REDUCE ENERGY CONSUMPTION IN THE WIRELESS SENSOR NETWORK BY USING EEL-MAC PROTOCOL

MOHEIMEN MOHOMED JLEIL JAWAD

SCHOOL OF COMPUTING
UUM COLLEGE OF ARTS AND SCIENCES
UNIVERSITI UTARA MALAYSIA
2015

Permission to Use

In presenting this project report in partial fulfilment of the requirements for a postgraduate degree from Universiti Utara Malaysia, I agree that the Universiti Library may make it freely available for inspection. I further agree that permission for the copying of this report in any manner, in whole or in part, for scholarly purpose may be granted by my supervisor(s) or, in their absence, by the Dean of Awang Had Salleh Graduate School of Arts and Sciences. It is understood that any copying or publication or use of this report or parts thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and to Universiti Utara Malaysia for any scholarly use which may be made of any material from my report.

Requests for permission to copy or to make other use of materials in this project report, in whole or in part, should be addressed to:

Dean of Awang Had Salleh Graduate School of Arts and Sciences
UUM College of Arts and Sciences
Universiti Utara Malaysia
06010 UUM Sintok

Abstrak

Nod Rangkaian Pengesan Tanpa Wayar (WSN) digunakan secara meluas dalam pelbagai sektor. Selama ini, WSN telah muncul sebagai penggerak untuk mengumpul dan memproses data dari lokasi yang jauh atau kawasan bencana. WSNs bergantung kepada kesederhaan perkakasan untuk membuat lapangan pengesan bersifat mampu milik dan tahan lama tanpa sokongan penyelenggaraan. Walau bagaimanapun, nod WSN mengalami banyak masalah seperti lampau dengar, perlanggaran, terminal tersembunyi, dengaran terbiar dan kependaman tinggi, yang mengakibatkan penggunaan tenaga yang tinggi, dengan itu menghadkan hayat nod. Selain itu, nod WSN amat bergantung kepada kuasa bateri yang terhad, tetapi sukar untuk menambah semula kuasa. Oleh itu, kajian ini mengkaji protokol Kawalan Capaian Medium (MAC) cekap tenaga yang direka untuk melanjutkan hayat kedua-duanya dengan pengurusan tenaga yang berkesan melalui penurunan masa terbiar dan peningkatan masa tidur untuk nod menjimatkan tenaga. Kajian ini juga bertujuan untuk mengurangkan kependaman antara nod dan nod tenggelam. Protokol hidbrid EEL-MAC bermula dengan fasa penyegerakan menggunakan TDMA untuk menyegerakkan semua nod dalam lapangan pengesan. Dalam fasa kedua, skim ini menggunakan mekanisme CSMA untuk komunikasi antara nod dan nod tenggelam. Kajian ini memberi dua sumbangan besar kepada rangkaian pengesan tanpa wayar. Pertama, protokol EEL-MAC menawarkan penjimatan tenaga penting dan memanjangkan jangka hayat rangkaian. Sumbangan kedua adalah pengenalan sambutan tinggi, dengan mereka bentuk komunikasi satu-hop untuk mengurangkan kedua-dua kelewatan dan kependaman hujung ke hujung.

Kata kunci: Penggunaan tenaga, Kependaman, Protokol, Memanjangkan hayat rangkaian.

Abstract

Wireless Sensor Network (WSN) nodes are broadly used in various sectors. Over the years, WSN has emerged as an enabler to collect and process data from remote locations or disaster areas. WSNs rely on hardware simplicity to make sensor field deployments both affordable and long-lasting without maintenance support. However, the WSN nodes experience a lot of problems such as, overhearing, collision, hidden terminal, idle listening and high latency, which resulted in high energy consumption, thus limiting the lifetime of the node. Moreover, WSN nodes are strongly dependent on their limited battery power, and replenishing them again is difficult. Therefore, this research investigates the energy-efficient Medium Access Control (MAC) protocols designed to extend both the lifetime by effective energy management through a reduction in idle time and increased sleep time for nodes to save energy. This study also aims to reduce the latency between nodes and sink node. The EEL-MAC hybrid MAC protocol starts by a synchronization phase using TDMA to synchronize all nodes in the sensor field. In the second phase the scheme uses the CSMA mechanism for communication between nodes and the sink node. In this study makes two significant contributions to wireless sensor networks. First, the EEL-MAC protocol offers significant energy savings and prolongs network lifetime. The second contribution is the introduction of high response, by designing a one-hop communication to reduce both end-to-end delay and latency.

Keywords: Energy consumption, Latency, Protocol, Prolongs the network lifetime.

Acknowledgement

In the Name of ALLAH, the Most Gracious and the Most Merciful. Peace is upon to Muhammad S.A.W., the messenger sent to guide people in a truthful way.
First, all praises and thanks goes to almighty ALLAH for giving me the patience, health and guidance to complete this thesis successfully, as well as giving me the chance to work in an environment such as Malaysia, and UUM in particular.

Furthermore, I would like to express my gratitude and special appreciation to my supervisors, Mr. Suwannit Chareen Chit and Dr. Mohd. Hasbullah Omar, who have been tremendous mentors for me. I would like to thank you both for your encouragement and advice in both pieces of research, as well as my career. It has been priceless.

I am grateful to my country, which gave me this opportunity despite the difficult conditions experienced by it and the people of Iraq. Words cannot express my thanks to my family, who have given me their support and prayers, love and encouragement to see their son succeed to get the master's degree in spite the wishes of health issues for to my dear father and darling mother. Moreover, I especially wish to express my love to my wife, who supported me and give me the conditions necessary and appropriate to study in alienation country, in spite of hardship, disease and study. Also, to my dear daughter for always putting a smile on my face.

Table of Contents

Permission to Use i
Abstrak ii
Abstract iii
Acknowledgement iv
Table of Contents v
List of Tables viii
List of Figures ix
List of Appendices x
List of Abbreviations xi

CHAPTER ONE INTRODUCTION 1
1.1 Introduction 1
1.2 Statement of Problem 4
1.3 Research Question 6
1.4 Objectives 7
1.5 Significance of Research 7
1.6 Contributions 8
1.7 Scope of The Study 8
1.8 Organization of The Thesis 9

CHAPTER TWO LITERATURE REVIEW 11
2.1 Introduction 11
2.2 Wireless Sensor Network (WSN) 12
2.3 Challenges of Wireless Sensor Network 15
 2.3.1 Energy Consumption 15
 2.3.2 Collision 16
 2.3.3 Latency 17
 2.3.4 Duty Cycle 17
2.4 Medium Access Control (MAC) 19
 2.4.1 Schedule-Based 21
 2.4.2 Contention-Based 22
  2.4.2.1 MS-MAC Protocol 23

2.4.3 Hybrid-Based 24
2.4.3.1 Z-MAC Protocol 25
2.4.3.2 LPRT-MAC Protocol 26
2.4.3.3 Speck-MAC Protocol 28
2.5 Related Work 30
2.6 Conclusion 32
CHAPTER THREE RESEARCH METHODOLOGY 33
3.1 Introduction 33
3.2 Definition The Problem and Analysis 33
3.3 The Proposed EEL-MAC Protocol Design 36
3.3.1 Phases Proposed Design 36
3.4 The Simulation Parameter and Performance Metrics 40
3.4.1 The Simulation Parameters 40
3.4.2 The Performance Metrics 42
3.4.2.1 Energy Consumption Performance Metrics 43
3.4.2.2 Latency Performance Metrics 43
3.5 Summary 44
CHAPTER FOUR PROTOCOL DESIGN AND SIMULATION RESULTS ... 45
4.1 Introduction 45
4.2 Design Phases for EEL-MAC Protocol 45
4.2.1 The Initialization Phase 46
4.2.2 The Communication Phase 48
4.2.3 The Pseudocode for The EEL-MAC Protocol. 51
4.3 Energy Consumption Analysis 52
4.4 Latency Analysis 54
4.5 Collision Analysis 54
4.6 Initial Simulation Results 55
4.6.1 Energy Consumption Results 56
4.6.2 Latency Results 60
4.7 Trace File 62
4.8 Summary 63

CHAPTER FIVE EVALUATION OF EEL-MAC PROTOCOL 64
5.1 Introduction 64
5.2 Evaluating the EEL-MAC's Extent of Enhancement 65
5.2.1 Energy Consumption Analysis 66
5.2.2 Latency Analysis..70
5.2.3 Throughput Analysis..72
5.3 Evaluating EEL-MAC Effectiveness 74
5.3.1 Energy Consumption Analysis 75
5.3.2 Latency Analysis..78
5.4 Discussion 80
5.5 Summary 83
CHAPTER SIX CONCLUSION AND FUTURE WORK 84
6.1 Introduction 84
6.2 Conclusion 84
6.3 Contribution 85
6.4 Limitations and Future Work 86
REFERENCES...87
APPENDIX 95

List of Tables

Table 2.1 Advantage and Disadvantage for MS-MAC Protocol 24
Table 2.2 Advantage and Disadvantage for Z-MAC Protocol.......... 26
Table 2.3 Advantage and Disadvantage for LPRT MAC Protocol.......... 28
Table 2.4 Advantage and Disadvantage for Speck-MAC Protocol 29
Table 3.1 Values of Parameters to Evaluate Enhance Used in The Simulation.......... 41
Table 3.2 Simulation Parameter to Evaluate Performance of EEL-MAC Protocol.......... 41
Table 4.1 Energy Consumption for Every Node in EEL-MAC Protocol 56
Table 4.2 Average Energy Consumption for EEL-MAC Protocol 58
Table 4.3 Average Energy Consumption Per Second for EEL-MAC Protocol 59
Table 4.4 Latency for EEL-MAC Protocol.......... 60
Table 4.5 Interval Time of Packet Generation for EEL-MAC Protocol 62
Table 5.1 Values of Parameters for EEL-MAC and MS-MAC Protocol.......... 66
Table 5.2 Average Energy Consumption for EEL-MAC and MS-MAC Protocols.......... 67
Table 5.3 Average Energy Consumption Per Sec for EEL-MAC and MS-MAC Protocols.. 69
Table 5.4 Presents Latency for EEL-MAC And MS-MAC Protocols. 71
Table 5.5 Throughput of EEL-MAC and MS-MAC Protocols.......... 73
Table 5.6 Simulation Parameters for EEL-MAC Protocl 75
Table 5.7 Energy Consumption for EEL-MAC and Other MAC Protocols (Razaque & Elleithy, 2014a).......... 77
Table 5.8 Latency For EEL-MAC and Other MAC Protocols(Razaque & Elleithy, 2014a). 79

List of Figures

Figure 1.1 Wireless Sensor Network (Dovlatabadi & Mohammadpoor, 2015) 2
Figure 2.1 Sensor Node Modules (Kazienko, Ribeiro, Moraes, & Albuquerque, 2011) 13
Figure 2.2 Deployment and Communication WSN (Labrador & Wightman, 2009) 14
Figure 2.3 One Duty Cycle 19
Figure 2.4 TDMA Divided to Frames and It Divided Into Slots Then Slot Assign to The Node (Almalag, 2013) 22
Figure 2.5 Superframe of LPRT MAC Protocol (Silva et al., 2011) 27
Figure 2.6 Fundamental Asynchronous Speck MAC (Ahmad et al., 2009) 29
Figure 3.1 Methodology 35
Figure 3.2 Ways to Switch The Work of The Phases EEL-MAC Protocol 38
Figure 3.3 Flowchart of Procedure for EEL-MAC Protocol 39
Figure 4.1 Broadcast SYNC Message in Initializtion Phase 47
Figure 4.2 Replay By TDMA Initialization Phase 48
Figure 4.3 Packet Communication Using CSMA in EEL-MAC Protocol 49
Figure 4.4 Communication Phase Using CSMA (a) 50
Figure 4.5 Communication Phase Using CSMA (b) 51
Figure 4.6 The Energy Consumption Per Node in EEL-MAC Protocol 57
Figure 4.7 Average Energy Consumption in EEL-MAC Protocol 58
Figure 4.8 Average Energy Consumption Per Second At Interval Time in EEL-MAC. 59
Figure 4.9 Latency in EEL-MAC Protocol 61
Figure 4.10 Latency The Interval Packets Generation in EEL-MAC Protocol 62
Figure 4.11 Part From Trace File 63
Figure 5.1 Average Energy Consumption for EEL-MAC and MS-MAC Protocols 68
Figure 5.2 Average Energy Consumption Per Second for EEL-MAC and MS-MAC Protocols 70
Figure 5.3 Latency for EEL-MAC and MS-MAC Protocols 72
Figure 5.4 Throughput Comparison for EEL-MAC and MS-MAC Protocols 74
Figure 5.5 Effectiveness Evaluation of EEL-MAC and Other MAC Protocols 78
Figure 5.6 Latency Evaluation Effectiveness for EEL-MAC and Other Protocols 80

List of Appendices

Appendix A: Language Awk Comment and Trace File ..…………………………......…... 95
Appendix B: Interface Simulation MAC protocols in NS2……………………………… 102

List of Abbreviations

AAS	: Automatic Active and Sleep
AM-MAC	: Adaptive Mobility-Supporting MAC
BN-MAC	: Boarder Node MAC
CFP	: Contention-Free Period
CSMA	: Carrier Sensing Multiple Access
CSMA/CA	: Carrier Sensing Multiple Access/Collision Avoided
CTS	: Clear To Send
DBNSP	: Dynamic Boarder Node Selection Process
DM-MAC	: Distribute Moving-MAC
EEL-MAC	: Enhance Energy and Latency MAC protocol
IDM	: Intelligent Decision-Making
LDSNS	: Least Distance Smart Neighboring Search
LLC	: Logical Link Control
LPL	: Lower Power Listening

LPRT-MAC	: Low Power Real Time-MAC
MAC	: Medium Access Control
MH-MAC	: A Mobility Adaptive Hybrid MAC
MS-MAC	: Mobile Sensor-MAC
NS2	: Network Simulator 2
ODFF	: Optimized Data Frame Format
OS	: Operating System
OTCL	: Object Oriented Tool Command Language
QoS	: Quality of Service
RF	: Radio Frequency
RTS	: Request To Send
S-MAC	: Sensor-MAC
TDMA	: Time division multiple access
WSN	: Wireless Sensor Network
Z-MAC	: Zebra-MAC

CHAPTER ONE
INTRODUCTION

1.1 Introduction

Wireless Sensor Network (WSN) has attracted tremendous attention from researchers in the recent years (Meng, Xie, & Xiao, 2013). Consisting of sensor nodes and a sink node, WSN is used to sense parameters such as temperature, pressure and radiation from the surroundings. The data is then relayed to the sink node, and a server (Suriyachai, Roedig, & Scott, 2012).

A sensor node consists of several modules, namely the sensing, processing and communication module. These modules are highly dependent on the scarce battery supply. Therefore, a major challenge in a WSN is its short network lifetime. Power replenishment is a challenging task as these nodes are scattered randomly (Cano, Bellalta, Sfairopoulou, & Oliver, 2011). Although there has been enormous development in WSN technology. However, the progress of battery technology has been slow, and researchers are seeking new ways to prolong the lifetime of the network (Corke et al., 2010).

A wireless sensor network is composed of a number of sensor devices and sink(s). Sensor nodes communicate with their neighbors through shared channels. As these nodes compete for channel access, a mechanism is needed to ensure that the sensor nodes are able to effectively send data to the sink node. Figure 1.1 illustrates the general architecture of a WSN deployment (Kabara & Calle, 2012).

The contents of the thesis is for internal user only

REFERENCES

Afonso, J. ., Rocha, L. A., Silva, H. R., & Correia, J. H. (2006). MAC Protocol for Low-Power Real-Time Wireless Sensing and Actuation. *2006 13th IEEE International Conference on Electronics, Circuits and Systems*, 1248–1251. doi:10.1109/ICECS.2006.379688

Ahmad, M. ., Dutkiewicz, E., & Huang, X. (2009). A survey of low duty cycle MAC protocols in wireless sensor networks. *Book Chapter In, Wireless Sensor Network.*, 69–91. Retrieved from http://cdn.intechopen.com/pdfs/13519/InTech-A_survey_of_low_duty_cycle_mac_protocols_in_wireless_sensor_networks.pdf

Algaet, M. A., Noh, Z. A. B. M., Shibghatullah, A. S., Milad, A. A., & Mustapha, A. (2014). A Review on Provisioning Quality of Service of Wireless Telemedicine for E-Health Services. *Middle-East Journal of Scientific Research*, *19*(4), 570–592. doi:10.5829/idosi.mejsr.2014.19.4.13583

Almalag, M. (2013). *Tdma Slot Reservation in Cluster-Based Vanets*. Old Dominion University.

Almalag, M., Olariu, S., & Weigle, M. C. (2012). TDMA cluster-based MAC for VANETs (TC-MAC). *World of Wireless, Mobile and Multimedia Networks (WoWMoM), 2012 IEEE International Symposium*, 1–6. doi:10.1109/WoWMoM.2012.6263796

Al-Yasiri, A., & Sunley, A. (2007). Data aggregation in wireless sensor networks using the SOAP protocol. *Journal of Physics: Conference Series*, *76*, 012039. doi:10.1088/1742-6596/76/1/012039

Arshad, S., Al-Sadi, A., & Barnawi, A. (2013). Z-MAC: Performance Evaluation and Enhancements. *Procedia Computer Science*, *21*, 485–490. doi:10.1016/j.procs.2013.09.066

Awwad, S., Ng, C., & Noordin, N. (2010). Cluster Based Routing Protocol with Adaptive Scheduling for Mobile and Energy Awareness in Wireless Sensor Network. *Proceedings of the Asia-Pacific Advanced Network*, *30*(2227-3026), 57 – 65. doi:10.1007/s11277-010-0022-8

Bachir, A., Dohler, M., Watteyne, T., & Leung, K. k. (2010). MAC Essentials for Wireless Sensor Networks MAC Essentials for Wireless Sensor Networks. *Communications Surveys & Tutorials, IEEE*, *12*(2), 222–248.

Bera, S. (2011). *Design and Implementation of a MAC protocol for Wireless Distributed Computing*. Retrieved from http://scholar.lib.vt.edu/theses/available/etd-06212011-022747/

Buettner, M., Yee, G. V., Anderson, E., & Han, R. (2006). X-MAC: a short preamble MAC protocol for duty-cycled wireless sensor networks. *Proceedings of the 4th International Conference on Embedded Networked Sensor Systems (SenSys 2006)*, 307–320. doi:10.1145/1182807.1182838

Cano, C., Bellalta, B., Sfairopoulou, A., & Oliver, M. (2011). Low Energy Operation in WSNs: A Survey of Preamble Sampling MAC Protocols. *Computer Networks*, *55*(15), 3351–3363. doi:10.1016/j.comnet.2011.06.022

Cheng, C., Tse, C. K., & Lau, F. C. M. (2010). An Energy-Aware Scheduling Scheme for Wireless Sensor Networks. *IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY*, *59*(7), 3427–3444.

Chiras, T., Paterakis, M., & Koutsakis, P. (2005). Improved medium access control for wireless sensor networks - a study on the S-MAC protocol. *2005 14th IEEE Workshop on Local & Metropolitan Area Networks*, 1–5. doi:10.1109/LANMAN.2005.1541537

Choi, S.-C., Lee, J.-W., & Kim, Y. (2008). An Adaptive Mobility-Supporting MAC Protocol for Mobile Sensor Networks. *VTC Spring 2008 - IEEE Vehicular Technology Conference*, 168–172. doi:10.1109/VETECS.2008.47

Corke, P., Wark, T., Jurdak, R., Hu, W., Valencia, P., & Moore, D. (2010). Sensor Networks. *Proceedings of the IEEE*, *8*(1), 24–29.

Dong, Q., & Dargie, W. (2013). A Survey on Mobility and Mobility-Aware MAC Protocols in Wireless Sensor Networks. *IEEE Communications Surveys & Tutorials*, *15*(1), 88–100. doi:10.1109/SURV.2012.013012.00051

Dong, Y., Li, Y. T., Chen, J., Lu, X., Zhou, X., & Zhou, L. (2013). LS-MAC: An adaptive locationaware MAC protocol for wireless sensor networks. *COIN. Beijing, China*. Retrieved from http://www.channelyi.com/papers/coin13.pdf

Dovlatabadi, R., & Mohammadpoor, M. (2015). Designing a Hybrid Clustering Routing Algorithm based on Cellular Learning Automata for Optimizing Lifetime of Wireless Sensor Networks. *ACSIJ Advances in Computer Science: An International Journal*, *4*(2), 61–69.

El-Hoiydi, A., & Decotignie, J. (2004). WiseMAC: an ultra low power MAC protocol for the downlink of infrastructure wireless sensor networks. *Computers and Communications, …*, *1*, 244–251. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1358412

Fang, W., Yu, K., Xiaobin, T., & Kai, Y. (2014). A hybrid MAC protocol for data transmission in Smart Grid. *Chinese Control Conference (CCC)*, *33*, 8228–8233. doi:10.1109/ChiCC.2014.6896378

Gama, O., Carvalho, P., Mendes, P. M., & Afonso, J. A. (2009). An improved MAC protocol with a reconfiguration scheme for wireless e-health systems requiring quality of service. *Wireless Communication, Vehicular Technology, Information Theory and Aerospace & Electronic Systems Technology*, 582–586. doi:10.1109/WIRELESSVITAE.2009.5172511

Gao, J. L. (2002). *Analysis of Energy Consumption for Ad Hoc Wireless Sensor Networks Using a Bit-Meter-per-Joule Metric*.

Hameed, S. A., Shaaban, E. M., Faheem, H. M., & Ghoniemy, M. S. (2009). Mobility-Aware MAC Protocol for Delay-Sensitive Wireless Sensor Networks. *In Ultra Modern Telecommunications & Workshops, 2009. ICUMT'09. International Conference*, 1–8.

Havinga, P., & Smit, G. (2000). Energy-efficient TDMA medium access control protocol scheduling. *Asian International Mobile Computing Conference (AMOC 2000)*, 1–9.

Healy, M., Newe, T., & Lewis, E. (2008). Wireless sensor node hardware: A review. *Sensors, 2008 IEEE*, 621–624. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=4716517

Huang, P., Xiao, L., Soltani, S., Mutka, M. W., & Xi, N. (2013). The evolution of MAC protocols in wireless sensor networks: A survey. *Communications Surveys & Tutorials*, *15*(1), 101–120. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6188353

Jadidoleslamy, H. (2014). A Survey on Medium Access Control Protocols based on Synchronous Duty Cycle Approach in Wireless Sensor Networks. *IJCSNS International Journal of Computer Science and Network Security*, *14*(3), 81–88. Retrieved from http://paper.ijcsns.org/07_book/201403/20140313.pdf

Javaid, N., Hayat, S., Shakir, M., Khan, M., Bouk, S., & Khan, Z. (2013). Energy Efficient MAC Protocols in Wireless Body Area Sensor Networks - A Survey. *Journal of Basic Applied Scientific Research (JBASR)*, 1–17.

Kabara, J., & Calle, M. (2012). MAC Protocols Used by Wireless Sensor Networks and a General Method of Performance Evaluation. *International Journal of Distributed Sensor Networks*, *2012*, 1–11. doi:10.1155/2012/834784

Kazienko, J., Ribeiro, I., Moraes, I., & Albuquerque, C. N. (2011). Practical evaluation of a secure key-distribution and storage scheme for wireless sensor networks using TinyOS. *CLEI ELECTRONIC JOURNAL*, *14*(1), 8. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Practical+Evaluation+of+a+Secure+Key-

Distribution+and+Storage+Scheme+for+Wireless+Sensor+Networks+Using+TinyOS#0

Khan, B., & Ali, F. (2011). Mobility Adaptive Energy Efficient and Low Latency MAC for Wireless Sensor Networks. *2011 Fifth International Conference on Next Generation Mobile Applications, Services and Technologies*, 218–223. doi:10.1109/NGMAST.2011.46

Klein, A. (2012). Preamble-Based Medium Access in Wireless Sensor Networks. In *Wireless Sensor Networks – Technology and Protocols*. Retrieved from http://cdn.intechopen.com/pdfs-wm/38789.pdf

Labrador, M. A., & Wightman, P. M. (2009). *Topology Control inWireless Sensor Networks*. Heidelberg: Springer.

Lanjewar, R. R., & Adane, D. S. (2014). Comparative Study of MAC Layer Protocols in Wireless Sensor Networks: A Survey. *International Journal of Engineering Trends and Technology (IJETT)*, *12*(1), 13–19. Retrieved from http://arxiv.org/abs/1406.4701

Liu, Y., & Ni, L. M. (2007). A new MAC protocol design for long-term applications in wireless sensor networks. *Parallel and Distributed Systems, 2007 …*, 1–8. doi:10.1109/ICPADS.2007.4447762

Maróti, M., Kusy, B., Simon, G., & Lédeczi, Á. (2004). The flooding time synchronization protocol. *Proceedings of the 2nd International Conference on Embedded Networked Sensor Systems. ACM*, 39–49. Retrieved from http://dl.acm.org/citation.cfm?id=1031501

McCanne, S., Floyd, S., Fall, K., & Varadhan, K. (1997). Network simulator ns-2. Retrieved from http://www.isi.edu/nsnam/ns/.

Meier, A., Motani, M., Siquan, H., & Künzli, S. (2008). DiMo: distributed node monitoring in wireless sensor networks. *In Proceedings of the 11th International Symposium on Modeling, Analysis and Simulation of Wireless and Mobile Systems*, 117–121. Retrieved from http://dl.acm.org/citation.cfm?id=1454526

Meng, W., Xie, L., & Xiao, W. (2013). Optimality analysis of sensor-source geometries in heterogeneous sensor networks. *IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS*, *12*(4), 1958–1967. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6463488

Park, P. (2011). *Modeling, Analysis, and Design of Wireless Sensor Network Protocols*. Universitetsservice US AB.

Pham, H., & Jha, S. (2005). Addressing Mobility in Wireless Sensor Media Access Protocol. *International Journal of Distributed Sensor Networks*, *1*(2), 269–280. doi:10.1080/15501320590966512

Polastre, J., Hill, J., & Culler, D. (2004). Versatile Low Power Media Access for Wireless Sensor Networks Categories and Subject Descriptors. *Proceedings of the 2nd International Conference on Embedded Networked Sensor Systems*, 95–107.

Raja, A., & Su, X. (2008). A Mobility Adaptive Hybrid Protocol for Wireless Sensor Networks. *2008 5th IEEE Consumer Communications and Networking Conference*, 692–696. doi:10.1109/ccnc08.2007.159

Ramchand, V., & Lobiyal, D. K. (2011). Z-MAC An Analytical Model For Wireless Sensor Network. *International Journal of Ad Hoc, Sensor & Ubiquitous Computing (IJASUC)*, *2*(4), 43–57. Retrieved from http://airccse.org/journal/ijasuc/papers/2411ijasuc04.pdf

Ray, S., Carruthers, J., & Starobinski, D. (2003). RTS/CTS-induced congestion in ad hoc wireless LANs. *Wireless Communications and Networking, 2003. WCNC 2003. 2003 IEEE*, *3*(C), 1516–1521 vol.3. doi:10.1109/WCNC.2003.1200611

Razaque, A. (2015). *Modular Energy Efficient Protocols For Lower Layers of Wireless Sensor Networks*. UNIVERSITY OF BRIDGEPORT. Retrieved from https://scholar.google.com/scholar?hl=en&q=MODULAR+ENERGY+EFFICIENT+PROTOCOLS+FOR+LOWER+LAYERS+OF+WIRELESS+SENSOR+NETWORKS&btnG=&as_sdt=1,5&as_sdtp=

Razaque, A., & Elleithy, K. M. (2014a). Energy-efficient boarder node medium access control protocol for wireless sensor networks. *Sensors (Basel, Switzerland)*, *14*(3), 5074–5117. doi:10.3390/s140305074

Razaque, A., & Elleithy, K. M. (2014b). Low Duty Cycle, Energy-Efficient and Mobility-Based Boarder Node—MAC Hybrid Protocol for Wireless Sensor Networks. *Journal of Signal Processing Systems*, 1–20. doi:10.1007/s11265-014-0947-3

Razaque, A., & Elleithy, K. M. (2014c). Mobility-Aware Hybrid Medium Access Control Protocol for Wireless Sensor Network (WSN). *Proceedings of the 2014 IEEE Sensors Applications Symposium, Rydges Lakeland Resort, Queenstown, New Zealand*, 18–20. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Mobility-Aware+Hybrid+Medium+Access+Control+Protocol+for+Wireless+Sensor+Network+(+WSN+)#0

Rebahi, Y., Mujica-V, V., & Sisalem, D. (2005). A reputation-based trust mechanism for ad hoc networks. *10th IEEE Symposium on Computers and Communications (ISCC'05)*, 37–42. doi:10.1109/ISCC.2005.17

Rhee, I., Warrier, A., Aia, M., Min, J., & Sichitiu, M. (2008). Z-MAC: a hybrid MAC for wireless sensor networks. *IEEE/ACMTRANSACTIONS ON NETWORKING*, *16*(3), 511–524. Retrieved from http://dl.acm.org/citation.cfm?id=1399564

Ruzzelli, A. G., Hare, G. M. P., Tynan, R., Cotan, P., & Havinga, P. J. M. (2006). Protocol assessment issues in low duty cycle sensor networks: The switching energy. *IEEE International Conference on Sensor Networks, Ubiquitous, and Trustworthy Computing -Vol 1 (SUTC'06)*, *1*, 136–143. doi:10.1109/SUTC.2006.1636169

Silva, H. D., Afonso, J. A., Macedo, P., & Rocha, L. A. (2011). Design and implementation of a wireless sensor network applied to motion capture. *The Portuguese Conference on Wireless*. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Design+and+Implementation+of+a+Wireless+Sensor+Network+applied+to+Motion+Capture#0

Sumathi, R., & Srinivas, M. G. (2012). A Survey of QoS Based Routing Protocols for Wireless Sensor Networks. *Journal of Information Processing Systems*, *8*(4), 589–602. doi:10.3745/JIPS.2012.8.4.589

Suriyachai, P., Roedig, U., & Scott, A. (2012). A survey of MAC protocols for mission-critical applications in wireless sensor networks. *IEEE COMMUNICATIONS SURVEYS & TUTORIALS*, *14*(2), 240–264. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5714974

Tang, L., Sun, Y., Gurewitz, O., & Johnson, D. B. (2011). EM-MAC: a dynamic multichannel energy-efficient MAC protocol for wireless sensor networks. *Proceedings of the Twelfth ACM International Symposium on Mobile Ad Hoc Networking and Computing. ACM*, 23. Retrieved from http://dl.acm.org/citation.cfm?id=2107533

Tripathi, B. S., & Kapoor, M. (2013). Review On DS SS-CDMA Transmitter and Receiver For Ad Hoc Network Using VHDL Implementation. *International Journal of Advances in Engineering & Technology*, *5*(2), 274–279. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:REVIEW+ON+DS+SS-CDMA+TRANSMITTER+AND+RECEIVER+FOR+AD+HOC+NETWORK+USING+VHDL+IMPLEMENTATION#0

Wong, K., & Arvind, D. K. (2006). SpeckMAC: low-power decentralised MAC protocols for low data rate transmissions in specknets. *Proceedings of the 2nd International Workshop on …*, 71–78. Retrieved from http://dl.acm.org/citation.cfm?id=1132996

Wu, C., Kumekawa, K., & Kato, T. (2010). A Novel Multi-hop Broadcast Protocol for Vehicular Safety Applications. *Journal of Information Processing*, *18*, 110–124. doi:10.2197/ipsjjip.18.110

Yadav, R., Varma, S., & Malaviya, N. (2009). A survey of MAC protocols for wireless sensor networks. *UbiCC Journal*, *4*(3), 827–833. Retrieved from http://www.ubicc.org/files/pdf/11_339.pdf

Yahya, B., & Ben-Othman, J. (2008). A scalable and energy-efficient hybrid-based MAC protocol for wireless sensor networks. *Proceedings of the 3nd ACM Workshop on Performance Monitoring and Measurement of Heterogeneous Wireless and Wired Networks - PM2HW2N '08*, 67–71. doi:10.1145/1454630.1454640

Ye, W., Heidemann, J., & Estrin, D. (2002). An Energy-Efficient MAC Protocol for Wireless Sensor Networks. *INFOCOM 2002. Twenty-First Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings. IEEE*, *3*(c), 1567–1576.

Ye, W., Heidemann, J., & Estrin, D. (2004). Medium Access ControlWith Coordinated Adaptive Sleeping forWireless Sensor Networks. *IEEE/ACM TRANSACTIONS ON NETWORKING*, *12*(3), 493–506.

Yigitel, M. A., Incel, O. D., & Ersoy, C. (2011). QoS-aware MAC protocols for wireless sensor networks: A survey. *Computer Networks*, *55*(8), 1982–2004. doi:10.1016/j.comnet.2011.02.007

Youssef, W., & Younis, M. (2007). Intelligent estimation of gateways count for reduced data latency in wireless sensor networks. *GLOBECOM - IEEE Global Telecommunications Conference*, 903–907. doi:10.1109/GLOCOM.2007.174

Zhang, J., Li, W., Cui, D., Zhao, X., & Yin, Z. (2009). The NS2-based simulation and research on wireless sensor network route protocol. *Proceedings - 5th International Conference on Wireless Communications, Networking and Mobile Computing, WiCOM 2009*, 4–7. doi:10.1109/WICOM.2009.5302699

Zhao, J., Sun, X., Wei, Z., & Li, Z. (2011). A New MAC Protocol for Moving Target in Distributed Wireless Sensor Networks. *Wireless Sensor Network*, *03*(02), 61–72. doi:10.4236/wsn.2011.32007

Zhao, Y., Miao, C., Ma, M., Zhang, J., & Leung, C. (2012). A survey and projection on medium access control protocols for wireless sensor networks. *ACM Computing Surveys*, *45*(1), 1–37. doi:10.1145/2379776.2379783