# Data Communication Protocols In Wireless Sensor Networks

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***Abstract*—With this study four, "Wireless Sensor Networks" protocols are being reviewed based on their functioning. "Low Energy Adaptive Clustering Hierarchy" (LEACH), "Power-Efficient Gathering in Sensor Information System" (PEGASIS), "Hybrid Energy-Efficient Distributed clustering" (HEED), and "Threshold Sensitive Energy Efficient Sensor Network" (TEEN) are some of the WSN protocols [1]. These network protocols are based on the hierarchical structure so they achieve their goal to gain energy efficiency by this functioning type, So it makes them interesting to study.**

**Included in this paper are some performance metrics which are developed and used to compare these protocols. Finally, we make a General analysis for the protocols concerning the performance metrics to create a generalized view.**

***Index Terms*—LEACH, PEGASIS, TEEN, HEED, ST, HT, SV, CH**

## I. Introduction

A wireless sensor network is a group of specialized sensors that helps to monitor and collect data from a central location where the conditions are diverse. Usually monitored parameters are temperature, humidity, pressure, wind direction, and speed. Data communication in WSN is more difficult than in traditional wireless networks due to huge amount of data which causes this network to suffer performance issues. There are various protocols designed to improve the energy processing capability, among those protocols are LEACH, PEGASIS, TEEN and HEED.

These four protocols are very similar in architecture but there are small differences, which help us to discuss which is better in performance.

## II. Protocols

### A. LEACH

Low Energy Adaptive Clustering Hierarchy (LEACH) is the first hierarchical adaptive cluster-based routing protocol for wireless sensor networks. It was first announced on HICSS by Wendi B. Heinzelman, A. Chandrakasan and H. Balakrishnan [2].The LEACH protocol is the first self-organizing protocol for wireless sensor networks which partitions the nodes into clusters.

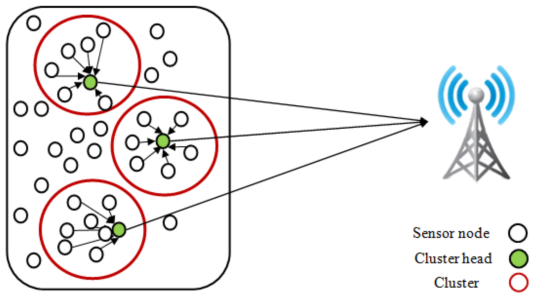


Fig. 1. Cluster organization for sensor networks [3]

LEACH protocol is basically a hierarchical protocol in which sensors (nodes) send data to cluster heads, cluster heads compress this data and send it to the central station(Figure 1). First some nodes are chosen as cluster heads. Then, other nodes in the network use the statuses that sent by cluster heads to choose the cluster that it wants to be a part of. Nodes choose the cluster head that costs the minimum energy to communicate. After clusters are established, every cluster head creates a schedule for the nodes in its cluster to determine when they will send their data. Therefore, all nodes except cluster heads close its radio component while it is not sending data. This helps to reduce energy loss. After then, the sensors -nodes- obtain the data. Then, they send this data to the cluster head. Data sent by more than one nodes to the cluster head are combined in the cluster head. The combined data is compressed and sent to the central station. Compression approach is another example of how reducing the energy loss is achieved in LEACH, therefore LEACH is used in wireless sensor networks to lengthen the network lifetime [4].

### B. TEEN

Threshold sensitive Energy Efficient sensor Network protocol (TEEN) is a reactive clustering routing protocol like LEACH which is formed in a hierarchical structure and uses a data centric method [5]. And what are the Reactive Networks? To explain it is the environment where sudden changes occur constantly, for example, some changes in temperature or humidity [7]. IF these kinds of changes need to be tracked TEEN protocol is preferred. This Protocol differs from others with its main characteristic by having two attributes "Hard Threshold Value" or "HT" and "Soft Threshold Value or "ST", these attributes are activated on certain conditions [6]. HT stands for controlling the value of interest which is initialized by the user, Once the sensed value by sensors is more than the value of HT the nodes will transmit data to cluster head (CH). Afterward sensed data will be stored in sensed value (SV) which is the internal variable since the nodes sense attribute continuously it needs to be controlled so here comes the second attribute of protocol ST. The transmission happens only if the next value differs from SV by an amount equal to or greater than the ST. So ST reduces the frequency of data transmission by avoiding little change of sensed attribute.

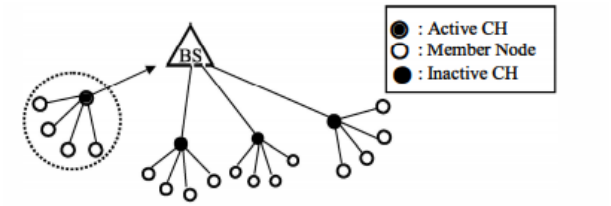


Fig. 2. Illustration of TEEN Protocol [5]

Afterward, data arrives at CH where it is processed or sent to Base Station or even to higher levels of CH. So only CHs need to aggregate data the nodes just transfer data to them which is energy-saving the advantage of clustering protocols but also need to be noticed that nodes take turns to become CHS in order to evenly hand out the energy consumption. CH selection is made randomly or by optimized algorithms. In Figure 2 it is showed how a cluster is activated once any member nodes starts to sense and the activated cluster head starts transmit data that it gathers from member nodes to the Base Station.

### C. HEED

The purpose of HEED is to extend the operating life of the network. For this reason, the most important factor in cluster head selection is based on the remaining energy amount of the node. It is not necessary to measure the remaining energy during head selection. Because it is known how much energy is consumed per bit for sensing, communication and processing, and therefore the remaining energy can be estimated.In order to increase energy efficiency and further extend network life, HEED also considers intra-cluster "communication cost" as a secondary cluster parameter. For example, cost may be a function of neighbor affinity or cluster density [8].

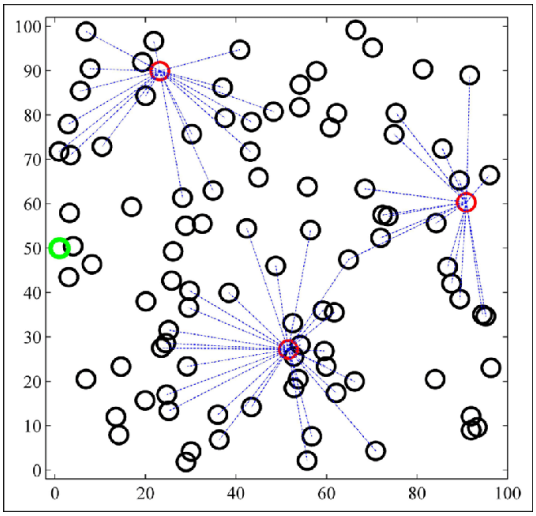


Fig. 3. Distribution of cluster head nodes in HEED protocol. [9]

HEED uses the primary cluster parameter to probabilistically select the first cluster head set. And it uses the secondary parameter to "break ties" between them. In this context, a tie means that a node is within the "range" of more than one cluster header. To get it what "range" signifies in this case, watch that a node ordinarily encompasses a number (e.g., seven) of discrete transmission control levels. The cluster radius is determined by the level of transmit power used for in-cluster announcements and during clustering. HEED calls this level the cluster power level. Cluster power level should be set for lower power levels of a node. This is because it is to increase spatial reuse and to separate the communication of clusters from higher power levels. High power levels should cover at least two cluster diameters to ensure that the inter-cluster liner will be bonded. If this condition is not fulfilled, clustering approach cannot be applied. Cluster power level determines the number of clusters in network. Determining an optimal cluster power level is irrelevant, because the network topology changes the cause of node failures and energy depletion [8].

### D. PEGASIS

Power Efficient Gathering in Sensor Information Systems protocol (PEGASIS) is a hierarchical routing protocol for Wireless Sensor Networks following a chain based approach.

The main idea in PEGASIS is to organize the sensor nodes to form a chain. A greedy algorithm is used for the construction of the chain. Starting from the node furthest from the base station, next closest neighbour of each node is chosen to be next in the chain. This process is repeated until the chain is completed. If any node dies, the chain is reconstructed to bypass the dead node.

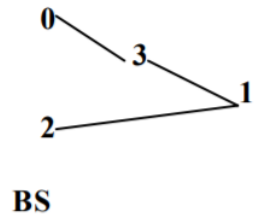


Fig. 4. Chain construction process with the greedy algorithm [10]

This structure allows each node to receive and transmit data to its close neighbours. Nodes take turns to be the cluster head for transmission to the base station. Data gets transmitted through each node and fuses with the data of the other nodes until it reaches the cluster node. Then, the cluster head transmits the final data to the base station. This allows an even distribution of energy among the sensor nodes and reduces the average energy consumption.

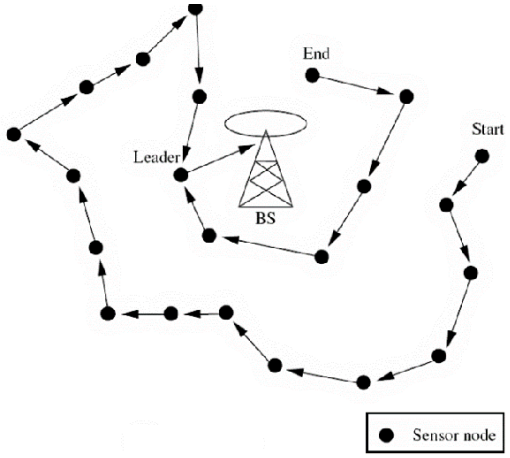


Fig. 5. Illustration of PEGASIS protocol [11]

## III. COMPARISON

### A. LEACH VS HEED

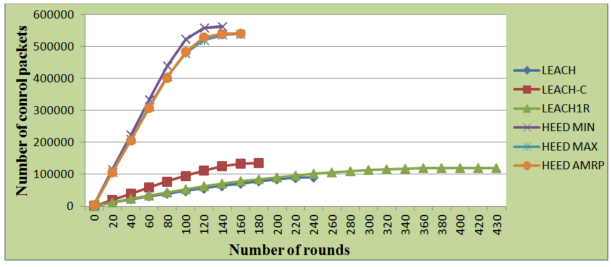


Fig. 6. Comparison of the number of control packets. [3]

As seen in Figure 6, this research was conducted for 6 different protocols in the reference source. In this subsection, only LEACH and HEED protocols will be compared. As can be seen in the figure, the number of packets and the number of rounds for LEACH and HEED protocols can be seen. HEED protocols appear to have more control packets. This is because HEED needs a few iterations to find the cluster headers, so it has to send more control packets.

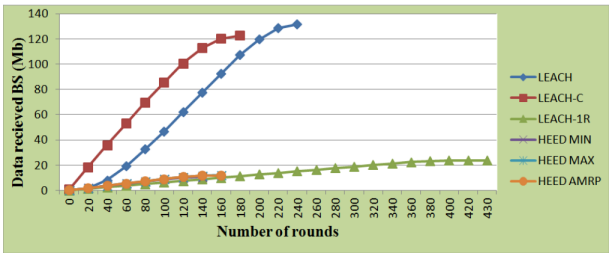


Fig. 7. Comparison of the number of control packets. [3]

As seen in Figure 7, the amount of data received by the Base Station per round for protocols is displayed. As seen in the simulation, it is seen that LEACH base transmits more data to the station [3]. At this point, the HEED protocol has transmitted less data. Since the sensors are the same, the amount of data collected will be the same. Here it is seen that the LEACH protocol, which transmits more data, transmits more data to the base station to transmit the same amount of data. It is clear here that the HEED protocol consumes less energy in data transmission. HEED protocol is more successful in data transmission than LEACH protocol.

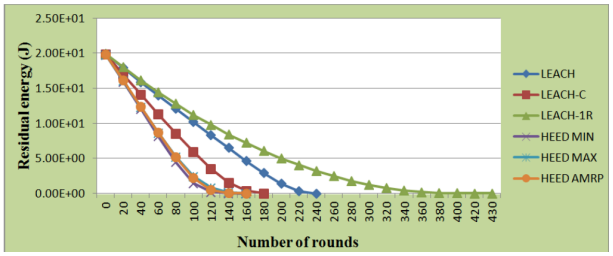


Fig. 8. Comparison of the number of control packets. [3]

Figure 8 shows the amount of energy remaining in the nodes at the end of each round according to the protocols. One of the biggest factors in the occurrence of energy differences here is the energy consumed during cluster head selection and the data received from the sensors are sent to the base station. Based on previous comparisons, the HEED protocol sent too many control packets during cluster head selection, although LEACH sent much less packets. While LEACH was sending too many packets during data transmission to the central station, HEED was sending much less packets. As a result of the simulation [3], it is seen that these two protocols are close to each other in terms of total working time and remaining energy.

### B. LEACH VS PEGASIS

In this section, we will focus on comparing the LEACH and PEGASIS protocols. They are both hierarchical protocols but PEGASIS uses a chain based model while LEACH uses a cluster based model.

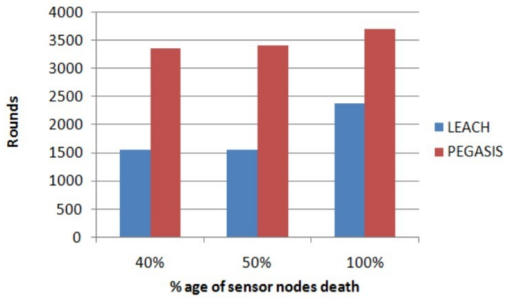


Fig. 9. Comparison of age of sensor nodes death [12]

As seen in Figure 9, sensor nodes can live for a longer amount of time using the PEGASIS protocol. The main reason behind this is the better distribution of energy with the chain based approach, extending the lifetime of the network.

TABLE I
COMPARISON TABLE OF LEACH AND PEGASIS [12]

| | LEACH | PEGASIS |
|---|---|---|
| Type of protocol | Hierarchical | Hierarchical |
| Data delivery model | Cluster Based | Chain Based |
| Data aggregation | Yes | No |
| Scalable | Yes | Yes |
| Power Consumption | High | Maximum |
| Transmission Delay | High | Low |
| Network Lifetime | High | Very High |

We can see a comparison of PEGASIS and LEACH in Table I. They are both hierarchical and scalable protocols.

As mentioned before, the biggest advantage of PEGASIS is its better power efficiency due to a more even distribution of energy among the nodes, extending their lifetime.

On the other hand, LEACH allows data aggregation unlike PEGASIS. LEACH is also better in terms of transmission delay because the long chain structure of PEGASIS can cause longer delays.

### C. LEACH VS PEGASIS VS TEEN

We will discuss four features to compare three protocols LEACH, PEGASIS, and TEEN these features are Hop Count, Expected Transmission Count(ETX) [13] which is "the estimated number of MAC layer transmissions that is needed for successfully delivering a packet through a wireless link without any error", Expected Transmission Time(ETT) [14] which was developed to be able to monitor metric that includes in it's process the link transmission rate i.e.,bandwidth factor, and Energy Consumption which are important measurements for protocols effectiveness.

TABLE II
COMPARISON ANALYSIS OF PROTOCOLS [13]

| | Performance Metrics | LEACH | PEGASIS | TEEN |
|---|---|---|---|---|
| 1 | Hop Count | Low | High | Low |
| 2 | ETX | Low | High | Very Low |
| 3 | ETT | Low | High | Very Low |
| 4 | Energy Consumption | High | Very Low | Low |

From Table II we can make the conclusion that among these protocols best performance has TEEN. But we have to keep in mind that the usages of these protocols are different. The reason for TEEN outperforming others is that TEEN's nodes get activated when sensed data is up to threshold, also each cluster head is not sending data all time, so the network throughput is very effective.

## IV. CONCLUSION

In this work we have studied and made a research about 4 different data transmission protocols used in wireless sensor networks and made comparisons between them based on their various properties. We described the structure of each protocol and explained its advantages and disadvantages.

## REFERENCES

[1] Sohraby, Kazem, Daniel Minoli, and Taieb Znati. Wireless sensor networks: technology, protocols, and applications. John wiley and sons, 2007.
[2] W. Heinzelman, A. Chandrakasan and H. Balakrishnan, "Energy- efficient communication protocol for wireless microsensor networks," in Proc. of the 33rd Annual Hawaii International Conference on System Sciences (HICSS), Maui, HI, Jan. 2000.
[3] Mohammed Omari, Warda Hadj Fateh, "Simulation, Comparison and Analysis of Wireless Sensor Networks Protocols: LEACH, LEACH-C, LEACH-1R, and HEED", 2015 4th International Conference on Electrical Engineering (ICEE)
[4] Amer O. Abu Salem, Noor Shudifat, "Enhanced LEACH protocol for increasing a lifetime of WSNs", 2019.
[5] A. Manjeshwar, D P. Agarwal, "TEEN: A Routing Protocol for Enhanced Efficiency in Wireless Sensor Networks", 2001.
[6] W. B. Heinzelman. "Application-Specific Protocol Archi-tectures for Wireless Networks". PhD thesis, MassachusettsInstitute of Technology, June 2000.
[7] P.Corke, T.Wark, R. Jurdak, et ai, "Environmental Wireless Sensor Networks," Phil. Trans. Roy. Soc. London, vo1.98, No.ll, pp. 1904- 1912, November 2010.
[8] Ossama Younis, Sonia Fahmy, "HEED: A Hybrid, Energy-Efficient, Distributed Clustering Approach for Ad Hoc Sensor Networks", IEEE Transactions on mobile computing, Oct – Dec 2004.
[9] Huang, Yourui, Chen, Zhenping, Han, Tao, Liu, Xiaotao, "One energy-efficient random-walk topology evolution method for underground wireless sensor networks",International Journal of Distributed Sensor Networks, 2018.
[10] Stephanie Lindsey,Cauligi S. Raghavendra Cauligi, "PEGASIS: Power-Efficient Gathering in Sensor Information Systems ", Proceedings of IEEE ICC 2001.
[11] Sankaliya, A. R., "PEGASIS : Power-Efficient Gathering in Sensor Information Systems.", International Journal of Scientific Research in Science and Technology 1 (2015): 108-112.
[12] Ouadi, Mohammed ,Hasbi, Abderrahim, "Comparison of LEACH and PEGASIS Hierarchical Routing Protocols in WSN", International Journal of Online and Biomedical Engineering (iJOE). 16. 159. 10.3991/ijoe.v16i09.14691
[13] Douglas S. J. De Couto, "High-Throughput Routing for Multi-Hop Wireless Networks" April 2004, pp 36-56
[14] R. Draves et aI, "Routing in Multi-Radio, Multi-Hop Wireless Mesh Networks" MobiCom '04, pp 114-128.