Universidad Autónoma de Baja California - UABC

FACULTAD DE INGENIERIA, ARQUITECTURA Y DISEÑO

MAESTRIA Y DOCTORADO EN CIENCIAS E INGENIERIA

MNH-WSN (Mobile Node Based Handoff for Wireless Sensor Network)

THESIS

In Partial Fulfillment for The Requirement of The Master's Degree of Engineering

By

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Ensenada, Baja California, Mexico May 2017

"MNH-WSN (Mobile Node Based Handoff for Wireless Sensor Network)"

A Thesis Submitted to Department of Telemática, Facultad De Ingeniería, Arquitectura Y Diseño, UABC, Universidad Autónoma de Baja California, In Partial Fulfillment for The Requirement of The Master's Degree of Engineering In (Network Engineering)

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February 2017

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CERTIFICATION

I, the Undersigned Certify that I have read the Thesis entitled:" MNH-WSN (Mobile Node Based Handoff for Wireless Sensor Network)" and hereby recommend for acceptance by the Universidad Autónoma de Baja California in partial fulfillment of the requirements for the degree of Master of engineering in Network Engineering.

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APPROVAL PAGE

This thesis entitled **“**MNH-WSN (Mobile Node Based Handoff for Wireless Sensor Network)” has been approved by the following examiner; chairman and department head for the degree of master of engineering in Networking Engineering at Universidad Autónoma de Baja California.

Date of Defense: <u>28/ 07 / 2017</u>

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DEDICATION

Dedicate to:

My Father, I may not be able to wish my dad a Happy Father's Day but I wish all fathers out there a joyous and fulfilling one. Even if you're not with your children—know that they love you just like I will always love my Daddy(MAMO) though he is no longer here with me, (Alhamdulillah).

ACKNOWLEDGEMENTS

Above all my thanks to the Almighty God, and. For his mercy and grace up on me during my education and life career. I would like to express my deepest gratitude to my thesis Advisor and instructor Dr. Juan-Ivan NIETO-HIPOLITO, for his valuable advice, guidance, encouragement and critical comment during this work. His contribution was appreciable. Even with a lot of work engaged we have discussed many times in his work and rest time. He devoted his time from the beginning of the thesis title to the completion of the thesis work. Without him this thesis would not have been realized. He is also the one practically taught me what responsibility, commitment and punctuality mean on the working process of my work.

I would like to express my sincere gratitude to my sponsor, Government and people of Mexico: helping me to have international scholarship and funding my costs.

I would like also to thank university of autonomous university of Baja California, Mexico (UABC), all the teachers, student and Staffs for their help by providing any type of data to conduct this work, her also I would like to thank especial person Carlos Ruben Aguilar Benson for his valuable support by giving necessary information about the software.

I am also indebted to all my friends, knowledge sharing and amazing time we spend together during my stay at UABC. I would like also to express my heartfelt thanks to my Family for all the scarification they made during my study. Without their support, it was impossible for me my second dream was real. I am indebted in countless ways, priceless & endless support. there continuous advice and encouragement were a synergy for my study. I would like to express my sincere thanks to all peoples around me for their day to day encouragement and support.

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ABSTRACT

Abstract— this document analyzes and implement a MAC layer handoff mechanism for WSN by introduce effective algorithm for reducing handoff time. By managing handoff from Mobile node (MN) side. At the end of the thesis it will show how, with this approach, it is possible to reduce mobile node handoff delay effectively. Every result shown in the analysis is done both in simulation and real-time implementation of algorithm. A result shows that, the total handoff delay time is the effective time duration achieved in handoff handling of mobile sensors. Physical environment test is done for sensor applications working in hospital and home, considering that sensors in such environment are used for very sensitive data communication, that's why it's very important to analyze the algorithm both in real environment and simulation. That's what is done.

Key words: *Mobility, Handoff, WSNs, IEEE 802.15.4, Data sending, notification*.

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LIST OF ACRONYMS AND ABBREVIATIONS

CN	coordinator node
CSMA-CA	carrier sense multiple access with collision avoidance
ED	energy detection
FCS	frame check sequence
FFD	full-function device
GTS	guaranteed time slot
LQI	link quality indication
LPDU	logical link control protocol data unit
LR-WPAN	low-rate wireless personal area network
LSB	least significant bit
MAC	medium access control
MCPS	MAC common part sublayer
MCPS-SAP	MAC common part sublayer service access point
MFR	MAC footer
MHR	MAC header
MIC	message integrity code
MLME	MAC sublayer management entity
MN	mobile node
MLME-SAP	MAC sublayer management entity service access point
MNH-WSN	Mobile Node based Handoff for Wireless Sensor Network
MSB	Most significant bit
MPDU	MAC protocol data unit
MSDU	MAC service data unit
PAN	personal area network

PC	personal computer
PD	PHY data
PD-SAP	PHY data service access point
PER	packet error rate
PHR	PHY header
PHY	physical layer
PIB	personal area network information base
PICS	protocol implementation conformance statement
PLL	phase-locked loop
PLME	physical layer management entity
PLME-SAP	physical layer management entity service access point
PN	pseudo-random noise
PPDU	PHY protocol data unit
PPM	pulse position modulation
PRBS	pseudo-random binary sequence
PRF	pulse repetition frequency
PSD	power spectral density
PSDU	PHY service data unit
PSSS	parallel sequence spread spectrum
RDEV	ranging-capable device
RF	radio frequency
RFD	reduced-function device
RFRAME	ranging frame
RMARKER	ranging marker
RSSI	receive signal strength indicator
RX	receive or receiver

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SDS-TWR	symmetric double-sided two-way ranging
SFD	start-of-frame delimiter
SHR	synchronization header
SIFS	short interframe spacing
SN	sink node
SNR	signal-to-noise ratio
TRX	transceiver
TX	transmit or transmitter
UWB	ultra-wide band
WPAN	wireless personal area network
WSN	wireless sensor network

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Table of Contents

kedir.besher@uabc.edu.mx

kedir.besher@uabc.edu.mx

List of Tables

kedir.besher@uabc.edu.mx

List of Figures

kedir.besher@uabc.edu.mx

Chapter 1 INTRODUCTION

1.1 Background information of the Organization

1.1.1 Mission of the organization

The major mission are integrally forming professional citizens , competent national, cross-border and international , free, critical, creative, supportive, entrepreneurial local levels, with a global, aware of their participation in global and capable sustainable development to transform their environment responsible vision and ethical comment ;and to promote, generate, implement, disseminate and transfer knowledge to contribute to sustainable development, the advantage of science, technology, humanist, and innovation of the Baja California and for the country [40].

1.1.2 Vision of the organization

In 2025, the UABC widely recognized as society responsible institute that contributes timely, relevant, and highest quality standards to increase the level of human development of Baja California society and the whole country, as well as being one of the five best education institutes in Mexico and the first 50 of Latin America in university education, generation innovative application and transfer of knowledge and promotion of science, culture and art [40].

1.2. Background of The Thesis

A wireless sensor network (WSN) consists of tiny devices which can be adjusted anywhere and can be attached to anything which is implemented using IEEE 802.15.4 standard. Due to these unique characteristics and low cost deployment, WSNs have rapidly developed in recent years. In traditional WSN, sensor nodes are static and hence very less amount of research work has been done in designing protocols for mobility management. But now days the major thing behind these mobile devices is making them confidential in their connection while they are moving, handoff. Improving handoff protocol to enhance mobility of sensor nodes will be accomplished by identifying trends and failed processes with the goal to reduce handoff delay times and data lost during the handoff.

The most valuable information collected through researchers that provides the weaknesses or errors that may occur during handoffs [1,2,3,4].

1. Poor handoff management protocol which is factor to medical error with inadequate handoffs playing a key role [1].

2. Full scanning which increases handoff delay during switching between different CNs. The delay sometimes reaches 90% of the total switching time which ultimately leads to high packet loss and breaking of connection [3,4].

3. Commonly existing handoff protocols are embedded in CN to manage MN mobility.

4. Limited mechanism of notifying the upper data layer to stop data sending during handoff.

5. Most of the schemes use parameters such as bandwidth and data rate for handoff. Similarly, researchers designed different schemes such as partial and per scanning which require less energy compared to traditional schemes [5]. Pre-scanning scheme scans available networks at once and hence there is no need to scan the available networks again and again. Similarly, partial scanning schemes scan only those networks which are available near the MN and hence require-less energy.

In a WSN environment, a MN is provided with the ability to move freely in a network of different CNs and it must be provided with the capacity of attaching to a new CN. Therefore, a handoff mechanism needs to provide WSNs to softly transfer the communication from one CN to another. These types of WSNs require frequent and dynamic topology to maintain the connection between the individual sensor nodes [8, 9]. Considering all these factors, this document proposes a new fast handoff mechanism described chapter 4 of this document.

1.3. Justification of The Investigation

The rapid evolution of wireless technologies and the significant growth of Wireless network services have made wireless communications a ubiquitous means for transporting information across many different domains. Within the framework of Wireless Sensor Networks (WSNs), there are many potential possibilities where a WSN can be deployed to support numerous applications. However, the current applications in real-life are very limited. The main reason for the delay in the adoption is the lack of a system level approach.

In this work, implementation environment is proposed for monitoring vital signs of patients at home and hospital. This scenario requires inter cell mobility; however, limited number of handoff mechanisms are designed to support this characteristic, so this is the primary factor incited as to work about the use of WSN in the field.

So here, MAC-layer protocol to manage handoff, called MNH-WSN (Mobile Node Based Handoff for Wireless Sensor Networks), which operates in the medium access control (MAC) sub-layer based on an interaction between the layers (physical and MAC). The protocol interacts with a sending data mechanism (like TCP protocol) to notify the starting or ending of a handoff process; therefore, the mechanism can stop or resume data sending, respectively. It prevents packet loss during the handoff process. MNH-WSN comprises two main processes to manage mobility: first the mobile node itself Monitor the overall connection status, update and check part, and Mobile Node Handoff Execution Process (HEP); they are responsible for generating the handoff notification messages and executing the handoff process, respectively. Therefore, the delays during these steps are used as the key performance metrics. To evaluate the proposal, physical test-bed in an indoor environment with the intention of obtaining practical results are used. The results demonstrate that the proposed protocol performs the handoff process with less delay than the selected reference work[1,13]. Also show that MNH-WSN is an appropriate solution to provide inter-cell mobility in WSNs. Furthermore, demonstrate the possibility of embedding the protocol in devices with limited resources using the IEEE 802.1.5.4 standard.

1.4. Contribution of The Thesis

To summarize the contributions of this work as follows:

1. Check and update part: MNH-WSN Have check and update part before handoff execution which is used to notify data sending mechanism before handoff start which lower the data loss during the process. Received signal strength (LQI) is used as decision criteria and pre-established thresholds, to effectively measure the link quality, avoiding unnecessary handoffs (the ping-pong effect). And constricting CN list table used for further processes.

2. HEP: MNH-WSN also, includes the Handoff Execution Process called (HEP) to enable mobility on MNs, based on an Early Discovery strategy. Here it allows MN to discover other CNs while the MN is still connected to its current CN. In addition, HEP notifies to the sending data mechanism when the handoff process finishes.

3. Implement MNH-WSN in a physical test-bed to validate its operation, and measures its performance, in intention to offers operational results of a handoff protocol.

4. During development considering power management, minimum delay time and money etc.) to make effective protocol.

1.5. Problem Statement

Routing in WSNs is challenging due to the inherent characteristics that distinguish them from other wireless networks. The main problem of statement is that there is limited number of special protocol that support the work of wireless sensor networks in the field of health or most of protocols with many problems. The other reason is that there is few mechanism to sending data (like TCP protocol) to notify the starting or ending of the handoff process so that prevents packet loss during the handoff process. More, most of handoff management protocols are managed or implemented from coordinator side but their use is for mobile node (end devices) just simply considering their limitation.

Generally, with some existing protocols in the area we have one of the following problems:

Scalability - The key questions that people are asking in this area are: whether wireless networks are scalable? According to Reference [22], the scalability of a method in a network is measured with respect to the triplet (environment E, independent parameter P, primary metric M). A method is scalable if the primary metric(s) considered does not become arbitrarily large when the independent parameter tends to be infinity in a environment defined by a certain set of environmental variables.

Fault tolerance - Sensor nodes are prone to failures. Some sensor nodes may fail or be blocked due to lack of power, physical damage or environmental interference. The failure of a few or all sensor nodes should not affect the overall task of the protocol sensor network.

Energy - Unlike traditional networks, where the focus is on maximizing throughput or minimizing node deployment, the major consideration in a sensor network is to extend the system lifetime, as well as extend system robustness. An interesting fact is that communication dominates processing in energy consumption. Thus, to make optimal use of energy, communication should be minimized as much as possible.

Simplicity - Sensors are usually low-cost devices with severe constraints in respect to energy source, power, computational capability and memory. Thus, the operating and networking software of a sensor node must be kept simpler as compared to desktop computers. This simplicity sometimes requires a break with conventional layering rules for networking software, since abstractions typically cost time and space.

Redundancy - Sensor nodes are densely deployed. This densely deployed network enables both data aggregation and multipath routing. Data aggregation is a method of accumulating data into one aggregated record that is otherwise presented through multiple records.

Dynamic changes - The topology of a sensor network changes very frequently due to mobility and failures. A sensor network system must be adaptable to changing connectivity (e.g., due to addition of more nodes, failure of nodes, etc.), as well as changing environmental stimuli.

In this thesis, mainly address to minimize the problems listed above and the others as much as possible because the varying application scenarios of wireless sensor networks require different routing protocols and approaches as well.

1.6 Objective of The Thesis

1.6.1 General Objective

Develop and implement a MAC-layer protocol to manage the handoff called MNH-WSN (Mobile Node Based Handoff for Wireless Sensor Network), which operates in the medium access control (MAC) sub-layer based on an interaction between the layers (physical and MAC).

1.6.2 Specific Objective

1. The protocol interacts with a sending data mechanism (like TCP protocol) to notify the starting or ending of the handoff process.

2. Develop Mechanism to prevents packet loss during the handoff process using HEP.

3. MNH-WSN comprises check and update, and handoff execution Process (HEP) parts.

4. Embedding handoff management in MN to make handoff easy and lower time delay.

5. Combing soft handoff, hard handoff and early discovery.

6. Implementing MNH-WSN in real environment test, validate its operation and collecting results.

This protocol considers the effectiveness of scalability, energy usage, fault tolerance, simplicity, redundancy, dynamic changes and many more related modern technologies in the field.

N.B All objectives mentioned above take place from MN side because in mobility is all time from mobile node side.

1.7 Significance of The Study

Medical Monitoring: A different application domain that can make use of wireless sensor network technology can be found in medical monitoring. This field ranges from monitoring patients in the hospital using wireless sensors to remove the constraints of tethering patients to big, bulky, wired monitoring devices, to monitoring patients in mass casualty situations [24], to monitoring people in their everyday lives to provide early detection and intervention for several types of disease [25]. This is a challenging environment in which dependable, flexible, applications must be designed using sensor data as input. Consider a personal health monitor application running on a computer that receives and analyzes data from several sensors (e.g., ECG, EMG, blood pressure, blood flow, pulse oximeter). The monitor reacts to potential health risks and records health information in a local database. that most sensors used by the personal health monitor will be use wireless communication, this application requires networking protocols that are efficient, reliable, scalable and secure. and existing network protocols are not suitable for these types of sensor network applications.

1.8 Scope of The Study

Scope of this work is developing and implementing a MAC-layer protocol to manage the handoff called MNH-WSN (Mobile Node Based Handoff for Wireless Sensor Network), which operates in the medium access control (MAC) sub-layer based on an interaction between the layers. This protocol interacts with a sending data mechanism (like TCP protocol) to notify the starting or ending of the handoff process; therefore, the mechanism can stop or resume data sending, respectively.

1.9 Target Beneficiaries of The Protocol

Implementing this scheme will increase the quality of service by monitoring MN's from CN to CN with reasonable time delay. Which make the implemented network manageable by itself without human interference. So, having self-manageable network environment will better the users(audience). The target audience of this protocol is principally elders, doctors and practitioners who wish to improve the quality and equity of their general medication system. Key beneficiaries would be organizations, hospitals, whose capacities for identifying quality constraints of their systems and to effectively redress those constraints would be enhanced. elders, doctors, their families and their communities are the ultimate beneficiaries: Especially elders with hard problems.

1.10 Technical & Operational Feasibility

The biggest technical challenge would be to have the distribution of CN in the area and battery life of the sensors so that the protocol works as accurately as possible. Once in place, the training of the employees takes a few days for them to be totally comfortable. Maintenance will be needed on the protocol for the addition of new activities. This maintenance will be done by any expert in the area. The technology I implemented is very reliable to ensure smooth transactions of data but will require updates when new products are introduced.

1.11 Legal & Political Feasibility

Since this is a thesis there's very few people involved. The biggest stakeholder would be the owners. So, in all manner it is legal.

1.12 Research Methodology

In Wireless Sensor Network (WSN), gathering sensed information and relay it to the base station using multi-hop communication in an energy efficient manner is of prominent importance [26]. Hardware implementation results prove that proposed scheme is effective to collect Intelligent Data at the Base station. The new protocol uses a wireless sensor network (WSN) to collect data which consists of spatially distributed autonomous sensors to cooperatively monitor physical or health conditions of the person, such as temperature, blood pressure, ECG.

A common function of sensor networks in which the information is sampled at sensor nodes and are transported to central base stations for further processing and analysis in this step MNH-WSN manages the success or faller of data sending, receiving process using MNH-WSN. It is known that time sensitive data needs to be transmitted back to the station in a near real time fashion for many data gathering applications such as sensors working with MNH-WSN because it is health related application and it use this data gathered from the sensors as an input and send for the doctor or the machine working with the system.

The three major stages of data collection are namely the deployment stage, the control message dissemination stage and the data delivery stage are managed with the effective manner as described by authors [27] [1]. Data gathering of MNH-WSN can reduce the communication cost, thereby extending the lifetime of sensor networks. It also can reduce the number of data packets transmitted and the data conflict thus raises the data accuracy and data collection efficiency through dealing with the redundant data in-network. The inherent redundancy in raw data collected from the sensors can often be eliminated by in-network data gathering. [28]. So, most of the work is not related to user based questioners and comments because it is all about expert based protocol, that means I did not enforced to propose questioners for the work.

1.12 Limitation of The Project

For a moment, biggest limitation is time, even if the protocol is doing well as proposed but still there are some ideas to improve like things what mentioned in recommendation part (6.3).

1.13 Outline of the thesis

The work is broken down into 7 steps and it will take about 1 year to complete. The thesis is broken down like this because it's the most effective way of completing. The structure of this schedule allows developer enough time to fully develop the Protocol to its wanted potential.

Outline of the thesis	**2015**	**2016**		**2017**	
		1st	**2nd**	**1st**	**2nd**
1 Introduction	■	■			
2 A state of the art survey in the communication of wireless sensor networks is presented.	■	■			
3. Technical Overview of IEEE 802.15.4 routing in wireless adhoc and sensor networks.	■		■		
4. General Scenarios.	■		■		
5.MNWSN-HaDaS Protocol	■			■	
6.Experimental Setup and Evaluation Metrics	■			■	
7. Analysis of Results	■				■

Table 1-1 Time table

1.14 Conclusion of The Chapter

To conclude the chapter, all about developing and implement a MAC-layer protocol to manage the handoff called MNH-WSN (Mobile Node Based Handoff for Wireless Sensor Network). By addressing major questions. first, reason why need to develop this protocol (MNH-WSN), because of limited protocols that support mobility of WSN and even the existing once take too much time to execute handoff mechanism more handoff is all about mobility, means handoff management is for mobile node but few existing are trying to manage mobility from CN side even mobility is all about MN, which is solved in this work. Second, solving the problem by dividing protocol in two various parts: check and update, and HEP which are responsible for generating the handoff notification messages and executing the handoff process, respectively. Third, scope coverage, developing and Implementing MNH-WSN in real environment test, validate its operation and collecting results. During development, it considered for WSN which work in health-related applications but after completing the protocol it's checked that works for any application as a general. In the final part of the chapter try to explain how much the new protocol is cost feasible, as shown there is no especial needed resource to implement the protocol in once WSN environment, that means it is cost effective.

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Chapter 2 LITRATURE REVIEW

2.1 Introduction of Existing Works

Understanding the mobility patterns of nodes is essential to design realistic models and resource efficient mobility estimation mechanisms. Based on the expected mobility patterns, protocol design can make plausible assumptions in dealing with communication handoff. This section deals with higher-level mobility patterns in wireless sensor networks and the abstract models that can represent them.

For MS-MAC [37,38,39] protocol, one obvious advantage is that a mobile node can keep transmitting and receiving data packets with its original neighbors while establishing connection with the nodes in a new virtual cluster. However, frequent synchronization can lead to high energy consumption. And such energy consumption is not limited to the mobile node itself, but also to all the neighbors which are two-hops away from it. Therefore, the neighbors may deplete their energy quickly even if they are stationary. From this point of view, the handover mechanism of MS-MAC is implemented by trading-off a higher energy expenditure of the neighbors around a mobile node for a lower latency in setting up a connection with a new virtual cluster.

The authors in [9] present an evaluation to compare signal strength and the number of frame retransmissions as a decision criterion for the start of handoff in wireless local area networks (WLANs). For this evaluation, authors employed the FTP and VoIP applications in a real environment and examined the effectiveness of these two criteria in terms of performance degradation due to reduction of signal strength and radio interference. Their results show that the performance degradation during handoff can be effectively prevented by utilizing the number of frame retransmissions. However, to implement this decision criterion it is required that the network's nodes implement the functions of acknowledgment and retransmission of packets, producing an increase in network traffic and energy consumption, which are critical parameters in WSNs unlike WLANs. The authors in [5][1] propose a handoff mechanism for health-care monitoring based on RSS. These works provide two important contributions: i) experiments on a real platform based on IEEE 802.15.4 radios to set two key thresholds: the minimum value of the link quality to start the handoff (-90 dBm) and the hysteresis margin necessary to complete the transfer (5 dBm). ii) it demonstrates the intrinsic relationship between handoffs and the transitional region; the evaluation showed that the most effective handoffs occur at the lower end of the transitional region just before moving to the disconnection region. A weakness found in [5] is that they use an unrealistic scenario since they did not include people carrying sensors across different rooms to capture the blocking effects of the human body and non-line of sight.

Authors in [10] made an empirical analysis about measurements in IEEE 802.11 wireless networks. Their focus was to evaluate the network performance under a proprietary handoff process. Their main contribution related to MNH-WSN was about the measuring methodology used. The author’s focus was scanning delays on MNs. Their conclusions gave me insights about key considerations for a handoff protocol. The authors of [11] propose a tier structure to join a static set of sensor devices and MNs. Static nodes perform backhaul tasks (such as routing data to SNs), while MNs use layer two backhaul services for data transmission. Their handoff protocol is triggered by RSS parameters. Their experimental results demonstrated that there are suitable conditions for mobility in devices using the IEEE 802.15.4 standard. Authors in [12] propose a soft handoff mechanism as part of a framework to support mobility in a WSN, which prevents connectivity breaks while the sensor nodes are moving. Furthermore, the proposal is characterized by the multi-sink approach to have shorter routes and reduce routing complexity. It also explains how to predict the link quality to allow mobile nodes to decide when to choose another SN. They implement a physical test-bed using IEEE 802.15.4 devices to evaluate the average delay of the soft handoff, this paper is used to compare the results of MNH-WSN. The main differences between the MNH-WSN and the reviewed solutions are: specific MAC layer design and soft handoff mechanism. These two main differences allow MNH-WSN to achieve the main goal of its design, which is to carry out a handoff process with the least impact on applications, as in results part shown.

2.2 Major Functions in The Existing Works

In paper [1], cross-layer protocol to manage the handoff, called WSN-HaDaS (Handoff aware of Data Sending), which operates in the transport layer and medium access control (MAC) sub-layer based on an interaction between the layers (transport and MAC). This protocol interacts with a sending data mechanism (like TCP protocol) to notify the starting or ending of the handoff process;

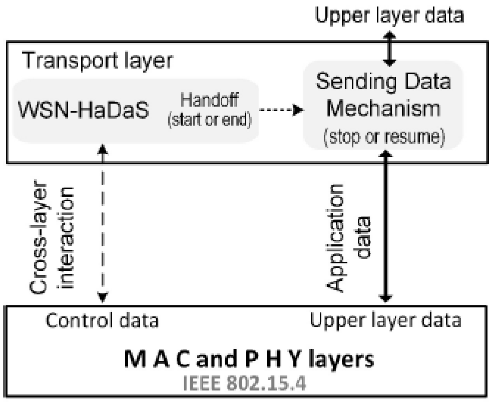

Figure 2-1 Cross-layer architecture of WSN-HaDaS Protocol [1]

therefore, the mechanism can stop or resume data sending, respectively. two main processes to manage mobility: here they have two major parts, The Monitoring Handoff Trigger (MHT) and Handoff Execution Process (HEP); they are responsible for generating the handoff warning messages and executing the handoff process, respectively.

Delay	Minimal	Maximal	Average	Std deviation
MHT	263	808	530	178.3
Hard-Handoff	2464	2749	2662	124.9
Soft-Handoff	792	841	823	19.4
Request session	83	86	84.66	1.07
Resume data	82	85	83.5	0.81

Table 2-1Average delay for each evaluation metric (milliseconds) [1]

Thus, the contribution of this paper [29] is threefold. First, using link quality indicator (LQI) history, a proactive algorithm is developed which tries to anticipate if the node is going to lose connectivity before it really happens. Second, they develop a fast coordinator discovery scheme that prevents a node from scanning all available channels. Third, developed an intelligent algorithm to choose the best coordinator to prolong the node connectivity time if possible. All three updates are designed considering the low computational power of the sensor node. In a beacon-enabled network, nodes should scan every single available channel to discover coordinators around. Here, they present a novel association scheme called greedy channel scan (GCS) that prevents node from scanning all available channels. The main idea of GCS is to scan only first few channels. However, the network setup algorithm has been developed in such a way that scanning only few channels is sufficient for the efficient neighbor discovery and association. The first algorithm tries to anticipate the link breakage by analyzing the LQI history. Thus, the algorithm decreases the time required by node to realize the link breakage from the coordinator. The second algorithm enables mobile node to scan only few channels and acquires network information about all the coordinators in the vicinity. The third algorithm increases the node connectivity time with a coordinator by performing handover to the coordinator that gives the longest connectivity time. The algorithm tries to anticipate if a node is moving away from or toward a coordinator by examining the LQI of the multiple beacons received from the same coordinator. The proposed association scheme provides support for mobility without involvement of any higher layer.

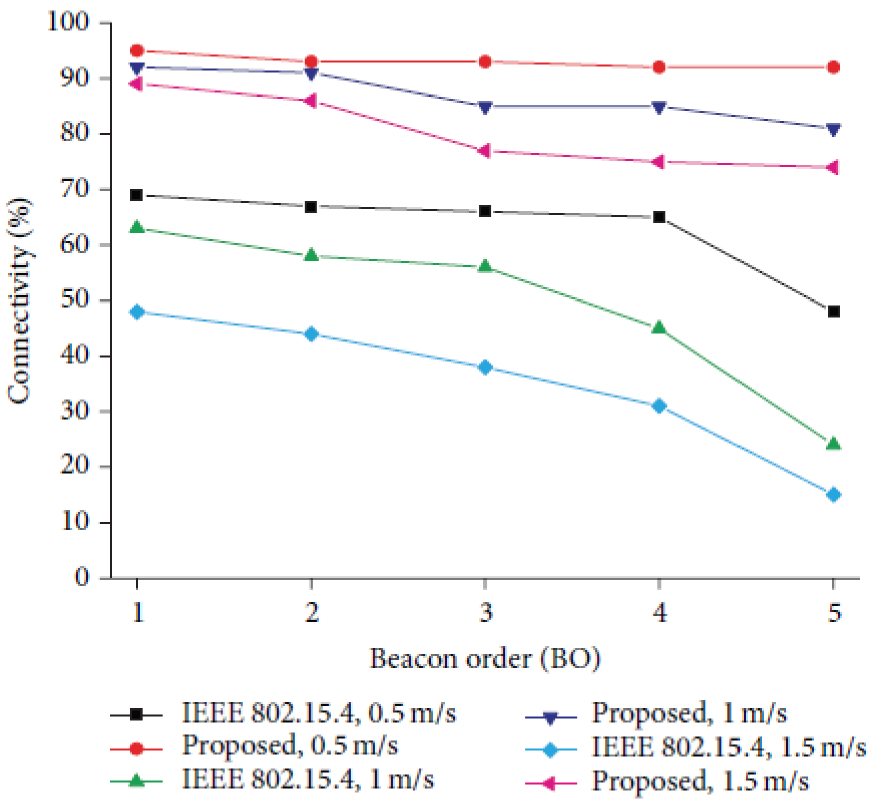

Figure 2-2 Node connectivity at different BO using proposed [29]

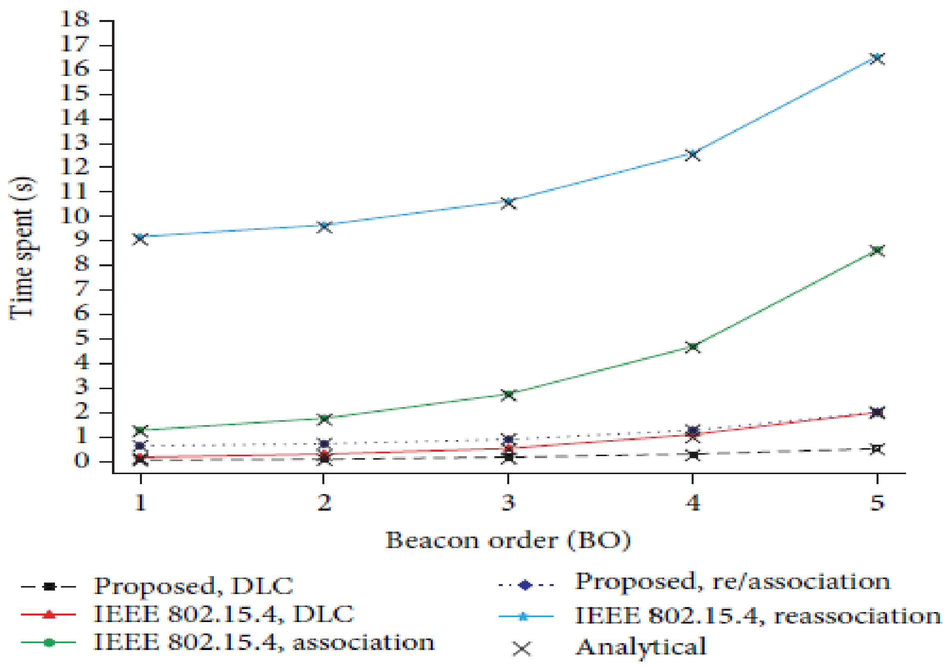

Figure 2-3 Total time spent for association at different beacon [29]

Let's us consider existing handoff mechanisms by their application environment :-

2.2.1 WSN for Healthcare Applications

Ashraf Darwish and Aboul Ella Hassanien [4] purpose of this paper is to provide a snapshot of current developments and future direction of research on wearable and implantable body area network systems for continuous monitoring of patients. This paper explains the key role of body sensor networks in medicine to minimize the need for caregivers and help the chronically ill and elderly people live an independent life, besides providing people with quality care. The paper provides several examples of state of the art technology together with the design considerations like unobtrusiveness, scalability, energy efficiency, security and provides a comprehensive analysis of the numerous benefits and drawbacks of these systems.

Some of the health applications of 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 [7,8,9].

2.2.1.1 Telemonitoring Of Human Physiological Data

The physiological data collected by sensor networks may be stored for an extended period, and can be used for medical investigations when needed. In addition, the installed 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 [30].

2.2.1.2 Tracking and Monitoring Doctors and Patients inside a Hospital

This is an application where the hospital controls its workers during working time, to control that they are in work place or not.

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

2.2.1.3 Drug Administration in Hospitals

If 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 sensor nodes that identify their allergies and required medication. Computerized systems as described in [31] have shown that they can help minimize the side effect of drugs.

In [4,8,11] Given the importance of addressing ways to provide smart healthcare for the elderly, chronically ill and children, researchers have started to explore technological solutions to enhance the provision of health and social care in a way which complements existing services. In this paper, they had presented some applications of how people could benefit from living in homes that have wireless sensor technologies for improving the quality of life and outlined issues to keep in mind during their development. The opportunities are immense. WSNs can open a huge market of consumer applications, mainly in healthcare monitoring and environmental applications. As a conclusion, they agree soon, the evolution of WBANs for symbiotic and bio-inspired architectures can significantly improve the health conditions and lifetime expectation for many people. Remote monitoring of patients, powered by the advent of mobility systems, is not a new idea. However, wireless sensor networks provide a low cost means to sense a given

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environment and thanks to its wireless nature, it proves to be adequate for unobtrusive deployment on the patient.

2.2 Mobility

In paper [12] the outers propose a framework for an effective support of mobility in WSNs. The innovative aspects of the framework consist of the use of mobile IPv6 (MIPv6) in wireless sensor networks, the use of Neighbor Discovery for discovery of sink nodes and subsequent node registration and, finally, the use of a soft hand-off approach which prevents connectivity breaks while the sensor nodes are moving.

[30] This paper surveys mobility related issues and mobility aware medium access control protocols in wireless sensor networks. Whereas the problem of mobility has extensively been addressed in the context of mobile and wireless communications as well as mobile ad hoc networks, a comprehensive survey about wireless sensor networks is lacking.

Dealing with mobility can pose some formidable challenges in protocol design, particularly, at the link layer. These difficulties require mobility adaptation algorithms to localize mobile nodes and predict the quality of link that can be established with them. This paper surveys the current state-of-art in handling mobility. It first describes existing mobility models and patterns; and analyzes the challenges caused by mobility at the link layer. It then provides a comparative study of several mobility-aware MAC protocols. networks may experience a change in topology due to some reasons, for example, when new nodes join the network and when existing nodes experience hardware failure or exhaust their batteries (and, therefore, become inaccessible to their neighbors). This type of change in the topology of the network occurs seldom and is described in the literature as a change in the topology due to a weak mobility [31]. Almost all the medium access control protocols in wireless sensor networks can deal with a slow change in a network's topology. However, these protocols enable nodes to perceive a change in their surrounding only at the beginning of each active period. Consequently, there is a delay in packet transmission whenever a topology change has occurred and the delay can be high in multi-hop networks. Since weak mobility takes place infrequently, the delay it introduces may be tolerable, nevertheless.

In contrast, a **strong mobility** is characterized by concurrent node joins and failures as well as physical movement of nodes [8]. Physical mobility is caused by the deliberate

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movement of objects or persons to which sensor nodes are attached. Similarly, it can occur when nodes are carried by external forces such as wind, water, or air [29,30,31].

Strong mobility results in a frequent topology change which in turn introduces the following problems:

- Mobility leads to a deterioration in the quality of an established link and, therefore, data transmission is prone to failure, which in turn increases the rate of packet retransmission.
- Mobility leads to frequent route changes, which result in a considerable packet delivery delay.
- A mobile node cannot immediately begin transmitting data upon joining a network, because its neighbors should first discover its presence and decide how to collaborate with it.
- In contention-based MAC protocols, mobility may increase packet collision while in schedule-based MAC protocols, two-hop neighborhood information becomes inconsistent once nodes enter or leave, leading to schedule inconsistencies.

Therefore, this paper makes the following contribution[8]:

- It discusses various mobility patterns and models in wireless sensor networks.
- It presents state-of-the-art mobility estimation techniques which are relevant for wireless sensor networks.

2.3 Mobility Estimation Technique

A mobility estimation technique employs a mobility model to predict a link quality, reserve resources, and facilitate a handover process [33]. Many estimation approaches utilize one or more of the following models:

2.3.1 Linear Model

A linear model predicts a node’s future state based on its current and past states, and can be static dynamic. A static model usually forecasts a mobile node’s position based on GPS information, by assuming it moves with the same speed and in the same direction [34]. By employing Kalman filters and extended Kalman filters [33], it is possible to deal with the dynamic aspects of mobility.

2.3.2 Information Theoretic Model

A node in this model maintains the history of base stations or nearby mobile individuals it encounters and applies a compression algorithm [35] to generate a dictionary of the recurrent observed paths [36].

2.3.3 Markov Chain Based Model

A calibrated Markov chain is produced with states and active/inactive cycles representing the access points and the behavior of mobile nodes, respectively. State conditions describe obstacles or restrictions in the environment [37].

2.3.4 Pattern Matching Model

A node first searches for patterns like the current scenario in its stored history and the one with the highest cross-correlation [38] is selected as a base for the link prediction [32].

2.4 Data Source for Mobility Estimation

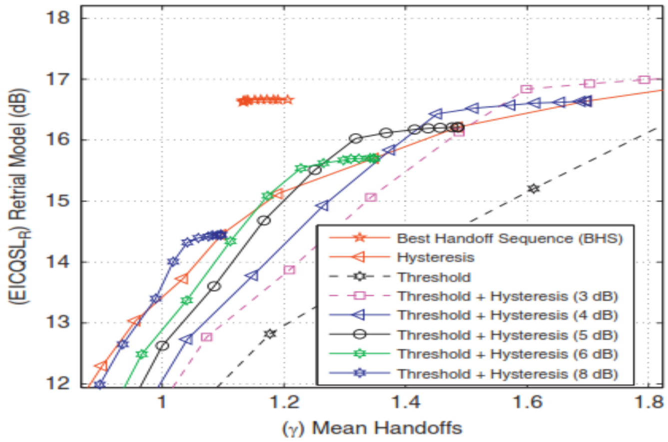
In the following subsections, some of the mobility estimation techniques and the data sources are briefly discussed. A comparison of the localization techniques is summarized in Table 2.2.

Localization Technique	Characteristics	Advantages	Disadvantages
GPS	Measures absolute coordinate	Precise; simple	High price; unavailable in enclosed space; additional hardware is needed
Pedometers	Employ hop-count approaches	Simple; scalable	Coarse-grained; error-prone
Robotics	Employ the Monte Carlo method	Support localization in both mapped and unmapped terrains	Prone to rotational and translational errors
RFID	Data are exchanged via radio waves	Capable of identification and tracking	Short communication range; passive; difficult for future extensions
Anchor node	Pre-existing nodes with globally known or unknown positions	Nodes can be accurately localized if anchors are enough	Cumulative estimation errors; may be unavailable
TOA	Employs a propagation time	No additional cost	Error prone; energy inefficiency
AOA	Employs Goniometers, gyroscopes or compass	Uses as prior-knowledge for the triangulation localization method	Inaccurate; can not be used alone
RSSI	Measures relative distance	No additional cost	Subjects to effects of fading and shadowing; the signal has a large variation
SNR	Reflects a node's current connectivity	Can be monitored by off-the-shelf devices; no hardware is needed	SNR is not sufficient to express link quality. SINR (interference included in the ratio) is a better expression.
Ultrasound	Employs a propagation time of ultrasonic signal	Accurate	The receivable range is limited; adds size and cost to devices
Accelerometers	Responds to both frequency and intensity of movement	Accurate; robust; practical	Adds cost and size of equipments; may not be available or deployable
Triangulation & trilateration	Calculates global coordinate based on local coordinate	No additional cost	Recalculation may be done; a few nodes' locations should be prior known

Table 2-2 Comparison among the data sources for mobility estimation [8,42]

2.5 MAC Layer Handoff Protocols Analysis

In paper [17] the group proposes an innovative approach for performance evaluation and comparison between existing handoff algorithms taking into consideration signal levels, call dropping, and handoff cost. Using the innovative approach, existing handoff algorithms are then compared in terms of signal quality and number of handoffs required to achieve a desired overall signal quality. They observe that the Threshold with Hysteresis method performs better than other known methods including the one used in the GSM standard. their results indicate that the Threshold with 4 dB Hysteresis method performs well for urban areas although with a high dropping probability, whereas the Threshold with 6 dB Hysteresis method suits for suburban areas with a low dropping probability. They find that handoff sequences obtained by existing handoff methods are less efficient than the optimal handoff sequence given in the paper by a margin of 29–45% for retrial model, and by 34–77% for non-retrial model.



EICQSL versus mean handoffs ($\bar{\gamma}$) values for retrial model, when $\delta = 0.9$.

Figure 2-4 handoff time from reference [17]

The mobile cluster MAC (MCMAC) [41] is a schedule based MAC protocol which extends LMAC [42] and GMAC [43] to support cluster mobility. Unlike most of the proposed mobility-aware MAC protocol, MCMAC is optimized for those nodes which travel in group. This is particularly the case in Body Area Networks, such as in healthcare applications, where several biomedical sensors are travelling together, being attached to the body of a patient. MCMAC categorizes the sensor nodes into a static network and a mobile cluster. The protocol defines a Reference Point Group Mobility (RPGM) model and a Random Waypoint Mobility (RWM) model to mimic the movement characteristics of mobile clusters and the individual node movement within a cluster. A frame in

MCMAC is divided into an active and a sleep period. Since the slot assignment method is different for static and mobile nodes, the active period is further divided into static active slots (SAS) and mobile cluster slots (MCS). Static nodes communicate with each other in the SAS part by dynamically occupying a unique transmission slot in its two-hop neighborhood. A static node can only transmit data in the specific slot it chooses and receives data in the remaining part of SAS. A guard time is inserted at the start and the end of every transmission slot to compute a node's phase difference with its direct neighbors for synchronization.

[42]M-MAC deals with mobility-related delays by adjusting the size of a frame and the proportion of the scheduled access interval to the random-access interval within a frame. However, it has several inherent limitations. Being computationally intensive is one of the limitations of M-MAC. The accuracy of the mobility handling mechanism depends on the accuracy of the predicted size of the next frame, which is estimated by all individual mobile nodes in the current round. This estimation, however, is made according to the change of the relative distance between nodes obtained by employing the AR1location evaluation model. Furthermore, the adjustment of the size of both the scheduled access interval and the random-access interval for the next frame as well as the size of the frame for the next round is only managed according to the historical statistics. Therefore, the node movements, which still occur in the current frame and round, are not taken into consideration after mobility is predicted, leading to latency and inaccuracy of mobility estimation.

2.6 Practices to be Preserved

As a practice, this work reserved many good practices of every different works, listed below as an example but not all of them.

The first and the most important good practice to be reserved in this work is a method described in paper [9] explains an evaluation to compare signal strength and the number of frame retransmissions as a decision criterion for the start of handoff in wireless local area networks (WLANs). From authors of paper [1] reserved the way how they used to solve early discovery, the time for checking LQI of the MN with its coordinator, and delays which are used as the key performance metrics, to evaluate the proposal. The authors in [5][1] propose a handoff mechanism for health-care monitoring based on RSS. Which indicate the minimum value of the link quality to start the handoff (-90 dBm) and the hysteresis margin necessary to complete the transfer (5 dBm) and relationship between handoffs and the transitional region. Authors in [10] [11] made an empirical analysis about measurements in IEEE 802.11 wireless networks. Their main contribution related to MNH-WSN was about the measuring methodology used and there are suitable conditions for mobility in devices using the IEEE 802.15.4 standard. Authors in [12] propose a soft handoff mechanism as part of a framework to support mobility in a WSN and it is also reserved in this work as a best practice as mentioned earlier these are some examples what reserved here to cam up with better solution.

2.7 Requirements of The Proposed System

2.7.1 Functional Requirements

Functionally the application will not have many interfaces that can interact with the user, more it is type of application that can help the network management of mobile nodes in the WLAN, just by choosing a coordinator with good link quality and making a link to do so it takes the link quality indicator, RSSI, and other environmental factors as a parameter and decide which coordinator is good to transfer data over the network, is done without loss of connection in the network.

To do so the scheme have two major functions which are

1, check and update: - it will do only monitoring handoff, to define when and how to trigger notification of transfer to MNs by using the LQI function, defined in IEEE 802.15.4, to measure the signal strength of received packets to evaluate the link quality from a MN.

LQI <= (thrQLQI) then send notification message …………. (1) more in chapter 4

Finally, it ends by generating notifying the HEP (chapter 3) function to act.

2, HEP: - which have 2 parts, decision, and association, to new coordinator. this function is excited only if the update and check generates notification, the first step is notifying the data sending mechanism and search for a new coordinator, make association by means of hard or soft handoff defending on the parameters. After all the communication between ED and new coordinator starts.

2.7.2 Non-Functional Requirements

For the work, most of nonfunctional requirements must be fulfilled because it is so sensitive issue(health), for example in case of accessibility MNH-WSN is all the time accessible with in the environment where it is installed, or in other word it is 24/7 application. Regarding the number of executions per a day or a hour it defend on the link quality of the coordinators and ED. In case of Performance Requirements and Reliability Requirements, it is fast and is very important for the users, they move freely without limitation, for the Network management, the application decide which coordinator is good for data transition over the environment, lastly for Doctors or service givers, make easy to follow their customers so they manage and take care all the time as much as the user is in the WLAN.

2.7.3 Proposed Solution in Addressing Problems of The Existing Once

The proposed solution is based on the improvement of a clustering algorithm and on the creation of a new handoff protocol that allows users to easily inform about their connection to the SN. Before this work, the protocol was developed by researchers of university of Baja Californian Ensenada branch(UABC) even though, there are difference with computation to new work. And the implementation of their protocol is only in simulation environment which is done in Telematic lab of UABC [1].

The proposed MNH-WSN protocol, uses as a strategy that the mobile node has all right to decide when and at what time needed to send notification and start HEP because in WSN the key role player is the MN, but when developing this protocol, the major problems of sensors are considered (memory and energy).

More the way how MNH-WSN handle early discovery, Total time for executing the hole handoff process and most of the protocols which are developed in the field (handoff) are only simulation based but in this case, everything is only hardware based, mean it is implementation based.

In short, the designed solutions are:

1, MNH-WSN Have notification part used to dispatch data sending mechanism before handoff start which lower the data loss during the process.

2, MNH-WSN embedded in MN to make handoff easy and finish in few microseconds, more considering handoff is all about the MN.

3, Combing soft handoff, hard handoff, early discovery, and implementing in MN (with its limitations).

4, Implementing MNH-WSN in real environment test, validate its operation and collecting results.

5, Hardware implementation rather than simulation results are shown in section results.

2.8 Summary of The Chapter

To summarize the chapter by constructing a table below.

MAC Protocols	Estimation techniques	Characteristics	Advantage	Disadvantage
MS-MAC [44]	Information theoretic model	1. A contention-based protocol extends SMAC. 2. A mobile node can connect with a new virtual cluster by running synchronization frequently.	1. It can communicate with the original neighbors while setting up connection with a new virtual cluster. 2. The synchronization frequency can adapt to the speed of a mobile node's neighbors.	1. It trades-off a higher energy cost for a less delay. 2. A neighbor of the mobile node consumes a significant amount of energy even if it is stationary.
M-MAC [45]	Auto-regression model/Kaman filter	1. A schedule-based protocol designed from TRAMA. 2. It adjusts the frame size and the proportion within a frame.	1. The time slot can be dynamically allocated by changing a frame's size and the proportion within a frame. 2. The proportion within a frame is changed more frequently than the frame size.	1. Computational intensive. 2. The accuracy depends on the AR-1 model. 3. Mobility is estimated based on historical statistics.
M_TDMA [48]	Information theoretic model	1. A schedule-based protocol on top of TDMA. 2. It uses the control part to learn mobility information and the data part to allocate slots to new nodes.	1. It guarantees collision-freedom. 2. It does not rely on any localization algorithm. 3. It uses the control and data parts to adapt to mobility without changing the frame size	1. Several assumptions are made. 2. Disconnection with the network may occur. 3. Energy and latency are increased.
MA-MAC [46]	Pattern matching model	1. A contention-based protocol based on XMAC. 2. It defines two thresholds for handling mobility.	1. Mobility can be handled in time. 2. Relay nodes can be discovered during the data communication.	1. Several assumptions are made. 2. It depends on network density and nodes' schedules. 3. The decision of two thresholds is critical.
Mobsense [41]	Information theoretic model	1. A schedule-based MAC protocol. 2. It uses mini-slots, discovery slots and multi-channel communication for handling mobility.	1. The discovery slots allows rapid network information gathering. 2. The multi-channel communication enables local scheduling. 3. The mini-slots ensure rapid admission and fast network convergence.	1. Multi-channel requires careful management of the media resource. 2. The order of the discovery slots and the access mini-slots is critical. 3. Mobility cannot be handled in time. 4. Collision may occur.
MCMAC [42]	Linear model	1. A schedule-based MAC protocol designed based on LMAC and GMAC. 2. It avoids adaptation time by using different slot assignment scheme for static and mobile nodes.	1. Guard time introduction ensures decentralized frame synchronization. 2. Transmission slot is dynamically selected in the SAS part. 3. Flexible slot assignment scheme avoids adaptation time once cluster moves.	1. Collision cannot be avoided due to state switching delay. 2. Collision can also happen due to hidden terminal problem. 3. Single channel limits the bandwidth and makes the throughput unsalable.
WSN-HaDaS [1]	Auto-regression model	1, extends soft handoff and hard handoff 2, use LQI value as evaluation matrix	1. Inform start and end of handoff 2. early discovery 3.LQI value limits for WSN in health area	1. run from CN side to control mobility of MN 2. simulation based only. 3. work only scanning only one channel. 4. delay time compered to MNH-WSN work.

Table 2-3 Comparison among the mobility-aware mac protocols

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Chapter 3 Technical Overview of IEEE 802.15.4

3.1 Motivation for Standard

802.15.4 standard was introduced by the IEEE to fill a niche left by the existing wireless network standards, which included:

- IEEE 802.15.1: Bluetooth, which is relatively low-power, low-rate wireless network technology, intended for point-to-point communications,
- IEEE 802.15.3: high-rate WPAN (Wireless Personal Area Network).

High-rate WPAN was driven by applications requiring high data rates and/or wide spatial coverage, often involving complex solutions with non-trivial power requirements. However, not all applications have such demanding needs. Some network applications involve the infrequent exchange of relatively small amount of data over restricted areas (for example, a home temperature monitoring and control network). Such applications are diverse in nature and represent considerable market potential.

Bluetooth was not designed for multiple-node networks, therefore the IEEE devised a WPAN standard based on a new set of criteria:

- Very low complexity,
- Ultra-low power consumption,
- Low data rate,
- Relatively short radio communication range,
- Use of unlicensed radio bands,
- Easy installation,
- Low cost.
- The IEEE 802.15.4 standard was born!

A central feature of the standard is the requirement for extremely low power consumption. The motivation for this strict power requirement is to enable the use of battery powered Network devices that are completely free of cabling (no Network or power cables), allowing them to be installed:

- Easily and cheaply (no costly cable installation needed),
- Possibly in locations where cables would be difficult or impossible to install.

However, low power consumption necessitates short ranges.

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3.2 Application Areas

The applications of IEEE 802.15.4 based networks are wide ranging, covering both industrial and domestic use. Essentially, for IEEE 802.15.4 to be used in a networking solution, the required data rate must be low (<= 250 kbps) and the maximum range for communicating devices must be short. In addition, a device with an autonomous power supply (no power cables) must have an extremely low power consumption. If these criteria are met, IEEE 802.15.4 may provide the ideal networking solution, particularly when cost and installation are significant issues.

Figure 3-1 IEEE 802.15.4 implementation area

3.2.1 Home automation and security

a wireless PAN provides a low-cost solution for electronic control within the home (for health, heating, ventilation, air-conditioning, lighting, doors, locks…). Another important application within the home is security – both intruder and fire detection.

3.2.2 Consumer products

wireless PANs can be built into consumer electronics products. The most obvious example is to provide a common remote control for the various components of a home entertainment system (TV, audio…). Other examples are computer systems and toys, in which a wireless radio link may be used to replace a point-to-point cable link (such as between a mouse and a PC).

3.2.3 Healthcare

this field employs sensors and diagnostic devices that can be networked by means of a wireless PAN. Applications include monitoring during healthcare programs such as fitness training, in addition to medical applications.

3.2.4 Vehicle monitoring

vehicles usually contain many sensors and diagnostic devices, and provide ideal applications for wireless PANs. A prime example is the use of pressure sensors in tires, which cannot be connected by cables.

3.2.5 Agriculture

wireless PANs can help farmers monitor land and environmental conditions to optimize their crop yields. Such networks can operate at very low data rates and latencies, but require wide geographical coverage – the latter issue is addressed by using network topologies that allow the relaying of messages across the network.

3.3 Radio Frequencies and Data Rates

IEEE 802.15.4 was designed to operate in unlicensed radio frequency bands. The unlicensed RF bands are not the same in all territories of the world, but IEEE 802.15.4 employs three possible bands, at least one of this should be available in each territory. The three bands are centered on the following frequencies: 868, 915 and 2400 MHz.

RF band	Frequency range	Data rate	Channel number(s)	Geographical area
868 MHz	868.3 MHz	20 kbps	0 (1 channel)	Europe
915 MHz	902-928 MHz	40 kbps	1-10 (10 channels)	America, Australia
2400 MHz	2405-2480 MHz	250 kbps	11-26 (16 channels)	Worldwide

Table 3-1 Frequency detail

The 868 and 915 MHz frequency bands offer certain advantages such as fewer users, less interference, and less absorption and reflection, but the 2.4 GHz band is far more widely adopted for several reasons:

- Worldwide availability for unlicensed use,
- Higher data rate (250 kbps) and more channels,
- Lower power (transmit/receive are on for a shorter time due to higher data rate),
- RF band more commonly understood and accepted by the marketplace (also used by Bluetooth and the IEEE 802.11 standard).

IEEE 802.15.4 includes energy detection functionality that can be used by higher software layers to avoid interference between radio communications. The range of a radio transmission is dependent on the operating environment, for example, indoors and outdoors. With a standard device (around 0 dBm output power), a range of over 200 meters can typically be achieved in open air. In a building, this can be reduced due to absorption, reflection, diffraction and standing wave effects caused by walls and other solid objects, but typically a range of 30 meters can be achieved. High power modules (greater than 15 dBm output power) can achieve a range of five times greater than a standard module.

3.4 Achieving Low Power Consumption

An important criterion of the IEEE 802.15.4 standard is the provision for building autonomous, low-powered devices. Such devices may be battery powered or solar powered, and require the ability to go to sleep or shut down. There are many wireless applications that require this type of device.

From a user perspective, battery power has certain advantages:

- Easy and low-cost installation of devices: no need to connect separate power supply,
- Flexible location of devices: can be installed in difficult places where there is no power supply, and can even be used as mobile devices,
- Easily modified network: devices can easily be added or removed, on a temporary or permanent basis.

A typical battery-powered network device presents significant technical challenges for battery usage. Since these devices are generally small, they use low-capacity batteries. Infrequent maintenance device is often another requirement, meaning long periods between battery replacement and the need for long life batteries. Battery use must therefore be carefully managed to make optimum use of very limited power resources over an extended period.

Low duty cycle: most of the power consumption of a wireless network device corresponds to the times when the device is transmitting. The transmission time as a proportion of the time interval between transmissions is called the duty cycle. Battery use is optimized in IEEE 802.15.4 devices by using extremely low duty cycles.

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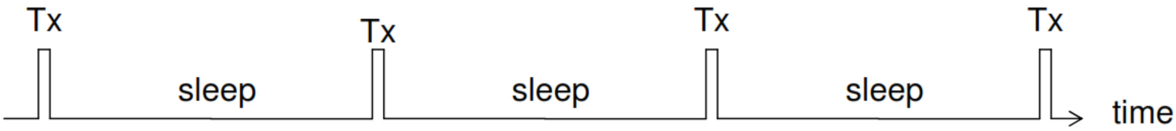
Low duty cycle: this is helped by making the transmission times short and the time interval between transmissions long. In all cases, when not transmitting, the device should revert to a low-power sleep mode to minimize power consumption.



Modulation: the modulation schemes used to transmit data (BPSK – Binary Phase Shift Keying – for 868/915 MHz, O-QPSK – Offset Quadrature Phase Shift Keying – for 2.4 GHz) minimize the power consumption by using a peak-to-average power ratio of one.

3.5 General Description

1. Specification of the PHY and MAC layer.

Low data rate: < 250 kbps, Personal operating space: 10 m.

Device types in LR-WPAN:

FFD (full-function device), PAN coordinator, coordinator, device.

RFD (reduced-function device), can talk only with a FFD.

Topologies:

Star topology,

Peer-to-peer topology.

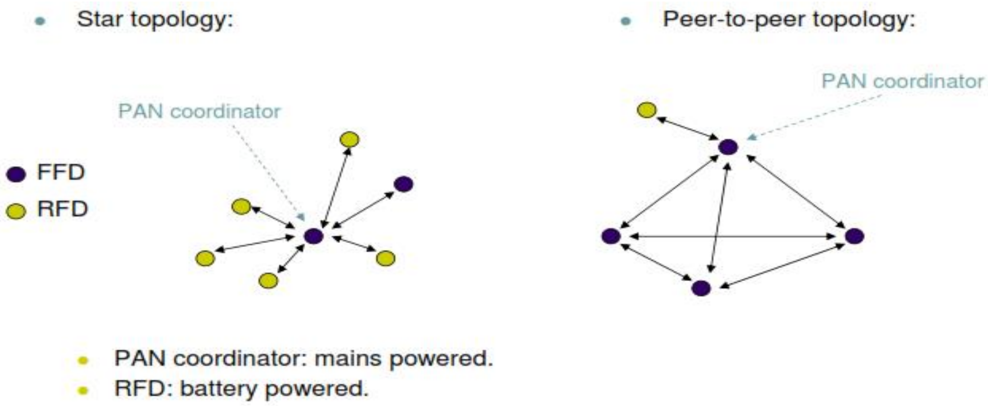


Figure 3-2 General topology of the standard

3.6 Architecture: OSI (open systems interconnection) 7-layer model

LR-WPAN:

- PHY layer: RF transceiver + low-level control mechanism,
- MAC sublayer: access to the physical channel for all types of transfer,

Upper layers: network and application layer, outside the scope of this standard.

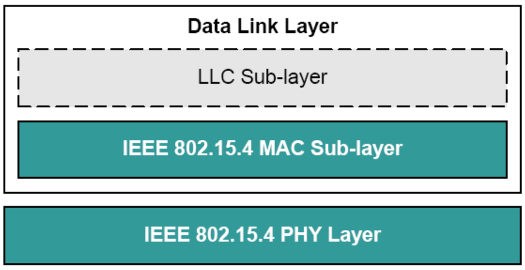


Figure 3-3 OSI level of the standard

3.7 Physical layer (PHY)

The physical layer also offers the following services to the MAC sublayer:

- PHY data service: provides a mechanism for passing data to and from the MAC sublayer,
- PHY management service: provides mechanisms to control radio communication settings and functionality from the MAC sublayer.

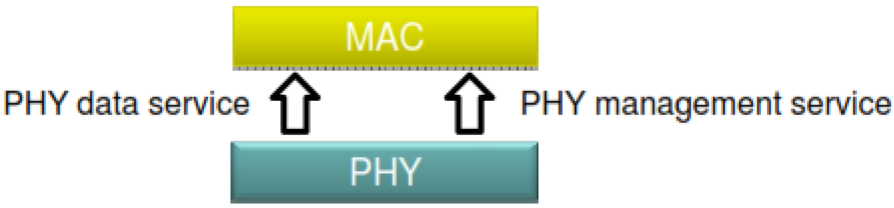


Figure 3-4 Physical layer

Information used to manage the PHY layer is stored in a database referred to as the PHY PIB (PAN Information Base).

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3.8 Medium Access Control (MAC) Sublayer

The main responsibilities of the MAC sublayer are as follows:

- Providing services for associating/disassociating devices with the network,
- Providing access control to shared channels,
- Beacon generation,
- Guaranteed timeslot management (if applicable).

The MAC sublayer also offers the following services to the next higher layer:

- MAC Data Service (MCPS): provides a mechanism for passing data to and from the next higher layer,
- MAC Management Services (MLME): provides mechanisms to control settings for communication, radio and networking functionality, from the form next higher layer.

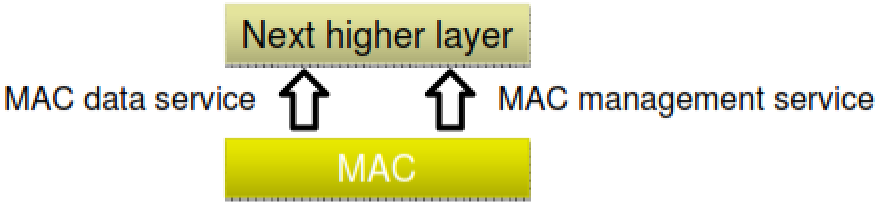

Figure 3-5 MAC layer

Information used to manage the MAC sublayer is stored in a database referred to as the MAC PIB (MAC PAN Information Base).

3.9 Data Frames and Acknowledgments

Communications in an IEEE 802.15.4 network are based on a system of data and MAC command frames, and optional acknowledgments. When a node sends a message to another node, the receiving node can return an acknowledge message. This simply confirms that it has received the original message and does not indicate that any action has been taken because of the message. Acknowledgments are provided by the MAC sublayer.

3.9.1 Data Transfer for A Beacon Enabled Mode

In this mode, the coordinator sends out a periodic train of beacon signals containing information that allows network nodes to synchronize their communications. A beacon also contains information on the data pending for the different nodes of the network.

Normally, two successive beacons mark the beginning and end of a superframe. A superframe contains 16 timeslots that can be used by nodes to communicate over the network. The total time interval of these timeslots is called Contention Access Period (CAP) during which nodes can attempt to communicate using CSMA/CA.

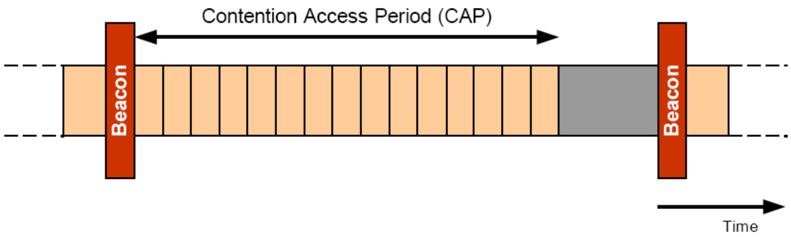

Figure 3-6 Data transfer for a beacon enabled mode

A node can also request to have timeslots (from the 16 available) assigned to it. These are consecutive timeslots called Guaranteed Timeslots (GTSs). They are located after the CAP and the total time interval of all GTSs (for all nodes) is called the Contention Free Period (CFP). Communication in the CFP does not require use of CSMA/CA. Use of GTSs reduces the CAP. It is possible to have a dead period at the end of the super frame (before the next beacon). This allows network devices to revert to low-power mode for part of the time, and to save power.

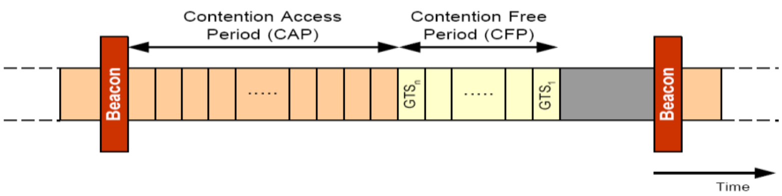

Figure 3-7 Super frame with GTSs

3.9.2 Data Transfer for Non-Beacon Enabled Mode

In non-beacon enabled mode, beacons are not transmitted on a regular basis by the coordinator (but can still be requested for associating a device with the coordinator). Instead, communications are asynchronous – a device communicates with the coordinator only when it needs to, which may be relatively infrequently. This allows power to be conserved. To determine whether there is data pending for a node, the node must poll the coordinator (in a beacon enabled network, the availability of pending data is indicated in the beacons). Non-beacon enabled mode is useful in situations where only light traffic is expected between the network nodes and the coordinator. In this case, the use of regular beacons may not be needed and will waste valuable power.

3.10 Channel Access

When transmitting a packet across a network without using Guaranteed Timeslots, the CSAM-CA (Carrier Sense Multiple Access – Collision Avoidance) mechanism is implemented to minimize the risk of a collision with another packet being transmitted in the same channel at the same time by another node. The transmitting node performs a Clear Channel Assessment (CCA) in which it first listens to the channel to detect whether the channel is already busy. It does not transmit the packet if it detects activity in the channel, but tries again after a random back-off period. A Clear Channel Assessment is required by the MAC sublayer and is implemented by the PHY lay

3.11 CSMA-CA Mechanism (Carrier Sense Multiple Access with Collision Avoidance)

Frame acknowledgement If the originator does not receive an acknowledgement after some period, it assumes that the transmission was unsuccessful and retries the frame transmission. If an acknowledgement is still not received after several retries, the originator can choose either to terminate the transaction or to try again. When the acknowledgement is not required, the originator assumes the transmission was successful.

3.11.1 PHY Specification

- Operating frequency range: 3 bands: 868-868.6 MHz (e.g., Europe), 902-928 MHz (e.g., North America), 2400-2483.5 MHz (worldwide).
- 3 modulations: BPSK (Binary Phase-Shift Keying), ASK (Amplitude Shift Keying), O-QPSK (Offset Quadrature Phase-Shift Keying).

PHY (MHz)	Frequency band (MHz)	Spreading parameters		Data parameters		
		Chip rate (kchip/s)	Modulation	Bit rate (kb/s)	Symbol rate (ksymbol/s)	Symbols
868/915	868-868.6	300	BPSK	20	20	Binary
	902-928	600	BPSK	40	40	Binary
868/915 (optional)	868-868.6	400	ASK	250	12.5	20-bit PSSS
	902-928	1600	ASK	250	50	5-bit PSSS
868/915 (optional)	868-868.6	400	O-QPSK	100	25	16-ary orthogonal
	902-928	1000	O-QPSK	250	62.5	16-ary orthogonal
2450	2400-2483.5	2000	O-QPSK	250	62.5	16-ary orthogonal

Table 3-2 Features of frequency bands

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Channel page (decimal)	Channel page (binary) (b_{31}, b_{30}, b_{29}, b_{28}, b_{27})	Channel number(s) (decimal)	Channel number description
0	00000	0	Channel 0 is in 868 MHz band using BPSK.
		1-10	Channels 1 to 10 are in 915 MHz band using BPSK.
		11-26	**Channels 11 to 26 are in 2.4 GHz band using O-QPSK.**
1	00001	0	Channel 0 is in 868 MHz band using ASK.
		1-10	Channels 1 to 10 are in 915 MHz band using ASK.
		11-26	Reserved.
2	00010	0	Channel 0 is in 868 MHz band using O-QPSK.
		1-10	Channels 1 to 10 are in 915 MHz band using O-QPSK.
		11-26	Reserved.
3-31	00011-11111	reserved	Reserved.

Table 3-3 Channels assignment

3.11.2 Physical Service Specification

Tasks of the PHY layer: Activation and deactivation of the RF transceiver, Energy detection (ED), Link Quality Indication (LQI), Channel selection, Clear Channel Assessment.

3.11.3 Physical Service Specification: Primitives

Primitives for the PHY data service	Request	Confirm	Indication
PD-DATA	√	√	√

Primitives for the PHY management service	Request	Confirm	Indication
PLME-CCA	√	√	
PLME-ED	√	√	
PLME-GET	√	√	
PLME-SET-TRX-STATE	√	√	
PLME-SET	√	√	

Table 3-4 Physical primitives

3.12 MAC Sublayer Specification

Tasks:

Generating network beacons if the device is a coordinator, Synchronizing to network beacons, Supporting PAN association and disassociation, Supporting device security, Employing the CSMA-CA (carrier sense multiple access with collision avoidance) mechanism for channel access, Handling and maintaining the GTS (guaranteed time slot) mechanism, Providing a reliable link between two peer MAC entities.

Primitives for MAC data service	Request	Confirm	Indication	Response
MCPS-DATA	√	√	√	
MCPS-PURGE	√	√		

Primitives for MAC management service	Request	Confirm	Indication	Response
MLME-ASSOCIATE	√	√	√	√
MLME-DISASSOCIATE	√	√	√	
MLME-BEACON-NOTIFY			√	
MLME-GET	√	√		

Table 3-5 MAC data service and MAC management service

3.12.1 MAC Sublayer Specification

Primitives for MAC management service	Request	Confirm	Indication	Response
MLME-GTS	√	√	√	
MLME-ORPHAN			√	√
MLME-RESET	√	√		
MLME-RX-ENABLE	√	√		
MLE-SCAN	√	√		
MLME-COMM-STATUS			√	
MLME-SET	√	√		
MLME-START	√	√		
MLME-SYNC	√		√	
MLME-POLL	√	√		

Table 3-6 MAC sublayer specification

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3.13 Device Management

3.13.1 PAN Coordinator Selection

- All networks must have one and only one PAN coordinator.
- This must be an FFD.
- The selection of the PAN coordinator is the first step in setting up an IEEE 802.15.4 based network.
- Once the PAN coordinator has been established, a PAN ID (identifier) must be assigned to the network. The PAN ID is assigned by the PAN coordinator considering the PAN IDs of any PAN coordinators that it can “hear”.

3.13.2 Device Association and Disassociation

- To join an IEE 802.15.4 based network, a device must first find a coordinator by conducting an active or passive channel scan.
- The device can then send an association request to the coordinator, which acknowledges the request and then determines whether it has sufficient resources to add the device to its network. The coordinator will then accept or reject the association request.
- The request to disassociate a device with a network can be made by either the coordinator or the device itself.

3.13.3 Orphan Devices

A device becomes an orphan if it loses communication with its coordinator. An orphan device will attempt to rejoin the coordinator by first performing an orphan channel scan to find the coordinator this involves sending out an orphan notification command across the relevant frequency channels. On receiving this message, the coordinator checks whether the device was previously a member of its network – if this was the case, it responds with a coordinator realignment command.

3.14 Channel Management

IEEE 802.15.4 offers channel management facilities concerned with allocating channels, ensuring channel availability for transmission and protecting channels from nearby interfering transmissions. IEEE 802.15.4 can scan the channels in each frequency band, allowing the higher layers to select the appropriate channel. When a network is set up, the channel of operation within the relevant frequency band must be chosen. This is done by the PAN coordinator. IEEE 802.15.4 provides an energy detection scan which can be used to select a suitable channel (normally the quietest channel). When a new device is introduced into a network, it must find the channel being used by the network. The new device is supplied with the PAN ID of the network and performs either of the following scans: Active channel scan in which the device sends beacon requests to be detected by one or more coordinators, which then send out a beacon in response, Passive channel scan (beacon enabled networks only) in which the device listens for periodic beacons being transmitted by a coordinator.

3.15 Device Addressing

Each device in an IEEE 802.15.4 network can have two types of address:

- IEEE (MAC) address: this is a 64-bit address, allocated by the IEEE, which uniquely identifies the device – no two devices in the world can have the same IEEE address. It is also sometimes called the extended address.
- Short address: this 16-bit address identifies the node in the network and is local to that network (thus two nodes on separate networks may have the same short address). The short address may be allocated by a coordinator when a node joins a network.

3.16 Chapter conclusion

Today's world is rich of sensor networks and simple control systems, means was strongly in mind when the IEEE 802.15.4 task group created its specification. Whether ping-pong-ball-sized sensors sprinkled across the ground in a forest or on Mars, in hospital or sensor/control networks that allow micro control of agricultural environments or commercial buildings, 802.15.4 provides the basic tools that ensure standards based, reliable, robust communications under most conditions. The existence of the standard has created an already growing silicon solution market, with more vendors joining the fray every month and helping to drive costs and power consumption down, while adding functionality and performance. The basic features of the PHY and MAC layers provide the hooks to upper layer network and applications developers to take advantage of these cost effective, small radio solutions, allowing those developers to concentrate on their application and the inexpensive delivery of data from a large, amorphous sensor network. The networking techniques already available, like that of the ZigBee Alliance, and the promise of some sort of marriage between IPv6 and 802.15.4, provide a vision of a future world where the simplest machines can interact with their world.

Chapter 4 MNH-WSN (Mobile Node based Handoff for WSN)

4.1 Background

Now a day the major thing behind WSN mobile devices is making them confidential in their connection while they are moving, handoff. Improving handoff protocol to enhance mobility of sensor nodes could be accomplished by identifying trends and failed processes with the goal to reduce handoff delay times and data lost during the handoff. The tradition schemes (mobile sensor applications without handoff management protocol) have mainly suffered from this problem. The most valuable information collected through researchers that provides the weaknesses or errors that may occur during handoffs [1,2,3,4].

1. Poor handoff management protocol that factor to medical error with inadequate handoffs playing a key role.

2. Full scanning which increases handoff delay during switching between different CNs. The delay sometimes reaches 90% of the total switching time which ultimately leads to high packet loss and breaking of connection [3,4].

3. Commonly Existing handoff protocols are embedded in CN to manage MN mobility [1].

4. Most of the schemes use parameters such as bandwidth and data rate for handoff. Similarly, researchers designed different schemes such as partial and per scanning which require less energy compared to traditional schemes [5]. Pre-scanning scheme scans available networks at once and hence there is no need to scan the available networks again and again. Similarly, partial scanning schemes scan only those networks which are available near the MN and hence require-less energy.

In a WSN environment, a MN is provided with the ability to move freely inside in a network of different CNs and it must be provided with the capacity of attaching to a new CN. Therefore, a handoff mechanism needs to provide WSNs to softly transfer the traffic from one CN to another. These types of WSNs require frequent and dynamic topology to maintain the connection between the individual sensor nodes [8, 9]. Considering all these factors, MNH-WSN propose a new handoff mechanism described below.

4.2 General Description of MNH-WSN

In MNH-WSN, MAC layer protocol, is initiated when an MN is moving away from its current CN and getting near to another CN. In other words, when the connectivity of MN with its current CN is dropped below a predefined threshold of signal strength (<-85dbm) [1] then it initiates a handoff process. Therefore, the handoff process is based on the LQ measurement from current CN it is connected. The LQ factor is also used for selecting a new CN for handoff among other CNs. MN is assumed to select an appropriate CN on the basis of the LQ of available CNs. Most important consideration in this regard is to redirect data flow from one CN to another as quickly as possible, to avoid possible packet loss and connection breaking during handoff. In short MNH-WSN is handoff management protocols which operate from MAC layer of MN with three major phases' initialization, check and update, and handoff execution. More it is embedded in to MN itself to manage handoff.

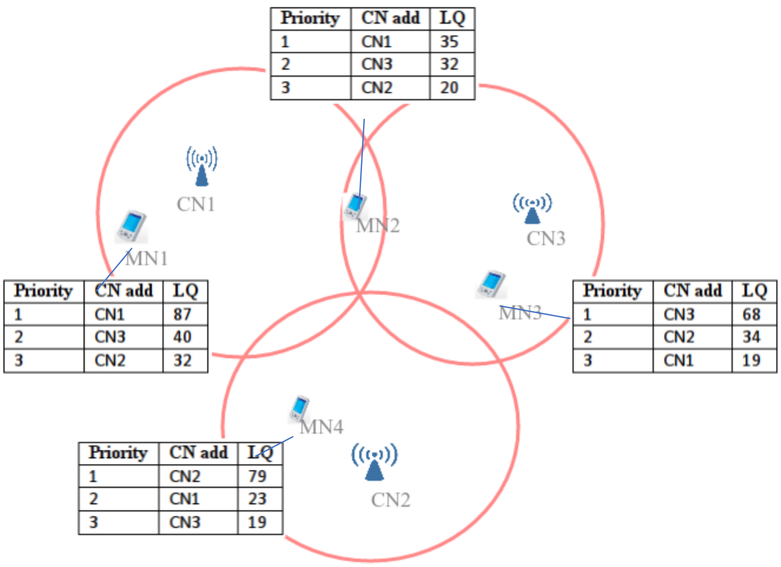


Figure 4-1 General MNH-WSN design consideration

As shown in figure 4-1 above in MNH-WSN every mobile node has its own table which contain list of CNs with Link quality priority from maximum to minimum, for the first-time MN will associate with first CN in the table so it is not used for handoff purpose, meanwhile at the middle of communication MN moves far from its current CN and link quality will reach the boundary (-85dbm). At this point the MNH-WSN reacts communication and informs to data sending mechanism that handoff process is started, to stop data sending. After informing the data sending mechanism(TCP/IP), MNH-WSN will send association request to next CN in its table, if MN not receive any response it will try for next in its list and automatically when it receive successful association response from one of them than it will inform to data sending mechanism to start data sending.

N.B(remember the following points)

1. MN table will store only 4 CNs once then every 1.5 minutes it will update its table, table memory is dynamically allocated but the maximum limit is 4.

2. Considering that CNs are placed with some range area sharing.

3. Considering everything as fully functional.

For more explanation let us take case of MN4 in the figure 4-1 in its table it has CN2 with link quality of 79, CN1 with link quality of 23, and CN3 with link quality of 19. This information is recoded during first active scan and MNH-WSN check that MN4 is currently connected to CN1 which is first CN in the table list, assuming that after while MN4 moves to more far from CN2 in the direction of CN1, during the communication MNH-WSN will not react until the link quality with CN2 <= -85dbm, when it reaches this limit line MNH-WSN automatically inform CN2 data sending mechanism not to send more data for MN4, and it will send association request to CN1, when CN1 responds successful response it will inform data sending mechanism to start data sending to CN1. If CN1 doesn't respond it will try for CN3 which is the last chance and if it could not receive any response after doing so if there is no result then it will call normal active scan and yet the result is negative then MN4 will go to sleep mode.

Below in figure 4-2 we have the general Architecture of MNH-WSN in OS layer.

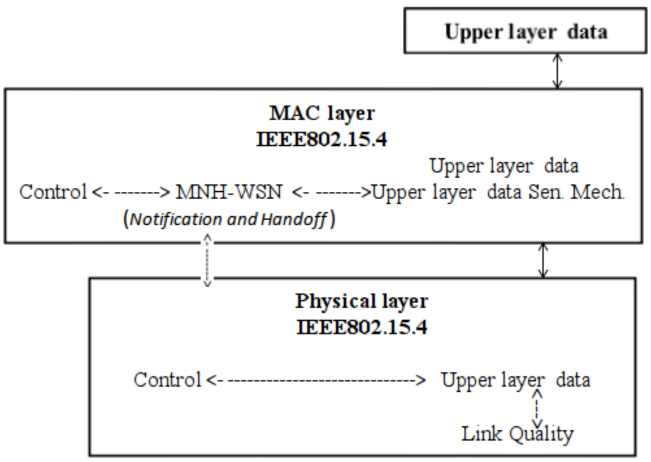


Figure 4-2 Architecture of MNH-WSN

4.3 Algorithm

MNs should select a target CNs before it performs a handoff. MNH-WSN use an achievable throughput(LQI) as a metric to determine an optimal target CN among neighbor CNs. The CN selection for the proposed handoff mechanism is conducted with an algorithm as follow: Once the MNs finds neighbor CNs with a scan method as introduced in [1, 4], it builds a look in the list for every neighbor CNs. Then the MNs performs collecting information about the achievable throughput of LQI on every CNs in the nearby. It is assumed to have the maximum achievable throughput which is determined by

$$\text{LQI } a_i \in \sum_{i,j=0} i \forall j : ai > aj \quad \text{.................................(Equ-2)}$$

where LQI = achievable throughput selected
i,j = link quality indicator value(0-255)
a=any coordinator

when there exists more than one CNs with the same maximum achievable throughput, MN connect automatically to the first one. the CN selection algorithm employs the LQI as its base matrix. The selective scanning procedure described below reduced the handoff latency in the experiments (Section 5) to a value Between 35% to 45% of the values obtained with the original handoff. Once again to summarize the procedure for MNH-WSN handoff mechanism as follows.

- LQI with a current CN is used as a major an input.
- Select an optimal CNs with the maximum achievable throughput and perform handoff. if this step can be actively performed by channel scanning as in [4].
- As far as conditions are fulfilled, protocol Send warring message to CNs to stop sending data to MN as well alert for MN.
- Executing handoff from MAC layer of the MN.

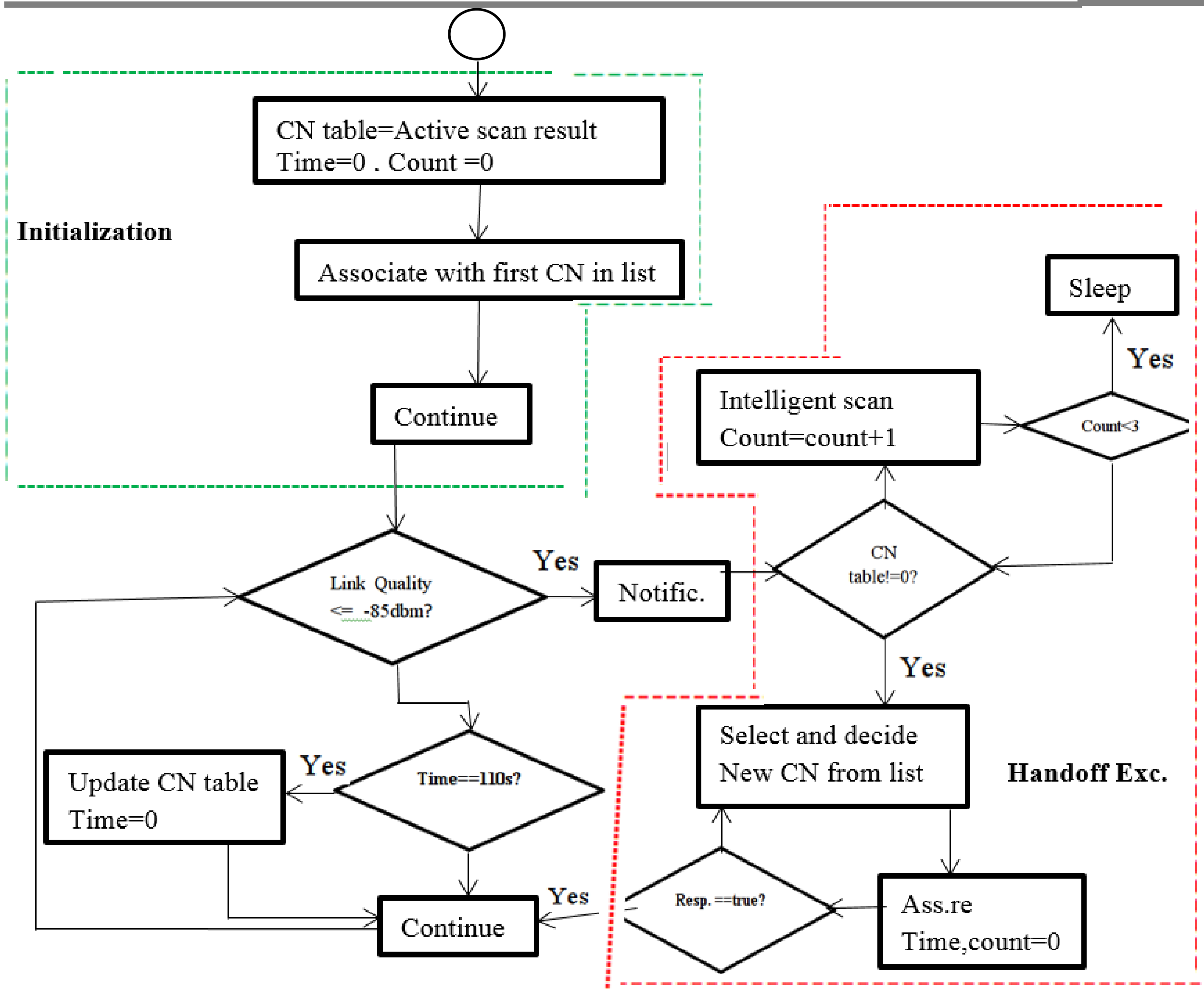


Figure 4-3 working algorithm of MNH-WSN

The algorithm has three major parts initializations, check and update, and handoff execution parts.

4.3.1 Initialization

The first step before handoff processes start is initializing the necessary information for future handoff processes. Initialization like CN table, time, counter.

CN table MN gathers information about the neighboring CNs by listening to beacon from CN during the initial scanning process. At the same time, MN creates a table, called “CN table,” storing neighboring CN’s information. CN table contains CN add (MAC address of CN), Priority, and link quality (LQ) value. Its priority level is based on the link strength starting with maximum to minimum.

4.3.2 Check and Update

After the initial connection is made the task of MNH-WSN is looking link quality of every packet communication. When the quality is less than -85dbm MNH-WSN will react, and send notification to data sending mechanism end by directing to handoff execution part.

4.3.2.1 Monitoring LQ Update

Other job of this part is updating table of its CN list, which is done by active scan for less than one second every 1:50 minutes.

4.3.2.2 Notification

A message sent by the MN to trigger a MNH-WSN in the MN. It adds an overhead of 2 bytes (n) in the MAC payload, which contains the command type (0xC0). Used to notify a CN not to send data to MN until it is notified to do so.

4.3.3 Handoff Execution Part

The probability of handoff is getting increased if the MN moves to the coverage area of another CN. When the LQ of the MN drops below a predefined handoff threshold, then MN triggers the re-association directly rather than scanning the available CNs. It is step where MNH-WSN change CN, selecting from its table list, by:

4.3.3.1 Soft Handoff

If the MN node has all necessary information about CN with whom it will connect next. Done according to paper [1]

4.3.3.2 Hard Handoff Called when MN has no CN in its table list or have a CN with incomplete information.

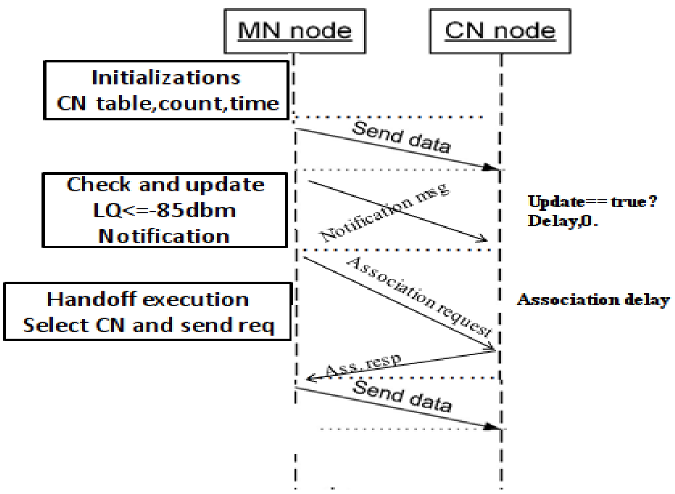


Figure 4-4 Sequence diagram

In the Figure 4.5 shown the sequence diagram of complete communication between MN, CN, and SN. MNH-WSN assumed that during the communication SN is connected to direct energy supply.

To explain Briefly, communication started by sending initial active scan from MN side when it is powered on and collecting all information about the CN's existing nearby at the same time it fills its CN table based on LQ, used for sorting inside its table, then it will send association request to CN with highest priority from its list. At this step, CN, will respond after checking initial security issues at the same time informs for SN about its new connection. So, now MN received response and real data communication started the only next function of MN is checking its quality of connection to CN during every 1:50 minutes and updating its table. But what if the quality is less than -85dbm then automatically MN send notification to CN and start handoff execution which includes selecting the next CN with better quality and sending association request after receiving the response from newly selected CN the normal function starts. Every step when CN node make connection or receive data it will send information to SN, which is used to update information from SN side about MN.

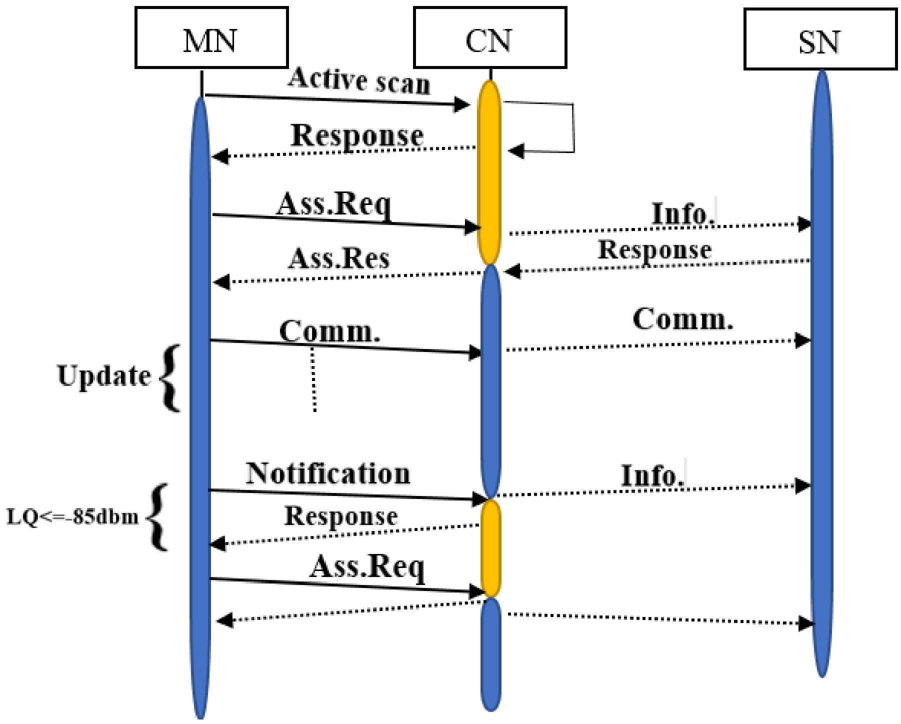
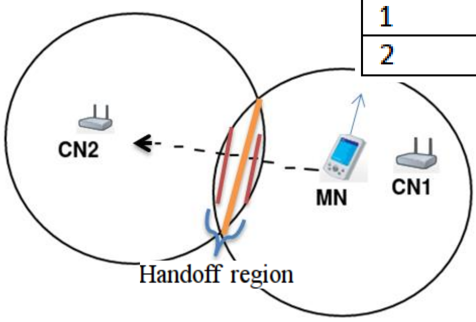


Figure 4-5 General sequence diagram of the MNH-WSN

4.4 Handoff Limit

This is the point where MNH-WSN will react communication and direct to handoff process. The lowest limit to process MNH-WSN is when the link quality is -85dbm, which is studded and decided by paper [1,6,5]. Here MNH-WSN has two important mechanisms used for handoff action, soft and hard handoff. During soft handoff MN will use CN in its table list but when if there is no CN list in its table then MN is enforced to do hard handoffs using active scan for less than one second. The yellow line in Figure 4-6 indicates that the limit of handoff line(-85dbm), when MN reaches this line from both CN1 and CN2 direction MNH-WSN will notify data sending mechanism to stop data sending and execute soft handoff. But the problem is when it reaches the red line without receiving any response then hard handoff is executed. Finally, it will decide to depend on the result, as designed by the algorithm in Figure 4-3.



Priority	CN add	LQ
1	CN1	86
2	CN2	08

Figure 4-6 MNH-WSN handoff limit

4.5 Use case diagrams

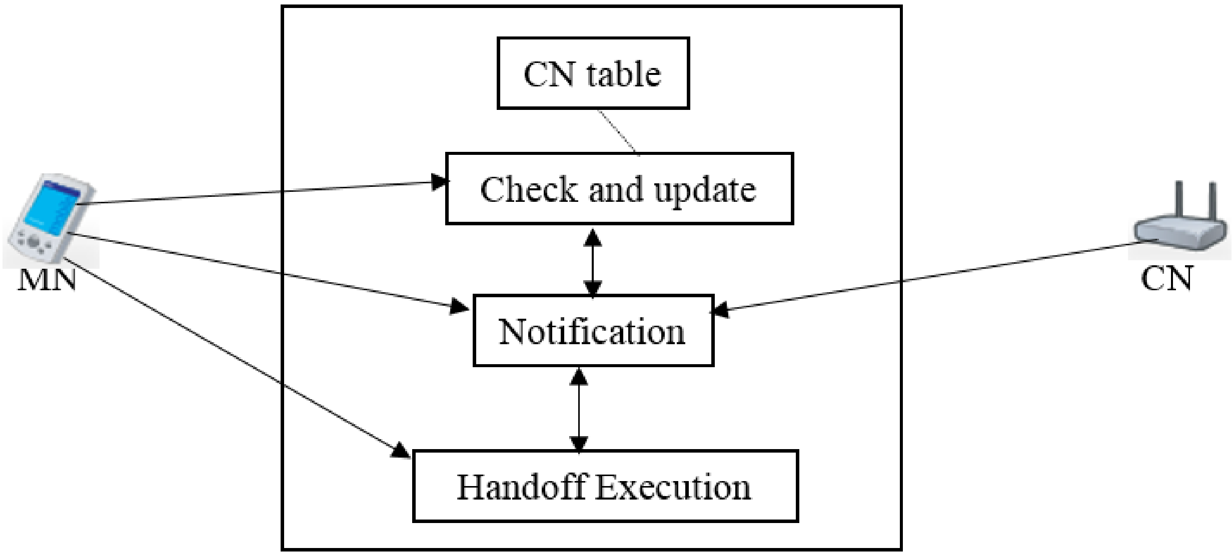


Figure 4-7 Use case diagram of MNH-WSN

4.5.1 Use Case Documentation (for each use case identified)

Name	Check and update
ID	H001
Description	This is step where MN is going to check every 1.5 minutes its connection quality with the CN, and if there is new information got from check then it will update its CN table so that it can be used in future process.
Actor	MN, CN
Organizational benefit	Here the benefit for the organization is that the organization(hospital) know the updated information about its patients as par as when the patients are in the hospital, that make easy mobile health management
Precondition	The only pre-condition is that the hospital accepts a patient as legal and give the WSN device to wear and connected to the hospital network
Post conditions	Rule of hospital
Frequency of use	From Starting until the end or until the patient end his/her medication and WSN device turned off.
Main courses	The WSN device must first ON and the user move any ware in the network coverage area of hospital and the system update that the WSN device connection status and handoff processes going under.
Exception	If the MN move out of network coverage the protocol notify and search for other solutions.
Next step	Dynamically manipulated.

Table 4-1 Use case documentation check and update

Name	Notification
ID	H002
Description	It is Warring message, a message that is generated when the user moves out or far from the currently connected CN, in protocol it is generated when the LQI value <-85dbm.
Actor	MN
Organizational benefit	It is used to send warring alarm to the CN that it is going far from the currently connected CN, no need to send data for a moment.
Precondition	The main precondition is that the value of LQI value <= 85 dbm
Post conditions	Handoff execution state automatically
Frequency of use	Dynamically
Main courses	Weather CN responds or not the MN will step up after sending this notification
Exception	The protocol search for other nearby CNs for communication, CN table.
Next step	Handoff execution.

Table 4-2 Use case documentation of notification

Name	Handoff executions (HEP)
ID	H003
Description	This is the step where the protocol executes handoff process; soft or hard handoff, during this step CN is informed that handoff execution is taking place and when it finishes also CN is informed.
Actor	MN
Organizational benefit	The main benefit is that for moment data sending mechanism is stopped its function in both MN and CN side. So, no data loss.
Precondition	Notification.
Post conditions	If new CN with good LQI value selected from CN table and request will be sent if no new CN with better LQI value, the protocol keep going for searching new CN.
Frequency of use	Equal to number of handoffs that taken place.
Exception	Search in both hard and soft handoffs mechanize.
Next step	Informing the CN that data sending process is ready.

Table 4-3 Use case documentation of HEP

4.6 Analysis Level Class Diagram (conceptual modeling)

this section describes classes of the protocol, their interrelationships (including inheritance, aggregation, and association), and the operations and attributes of the classes.

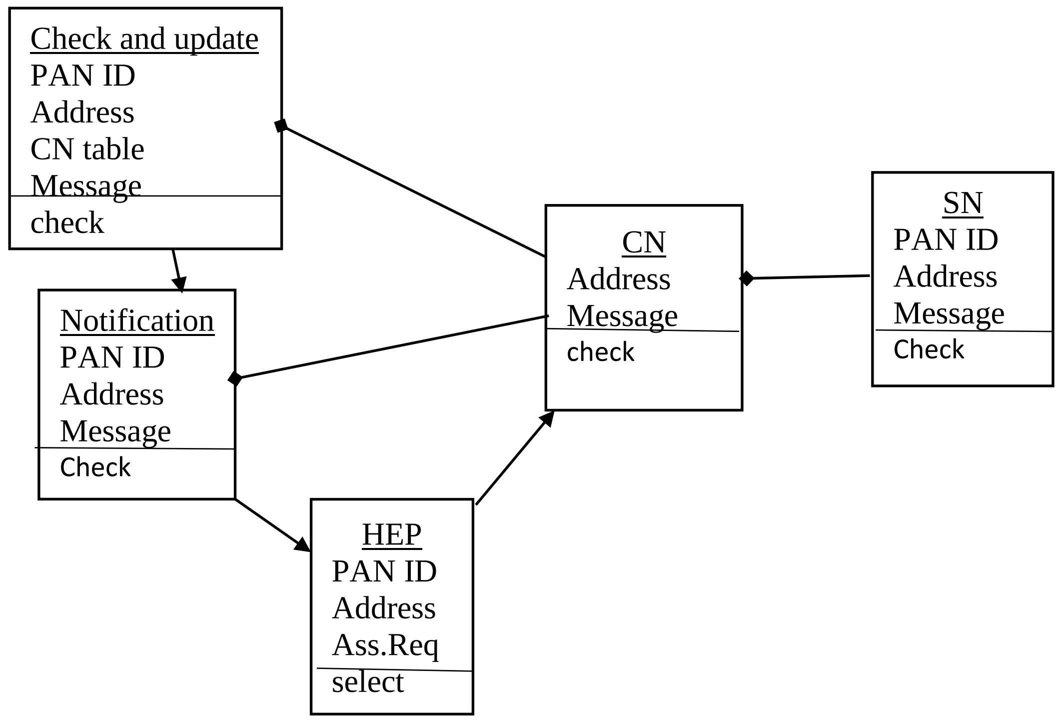


Figure 4-8 Conceptual diagram of MNH-WSN

4.7 User Interface Prototyping

In the protocol, there is no any user interaction, that means the protocol take its input from physical layer (LQI value) from incoming message, process in MAC layer of the MN, send notification and warring message from MAC layer of MN to CN, execute HEP also prom same layer of the MN.

4.8 Supplementary Specifications

4.8.1 Functionality

MNH-WSN try to see only selected lists of functional requirements that are common to more than one use case.

4.8.1.1 Protocol Errors

All protocol errors shall be returned to initial step, where the running process started, to restart the hole process. Network connection errors shall result in an orderly down of the protocol. Protocol error messages shall include a text description of the error, the step where error code occurred (if applicable), a data stamp, and a time stamp. All system errors shall be retained in the Error step.

4.8.1.2 Remote Access

All functionality shall be available remotely through a Wireless connection. This may require controllers running as coordinator(CNs) and sink node(SN).

4.8.1.3 Usability

This section lists all those requirements that relate to, or affect, the usability of the system.

4.8.2 Type of Application Running from The Mobile Sensor Node

There is no limitation for the applications which run from MN even if I considered only for health monitoring purpose at the time of development.

4.8.3 Design for Ease-of-Use

The Protocol no need user interaction that means; the user no need to interact with the protocol, it dynamically manages itself and the user only receive messages if there is something wrong going regarding coverage area. In short no need to design user interface.

4.8.4 Online Help

Regarding online help or wireless customer management help the doctor can take some action (call...) when he/she receive some important data about the health status of his/her patient.

4.8.5 Availability

MNH-WSN shall be available 24 hours a day, 7 days a week. There shall be no more.

4.8.6 Performance

The performance characteristics of Protocol is outlined in this section.

4.8.6.1 Simultaneous Users

The protocol shall support several users as much as the protocol IEEE802.15.4 supports, but the environmental influence factors not take in consideration during protocol development. Also, support simultaneous user’s, local servers at any time.

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4.8.6.2 Database Access Response Time

The protocol shall provide access to the hospital/home database with real time communication if there is no any external factor and latency depend on the connection in that specific environment.

4.8.6.3 Transaction Response Tim

During development time, MNH-WSN proposed that the protocol must be able to complete 80% of all transactions within 2 seconds, which is indication for good handoff handling time [1,13].

4.9 Design Constraints

Considering all conditions as listed above, more over the protocol wok effectively without considering the applications running from MN side.

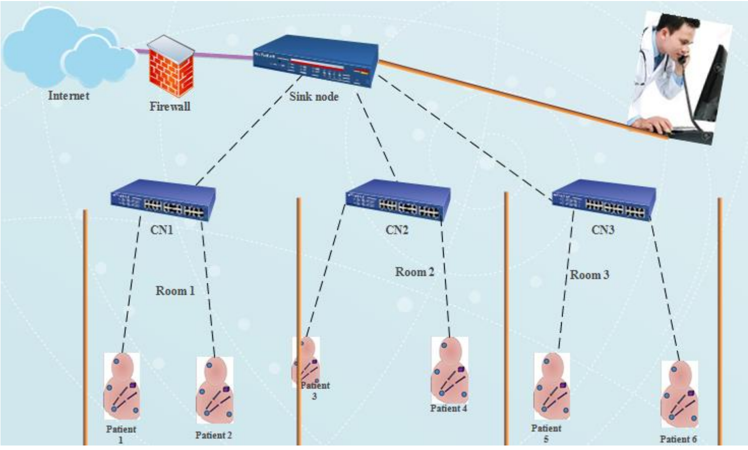

Figure 4-9 General implementation design

4.10 Implementation algorithm

For the coding purpose, CodeWarrior V-6.3 and Freescale for requirements of materials used. So, the algorithm shown below in three consecutive parts are the real implementation inside the code.

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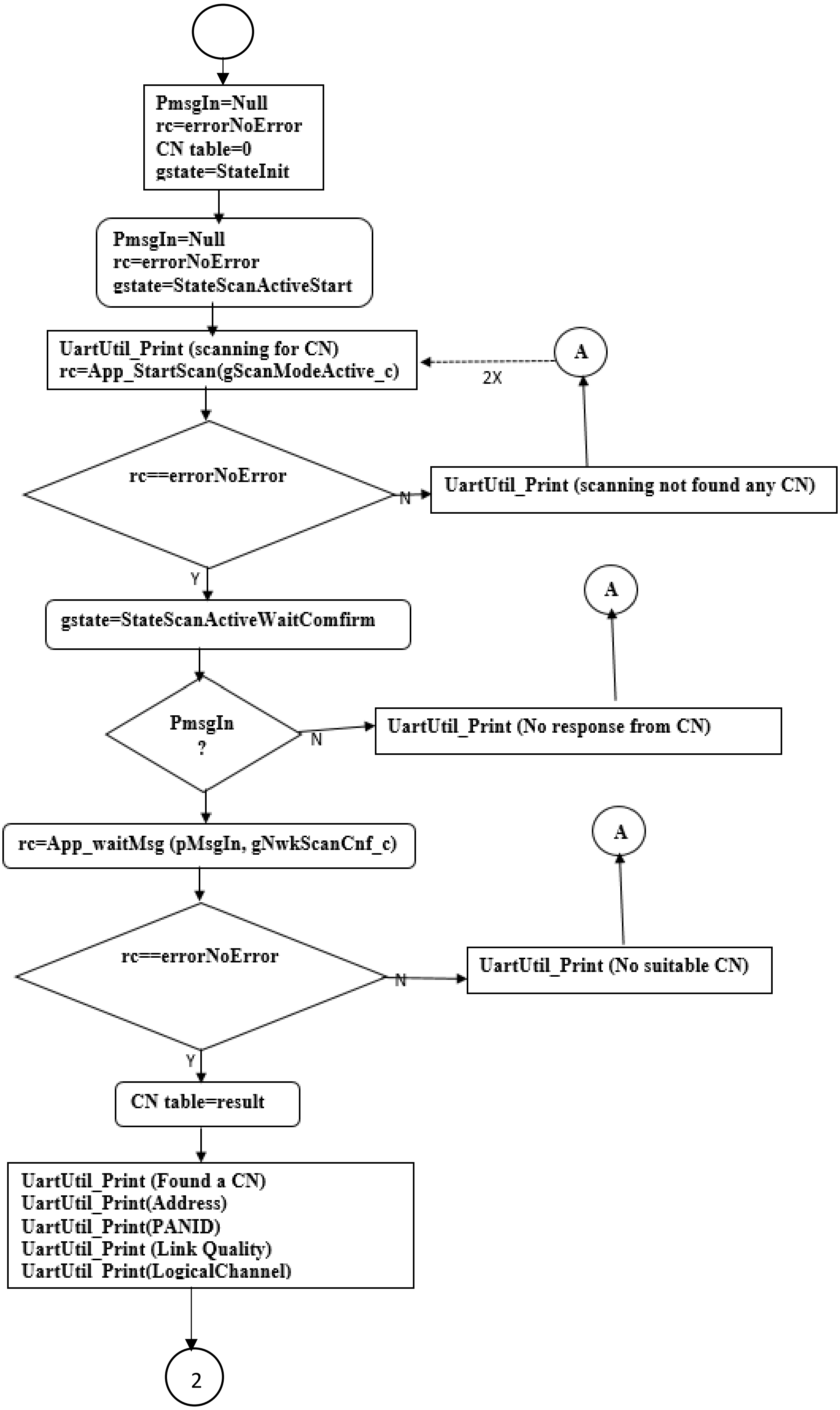

Figure 4-10 First programing part

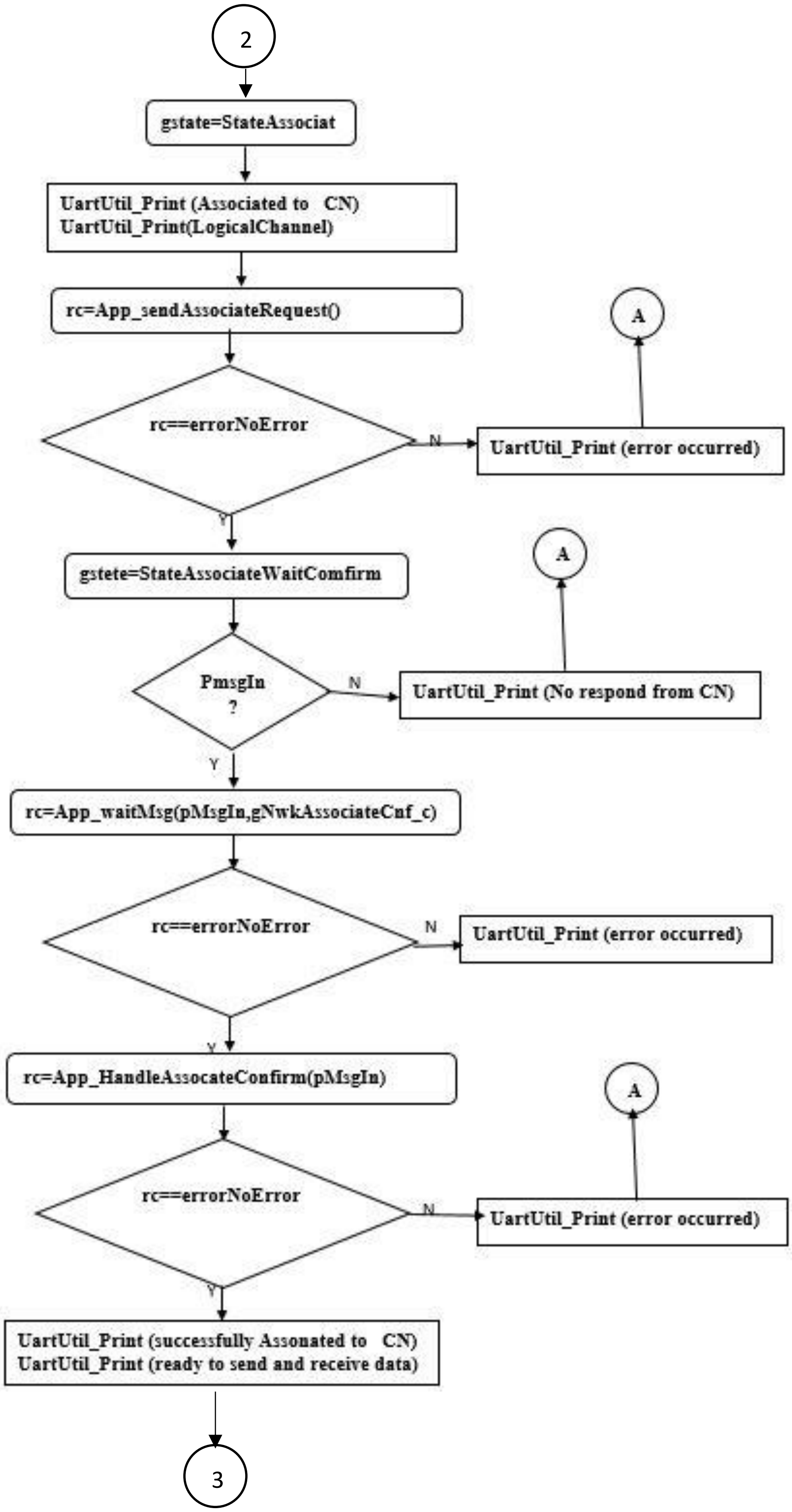

Figure 4-11 Second algorithm part of programing

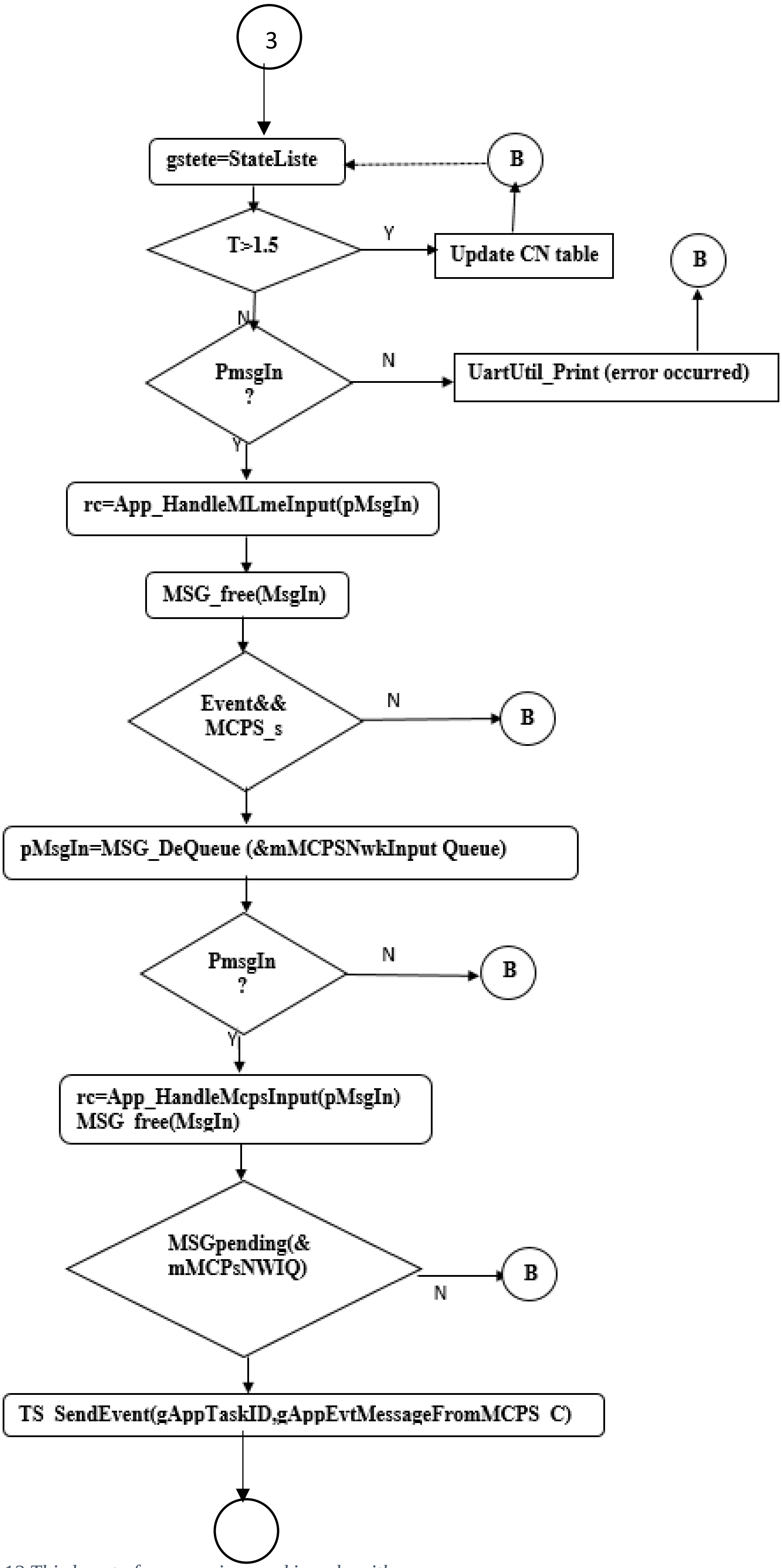

Figure 4-12 Third part of programing working algorithm

4.11 Chapter Conclusion

This chapter presented, a survey of how MNH-WSN protocol works. Beginning by introducing how it manages handoff mobility at various layers, particularly, at the MAC layer. To efficiently address, first the general working algorithm is introduced, handoff limits, and major two process (check and update, HEP) to accomplish the goal. Following the basic description of MNH-WSN next explained how the role players (MN and CN) communicate and bit explanation of class model with the mechanism of data transfer between them. Finally, the chapter present some part of coding examples that are used in normal implementation doing so, doing so look closely at the IEEE standard and the features that are natively part of the standard. Some of the various networking protocols that are proposed for or being used on top of this standard will be considered during development.

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Chapter 5 Performance Evaluation

5.1 Test Environment

To evaluate the performance of MNH-WSN with the handoff mechanism of IEEE 802.15.4 standard. It is important to set all transmission ranges of MN equal to 100 m, and use random topologies with different numbers of MNs in each experiment (1-3MNs). For simulation, the number of MNs in a network varies from 5 to 10. All results are obtained by taking average of around 20 different experimental values in both real implementation and simulation.

The experiments are done in home as well as in UABC telematics lab in Baja California University. Materials used for the evaluation are 2x (MC1321X sensors as a CNs), 3x (13192-SARD as MNs), 1322X-SRB, MC1322x USB Dongle, DURACELL 9V battery. Two 2.4GHz laptops with Windows 7 and Ubuntu 15.04 for analyzing results, the implementation result is collected using termite 2.9 as a display and for simulation using omnet-4.6.

5.2. Handoff Probability

As explained in the above chapters, MN have everything to decide and act during the communication, when the handoff starts, with which CN going to link, and informing data sending mechanism about the process. MN re-associate directly by using information of CNs table it has before, which is constructed during active scan step. When it's LQ with its current CN drops below a predefined threshold (-85dbm). At that line (red line in fig-4.6), the MN will decide to make handoff (soft or hard handoff). The decision to make soft or hard handoff is depend on the information what it has as described by authors [1]. So, most of the time the probability of handoff depends on mobility of MN and the link quality it has with CNs nearby.

5.3 Failer Probability

It has very rear failer probabilities which happen when the MN will not have all necessary information about the new CN to which it need to connect. The other failer may be due to high speed movement of the MN in specific interval like 10m in one second or more, the reason why this error happened is that the protocol consideres elders will not have such speed in given amount of time which is also explained well in paper [1]. Or sometimes if there is possibility during active scan MN could not get any CN in the current motion direction and out of range with current CN, so the handoff did not have best diction which is calling one second table update. But for managing failer probability in MNH-WSN protocol.

- MN will check up coordinators around itself every 1:5 minutes.
- Hard handoff included (including fast scan for surrounding CNs only for short period).
- Finally, after all if there is no CN, handoff call active scan and stile no result end up with sleep mode.

5.4 Average Handoff Delay

The common handoff delays are authentication delay and re-association delay, Figure 5.1 indicates that the average soft handoff delay gradually increases as the transmission range becomes larger, which is in color yellow. The protocol can successfully provide communication service as much as the average handoff delay is below 50ms in any case, which is the best time as described by different authors.

The other lines, the green and red one, are average delay of soft handoff boundary and hard handoff in MNH-WSN protocol. Even if it is above 50ms its very satisfactory results, this graph is taken from simulation environment of omnet-4.6. The other lines are active scan and orphan scan graphs.

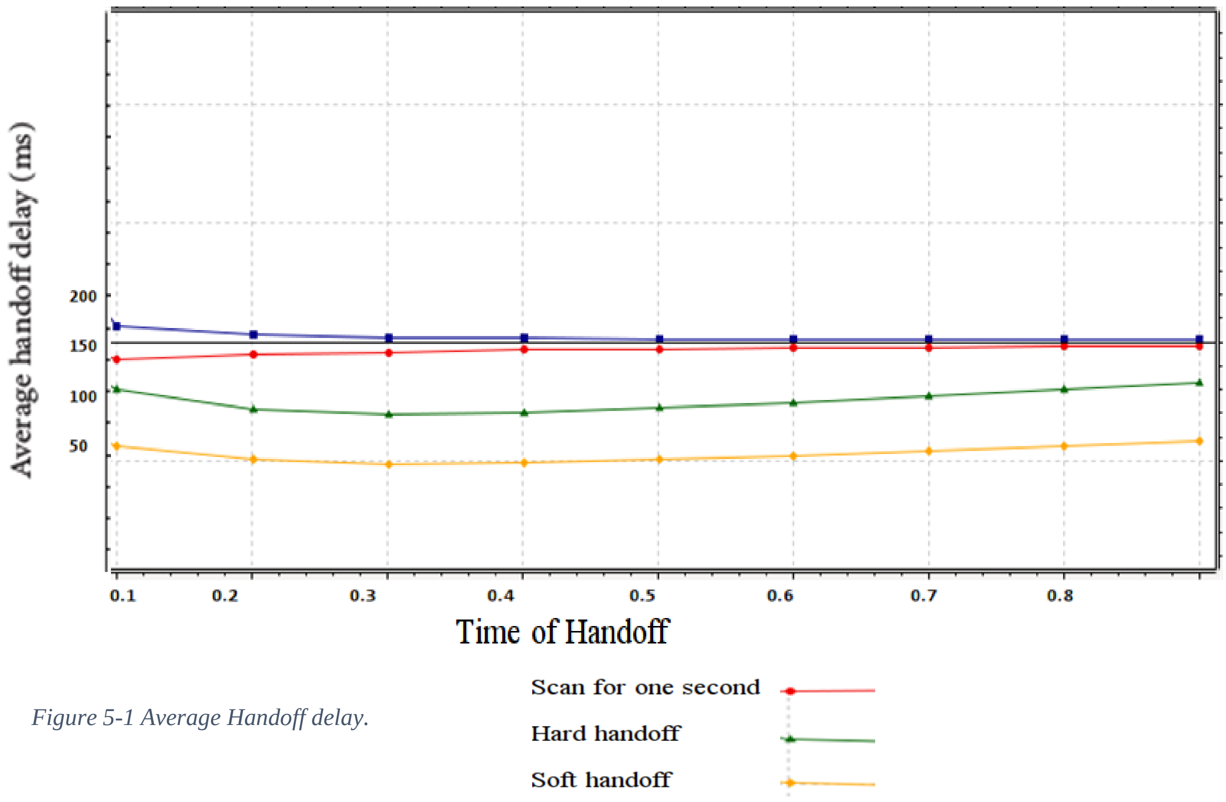

Figure 5-1 Average Handoff delay.

It is shown that the new protocol significantly reduces the handoff delay against the passive and active scanning techniques of IEEE 802.15.4 standard. MNH-WSN requires much less time to associate with the best CN among neighboring CNs by taking advantage of the information available in the CN table.

5.5 Handoff Packet Loss

During the simulation and implementation on the ground the results were exactly same for this part which indicating have less than 1% of data loss, which is occurred during active scan of 1 second or association delay. This happens when the handoff protocol is in failer state, cases explained in part 5.3.

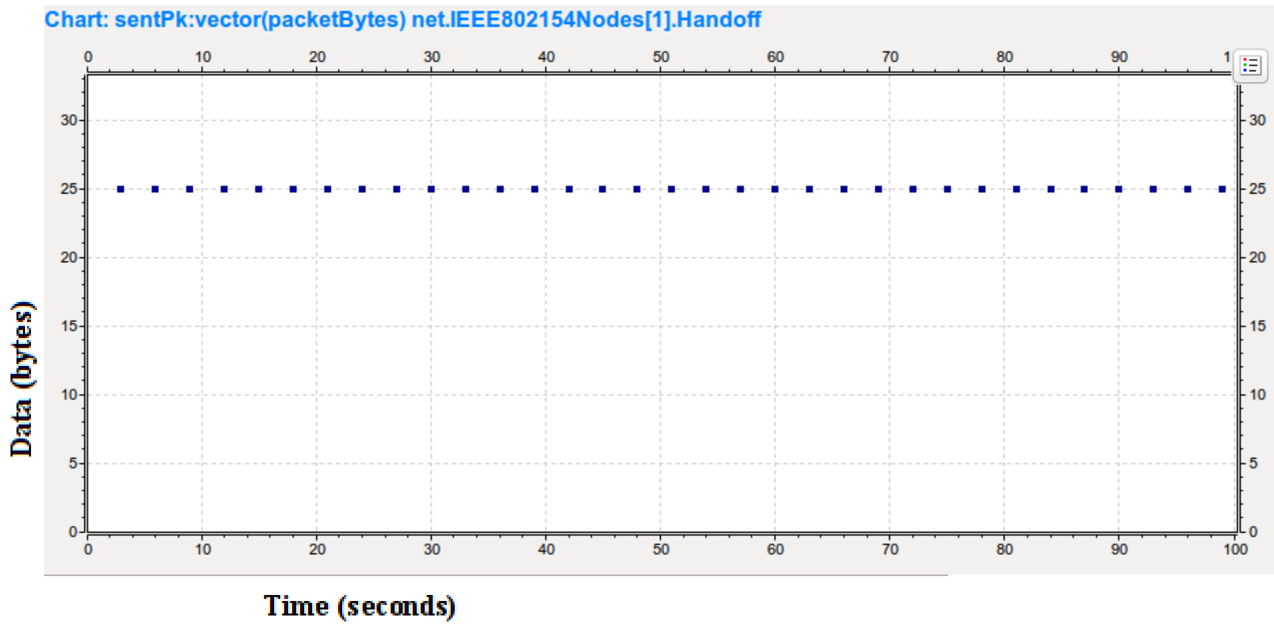

Figure 5-2 Packets sent under the handoff protocol control

5.6 Handoff Packet Delay After Implementing MNH-WSN

To analyzing packet delay before it reaches its destination and most of the time is same as the implementation environment, as the implementation is on IEEE802.15,4 standard the packet delay after implementing MNH-WSN resulted same. Shown below.

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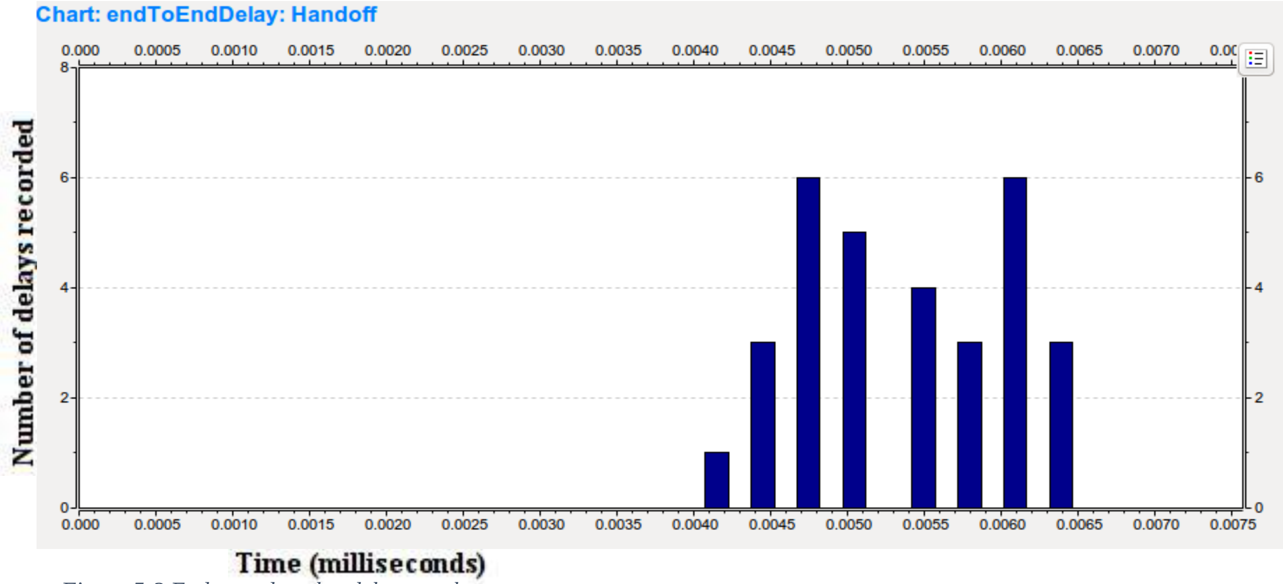

Figure 5-3 End to end packet delay graph

As the result show, there is no change in delay of normal packages which are exchanged between MN and CN through implementing handoff protocol.

5.7 Date collected from the hardware implementation are as follow

Results collected from hardware implementations: -

Step 1:

The first step is active scan step where MN will scan for nearby CNs, at the same time the designed protocol will collect and construct its CN table. After scan completed the protocol send association request to the CN with highest Link Quality from its list. When all things are going well the result look like below.

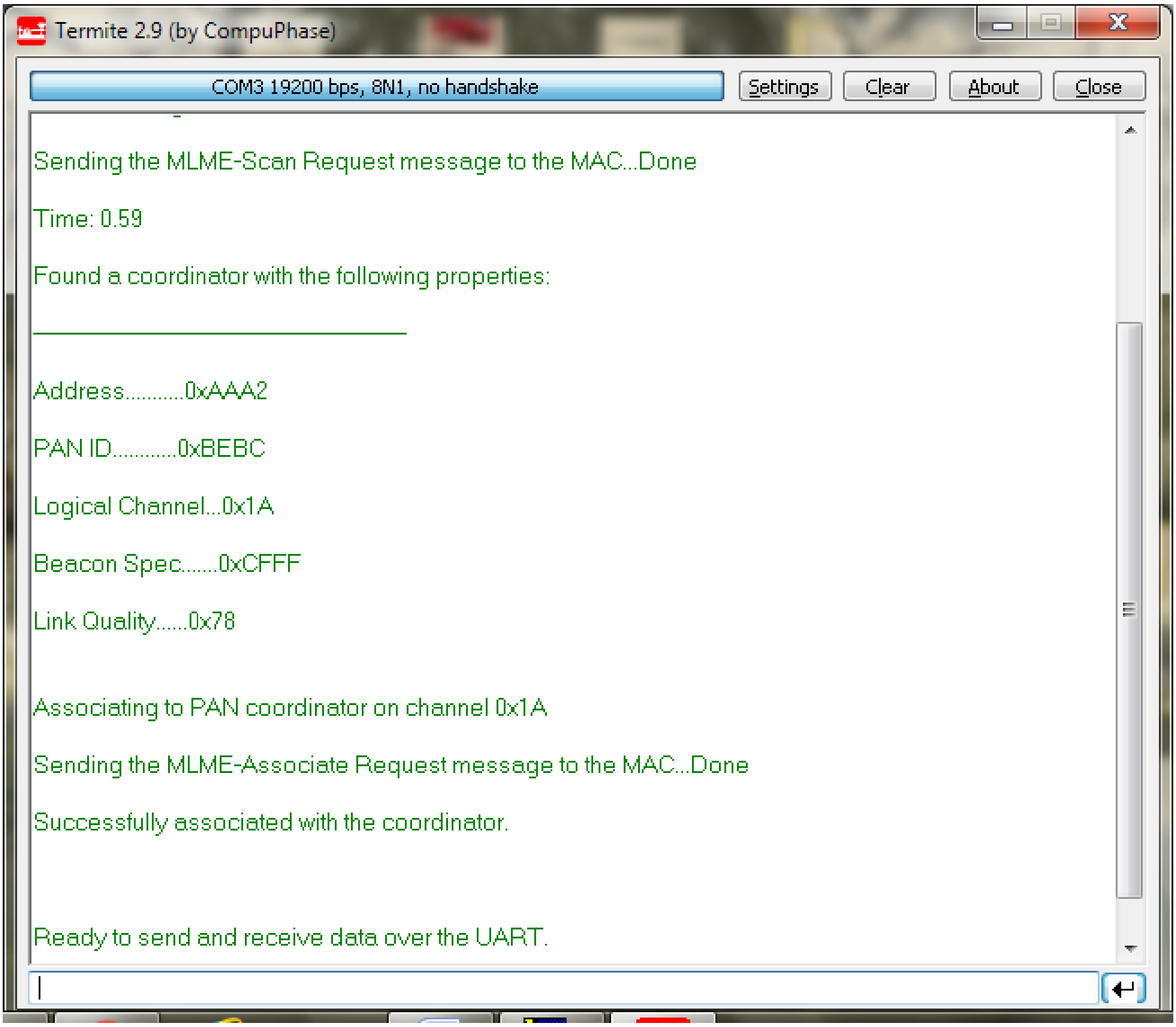

Figure 5-4 Handoff protocol active scan step window.

Step 2: Handoff step: this step is called when the MN is out of range of current CN or may be in range but less than -85dbm, which is the lowest link quality limit in MNH-WSN to take handoff. The image below is the highlight what it looks like.

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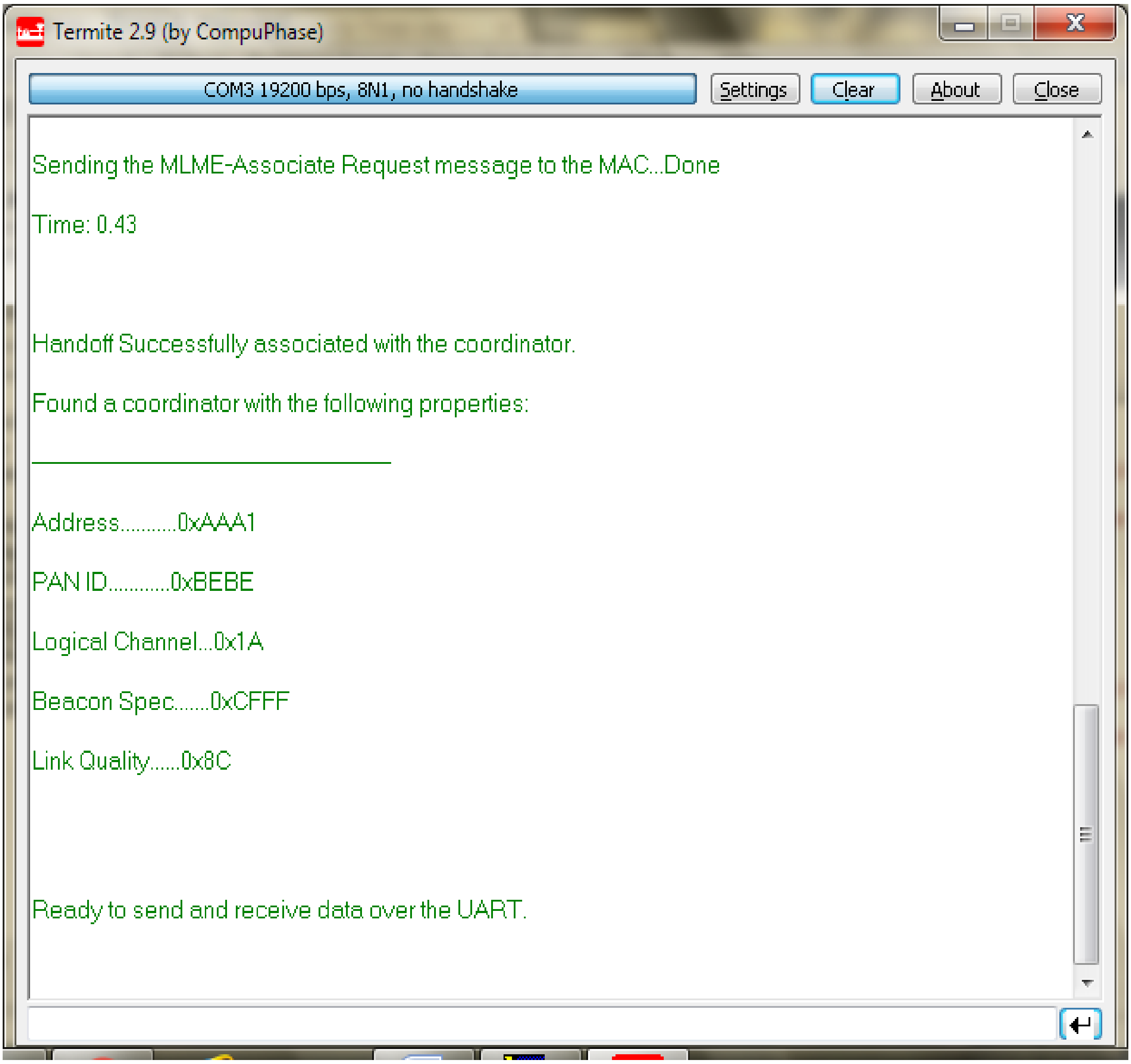

Figure 5-5 Handoff Successes message window

After this message, the normal communication starts with the new CN and every 1.50 minutes MN updates its table by scanning maximum for 1 second if there is new CNs nearby.

If it did not find any CN during Handoff the below message is displayed:

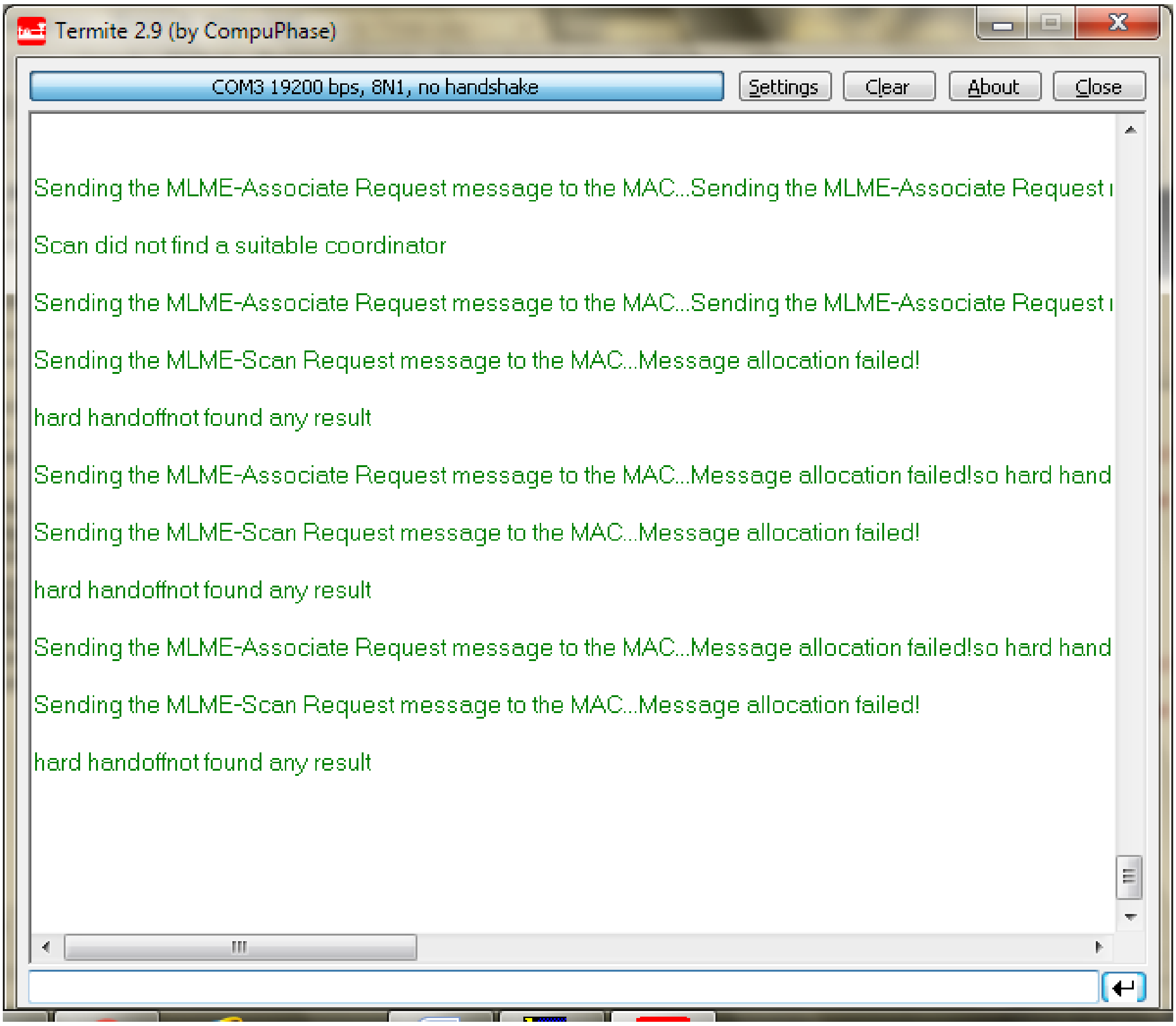

Figure 5-6 Error message window

After trying with all CNs in its list, the protocol call handoff active scan for 1 second and stile if there is no CNs found then it will call full handoff active scan, which is step 1. After all these if there is no CNs the MN will get in to sleep mode.

5.8 Delays Analysis on MNH-WSN

The mechanism used to compare is proposed in [1, 13]. The way they did is using soft handoff as a solution for problems of mobility and implementing for health-related applications of WSN in case of Author [1] and integrating soft handoff as a part of framework in WSN in the case of the second author [13].

Delay	Min	Max	Average
Soft-handoff WSN HaDaS[1]	1.0554	1.6498	1.3545
MIPv6 Soft-handoff[13]	2.0817	2.1247	2.1047
MNH-WSN	0.4388	0.5901	0.51445

Table 5-1 Over all delay compares

5.9 Chapter Conclusion

MNH-WSN, analytical and simulation results demonstrated that the algorithm is highly efficient in terms of both connectivity and time. With the implementation of new scheme, proved by IEEE 802.15.4 the new ability to handle mobility. It supports a new scheme through numerous extensive simulations study. MNH-WSN's scheme significantly reduces the handoff delay and packet loss during a handoff process. More it provides the lowest possible handoff delay which can be easily adopted for real time implementation not only in health in any area. If needed it can be used with the existing technology without any modification in the architecture.

Chapter 6 Conclusion and Recommendation

6.1 Conclusion

Wireless sensor networks that support mobility have many applications in areas such as healthcare, supply-chain, toxic gas detection in disaster areas, etc. Due to the criticality of the applications, the way mobility should be captured and handled requires a careful planning. Most of the proposed MAC protocols investigated in this thesis assume a mixed deployment in which both static and mobile nodes are present. In fact, most approaches implicitly assume that the number of static nodes is significantly larger than the number of mobile nodes. by believing that this is a realistic assumption.

Transfer of an ongoing data from one CN to another CN without loss of connection and data can only be possible through an optimal handoff procedure. If a handoff delay of approximately 50ms that is good handoff handling mechanism [1,3,38,39,40].

In this thesis, new fast handoff protocol called MNH-WSN is proposed which eliminates scanning delay when the MN decides to do handoff. MNH-WSN has three parts, initialization, check and update, and handoff execution. Using initialization or check and update the MN stores CNs in CN table to be used for any future possible handoffs that is done by handoff execution. To support the logics described, numerous extensive simulations study and practical implementations both resulted tangible output. As shown in result analysis section. MNH-WSN significantly reduces the handoff delay and packet loss during a handoff process. MNH-WSN provides the lowest possible handoff delay which can be easily adopted for real time communication. More it can be used with the existing technology without any modification in the architecture.

6.2 Publication

Article: In International Journal of Engineering and Technical Research V5(12) · December 2016.

DOI: 10.17577/IJERTV5IS120032

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6.3 Recommendation

“Nothing is prefect even if it seems for specific moment” So, as expert have some recommendation for anyone how interested to work around the title for the future:

- **Early discovery**: design effective mechanism, making it without any intelligent active scan even if it is for limited time.
- **CN table limit**: without limitation of CNs list in MN table. Expecting some unusual way to resolve memory limitation of MNs.
- **Current movement direction**: mechanism to determine the current movement direction of MN.
- **Speed independen**t: Designing mechanism without assuming the speed of MN.
- **Factors**: Take consideration of several factors which are not considered in this work like physical environment, signal interference ...etc.

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ANNEXES:

Annex1: Sample of code from the protocol

```
/*************************************************************************
*Mac Application Task event processor.  This function is called to
* process all events for the task. Events include timers, messages and any
* other user defined events
* Interface assumptions: None
* Return value: None
************************************************************************/
void AppTask(event_t events)
{
  /* Pointer for storing the messages from MLME, MCPS, and ASP. */
  void *pMsgIn;
  /* Stores the status code returned by some functions. */
  uint8_t rc;
  pMsgIn = NULL;
  /* Dequeue the MLME message */
  if (events & gAppEvtMessageFromMLME_c)
  {
    /* Get the message from MLME */
    pMsgIn = MSG_DeQueue(&mMlmeNwkInputQueue);
    /* Any time a beacon might arrive. Always handle the beacon frame first */
    if (pMsgIn)
    {
      rc = App_WaitMsg(pMsgIn, gNwkBeaconNotifyInd_c);
      if(rc == errorNoError)
      {
        /* ALWAYS free the beacon frame contained in the beacon notify indication.*/
        /* ALSO the application can use the beacon payload.*/
        MSG_Free(((nwkMessage_t *)pMsgIn)->msgData.beaconNotifyInd.pBufferRoot);
        UartUtil_Print("Received an MLME-Beacon Notify Indication\n\r", gAllowToBlock_d);
      }
    }
  }
  /* The application state machine */
  switch(gState)
  {
  case stateInit:
    /* Print a welcome message to the UART */
    UartUtil_Print("\n\rMyWirelessApp Demo Non Beacon End Device application is initialized and
ready.\n\r\n\r", gAllowToBlock_d);
    /* Goto Active Scan state. */
    gState = stateScanActiveStart;
    TS_SendEvent(gAppTaskID_c, gAppEvtDummyEvent_c);
    break;
  case stateScanActiveStart:
    /* Start the Active scan, and goto wait for confirm state. */
    UartUtil_Print("Start scanning for a PAN coordinator\n\r", gAllowToBlock_d);
    /*print a message on the LCD also*/
    LCD_ClearDisplay();
    LCD_WriteString(1,"Start scanning");
    LCD_WriteString(2,"for coordinator");
    rc = App_StartScan(gScanModeActive_c);
    if(rc == errorNoError)
    {
      gState = stateScanActiveWaitConfirm;
```


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```
    }
    break;

  case stateScanActiveWaitConfirm:
    /* Stay in this state until the Scan confirm message
       arrives, and then goto the associate state. */
    if (events & gAppEvtMessageFromMLME_c)
    {
      if (pMsgIn)
      {
        rc = App_WaitMsg(pMsgIn, gNwkScanCnf_c);
        if(rc == errorNoError)
        {
          rc = App_HandleScanActiveConfirm(pMsgIn);
          if(rc == errorNoError)
          { UartUtil_Print("Time: 0.59\n\r", gAllowToBlock_d);
            UartUtil_Print("Found a coordinator with the following properties:\n\r", gAllowToBlock_d);
            UartUtil_Print("--------------------------------------------------", gAllowToBlock_d);
            UartUtil_Print("\n\rAddress...........0x",                                    gAllowToBlock_d);
UartUtil_PrintHex(mCoordInfo1.coordAddress, mCoordInfo1.coordAddrMode == gAddrModeShort_c ?
2 : 8, 0);
            UartUtil_Print("\n\rPAN                     ID...........0x",                 gAllowToBlock_d);
UartUtil_PrintHex(mCoordInfo1.coordPanId, 2, 0);
            UartUtil_Print("\n\rLogical                 Channel...0x",                   gAllowToBlock_d);
UartUtil_PrintHex(&mCoordInfo1.logicalChannel, 1, 0);
            UartUtil_Print("\n\rBeacon                  Spec.......0x",                  gAllowToBlock_d);
UartUtil_PrintHex(mCoordInfo1.superFrameSpec, 2, 0);
            UartUtil_Print("\n\rLink                    Quality......0x",                gAllowToBlock_d);
UartUtil_PrintHex(&mCoordInfo1.linkQuality, 1, 0);
            UartUtil_Print("\n\r\n\r", gAllowToBlock_d);
            gState = stateAssociate;
            TS_SendEvent(gAppTaskID_c, gAppEvtDummyEvent_c);
          }
          else
                {
            UartUtil_Print("Scan did not find a suitable coordinator\n\r", gAllowToBlock_d);
            /*print a message on the LCD also*/
            LCD_ClearDisplay();
            LCD_WriteString(1,"No coordinator");
            LCD_WriteString(2,"found.");
                }}}} break;

  case stateAssociate:
    /* Associate to the PAN coordinator */
    UartUtil_Print("Associating to PAN coordinator on channel 0x", gAllowToBlock_d);
    UartUtil_PrintHex(&(mCoordInfo1.logicalChannel), 1, gPrtHexNewLine_c);
    /*print a message on the LCD also*/
    LCD_ClearDisplay();
    LCD_WriteString(1,"Associating to ");
    LCD_WriteString(2,"PAN coordinator");
    rc = App_SendAssociateRequest();
    if(rc == errorNoError)
      gState = stateAssociateWaitConfirm;
    break;

  case stateAssociateWaitConfirm:
    /* Stay in this state until the Associate confirm message
       arrives, and then goto the Listen state. */
    if (events & gAppEvtMessageFromMLME_c)
    {
```


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```
    if (pMsgIn)
    {
     rc = App_WaitMsg(pMsgIn, gNwkAssociateCnf_c);
     if(rc == errorNoError)
     {
       rc = App_HandleAssociateConfirm(pMsgIn);
       if (rc == errorNoError&& l==1)
       {
       UartUtil_Print("Successfully associated with the coordinator.\n\r", gAllowToBlock_d);
      // UartUtil_Print("We were assigned the short address 0x", gAllowToBlock_d);
     //    UartUtil_PrintHex(maMyAddress,    mAddrMode    ==    gAddrModeShort_c    ?2    :8,    0);
UartUtil_Print("\n\r\n\rReady to send and receive data over the UART.\n\r\n\r", gAllowToBlock_d);
       /*print a message on the LCD also*/
       LCD_ClearDisplay();
       LCD_WriteString(1,"Ready to send");
       LCD_WriteString(2,"and receive data");
       /* Startup the timer */
       TMR_StartSingleShotTimer(mTimer_c, mPollInterval, AppPollWaitTimeout);
       /* Go to the listen state */
       gState = stateListen;
       TS_SendEvent(gAppTaskID_c, gAppEvtDummyEvent_c);
       }
       else if (rc == errorNoError&& l>1) {
       UartUtil_Print("Time: 0.43\n\r", gAllowToBlock_d);
       UartUtil_Print("\n\r\n\r", gAllowToBlock_d);
       UartUtil_Print("Handoff Successfully associated with the coordinator.\n\r", gAllowToBlock_d);
       UartUtil_Print("Found a coordinator with the following properties:\n\r", gAllowToBlock_d);
        UartUtil_Print("--------------------------------------------------", gAllowToBlock_d);
        UartUtil_Print("\n\rAddress...........0x",                          gAllowToBlock_d);
UartUtil_PrintHex(mCoordInfo2.coordAddress, mCoordInfo1.coordAddrMode == gAddrModeShort_c ?
2 : 8, 0);
        UartUtil_Print("\n\rPAN              ID............0x",             gAllowToBlock_d);
UartUtil_PrintHex(mCoordInfo2.coordPanId, 2, 0);
        UartUtil_Print("\n\rLogical          Channel...0x",                 gAllowToBlock_d);
UartUtil_PrintHex(&mCoordInfo2.logicalChannel, 1, 0);
        UartUtil_Print("\n\rBeacon           Spec.......0x",                gAllowToBlock_d);
UartUtil_PrintHex(mCoordInfo2.superFrameSpec, 2, 0);
        UartUtil_Print("\n\rLink             Quality......0x",              gAllowToBlock_d);
UartUtil_PrintHex(&mCoordInfo2.linkQuality, 1, 0);
        UartUtil_Print("\n\r\n\r", gAllowToBlock_d);
UartUtil_Print("\n\r\n\rReady to send and receive data over the UART.\n\r\n\r", gAllowToBlock_d);
       /*print a message on the LCD also*/
       LCD_ClearDisplay();
       LCD_WriteString(1,"Ready to send");
       LCD_WriteString(2,"and receive data");
       /* Startup the timer */
       TMR_StartSingleShotTimer(mTimer_c, mPollInterval, AppPollWaitTimeout);
       /* Go to the listen state */
       gState = stateListen;
       TS_SendEvent(gAppTaskID_c, gAppEvtDummyEvent_c);
       }

       else
       {
       UartUtil_Print("\n\rAssociate Confirm wasn't successful... \n\r\n\r", gAllowToBlock_d);
       gState = stateScanActiveStart;
         TS_SendEvent(gAppTaskID_c, gAppEvtDummyEvent_c);
       }
     }
    }
```

```
    }
    break;

  case stateListen:
    /* Transmit to coordinator data received from UART. */
    if (events & gAppEvtMessageFromMLME_c)
    {
      if (pMsgIn)
      {
        /* Process it */
        rc = App_HandleMlmeInput(pMsgIn);
      }
    }

    if (events & gAppEvtRxFromUart_c)
    {
      /* get byte from UART */
      App_TransmitUartData();

    }
    break;
  }

  if (pMsgIn)
  {
    /* Messages must always be freed. */
    MSG_Free(pMsgIn);
  }

   /* Handle MCPS confirms and transmit data from UART */
  if (events & gAppEvtMessageFromMCPS_c)
  {
    /* Get the message from MCPS */
    pMsgIn = MSG_DeQueue(&mMcpsNwkInputQueue);
    if (pMsgIn)
    {
      /* Process it */
      App_HandleMcpsInput(pMsgIn);
      /* Messages from the MCPS must always be freed. */
      MSG_Free(pMsgIn);
    }
  }

  /* Check for pending messages in the Queue */
  if(MSG_Pending(&mMcpsNwkInputQueue))
    TS_SendEvent(gAppTaskID_c, gAppEvtMessageFromMCPS_c);
  if(MSG_Pending(&mMlmeNwkInputQueue))
    TS_SendEvent(gAppTaskID_c, gAppEvtMessageFromMLME_c);
}
```

Annex2: Hand off part specifically

```
/******************************************************************************
* The App_HandleScanActiveConfirm(nwkMessage_t *pMsg) function will handle the
* Active Scan confirm message received from the MLME when the Active scan has
* completed. The message contains a list of PAN descriptors. Based on link
* quality inforamtion in the pan descriptors the nearest coordinator is chosen.
* The corresponding pan descriptor is stored in the global variable mCoordInfo.
*
* The function may return either of the following values:
*   errorNoError:       A suitable pan descriptor was found.
*   errorNoScanResults: No scan results were present in the confirm message.
*
******************************************************************************/
static uint8_t App_HandleScanActiveConfirm(nwkMessage_t *pMsg)
{
  void    *pBlock;
  uint8_t panDescListSize = pMsg->msgData.scanCnf.resultListSize;
  uint8_t rc = errorNoScanResults;
  uint8_t j,i;
  uint8_t bestLinkQuality = 0;
  panDescriptorBlock_t *pDescBlock = pMsg->msgData.scanCnf.resList.pPanDescriptorBlocks;
  panDescriptor_t *hd;//*pPanDesc,*hd,*pPanDesc,*hd,


  /* Check if the scan resulted in any coordinator responses. */

  if (panDescListSize > 0)
  {
    /* Check all PAN descriptors. */
    while (NULL != pDescBlock)

    {
```


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```
    for (j = 0; j <= pDescBlock->descriptorCount; j++)

    mn[j]= &pDescBlock->descriptorList[j];

     for (i = 0; i < pDescBlock->descriptorCount; i++)
       {
        for (j = 0; j < pDescBlock->descriptorCount; j++)

    {
    if( ( mn[j]->superFrameSpec[1] & gSuperFrameSpecMsbAssocPermit_c) &&
          ((mn[j]->superFrameSpec[0] & gSuperFrameSpecLsbBO_c) == 0x0F) )
      {
          if(mn[j]->linkQuality < mn[j+1]->linkQuality){
           hd= mn[j];
            mn[j]=mn[j+1];
            mn[j+1]=hd;
          }
         }
        }
       }
 FLib_MemCpy(&mCoordInfo, mn[0], sizeof(panDescriptor_t));
         bestLinkQuality = mn[0]->linkQuality;
          rc = errorNoError;
              n=0;
                }
    /* Free current block */
    pBlock =pDescBlock;
    pDescBlock = pDescBlock->pNext;
    MSG_Free(pBlock);
  }
 if (pDescBlock)
    MSG_Free(pDescBlock);
 return rc;
}
```


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Annex 3: Message Handling part

```
/******************************************************************************
**
* The App_HandleMcpsInput(mcpsToNwkMessage_t *pMsgIn) function will handle
* messages from the MCPS, e.g. Data Confirm, and Data Indication.
*
******************************************************************************
*/
static void App_HandleMcpsInput(mcpsToNwkMessage_t *pMsgIn)
{
/* Stores the status code returned by some functions. */
  uint8_t rc;
  switch(pMsgIn->msgType)
  {
    /* The MCPS-Data confirm is sent by the MAC to the network
       or application layer when data has been sent. */
  case gMcpsDataCnf_c:
    if(mcPendingPackets)
      mcPendingPackets--;
    break;

  case gMcpsDataInd_c:

    /* Copy the received data to the UART. */
    UartUtil_Tx(pMsgIn->msgData.dataInd.pMsdu, pMsgIn->msgData.dataInd.msduLength);
    /* Since we received data, the coordinator might have more to send. We
       reduce the polling interval to raise the throughput while data is
```

```
     available. */

  if(pMsgIn->msgData.dataInd.mpduLinkQuality<=10){
  UartUtil_Print("LQ limited so disassosation sent to PAN!\n\r", gAllowToBlock_d);
     sendDisAssociateRequest() ;

     n=n+1;
      FLib_MemCpy(&mCoordInfo, mn[n], sizeof(panDescriptor_t));

      rc= App_SendAssociateRequest();
       if(rc == errorNoError)
       gState = stateAssociate;
        else
        UartUtil_Print("not found!\n\r", gAllowToBlock_d);

        TS_SendEvent(gAppTaskID_c, gAppEvtDummyEvent_c);

     }
   mPollInterval = mDefaultValueOfPollIntervalFast_c;
   /* Allow another MLME-Poll request. */
  mWaitPollConfirm = FALSE;

   break;
  }
}
```


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Annex 4: General senario .ini

```
[General]
network = ieee802154.simulations.net
sim-time-limit = 100s

###----- Scenario: Node transmits to coordinator in non-beacon-enabled PAN ----###
# Two single and static IEEE 802.15.4 Hosts, one sender node and one coordinator
# Scenario from 802.15.4 standard - Figure 7 and Figure 70
# Communication from a node to a coordinator in a non-beacon-enabled PAN
# Acknowledgments disabled
# CAP transmission
# Direct transmission
# Beacon Order      = 15 -> no regular beacon, only when requested
# Superframe Order  = 15 -> no superframe
# --> Non-Beacon-Enabled Mode
###---------------------------------------------------------------###


*.numHosts=4

seed-0-lcg32 = 111  # switch around this seed if u want different startup behaviours
*.IEEE802154Nodes[*].Network.stdLLC.rng-0 = 0   # specify which #RNG is used per node / module

*.IEEE802154Nodes[*].mobility.initFromDisplayString = false    # set XYZ positions manually

*.IEEE802154Nodes[0].mobility.initialX = 90m
*.IEEE802154Nodes[0].mobility.initialY = 100m
*.IEEE802154Nodes[0].mobility.initialZ = 0m
*.IEEE802154Nodes[2].mobility.initialX = 280m
*.IEEE802154Nodes[2].mobility.initialY = 250m
*.IEEE802154Nodes[2].mobility.initialZ = 0m
*.IEEE802154Nodes[3].mobility.initialX = 460m
*.IEEE802154Nodes[3].mobility.initialY = 250m
*.IEEE802154Nodes[3].mobility.initialZ = 0m
*.IEEE802154Nodes[1].mobility.initialX = 10m
*.IEEE802154Nodes[1].mobility.initialY = 12m
*.IEEE802154Nodes[1].mobility.initialZ = 0m
*.IEEE802154Nodes[4].mobility.initialX = 460m
*.IEEE802154Nodes[4].mobility.initialY = 250m
*.IEEE802154Nodes[4].mobility.initialZ = 0m
**.IEEE802154Nodes[1].mobilityType = "ConstSpeedMobility"
**.IEEE802154Nodes[1].mobility.initFromDisplayString = false
**.IEEE802154Nodes[1].mobility.speed = 5mps
*.IEEE802154Nodes[*].application.packetLength = 25Byte
*.IEEE802154Nodes[*].application.protocol = 1
*.IEEE802154Nodes[*].application.sendInterval = 1s
*.IEEE802154Nodes[1].application.numPackets = 100
*.IEEE802154Nodes[*].application.startTime = 10s       # set this past the mac start time
                        # 100 packets, one per second plus 10s start time
# for IPvxTrafGen use a destination address where the 802.15.4 MAC is represented by the last 8 toupels,
LLC::tokenDest converts it into 802.15.4 MAC
```

```
# To disable the traffic generator, set destAddresses to ""2001:0DB8:85A3:08D3:0AAA:0000:0000:0001
*.IEEE802154Nodes[1].application.destAddresses = "2001:0DB8:85A3:08D3:0AAA:0000:0000:0001
1001:0DB8:85A3:08D3:0AAA:0000:0000:0001"
#*.IEEE802154Nodes[1].application..destAddresses2 = "1001:0DB8:85A3:08D3:0AAA:0000:0000:0001"
*.IEEE802154Nodes[*].NIC.MAC.IEEE802154Mac.startWithoutStartReq = true
*.IEEE802154Nodes[0].NIC.MAC.IEEE802154Mac.isPANCoordinator = true
*.IEEE802154Nodes[2].NIC.MAC.IEEE802154Mac.isPANCoordinator = true
*.IEEE802154Nodes[3].NIC.MAC.IEEE802154Mac.isPANCoordinator = true
*.IEEE802154Nodes[4].NIC.MAC.IEEE802154Mac.isPANCoordinator = true
#*.IEEE802154Nodes[0].NIC.MAC.IEEE802154Mac.isRecvGts = false         # node[0] is sending the GTS
*.IEEE802154Nodes[1].NIC.MAC.IEEE802154Mac.isPANCoordinator = false

*.IEEE802154Nodes[*].Network.stdLLC.TXoption = 0           # 0 = direct transmission without acks
(Figure 70 of 802.15.4-2006)
*.IEEE802154Nodes[*].Network.stdLLC.ScanDuration = 1.5       # [aBaseSuperframeDuration * (2^n +
1)] this is n so - value is Symbols

*.IEEE802154Nodes[*].Network.stdLLC.BeaconOrder = 15         # disable superframe / beacons
*.IEEE802154Nodes[*].Network.stdLLC.SuperframeOrder = 15
*.IEEE802154Nodes[*].NIC.MAC.IEEE802154Mac.BeaconOrder = 15    # disable superframe / beacons
*.IEEE802154Nodes[*].NIC.MAC.IEEE802154Mac.SuperframeOrder = 15
**.constraintAreaMinX = 0m
**.constraintAreaMinY = 0m
**.constraintAreaMinZ = 0m
**.constraintAreaMaxX = 600m
**.constraintAreaMaxY = 400m
**.constraintAreaMaxZ = 0m

**.updateInterval = 0.1s
```

Annex 5: Handoff.cc from simulation part

```
#ifdef _MSC_VER
#  pragma warning(disable:4101)
#  pragma warning(disable:4065)
#endif

#include <iostream>
#include <sstream>
#include "handoff_m.h"

USING_NAMESPACE


// Another default rule (prevents compiler from choosing base class' doPacking())
template<typename T>
void doPacking(cCommBuffer *, T& t) {
   throw cRuntimeError("Parsim error: no doPacking() function for type %s or its base class (check .msg
and _m.cc/h files!)",opp_typename(typeid(t)));
}

template<typename T>
void doUnpacking(cCommBuffer *, T& t) {
```

```
    throw cRuntimeError("Parsim error: no doUnpacking() function for type %s or its base class (check
.msg and _m.cc/h files!)",opp_typename(typeid(t)));
}



// Template rule for outputting std::vector<T> types
template<typename T, typename A>
inline std::ostream& operator<<(std::ostream& out, const std::vector<T,A>& vec)
{
    out.put('{');
    for(typename std::vector<T,A>::const_iterator it = vec.begin(); it != vec.end(); ++it)
    {
        if (it != vec.begin()) {
            out.put(','); out.put(' ');
        }
        out << *it;
    }
    out.put('}');

    char buf[32];
    sprintf(buf, " (size=%u)", (unsigned int)vec.size());
    out.write(buf, strlen(buf));
    return out;
}

// Template rule which fires if a struct or class doesn't have operator<<
template<typename T>
inline std::ostream& operator<<(std::ostream& out,const T&) {return out;}

Register_Class(handoff);

handoff::handoff(const char *name, int kind) : ::cMessage(name,kind)
{
    this->source_var = 0;
    this->destination_var = 0;
    this->hopCount_var = 0;
}

handoff::handoff(const handoff& other) : ::cMessage(other)
{
    copy(other);
}

handoff::~handoff()
{
}

handoff& handoff::operator=(const handoff& other)
{
    if (this==&other) return *this;
    ::cMessage::operator=(other);
    copy(other);
    return *this;
}
```

```
void handoff::copy(const handoff& other)
{
   this->source_var = other.source_var;
   this->destination_var = other.destination_var;
   this->hopCount_var = other.hopCount_var;
}

void handoff::parsimPack(cCommBuffer *b)
{
   ::cMessage::parsimPack(b);
   doPacking(b,this->source_var);
   doPacking(b,this->destination_var);
   doPacking(b,this->hopCount_var);
}

void handoff::parsimUnpack(cCommBuffer *b)
{
   ::cMessage::parsimUnpack(b);
   doUnpacking(b,this->source_var);
   doUnpacking(b,this->destination_var);
   doUnpacking(b,this->hopCount_var);
}

int handoff::getSource() const
{
   return source_var;
}

void handoff::setSource(int source)
{
   this->source_var = source;
}

int handoff::getDestination() const
{
   return destination_var;
}

void handoff::setDestination(int destination)
{
   this->destination_var = destination;
}

int handoff::getHopCount() const
{
   return hopCount_var;
}

void handoff::setHopCount(int hopCount)
{
   this->hopCount_var = hopCount;
}

class handoffDescriptor : public cClassDescriptor
{
```


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```
 public:
  handoffDescriptor();
  virtual ~handoffDescriptor();

  virtual bool doesSupport(cObject *obj) const;
  virtual const char *getProperty(const char *propertyname) const;
  virtual int getFieldCount(void *object) const;
  virtual const char *getFieldName(void *object, int field) const;
  virtual int findField(void *object, const char *fieldName) const;
  virtual unsigned int getFieldTypeFlags(void *object, int field) const;
  virtual const char *getFieldTypeString(void *object, int field) const;
  virtual const char *getFieldProperty(void *object, int field, const char *propertyname) const;
  virtual int getArraySize(void *object, int field) const;

  virtual std::string getFieldAsString(void *object, int field, int i) const;
  virtual bool setFieldAsString(void *object, int field, int i, const char *value) const;

  virtual const char *getFieldStructName(void *object, int field) const;
  virtual void *getFieldStructPointer(void *object, int field, int i) const;
};

Register_ClassDescriptor(handoffDescriptor);

handoffDescriptor::handoffDescriptor() : cClassDescriptor("handoff", "cMessage")
{
}

handoffDescriptor::~handoffDescriptor()
{
}

bool handoffDescriptor::doesSupport(cObject *obj) const
{
  return dynamic_cast<handoff *>(obj)!=NULL;
}

const char *handoffDescriptor::getProperty(const char *propertyname) const
{
  cClassDescriptor *basedesc = getBaseClassDescriptor();
  return basedesc ? basedesc->getProperty(propertyname) : NULL;
}

int handoffDescriptor::getFieldCount(void *object) const
{
  cClassDescriptor *basedesc = getBaseClassDescriptor();
  return basedesc ? 3+basedesc->getFieldCount(object) : 3;
}

unsigned int handoffDescriptor::getFieldTypeFlags(void *object, int field) const
{
  cClassDescriptor *basedesc = getBaseClassDescriptor();
  if (basedesc) {
    if (field < basedesc->getFieldCount(object))
      return basedesc->getFieldTypeFlags(object, field);
    field -= basedesc->getFieldCount(object);
  }
```

```
    static unsigned int fieldTypeFlags[] = {
        FD_ISEDITABLE,
        FD_ISEDITABLE,
        FD_ISEDITABLE,
    };
    return (field>=0 && field<3) ? fieldTypeFlags[field] : 0;
}

const char *handoffDescriptor::getFieldName(void *object, int field) const
{
    cClassDescriptor *basedesc = getBaseClassDescriptor();
    if (basedesc) {
        if (field < basedesc->getFieldCount(object))
            return basedesc->getFieldName(object, field);
        field -= basedesc->getFieldCount(object);
    }
    static const char *fieldNames[] = {
        "source",
        "destination",
        "hopCount",
    };
    return (field>=0 && field<3) ? fieldNames[field] : NULL;
}

int handoffDescriptor::findField(void *object, const char *fieldName) const
{
    cClassDescriptor *basedesc = getBaseClassDescriptor();
    int base = basedesc ? basedesc->getFieldCount(object) : 0;
    if (fieldName[0]=='s' && strcmp(fieldName, "source")==0) return base+0;
    if (fieldName[0]=='d' && strcmp(fieldName, "destination")==0) return base+1;
    if (fieldName[0]=='h' && strcmp(fieldName, "hopCount")==0) return base+2;
    return basedesc ? basedesc->findField(object, fieldName) : -1;
}

const char *handoffDescriptor::getFieldTypeString(void *object, int field) const
{
    cClassDescriptor *basedesc = getBaseClassDescriptor();
    if (basedesc) {
        if (field < basedesc->getFieldCount(object))
            return basedesc->getFieldTypeString(object, field);
        field -= basedesc->getFieldCount(object);
    }
    static const char *fieldTypeStrings[] = {
        "int",
        "int",
        "int",
    };
    return (field>=0 && field<3) ? fieldTypeStrings[field] : NULL;
}

const char *handoffDescriptor::getFieldProperty(void *object, int field, const char *propertyname)
const
{
    cClassDescriptor *basedesc = getBaseClassDescriptor();
    if (basedesc) {
        if (field < basedesc->getFieldCount(object))
```


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```
            return basedesc->getFieldProperty(object, field, propertyname);
        field -= basedesc->getFieldCount(object);
    }
    switch (field) {
        default: return NULL;
    }
}

int handoffDescriptor::getArraySize(void *object, int field) const
{
    cClassDescriptor *basedesc = getBaseClassDescriptor();
    if (basedesc) {
        if (field < basedesc->getFieldCount(object))
            return basedesc->getArraySize(object, field);
        field -= basedesc->getFieldCount(object);
    }
    handoff *pp = (handoff *)object; (void)pp;
    switch (field) {
        default: return 0;
    }
}

std::string handoffDescriptor::getFieldAsString(void *object, int field, int i) const
{
    cClassDescriptor *basedesc = getBaseClassDescriptor();
    if (basedesc) {
        if (field < basedesc->getFieldCount(object))
            return basedesc->getFieldAsString(object,field,i);
        field -= basedesc->getFieldCount(object);
    }
    handoff *pp = (handoff *)object; (void)pp;
    switch (field) {
        case 0: return long2string(pp->getSource());
        case 1: return long2string(pp->getDestination());
        case 2: return long2string(pp->getHopCount());
        default: return "";
    }
}

bool handoffDescriptor::setFieldAsString(void *object, int field, int i, const char *value) const
{
    cClassDescriptor *basedesc = getBaseClassDescriptor();
    if (basedesc) {
        if (field < basedesc->getFieldCount(object))
            return basedesc->setFieldAsString(object,field,i,value);
        field -= basedesc->getFieldCount(object);
    }
    handoff *pp = (handoff *)object; (void)pp;
    switch (field) {
        case 0: pp->setSource(string2long(value)); return true;
        case 1: pp->setDestination(string2long(value)); return true;
        case 2: pp->setHopCount(string2long(value)); return true;
        default: return false;
    }
}
```

```
const char *handoffDescriptor::getFieldStructName(void *object, int field) const
{
    cClassDescriptor *basedesc = getBaseClassDescriptor();
    if (basedesc) {
        if (field < basedesc->getFieldCount(object))
            return basedesc->getFieldStructName(object, field);
        field -= basedesc->getFieldCount(object);
    }
    switch (field) {
        default: return NULL;
    };
}

void *handoffDescriptor::getFieldStructPointer(void *object, int field, int i) const
{
    cClassDescriptor *basedesc = getBaseClassDescriptor();
    if (basedesc) {
        if (field < basedesc->getFieldCount(object))
            return basedesc->getFieldStructPointer(object, field, i);
        field -= basedesc->getFieldCount(object);
    }
    handoff *pp = (handoff *)object; (void)pp;
    switch (field) {
        default: return NULL;
    }
}
```


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