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Survey on Wireless Sensor Network Protocol to Enhance the Network Lifetime

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Abstract: Wireless sensor network consists of sensor nodes which are powered by battery; to communicate with each other for environment monitoring. Energy efficiency is the main issue in wireless sensor networks. Therefore, to maximize network lifetime and achieve maximum reliability and scalability, routing techniques have been developed. LEACH is the conventional hierarchical clustering protocol widely used in WSNs. This paper reviews the taxonomy of WSN routing protocols and also highlights issues in LEACH protocol along with disadvantages. The objective of this paper is to provide brief detail of some LEACH improved versions. Finally this paper compares some features of LEACH protocol variants.

Keywords: WSN, LEACH, HEED, LEACH-C, Network lifetime.

I. INTRODUCTION

Wireless Sensor Networks (WSNs) is considered as one of the most powerful technologies in 21st century. Recent advancement in Micro-electronic-mechanical-systems (MEMS) and wireless communication system, tiny, cheap and smart sensor nodes collaborated with wireless links and the internet deployed in physical area which provide many opportunities in various applications, for example battle field surveillance, environment monitoring, and health care applications.

Wireless Sensor Network is a special kind of non-infrastructure networks capable of wireless communication having large number of low-cost sensor nodes with limited power and multi-functional capability. A typical sensor node includes four basic components: a sensing unit, a processing unit, a communication unit, and a power unit as in figure 1.

WSNs are not centralized one as no static infrastructure exists. Peer-to-peer communication exists between nodes. Multi-hopping can cause a sensor node to communicate with a node that is not in radio range of each other via intermediate nodes. So WSN provides flexibility of adding or removing nodes in the network. The network can be divided into no. of clusters called clustering. In each cluster, one of the sensor nodes is elected as Cluster Head (CH) and the rest of the nodes act as Cluster Members (CM). All sensor nodes work in cooperation within each cluster to serve the request. Cluster head collects the data from its members and data aggregation is done by each cluster head to remove data redundancy and forwarded to the sink. As cluster head consumes more energy than cluster members, the workload of cluster heads is distributed among all nodes in wireless sensor network by rotating their roles to equalize energy consumption called Cluster Head rotation.

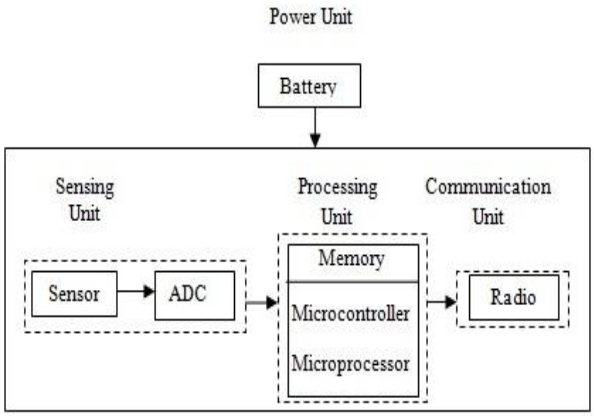

Fig. 1: Sensor Node Structure

Energy consumption is an important issue in WSN because sensor nodes are battery operated and cannot function without enough power level. The ever changing network topology and limited power-supply nodes make WSN quite challenging and become a popular research area.

II. CHARACTERISTICS OF WSNS

Unlike traditional wireless sensor networks like MANETs, WSN has unique characteristics as follows:

A. Dynamic Network Topology**:** Network topology changes frequently as nodes can be added or removed, node failure, energy depletion, or channel fading.
B. Application Specific: The design requirement of the network varies with required application.
C. Energy constrained**:** Nodes are portable and are highly limited in energy, computation and storage capacities. This is the most important design consideration of WSN.

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D. Self-configurable: Nodes are randomly deployed without careful planning. Once deployed, nodes have to configure autonomously themselves into a communication network.

III. WSN ROUTING PROTOCOLS

To optimize energy consumption in the network is to b. implement routing protocols defining set of rules specifying how message packets transfer from source to destination in a network efficiently and with less amount of energy consumed. Figure 2 shows the classification of routing protocols in WSNs.

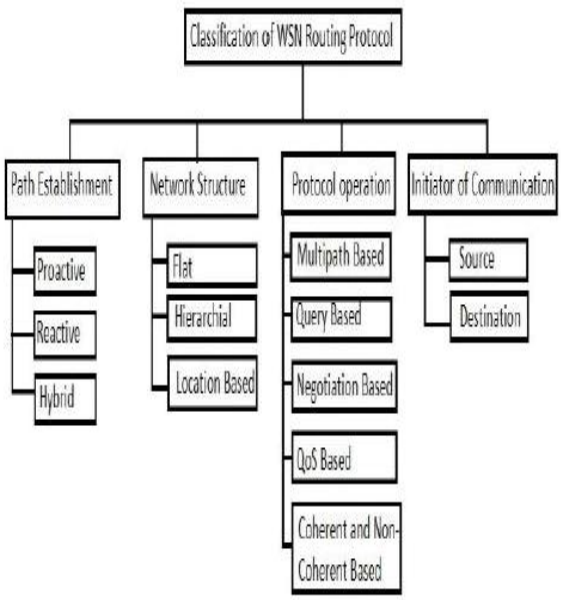

Fig. 2: Classification of WSN Routing Protocols

A. Path Establishment

a. Pro-Active (or Table Driven): Routing Protocols compute all the routes using classical routing strategies such as distance-vector before they are really needed and then store these routes in a routing table in each node. When a route changes, the change has to be propagated throughout the network periodically. Since a WSN could consist of thousands of nodes and needs a higher rate of routing table updates, the routing table that each node would have to keep could be huge and therefore proactive protocols are not suited to WSNs.
b. Reactive (or on-demand): Routing Protocols discover routes to destination only when they are needed by broadcasting route query or request messages into the network.
c. Hybrid protocols use a combination of these two ideas.

B. Network Structure

a. Flat-based Routing Protocols: Each node plays the same role in performing a sensing task and all sensor nodes are peers.
b. Hierarchical-based Routing Protocols: In this type of routing, sensor nodes are organizes into clusters, where the nodes with higher energy as served as cluster head(CH) used to collect data from cluster members(CM) having lower energy. The sensed data is sent to cluster heads by cluster members where data aggregation and data fusion is done to decrease the number of transmitted messages to the sink. This process of creating the clusters and cluster head rotation increases the network lifetime cycle, network scalability, and network reliability.
c. Location-based Routing Protocols: In this type of routing protocols, sensor nodes communicate on the basis of location of each node with other node. This location or distance can be measured by two ways- the distance between two neighboring nodes can be estimated by incoming signal strength from the source or using GPS (Global Positioning System).

C. Protocol Operation

a. Multipath-based Routing: It uses multiple paths rather than single path in order to increase fault-tolerance of the network on expense of increasing energy consumption and overhead of sending periodic messages to the alternative paths in order to keep them alive.
b. Query-based Routing: The destination node propagates a query to the network to send data. The node having data matching the query sends data to the desired node. Usually these queries are in natural language.
c. Negotiation-based Routing: This routing protocol takes communication decisions based on availability of resources in the network suppressing duplicate information and prevent redundant data from being sent to the next sensor node.
d. QoS-based Routing: This routing protocol balances the network between energy consumption and data quality in order to satisfy certain QoS metrics such as delay, and bandwidth.
e. Coherent-based Routing: In this routing protocol, the local processing of data is based on minimum processing (coherent) and the full processing (non-coherent).

IV. CLUSTER BASED HIERARCHICAL ROUTING PROTOCOLS: OVERVIEW

Low-Energy Adaptive Clustering Hierarchy (LEACH)] is a typical hierarchical clustering routing protocol, which adopts distributed clustering algorithm where cluster-head rotation mechanism, data aggregation, and data fusion technologies effectively improves the lifetime of network. In order to optimize energy in the network, nodes are selected as cluster head circularly and randomly. The normal nodes called cluster members join the corresponding cluster head nodes on the basis of principle of proximity. Normal nodes sense data and send directly to the cluster head nodes. The cluster head nodes receive sensed data, aggregate the data to remove redundancy and fusion processes are carried out and data is send to the sink (or Base Station). So LEACH increases network lifetime

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by decreasing network energy consumption, and reducing number of communication messages by data aggregation and fusion. The process of formation of clusters in LEACH is shown in figure 3.

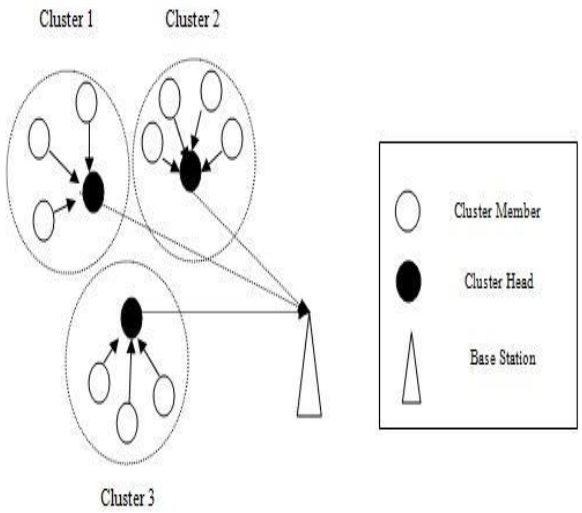

Fig. 3: Formation of Clusters in LEACH

In order to achieve the design goal the key tasks performed by Leach are as follows:

- Randomized rotation of the cluster heads and the corresponding clusters.
- Global communication reduction by the local compression.
- Localized co-ordination and control for cluster setup and operation.
- Low energy media access control.
- Application specific data processing.

A. Running Process of LEACH

The Leach operation is classified into different rounds, and each of these rounds has mainly two phases: the Set-up Phase and the Steady-state for data transmission.

a. The Set-up Phase: First, the LEACH protocol randomly selects cluster heads (CHs) by randomly generating a number (n) between 0 and 1, for each node. If this randomly generated number is less than the threshold value given by threshold function T (n), the node would be selected as cluster head node.

$$T(n) = \begin{cases} p/\left(1 - p\left(r \bmod \frac{1}{p}\right)\right), & n \in G \\ 0, & n \notin G \end{cases}$$

Where P is the cluster-head probability and G is the set of nodes that never be chosen as cluster-head nodes before 1/p round.

After the selection of cluster head nodes, each cluster-head node will send information via CDMA code to other nodes and normal nodes will join the corresponding cluster-head nodes. Then the cluster head nodes use TDMA to provide data transmission time for every node connected to them.

b. The Steady-state: This stage is for data transmission where normal nodes sense data and send this sensed data to their respective cluster-head nodes. The processing of received data (data aggregation and data fusion) is done by cluster head nodes and processed data will be sent to the base station.

V. DEFICIENCIES IN CLASSICAL LEACH PROTOCOL

A. Unreasonable cluster head selection: LEACH protocol doesn't take residual energy of each node into consideration for the selection of cluster head node as each node has equal probability of becoming cluster head. If low-energy node is being selected as cluster head node, then the network fails soon due to high energy consumption causes adverse to energy balancing among the network. This results data loss and lower in survival time of the network.

B. Unreasonable distribution of cluster heads: The random selection algorithm of cluster head nodes causes problem of imbalance in energy load. Distance factor is not considered in cluster formation due to which sometimes very big clusters and very class clusters exist at the same time in the network. More the distance between cluster head node and base station, more the energy consumption of that node.

C. More responsibility on Cluster Head node: Cluster head nodes perform data aggregation and send processed data to the base station in single-hop due to which cluster head nodes deplete their energy too fast as compared to normal nodes. Also if a cluster head node fails, the whole nodes linked to it will deplete their energy too.

VI. HEED

HEED (Hybrid Energy Efficient Distributed) protocol is the clustering protocol. It uses using residual energy as primary parameter and network topology features (e.g. node degree, distances to neighbors) are only used as secondary parameters to break tie between candidate cluster heads, as a metric for cluster selection to achieve load balancing. In this all nodes are assumed to be homogenous i.e. all sensor nodes are equipped with same initial energy. But, in this paper we study the impact of heterogeneity in terms of node energy. We assume that a percentage of the node population is equipped with more energy than the rest of the nodes in the same network - this is the case of heterogeneous sensor networks. As the lifetime of sensor networks is limited there is a need to re-energize the sensor network by adding more nodes. These nodes will be equipped with more energy than the nodes that are already in use, which creates heterogeneity in

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terms of node energy, leads to the introduction of H-HEED protocol.

VII. LEACH-C

Due to distributed clustering algorithm, LEACH protocol offers no guarantee about the effective location and optimal number of cluster head nodes. LEACH-C protocol uses the centralized clustering algorithm. This protocol is proposed as an improvement of the LEACH protocol. For producing better performance, this protocol dispersing the cluster head nodes throughout the network. It is useful, where sensor nodes have to transfer data through a long distance and less energy consumed. LEACH-C is divided into phases as LEACH: setup phase and steady state phase. Steady state phase is same as LEACH. In LEACH-C, during setup phase each sensor node sends information about their current node location and residual node energy to base station at start of each round. Based on the information, BS considers some nodes as cluster head nodes and non cluster nodes.

Using central clustering algorithm, BS computes average energy level and whichever nodes have energy level below average energy level cannot be categorized as cluster head nodes for current round. The nodes that have energy more than average energy are selected for cluster heads. This algorithm minimizes the amount of energy for non cluster head nodes to transmit their data to the cluster head nodes by minimizing the distance between all cluster head nodes and non cluster head nodes. BS considers some nodes as CHs and Non CHs. BS broadcasts a message of cluster head IDs to all nodes. If node ID is same as cluster head ID, is selected as cluster head and determine TDMA schedule for data transfer. Steady phase of LEACH-C is identical to that of LEACH, but LEACH-C enhances the number of packets received at the BS. It is because of their optimal selection of CHs.

VIII. RELATED WORK

Several researchers have evaluated and presented comparative analysis of WSN Routing protocols. Several conclusions have been drawn by evaluating the performance of routing protocols. Alakesh Braman et al. provided a brief introduction of routing challenges and some design issues in WSNs. This paper also provided the comparative analysis of various routing protocols along with the most energy efficient protocol (LEACH) along some of the improve versions of it. J.Gnanambigai et al. surveyed the different hierarchical routing protocols derived from LEACH. This paper highlighted issues and drawbacks of LEACH and discussed a comparative study of features and performance issues of all hierarchical protocols.

Mian Ahmad Jan et al. presented a brief survey of Cluster-Based Hierarchical routing protocols that how protocols organize nodes into clusters. A comparison among clustering protocols taking features such as their transmission mode and selection algorithms for CHs has been carried out. M.Usha et al. provided the comparative analysis of LEACH and its descendants based on metrics like mobility, reliability and hop count. Vinay Kumar et al. presented taxonomy of energy efficient clustering algorithms in WSNs and also presented the timeline and description of LEACH and its descendants. P.Manimala et al.surveyed different hierarchical protocols developed from LEACH along with their pros and cons.

IX. CONCLUSION

Efficiently use of energy in the network has been the main issue in WSNs for prolonging lifetime of the network. LEACH has found one of the most energy efficient protocols used in WSN. In this survey, LEACH protocol has been discussed with its drawbacks and how these drawbacks are overcome by its descendants. A brief study of various improved versions of LEACH protocol has been done in order to compare performance of these descendants with the classical LEACH. It is concluded from given survey that for prolonging network lifetime of WSN, there is need to explore more robust, reliable and efficient protocols in future.

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