International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-5, March 2020

# Research Trends in Energy-Efficient Routing Protocols for Wireless Sensor Network

**Parvinder Singh, Rajeshwar Singh**

***Abstract:*** ***The technological advances in wireless communication systems and digital data processing techniques has given rise to many innovative intelligent networks. One such network is wireless sensor network (WSN). In recent past, huge growth has been perceived in the applications of WSN. In wireless sensor network, the battery powered sensor nodes are scattered in a monitoring area and it is impossible to replace the batteries of sensor nodes after deployment. Therefore, energy efficiency remains a prime concern in design of WSNs. The routing protocols help to find energy efficient routes and increases the lifetime of WSNs. The cluster-based routing techniques play an important role in design of energy efficient WSNs. However, authors analyzed two types of sensor networks in the literature such as homogeneous and heterogeneous networks. In homogeneous clustering, all sensor nodes possess same level of initial energy and cluster head (CH) formation probability of each node in such networks remains equal. In heterogeneous clustering, the nodes are bifurcated into three energy levels such as normal node, advanced node and super node. Therefore, the CH formation probability of a node in such network depends on the type of node. This paper presented a survey on recent energy efficient routing protocols in homogeneous as well as heterogeneous wireless sensor networks. The energy efficient routing protocols are classified based on some quality of service (QoS) metrics such as energy efficiency, network lifetime, network stability, cluster head selection threshold and heterogeneity levels***.

***Keywords*** **:** ***Energy efficient routing protocols, Wireless Sensor Networks, Heterogeneous networks, Clustered Routing.***

## I. INTRODUCTION

The Wireless Sensor Networks consist of many low power sensor nodes which sense and collect information from the environment and communicate with the nearby nodes for multi-hop transmission. The emanate applications of WSNs involved intelligent transportation, smart buildings, smart houses, defense reconnaissance, intelligent surveillance, geographic directed queries and distributed situation recognition etc. [1]. For occasion, WSNs find use in habitat monitoring and disaster control applications such as landslide detection, fire detection, air pollution detection [2-4]. The WSNs are also preferred in human health monitoring such as cancer detection, glucose measurement and large casualty disaster management. Many different advantages of WSNs technology involved accuracy scalability, lesser implementation cost and proficiency of implementation to new networking technology. The sensor nodes communicate with each other through single-hop communication or multi-hop communications for data transfer to Base Station (BS). The node hardware architecture shown in figure 1 involves a sensor node, a microcontroller unit, an analog to digital converter, a transmitter, a receiver and a memory unit.

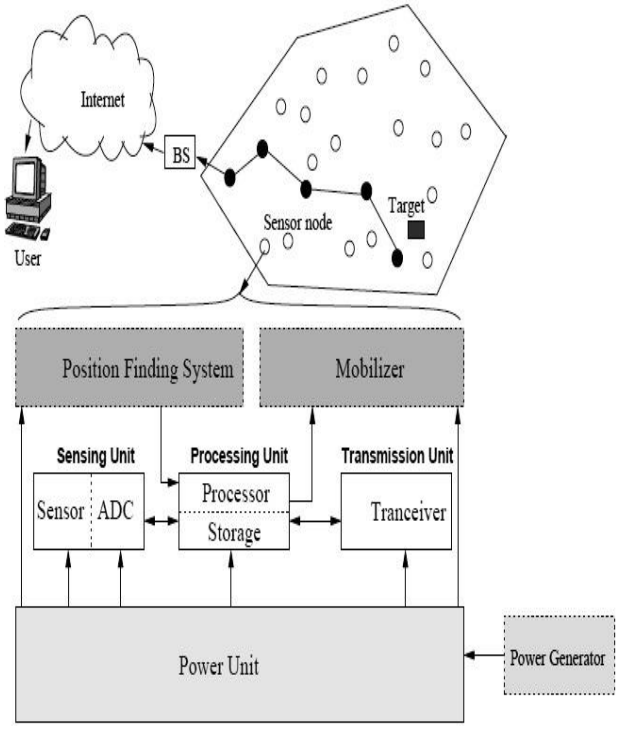


**Fig. 1. Node hardware architecture**

Due to the limitations of a sensor node in terms of processing capability, limited bandwidth and low battery power, the energy efficient routing remains a critical aspect in WSNs. The routing algorithms in wireless sensor networks are used to discover and maintain the energy efficient routes from source node to the destination node. Based on literature, the routing protocols can be broadly categorized into three types such as clustered or hierarchal routing: flat routing and location-based routing. The routing techniques classification is given in [5]. These classifications are based on communication technique, topology technique and link reliability techniques and presented in figure 2. The routing protocols design also influenced by energy consumption, deployment method, and security. The routing protocols are shown in figure 2.

Revised Manuscript Received on March 30, 2020.
* Correspondence Author
**Parvinder Singh***, Research Scholar, ECE Department, IK Gujral Punjab Technical University, Jalandhar, India. Email: er.parvinder@gmail.com
**Rajeshwar Singh**, Director, Doaba Group of Colleges, Rahon, SBS Nagar, India. Email: rajeshwar.rajata@gmail.com

The flat routing protocols assign same role to every node in terms of sensing environmental data. In this routing procedure the base station transmits query-based applications to sensor network and wait for reply from sensor nodes. The hierarchical based routing protocols maintains scalability, stability and energy efficiency by arranging nodes into different clusters. The basic idea is to elect the CH having higher remaining energy.

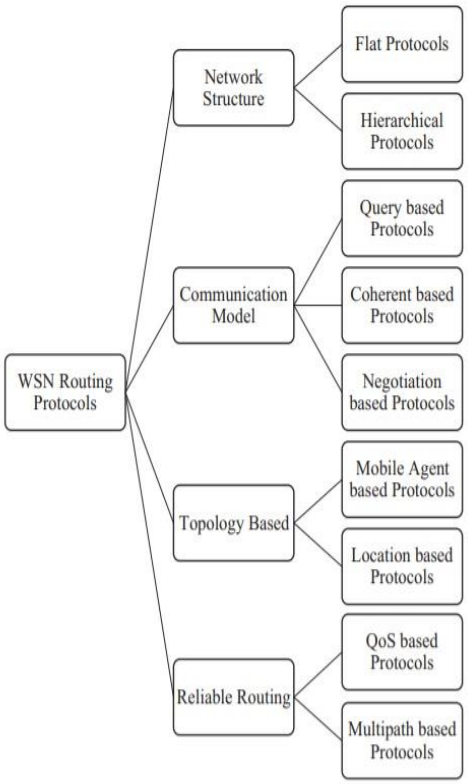


**Fig. 2. Routing protocols in WSN.**

The WSNs collect information with the help of sensor nodes (SNs) and convey this information to BS in a distributed manner without any pre-designed infrastructure [10]. The SNs are randomly deployed in a remote location whereby they sense information and transmits this information for measuring a physical phenomenon as shown in figure 3.

In figure 3, every SNs convey the sensed information to the base station based on some rules. The set of these rules is called routing protocol. The routing protocols clarify the communication procedure among SNs and identify the cost-efficient routes in order to transmits the collected information towards the base station [11]. The routing algorithm specify the most optimized route based on some QoS parameters. Most of the routing algorithms are based clustering techniques. The primary objective of the cluster-based routing scheme is to improve the energy efficiency and enhances the network lifespan. As a result, the most challenging feature of a routing protocol is to create a balance among various QoS requirements.

The energy efficiency of SNs must therefore be properly managed to improve the network lifetime. The numerous energy-balanced and energy-efficient protocols have been presented for wireless sensor networks. These protocols attempt to improve the network lifetime by decreasing the energy dissipation in every SN. However, the energy-efficient may result in network partitioning despite of enough remaining energy in SNs.

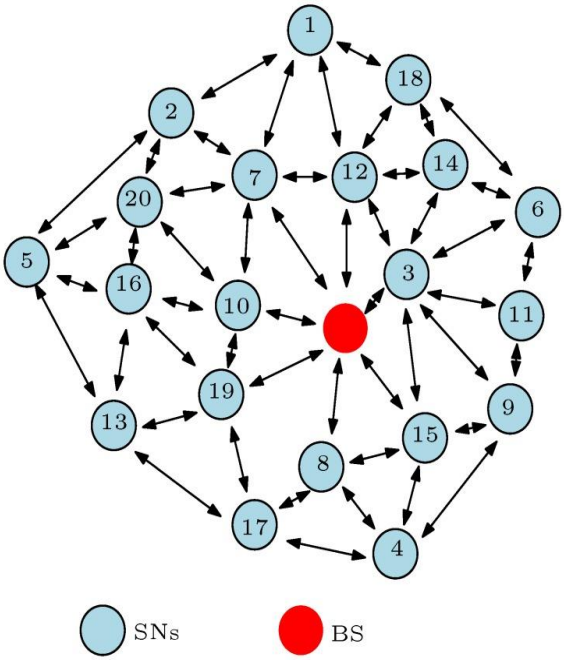


**Fig. 3. An example of simple WSN.**

For instant, consider the WSN clustering of figure 4. In this clustering procedure, the non-cluster head (nCH) nodes transmits the information to the base station through their CH via single-hop communication. As shown in figure, the nCH of cluster 3 (C3) have enough energy to communicate but CH node depleted its energy. Therefore, in spite of enough SN energy, the cluster remain isolated from the entire network.

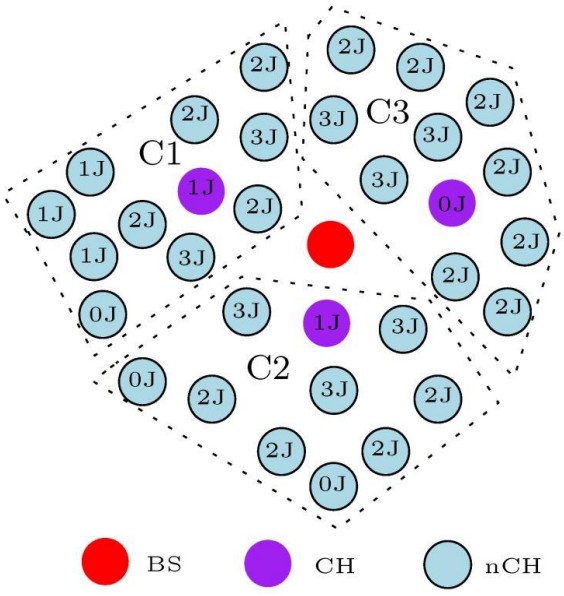


**Fig. 4. An example of clustered WSN.**

The main contribution of this paper lies in the complete analysis of the energy efficient routing protocols in terms of concepts, importance and principles of energy efficiency in WSNs. There have been numerous research papers published on energy efficient routing in past and are described in section 2. However, this paper presents contrasting picture of energy-balanced and energy-efficient routing protocols in WSNs.

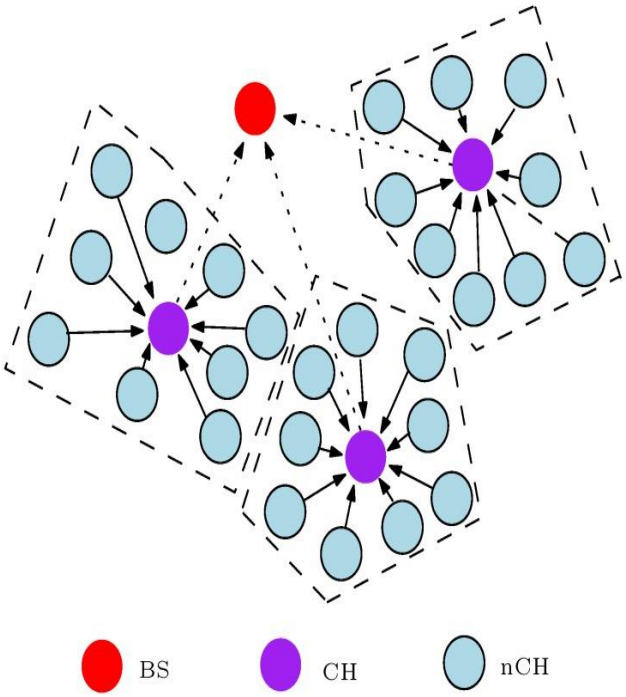


**Fig. 5. Clustered WSN in single-hop mode.**

Hence, in this paper we present an extensive survey of various state-of-art protocols that optimize the energy dissipation in SNs and increase the lifetime of network. In addition, we combined these routing protocols based on decision variables, solution types, strength of decision variables and weakness of the decision variables.

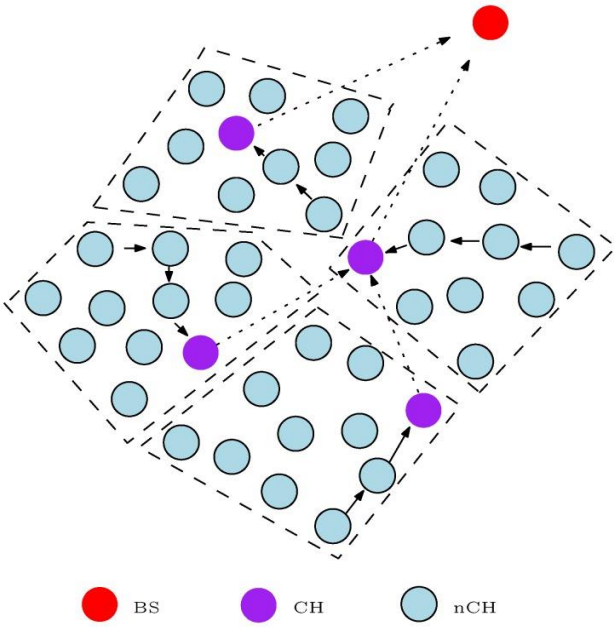


**Fig. 6. Clustered WSN in multi-hop mode.**

We are sure that this survey helps researchers to select the most appropriate routing protocol based on network formulations and application requirements. The energy efficient routing protocols can further be classified as single hop communication, multi-hop communication, single-path communication and multipath communication. The single hop data transmission from CH to the BS is shown in figure 5.

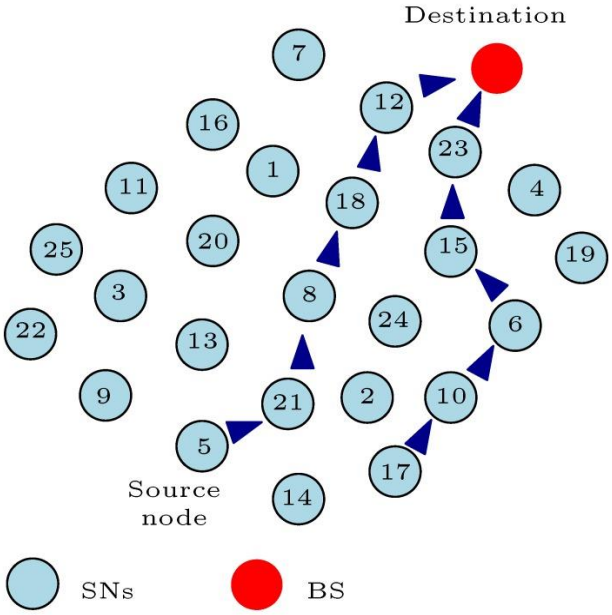


**Fig. 7. Single-path routing in WSN.**

The multi-hop communication mode is shown in figure 6. In multi-hop mode, the CH which is far away from BS forward its segregated data after taking help from other CH. The single-path scenario of WSN is shown in figure 7. In this routing technique, a single path is used by SNs to transmit its information towards the BS. However, multi-path routing shown in figure 8 provide realistic solution to achieve quality of service (QoS) requirements.

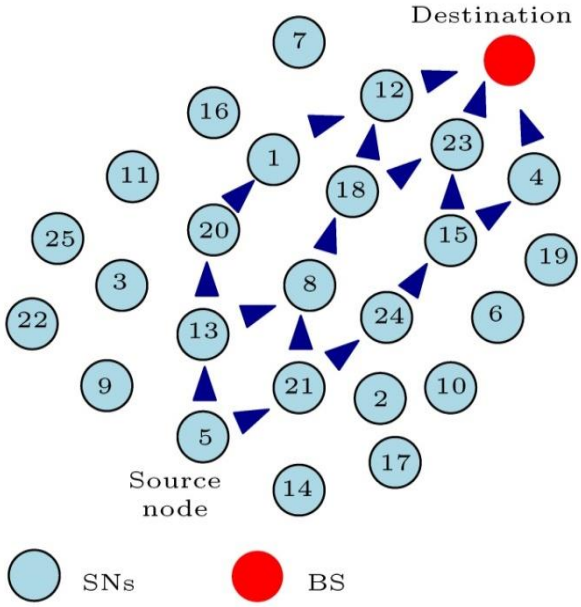


**Fig. 8. Multi-path routing in WSN.**

The multi-hop routing for two different scenarios are shown in figure 9. Path (a) is the shortest path from SN to the BS while path (b) is the energy efficient path from SN to BS.

**Table 1. Summary of related works**

| Year | Survey Paper | Contributions |
|---|---|---|
| 2002 | [30,31] | ✓ Discussed the potential applications and factors affecting the design of WSNs.<br>✓ Outlined the communication architecture for WSNs |
| 2004 | [11] | ✓ Analyzed the difficulties in designing a routing protocol for WSNs.<br>✓ Classified routing strategies into flat, hierarchical, and location-based routing.<br>✓ Defined some metrics such as negotiation-based, QoS-based and multipath-based to classify routing protocols.<br>✓ Compared the different routing protocols for WSNs, stating their strengths and weaknesses. |
| 2005 | [32] | ✓ Provided a general survey on routing protocols for WSNs.<br>✓ Classified routing protocols into data-centric, hierarchical, and location-based. |
| 2006 | [12] | ✓ Discussed the challenges and logic in developing a clustering algorithm for WSNs.<br>✓ Discussed the problems that face the practical design of clustering routing techniques for WSN applications.<br>✓ Classified clustering routing algorithms for WSNs based on the clustering objectives and design principles. |
| 2007 | [13] | ✓ Introduced taxonomy to classify clustering routing protocol.<br>✓ Discussed the strengths and weaknesses of different clustering routing algorithms.<br>✓ Compared different clustering techniques using some measures such as cluster stability, location-awareness, convergence rate |
| 2008 | [33] | ✓ Provided an overview of different WSN applications.<br>✓ Classified the challenges in WSNs into three categories.<br>✓ Presented the main research development in the mentioned categories. |
| 2009 | [34] | ✓ Provided a survey on energy consumed by SN hardware components.<br>✓ Divided SN's hardware into four main components.<br>✓ Classified the energy saving schemes for WSNs into duty-cycling, data-driven, and mobility-based.<br>✓ Elaborated on the importance of conserving energy consumed by SN hardware components. |
| 2010 | [38] | ✓ Discussed and compared different energy-efficient hierarchical cluster-based routing protocols for WSNs. |
| 2011 | [35] | ✓ Provided a survey on energy-efficient routing protocols for WMSNs.<br>✓ Defined the design challenges and limitations of energy-efficient routing protocols for WMSNs.<br>✓ Classified the energy-efficient routing protocols for WMSNs based on some metrics such as QoS requirement, data delivery model. |
| 2011 | [36] | ✓ Provided a survey on swarm intelligence-based routing protocols for WSNs.<br>✓ Discussed the general principles and applications of swarm intelligence-based routing for WSNs.<br>✓ Proposed a taxonomy to classify swarm intelligence-based routing protocols for WSNs |
| 2011 | [14] | ✓ Provided a survey on energy-efficient clustering routing protocols for heterogeneous WSNs.<br>✓ Compared fifteen routing protocols based on the clustering method, clustering attributes, location-awareness, and heterogeneity level |
| 2012 | [39] | ✓ Classified clustering routing protocols based on their objectives and methods.<br>✓ Provided taxonomy to the studied clustering routing protocols.<br>✓ Discussed the strengths and weaknesses of the techniques used in the studied clustering routing protocols.<br>✓ Summarizes the issues and solutions of the attributes and characteristics of clustering approaches. |
| 2012 | [15] | ✓ Presented the advantages and applications of clustering techniques for WSNs.<br>✓ Introduced taxonomy to classify clustering routing protocols for WSNs.<br>✓ Compared different clustering routing protocols based on measures such as scalability, energy efficiency, cluster stability, load balancing. |
| 2012 | [37] | ✓ Classified energy-efficient routing protocols into three categories, stating their strengths and weaknesses.<br>✓ Explained the areas of application of different energy-efficient routing protocols |
| 2012 | [16] | ✓ Discussed the notion and challenges of multipath routing protocols for WSNs.<br>✓ Classified the surveyed multipath routing protocols while outlining their pros and cons. |

| | | |
|---|---|---|
| 2012 | [17] | ✓ Classified multipath routing protocols for WSNs into infrastructure-based, non-infrastructure-based, and coding-based.<br>✓ Explained the evaluation metric, objectives, and challenges in designing a multipath routing protocol for WSNs. |
| 2013 | [18] | ✓ Investigated the advantages of different multipath routing protocols for WSNs.<br>✓ Classified different multipath routing protocols for WSNs based on their features. |
| 2013 | [4] | ✓ Provided a survey on energy-efficient routing protocols for WSNs.<br>✓ Classified energy-efficient routing protocols for WSNs based on the topology, communication model, network structure, and reliable routing schemes.<br>✓ Compared different energy-efficient routing protocols for WSNs, stating their advantages and disadvantages. |
| 2014 | [10] | ✓ Provided a general overview of WSNs, stating the areas of application and challenges of WSNs.<br>✓ Reviewed the prime research work and testbeds, standards and platforms, and the techniques and principles of WSNs.<br>✓ Outlined the current happenings in WSN research that considers the possible interaction between WSNs and other technologies. |
| 2016 | [19] | ✓ Compared different multipath routing protocols for WMSNs based on their working operations.<br>✓ Provided the advantages and disadvantages of different multipath routing protocols for WMSNs. |
| 2017 | [40] | ✓ Classified the different types of routing protocols based on their working.<br>✓ Provide an energy efficient heterogeneous routing protocol (ATEER) for WSNs by removing the redundancy in the network. |
| 2018 | [41] | ✓ Provide a study on the energy efficiency of the recent proactive routing protocols from different angles.<br>✓ Proved that energy overhead and route selection are the most effective aspects of network lifetime and network efficiency. |
| 2019 | [42] | ✓ Proposed an energy efficient genetic algorithm-based approach with the concept of Virtual Grid based Dynamic Routes Adjustment (VGDRA) which enhances the overall performance of wireless sensor networks. |

## II. RELATED WORK

The benefits of designing energy-balanced and energy-efficient routing protocols for wireless sensor networks cannot be ignored. There are lot of ongoing work on energy-efficient protocol for wireless sensor networks. The primary goal of the energy-efficient routing protocol is to optimize the energy dissipation while performing the network activities. In this section we discuss few of the existing survey papers on WSNs and explain the difference between our work and the existing work. The related work on routing in WSNs is summarized in Table 1.

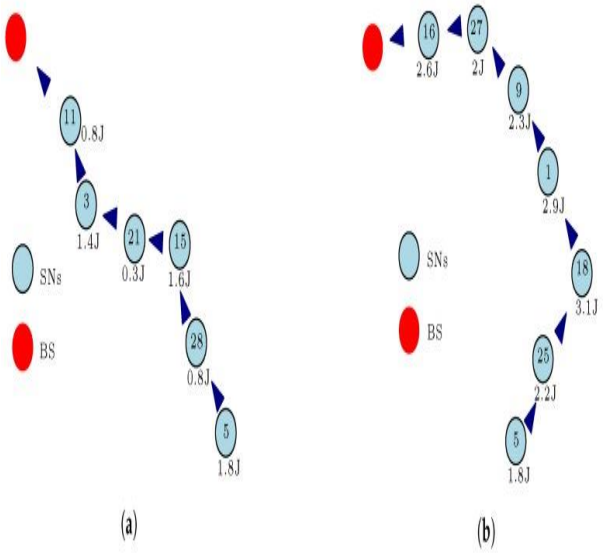


**Fig. 9. Routing of packets in multi-hop mode (a) Shortest path to Base Station (b) Energy-efficient path to Base Station.**

## III. SURVEY FINDINGS AND RESEARCH DIRECTIONS

The purpose of research on energy-efficient routing is to suggest permanent solution to the energy efficiency optimization problem in wireless sensor networks. The option to choose a set of decision variables for energy-efficient routing is still an open research area. We conclude that one variable such as residual energy of SNs cannot guarantee an energy-balanced and energy-efficient path in maximum cases. As explained, all the decision variables have merits and demerits. Hence, integrating the decision variables into a fitness function and choose the cluster head based on this function ensure an optimized energy-efficient path towards base station. In addition, the trade-off between the variables sometimes makes the route-finding problem NP-hard and involve high complexity delay and computational time. Moreover, the decision variable choice depends on the type of application. Therefore, the researchers must consider the network requirements while choosing the input variables. Furthermore, most of the researchers used hop distance, residual energy and hop count as the critical factors while formulating the mathematical fitness function of the protocol. We also observed that BS position play an important role in energy-efficient routing protocol design.

Therefore, many existing protocols may not work efficiently if the position of BS is changed. In the end, we presented a detailed survey on routing variables used to optimize the routing related to energy aware WSNs.

## IV. CONCLUSIONS

Energy efficiency is a primary optimization problem in WSNs due to dependency of SNs on battery power. The power consumption rate of sensor devices through efficient routing should be properly managed for long network lifetime and network reliability. The energy management issues pose challenges in WSNs due to complex formulations and network structure. However, Practitioners and researchers have developed various techniques to reduce energy consumption in WSNs. The various techniques worked on energy savings either by SN devices hardware or during data transmission. This study presented the survey of different energy-balanced and energy-efficient routing protocols which attempts to improve the network lifetime after reducing the energy consumption of sensor nodes. Table 1 in section 2 summarized the existing survey papers on energy-efficient routing protocols in WSNs. In section 3, we also explained the taxonomy, findings and research directions related to routing in WSNs. Furthermore, we classified the routing protocols based on decision variables, algorithm type and solution types used to successfully solve energy optimization problem. Therefore, this survey work opens new research directions in developing energy-efficient routing protocols in WSNs.

## REFERENCES


1. W. Yi, K. Lo, T. Mak, K. Leung, Y. Leung, and M. Meng, "A Survey of Wireless Sensor Network Based Air Pollution Monitoring Systems," Sensors, vol. 15, no. 12, pp. 31392–31427, Dec. 2015.
2. D. Chen., Z. Liu., L. Wang, M. Dou, J. Chen and L. Hui, "Natural disaster monitoring with wireless sensor networks: A case study of data-intensive applications upon low-cost scalable systems", in Mobile Networks and Applications, vol.18, no. 5, pp. 651-663, October 2013.
3. Singh, P., & Singh, R. (2019). Energy-Efficient QoS-Aware Intelligent Hybrid Clustered Routing Protocol for Wireless Sensor Networks. Journal of Sensors, 2019.
4. N. A. Pantazis, S. A. Nikolidakis and D. D. Vergados, "Energy-Efficient Routing Protocols in Wireless Sensor Networks: A Survey," in IEEE Communications Surveys & Tutorials, vol. 15, no. 2, pp. 551-591, Second Quarter 2013.
5. M. P. Đurišić, Z. Tafa, G. Dimić, & V. Milutinović, "A survey of military applications of wireless sensor networks", in Mediterranean conference on embedded computing (MECO), pp. 196-199, June 2012.
6. D. S. Ghataoura, J. E. Mitchell, & G. E. Matich, "Networking and application interface technology for wireless sensor network surveillance and monitoring", in IEEE Communications Magazine, vol. 49, no.10, pp. 90-97, 2011.
7. H. Alemdar, & C. Ersoy, " Wireless sensor networks for healthcare: A survey", in Computer networks, vol.54, no. 15, pp. 2688-2710, 2010.
8. J. Ko, C. Lu, M. B. Srivastava, J. A. Stankovic, A. Terzis and M. Welsh, "Wireless Sensor Networks for Healthcare," in Proceedings of the IEEE, vol. 98, no. 11, pp. 1947-1960, Nov. 2010.
9. P. Neves, M. Stachyra, J. Rodrigues, "Application of wireless sensor networks to healthcare promotion", in J. Commun. Softw. Syst., vol. 4, pp. 181–190, 2008.
10. P. Rawat, K.D. Singh, H. Chaouchi, J.M. Bonnin, "Wireless sensor networks: A survey on recent developments and potential synergies", in J. Supercomput., vol. 68, pp. 1–47, 2014.
11. J.N. Al-Karaki, A.E. Kamal, "Routing techniques in wireless sensor networks: A survey", in IEEE Wirel. Commun. , vol. 11, pp. 6–28, 2004.
12. O. Younis, M. Krunz and S. Ramasubramanian, "Node clustering in wireless sensor networks: recent developments and deployment challenges," in IEEE Network, vol. 20, no. 3, pp. 20-25, May-June 2006.
13. A.A. Abbasi, M. Younis, "A survey on clustering algorithms for wireless sensor networks", in Comput. Commun. , vol. 30, pp. 2826–2841, 2007.
14. R. Sheikhpour, S. Jabbehdari, A. Khadem-Zadeh, "Comparison of Energy Efficient Clustering Protocols in Heterogeneous Wireless Sensor Networks", in J. Adv. Sci. Technol., vol. 36, pp. 27–40, 2011.
15. X. Liu, "A Survey on Clustering Routing Protocols in Wireless Sensor Networks", Sensors, vol. 12, pp. 11113–11153, 2012.
16. M. Radi, B. Dezfouli, K. Abu Bakar, M. Lee, "Multipath Routing in Wireless Sensor Networks: Survey and Research Challenges", Sensors, vol. 12, pp. 650–685, 2012.
17. K. Sha, J. Gehlot, R. Greve, "Multipath Routing Techniques in Wireless Sensor Networks: A Survey", in Wirel. Pers. Commun., vol. 70, pp. 807–829, 2012.
18. M. Masdari, M. Tanabi, "Multipath Routing protocols in Wireless Sensor Networks: A Survey and Analysis", in J. Future Gener. Commun. Netw., vol. 6, pp. 181–192, 2013.
19. A.A. Anasane, R.A. Satao, "A Survey on various Multipath Routing protocols in Wireless Sensor Networks", in Procedia Comput. Sci., vol. 79, pp. 610–615, 2016.
20. Y. Zhang, S. He, J. Chen, Y. Sun, X. Shen, "Distributed sampling rate control for rechargeable sensor nodes with limited battery capacity", in IEEE Trans. Wirel. Commun., vol. 12, pp. 3096–3106, 2013.
21. S. He, J. Chen, F. Jiang, D.K.Y. Yau, G. Xing, Y. Sun, "Energy provisioning in wireless rechargeable sensor networks", in IEEE Trans. Mobile Comput., vol. 12, pp. 1931–1942, 2013.
22. P. Cheng, S. He, F. Jiang, Y. Gu, J. Chen, "Optimal scheduling for quality of monitoring in wireless rechargeable sensor networks", in IEEE Trans. Wirel. Commun., vol. 12, pp. 3072–3084, 2013.
23. L. He, L. Fu, L. Zheng, P. Cheng, Y. Gu, J. Pan, J. Chen, "ESync: An energy synchronized charging protocol for rechargeable wireless sensor networks", in ACM Int. Symp. Mobile Ad Hoc Netw. Comput., vol. 15, pp. 247–256, 2014.
24. L. Fu, P. Cheng, Y. Gu, J. Chen, T. He, "Optimal charging in wireless rechargeable sensor networks", in IEEE Trans. Veh. Technol., vol. 65, pp. 278–291, 2016.
25. C. Lin, Z. Wang, D. Han, Y. Wu, C.W. Yu, G. Wu, "TADP: Enabling temporal and distantial priority scheduling for on-demand charging architecture in wireless rechargeable sensor Networks", in Journal of Systems Architecture, vol. 70, pp. 26–38, 2016.
26. Y. Zhang, S. He, J. Chen, "Data gathering optimization by dynamic sensing and routing in rechargeable sensor networks", in IEEE/ACM Trans. Netw., vol. 24, pp. 1632–1646, 2016.
27. C. Lin, G. Wu, M.S. Obaidat, C.W. Yu, "Clustering and splitting charging algorithms for large scaled wireless rechargeable sensor networks", in J. Syst. Softw., vol. 113, pp. 381–394, 2016.
28. C. Lin, Y. Wu, Z. Liu, M.S. Obaidat, C.W. Yu, G. Wu, "GTCharge: A game theoretical collaborative charging scheme for wireless rechargeable sensor networks", in J. Syst. Softw., vol. 121, pp. 88–104, 2016.
29. C. Lin, D. Han, J. Deng, G. Wu, "P2S: A Primary and Passer-by Scheduling Algorithm for On-Demand Charging Architecture in Wireless Rechargeable Sensor Networks", in IEEE Trans. Veh.Technol.2017,doi:10.1109/TVT.2017.2683493.
30. I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci, "Wireless sensor networks: A survey", in Comput. Netw., vol. 38, pp. 399–422, 2002.
31. I. F. Akyildiz, Weilian Su, Y. Sankarasubramaniam and E. Cayirci, "A survey on sensor networks," in IEEE Communications Magazine, vol. 40, no. 8, pp. 102-114, Aug. 2002.
32. K. Akkaya, M. Younis, "A survey on routing protocols for wireless sensor networks", in Ad Hoc Netw., vol. 3, pp. 325–349, 2005.
33. J. Yick, B. Mukherjee, D. Ghosal, "Wireless Sensor Network Survey", in Comput. Netw., vol. 52, pp. 2292–2330, 2008.
34. G. Anastasi, M. Conti, M. Francesco, A. Passarella, "Energy Conservation in Wireless Sensor Networks: A survey", in Ad Hoc Netw., vol. 7, pp. 537–568, 2009.
35. S.B. Ehsan, B. Hamdaoui, "A Survey on Energy-Efficient Routing Techniques with QoS Assurances for Wireless Multimedia Sensor Networks", in IEEE Commun. Surv. Tutor., vol. 14, pp. 265–278, 2011.
36. M. Saleem, A. Gianni, D. Caro, M. Farooq, "Swarm intelligence-based routing protocol for wireless sensor networks: Survey and future directions", in Inf. Sci., vol. 181, pp. 4597–4624, 2011.
37. M.R. Mundada, S. Kiran, S. Khobanna, R.N. Varsha, S.A. George, "A Study on Energy Efficient Routing Protocols in Wireless Sensor Networks" in Int. J. Distrib. Parallel. Syst., vol. 3, pp. 311–330, 2012.

38.S.K. Singh, M.P. Singh, D.K. Singh, "A Survey of Energy-Efficient Hierarchical Cluster-Based Routing in Wireless Sensor Networks", in Int. J. Adv. Netw. Appl., vol. 2, pp. 570–580, 2010.
39.S. Naeimi, H. Ghafghazi, C. Chow, H. A Ishii, "Survey on the Taxonomy of Cluster-Based Routing Protocols for Homogeneous Wireless Sensor Networks", Sensors, vol. 12, pp. 7350–7409, 2012.
40.R. Singh, and A. K. Verma. "Energy efficient cross layer based adaptive threshold routing protocol for WSN", in AEU-International Journal of Electronics and Communications, vol. 72, pp. 166-173, February 2017.
41.R. E. Mohamed, A. I. Saleh, A. Maher, and A. S. Samra, "Survey on wireless sensor network applications and energy efficient routing protocols" in Wireless Personal Communications, vol. 101, no. 2, pp. 1019-1055, 2018.
42.A. Saini, A. Kansal, N. S. Randhawa, "Minimization of Energy Consumption in WSN using Hybrid WECRA Approach", in Procedia Computer Science, vol. 155, pp. 803-808, 2019.

## AUTHORS PROFILE

**Parvinder Singh** is presently working as PhD Research Scholar in IK Gujral Punjab Technical University, Jalandhar in Electronics and Communication Engineering department. He did his master's degree in Electronics and communication from DAVIET, Jalandhar. He has more than 14 years of teaching experience. His current research interests include Wireless Adhoc Networks (Energy, Security, and Routing), Wireless Sensor Networks, Mobile Ad hoc Network Routing and Wireless Communications.

**Prof. (Dr.) Rajeshwar Singh** is presently working as Director, Doaba Khalsa Trust Group of Institutions, SBS Nagar, Punjab. He received his Ph.D. Engineering degree from Department of Electronics and Communication Engineering, Faculty of Engineering, BIT Sindri, Dhanbad, Jharkhand. His Master of Engineering degree is in Electronics and Communication Engineering with specialization in Digital Systems from Motilal Nehru Regional Engineering College (currently NIT), Allahabad, U.P. He received his AMIE (India) degree in 1992 from The Institutions of Engineers, Calcutta. He has also received Master of Business Administration (MBA) in Information Technology from MD University, Rohtak, Haryana. He has more than 26 years of experience in teaching and industry. He has published more than 100 papers in national and international journals / conferences of repute. He has also published four books in the field of Engineering and Technology. His current research interests include Swarm Intelligence based Optimization (Energy, Security, Routing), Wireless Sensor Network, intellectual information technology, Mobile Ad hoc Network Routing, Coding theory, cryptography, e-governance and Educational Planning. He is member of ISTE, AMIE and various engineering organizations. He is also editor-in-chief/editor/ reviewer of various national and International Journals.