Introduction to Wireless Sensor Networks its Applications and Use Cases

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Abstract

WSNs are infrastructure-less networks that are why these networks can be easily deployed in any disaster situations like floods, battlefields, etc. They are easy, fast, and cost-effective to deploy for some limited period [3]. Due to the limited energy and open nature of WSNs the energy and security of the network become the major challenge. The network energy can be saved with the help of efficient routing which will enhance the network lifetime. In this paper various routing protocols like LEACH (Low Energy Adaptive Clustering Hierarchy), PEGASIS (Power-Efficient Gathering in Sensor Information Systems), etc. LEACH routing protocols are reviewed that are designed based on clustering architecture where the network is divided into various clusters also known as zones based on their energy.

Keywords: Energy, WSN, Sensor, Zone, Routing

I. Introduction

Due to the continuous development in the field of wireless networks and communications, wireless networks have become one of the attractive fields to explore for various researchers [1]. WSNs are used to acquire real-time information for the surroundings by sensing the environment. In traditional WSNs the sensor nodes are placed in a way that they can communicate and send or receive data to each other. All the sensor nodes are wireless and portable with no direct power source but with limited battery power. Therefore, to continuously monitor or sense the environment sensor node must send the sensed data to the server which will consume the node energy. As sensor nodes had limited energy, so their energy will deplete with time.

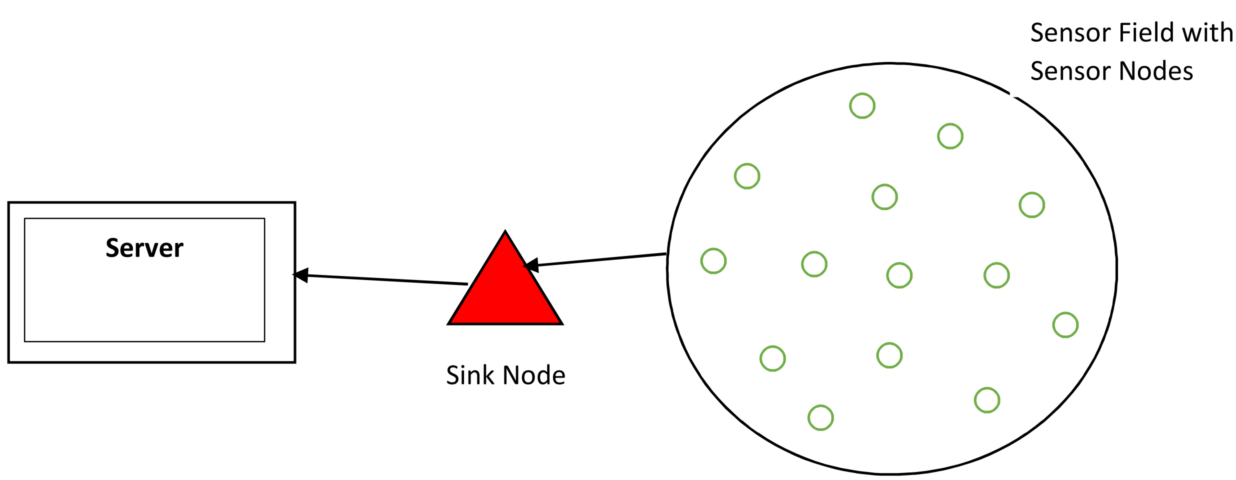

Figure 1: Wireless Sensor Networks Communication Architecture [Source: Created for this work referring [2]

As shown in Figure 1, the wireless communication network architecture has the following major components:

- **a.** Sensor Field: Sensor field is defined as the physical location with defined dimensions where the wireless sensor node can be deployed. The area of sensor field varies from several meters to kilometers. The sensor nodes are deployed in a way that all nodes are connected through single or multi-hop connectivity within the sensor field.
- **b.** Sensor Nodes: Sensor nodes are defined as small wireless devices with sensing and transmission capability. Sensor nodes can continuously monitor the environment and send the sensed data to the sink node. Sensor nodes are battery-operated devices. The lifetime of sensor nodes can vary from several hours to days depending on energy usage.
- **c.** Sink Node: Sink node is also known as a base station that is placed near the network boundaries. Sink node will be responsible to collect all the data from the network nodes and to pre-process the data to reduce the burden of data forwarding to the server. Commonly, duplicate and corrupt data will be discarded during the pre-processing.
- **d.** Server: The server will store all the data and forward it to users or network upon authenticated request for data.

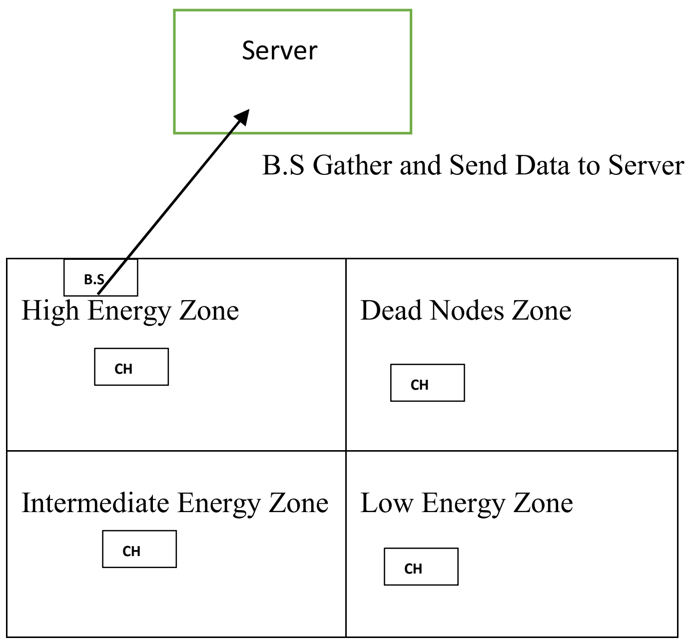

Figure 2 Clustering Based Hierarchical Routing Protocol

A clustered based network is shown in figure 2, the dead nodes and low energy zones are far from the base station. The nodes in low energy zone cannot transmit data directly to the bases station, as it will consume high energy which may results in energy depletion for the sender node. The low energy node forwards the data to the intermediate or high energy zone to forward the data to the base station. Every zone has its CH (Cluster Head), which is a selected node to forward or receive data in every round. The CH is selected based on energy and distance in most of the routing protocols. The CH node will be elected in every round to balance the energy consumption within the zone. The CH will forward data to other zone CH based on the near available CH. The selection of CH will balance the energy consumption within the zone and helps to enhance the node's lifetime. Clustered routing will also lower the burden on low energy nodes and the maximum forwarding is done by the high energy nodes. In this way, the network nodes in other zones can survive for a longer period than expected in case of non-clustered routing. Further, the base station aggregates all the data and forwards it to the server after pre-processing the data [4]. The PEGASIS routing is based on a chaining method, where several sink nodes are mobile in nature and collect data from the other nodes by visiting them which form a chain-like structure.

Table I Analysis of Various Routing Protocols (Source: Created for this work)

Routing Protocols	Advantages	Disadvantages	Contribution
LEACH [4]	Low energy usage Less overhead Low complexity	Random CH selection One hop transmission	The network will elect CH randomly as the result in the case of CH with low energy may deplete during data forwarding resulting in data drop.
PEGASIS [5]	Less Clustered Zones Chain Based multihop Less overhead	Dynamic chain topology require updates Multihop transmission add on the transmission delay Chaining will consume extra energy	Better performer than LEACH focusing on enhancing network lifetime. The chain formation and collection of data from point to point consume extra energy also the delay is higher.
TEEN [6]	Better data aggregation Suitable for real-time application	Overlapping cluster heads with in the range Continuous sensing consume more energy	Due to constant sensing of the environment, the energy will be consumed regularly, but the data will not be transmitted frequently.
SEH [7]	Use a free external power No pollution green computing Less loss of energy preservation More network lifetime	Additional hardware add on in the network deployment cost More overheads	The proposed framework uses the solar energy panel to supply energy to sensor devices, the energy can be stored for a longer period and can be supplied to sensors continuously almost making the network operational 24 x 7 with all active network nodes.
RCER [8]	Unique IDs allotment enforce security by allowing authenticated user only Location-aware to calculate shortest transmission path	Additional delay is added in network start to allocate unique IDs Acknowledgment receiving add on extra packets and	RCER is a heterogeneous based routing protocol that helps in minimal energy consumption. The protocol reduces the overheads as no CH are required but the available heterogeneous nodes will

	Heterogeneous nodes had more energy used for packets forwarding and decreasing the network burden.	delay for next transmission	transmit the data to the base station. The RCER protocol had shown better energy consumption, network delay, and throughput.
QUASI [9]	Fitness based CH selection Distance aware data transmission Periodic CH selection Fewer overheads	Random initial CH selection Faulty fitness quotient sometime	Quasi based framework will select the CH based on a genetic algorithm where the fitness value will be computed. It the fitness value is greater than the defined threshold only then CH will be elected. Fewer changes in CH results in enhancing network lifetime and throughput.
GCEEC [10]	Centroid based cluster head selection Gateway nodes reduce the CH burden Data aggregation option is also available with the gateway node	More complex as centroid need to be calculated in every round Add on cost for gateway nodes Dual data aggregation	The framework uses the centroid method to elect the nodes as CH, at the same time network has gateway nodes that are capable to collect and transmit the data to the base station after aggregation operation. The aggregation operation reduces data forwarding burden results in energy saving and minimizing the overall global network cost
GWO [11]	All nodes with the different energy level Intelligent CH selection Energy and distance aware protocol with dynamic information Advance nodes are selected as CH	More complex as parametric equations are involved in the calculation of fitness value Advance nodes are preferred for CH without considering the distance	The proposed grey wolf optimizer framework will select CH based on fitness value in every round. The fitness values will serve as input weights to make networks learn dynamically and elect CH based on the best availability. Advance nodes are elected as CH to balance the energy usage in the network and to enhance the network's lifetime.

MCDA [12]	Improved inter-cluster communication CH selection is done based on CH in-between distance Less data drop Fewer overheads	Weighted based CH selection add on network delay Training required for dynamic decisions	The network is promising in terms of CH selection as the attempt was made to improve inter-cluster communication. The inter-cluster communication helps in predicting the least distance between the elected CHs. The forwarding of data will be easy and less time consuming as the distance between CHs are less and transmission consume lesser energy.
HEED [13]	Balanced CH selection Low overheads Uniform and random nodes distribution Inter-cluster communication	Random distribution may create energy holes Complexity Nodes are distributed with varying residual energy	A distributed clustering-based hierarchical framework where the CH is selected based on residual energy but all the information will be acquired from neighbors. As the CH will be selected based on residual energy, so a node can be elected as CH for one or more time.

Table II Comparison of Various Routing Protocols (Source: Created for this work)

Protocol	Load	Path Selection	Aggregation	Network Lifetime	Scalability
LEACH [4]	Medium	Proactive	Yes	Good	Low
PEGASIS [5]	Medium	Reactive	No	Excellent	Very Low
TEEN [6]	Good	Reactive	Yes	Excellent	Low
SEH [7]	Average	Proactive	Yes	Infinite	Good
RCER [8]	Good	Reactive	Yes	Good	Good
QUASI [9]	Good	Hybrid	No	Excellent	Low
GCEEC [10]	Medium	Hybrid	Yes	Good	Good
GWO [11]	Good	Hybrid	Yes	Good	Average
MCDA [12]	Medium	Reactive	Yes	Excellent	Good
HEED [13]	Medium	Hybrid	Yes	Average	Average
ICSCA [14]	Good	Hybrid	Yes	Good	Good
M-IWOCA [15]	Good	Reactive	Yes	Excellent	Good

Table III Abbreviations Used

LEACH	**Low Energy Adaptive Clustering Hierarchy Protocol**

PEGASIS	Power Efficient Gathering in Sensor Information Systems
TEEN	Threshold-sensitive Energy Efficient Network
SEH	Solar Energy Harvesting
RCER	Reliable Cluster-based Energy-aware Routing
GCEEC	Gateway Clustering Energy-Efficient Centroid
MCDA	Multicriteria Decision Analysis
HEED	Hybrid Energy-Efficient Distributed
ICSCA	Improved Cuckoo Search-based Clustering Algorithm
GWO	Grey Wolf Optimizer
M-IWOCA	Modified Invasive Weed Optimization Based Clustering Algorithm

II. Applications Areas and Use Case of Wireless Sensor Networks

WSNs are almost used everywhere in our daily life and field. Some of the Major applications of WSNs are as below:

1. **Healthcare:** WSNs are used in the sector of health to monitor the condition and health parameters of the patient in real-time. The wireless sensor nodes are used to sense the various health parameters of a patient and forward the data to the hospital server or doctor screen. Also in case of some critical parameters, the WSNs are capable to raise a beacon to the doctor or nurse. WSNs help save the patient life. Other health applications are like wearable health devices, home monitoring, and assistant system.
2. **Battle-Field**: A disaster situation, where the soldiers need to communicate with each other to battle together. In this situation, WSNs are easy and can be deployed rapidly. The soldiers can send and receive signals from other locations also the fighter jets can communicate using wireless transmission media.
3. **Under Water Sensor Networks (UWSN):** The WSNs can also be deployed underwater to sense the various required parameters like temperature, depth, and detect activities. It also helps the sub-marines to communicate and to transmit the sensed data over the server [16].
4. **Agriculture:** WSNs are also used in the field of agriculture to sense the environment and in case of any problem the signal can be sent to farmers to save the crops from damage. It is used in agriculture to detect water temperature, rain, soil quality, etc. [7].
5. **Surveillance:** WSNs are also used for surveillance purposes to sense and monitor the environment for sending the data over the server [17].
6. **Power, Traffic and Pollution Monitoring:** The WSNs are also used to sense environmental pollution and to monitor the traffic. They can be used as intelligent devices to sense and monitor the environment.
7. **Intelligent Transport System:** WSNs are used in self-driving cars as well as to sense the surroundings for self-parking. Also in case of any emergency WSNs can automatically send the signal to the server.
8. **Advance Industry:** Industry is using WSNs in every unit to reduce human efforts like for machines temperature sensing and other parameters like automatic attendance, entry, and exit.
9. **Intruder Detection:** Intruder can be detected by deploying a seismic sensor that will help the soldiers, police, or other security agencies to detect the location of the intruder in real-time to prevent the loss.

There are several other applications of WSNs like Tsunami detection, forest fire detection, pollution monitoring and control, greenhouse, crop, water, and animal monitoring, etc. The applications of WSNs are in every field [18].

References

[1] X. Zhang, X. Lu, and X. Zhang, "Mobile wireless sensor network lifetime maximization by using evolutionary computing methods," *Ad Hoc Networks*, vol. 101, no. Feburary, p. 102094, 2020.

[2] M. Shafiq, H. Ashraf, A. Ullah, and S. Tahira, "Systematic Literature Review on Energy Efficient Routing Schemes in WSN – A Survey," *Mob. Networks Appl.*, vol. 25, no. 3, pp. 882–895, 2020.

[3] D. B.D. and F. Al-Turjman, "A hybrid secure routing and monitoring mechanism in IoT-based wireless sensor networks," *Ad Hoc Networks*, vol. 97, no. October, p. 102022, 2020.

[4] H. Zayed, M. Taha, and A. Hatem, "Performance Evaluation of MODLEACH and MIEEPB Routing Protocols In WSN Performance Evaluation of MODLEACH and MIEEPB Routing Protocols In WSN," in *2018 International Conference on Electrical, Electronics, Computers, Communication, Mechanical and Computing (EECCMC)*, 2019, no. January, pp. 1–5.

[5] A. A. Hussein and R. A. Khalid, "Improvements of PEGASIS Routing Protocol in WSN Improvements of PEGASIS Routing Protocol in WSN," *Int. Adv. J. Eng. Res.*, vol. 2, no. 11, pp. 01–14, 2019.

[6] O. P. Asqui, L. A. Marrone, and E. E. Chaw, "Evaluation of TEEN and APTEEN hybrid routing protocols for wireless sensor network using NS-3," *Adv. Intell. Syst. Comput.*, vol. 1137 AISC, pp. 589–598, 2020.

[7] H. Sharma, A. Haque, and Z. A. Jaffery, "Maximization of wireless sensor network lifetime using solar energy harvesting for smart agriculture monitoring," *Ad Hoc Networks*, vol. 94, no. July, p. 101966, 2019.

[8] K. Haseeb *et al.*, "RCER: Reliable Cluster-based Energy-aware Routing protocol for heterogeneous Wireless Sensor Networks," *PLoS One*, vol. 14, no. 9, pp. 1–24, 2019.

[9] N. R. Malisetti and V. K. Pamula, "Performance of Quasi Oppositional Butterfly Optimization Algorithm for Cluster Head Selection in WSNs," *Procedia Comput. Sci.*, vol. 171, no. 2019, pp. 1953–1960, 2020.

[10] K. N. Qureshi, M. U. Bashir, J. Lloret, and A. Leon, "Optimized Cluster-Based Dynamic Energy-Aware Routing Protocol for Wireless Sensor Networks in Agriculture Precision," *J. Sensors*, vol. 2020, no. January, pp. 1–19, 2020.

[11] X. Zhao, S. Ren, H. Quan, and Q. Gao, "Routing protocol for heterogeneous wireless sensor networks based on a modified grey wolf optimizer," *Sensors (Switzerland)*, vol. 20, no. 3, pp. 1–18, 2020.

[12] L. Aziz and H. Aznaoui, "Efficient Routing Approach Using a Collaborative Strategy," *J. Sensors*, vol. 2020, no. Februrary, pp. 1–17, 2020.

[13] D. Nam, "Comparison Studies of Hierarchical Cluster-Based Routing Protocols in Wireless Sensor Networks," in *Proceedings of 35th International Confer- ence on*

Computers and Their Applications Comparison, 2020, vol. 69, pp. 334–322.

[14] G. P. Gupta, “Improved Cuckoo Search-based Clustering Protocol for Wireless Sensor Networks,” in *Procedia Computer Science*, 2018, vol. 125, pp. 234–240.

[15] R. Sharma, V. Vashisht, and U. Singh, “Fuzzy modelling based energy aware clustering in wireless sensor networks using modified invasive weed optimization,” *J. King Saud Univ. - Comput. Inf. Sci.*, vol. 63, no. Novemebr, p. 10, 2019.

[16] T. Islam and Y. K. Lee, “A comprehensive survey of recent routing protocols for underwater acoustic sensor networks,” *Sensors (Switzerland)*, vol. 19, no. 19, 2019.

[17] Y. Harbi, Z. Aliouat, A. Refoufi, S. Harous, and A. Bentaleb, “Enhanced authentication and key management scheme for securing data transmission in the internet of things,” *Ad Hoc Networks*, vol. 94, no. July, p. 101948, 2019.

[18] D. Kandris, C. Nakas, D. Vomvas, and G. Koulouras, “Applications of Wireless Sensor Networks : An Up-to-Date Survey,” *Appl. Syst. Innov.*, vol. 3, no. 14, pp. 1–24, 2020.