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

Kedir Mamo Besher, Juan-Ivan Nieto-Hipolito, Juan De Dios Sánchez-López, Mabel Vazquez-Briseno, Maria De los Ángeles Cosio-Leon.
Universidad Autonoma De Baja California Facultad De Ingenieria Arquitectura Y Diseño. Programa De Maestría Y Doctorado En Ciencias E Ingeniería, Mydci. Ensenada, Baja California, México.
Raymundo Buenrostro Mariscal Universidad de Colima (UdeC), Colima, México.

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

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

I INTRODUCTION

With growing technology and population the role of wireless sensor networks (WSN) is very high; helping the growing technology in every life aspect of human's day to day activity. Among the common application areas of these tiny, small device is in health, for collecting vital signals of the patients during their medication in hospital or it may be in home. A lot of effort has been put in the research community for solving critical problems in the area which is mobility and data loss. But the challenge is continuous stile now. Every researcher in the filed agree that sensors working in such application must need to be support mobility good enough as much as in coverage area. Which result zero or very les amount of data loss during the communication period. That's why applications of WSN in the area is open problem which is stile challenging. Limitations listed above and others led us to design a new algorithm and implement to check its functionality in the area which ended with good output in our work.

In generally while implementing WSN in any application, the common role players are mobile nodes (MN), coordinators (CN) and sink nodes (SN). Most problems arises from MN side during communication are because of mobility which leads to data loss, most of the time during handoff. To prevent such limitations during mobility the best mechanism is designing good handoff handling mechanism for MN. In our work mobile node (MN) have everything to decide about its communication to a coordinator (CN). We decided to manage handoff from MN side by implementing small and effective algorithm, the first reason is that mobility is all about MN so managing mobility from CN side will increase the handoff delay time. Second the main data source is MN, but when designing such mechanism it is very important to consider the limitations that MNs had (memory, battery). In section III we will explain our algorithm in detail. The rest of the paper is organized as follows: in Section II, we briefly introduce some of the work that has already been done on the subject, Section III shows our new fast handoff approach (MNH-WSN), Sections IV show the implementation details and the experiment results, Section V concludes the paper.

II RELATED WORK

As described by the authors [5], [6], [7], the robustness of the WSN application depends greatly on the proper management of mobility to ensure connectivity. There are some efforts done to minimize the association duration in IEEE 802.15.4. In IEEE 802.15.4e [8], optional fast association (FastA) is defined, which allows a device to associate in a reduced duration. However, most of the efforts are limited to mobility management, decreasing the duration of association message exchange [9], increasing connectivity [10] or coordinator discovery [11], whereas manipulating this all in one has been left. Which is main idea of handoff, however the problem is continued as open problem until today. And more very few of them are considered handling handoff from MN side by accepting its limitations. Authors of WSN-HaDaS [1], most of them are also member of this work, designed an algorithm which can manage handoff from CN side with the following contributions:

- Monitoring Handoff Trigger (MHT) process to decide the appropriate time to send a warning message that is because they try to manage from CN side.
- Handoff Execution Process (HEP) to enable mobility on MNs.

Finally they validated its operation, and measured its performance. However in this new design the application handling shifted from CN to MN which resulted in effective time difference between the two works. More we designed short and effective algorithm by considering MNs limitation.

The most important work what we considered when we are designing our algorithm is that the paper in [6] which propose a handoff mechanism for health-care monitoring based on RSS. Here two important contributions are:

- In IEEE 802.15.4 radios to set handoff 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).
- 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 dis-connection region. More the physical test they did to check effect of different environmental factors.

Soft handoff mechanism as part of a framework to support mobility in a WSN which is done by R. Mendao, J. Sa, and F. Boavida, in there paper called "MIPv6 soft hand-off for multi-sink wire-less sensor networks"[13]. In this work they try to solve mobility problem by soft handoff especially for IPV6.which is also implemented in our work but with different handling mechanism. In short the difference between works so far done and ours is that:

- MNH-WSN Have notification part used to notify data sending mechanism before handoff start which lower the data loss during the process.
- MNH-WSN embedded in MN to make handoff easy and finish in few microseconds, more considering handoff is all about the MN, so we let MN to decide on the handoff process.
- Combing soft handoff, hard handoff, early discovery, and implementing in MN (with its limitations).
- Implementing MNH-WSN in real environment test, validate its operation and collecting results. Hardware implementation rather than simulation results are shown in section results.

III.MNH-WSN (Mobile Node based Handoff for WSN)

A. Background

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 a days the major thing behind these mobile devices is making them confidential in their connection while they moving, handoff. Improving handoff protocol to enhance mobility of sensor nods will 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 have mainly suffered from this problem.

There most important 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 major 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.
4. Have no 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 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, we propose a new fast handoff mechanism described below.

B. 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 processes 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. The MN is assumed to select an appropriate CN on the basis of the LQ of the available CNs. The important consideration in this regard is to redirect data from one CN to another as quickly as possible, in order 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.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 12, December-2016

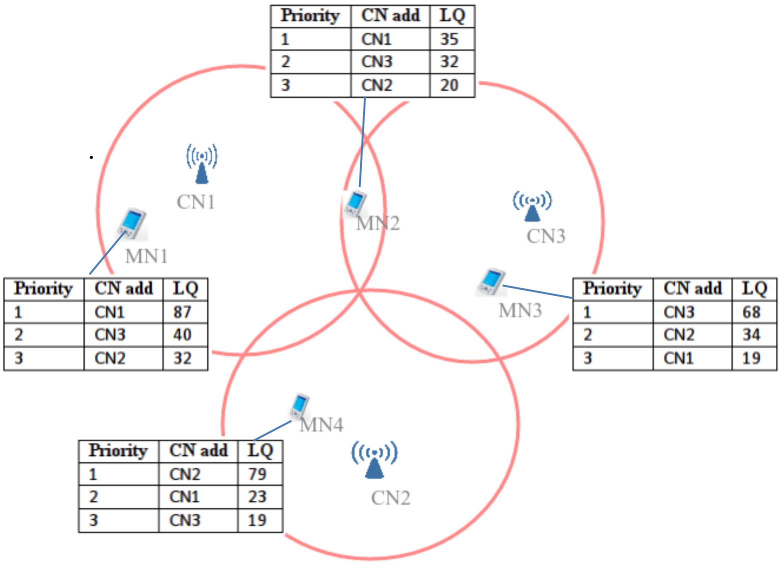

Fig-1 General MNH-WSN design consideration

In MNH-WSN every mobile node have 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 data sending mechanism that handoff process is started 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 will inform for data sending mechanism to start data sending.

N.B 1. MN table will store only 4 CNs once then every 1.5 minutes it will update its table,

2. Considering that CNs are placed with some range area sharing.
3. Considering everything fully functional.

For more explanation let us take case of MN4 in the figure 1 in its table it have 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 is les or equal to -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 then it will display that the handoff couldn't find any CN response and call intelligent active scan for less than one second, after doing so if there is no result then it will call normal active scan and stile the result is negative then MN4 will go to sleep mode. Below in figure-2 we have the general Architecture of MNH-WSN in MAC layer.

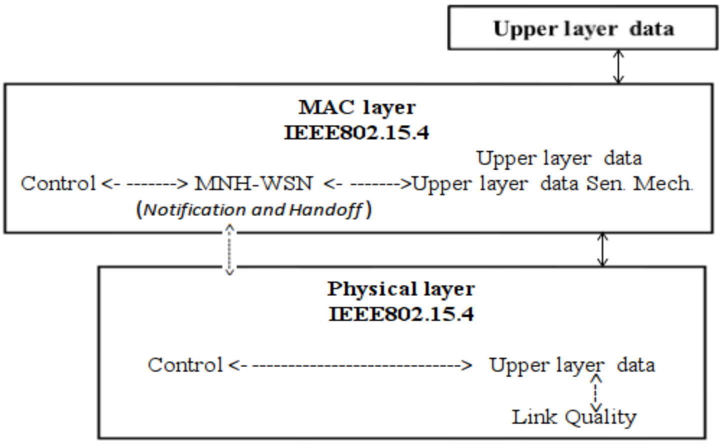

Fig-2 Architecture of MNH-WSN

C. Algorithm

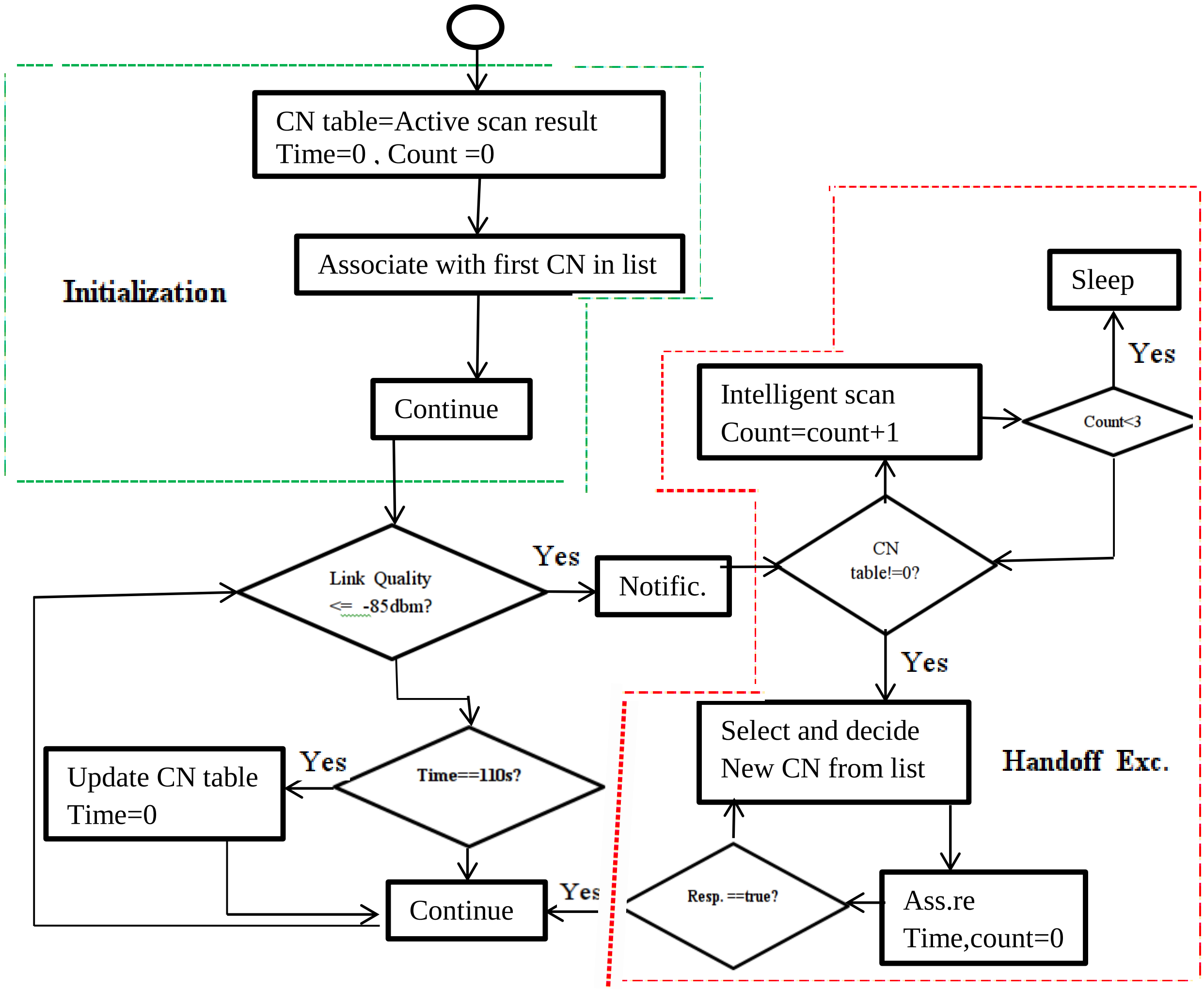

Fig-3 General work algorithm of MNH-WSN

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

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.

2. Check and update

After the first connection is made 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.

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.

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 no to send data to MN utile it is notified.

3. Handoff execution part The probability of handoff are 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-

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 12, December-2016

association directly rather than scanning the available CNs. It is step where MNH-WSN change CN, selecting from its table list, by :

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

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

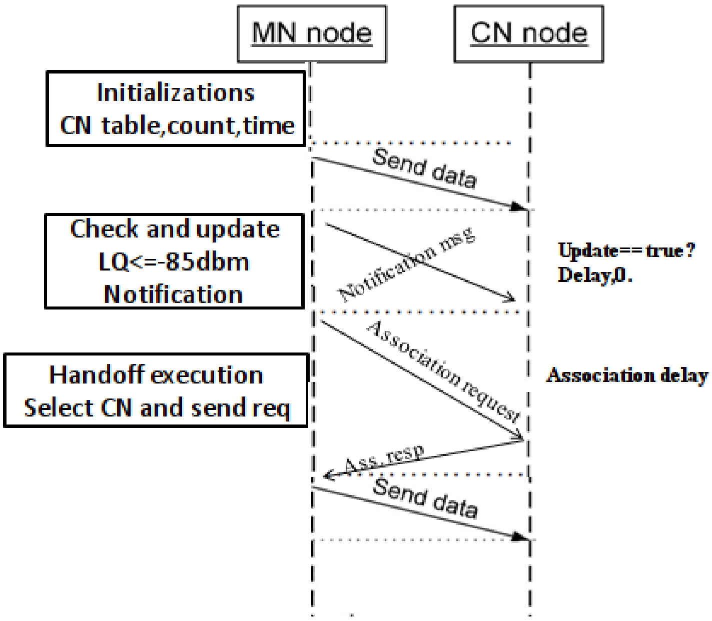

Fig-4 Sequence diagram

D. Handoff limit

The line 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 5 indicate 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 depending on the result, as designed by the algorithm in fig-3.

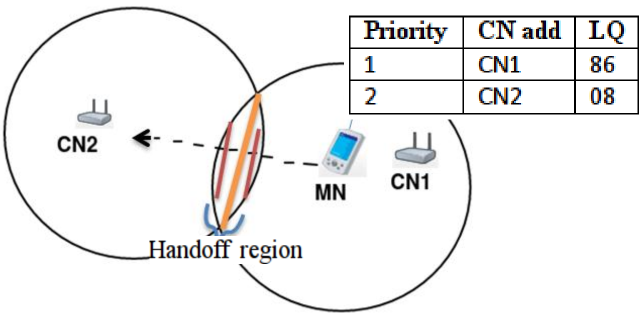

Fig-5 MNH-WSN handoff limit

IV RESULTS

Evaluation is done by compering Performance of MNH-WSN with the handoff mechanism of IEEE 802.15.4 standard, Soft-Handoff WSN-HaDaS[1], and MIPv6 Soft-Handoff [13]. For evaluation we 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 100 different experimental values in both real implementation as-wells in simulation.

A. 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	Aver
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-1 over all delay compares

B. Packet Loss During MNH-WSN

During our simulation and implementation on the ground the results are 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.

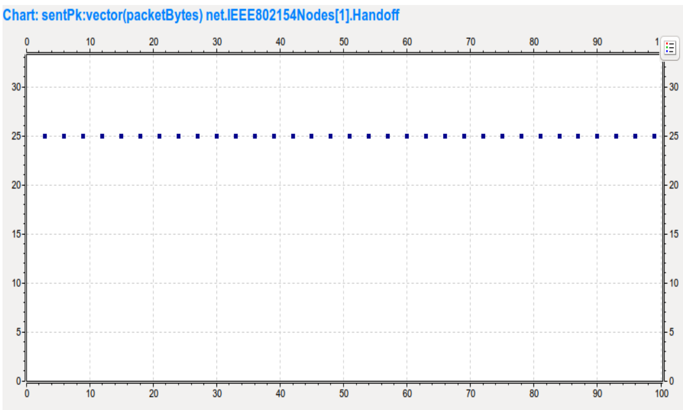

Fig-6 *packets sent under the handoff protocol control*

We did implementation and simulation by sending 25MB packet with some interval before implementing and after implementing MNH-WSN and the result show that there is no data loss after implementing the protocol.

C. Packet Delay After Implementing MNH-WSN

This is all about how much the packet delay before it reaches its destination and most of the time is same as the implementation environment, as our implementation is on

IEEE802.15.4 standard the packet delay after implementing our protocol resulted same. Shown below.

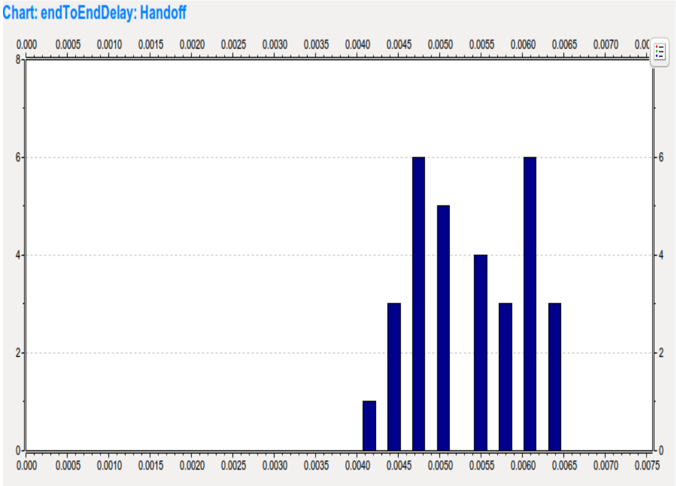

Fig-7 End to end packet delay graph

D. *Average Handoff Delay*

The common MNH-WSN delays are authentication delay and re-association delay, Figure 5 indicates that the average soft handoff delay gradually increases as the transmission range becomes larger, which is color yellow. It is clear that 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 once, are average delay of soft handoff boundary and hard handoff in my protocol. Even if it is above 50ms its very good results, this

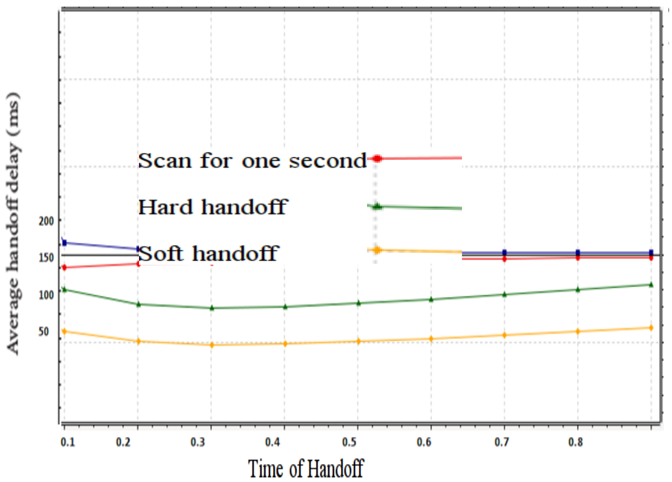

Fig-7 Average MNH-WSN Delay

E. *Handoff Failure Probability*

As previously described, in my scheme, MN triggers the re-association directly by using the information of CN table when its LQ drops below a predefined threshold. At that time, there is a possibility of handoff failure due to wrong information of CN table. 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. The other failer may be due to high speed movement of the MN in specific interval like 10m in one second or more. As a solution :

1. MN will check up coordinators around it self every 1.50 minutes.

2. Hard handoff included (including fast scan for surrounding CNs only for 1 second).

3. Finally after all if there is no CN, handoff call active scan and stile no result end up with sleep mode.

Hardware implementation demos

Displaying data is collected by using termite-2.9.

Step 1: initial stage

The first step is active scan step where MN will scan for nearby CNs, at the same time MNH-WSN will collect and construct its CN table. Below screen shot of initial step in MNH-WSN

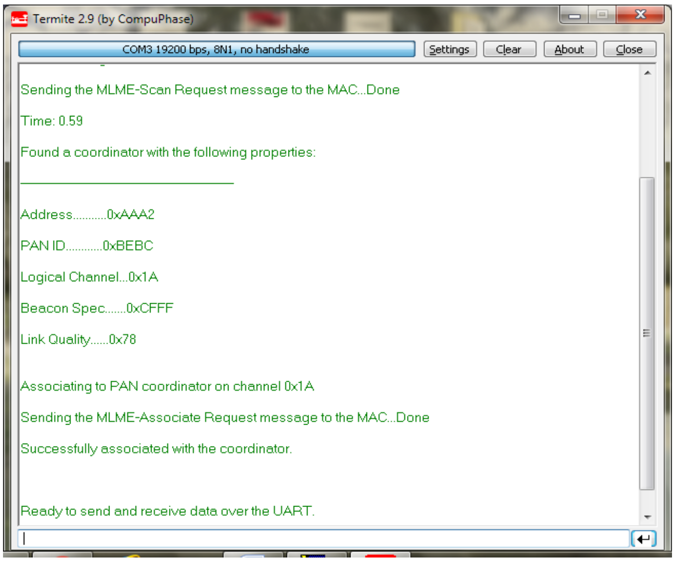

Fig-8 MNH-WSN active scan step window

Step 2: MNH-WSN 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 my protocol to take handoff. The image below is the highlight what it look like.

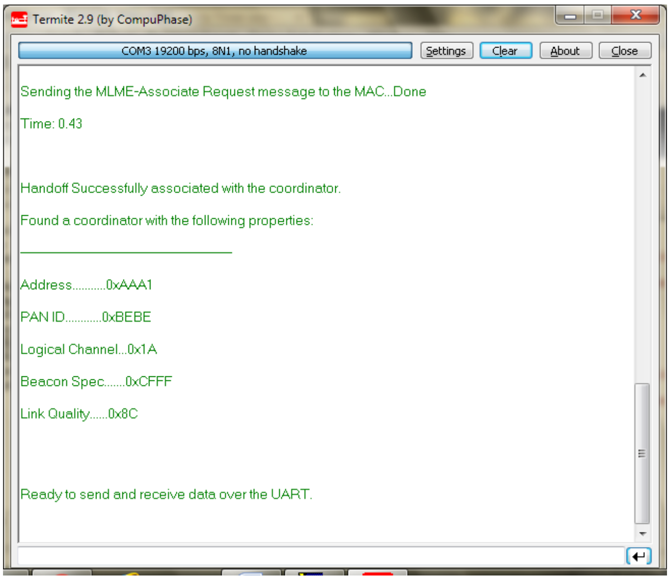

Fig-9 MNH-WSN handoff step window

After this message the normal communication starts with the new CN and every 1.5 minutes MN updates its table by scanning maximum for 1 second if there is new CNs nearby. If it doesn't find any CN during Handoff the below message is displayed:

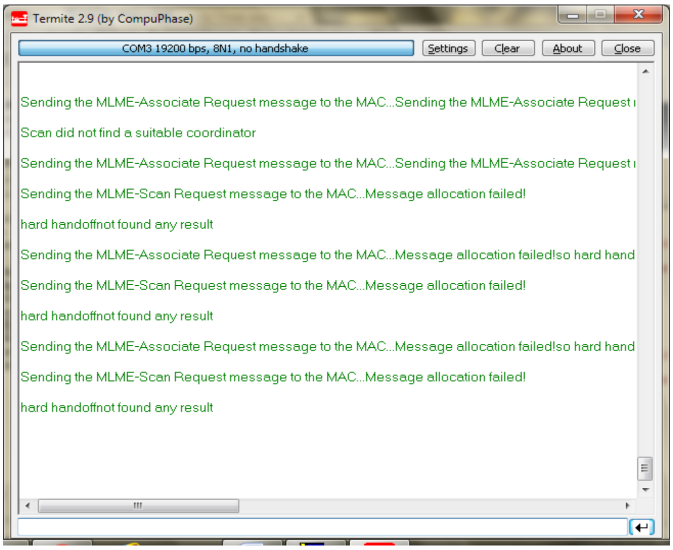

Fig-10 Error message window

V CONCLUSION

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.

In this paper, we proposed a new fast handoff protocol called MNH-WSN which eliminates scanning delay when the MN decides to 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. We did numerous extensive simulations study and practical implementations both resulted tangible output. As shown in result analysis part. 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.

VI. REFERENCES

[1] Raymundo BUENROSTRO-MARISCAL, Maria COSIO-LEON, Juan-Ivan NIETO-HIPOLITO, Juan-Antonio GUERRERO-IBANEZ, Mabel VAZQUEZ-BRISENO, and Juan-de-Dios SANCHEZ-LOPEZ. WSN-HaDaS: A Cross-Layer Handoff Management Protocol for Wireless Sensor Networks, a Practical Approach to Mobility. IEICE Transaction Communications, Vol e98-B, no. 7, pp. 1333-1344. [2] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless sensor networks: A survey," Comput. Netw., vol.38, no.4,p.393422, March 2002.

[2] J. Gutiérrez, E. Callaway, and R. Barrett, Low-rate wireless personal area networks: enabling wireless sensors with IEEE 802.15.4, IEEE standards wireless networks series, Standards Information Network,IEEE Press, 2004.

[3] A. Darwish and A.E. Hassanien, "Wearable and implantable wireless sensor network solutions for healthcare monitoring," Sensors, vol.11, no.6, pp.5561–5595, May 2011.

[4] L.A.N. Man, S. Committee, and I. Computer, "IEEE Standard for Information technology- Telecommunications and information exchange between systems- Local and metropolitan area networks Specific requirements–Part 15.4: Wireless MAC and PHY Specifications for Low-Rate WPANs," Control, vol.2006, no.September,2006.

[5] H. Fotouhi, M. Zuniga, M. Alves, A. Koubaa, and P. Marron,"Smart-HOP: a reliable handoff mechanism for mobile wireless sensor networks," in Wireless Sensor Networks, ed. G.P. Picco and W. Heinzelman, Lecture Notes in Computer Science, no.7158, pp.131–146, Springer Berlin Heidelberg, Jan. 2012.

[6] K. Tsukamoto, Y. Hori, and Y. Oie, "Transport layer mobility management across heterogeneous wireless access networks," IEICE TRANSACTIONS on Communications, vol.E90-B, no.5, pp.1122– 1131, May 2007.

[7] S. Kameda, H. Oguma, N. Izuka, F. Yamagata, Y. Asano, Y. Yamazaki, S. Tanifuji, N. Suematsu, T. Takagi, and K. Tsubouchi, "Proposal of heterogeneous wireless network with handover in application layer: Feasibility study based on field trial results," IEICE TRANSACTIONS on Communications, vol.E95-B, no.4, pp.1152–1160, April 2012.

[8] Q. Dong and W. Dargie, "A survey on mobility and mobility-aware mac protocols in wireless sensor networks," Communications Surveys Tutorials, IEEE, vol.15, no.1, pp.88–100, First 2013.

[9] K. Tsukamoto, T. Yamaguchi, S. Kashihara, and Y. Oie, "Experimental evaluation of decision criteria for WLAN handover: Signal strength and frame retransmission," IEICE TRANSACTIONS on Communications, vol.E90-B, no.12, pp.3579–3590, Dec. 2007.

[10] S. Kim, S. Choi, S. kyu Park, J. Lee, and S. Kim, "An empirical measurements-based analysis of public wlan handoff operations," Communication System Software and

Middleware, 2006. Comsware 2006. First International Conference on, pp.1 –6, 0-0 2006.

[11] D.K. Lee, T.H. Kim, S.Y. Jeong, and S.J. Kang, "A three-tier middleware architecture supporting bidirectional location tracking of numerous mobile nodes under legacy wsn environment," Journal of Systems Architecture, vol.57, no.8, pp.735 – 748, 2011.

[12] R. Mendao, J. Sa, and F. Boavida, "MIPv6 soft hand-off for multi sink wireless sensor networks," in Smart Wireless Sensor Networks, ed. Y.K. Tan, InTech, Dec. 2010.

[13] N. Timmons and W. Scanlon, "Analysis of the performance of ieee802.15.4 for medical sensor body area networking," Sensor and AdHoc Communications and Networks, 2004. IEEE SECON 2004. 2004 First Annual IEEE Communications Society Conference on,pp.16–24, Oct 2004.

[14] Y.D. Lee and W.Y. Chung, "Wireless sensor network based wearable smart shirt for ubiquitous health and activity monitoring," Sensors and Actuators B: Chemical, vol.140, no.2, pp.390 – 395, 2009.

[15] J. Gallego, A. Hernandez-Solana, M. Canales, J. Lafuente, A. Valdovinos, and J. Fernandez-Navajas, "Performance analysis of multiplexed medical data transmission for mobile emergency care over the umts channel," Information Technology in Biomedicine, IEEE Transactions on, vol.9, no.1, pp.13–22, March 2005.

[16] S. Arnon, D. Bhastekar, D. Kedar, and A. Tauber, "A comparative study of wireless communication network configurations for medical applications," IEEE Wireless Commun., pp.56–61, 2003.

[17] M.N. Halgamuge, H.L. Vu, K. Ramamohanarao, and M. Zukerman,"A call quality performance measure for handoff algorithms," Int. J. Commun. Syst., vol.24, no.3, p.363383, March 2011.

[18] E.C. PANASONIC, LR-WPAN Module P/N PAN802154HAR00,Application Note, a ed. PANASONIC, 3 2005.

[19] L. , Varela, P. Ortiz, and H. Chvez, "Velocidad de la marcha como indicador de fragilidad en adultos mayores de la comunidad en lima, peru," : Revista Espanola de Geriatria y Gerontologia, vol.45, no.1, pp.22–25, 2010.

[20] D. Networks, "Daintree networks pty ltd 2011."

[21] IETF ANS Ad-hoc Network Scaling Research Subgroup, Internet Draft: Notes on Scalability of Wireless Ad-hoc Networks, 1 December, 2003.

[22] W. Heinzelman, A. Chandrakasan, and H. Balakrishnan. Energy efficient communication protocol for wireless microsensor networks. In Proceedings of the 33rd International Conference on System Sciences (HICSS), Hawaii, USA, pages 56{73. IEEE Computer Society, 2000.

[23] D. Malan, T. Fulford-Jones, M. Welsh, and S. Moulton. Codeblue: An ad hoc sensor network infrastructure for emergency medical care. In Proceedings of the International Workshop on Wearable and Implantable Body Sensor Networks, 2004.

[24] University of rochester center for future health.

[25] Bhat Geetalaxmi Jayram , D. V. Ashoka," Merits and Demerits of Existing Energy Efficient Data Gathering Techniques for Wireless Sensor Networks", International Journal of Computer Applications (0975-8887),Vol. 66, Issue 9, March 2013.

[26] Feng Wang And Jiangchuan Liu, "Networked Wireless Sensor Data Collection: Issues, Challenges, And Approaches", IEEE International Journal of Scientific & Engineering Research, Volume 5, Issue 2, February-2014 794 ISSN 2229-5518

[27] Zhenzhen Ye, Alhussein A. Abouzeid and Jing Ai," Optimal Policies for Distributed Data Aggregation in Wireless Sensor Networks", 2004.

Kedir Mamo Besher

Received BSC from Arbaminch University, Ethiopia in Computer science and IT studded Master of engineering in Network Engineering (wireless sensor network) in University of Baja California, Ensenada, Mexico

Maria Cosio Leon received the M.Sc. degree in 2008 from the University of Colima, Mexico. She received her Ph.D. in 2012 from the Autonomous University of Baja California (UABC), Mexico. Her scientific interests are in wireless sensor networks and routing protocols using bio-inspired algorithms.

Juan Ivan Nieto Hipolito received the M.Sc. degree in 1994 from CICESE Research Center, Mexico. From February 2001 to July 2005 he was a Ph.D. student at the Computer Architecture Department of the Polytechnic University of Catalonia (UPC) in Spain. Since August 1994 he is a full professor at the Autonomous University of Baja California (UABC), Mexico. His scientific interests are in wireless networks performance, mac and routing protocols.

Universidad de Colima

Raymundo Buenrostro Mariscal received his M.Sc. degree in Electronics and Telecommunications from CICESE Research Center, Mexico, in 2006. He received the B.E. degree in Electronics and Telecommunications from the University of Colima (Udec). He received his PHD from university Baja California, Mexico. His research interests include wireless sensor networks, transport and MAC protocols.

Mabel Vazquez-Briseno received her Ph.D. in Computer Science from Telecom SudParis (ex INT) and Pierre et Marie Curie University, France in 2008. She received the M.Sc degree in Electronics and Telecommunications from CICESE Research Center, Mexico, in 2001. She is now a researcher-professor at the Autonomous University of Baja California. Her research interests include computer networks, mobile computing and protocols.

Juan de Dios Sanchez Lopez received the B. Eng. (Electrical Engineering) degree from the Mechanical and Electrical Department of the Technological Institute of Madero City in 1988. He received his M.Sc. and Ph.D. degree from the CICESE Research Center, Mexico in 1999 and 2009 respectively. His research interests include wireless communications, analog-digital signal processing

The authors are with the research group of Telematic, Autonomous University of Baja California, Ensenada-BC, Mexico.