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Classification and Comparison of Different Hierarchical Routing Protocols in Wireless Sensor Networks

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Abstract: *The wireless sensor networks (WSNs) is one of the emerging research field in the scientific world. Sensor nodes are power limited main components of WSNs which are scattered in the sensor field. Basically sensor nodes are small tiny devices that have responsibilities of sensing the surrounding, computation and communication of sensed data. Enhancing the durability of sensor network and to make energy efficient routing protocol, are two special needs of WSN. This paper gives a brief introduction about the wireless sensor network including its application, limitation and review of various hierarchical routing protocols. In hierarchical routing, nodes are organized in the form of cluster. Each cluster has a special node called cluster head to perform data transmission from all its members to the base station. We also perform comparison between these protocols in terms of various network parameters.*

Keywords: *Hierarchical Routing, LEACH, LEACH- C, PEGASIS and HEED.*

1. INTRODUCTION

A wireless sensor network contains number of sensor nodes which are restricted in energy and radio range. These sensors are located randomly over the changing environment to sense the environment. These sensed information is then send to sink node.

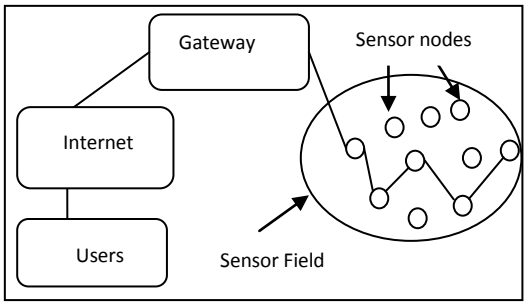

Figure1: Architecture of WSNs

Sensor nodes consume their limited energy to perform functions like collecting, processing and aggregating the data and pass it to gateway node (sink) then user can access the data through the internet as shown in figure 1 [1]-[2].
The WSNs is used in various fields of everyday life activities or services like Monitoring and Controlling Traffic, Weather areas, Structural Health Monitoring, Agriculture, Healthcare and medical research, Homeland Security, Military applications, Monitor environmental pollutant detection of chemical/biological agents, Fire Detection in forest[3].

2. LIMITATIONS OF WSN

Whether the WSNs have unlimited applications and starting to become a reality in this world, but WSNs have some limitations such as:-

- Restricted Energy(Energy consumption)
- Durability of Network
- Dynamic topology
- Application specific Dependency
- Power restrictions
- Limited computational resources
- Cluster formation and CH selection
- Security issues
- Synchronization
- Aggregation of data
- Repair Mechanisms
- Quality of Service (QoS)

To make network stability long last it should require sensor node consume less energy and become available in the network for long time. Thus energy consumption is an important issue of WSN which required a way to reduce the energy consumptions of sensor nodes used in WSN [4].

3. CLASSIFICATION OF NETWORK ROUTING PROTOCOL

On the basis of network structure routing in WSNs can be categorized into three 3categories:
Therefore this paper is mainly focus on hierarchical base routing protocol LEACH, LEACH-C, PEGASIS and HEED. Also show the comparison between them.

3.1 Flat-based routing (Data Centric):

All nodes in network have equal responsibility and perform same functions.

3.2 Location-based routing (Geographic):

In this, all nodes have their roles to route data according to their locations.

3.3 Hierarchical-based routing(Clustering):

In this scheme, sensor nodes of network are organized in number of groups these groups are called cluster. Each cluster

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has a special node called cluster head and the rest nodes are called members of that cluster. Cluster head is responsible for many functions like receiving data from its members, aggregating them and transmit data to the base station. Cluster formation concept reduces the energy consumption of nodes [5].

4. CLUSTERED ROUTING IN WSN

1. LEACH Protocol

Low Energy Adaptive Cluster Hierarchy (LEACH) [6] distributes the energy to sensor node randomly which indicate even distribution of energy over the network. In LEACH, sensor nodes organized themselves in a form of clusters and every cluster is associated with a cluster head. CH is selected randomly so that the energy dissipation among nodes can be balanced [6].LEACH Algorithm contains a periodic process in which each round has two phases-

Setup phase

a) Advertisement Phase: In this phase, the CHs send advertisement packet to their neighborhood. By this packet, nodes get to know to which CH they are belonging. Every node n in the network chooses a random number *k* between 0 and 1. If $k < T(n)$ for node *n*, the node becomes a cluster-head. The selection of cluster heads will be done by the following equation (1):

$$T(n)\begin{cases} \frac{P}{1-P\left[r*mod\left(\frac{1}{P}\right)\right]} & if n \epsilon G \\ 0 & Otherwise \end{cases} \quad (1)$$

Where P = the desired percentage of cluster heads (e.g., P= 0.05), r=the current round, and G is the set of nodes that have not been cluster-heads in the last $1/P$ rounds [6].

b) Cluster Set-up Phase: CH received information about its member nodes.

c) Schedule Creation: CHs provide a time schedule for each node in which they can send their data to respective CH.

Steady-State phase

Data Transmission: In first transmission all nodes transmit their data to respective CH. In second transmission once CH received all data from its members it minimize the data without losing meaning of data so that it can save energy instead of sending the complete data. And then send minimized data to destination node (sink).

Although LEACH protocol reduces the transmission energy and does not require global knowledge of network but still it have problems like:

• CHs are randomly selected, so network cannot remain with uniform energy dissipation.

• Because LEACH uses single hop transmission so it is not able to cover a wide area.

2. LEACH-C Protocol

The only difference between LEACH protocol and LEACH-C protocol is in their Setup phase however the Steady state phase remains ideal in both of them. In LEACH-C cluster formation is performed by the base station (sink), unlike LEACH where nodes self-elect themselves as CH. Initially in the LEACH-C, all nodes of the network send their information like: location, energy level to the Base Station (BS) [7]. After this BS calculates optimal number for nodes can be CH. Only those nodes can be CH who has sufficient energy. Advantages of this protocol over LEACH are number of CH in LEACH are not fixed it changes according to round to round but in LEACH-C BS calculates number of CH for every round.

Drawback of LEACH-C is sink node require global knowledge of network for cluster formation.

3. PEGASIS Protocol

Power-Efficient Gathering in Sensor Information Systems (PEGASIS) [8] in which sensor nodes are organized in the form of chain then each node can transmits and receives data from its neighbor and only one node is selected as leader from that chain to transmit the data to the base station (sink). The chain construction is performed in a greedy way. Unlike the LEACH it avoids cluster formation and uses only one node in a chain to transmit to the BS (sink) instead of using multiple nodes (CH).In LEACH multiple nodes are selected as CH from different clusters to transmit the aggregated data to the BS but in PEGASIS only one node is selected as leader to transmitting the data to BS. Node is selected as leader by ***r mode n*** equation to transmit to BS in round r where n is no of nodes in the network. When a sensor fails or dies due to low battery power, the chain is reconstructed using the same greedy approach by bypassing the failed sensor.

Disadvantage of PEGASIS is when no of nodes increase in network then chain length will also increase so PEGASIS introduces excessive delay for distant node on the chain. In addition the single leader can become a bottleneck.

So Hierarchical-PEGASIS was introduced which is an extension to PEGASIS, in order to decrease the delay incurred for packets during transmission to the BS simultaneous transmissions of data messages are pursued.

4. HEED Protocol

Hybrid Energy Efficient Distributed clustering Protocol (HEED) protocol [9] also uses the basic LEACH protocol scheme with some advancement. In this protocol, CH selection is based on two parameters residual energy of node and network topology. When any node left unattended, means node is neither a CH nor a member of a cluster in any iteration of CH selection process then that node have doubled probability to become CH in the next iteration of CH selection process. Node, which has more residual energy have more chances to be a CH. Thus residual energy of any node is the primary parameter for the CH selection. When a node has more than one CH (node falls within range of more than one CH) then it should require deciding one CH for that node because each node should has only one CH at any time. This tie situation can be solved by intra cluster communication cost. In tie situation node chooses that CH or becoming a member of that CH to which this node has lower intra communication cost to save the energy. As this routing scheme has probabilistically self-elected independent CH

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selection process but it cannot provide the guarantee of optimal elected set of CH. Each node performs neighbor discovery, and broadcasts its cost to the detected neighbors. This protocol includes three steps for selection of the CHs which are initialization phase, repetition phase and final phase. In initialization phase each node sets its probability of becoming a cluster head, *CHprob*, as follows

$$CH_{prob} = (C_{prob} \times \left(\frac{E_{residual}}{E_{max}}\right)) \qquad (2)$$

In repetition phase node keeps on discovering the node with lower communication cost. When node does not find an appropriate node then it selects itself as a CH. In final phase, nodes are selected CH. Where, *Cprob*is the initial percentage of cluster heads among n nodes, while *Eresidual* and *Emax* are the residual and the maximum energy of a node (fully charged battery), respectively [9].

5. COMPARISON

As discussed above all protocols have their own merits and demerits thus protocols are application specific. In this section we compare all discussed routing protocol based on some network parameters as architecture, hop, CH selection criteria etc. as shown in the table 1. Only LEACH-C protocol include selection of CH by the base station so this protocol require global knowledge of network whereas in the rest of protocols CH selection is performed independently by probabilistic approach.

Table 1: Comparison of various routing protocols

Scheme	Advantage	Disadvantage	Architecture	Cluster Formation	Cluster head Selection criterion	Cluster Stability	Global knowledge of network
LEACH	Low energy distributed protocol	Not applicable for large area network because clustering leads overhead	Distributed	Present	Elected rotation-wise by probabilistic approach	Very low	Not Required
LEACH-C	Less data transmission energy than LEACH	Overhead	Centralized	Present	Selected by BS w.r.t. nodes energy and distance	Low	Required
PEGASIS	Transmission distance for most nodes reduced	Redundant data transmission	Linear	Not present	No CH present	NA	Not Required
HEED	Requires only local information to form the clusters	Lots of packets are broadcasted due to several iteration to form clusters	Distributed	Present	Based on Residual energy, intra cluster communication	Higher than LEACH C	Not Required

6. CONCLUSION AND FUTURE WORK

This paper provides a complete review of some hierarchical routing protocols named as LEACH, LEACH C, PEGASIS and HEED. Also do the comparison between these protocols in terms of their advantage, disadvantage and various other parameters. There is lot more to perform research work in terms of energy dissipation and network lifetime. As WSN have tremendous growth in almost all areas of life, still it requires some advance methodology to solve the energy efficiency problem.

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