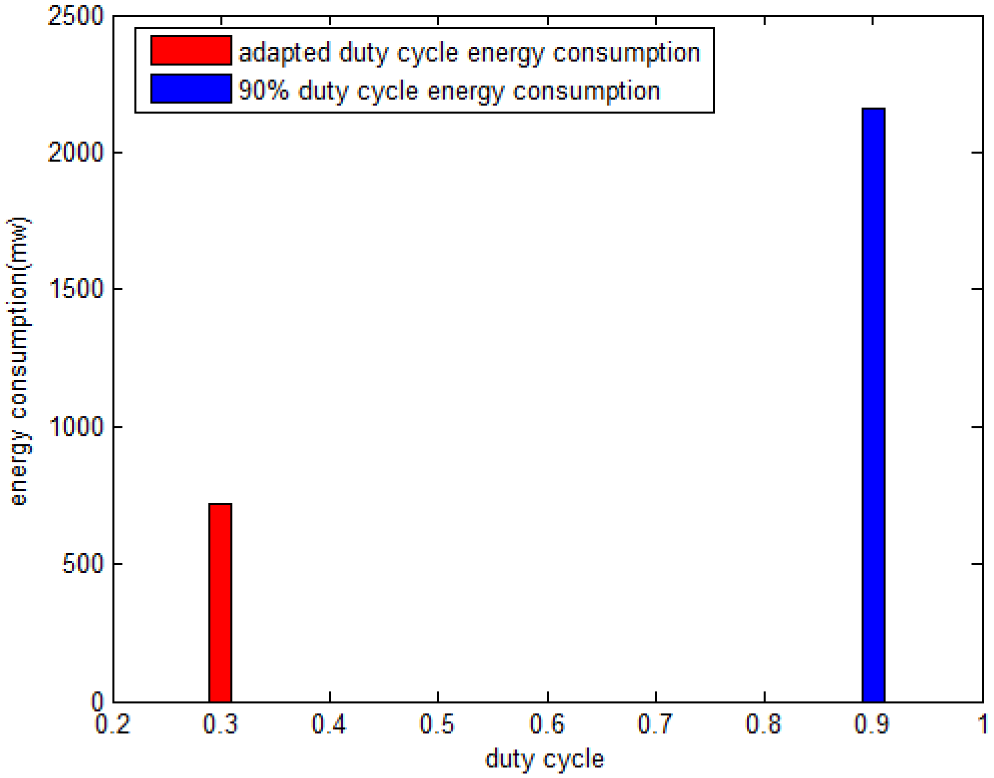


Figure : The energy consumption of 200 wireless sensor nodes with various duty cycles



4-3 Comparing with the neighborhood discovery density estimation.

There are few models to estimate the network density, one of them is based on the received power strength (RSS) which is introduced in the first section, and besides this model there is also the neighborhood discovery model which is also one of the popular models to estimate the network density. The density estimation of the neighborhood discovery model can also be used to adapt the duty cycle. The formula for the adapted duty cycle is written as:

$$d(t) = d_0 \left(\frac{1}{N(t) + 1} \right)$$

d0 is constant which equals to 0.5, N(t) is the number of the neighboring wireless sensor nodes. The needed duty cycle for each wireless sensor node is calculated. With the increase of the number of neighboring wireless sensor nodes, the duty cycle is very small. The reachability by using this adapted duty cycle is compared with the duty cycle which is proposed in this work. For each wireless sensor node there are 40% neighbors can be reached.

Figure : The comparison of the averaged reachability for 50 wireless sensor nodes between the adapted duty cycle by using RSS and the adapted duty cycle by using neighborhood discovery, preamble length = 0.1s

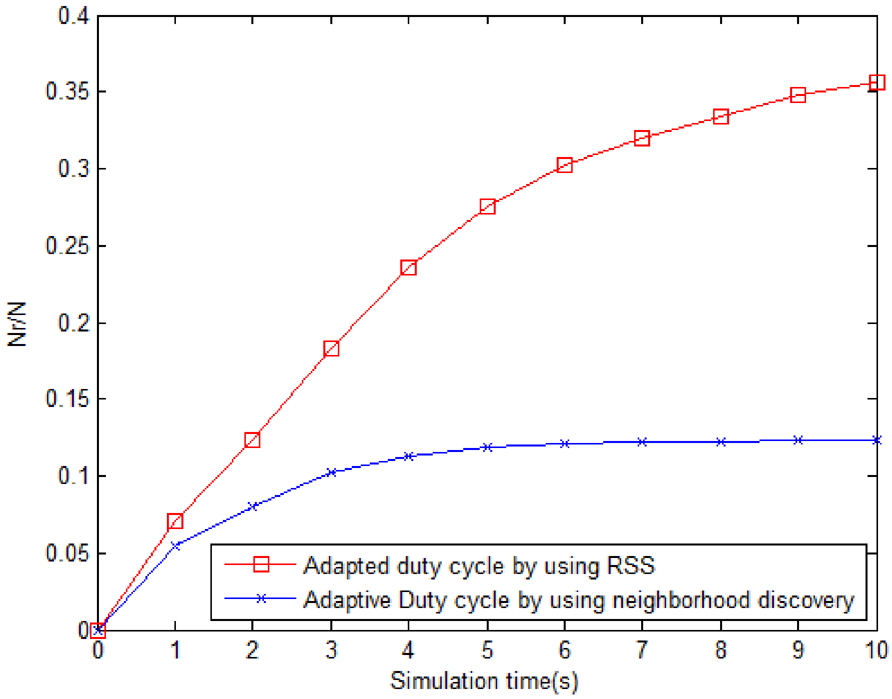


Figure 21 shows the reachability versus the simulation time for a WIRELESS SENSOR NODE with 50 wireless sensor nodes in the field. From this figure it can be seen that the reachability in combination with the adapted duty cycle by using neighborhood discovery is lower than the reachability in the case of the adapted duty cycle in combination with RSS based density estimation. The preamble length of 0.1s was used in this simulation.

Figure : The comparison of the averaged reachability for 100 wireless sensor nodes between the adapted duty cycle by using RSS and the adapted duty cycle by using neighborhood discovery, preamble length = 0.1s

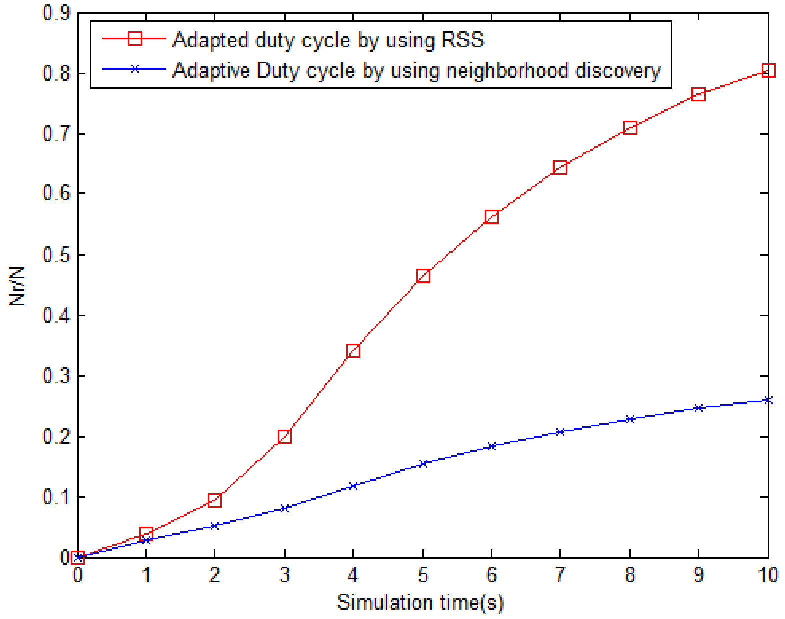


Figure 22shows the reachability versus the simulation time for a Wireless Sensor Node with 100 wireless sensor nodes in the field. From this figure it can be seen that the reachability in combination with the adapted duty cycle by using RSS based density estimation is larger than the reachability in the case of the adapted duty cycle by using neighborhood discovery. The preamble length of 0.1s was used in this simulation.

Figure : The comparison of the averaged reachability between the adapted duty cycle by using RSS and the adapted duty cycle by using neighborhood discovery, preamble length = 0.1s

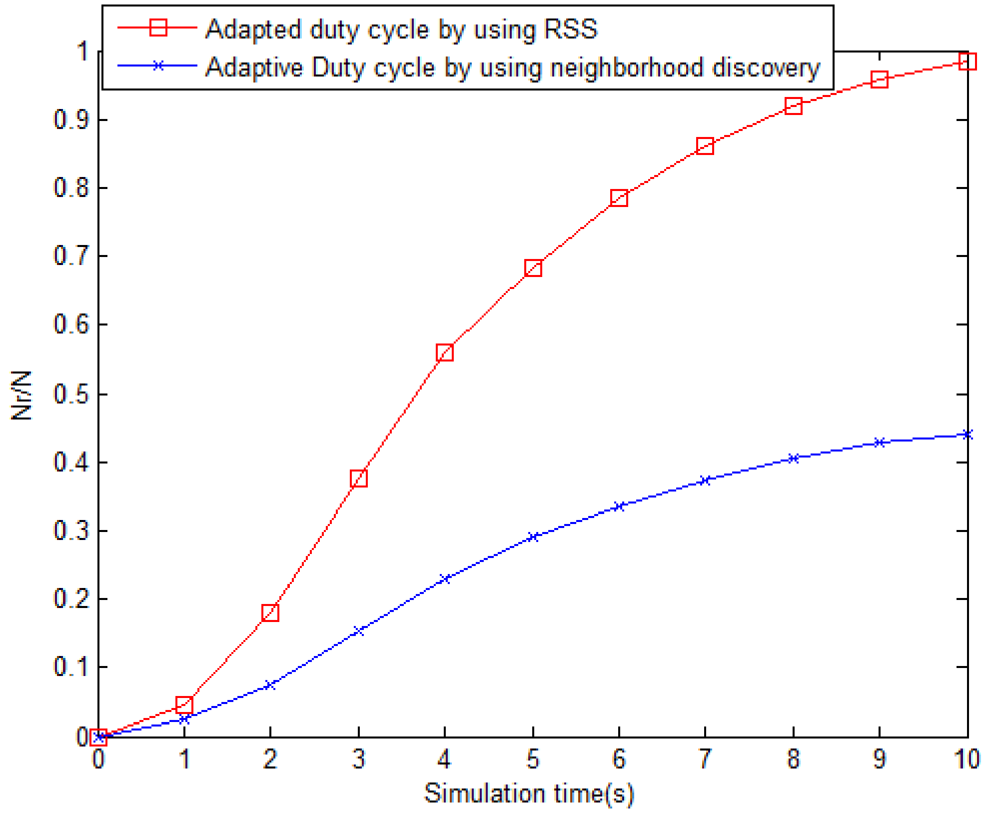


Figure 23 shows the reachability versus simulation time for a Wireless Sensor Node with 200 wireless sensor nodes in the field. From this figure it can be seen that the reachability in combination with the adapted duty cycle by using RSS based density estimation is larger than the reachability in the case of the adapted duty cycle by using neighborhood discovery. The preamble length of 0.1s is used in this simulation. From this comparison it can be concluded that the adapted duty cycle by using RSS based density estimation has a much better reachability, it does not matter if it is in a dense network or in a sparse network. The method with RSS based density estimation uses a larger duty cycle, thus it consumes more energy than the other model. The adapted duty cycle by using neighborhood discovery density estimation has a better reachability in the sparse network than in the dense network. Therefore, there is a tradeoff between these two models. It depends on what the purpose of the network is, if the reachability is more important than energy conservation then the model proposed in this work should be applied. In order to avoid the collision problem, it is assumed that there is only one neighbor can be reached for each wireless sensor node. (Fengju, 2013)Based on this assumption, the reachability versus simulation time for 50 wireless sensor nodes are plotted in Figure 23. It is can be seen that the reachability in combination with the adapted duty cycle by using RSS based density estimation is two times more than the reachability in the case of the adapted duty cycle by using neighborhood discovery. The preamble length is 0.005s in this simulation.

4-4 Conclusion

In this chapter the proposed adapted duty cycle is first compared with the fixed duty cycle and afterwards it was compared with the adapted duty cycle in combination with using neighborhood discovery density estimation. From the first comparison it shows that the adapted duty cycle has almost the same reachability as the 90% fixed duty cycle however it consumes less energy than the 90% duty cycle. Although the 10% duty cycle consumes even less energy, the reachability is incomparable with the reachability of the adapted duty cycle since it is much lower. Not only the duty cycle but also the preamble length can be reduced by increasing the node density and still maintaining the same amount of reachability. From the second comparison it can be seen that the proposed model has a much better reachability than the other method. There is also a tradeoff between the reachability and the energy consumption, if the energy consumption is more desirable then is preferred. Otherwise the model proposed in this work should be used, it gives a high reachability within a short time.

CHAPTER 5: DISCUSSION OF FINDINGS AND CONCLUSION

5.1 Discussion of Findings

From the results of the research it is evident that path loss varies upwards with increase in distance between the nodes. The Previous section demonstrates a steady rise in data and path loss with increase in distance between the transmitter and the receiver. This implies that when a data relay is used, the interference on the signal due to free space data and path loss is reduced thus enhancing energy reduction during transmission. Wireless node placement in relation to coordinator and relay can vary to achieve optimal distance separating the transmitter and receiver. The received signal strength indicator (RSSI) parameter can be used to check the signal strength. From the simulation model, a peridogram is used to capture this on magnitude verses frequency plot as shown in the following:

5.2 Performance Metrics

5.2.1 Path Loss Calculation

Path loss shows the relative strength between the transmitted power at the sending wireless node and received power at the wireless receiver. The path loss between the wireless sending and the wireless receiving antenna was calculated as a function of distance parameter using the formula described earlier in equation (1):

$$PL(d) = PL0 + 10n\log10(d/d0)$$

5.3 Conclusion

In a Wireless Sensor Node it is not necessary for each wireless sensor node to be active all the time so in this work an asynchronous sleep scheduling is proposed by using an adapted duty cycle where the duty cycle is based on the RSS density estimation for each wireless sensor node. In this work it shows that the effects of the wireless sensor node density on the needed duty cycle in order to reach the same reachability. From Chapter 3 it was concluded that with the increases of the duty cycle, the reachability also increases. When the network density increases then the reachability also increases for the same duty cycle. For the same amount of reachability in combination with a higher wireless sensor node density a lower duty cycle can be used and within a shorter time. However, for a Wireless Sensor Node with a lower wireless sensor node density a higher duty cycle is needed and it may take a longer time to reach the same reachability. This indicated that the duty cycle needs to be adapted to the network density. Besides the effects of the duty cycle, the preamble also plays an important role. From the simulation results it can be seen that with the increase of the preamble length, the reachability also increases for the same network typology. In order to reach the same amount of reachability in a shorter time a longer preamble can be used. But the trade off is that a longer preamble length costs more energy of the transmitter. However, a smaller preamble length needs a longer time to reach the same reachability. (Fengju, 2013)

For reaching the same amount of reachability in a dense network a smaller preamble length is needed. In contrary, in a sparse network a longer preamble length should be used. Based on the effects described above an analytical model was given which shows that the expected number of the received nodes is a function of the wireless sensor node density nodes/m2, the transmission range R m, the preamble p and the duty cycled. Through the validation it can be seen that the analytical model and matlab simulation matches to each other. It can be concluded that by increasing the duty cycle, the number of the reached nodes always increases. Further effects that influence the number of the reached nodes are if the node density increases, or the transmission range increases, or the preamble length increases then the number of the reached nodes also increases. The percentage of the number of the reached neighbors over the total number of the neighbors keeps the same if the transmission range increases, or the node density increase. With the increase of the preamble the percentage of the number of the reached neighbors over the total number of the neighbors also increases. It was also proved that for a Wireless Sensor Node the same amount of reachability can be achieved by either using a smaller preamble length in combination with a larger duty cycle or a lager preamble length in combination with a smaller duty cycle. Finally the proposed duty cycle is compared with the fixed duty cycle and the adapted duty cycle in combination with using neighborhood discovery density estimation. From the first comparison it shows that e adapted duty cycle has almost the same reachability as the 90% fixed duty cycle however it consumes less energy than the 90% duty cycle. As stated by (Fengju, 2013) Although the 10% duty cycle consumes even less energy, the reachability is incomparable with the reachability of the adapted duty cycle since it is much lower. Not only the duty cycle but also the preamble length can be reduced by increasing the node density and still maintaining the same amount of reachability. From the second comparison it can be seen that the proposed model has a much better reachability than the other method. There is also a tradeoff between the reachability and the energy consumption, if the energy consumption is more desirable then is preferred. Otherwise the model proposed in this work should be used; it gives a high reachability within a short time.

5-2 Future work

Possible future works concerning extensions or improvements for the adapted duty cycle algorithm based on the RSS density estimation of each wireless sensor node can be:

- Since cooperative density estimation has less variance, the cooperative density estimation can be simulated to adapt the duty cycle.
- Collision detection.
- Energy consumption can be simulated.
- Path loss exponent can be changed from 3 to 6, consider the shadowing effect, multi-path effect, etc.
- A real life application can be implemented.

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