FUZZY LOGIC SYSTEM AND MEDIATION DEVICE NODE WITH GRIDS FOR ENERGY SAVING IN WIRELESS SENSOR NETWORK

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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DEDICATION

This thesis is dedicated to my beloved one's.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

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April 2019

Chairman : Kweh Yeah Lun, PhD
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Wireless Sensor Networks (WSN) are widely used in many applications. However, it still suffering from many issues such as packet loss, idle listening, high delay, and distance between nodes which all contribute to increase energy consumption and dissipation in WSN. In order to reduce this energy dissipation, this research concentrates on the Hierarchal routing Medium Access Control (MAC) protocols on how to solve the aforementioned problems. This research proposes the Grid Mediation Device (GMD) Node to minimize the idle listening of the active dura- tion for each node, the nodes are put to sleep mode for a reasonably long period of time and they wake up for a short time only to receive data. This behavior reduces the energy consumption for each sensor while minimizing the delay since the clusterheads will not wait for the sleeping nodes that have no data to send. Thereafter, the active clusterheads will be also put in the sleeping mode once they finish their data transmission. Simulation and mathematical model of the proposed GMD protocol have confirmed that the proposed GMD can improve the lifetime for all sensor nodes in the network, due to minimizing the idle listening time for each node. Moreover, adding Multi-levels of grids and Multi-level of MD node to the GMD protocol that will minimize the distance of sending data from each level cluster grid to another level until reach to the base station instead of sending data directly from any cluster to the base station, because the path between nodes and cluster head is not reliable and the nodes are far from each other in different grid. This research leads to reduce packets lost problem as well makes the network more reliable which is another contribution of this study. Lastly, this research adding Fuzzy logic system to the grids to minimize the problem of the distance between nodes as using three fuzzy logic criteria for each node will lead to choosing the optimal location and energy for each clusterhead and each node. The three pro- posed protocols have been compared to the Two-Dimensional Technique Based on Centre of Gravity and Energy (TDTCGE) protocol which is used two-dimensional technical centers (energy Centres and Gravity Centres) that will help to reduce the energy consumption and distances between nodes. Moreover, some of the proposed protocol derives better system performance such as end-

to-end delay, throughput, lifetime, and energy saving. The Grid Mediation Device (GMD) protocol with Mathematical model has improved the lifetime around 88% as compared with the TDTCGE. In addition, The Fuzzy Logic grids (FLG) protocol saves more than 8% energy battery by adding the Fuzzy logic with the three criteria's (Distance between nodes, distance to the basestation, residual energy) that will minimize the radius competitions between nodes and the clusterhead, and between the nodes and BS by 52% more than TDTCGE protocol. GMD Simulation protocol de- creases the mean of delay by 40% because of the sleeping mode, and which node has data that it has the turn to transmit data only. In addition, Multilevel GMD Proposed protocol reduces the packets lost by 65%. This Research Work improves the lifetime and saving more energy which is also more reliable and efficiency for the wireless sensor network.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

SISTEM LOGIK KABUR DAN NOD PERANTI PENGANTARAAN BERGRID UNTUK PENJIMATAN TENAGA DALAM RANGKAIAN PENDERIA TANPA WAYAR

Oleh

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Rangkaian Sensor Tanpa Wayar (WSN) digunakan secara meluas dalam banyak aplikasi. Walau bagaimanapun, ia masih mengalami banyak masalah seperti Pelang- garaan paket, pendengaran tidak aktif dan kelewatan transmisi menyumbang kepada pembaziran tenaga dalam Rangkaian Sensor Tanpa Wayar (WSN). Bagi mengu- rangkan kehilangan tenaga, kajian ini memberi perhatian kepada protokol yang dinamakan sebagai Kawalan Capaian Medium Pengalhalan Bertingkat (MAC) untuk mengurangkan penggunaan tenaga, kelewatan dan juga memperbaiki peng- hantaran serta jangka hayat bagi WSNs. Dengan menggunakan nod Mediation Device (MD) bagi meminimumkan pendengaran tidak aktif semasa tempoh ak- tif bagi setiap nod, nod-nod diletakkan dalam mod tidur untuk satu tempoh masa yang munasabah.Nod-nod ini akan hanya bangun dalam tempoh yang singkat untuk memerima paket. Proses ini memperbaiki jangka hayat untuk se- tiap sensor dan pada masa yang sama meminimumkan kelewatan kerana Ketua Kluster tidak akan menunggu nod-nod yang tiada penghantaran data. Dengan ini juga, Ketua Kluster akan berada dalam keadaan tidur. Grid Mediation De- vice (GMD) yang dicadangkan akan menggunakan nod MD dengan grid di dalam rangkaian dua dimensi di mana paket beacon digunakan untuk meletakkan nod- nod dalam mod tidur apabila nod-nod ini tiada penghantaran data. Ini akan membantu menjimatkan penggunaan tenaga dalam rangkaian. Selain daripada simulasi keputusan dipaparkan, satu formula matematik juga telah dicadangkan untuk memperbaiki jangka hayat untuk semua nod-nod sensor di dalam rangka- ian menggunakan protokol GMD. Malahan, penambahan grid pelbagai tahap dan MD pelbagai tahap kepada protokol GMD membantu meminimumkan kehilan- gan paket dan kelewatan. Ini membuatkan rangkaian lebih boleh dipercayai and seterusnya menjadi satu lagi sumbangan dalam kajian ini. Ini kerana laluan di antara nod dan Ketua Kluster secara umumnya lebih boleh dipercayai dan nod- nod adalah jauh antara satu sama lain. Akhir sekali, kajian ini menambah sistem logik Kabur kepada grid bagi menentukan nod sensor yang optimum dan juga lokasi Ketua Kluster. Selain itu, kajian

ini mengaplikasikan sistem logik Kabur kepada grid-grid. Ini juga membantu mengurangkan masalah yang dikaitkan den- gan jarak komunikasi nod-nod sensor (secara bersama) dan juga kehilangan tenaga oleh nod-nod sensor dan cluster heads mereka. Tiga protokol yang dicadangkan telah dibandingkan dengan protokol Two-Dimensional Technique Based on Centre of Gravity and Energy (TDTCGE) di mana ia menggunakan teknik dua dimensi (i.e. pusat tenaga dan pusat graviti) untuk mengurangkan penggunaan tenaga dan jarak antara nod. Malahan, sesetengah protokol yang dicadangkan menghasilkan prestasi sistem yang lebih baik dari segi kelewatan hujung ke hujung, penghan- taran, jangka hayat dan penjimatan tenaga. Protokol GMD dan model matem- atiknya memperbaiki jangka hayat TDTCGE dengan anggaran 88%. Tambahan pula, protokol logik kabur grids (FLG) menjimatkan lebih 8% tenaga bateri hasil daripada penambahan logik kabur kepada ketiga-tiga kriteria (iaitu jarak antara nod, jarak antara styesn utama, dan baki tenaga). Mekanisma ini meminimumkan radius persaingan antara nod dan Ketua Kluster mereka, dan nod-nod dengan BS sebanyak 52% bila dibandingkan dengan protokol TDTCGE. Simulasi pro- tokol GMD mengurangkan purata kelewatan sebanyak 40% kerana ia melibatkan mod tidur. Tambahan juga, protokol GMD pelbagai tahap yang dicadangkan ini mengurangkan kehilangan paket sebanyak 65%. Kajian ini berjaya memperbaiki jangka hayat rangkaian dan menjimatkan tenaga serta menyediakan rangkaian yang boleh dipercayai dan ceka.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

LEACH	Low Energy Adaptive Clustering Hierarchy
MAC	Medium Access Control
RTS	Request To Send
S-MAC	Sensor MAC
TCP	Transport Control Protocol
TDMA	Time Division Multiple Access
T-MAC	Timeout MAC
TDTCGE	Two Dimensional Technique Based On Center of Gravity and Energy Center
UDP	Universal Data Protocol
WLAN	Wireless Local Area Network
WPAN	Wireless Personal Area Network
WSN	Wireless Sensor Network
CDMA	Code Division Multiple Access
RTS	Request To Send
CTS	Clear To Send
WSN	Wireless Sensor Networks
ACK	Acknowledgment
MD	Mediation Device
GMD	Grid Mediation Device
FLG	Fuzzy Logic Grid
CBR	Constant Bit Rate
BS	Base Station
SNR	Clusterhead Signal to Noise Ratio

CHAPTER 1

INTRODUCTION

1.1 Research Background

Recent advances in micro-electromechanical systems, tiny microprocessors, and low power radio technologies have led to the creation of low-cost, low-power, multi-functional, miniature sensor devices that can detect and react to changes in the physical phenomena of their surrounding environments. Wireless Sensor Networks (WSNs) typically consist of a base station or sink node and some wireless sensor nodes. Each sensor node is a unit with wireless networking capability that can collect and process data independently. Figure 1.1 shows a sample sensor node [1]. These small system platforms which integrate sensors, processors, and transceivers have also been referred to as motes [5, 6].

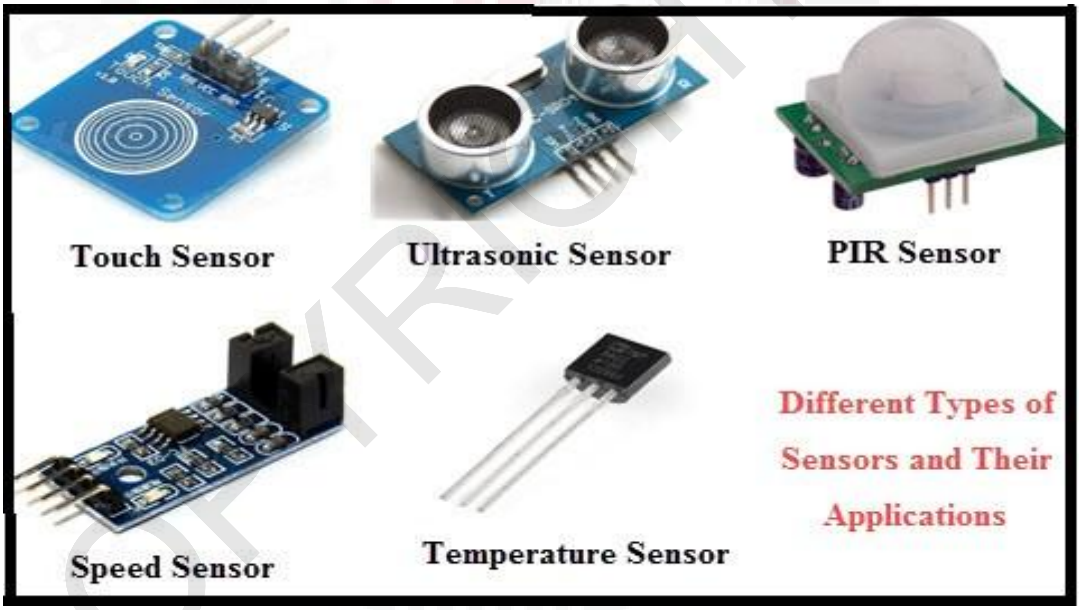

Figure 1.1 : Small sensors devices [1]

WSNs are envisioned for a wide range of applications, from environmental surveillance, inventory tracking, health monitoring, and home automation to applications as diverse as even networking in or around a human body. Sensor networks mon- itor phenomena as diverse as moisture, temperature, speed, and location using optical, motion, and piezoelectric detectors.

For many of these applications, the sensor networks will share some common fea- tures. Since small batteries will power nodes, the radio itself, together with the protocol stack design must be energy-efficient.

The term “energy efficiency” is regarded as a major consideration and one of the most important requirements in WSN. Sensor nodes are expected to operate for long periods of time, running off batteries or ambient energy sources. Because the biggest consumer of energy is the radio, many researchers have focused on creating energy-efficient or low-energy-consuming routing MAC protocols [3, 5, 6, 7, 8].

The most important challenge for all WSNs is to minimise energy consumption. Increasing the energy efficiency of the network leads to prolonging the battery and network lifetime. This may be achieved by considering energy awareness issues in all aspects of the design and operation of each sensor node. Moreover, energy-saving protocols and techniques need to be designed for collective groups of communicating sensor nodes to have better overall performance and improved energy efficiency in many WSN routing MAC protocols.

1.2 Problem Statement

Energy efficiency is considered to be the main challenge for WSNs, and it has a large impact on a given system’s lifetime. Each sensor, within a WSN, consists of different energy consuming parts, namely the Central Processing Unit (CPU), the microcontroller, the transmitter, and the receiver. The current research is done in the area of hierarchy routing Medium Access control (MAC) protocols in WSNs. Specifically, there are some of the proposed hierarchical routing MAC algorithms that does not satisfy all these requirements of previous protocols. Previous re-searches have extensively studied and proposed different Hierarchy routing MAC protocols. One of such is the Two-Dimensional Technique Based on Centre of Gravity and Energy Centre in WSN (TDTCGE) protocol that aims at addressing the problem of energy consumption by choosing the nearest node to the basesta- tion as a clusterhead. Although the TDTCGE effectively reduces this distance, it has left several other issues unsolved. These include:

- The TDTCGE research has not solved the problem of idle listening for each cluster head. Idle listening consumes a lot of energy in the TDTCGE because the cluster head radio transceiver is always ON which consumes a lot of energy which leads to minimize lifetime for each sensor in the network.

- The research of the TDTCGE has not minimised the radius distance between each node. This increases the energy consumed during clusterhead selection. Furthermore, clusterheads are far a way of basestation and centers.

- At the same time, the TDTCGE research focused on single hop routing, However, the incurred delay in sending data between clusters for routing the data to the basestation have not been addressed. Also, farther away from the cluster head incur delay when sending data to the basestation which warrants an improvement in throughput performance.

- The TDTCGE research loses many packets because clusterheads sends data directly from far away distance which leads to packets loss; additionally, the TDTCGE research needs to minimise the distance between nodes to choose a suitable node position and optimal path.

1.3 Research Objectives

The primary goal of this research is to propose an efficient protocol with a mathe- matical model that increases the network lifetime for wireless sensor networks and improves the performance of the WSN. To achieve this aim, the following are the main objectives to be accomplished in this thesis:

- To propose a GMD mathematical model to reduce idle listening on the radio transceiver. This will improve the lifetime of the network.

- To propose a multiple criteria's selection strategy with grids to minimise the radius distance between nodes in the TDTCGE protocol in order to save energy.

- To propose a GMD protocol that minimizes the sensor node transfer delay to the basestation and improves on the throughput performance.

- To propose a protocol of Multilevel GMD that minimises the loss packets from the source node to the destination node more effectively than in the TDTCGE protocol.

1.4 Research Scope

As previously mentioned, the major sources of energy dissipation are those of idle listening. Many routing protocols have been proposed to overcome these energy-wasting processes. In this work, we focus on enhancing the TDTCGE Routing Protocol.

This work particularly falls under the Wireless Sensor Networks routing protocol. WSN routing protocols are divided into four parts: route processing, network structure, network operations, initiator of communications.

Network Structures are divided into three parts: flat protocols, hierarchal protocol, and location-based protocol. Our work falls under the category of the hierarchical protocols (see Figure 1.2).

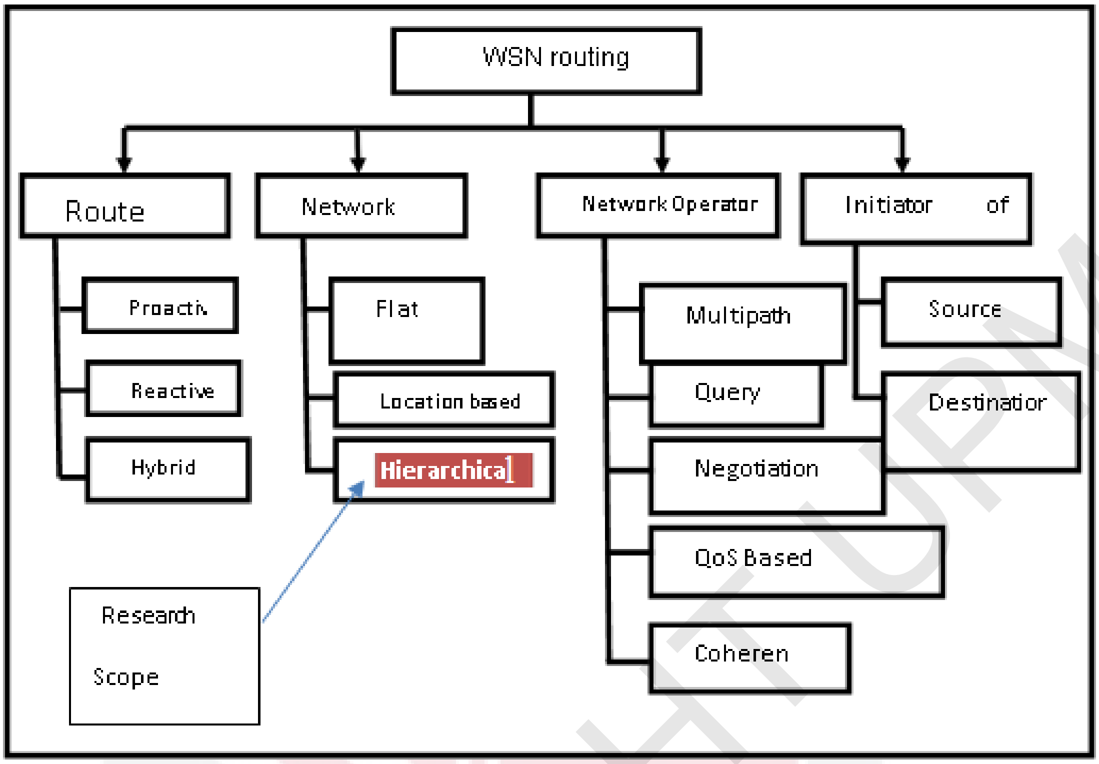

Figure 1.2 : Wireless Sensor Networks routing protocol

1.5 Research Contributions

The main contributions of this research are described as follows:

i. Developing an efficient protocol by adding fuzzy logic with grids to choose an optimal cluster head by using three criteria (distance to BS, the distance between sensor nodes and residual energy) to minimise the radius distance between nodes and save their energy in WSN.

ii. Developing an efficient protocol by adding an MD node with grids which introduces sleep beacons to minimise the idle listening and delay in the TDTCGE protocol and improve its throughput performance.

iii. Designing a mathematical model for an MD node will improve the lifetime by using mathematical formulas.

iv. Designing a GMD Multi-level protocol which reduces the packet loss of the TDTCGE protocol. (see Figure 1.3).

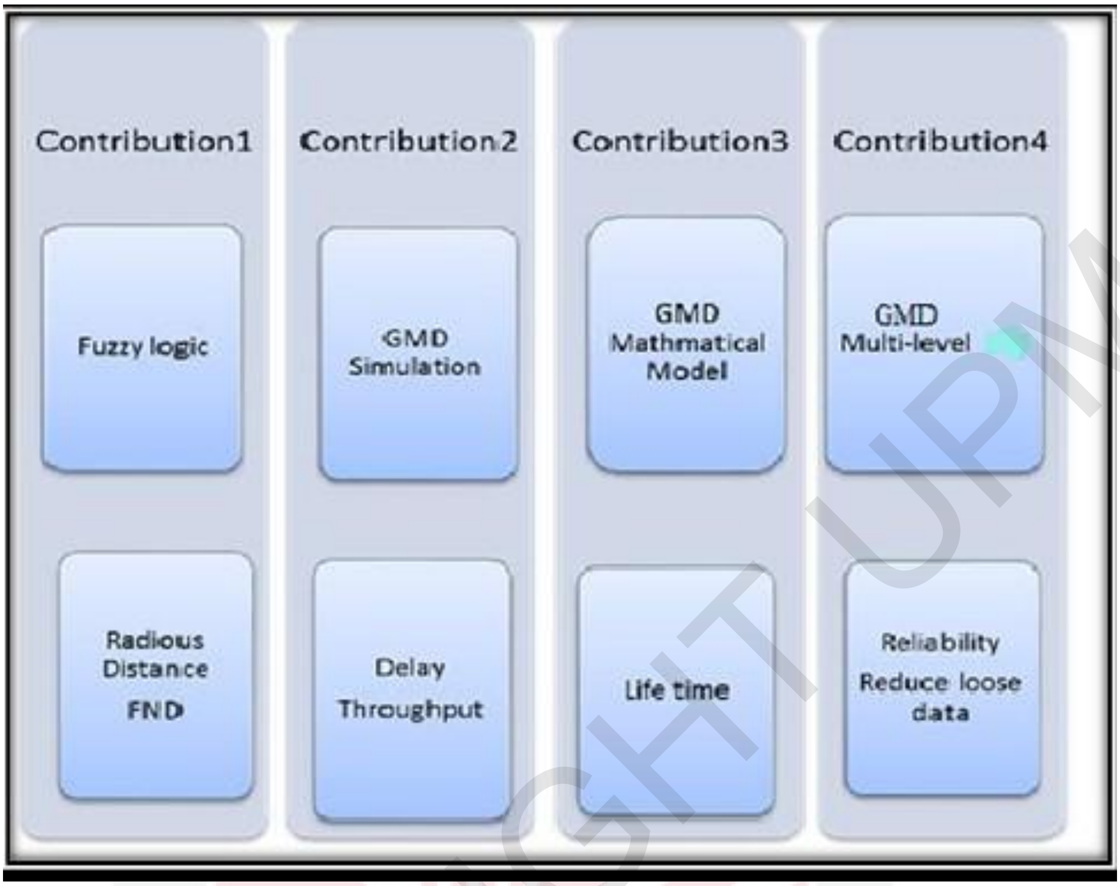

Figure 1.3 : Research Contributions

1.6 Thesis Organisation

The rest of this thesis is organized as follows: Chapter 2, introduces the WSN challenges, and techniques aimed at achieving energy efficiency. Related works have also been discussed with comparisons. Chapter 3 describes the methodology of the research work explaining all the processes in details. It focuses on two main energy consuming consumption and proposes a technique to overcome these problems. Chapter 4 discusses the proposed fuzzy logic system with grids and clarify all the phases and the stages of this fuzzy logic system. Chapter 5 presents the proposed the GMD protocol. Here the functional procedure of the MD node with its impact on message transfer delay and throughput are described. This chapter also explores the GMD mathematical model with grids and the effective formulas on the network life time. Chapter 6 illustrates the GMD Multilevel protocol and the optimal reliable path with its effect on reducing the packet loss. Chapter 7 concludes this research and recommends some promising directions for future research.

REFERENCES

[1.] B. A. Attea and E. A. Khalil, "new evolutionary based routing protocol for clustered heterogeneous wireless sensor networks," *in Applied Soft Computing,* vol. 12, pp. 1950–1957, 2012.

[2.] S. Lindsey and C. S. Raghavendra, "Pegasis: Power-efficient gathering in sensor information systems," *in IEEE Aerospace Conference Proceedings pp,* vol. 3, pp. 3–1130, 2002.

[3.] O. C. Omeni, O. Eljamaly, and A. J. Burdett, "Energy efficient medium access protocol for wireless medical body area sensor networks," in *International Summer School and Symposium on Medical Devices and Biosensors,* 2007, pp. 29–32.

[4.] G. V. Merrett and Y. K. Tan, *Wireless sensor networks: application-centric design.* InTech, 2010.

[5.] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy- efficient communication protocol for wireless microsensor networks," in *Proceedings of the 33rd Annual Hawaii International Conference on System Sciences,* 2000.

[6.] W. Ye, J. Heidemann, and D. Estrin, "An energy-efficient mac protocol for wireless sensor networks," *in Proceeding of INFOCOM,* vol. 2002, pp. 1567–1576, 2002.

[7.] P. Joseph, H. Jason, and C. David, "Versatile low power media access for wireless sensor networks," in *Proceedings of the 2nd international conference on Embedded networked sensor systems Baltimore.* MD, USA: ACM, 2004.

[8.] G. P. Halkes and K. G. Langendoen, "Crankshaft: An energy-efficient mac-protocol for dense wireless sensor networks," in *Lecture Notes in Computer Science. vol. 4373: , Heidelberg.* Berlin: Springer, 2007, pp. 228–244.

[9.] Y. Wei, H. John, and E. Deborah, "Medium access control with coordinated adaptive sleeping for wireless sensor networks," *IEEE/ACM Trans. Netw.,* vol. 12, pp. 493–506, 2004.

[10.] B. Bougard, F. Catthoor, D. C. Daly, A. Chandrakasan, and W. Dehaene, "Energy efficiency of the ieee 802.15.4 standard in dense wireless microsensor networks: modeling and improvement perspectives," *in IEEE Proceedings of Design, Automation and Test in Europe pp,* pp. 196–201, 2005.

[11.] R. Szewczyk, J. Polastre, A. Mainwaring, and D. Culler, "Lessons from a sensor network expedition," in *vol. 2920: , Heidelberg.* Berlin: Springer, 2004, pp. 307–322.

[12.] S. Robert, M. Alan, P. Joseph, A. John, and C. David, "An analysis of a large-scale habitat monitoring application," in *Proceedings of the 2nd international conference on Embedded networked sensor systems Baltimore.* MD, USA: ACM, 2004.

[13.] I. Mohammad, M. Imad, and K. Laurie, "Handbook of sensor networks: Compact wireless and wired sensing systems: Crc press, inc," vol. 2004.

[14.] M. P. Rajasekaran, S. Radhakrishnan, and P. Subbaraj, "Remote monitor- ing of post-operative patients using wireless sensor networks," *International Journal of Healthcare Technology and Management*, vol. 9, pp. 247–257, 2008.

[15.] R. Ramanathan and J. Redi, "A brief overview of ad hoc networks: challenges and directions," *IEEE Communications Magazine*, vol. 40, pp. 20–22, May 2002.

[16.] K. Holger and W. Andreas, "Protocols and architectures for wireless sensor networks: John wiley sons," vol. 2005.

[17.] M. Messina, Y. Y. Lim, E. Lawrence, D. Martin, and F. Kargl, "Implementing and validating an environmental and health monitoring system " in fifth international conference on information technology: New generations, 2008, pp. 994-999."

[18.] K. Sohrabi, J. Gao, V. Ailawadhi, and G. J. Pottie, "Protocols for self- organization of a wireless sensor network," *IEEE Personal Communications*, vol. 7, pp. 16–27, 2000.

[19.] H. Douglas, S. Vinaitheerthan, L. Yung-Hsiang, B. Saurabh, and L. Zhiyuan, "Adaptive correctness monitoring for wireless sensor networks using hierarchical distributed run-time invariant checking," *ACM Trans. Auton. Adapt*, vol. 2, 2007.

[20.] B. Marcel, K. Reiner, and M. Clemens, "A method for self-organizing communication in wsn based localization systems: Hashslot," in *Proceedings of the 32nd IEEE Conference on Local Computer Networks: IEEE Computer Society*, 2007.

[21.] I. F. Akyildiz and I. H. Kasimoglu, "Wireless sensor and actorstar, open networks: research challenges," *Ad Hoc Networks*, vol. 2, pp. 351–367, October 2004.

[22.] D. T. van and L. Koen, "An adaptive energy-efficient mac protocol for wireless sensor networks," in *Proceedings of the 1st international conference on Embedded networked sensor systems Los Angeles.* California, USA: ACM, 2003.

[23.] G. Pei and C. Chien, "Low power tdma in large wireless sensor networks," *inIEEE Military Communications Conference, MILCOM*, vol. 2001, 2001.

[24.] M. Younis, M. Youssef, and K. Arisha, "Energy-aware routing in cluster- based sensor networks," in *Proceedings of the 10th IEEE International Symposium on Modeling.* Analysis, and Simulation of Computer and Telecommunications Systems (MASCOTS'02): IEEE Computer Society, 2002.

[25.] A. K. Das, R. J. Marks, P. Arabshahi, and A. Gray, "Power controlled minimum frame length scheduling in tdma wireless networks with sectored antennas," *in IEEE Proceeding of INFOCOM*, vol. 2005, no. 24, pp. 1782–1793, 2005.

[26.] K. Langendoen and G. Halkes, *Energy Efficient Medium Access Control.* in Embedded Systems Handbook: CRC, 2005.

[27.] S. Selvakennedy and S. S. Sinnappan, "A configurable time-controlled clustering algorithm for wireless sensor networks," 2005, in Parallel and Distributed Systems, Proceedings. 11th International Conference on, vol. 2.

[28.] Z. Cheng, M. Perillo, B. Tavli, W. Heinzelman, S. Tilak, and N. Abu- Ghazaleh, "Protocols for local data delivery in wireless microsensor networks," vol. 45, August 2002.

[29.] A. Manjeshwar and D. P. Agrawal, "Teen: a routing protocol for enhanced efficiency in wireless sensor networks," *in Proceedings*, vol. 15, pp. 2009–2015, 2001.

[30.] V. Loscr`ı, G. Morabito, and S. Marano, "A two-levels hierarchy for low- energy adaptive clustering hierarchy," *[*, vol. 13, 2006.

[31.] M. Yassein, A. Al-zou'bi, Y. Khamayseh, and W. Mardini, "Improvement on leach protocol of wireless sensor network (vleach)," *JDCTA: International Journal of Digital Content Technology and its Applications*, vol. 3, no. 2, pp. 132–136, 2009.

[32.] Y. Yu, R. Govindan, and D. Estrin., "Geographical and energy aware rout- ing: A recursive data dissemination protocol for wireless sensor networks," UCLA/CSD-TR-01-0023, UCLA, Technical Report, May 2001.

[33.] N. H. Mak2 and W. K. G. Seah1, "How long is the lifetime of a wireless sensor network?" *School of Computing, National University of Singapore, IEEE Manuscript submitted to AINA .*, vol. 2009.

[34.] A. Manjeshwar and D. P. Agrawaly", "Apteen: A hybrid protocol for efficient routing and comprehensive information retrieval in wireless sensor networks," in Proceedings of the International Parallel and Distributed Processing Symposium (IPDPS. 02)/02 17.00§c IEEE, 2002, pp.1530 − −2075.

[35.] S. Ganesh and R. Amutha, "Efficient and secure routing protocol for wireless sensor networks through optimal power control and optimal handoff-based recovery mechanism," *Journal of Computer Networks and Communications*, vol. 2012, 2012.

[36.] S. A. Nikolidakis, D. Kandris, D. D. Vergados, and C. Douligeris, "Energy effi- cient routing in wireless sensor networks through balanced clustering," *Algorithms*, vol. 6, no. 1, pp. 29–42, 2013.

[37.] N. Batra, A. Jain, and S. Dhiman, "An optimized energy efficient routing algorithm for wireless sensor network," *International Journal of Innovative Technology and Creative Engineering*, vol. 1, p. 5, 2011.

[38.] A. G. Delavar and A. A. Baradaran, "Crcwsn: Presenting a routing algorithm by using re-clustering to reduce energy consumption in wsn. international journal of computers communications control, 2013. (isi)(issn 1841-9836) 8(1): p. 61-69."

[39.] S. Sharma and S. K. Jena, "Cluster based multipath routing protocol for wireless sensor networks," *ACM SIGCOMM Computer Communication Review*, vol. 45, no. 2, pp. 14–20, 2015.

[40.] V. V. Deshpande and A. R. B. Patil, "Energy efficient clustering in wireless sensor network using cluster of cluster heads," *In Wireless and Optical Communications Networks (WOCN)*, vol. 2013, pp. 1–5, 2013.

[41.] A. Norouzi, F. S. Babamir, and A. H. Zaim, "A novel energy efficient routing protocol in wireless sensor networks," *Wireless Sensor Network*, vol. 3, p. 10, 2011.

[42.] B. Nazir and H. Hasbullah, "Energy balanced clustering in wireless sensor net- work," *In Information Technology (ITSim)*, vol. 2010, pp. 569–574, 2010.

[43.] S. K. Mammu, A. Sharma, U. Hernandez-Jayo, and N. Sainz, "A novel cluster-based energy efficient routing in wireless sensor networks," *In Advanced informa- tion networking and applications (AINA)*, vol. 2013, pp. 41–47, 2013.

[44.] A. Heydariyan, A. A. Baradaran, and E. Rezaei, "" tdtcge: Two dimensional technique based on center of gravity and energy center in wireless sensor network"," *Journal of Basic and Applied Scientific Research (ISI)(ISSN:*, vol. 2090, pp. 194– 201, 2013.

[45.] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless sensor networks: a survey," *Comput. Netw.*, vol. 38, pp. 393–422, 2002.

[46.] N. Q. U. K. Z. J. N. Shakeel, U.; Jan, "Drads: Depth and reliability aware delay sensitive routing protocol for underwater wsns." *In Proceedings of the 2016 10th International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS), Fukuoka, Japan,*, p. 78–83, 2016.

[47.] I. K. T. H. M. K. Z. Q. U. J. N. Shah, P.M.; Ullah, "Mobisink: Cooperative routing protocol for underwater sensor networks with sink mobility." *In Proceedings of the 2016 IEEE 30th International Conference on Advanced Information Networking and Applications (AINA), Crans-*

Montana, Switzerland,, p. 189–197, 2016.

[48.] S. A. A. I. M. K. A. G. M. Javaid, N.; Hussain, "Region based cooperative rout- ing in underwater wireless sensor networks." *J. Netw. Comput. Appl.*, vol. 92, p. 31–41., 2017.

[49.] N. G. S. I. S. I. M. H. N. N. K. Abbasi, J.S.; Javaid, "Balanced energy efficient rect- angular routing protocol for underwater wireless sensor networks." *In Proceedings of the 2017 13th International Wireless Communications and Mobile Computing Conference (IWCMC), Valencia, Spain,*, p. 1634–1640., 2017.

[50.] Y. K. I. Rahman, M.A.; L ee, "Eecor: An energy-efficient cooperative opportunistic routing protocol for underwater acoustic sensor networks." *EEE Access*, vol. 6, p. 14119–14132., 2017.

[51.] A. A. I. K. K.-M. M. H. Shah, S.; Khan, "Localization free energy efficient and cooperative routing protocols for underwater wireless sensor networks." *Symmetry*, vol. 10, p. 498, 2018.

[52.] J.-M. Kim, S.-H. Park, Y.-J. Han, and T.-M. Chung, "Chef: cluster head election mechanism using fuzzy logic in wireless sensor networks," *In Advanced communi- cation technology*, vol. 2008, no. 10, pp. 654–659, 2008.

[53.] H. Su and X. Zhang, *Energy-efficient clustering system model and Reconfigura- tion schemes for wireless sensor networks.* in proc. of the 40thConference on Information Sciences and Systems (CISS 2006), March 2006, 2006.

[54.] J. C. Bezdek, R. Ehrlich, and W. Full, "Fcm: The fuzzy c- means clustering algorithm," *Computers Geosciences*, vol. 10, no. 2-3, pp. 255–260, 2005.

[55.] D. R. Gupta, Indranil and S. Sampalli, "Cluster-head election using fuzzy logic for wireless sensor networks," *In Communication Networks and Services Research Conference, 2005. Proceedings of the 3rd Annual, . IEEE,* 2005.

[56.] C. Otto, A. Milenkovic, C. Sanders, and E. Jovanov, "System architecture of a wireless body area sensor network for ubiquitous health monitoring," *Journal of Mobile Multimedia*, vol. 1, pp. 307–326, 2006.

[57.] H. Wang, P. Wang, P. Tu, and J. Yang, "A redundant and energy- efficient cluster- head selection protocol for wireless sensor network," in *International Conference on Communication Software and,* I. Second, Ed. 2010: Networks, pp. 554–558.

[58.] F. Al-Ma'aqbeh, O. Banimelhem, E. Taqieddin, F. Awad, and M. Mowafi, "Fuzzy logic-based energy efficient adaptive clustering protocol," in *Proceedings of the 3rd International Conference on Information and Communication Systems*. p. 21. ACM, 2012.

[59.] P. Nayak and A. Devulapalli, "A fuzzy logic-based clustering algorithm for wsn to extend the network lifetime," *IEEE sensors journal*, vol. 16, no. 1, pp. 137–144, 2016.

[60.] P. Nayak, D. Anurag, and V. V. N. A. Bhargavi, "Fuzzy based method super cluster head election for wireless sensor network with mobile base station (fm-schm)," in *Proc. 2nd Int.* Conf. Adv. Comput. Methodol, 2013, pp. 422–427.

[61.] T. Sharma and B. Kumar, "F-mchel: Fuzzy based master cluster head election leach protocol in wireless sensor network," *International Journal of Computer Science and Telecommunications*, vol. 3, no. 10, pp. 8–13, 2012.

[62.] C. W. G. S. Chen, M. and V. C. Leung, "Balanced itinerary planning for multiple mobile agents in wireless sensor networks," *In International Conference on Ad Hoc Networks, Springer*, p. 416–428., 2010a.

[63.] W. Alec and E. C. David, "A transmission control scheme for media access in sensor networks," in *Proceedings of the 7th annual international conference on Mobile computing and networking Rome*. Italy: ACM, 2001.

[64.] D. G. P. Halkes and K. G. Langendoen, "T. v," in *"Comparing Energy-Saving MAC Protocols for Wireless Sensor Networks, Mobile Networks and Applications, Netherlands, vol. 10*, 2005, pp. 783–791.

[65.] I. E. T. F. (IETF), *in Ad hoc On-Demand Distance Vector (AODV) Routing draft- ietf-manet-aodv-13: Mobile Ad Hoc Networking Working Group*, 2003.

[66.] R. G. Sargent, "Verification and validation of simulation models," *Journal of sim- ulation*, vol. 7, no. 7, pp. 12–24., 2013.

[67.] R. Rathna and A. Sivasubramanian, "Improving energy efficiency in wireless sensor networks through scheduling and routing," *IJASSN*, vol. 2, no. 1, pp. 21–7, 2012.

[68.] S. Eugene, C. Seong-Hwan, I. Nathan, M. Rex, S. Amit, W. Alice, and C. Anantha, "Physical layer driven protocol and algorithm design for energy-efficient wireless sensor networks," in *Proceedings of the 7th annual international conference on Mobile computing and networking Rome*. Italy: ACM, 2001.

[69.] I. Demirkol, C. Ersoy, and F. Alagoz, "Mac protocols for wireless sensor networks: a survey," *vol.*, vol. 44, pp. 115–121, April 2006.

[70.] El-Hoiydi and J. d. Decotignie, *WiseMAC: An Ultra Low Power MAC Protocol for Multi-hop Wireless Sensor Networks.* Berlin: Springer, 2004, vol. 3121:.

[71.] L. M. S. C. of the IEEE Computer Society, “in wireless lan medium access control (mac) and physical layer (phy) specifications for low-rate wireless personal area networks (lr-wpans),” *New York, NY, USA: IEEE,,* 2003.

[72.] R. Venkatesh, O. Katia, and J. J. Garcia-Luna-Aceves, “Energy-efficient collision- free medium access control for wireless sensor networks,” in *Proceedings of the 1st international conference on Embedded networked sensor systems Los Angeles.* California, USA: ACM, 2003.

[73.] P. Lin, C. Qiao, and X. Wang, “Medium access control with a dynamic duty cycle for sensor networks,” *in IEEE Wireless Communications and Networking Conference, WCNC pp,* pp. 1534–1539, 2004.

[74.] L. Jing and Y. L. Georgios, “A bit-map-assisted energy-efficient mac scheme for wireless sensor networks,” in *Proceedings of the third international symposium on Information processing in sensor networks Berkeley.* California, USA: ACM, 2004.