



A Review on Low Energy Adaptive Clustering Hierarchy (LEACH) Routing Protocol in WSN

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Abstract -- A wireless sensor network consists of multiple numbers of nodes which enables the monitoring of a variety of environment in different location for applications that may include inventory management, habitat monitoring, forest fire detection, military application, vehicle tracking, disaster relief, and machine failure diagnosis. In WSN design, routing protocol with energy efficiency has been a challenging task. Efficiency, reliability and security must be essential in designing a routing protocol. In WSN numerous mechanisms have been proposed to reduce the impact of energy dissipation on communication protocols. The LEACH (Low-Energy Adaptive Clustering Hierarchy) [1] protocol is an elegant solution to this energy dissipation and data collection problem. In LEACH a small number of clusters are formed in a self-organized manner. In this paper we have analyzed routing techniques in WSN and LEACH protocol based on the research of LEACH protocol.

Keywords-- WSN, routing techniques, energy efficiency, LEACH, merits and demerits of LEACH, attacks

I. Introduction

In our daily lives we are constantly surrounded by thousands of wireless networks. Wireless sensor network is made of several tiny sensor nodes which are used to monitor physical or environmental conditions such as temp, pressure, sound, vibration at these locations. Each node has limited resources. When these large number of tiny sensor nodes form a wireless network and collaborate locally with each other in the neighborhood to perform some designated task, the task performed by the whole network is quite useful. Different kind of wireless sensor networks depends on the type of nodes or architecture of sensor networks. Shashi Phoha (Editor) et al [2] presents that Wireless sensor networks would constitute an important part of the next evolution in automation and many other areas too. The main task of wireless sensor nodes is to sense and collect data from a target field, process the data, and transmit the information back to specific sites where the underlying application resides. To set up route between target field and specific sites we need to develop energy efficient routing protocols. Route selection must satisfy the criteria such that it is secure, reliable and network lifetime is increased. The features of the environment within which sensor nodes typically do functioning, coupled with severe resource and energy constraint, make the routing problem very challenging. Since WSN is the class of wireless communication where data throughputs are very low and it is almost impossible to replace the battery for network with thousands of physically embedded nodes deployed over an inaccessible terrain, energy efficiency often comes as the first concern. Data fusion is a meaningful technique to save energy [3]. In Section II a brief taxonomy is provided for the basic routing strategies used to keep a balance between responsiveness and energy efficiency. LEACH protocol is one of the examples of energy efficient routing protocol supporting clustered architecture. Section III is providing a brief taxonomy of LEACH with its working procedure, section IV and V describes attacks in LEACH and merits and demerits of LEACH respectively.

II. Network Architecture Based Routing Techniques In Wsn

A number of limitations exist in routing in sensor networks are: dynamicity, high power consumption, low bandwidth, high error rates, and high delay. The design of routing protocol in WSNs is affected by many of challenging factors which must be overcome for efficient communication is achieved. G.H. Raghunandan et al [4] present some of the routing challenges and design issues that affect routing process in WSNs. Node deployment, scalability, autonomy, fault tolerance, working environment are some of these challenging factors according to G.H Raghunandan. The design of routing protocols for WSNs must consider the power and resource limitations of the network sensor nodes, the time-varying quality of the wireless channel or links, and the possibility for packet delay and their loss. To address these design specifications, several routing strategies for WSNs have been proposed.

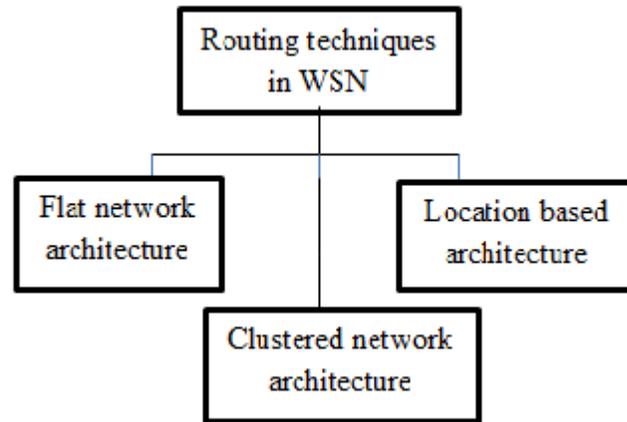


Fig.1 Routing Techniques in WSN

1). **Flat Network Architecture:** Flat network architecture is first class of routing technique in WSN. All nodes are considered as peers and sensor nodes work together to carry out the sensing task. Main feature of flat routing is that it provides equal functionality for all sensor nodes [5]. Flat network architecture has several others features, including tiniest overhead for infrastructure maintains and the capability for the finding of various routing paths between nodes which are communicating for fault tolerance [5].

2). **Clustered Network Architecture:** Clustered based network routing technique is key technique for prolonging network lifetime of a routing protocol. This class of routing techniques provides energy efficiency, scalability, and durability for clustered routing protocols. Here sensor nodes are arranged in clusters in which a node with greater residual energy is considered as cluster head. Cluster head works as the head of each cluster. Responsibility of cluster head is to coordinate activities for each cluster and passing information between clusters. Clustering has ability to reduce energy consumption and extend the lifetime of the network. Clustered architecture provides different functionality for a number of nodes [5].

3). **Location Based Approach:** A 3rd class of routing techniques is based on addressing of sensor nodes which depends on their geographic location. Distance of neighboring nodes is evaluated on the basis of received signal strength. Location-based routing is used in such area of applications where the node's position inside the network geographical coverage area is relevant to the query issued by the source node. Such type of a query may specify a specific area where a phenomenon of interest may occur or the vicinity to a specific point in the network environment. In this approach data routing depends upon the node's position [5]. Several routing algorithms have been proposed for data dissemination in WSNs.

III. Leach: A Pioneering Clustering Routing Approach For Wsns

A. Pravin Renold et al [6] states that the routing protocol plays a main role in transmitting the data from source by forming a route to the destination via intermediate nodes and also helps for the effective usage of the power of the nodes when not in the mode of transmission. M. Bala Krishna et al [7] presents that Energy efficient and energy aware protocols in sensor networks are based on the following characteristics:

1. **Data Aggregation:** collects data samples from a set of sensor nodes
2. **Data acquisition:** collects data samples periodically or event based
3. **Duty cycle:** Enables the radio-receiver of a sensor node in sleep or idle state to increase the node life cycle
4. **Cluster:** set of nodes with similar attributes like node distance and signal strength which are grouped together
5. **Mobility:** static sensor nodes save more energy as compared to dynamic sensor nodes. Mobile sensor nodes are used if the energy levels of nodes are uneven and enhance the data delivery rate [7].

The LEACH (Low Energy Adaptive Clustering Hierarchy) protocol is an energy-conserving routing protocol for wireless sensor network which is based on clustered based hierarchical routing technique. The basic idea of LEACH has been an ideal inspiration for many of subsequent clustering routing protocols. The main aim of LEACH is to select sensor nodes as CHs by rotation in each round, so the high energy dissipation in communicating with the BS is spread to all sensor nodes in the network. In section A there is brief discussion of working of LEACH protocol, merits and demerits of LEACH, attacks in LEACH protocol.

1). Working procedure of LEACH

LEACH was proposed by Heinzelman, Chandrakasan and Balakrishnan which is an adaptive clustering algorithm based on hierarchical cluster based routing technique for wireless sensor networks. LEACH organizes the nodes in to clusters. LEACH randomly selects nodes of cluster as cluster-heads (CH) and performs time to time reelection. Cluster Head (CH)

responsibility is to create and manipulate a TDMA (Time division multiple access) based schedule and passing aggregated data from each node to the BS where these data is required using CDMA (Code division multiple access). And all the remaining nodes acts as cluster members. The operation of leach protocol is split into two main phases: set up and steady.

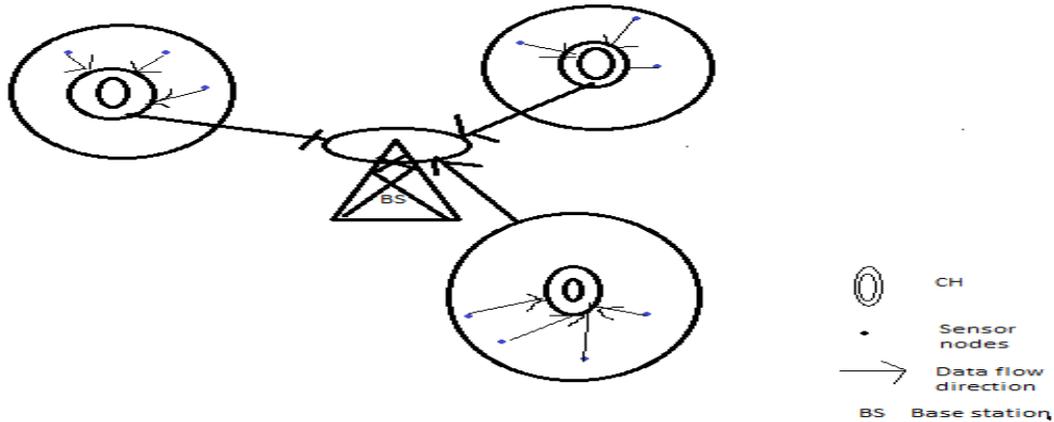


Fig 2 Architecture of LEACH.

2). **Two Phases of Leach:** LEACH is divided into rounds where each round consists of two phase, set-up phase which is responsible for cluster formation and steady phase which is responsible for data transmission

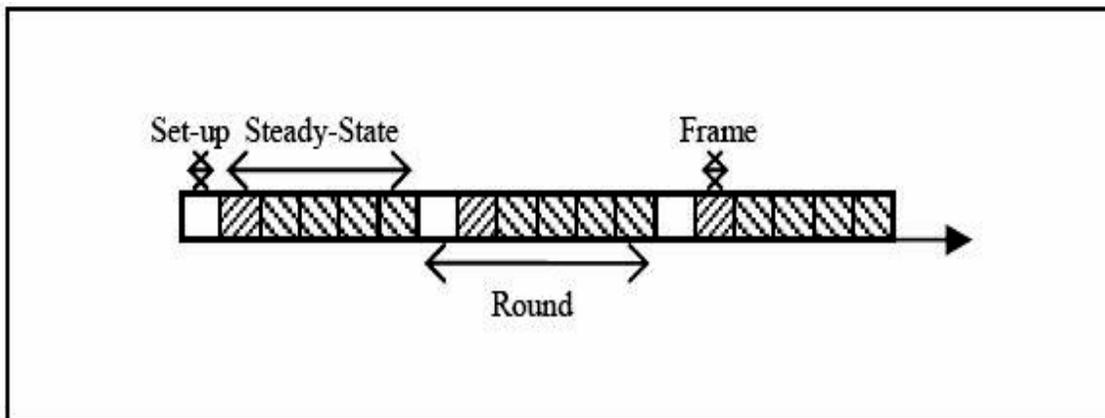


Fig.3 LEACH protocol phases [11]

Cluster setup Phase: First step is cluster head selection. At the first of each round, each node selects a random number between 0s and 1 and compares it to the threshold shown in formula. If the selected random number is less than the threshold, the node would be selected as a cluster head for the current round. The threshold $T(n)$ is calculated as

$$T(n) = \begin{cases} \frac{P}{1 - p^{(r \cdot \text{mod}(1/p))}}, & \text{if } n \in G; \\ 0, & \text{else} \end{cases}$$

Here P is the desired percentage of nodes which are cluster head here, r is the current round, and G is defined as the set of nodes that has not been selected as cluster-heads in the past $1/P$ rounds. This states that all sensor nodes eventually spend equal energy. After selection of cluster head, it advertises his selection to all remaining nodes. All nodes choose their nearest cluster head when they receive advertisement message based on the received signal strength. Then TDMA schedule is assigned by the CH for their cluster members or nodes.

In order to avoid signal interference near the cluster, cluster head can determine the CDMA codes which all nodes used. The CDMA codes which is used in the current phase and TDMA timing information will be sent together. When nodes within the cluster receive the message, they will send data to the cluster head in their own time slot. Algorithm will enter a stable phase. Heewook Shin et al. [12] show the setup phase by following diagram shown in fig 4.

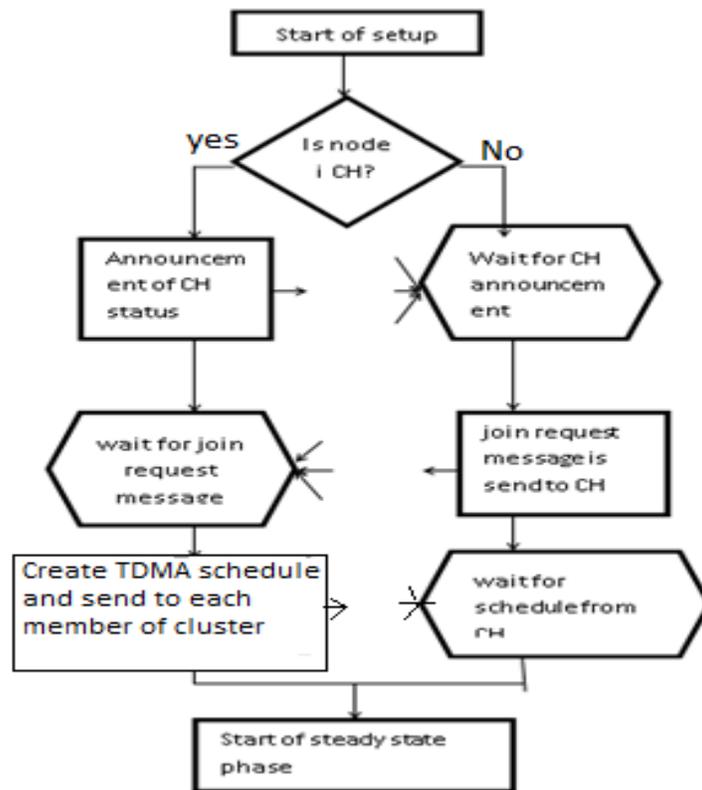


Fig.4 Cluster set up phase

Steady Phase: The steady state phase is the data transmission step. During this phase, nodes in each cluster send their data based on the allocated transmission time to their local cluster heads. To reduce the energy dissipation, the receiver of all non-cluster head nodes would be turned off until the nodes' defined allocated time. After receiving all the data from the nodes, the cluster head aggregates all the data sent from the member nodes into a single signal and transfers it to the base station.

IV. Attacks In Leach

LEACH protocol is more secure routing protocol when compared to traditional routing protocols. Leach is difficult to attack because in LEACH protocol, the only node that have direct communication link to base station is CH whereas in traditional multi-hopping routing protocols, the nodes in the vicinity of the base station are more likely to compromise. In LEACH; position of CHs can be any wherein the network irrespective of the base station. As CHs are periodically randomly changed so for the adversary spotting these CHs is very difficult. However, because it is a cluster-based protocol, rely upon fundamentally on the CHs for data aggregation and routing, attacks involving CHs are the most harmful. If any malicious nodes become a CH, then it can introduce and speed up attacks in our network which may be one of the attacks like Sybil attack, HELLO flood attack and selective forwarding attack. By taking advantage of this an intruder can broadcast a powerful advertisement to all the nodes in the network which may create that every node selecting the adversary as the cluster-head. After this adversary can then selectively transfer information to the base-station or modify or dump it.

Key management is an effective method to improve security for a network. These key management schemes typically consider that a node has an interaction with a quite static set of neighbors and that most of its neighborhood is discovered right after the deployment. However, in LEACH clusters are created dynamically (at random) and periodically, which have variation in interactions among the nodes and requires that any node needs to be ready to join any CH at any time. A number of standard key distribution schemes are presented but most of them are ill-suited to WSNs: considering an example, public key based distribution needs a lot of processing; global keying is quite exposed for attack; whereas a complete pairwise keying needs a huge memory [13]. And since WSNs consists of sensors with small computational power and negligible memory they are unable to incorporate these security mechanism

V. Merits And Demerits Of Leach

Based on analysis of LEACH protocol we have found some merits and demerits of LEACH protocol. Qing Bian et al. [8] also present some of the advantages and disadvantages of LEACH protocol on the basis of analysis of LEACH

1) Merits: The LEACH protocol as a typical sub-cluster routing protocol has the following advantages:

1. In leach protocol the hierarchy, selection of path and routing information is comparatively easy, and there is no requirements for network sensor nodes to keep large amounts of routing information, and do not need complex functions.
2. Second advantage is the cluster head node is randomly selected, the opportunity of each node is equal, and the load of whole network is balance. So that nodes, which is out of energy, can be randomly distributed.
3. And the LEACH algorithm uses hierarchical structure; due to data fusion mechanism cluster head reduces the energy consumption of data transmission, and therefore compared to the general multi-hop routing protocols and static clustering algorithm, LEACH protocol minimizes energy dissipation in sensor networks. LEACH can extend the network life-cycle of 15%.[9].

2) Demerits: Shijin Dai Xiaorong Jing et al [10] provides some problems of LEACH. They said that LEACH provided many good features to the sensor network; however, it suffers from the following problems discussed below.

It can't be applied to time critical applications. The nodes on the route from a hot spot to the sink might drain their energy quickly, which is known as "hot spot" problem.

Qing Bian et al. [8] presents that there are a number of deficiencies in LEACH algorithm, such as: LEACH does not consider the residual energy of each node in the account. Because the cluster head in LEACH protocol are randomly generated, energy consumption can be evenly distributed in the network; however, it ignores residual energy of nodes, geographic location and other information in the election of cluster head node. So it can easily lead to exhaust the energy quickly in cluster head nodes. LEACH assumes that all the nodes can be directly communicate with the cluster head node and the base station node, the actual network of base stations are usually far away from the sensing area, this would make the cluster head which is far from the base station is easier to fail. Therefore, expansion of the network is not strong, and is not suitable for large networks. Because the distribution of cluster head is totally dependent on the random number, so the number of the cluster heads can be big at a regional, and the number of the cluster heads will be little at other regional. In the cluster-heads centralized regional, the number of the general node is very little, and this can have lost the meaning of hierarchical routing; in cluster-heads sparse region, cluster head node is responsible for more data, where the distance from the cluster head is far, transmitted signal energy consumption is too large.

VI. Conclusion

Routing protocol has become an emerging topic of research now days. To increase the network lifetime of network, clustering approach is a primary approach to reduce the energy dissipation in WSN. Maximizing network lifetime is a major challenge in designing an efficient protocol. In this article we have analyzed the LEACH protocol which is an energy efficient reliable clustered routing protocol based on the network architecture of clustered routing technique. LEACH protocol is described and analyzed on the bases of network lifetime, stability period and the network throughput. The focus of this article is to study the advantages and disadvantages of the LEACH algorithm, and improve the algorithm for those disadvantages. Energy efficiency is primary concern which must be taken into consideration in any routing protocol. Although LEACH is best protocol in amongst all the routing protocols of WSN still it needs to be improved. This protocol can still be improved using three performance metrics average end to end delay, average delivery ratio of packets and energy consumption.

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