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Hierarchical Clustering Algorithm LEACH -A Review

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***ABSTRACT* - Wireless Sensor Network provides the means of developing a sensor node with low weight, cheap processor and less power. Wireless sensor networks consist of minor battery driven devices with restricted energy resources. Sensor nodes can self-organize to form networks and communicate with each other using their wireless interfaces and transmit to the destination as multi-hop. Energy proficiency is a vital design issue that needs to be boosted in order to increase the life span of the network. Numerous protocols have been designed to increase the operative life span of a network with a restricted energy supply. Hierarchical routing protocols are the best known protocols to minimize the energy consumption. Leach is one of the fundamental hierarchical routing protocols that can be used for minimizing the energy consumed in collecting and disseminating the data. In this paper we have discussed the LEACH protocol and its variants.**

I. INTRODUCTION

WSN is a very large array of diverse sensor nodes that are interconnected by a communication network. The fundamental objectives for WSN are reliability, accuracy, flexibility, cost effectiveness, and ease of deployment [12]. WSN is made up of individual multifunctional sensor nodes. The design of WSN is influenced by many factors, including fault tolerance, scalability, production costs, operating environment, sensor network topology, hardware constraints, transmission media, and power consumption[1].

The components of a sensor node are shown in Fig 1. The sensor node senses the physical quantity being measured and converts it into an electrical signal. Then, the signal is fed to an A/D converter and is ready to be used by the processor. The processor will convert the signal into data depending on how it is programmed and it sends the information to the network by using a transceiver. The power unit may be supported by solar cells or battery.
These sensor nodes operate in an ad-hoc manner and they have specific features. The design for all protocols focuses on the extension of network lifetime, since sensor nodes have a limited amount of energy.

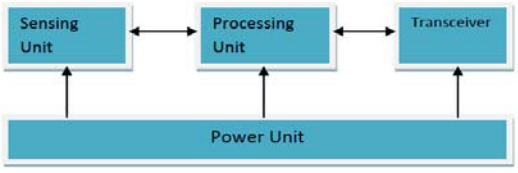

Fig 1. Components of a sensor node.

The implicit operations of WSN are a variety of information processing techniques. These are used for the manipulation and analysis of sensing data, the extraction of significant features, and the efficient storage and transmission of important information. Some application examples of WSNs include:

- Target field imaging
- Intrusion detection
- Weather monitoring
- Security and tactical surveillance
- Distributed computing
- Detecting ambient conditions such as temperature, movement, sound, light, or presence of certain objects
- Inventory control

Despite the innumerable applications of WSNs, these networks have several restrictions, which should be considered when designing any protocol for these networks. Some of these limitations include:

- Limited energy supply. WSNs have a limited supply of energy. Thus, energy-conserving communication protocols are necessary.
- Limited computation. Sensor nodes only have limited computing power. It includes simple operations of data compression and analog to digital processing.
- Communication. The bandwidth of the wireless links connecting sensor nodes is often limited, thus constraining the inter sensor communication.

II. LEACH

Heinzelman et al. [2] introduced a hierarchical clustering algorithm for sensor networks called Low Energy Adaptive Clustering Hierarchy (LEACH). LEACH is a cluster-based protocol that includes distributed cluster formation. . LEACH randomly selects a few sensor nodes as cluster heads and rotates this role to evenly distribute the energy load among the sensors in the network. It creates the clusters of the sensor nodes that are based upon signal strength. The local cluster heads are used as routers to the sink. In LEACH, the cluster heads compress the data, that is arriving from the member nodes and it send an aggregated packet to the BS. It helps to reduce the amount of information that is transmitted to the BS. It uses TDMA/CDMA MAC to reduce inter- and intra-cluster collisions.

The operation of LEACH is separated into two phases: the setup phase and the steady state phase. The duration of the steady state phase is longer than the duration of the setup phase in order to minimize overhead.

A. Setup phase:

In this phase, a predetermined fraction of nodes, p, elect themselves as cluster heads . A sensor node chooses a random number, r, between 0 and 1. The node becomes a cluster head for that current round, if the random number is less than a threshold value, T(n). The threshold value is calculated based on the following formula:

$$T(n) = \begin{cases} P/(1-P*(r \bmod 1/P)) & \text{if } n \epsilon G \\ 0 & \text{else} \end{cases}$$

where G is the set of nodes that that have not been cluster heads in the last 1/p rounds. Using this threshold , T(n), each node will be a cluster-head at some point within 1/p rounds. Nodes that have been cluster heads cannot become cluster heads for a second time for P rounds. After that, each node has a 1/p probability of becoming a cluster head in every round.

After the cluster heads have been elected, they broadcast an advertisement message to the rest of the nodes in the network that they are the new cluster heads. Upon receiving this advertisement, all the non-cluster head nodes decide on the cluster to which they want to belong, based on the signal strength of the advertisement. The non-cluster head nodes inform the appropriate cluster heads that they will be members of the cluster.

B. Steady Phase

After receiving all the messages from the nodes that would like to be included in the cluster and based on the number of nodes in the cluster, the cluster head node creates a TDMA schedule and assigns each node a time slot when it can transmit. This schedule is broadcast to all the nodes in the cluster. During the steady state phase, the sensor nodes can begin sensing and transmitting data to the cluster heads. The cluster head node, after receiving all the data, aggregates them before sending them to the base station. After a certain time, which is determined a priori, the network goes back into the setup phase again and enters another round of selecting new cluster heads. Each cluster communicates using different CDMA codes to reduce interference from nodes belonging to other clusters.

III. LIMITATIONS OF LEACH

Although LEACH is able to increase the network lifetime, but still there are number of issues about the assumptions used in this protocol. LEACH assumes that all nodes can transmit with enough power to reach the base station if needed. Secondly, cluster head selection is probabilistic, so it is possible that the node with low energy may be selected as cluster head. When this low energy node dies the whole cluster becomes non-functional. It is also assumed that the cluster head has a long communication range so that the data can reach the base station directly. But this assumption is not always true because the network is deployed in large region and therefore all the cluster heads may not communicate directly. Also , nodes may be located far away which might not be included in any cluster.

IV. VARIANTS OF LEACH

Keeping in view the problem of LEACH, various modifications have been made to the LEACH protocol. Some of these are LEACH-C [3], E-LEACH [4], TL-LEACH [5], LEACH-H [6], M-LEACH [7], V-LEACH [8], LEACH-B [9], FZ-LEACH [10] and U-LEACH [11].

In LEACH protocol the cluster heads are not uniformly distributed. They may be located at any place in the cluster. LEACH-C [3] is an improvement over the LEACH protocol. This protocol uses the centralized clustering algorithm, and the steady-state phase that is used by LEACH. In LEACH-C each node sends their current location information and residual energy level to the sink.

In Energy LEACH (E-LEACH) protocol the cluster head selection is based on the residual energy level of the nodes. The residual energy level decides that whether the node will become a cluster head or not after the first round [4]. In this protocol all nodes have equal probability to become the cluster head in the first round. The residual energy level in the second round is different for each node because of the first round communication. In this protocol the nodes that have a more energy level will become the cluster head rather than the nodes with low energy level. Therefore, this protocol improves the cluster head selection procedure.

The problem in LEACH protocol may occur when the cluster head is far away from the base station. The cluster head which is far away from base station require more energy to transfer the information to the base station and therefore it will die soon. Therefore to solve this problem Two-level LEACH (TL-LEACH) protocol [5] was designed. In this protocol, the cluster head is responsible for collection and fusion of data like LEACH protocol from respective cluster members, but the cluster heads will not directly forward the data to the base station. It uses one of the cluster head that lies between cluster head and base station as a relay station.

LEACH-H [6] (Hybrid Cluster Head Selection Leach) was proposed in order to overcome the defect of short survival time and low degree of load balancing in case of LEACH. It uses the advantages of LEACH and LEACH-C. Cluster head is selected in the first round by base station in Leach-H, which effectively resolves the problem that the number of cluster head is uncertain in Leach. In the other rounds , the new cluster head used in the next round is selected in their own cluster by the current cluster head in Leach-H, which resolves the issue of the dependence on the base station in Leach-C.

If the cluster head is far away from base station then it may require large amount of energy to transmit the data to base

station. In this case, Multihop-LEACH (M-LEACH) protocol [7] can be used. It works by changing the transmission mode between cluster heads and base station from single hop to multi hop. This protocol chooses the best possible path between the cluster head and base station by using the other cluster heads as relay stations to send data to base station.

In LEACH protocol the cluster head is responsible for receiving data from cluster members, fusion of received data and then send it to the base station. If base station is far away from cluster head then cluster head will die soon as compared to other nodes because the energy will dissipate in receiving and forwarding of the data. If the cluster head dies then the data collected by the cluster head will never reach to the base station and therefore the cluster will become useless.

V-LEACH [8] protocol solves this problem by introducing the vice-cluster head. In V-LEACH protocol a cluster contains a cluster head, vice-cluster head and cluster nodes. In this protocol if the cluster head dies then vice-cluster head will start working as cluster head and the cluster head data will reach to the base station. There is no need to elect the new cluster head, so it will save the energy and enhance the network life time.

LEACH-B [9] solves the problems, number of cluster heads and the ignorance of the node's residual energy, found in LEACH. This protocol adds a second selection of cluster heads to modify the number cluster-head in the set-up phase considering the node's residual energy per round. In order to save the energy consumption and to prolong the life span of the network, the protocol ensures that the partition of cluster is balance and uniform.

FZ-LEACH [10] eliminates the problem the reduction in lifetime of WSN occurred due to large and very small clusters in the network by forming Far-Zone. Far-Zone is a group of sensor nodes which are placed at locations where their energies are less than a threshold.

LEACH utilizes randomized rotation of Cluster-Heads (CHs) to evenly distribute the energy among the sensors in the network. But LEACH cannot select CHs uniformly throughout the network. Therefore there is the possibility that the elected CHs will be concentrated in certain area of the network. Hence, some nodes will not have any CHs in their vicinity. U-LEACH [11] is an approach to address this problem. It describes a Uniform Distribution Technique (UDT) for selecting CHs and their corresponding clusters.

V. CONCLUSION

The primary limiting factor for the lifetime of the sensor network is the energy supply. Each sensor node must be designed in such a manner that it utilizes its battery supply in order to maximize total network lifetime. Clustering in the network's topology reduces number of transmissions in the network. It also provides energy efficiency as cluster heads aggregates the data from its cluster members, thereby reduce duplication of transmission and enhances the network lifetime. In this paper, we have presented selected clustering protocols for WSNs which describes various modifications carried over the primitive LEACH and highlighted their features. Some of the achievements derived by the discussed cluster-based routing protocols are scalability, heterogeneity and prolonging network lifetime.

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