LEACH Routing Protocol In Wireless Sensor Networks

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Abstract - **Wireless sensor networks, since the first moment they were developed, emerged as a techonology that was quickly adapted and used for it's benefits. A Wireless Sensor Network consists of a network of nodes that are used to communicate the information between with each other. Wireless Sensor Networks are considered as one of the key technologies of the 21st century. Sensors are used for important application in different fields like military, bio-medical application, environmental monitoring, weather, seismic detection, smart spaces and process monitoring. The sensor nodes have some constraints due to their limited energy, storage capacity and computing power. Wireless sensor networks have explored to many new protocols specifically designed for sensor networks where energy is an important issue. This paper analyses the performance of LEACH protocol taking in consideration various specifications. LEACH (Low Energy Adaptive Clustering Hierarchy), a clustering-based protocol that utilizes randomized rotation of local cluster base stations (cluster-heads) to evenly distribute the energy load among the sensors in the network. LEACH uses localized coordination to enable scalability for dynamic networks, and incorporates data fusion into the routing protocol to reduce the amount of information that must be transmitted to the base station. LEACH includes distributed cluster formation, local processing to reduce global communication, and randomized rotation of the cluster-heads. Together, these features allow LEACH to achieve the desired properties.**

Keywords: ***Wireless Sensor Networks, routing protocols, LEACH protocol***

I. INTRODUCTION

A Wireless Sesnsor Network (WSN) is a set of hundreds or thousands of micro sensor nodes. This nodes are equipped with sensors, microprocessors and radio transceivers, thus they have the capabilities of sensing, establishing wireless communication between each other and doing computational and processing operations. The important requirements [1] of a WSN are: (1) A large number of sensors (2) Attachemnet of stationary sensors (3) Low energy consumption (4) Self-configuration abilities (5) Collaborative signal processing (6) Querying ability. WSNs are used in a many domains of our life. Some of the most important domains are:

- Habitat monitoring
- Military environment
- Medical and health field
- Industrial field
- Security and surveillance
- Biological, radiological, nuclear, and explosive material, etc.

Sensor nodes [2], are equipped with small, often irreplaceable batteries with limited power capacities. They can be deployed manually or be randomly dropped. They are self configuring, containing one or more sensors, with embedded wireless communications and data processing components and a limited energy source.

Each sensor node in the network consists of three subsystem:

1. The sensor subsystem which is used to sense the environment,
2. The processing subsystem wich performs the local computations on the sensed data,
3. The communication subsystem which is responsible for sharing the sensed data with the neighboring sensor nodes.

The use of wireless sensor networks is increasing day by day but the problem of energy constraints prevails as there is limited battery life. Since a large number of low-powerd sensor nodes have to be networked together, conventional techniques such as direct transmission from any specified node to the base station have to be avoided because in the direct transmission protocol, when a sensor node transmits data directly to the base station, the energy loss incurred can be quite extensive depending on the location of the sensor nodes relative to the base station. In such scenario, the nodes that are further away from the base station will dissipate the power heavily so their batteries are drained much faster than those nodes that are closer to the base station

In order to save energy dissipation caused by communication in wireless sensor networks, it is necessary to schedule the state of the nodes, changing the transmission range between the sensing nodes, use of efficient routing and data routing methods and avoiding the handling of unwanted data.

Routing in WSN [3] can be devided into flat, hierarchical, and location based routing depending on the network structure.

Hierachical Routing is the well-known technique with special advantages related to scalability and efficient communication. This technique is used by known protocols such as LEACH, PEGASIS, TEEN and APTEEN. In hierarchical architecture, higher energy nodes can be used to process and send the information, while low-energy nodes can be used to perform the sensing in the proximity of the target.

The Low-Energy Adaptive Clustering Hierarchy (LEACH) is a cluster based routing protocol. In this paper section 2 will introduce LEACH routing protocol in detail, Section 3 will cover the simulation of LEACH protocol and section 4 shows the simulation analysis by varying percentage of cluster heads in the network in each simulation of LEACH protocol. Section 5 concludes this paper.

2. REVIEW OF LEACH PROTOCOL

Low Energy Adaptive Clustering Hierarchy (LEACH) protocol for sensor networks is proposed by W. R. Heinzelman et.al [4] which minimizes energy dissipation in sensor networks. It is a very famous hierarchical routing algorithms for sensor networks which make clusters of the sensor nodes based on the received signal strength. The clustering technique proved to be very useful to reduce the energy consumption and increase the network lifetime. The entire network is divided into clustes in the LEACH protocol. One sensor node in each cluster must act as a cluster head and all remaining sensor nodes are member nodes of that cluster. Communication between the member nodes and sink is only possible via the cluster head. The cluster head collects, aggregate, and forward the data from member nodes to the sink. The cluster head consumes more energy due to the additional functions and this node can die quickly if it continuously plays the role of a cluster head. LEACH resolved this problem by changing dynamically the role of nodes as cluster heads.

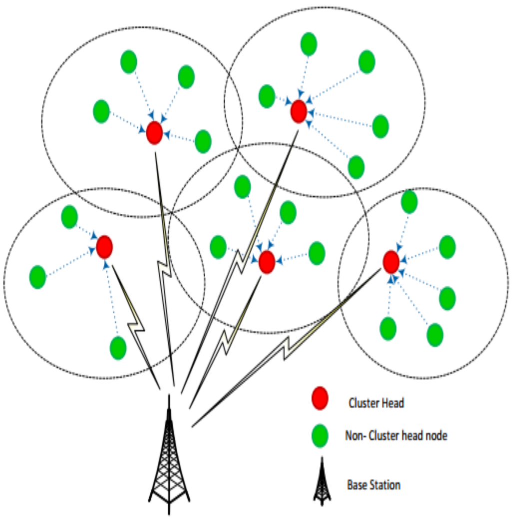

Fig. 1 LEACH Architecture

LEACH [5] works in rounds. The operations that are carried out in each round consist of two phases known as setup phase and steady state phase. The organization of clusters and selection of cluster heads (CHs) are done in the set up phase of the LEACH. The data are sent to the sink during the second or steady state phase.

Set up phase: During this phase[6] , the formation of clusters and the election process of cluster heads are performed. First of all, the whole network is divided into clusters. Now starts the clusters head election process. The CH selection criteria of a member node are the recommended percentage P and the earlier record as a CH. If the node is not a CH in proceding 1/P rounds, it produces a number between 0 and 1. The node becomes a cluster head for the current round if the number is less than the following threshold T (n):

$$T(n) = \begin{cases} \frac{P}{1-P*\left(r \bmod \frac{1}{P}\right)} & if\ n \in G \\ 0 & \end{cases} \qquad (1)$$

where

G = Group of nodes not selected as CHs in preceding 1/p rounds;

P = Recommended percentage of CH;

R = Current round.

During this phase, each node decides whether or not to become a cluster head (CH) for the current round. This decision is based on choosing a random number between 0 and 1, if number is less than a threeshold T (n), the node becomes a cluster head for the current round. The cluster head node sets up a TDMA schedule and transmits this schedule to all the nodes in its cluster, completing the setup phase which is followed by a steady-state operation.

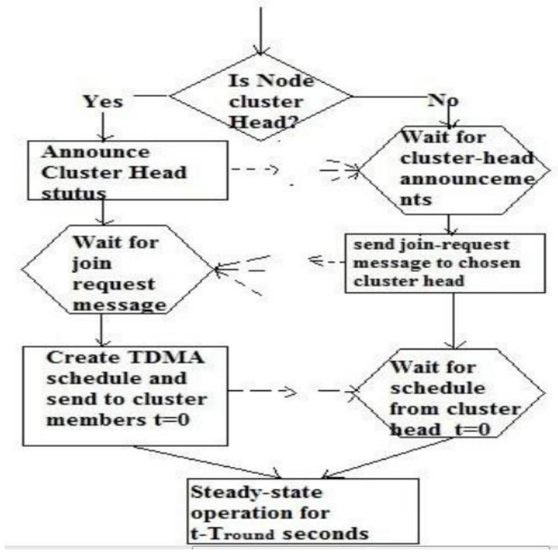

Fig.2 Flow chart of the Set-up phase of the LEACH protocol

Steady- state phase: The steady-state operation is broken into frames, where nodes send their data to the cluster head at most once per frame during their allocated slot shown in figure 3.

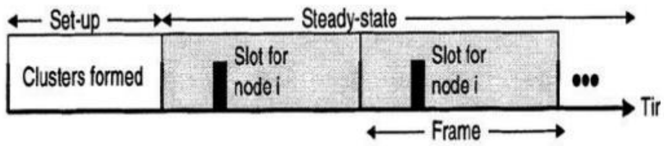

Fig. 3 Time line operation of LEACH

It assumes nodes always have data to send, they send it during their allocated transmission time to the cluster head. This transmission uses a minimal amount of energy (chosen based on the received strength of the cluster-head advertisement). The radio of each non-cluster - head node can be turned off until the node's allocated transmission time, thus minimizing energy dissipation in these nodes. The cluster-head node must keep its receiver on to receive all the data from the nodes in the cluster. When all data has been received, the cluster head node performs signal processing functions to compress the data into a single signal. For example, if the data are audio or seismic signals, the cluster-head node can beamform the individual signals to generate a composite signal. This composite signal is sent to the base station. Since the base station is far away, this is a high-energy transmission.

Although LEACH can increase the network lifetime, it still makes a lot of assumptions. LEACH assumes that all the nodes transmit with enough power to reach the Base Station (BS). For this reason LEACH is not applicable to networks that are deployed in large regions. LEACH also assumes that all nodes begin with the same amount of energy capacity in each election round, assuming that being a CH consumes approximately the same amount of energy for each node.

Table 1. Characteristics of LEACH protocol [3]

Protocol Metrics	LEACH
Cluster Formation	Yes
Chain Formation	No
Cluster Head (CH)	Yes
Master CH	No
Data Aggregation	Yes
Mobility	Fixed BS
Scheduling	TDMA, CDMA
Network Lifetime	Good
Energy Efficient	Good
Commnication	Single-hop
QoS	No

3. SIMULATION OF LEACH PROTOCOL

3.1 Simulation Parameters

To simulate the LEACH protocol, MATLAB [7] is used. LEACH protocol works in rounds. The total number of nodes used for the experiment is 200. The nodes are distributed in a an area of 100x100. In this simulation we will observe how the number of cluster heads (CH), number of packets sent to CH and number of packets sent to BS change when we decrease the initial energy of the node.

Table 2. Simulation Parameters

Parameter	Value
Simulation Area	100x100
Number of nodes	100
Numer of rounds	200
Iniatial energy	$E_0 = 0.5$; $E_0 = 0.2$ J
Nodes distribution	Nodes are distributed randomly
Optimal election probability	0.1

3.2 Simulation Results

This section discusess simulation results performed on LEACH Protocol.

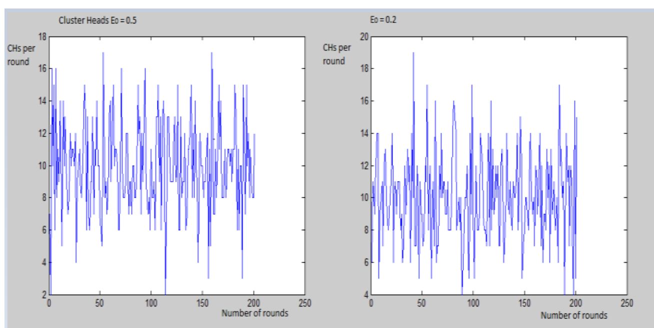

Fig. 4 Number of CH vs number of rounds

Figure 4 shows the comparison of cluster heads (CH) election in 2 different scenarios. The first scenario is when the initial energy of the nodes is $E_0 = 0.5$. The second scenario is when the energy is $E_0 = 0.2$.

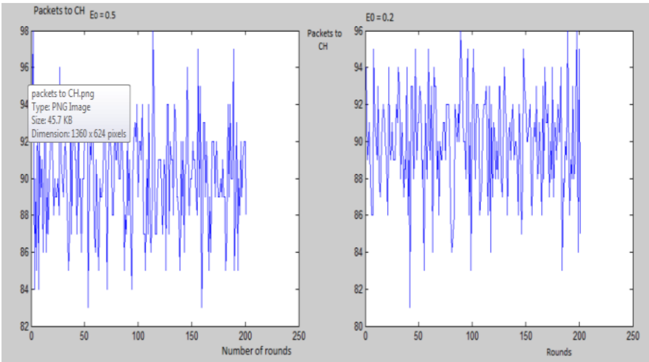

Fig 5. Number of packets send to CH vs Number of nodes

Figure 5 shows the number of packets sent to the cluster heads in two scenarios: the first scenario when the iniatial energy is E_0 = 0.5 and the second scenario when E_0 = 0.2.

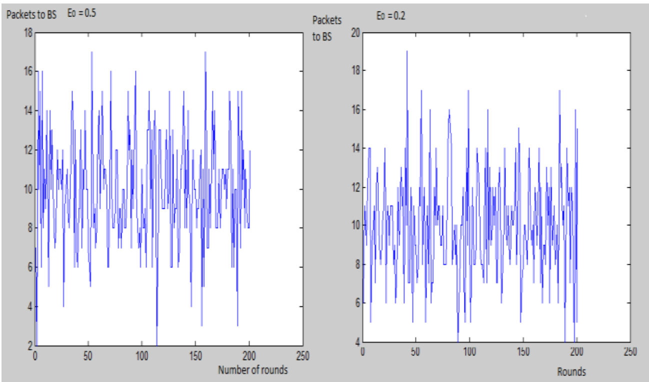

Fig. 6 Number of packets sent to BS vs number of rounds

Figure 6 shows the number of packets sent to the BS when the initital energy of the nodes chandes from E_0 = 0.5 to E_0 = 0.2 .

4. CONCLUSION

The Hierarchical routing protocol LEACH is energy efficient for the sensor network. By varying the initial energy of the nodes in the network, the performance changed. From the above results we can observe that the difference between the results in the second scenario (E_0 = 0.2), is very slight in comparison to the first scenario (E_0 = 0.5). If we look at the exact values, we will se that during the simulation rounds the number of CHs, the number of packets sent to the CH and the BS in both scenarios varies, in some rounds the number is higher when the initial energy is E_0 = 0.5, and in other cases is lower. From the simulation results shown in figure 4, 5, 6 we can determine that when the initial energy is decreased, the number of cluster heads, packets sent to the CHs and packets sent to the BS, is slightly lower compared to the results when the initial energy was higher.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] Nitaigour P. Mahalik, “Sensor Networks and Configuration: Fundamentals, Standards, Platforms, and Applications”, Chapter 1 , 7 & Spinger, 2007.

[2] Geetu, Sonia Juneja: “ Performance Analysis of SPIN and LEACH Routing Protocol in WSN” International Journal Of Computational Engineering Research (ijceronline.com) Vol. 2 Issue. 5.

[3] Jamal N. Al-Karaki, Ahmed E. Kamal. “Routing Techniques In WirelessSensor Networks: A Survey”, IEEE Wireless Communications,December 2004.

[4] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, “Energy Efficient Communication Protocol for Wireless Micro Sensor Networks”, Proceedings of IEEE HICSS, Jan 2000.

[5] Stefanos A. Nikolidakis, Dionisis Kandris, Dimitrios D. Vergados , Christos Douligeris **, “**Energy Efficient Routing in Wireless Sensor Networks Through Balanced Clustering”, *Algorithms, 6,* 29-42; doi:10.3390/a6010029, ISSN 1999-4893, 2013

[6] Rajesh Patel, Sunil Priyani, Vijay Ukani, “Energy and Throughput Analysis of Hierarchical Routing Protocol (LEACH) for Wireless Sensor Network*, “International Journal of Computer Applications* (975 – 8887) Volume 20– No.4, April 2011.

[7] Meenakshi Sharma, Anil Kumar. Shaw, “Transmission Time and Throughput analysis of EEE LEACH, LEACH and Direct Transmission Protocol: A Simulation Based Approach”, Advanced Computing: An International Journal (ACIJ), Vol.3, No.5, September 2012.

[8] P.T.V. Bhuvaneswari and V. Vaidehi, “Enhancement techniques incorporated in LEACH -A Survey”, Indian Journal of Science and Technology Vol.2 No5 (May2009)