A GRID-BASED RELIABLE ROUTING (GBRR) PROTOCOL FOR WIRELESS SENSOR NETWORKS

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A GRID-BASED RELIABLE ROUTING (GBRR) PROTOCOL FOR WIRELESS SENSOR NETWORKS

By

JIANG CAILING

Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Computer Science

January 2019

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DEDICATION

"To my beloved father and mother, thank you for all your support in term of spiritual and encouragement"

"To all my fellow friends, laboratory colleagues and lecturers, thank you for all your support and help"

"To my supervisor who guided and help me, Assoc. Prof. Dr. Rohaya Latip"

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Computer Science

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January 2019

Supervisor: Assoc. Pro. Dr. Rohaya Latip

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ABSTRACT

Since the sensors have the characteristics of self-organizing and low cost and the wireless sensor network develops rapidly, more reliable routing algorithms are required to perform better forwarding. In wireless sensor network, due to the limited power and the non-equivalence of the sensor nodes, it is necessary to reduce energy consumption reasonably to prolong the network lifetime. In the traditional protocols, energy model is adopted by LEACH with uniform distribution of sensor nodes and without the consideration of residual energy, which leads to the large number of packets dropped and instable network environment. When encountering the obstacles and voids, the routing with perimeter and greedy algorithms are unable to proceed. In order to balance and minimize the energy consumption, a Grid-Based Reliable Routing (GBRR) protocol is presented. In this research, collaborated with clustering and grid-based routing features, the proposed protocol uses a combination of clustering protocols and geographical protocols with greedy algorithm to accomplish the scalability and

adaptability of the randomly deployed sensor networks in a dense and large-scale network. By adopting right hand rule strategy, the packets walk around the perimeter and voids are avoided. Simulation was adopted using MATLAB. The simulation results show that the GBRR efficiently identifies the redundant nodes and reroutes them avoiding obstacles and voids while improving network lifetime and energy consumption.

Key words: *wireless sensor network, energy consumption, LEACH, GBRR, network lifetime*

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Sarjana Sains Komputer

PROTOKOL PENGHALAAN DIPERCAYAI BERASASKAN GRID UNTUK RANGKAIAN SENSOR TANPA WAYAR

Oleh

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ABSTRAK

Sensor mempunyai ciri-ciri sendiri mengatur dan kos rendah dan rangkaian sensor tanpa wayar berkembang pesat, algoritma penghalaan yang boleh dipercayai diperlukan untuk melaksanakan penghantaran yang lebih baik. Dalam rangkaian sensor tanpa wayar, disebabkan kuasa terhad dan kesamaan nod sensor, diperlukan untuk mengurangkan penggunaan tenaga dengan semestinya memanjangkan hayat rangkaian. Dalam protokol tradisional, model tenaga diadopsi oleh LEACH dengan pengedaran seragam nod sensor dan tanpa pertimbangan tenaga sisa, yang membawa kepada banyak paket yang dijatuhkan dan menstabilkan persekitaran rangkaian. Apabila menghadapi halangan dan lompang, laluan dengan perimeter dan algoritma tamak tidak dapat diteruskan. Untuk pengimbangan dan meminimumkan penggunaan tenaga, protokol Grid-Based Reliable

Routing (GBRR) dicadangkan. Dalam penyelidikan ini, kerjasama dengan ciri-ciri routing berasaskan klustering dan grid, protokol yang dicadangkan menggunakan gabungan protokol kluster dan protokol geografi dengan algoritma tamak untuk mencapai skalaan dan sesuaian rangkaian sensor yang digunakan secara rawak dalam rangkaian padat dan berskala besar. Dengan menggunakan strategi peraturan tangan kanan, paket-paket yang berjalan mengelilingi perimeter dan lompang akan dielakkan. Simulasi diguna pakai MATLAB. Hasil penyelakuan menunjukkan bahawa GBRR cekap mengenalpasti nod berlebihan dan mengarahkan mereka mengelakkan rintangan dan lompang semasa meningkatkan kehidupan rangkaian dan penggunaan tenaga.

Kata kunci: *rangkaian sensor tanpa wayar, penggunaan tenaga, LEACH, GBRR, hayat rangkaian*

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Last but not least, I' d like to thank all my friends and my family for their unceasing love, encouragement and support.

APPROVAL

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DECLARATION

Declaration by graduate student

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LIST OF ABBREVIATIONS

GBRR	Grid-Based Reliable Routing
WSN	Wireless Sensor Network
BS	Base Station
GPS	Global Position System
MEMS	Micro-Electro-Mechanical System
LEACH	Low Energy Adaptive Clustering Hierarchy
EEUC	Energy-Efficient Uneven Clustering
LEACH-RA	Low Energy Adaptive Clustering Hierarchical-Redundancy Aware
LEACH-C	LEACH-Centralized
SA	Simulated Annealing
LEACH-F	LEACH-Fixed
HEED	Hybrid Energy-Efficient Distributed
DK-LEACH	Dynamic K value LEACH
EADU	Energy-aware Distributed Clustering
GPSR	Greedy Perimeter Stateless Routing
EGPSR	Enhanced Greedy Perimeter Stateless Routing

GPSR-I	GPSR-Improved
EA-GPSR	Energy Ability Greedy Perimeter Stateless Routing
NAPU	Neighbour-Awareness Position Update
GEAR	Geographical and Energy Aware Routing
GAF	Geographic Adaptive Fidelity
GAF-HEX	Hexagonal Geographic Adaptive Fidelity
GBCR	Grid-Based Coordinated Routing
NUGBCR	Non-Uniform Gird-Based Coordinated Routing
GMCAR	Grid-based Multipath with Congestion Avoidance Routing
VANETs	Vehicular Ad Hoc Networks
EADC	Energy-aware Distributed Clustering
EADUC	Energy-aware Distributed Unequal Clustering

CHAPTER 1

INTRODUCTION

1.1 Research Background

With the rapid development of modern sensor technology, wireless communication technology, microelectronics technology and embedded computer technology, a very meaningful and challenging research field - Wireless Sensor Network (WSN), has been come into being (Pottie and Kaiser, 2000). WSN consists of multiple single sensors, each of which can interact with the environment through sensing or controlling parameters. By means of a wireless way (Lewis, 2004), nodes are able to communicate with each other, self-organize into a network, cooperatively sense the multi-dimensional information of monitoring objects (including temperature, humidity, noise, light, pressure, etc.), and process and publish the collected data in the network, which is a new type of sensor network. At the same time, it is also an interdisciplinary field, which is known as one of the most promising technologies in the 21st century.

Since WSN has the ability to monitor in real-time environmental and acquire real-world information, and does not require fixed network support and strong invulnerability features, it has broad application value (Ramanathan and Redi, 2002). Developed countries, such as the United States, attach great importance to the development of WSN. The Institute of Eleetrical and Electronies Engineers (IEEE) is striving to promote the application and development of WSN. Some universities, such as MIT and UC Berkeley, have developed the basic knowledge and key technologies of WSN.

In many WSN applications, the power supply of sensor nodes in the network is often unable to replenish. In this case, energy efficiency is a very important indicator, because it usually requires the system to work as long as possible. In other types of networks such as Ad Hoc networks (Chau, 2002; Ramanathan and Redi, 2002), power supply may not be the focus of consideration, while parameters such as output accuracy may be more important. In addition, in some WSN applications, factors, such as allowable size and node cost should, also need to be considered. Because size is closely related to the capacity of the battery, cost is directly related to the performance of the sensor, and performance ultimately affects the accuracy of the results. Moreover, when a distributed system with a large number of nodes is compared with a centralized system with fewer nodes, factors, such as the number of nodes and the cost, are taken into account (Gungor et al, 2010).

This study mainly considers that when the node structure is simple but the number of nodes is large, the energy efficiency of the node can be realized and the network lifetime can be prolonged.

1.2 Problem Statement

In the traditional routing protocol, energy model is adopted by LEACH with uniform distribution of sensor nodes and without the consideration of residual energy, which leads to the large number of packets to be dropped and instable network environment. When encountering the obstacles and voids, the routing with perimeter and greedy algorithms are unable to proceed. Therefore, based on these issues, in this study the problems are summarized:

1) The residual energy of the nodes is not considered, it is possible that the nodes with low energy will act as the cluster head, therefore, the data cannot be transmitted to the Base Station (BS) and will be dropped if the head is dead;
2) The traditional protocol based on LEACH protocol cannot guarantee the uniform distribution of cluster heads due to large scale networks, which will cause a large density of cluster heads in some regions;
3) Although the voids can be reduced by the dense deployment of sensor nodes, obstacles and voids still exist due to an uneven terrain, therefore, the separated clusters cannot communicate with each other, making the network unreliable and instable, which leads to a number of packets dropped.

1.3 Research Objectives

The main objective of this research is to re-implement the GBRR protocol to balance and reduce the energy consumption. Below are the details of this research objectives:

1) to develop an electing method of the cluster head;
2) to develop a grid-based protocol to reduce the number of exhausted cluster heads due to the unbalanced number of nodes;
3) to deploy greedy algorithm with right hand rule strategy to reduce the voids due to the uneven terrain.

1.4 Research Scope

The scope of this project is to re-implement the GBRR protocol that was proposed by Xiaoliang et al. (2016), which will improve communication in wireless sensor networks.

This simulation is in MATLAB and only restricted to wireless sensor nodes with and without obstacles.

1.5 Thesis Organization

Five chapters are consisted in this thesis:

- Chapter 1 (Introduction): contains the research background and problem statements, which describe research issues. Based on the issues, the objectives are listed corresponding to each objective. Then the research scope is given.
- Chapter 2 (Literature Review): gives and overview of the WSNs and existing typical protocols in WSN. Especially, the related work is described briefly and different algorithms are compared.
- Chapter 3 (Research Methodology): illustrates the methodology used to develop the GBRR protocol and describe the whole process. How to design and implement this research are explicated in detail.
- Chapter 4 (Results and Discussions): consists of the output produced by the simulation and discussions about the results. Residual energy and energy consumption are analyzed in this chapter.
- Chapter 5 (Conclusion and Future Work): summarizes this research and gives the future work.

REFERENCES

Ramanathan, R., & Redi, J. (2002). A brief overview of ad hoc networks: challenges and directions. *IEEE communications Magazine*, *40*(5), 20-22.

Pottie, G. J., & Kaiser, W. J. (2000). Wireless integrated network sensors. *Communications of the ACM*, *43*(5), 51-58.

Lewis, F. L. (2004). Wireless sensor networks. *Smart environments: technologies, protocols, and applications*, 11-46.

Raghavendra, C. S., Sivalingam, K. M., & Znati, T. (Eds.). (2006). *Wireless sensor networks*. Springer.

Gungor, V. C., Lu, B., & Hancke, G. P. (2010). Opportunities and challenges of wireless sensor networks in smart grid. *IEEE transactions on industrial electronics*, *57*(10), 3557-3564.

Akyildiz, I. F., Su, W., Sankarasubramaniam, Y., & Cayirci, E. (2002). A survey on sensor networks. *IEEE communications magazine*, *40*(8), 102-114.

Arampatzis, T., Lygeros, J., & Manesis, S. (2005, June). A survey of applications of wireless sensors and wireless sensor networks. In *Intelligent Control, 2005. Proceedings of the 2005 IEEE International Symposium on, Mediterrean Conference on Control and Automation* (pp. 719-724). IEEE.

Akkaya, K., & Younis, M. (2005). A survey on routing protocols for wireless sensor networks. *Ad hoc networks*, *3*(3), 325-349.

Chee, Y. H., Niknejad, A. M., & Rabaey, J. M. (2006). An ultra-low-power injection locked transmitter for wireless sensor networks. *IEEE Journal of Solid-State Circuits*, *41*(8), 1740-1748.

Mihoubi, M., Rahmoun, A., Lorenz, P., & Lasla, N. (2018). An effective Bat algorithm for node localization in distributed wireless sensor network. *Security and Privacy*, *1*(1), e7.

Al-Sultan, S., Al-Doori, M. M., Al-Bayatti, A. H., & Zedan, H. (2014). A comprehensive survey on vehicular ad hoc network. *Journal of network and computer applications*, *37*, 380-392.

Chong, C. Y., & Kumar, S. P. (2003). Sensor networks: evolution, opportunities, and challenges. *Proceedings of the IEEE*, *91*(8), 1247-1256.

Znati, T., Raghavendra, C., & Sivalingam, K. (2003). Guest editorial: special issue on wireless sensor networks. *Mobile Networks and Applications*, *8*(4), 425-425.

So, J., & Vaidya, N. H. (2003). *A multi-channel MAC protocol for ad hoc wireless networks*. Technical Report, CS Dept., Univ. of Illinois at Urbana-Champaign.

Jin, K. T., & Cho, D. H. (2002). Multi-code MAC for multi-hop wireless Ad Hoc networks. In *Vehicular Technology Conference, 2002. Proceedings. VTC 2002-Fall. 2002 IEEE 56th* (Vol. 2, pp. 1100-1104). IEEE.

Patil, M., & Biradar, R. C. (2012, December). A survey on routing protocols in wireless sensor networks. In *Networks (ICON), 2012 18th IEEE International Conference on* (pp. 86-91). IEEE.

Karl, H., & Willig, A. (2007). *Protocols and architectures for wireless sensor networks*. John Wiley & Sons.

Healy, M., Newe, T., & Lewis, E. (2009, February). Security for wireless sensor networks: A review. In *Sensors Applications Symposium, 2009. SAS 2009. IEEE* (pp. 80-85). IEEE.

Al-Karaki, J. N., & Kamal, A. E. (2004). Routing techniques in wireless sensor networks: a survey. *IEEE Wireless Communications, 11*(6), 6-28.

Dulman, S., Nieberg, T., Wu, J., & Havinga, P. (2003, March). Trade-off between traffic overhead and reliability in multipath routing for wireless sensor networks. In *Wireless Communications and Networking, 2003. WCNC 2003. 2003 IEEE* (Vol. 3, pp. 1918-1922). IEEE.

Van Greunen, J., & Rabaey, J. (2003, September). Lightweight time synchronization for sensor networks. In *Proceedings of the 2nd ACM international conference on Wireless sensor networks and applications* (pp. 11-19). ACM.

Noh, D. K., & Hur, J. (2013). Energy-aware topology control for reliable data delivery in solar-powered WSNs. *EURASIP Journal on Wireless Communications and Networking*, *2013*(1), 258.

Khan, M. A., Khan, A., Shah, S. K., & Abdullah, A. (2013). An Energy Efficient Color Based Topology Control Algorithm for Wireless Sensor Networks. *Wireless Sensor Network*, *5*(01), 1.

Ababneh, N., & Selvadurai, S. (2006). Topology control algorithms for wireless sensor networks: an overview. *International Journal on Wireless & Optical Communications*, *3*(01), 49-68.

Lee, C. Y., Shiu, L. C., Lin, F. T., & Yang, C. S. (2013). Distributed topology control algorithm on broadcasting in wireless sensor network. *Journal of Network and Computer Applications*, *36*(4), 1186-1195.

Hui, L. (2011). Integrated topology control and routing in wireless sensor networks for prolonged network lifetime. *Ad Hoc Networks, 9*(5), 835-851.

Han, G., Dong, Y., Hui, G., Wu, D., & Wu, D. (2015). Cross-layer optimized routing in wireless sensor networks with duty cycle and energy harvesting. *Wireless Communications & Mobile Computing*, *15*(16), 1957-1981.

Karthi, J. S., Rao, S. V., & Pillai, S. S. (2015, December). Performance analysis of wireless sensor networks with IEEE 802.15. 4 mac based on variation in packet size. In *Control, Instrumentation, Communication and Computational Technologies (ICCICCT), 2015 International Conference on*(pp. 46-50). IEEE.

Karthikeyan, A., Shankar, T., Srividhya, V., & Pravallika, R. V. L. (2012, December). Energy efficient MAC protocol for energy latency tradeoff in wireless sensor network traffic. In *Computational Intelligence & Computing Research (ICCIC), 2012 IEEE International Conference on* (pp. 1-5). IEEE.

Feng, C., & Zhang, L. H. (2012, July). A modified shuttled frog leaping algorithm for solving nodes position in wireless sensor network. In *Machine Learning and Cybernetics (ICMLC), 2012 International Conference on* (Vol. 2, pp. 555-559). IEEE.

Li, X., Tang, Q., & Sun, C. (2016). The impact of node position on outage performance of RF energy powered wireless sensor communication links in overlaid deployment scenario. *Journal of Network and Computer Applications*, *73*, 1-11.

Cheng, C. H., Luo, W. J., Lin, Y. W., & Sun, C. C. (2013, June). Position location techniques in wireless sensor networks using reference node algorithm. In *Consumer Electronics (ISCE), 2013 IEEE 17th International Symposium on* (pp. 73-74). IEEE.

Kuriakose, J., Joshi, S., Raju, R. V., & Kilaru, A. (2014). A review on localization in wireless sensor networks. In *Advances in signal processing and intelligent recognition systems* (pp. 599-610). Springer, Cham.

Rhee, I. K., Lee, J., Kim, J., Serpedin, E., & Wu, Y. C. (2009). Clock synchronization in wireless sensor networks: An overview. *Sensors*, *9*(1), 56-85.

Gong, F. (2016). Clock Synchronization in Wireless Sensor Networks: Performance Analysis and Protocol Design.

Lu, Z. (2013). D2f: a routing protocol for distributed data fusion in wireless sensor networks. *Wireless Personal Communications, 70*(1), 391-410.

Fu, J. S., & Liu, Y. (2015). Double cluster heads model for secure and accurate data fusion in wireless sensor networks. *Sensors*, *15*(1), 2021-2040.

Li, Y., Liu, F., & Ding, L. (2011, October). Research about security mechanism in wireless sensor network. In *Image Analysis and Signal Processing (IASP), 2011 International Conference on* (pp. 447-451). IEEE.

Reegan, A. S., & Baburaj, E. (2013, March). Key management schemes in wireless sensor networks: a survey. In *Circuits, Power and Computing Technologies (ICCPCT), 2013 International Conference on* (pp. 813-820). IEEE.

Xuyong, H., Pei, L., Shihong, M., & Xin, W. U. (2007). Application of wireless sensor networks in power monitoring system. *Automation of Electric Power Systems*, 31(7), 99-103.

Jain, S., & Grover, A. (2014). Routing Techniques in Wireless Sensor Networks. International Journal of Computer Applications, 94(6).

Sha, K., Gehlot, J., & Greve, R. (2013). Multipath routing techniques in wireless sensor networks: A survey. *Wireless personal communications*, *70*(2), 807-829.

Kalore, S. V., & Rewagad, P. (2015, March). A review on efficient routing techniques in wireless sensor networks. In *Computer Engineering and Applications (ICACEA), 2015 International Conference on Advances in* (pp. 803-807). IEEE.

Misra, S., & Goswami, S. (2014). Routing in Wireless Sensor Networks. *Proceedings of the Third International Conference on Soft Computing for Problem Solving*.

Junghare, A. M., Shimpi, D. M., Junghare, A. M., & Shimpi, D. M. (2013). Routing Protocols in Wireless Sensor Network: A Survey. *Foundation of Computer Science (FCS)*.

Singh, S. K., Singh, M. P., & Singh, D. K. (2010). Routing protocols in wireless sensor networks–A survey. *International Journal of Computer Science & Engineering Survey (IJCSES)*, *1*(2), 63-83.

Bolanakis, D. E. (2016, June). MEMS barometers in a wireless sensor network for position location applications. In *Applications of Commercial Sensors (VCACS), 2016 IEEE Virtual Conference on* (pp. 1-8). IEEE.

Heinzelman, W. B., Chandrakasan, A. P., & Balakrishnan, H. (2002). An application-specific protocol architecture for wireless microsensor networks. *IEEE Transactions on wireless communications*, *1*(4), 660-670.

Singh, S. P., & Sharma, S. C. (2015). A survey on cluster based routing protocols in wireless sensor networks. *Procedia computer science*, *45*, 687-695.

Ayoob, M., Zhen, Q., Adnan, S., & Gull, B. (2016, April). Research of improvement on LEACH and SEP routing protocols in wireless sensor networks. In *Control and Robotics Engineering (ICCRE), 2016 IEEE International Conference on*(pp. 1-5). IEEE.

Arora, V. K., Sharma, V., & Sachdeva, M. (2016). A survey on LEACH and other's routing protocols in wireless sensor network. *Optik-International Journal for Light and Electron Optics*, *127*(16), 6590-6600.

Huang, T., Kai, Y. I., Cui, G., & Wang, Y. (2016). Hierarchical routing protocol based on non-uniform clustering for wireless sensor network. *Journal of Computer Applications*, 36(1), 66-71.

Liu, X. (2015). A typical hierarchical routing protocols for wireless sensor networks: a review. IEEE Sensors Journal, 15(10), 5372-5383.

Sabor, N., Sasaki, S., Abo-Zahhad, M., & Ahmed, S. M. (2017). A comprehensive survey on hierarchical-based routing protocols for mobile wireless sensor networks: review, taxonomy, and future directions. *Wireless Communications and Mobile Computing*, *2017*.

Varshney, S., Kumar, C., & Swaroop, A. (2015, March). A comparative study of hierarchical routing protocols in wireless sensor networks. In *Computing for Sustainable Global Development (INDIACom), 2015 2nd International Conference on* (pp. 1018-1023). IEEE.

Mohanty, P., & Kabat, M. R. (2014). A hierarchical energy efficient reliable transport protocol for wireless sensor networks. *Ain Shams Engineering Journal*, *5*(4), 1141-1155.

Heinzelman, W. R., Chandrakasan, A., & Balakrishnan, H. (2000, January). Energy-efficient communication protocol for wireless microsensor networks. In *System sciences, 2000. Proceedings of the 33rd annual Hawaii international conference on* (pp. 10-pp). IEEE.

Dhawan, H., & Waraich, S. (2014). A comparative study on LEACH routing protocol and its variants in wireless sensor networks: a survey. *International Journal of Computer Applications*, *95*(8).

Khediri, S. E., Nasri, N., Wei, A., & Kachouri, A. (2014). A new approach for clustering in wireless sensors networks based on LEACH. *Procedia Computer Science*, *32*, 1180-1185.

Singh, S. (2016, January). Improved O-LEACH protocol: A clustering based approach in wireless microsensor network. In *Intelligent Systems and Control (ISCO), 2016 10th International Conference on* (pp. 1-4). IEEE.

Palan, N. G., Barbadekar, B. V., & Patil, S. (2017, January). Low energy adaptive clustering hierarchy (LEACH) protocol: A retrospective analysis. In *Inventive Systems and Control (ICISC), 2017 International Conference on* (pp. 1-12). IEEE.

Razaque, A., Mudigulam, S., Gavini, K., Amsaad, F., Abdulgader, M., & Krishna, G. S. (2016, April). H-LEACH: Hybrid-low energy adaptive clustering hierarchy for wireless sensor networks. In *Systems, Applications and Technology Conference (LISAT), 2016 IEEE Long Island* (pp. 1-4). IEEE.

Thakkar, A. (2016, October). An improved advanced low energy adaptive clustering hierarchy for a dense wireless sensor network. In *Communication and Electronics Systems (ICCES), International Conference on* (pp. 1-6). IEEE.

Abushiba, W., Johnson, P., Alharthi, S., & Wright, C. (2017, December). An energy efficient and adaptive clustering for wireless sensor network (CH-leach) using leach protocol. In *Computer Engineering Conference (ICENCO), 2017 13th International* (pp. 50-54). IEEE.

Das, A. K., Chaki, R., & Dey, K. N. (2016). The Design of Hierarchical Routing Protocol for Wireless Sensor Network. In *Advanced Computing and Systems for Security* (pp. 223-233). Springer, New Delhi.

Nayak, P., & Devulapalli, A. (2016). A fuzzy logic-based clustering algorithm for WSN to extend the network lifetime. *IEEE sensors journal*, *16*(1), 137-144.

Batra, P. K., & Kant, K. (2016). LEACH-MAC: a new cluster head selection algorithm for Wireless Sensor Networks. *Wireless Networks*, *22*(1), 49-60.

Chen, C., He, Z., Sun, H., Kuang, J., Bai, D. M., & Yang, C. (2013, November). A grid-based energy efficient routing protocol in Wireless Sensor Networks. In *Wireless and Pervasive Computing (ISWPC), 2013 International Symposium on* (pp. 1-6). IEEE.

Khamiss, A. A., Chai, S. C., Zhang, B. H., & Qiao, L. I. (2016). Energy-balanced on demand clustering improved leach protocol for wireless sensor networks. *Journal of Beijing University of Technology (English edition)*, 25(3), 353-364.

Zhang, C. S., Xing, J., & Zhao, S. Q. (2016). Energy-efficeent Uneven Clustering Algorithm. *Computer Engineering and Applications*, *52*, 106-109.

Duo, P., Suoping, L., & Qiuyu, Z. (2016). Uneven Clustering Energy-Efficient Routing for Farmland Wireless Sensor Network. *Sensor Letters*, *14*(11), 1106-1111.

Zhang, R. B., & Cao, J. F. (2010). Uneven clustering routing algorithm for wireless sensor networks based on ant colony optimization. *Journal of Xi'an Jiaotong University*, *44*(6), 33-38.

Sivajothi, E., Vijayalakshmi, N., Swaminathan, A., & Vivekanandan, P. (2015). Low energy adaptive clustering hierarchy--redundancy aware protocol (LEACH-RA). Advances in Natural and Applied Sciences, 9(13), 1-7.

Chen, Y. L., Wang, N. C., Shih, Y. N., & Lin, J. S. (2014). Improving low-energy adaptive clustering hierarchy architectures with sleep mode for wireless sensor networks. *Wireless personal communications*, *75*(1), 349-368.

Chen, Y. L., Shih, Y. N., & Lin, J. S. (2013, July). A four-layers hierarchical clustering topology architecture with sleep mode in a wireless sensor network. In *Complex,*

Intelligent, and Software Intensive Systems (CISIS), 2013 Seventh International Conference on (pp. 335-339). IEEE.

lal Parmar, A. M., & Thakkar, A. (2016). An improved modified LEACH-C algorithm for energy efficient routing in Wireless Sensor Networks. *Nirma University Journal of Engineering and Technology*, *4*(2), 1-5.

Omari, M., & Laroui, S. (2015, December). Simulation, comparison and analysis of Wireless Sensor Networks protocols: LEACH, LEACH-C, LEACH-1R, and HEED. In *Electrical Engineering (ICEE), 2015 4th International Conference on* (pp. 1-5). IEEE.

Ding, X. X., Ling, M., Wang, Z. J., & Song, F. L. (2017). Dk-leach: An optimized cluster structure routing method based on leach in wireless sensor networks. *Wireless Personal Communications*, *96*(4), 6369-6379.

Sivakumar, P., & Radhika, M. (2018). Performance Analysis of LEACH-GA over LEACH and LEACH-C in WSN. *Procedia Computer Science*, *125*, 248-256.

Yassen, M. B., Aljawaerneh, S., & Abdulraziq, R. (2016, September). Secure low energy adaptive clustering hierarchal based on internet of things for wireless sensor network (WSN): Survey. In *Engineering & MIS (ICEMIS), International Conference on* (pp. 1-9). IEEE.

Pandya, N. K., Kathiriya, H. J., Kathiriya, N. H., & Pandya, A. D. (2015, May). Design and simulation of enhanced MODLEACH for wireless sensor network. In *Computing, Communication & Automation (ICCCA), 2015 International Conference on* (pp. 336-341). IEEE.

Rafiq, A., Munir, E. U., Rafique, M. M., & KhanΨ, S. U. (2015, December). A consistent approach towards clustering in low energy adaptive clustering hierarchy protocol. In *High-Capacity Optical Networks and Enabling/Emerging Technologies (HONET), 2015 12th International Conference on* (pp. 1-5). IEEE.

Younis, O., & Fahmy, S. (2004). HEED: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks. *IEEE Transactions on mobile computing*, *3*(4), 366-379.

Prabowo, S., Abdurohman, M., & Erfianto, B. (2015, May). (EDsHEED) Enhanced Simplified Hybrid, Energy-efficient, Distributed Clustering for Wireless Sensor Network. In *Information and Communication Technology (ICoICT), 2015 3rd International Conference on* (pp. 97-101). IEEE.

Jain, A. K., Chargolra, V., & Prasad, D. (2015, October). Reliable state-full hybrid energy efficient distributed clustering protocol for wireless sensor networks: RS-HEED. In *MOOCs, Innovation and Technology in Education (MITE), 2015 IEEE 3rd International Conference on* (pp. 396-401). IEEE.

Xiao, G., Sun, N., Lv, L., Ma, J., & Chen, Y. (2015). An HEED-based study of cell-clustered algorithm in wireless sensor network for energy efficiency. *Wireless Personal Communications*, *81*(1), 373-386.

Xian, Q., & Long, Y. (2016, May). An enhanced greedy perimeter stateless routing algorithm for wireless sensor network. In *Online Analysis and Computing Science (ICOACS), IEEE International Conference of* (pp. 181-184). IEEE.

Li, S., Gao, H., & Wu, D. (2016, August). An energy-balanced routing protocol with greedy forwarding for WSNs in cropland. In *Electronic Information and Communication Technology (ICEICT), IEEE International Conference on* (pp. 1-7). IEEE.

Mahmood, B. A., & Manivannan, D. (2015). Position based and hybrid routing protocols for mobile ad hoc networks: a survey. *Wireless Personal Communications*, *83*(2), 1009-1033.

Revathi, A., & Malathy, N. (2016, January). VAGR—Void aware in geographic routing for wireless sensor networks. In *Intelligent Systems and Control (ISCO), 2016 10th International Conference on* (pp. 1-6). IEEE.

Houssaini, Z. S., Zaimi, I., Oumsis, M., & Ouatik, S. E. A. (2016, October). Improvement of GPSR protocol by using future position estimation of participating nodes in vehicular ad-hoc Networks. In *Wireless Networks and Mobile Communications (WINCOM), 2016 International Conference on* (pp. 87-94). IEEE.

Karkazis, P., Leligou, H. C., Orphanoudakis, T., & Zahariadis, T. (2012, July). Geographical routing in wireless sensor networks. In *Telecommunications and Multimedia (TEMU), 2012 International Conference on* (pp. 19-24). IEEE.

Aissani, M., Bouznad, S., Allia, S. E., & Hariza, A. (2013). Repellent voids for improving geographical routing efficiency in wireless sensor networks. *International Journal of Communication Networks and Distributed Systems*, *11*(2), 172-197.

Al-Ariki, H. D. E., & Swamy, M. S. (2017). A survey and analysis of multipath routing protocols in wireless multimedia sensor networks. *Wireless Networks*, *23*(6), 1823-1835.

Won, M., Zhang, W., & Stoleru, R. (2013). GOAL: A parsimonious geographic routing protocol for large scale sensor networks. *Ad Hoc Networks*, *11*(1), 453-472.

Chang, G. Y., Sheu, J. P., Chen, C. W., Wang, S. Y., & Huang, J. F. (2014, September). A hole avoiding routing protocol in wireless sensor networks. In *Internet of Things (iThings), 2014 IEEE International Conference on, and Green Computing and Communications (GreenCom), IEEE and Cyber, Physical and Social Computing (CPSCom), IEEE* (pp. 75-79). IEEE.

Ducrocq, T., Hauspie, M., Mitton, N., & Pizzi, S. (2014, May). On the impact of network topology on wireless sensor networks performances: Illustration with geographic routing. In *Advanced Information Networking and Applications Workshops (WAINA), 2014 28th International Conference on*(pp. 719-724). IEEE.

De Oliveira, H. A., Boukerche, A., Guidoni, D. L., Nakamura, E. F., Mini, R. A., & Loureiro, A. A. (2015). An enhanced location-free Greedy Forward algorithm with hole bypass capability in wireless sensor networks. *Journal of Parallel and Distributed Computing*, *77*, 1-10.

Liu, J., Shen, H., Yu, L., Narman, H. S., Zhai, J., Hallstrom, J. O., & He, Y. (2018). Characterizing data deliverability of greedy routing in wireless sensor networks. *IEEE Transactions on Mobile Computing*, *17*(3), 543-559.

Karp, B., & Kung, H. T. (2000, August). GPSR: Greedy perimeter stateless routing for wireless networks. In *Proceedings of the 6th annual international conference on Mobile computing and networking* (pp. 243-254). ACM.

Seok, K. K., & Saxena, N. (2013, October). Analysis of a novel advanced greedy perimeter stateless routing algorithm. In *ICT Convergence (ICTC), 2013 International Conference on* (pp. 831-834). IEEE.

Zaimi, I., Houssaini, Z. S., Boushaba, A., & Oumsis, M. (2016, October). An improved GPSR protocol to enhance the video quality transmission over vehicular ad hoc networks. In *Wireless Networks and Mobile Communications (WINCOM), 2016 International Conference on* (pp. 146-153). IEEE.

Wang, L., & Liang, H. (2012, July). Research and improvement of the wireless sensor network routing algorithm GPSR. In *Computing, Measurement, Control and Sensor Network (CMCSN), 2012 International Conference on* (pp. 83-86). IEEE.

Yi, S., Huang, X., & Wang, C. (2015, December). EA-GPSR, a routing protocol for energy harvesting wireless sensor networks. In *Computer Science and Network Technology (ICCSNT), 2015 4th International Conference on* (Vol. 1, pp. 1029-1032). IEEE.

Cao, Y., Liu, X. Y., Kong, L., Wu, M. Y., & Khan, M. K. (2016, December). EHR: Routing Protocol for Energy Harvesting Wireless Sensor Networks. In *Parallel and Distributed Systems (ICPADS), 2016 IEEE 22nd International Conference on* (pp. 56-63). IEEE.

Cui-fang, X. I. N. G., Lin, Y. A. N. G., & Qing-long, H. A. N. (2014). Development of a New routing protocol based on GPSR for wireless sensor networks. *Applied Mechanics & Materials*.

LIU, Z., FENG, X., ZHANG, X., LIU, Y., ZHANG, J., & ZHANG, J. (2016). An Improved GPSR Routing Algorithm Based on Interest Gradient and Energy

Gradient. *Journal of Changchun University of Science and Technology (Natural Science Edition)*, *3*, 030.

Ning, Z., Jung, Y., Jin, Y., & Kim, K. C. (2009, March). Route Optimization for GPSR in VANET. In *Advance Computing Conference, 2009. IACC 2009. IEEE International* (pp. 569-573). IEEE.

Shu, W., Wang, P., Guo, A., Wang, X., & Liu, F. (2009). Enhanced GPSR using Neighbor-Awareness Position Update and Beacon-assist Geographic Forwarding in vehicular ad hoc networks. *Intelligent Vehicles Symposium* (pp.1143-1147). IEEE.

Frey, H., & Stojmenovic, I. (2005). Geographic and energy aware routing in sensor networks. *Handbook of Sensor Networks: Algorithms and Architectures*, *1*, 381-415.

Sheltami, T. R., Shakshuki, E. M., & Maarouf, I. K. (2009, March). Performance evaluation for geographical and energy aware routing protocol. In *GCC Conference & Exhibition, 2009 5th IEEE* (pp. 1-5). IEEE.

Yang, D., Li, X., Sawhney, R., & Wang, X. (2009). Geographic and energy-aware routing in wireless sensor networks. *International Journal of Ad Hoc and Ubiquitous Computing*, *4*(2), 61-70.

Karlof, C., & Wagner, D. (2003, May). Secure routing in wireless sensor networks: Attacks and countermeasures. In *Sensor Network Protocols and Applications, 2003. Proceedings of the First IEEE. 2003 IEEE International Workshop on* (pp. 113-127). IEEE.

Douceur, J. R. (2002, March). The sybil attack. In *International workshop on peer-to-peer systems* (pp. 251-260). Springer, Berlin, Heidelberg.

Hu, Y. C., Perrig, A., & Johnson, D. B. (2006). Wormhole attacks in wireless networks. *IEEE journal on selected areas in communications*, *24*(2), 370-380.

Shan-Shan, Z. (2008). Security improvement of gear protocol in wireless sensor network. Computer Engineering, 34(21), 136-138.

Zhang, G., Zhang, Y., & Chen, Z. (2013). Using trust to secure geographic and energy aware routing against multiple attacks. *PloS one*, *8*(10), e77488.

Singh, P. K., Prajapati, A. K., Singh, A., & Singh, R. K. (2016, March). Modified geographical energy-aware routing protocol in wireless sensor networks. In *Emerging Trends in Electrical Electronics & Sustainable Energy Systems (ICETEESES), International Conference on* (pp. 208-212). IEEE.

Li, S., Gao, H., & Wu, D. (2016, August). An energy-balanced routing protocol with greedy forwarding for WSNs in cropland. In *Electronic Information and*

Communication Technology (ICEICT), IEEE International Conference on (pp. 1-7). IEEE.

Attoungble, J. M. K., & Okada, K. (2012). A novel energy efficient routing protocol for wireless sensor networks: Greedy routing for maximum lifetime. *IEICE transactions on communications*, *95*(12), 3802-3810.

Hsu, M. T., Lin, F. Y. S., Chang, Y. S., & Juang, T. Y. (2009, June). Reliable greedy forwarding in obstacle-aware wireless sensor networks. In *International Conference on Algorithms and Architectures for Parallel Processing* (pp. 797-808). Springer, Berlin, Heidelberg.

Soni, V., & Mallick, D. K. (2016, March). An optimal geographic routing protocol based on honeycomb architecture in wireless sensor networks. In *Electrical, Electronics, and Optimization Techniques (ICEEOT), International Conference on* (pp. 4440-4444). IEEE.

Soni, V., & Mallick, D. K. (2015). A novel scheme to minimize hop count for GAF in wireless sensor networks: two-level GAF. *Journal of Computer Networks and Communications*, *2015*.

Soni, V., & Mallick, D. K. (2017). FTGAF-HEX: fuzzy logic based two-level geographic routing protocol in wireless sensor networks. *Microsystem Technologies*, *23*(8), 3443-3455.

Akl, R., & Sawant, U. (2007, January). Grid-based coordinated routing in wireless sensor networks. In *Consumer Communications and Networking Conference, 2007. CCNC 2007. 4th IEEE* (pp. 860-864). IEEE.

Akl, R., Kadiyala, P., & Haidar, M. (2009). Nonuniform grid-based coordinated routing in wireless sensor networks. *Journal of sensors*, *2009*.

Banimelhem, O., & Khasawneh, S. (2012). GMCAR: Grid-based multipath with congestion avoidance routing protocol in wireless sensor networks. *Ad Hoc Networks*, *10*(7), 1346-1361.

Zhu, Y., Jiang, R., Yu, J., Li, Z., & Li, M. (2014). Geographic routing based on predictive locations in vehicular ad hoc networks. *EURASIP Journal on Wireless Communications and Networking*, *2014*(1), 137.

Aznaoui, H., Raghay, S., & Aziz, L. (2016). Location-Based Routing Protocols GAF and its enhanced versions in Wireless Sensor Network a Survey. *International Journal of Computer Science and Information Security*, *14*(6), 497.

Yadav, L., & Sunitha, C. (2014). Low Energy Adaptive Clustering Hierarchy in Wireless Sensor Network (LEACH). *International journal of computer science and information technologies*, *5*(3), 4661-4664.

Yu, J., Qi, Y., Wang, G., & Gu, X. (2012). A cluster-based routing protocol for wireless sensor networks with nonuniform node distribution. *AEU-International Journal of Electronics and Communications*, *66*(1), 54-61.

Yu, J., Qi, Y., Wang, G., Guo, Q., & Gu, X. (2011). An energy-aware distributed unequal clustering protocol for wireless sensor networks. *International Journal of Distributed Sensor Networks*, *7*(1), 202145.

Raja, B., Rajakumar, R., Dhavachelvan, P., & Vengattaraman, T. (2016, December). A survey on classification of network structure routing protocols in wireless sensor networks. In *Computational Intelligence and Computing Research (ICCIC), 2016 IEEE International Conference on* (pp. 1-5). IEEE.

Singh, A. K., Bhalla, A., Kumar, P., & Kaushik, M. (2017, September). Hierarchical routing protocols in WSN: A brief survey. In *Advances in Computing, Communication & Automation (ICACCA)(Fall), 2017 3rd International Conference on* (pp. 1-6). IEEE.

Priya, B., & Manohar, S. S. (2016). Lifetime enhancement of cluster based wireless sensor network through energy efficient MAC protocol. *Circuits and Systems*, *7*(09), 2296.

Apoorva, S. K., & Sreerangaraju, M. N. (2017). ENERGY EFFICIENT ROUTING PROTOCOL FOR WIRELESS SENSOR NETWORKS.

Kulik, J., Heinzelman, W., & Balakrishnan, H. (2002). Negotiation-based protocols for disseminating information in wireless sensor networks. *Wireless networks*, *8*(2/3), 169-185.

Anand, S., & Chandel, S. (2014). Comparison of Routing protocols in Wireless Sensor Networks: A Detailed Survey. *International Journal of Engineering and Science (IJES)*, *3*(12), 20-27.

Li, C., Wang, L., He, Y., Zhao, C., Lin, H., & Zhu, L. (2014). A link state aware geographic routing protocol for vehicular ad hoc networks. *EURASIP Journal on Wireless Communications and Networking*, *2014*(1), 176.

Gaynor, M., Moulton, S. L., Welsh, M., LaCombe, E., Rowan, A., & Wynne, J. (2004). Integrating wireless sensor networks with the grid. *IEEE Internet Computing*, *8*(4), 32-39.

Anipindi, K. (2002). Routing in Sensor Networks. *University of Texas at Arlington, Arlington, http://crystal. uta. edu/~ kumar/cse6392/termpapers/Kalyani_paper. pdf*.

Jianzhong, L., & Hong, G. (2008). Survey on Sensor Network Research [J]. *Journal of Computer Research and Development*, *1*, 1-15.

Arampatzis, T., Lygeros, J., & Manesis, S. (2005, June). A survey of applications of wireless sensors and wireless sensor networks. In *Intelligent Control, 2005. Proceedings of the 2005 IEEE International Symposium on, Mediterrean Conference on Control and Automation* (pp. 719-724). IEEE.

Akyildiz, I. F., Su, W., Sankarasubramaniam, Y., & Cayirci, E. (2002). Wireless sensor networks: a survey. *Computer networks*, *38*(4), 393-422.

Kuhn, F., Wattenhofer, R., & Zollinger, A. (2008). An algorithmic approach to geographic routing in ad hoc and sensor networks. *IEEE/ACM Transactions on Networking (TON)*, *16*(1), 51-62.

Chen, S., Fan, G., & Cui, J. H. (2006). Avoid'void'in geographic routing for data aggregation in sensor networks. *International Journal of Ad Hoc and Ubiquitous Computing*, *1*(4), 169-178.