

Hierarchical Routing Scope & Limitations in WSN

Ravinder Kumar¹, Dr. Ajay Jangra

¹Student, ² Asst. Proff., CSE department, UIET Kurukshetra University

¹ravinder.lehra89@gmail.com, ²er_jangra@yahoo.co.in

Abstract: Wireless Sensor Networks (WSN) is emerging technology and WSN mainly consists of small nodes which are left unattended on the site to gather information, these nodes gather information and send information to base-station (gateway) which is far away from these sensor nodes. Sensor nodes are battery powered, once battery power consumed it cannot be recharged, so energy efficiency is the important issue in WSN to enhance the network life. In this paper we discuss about hierarchical routing (HR), its various protocols, Limitations and future scope. HR is cluster based technique with data aggregation overcome limitations of single-tier network.

Keywords: WSN, Architecture, Applications of WSN, Hierarchical Routing, Limitations, LEACH.

1. INTRODUCTION

Sensor Networks are widely used to gather information from surroundings in which these are undertaken as used in many applications like sensing weather conditions, target tracking and target detection, military surveillance, health monitoring and many other applications. A wireless sensor network (WSN) generally consists of a base station (gateway) that can communicate with a number of wireless sensors via a radio link. Data is collected at the wireless sensor node, compressed and transmitted to the gateway directly or, if required, uses other wireless sensor nodes to forward data to the gateway. The transmitted data is then presented to the system by the gateway connection [1]. A WSN typically has little or no infrastructure. It consists of a number of sensor nodes (few tens to thousands) working together to monitor a region to obtain data about the environment. There are two types of WSNs: Structured and Unstructured. An unstructured WSN is one that contains a dense collection of sensor nodes. Sensor nodes may be deployed in an ad hoc manner into the field. Once deployed, the network is left unattended to perform monitoring and reporting functions. In a structured WSN, all or some of the sensor nodes are deployed in a pre-planned manner. The advantage of a structured network is that fewer nodes can be deployed with lower network maintenance and management cost. In WSNs, each node may be equipped with a variety of sensors, nodes then organized in clusters, detecting events. Each node has sufficient processing power to make a decision, and in turn broadcasts the decision to other nodes in the cluster. One node may act as the cluster master and the communication takes place through radio waves using a protocol such as IEEE802.11 or Bluetooth [1][2].

Communication architecture of wireless sensor networks consists of user, sink, and sensor node shown in figure. In the communication architecture, a user connects with a network and communicates a sink through a task manager node. A sink instructs sensor nodes to carry out tasks interested by the user, and sensor nodes gather data and forward it to the sink by wireless multi-hop communication manner [6].

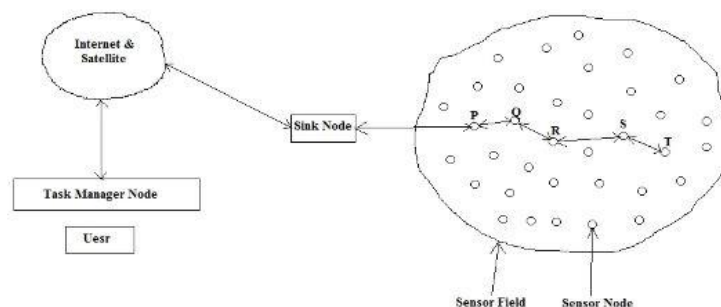


Fig 1: Communication architecture of WSN

Sensor node architecture; A key feature of any wireless sensing node is to minimize the power consumed by the system. Therefore, it is necessary to send data over the radio network only when required. The sensor nodes are small devices that consists of four basic components 1) Sensing Unit, 2) Processing Unit, 3) Communication Unit or Transceiver Unit, 4) Power Unit. Processing Unit is composed of memory unit and controller (CPU). These sensor nodes have limited battery power, communication range and memory [4][6].

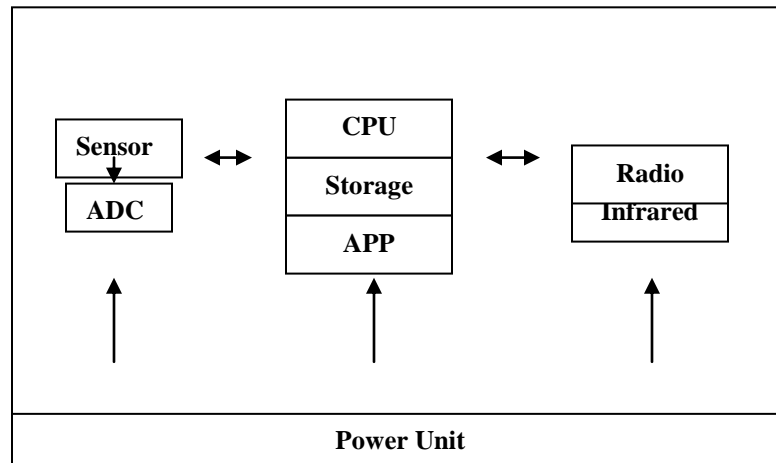


Fig 2: Sensor Node Components

In most cases, the sensors forming these networks are deployed randomly and left unattended and are expected to perform their function properly and efficiently, but Sensor networks are also energy constrained. An appropriate solution for this problem is to implement routing protocols that perform efficiently and utilizing the less amount of energy as possible for the communication among nodes[4][6].

2. APPLICATIONS OF WSN

Wireless sensor networks is an emerging technology, as this technology broaden, new ideas comes in front to use these sensor nodes in different ways and in different fields. Main wsn applications are [2]:

Tracking application include number of fields in which we apply sensor nodes for tracking. In military enemy tracking, in habitat animal tracking ,public application include traffic tracking and vehicle tracking and in some business applications humane tracking is also done.

Monitoring application include security detection in military services, animal monitoring in habitat, inventory monitoring in business applications. Public/industrial applications include no. of application, for example structural monitoring, factory monitoring, inventory monitoring, machine monitoring, chemical monitoring. Health monitoring include monitoring of patient health, environment monitoring include monitoring weather conditions. Other applications include nuclear reactor control, fire monitoring and in field experiments[2][3].

3. ROUTING

Wireless Sensor Networks are the emerging technology composed of sensors, communication and computer technologies. The limited amount of energy of sensor node makes it difficult to performs its function for long time, so energy efficiency is an important factor in WSNs[2][5][6]. Once the node's energy get depleted, it stops performing its function, so information related to that node cannot be received, so energy efficiency and its optimization is necessary to enhance network lifetime. An appropriate solution for this problem is to implement routing protocols that perform efficiently and utilizing the less amount of energy as possible for the communication among nodes. The function of routing protocol for wireless sensor networks is to establish the routing between the sensor nodes and the cluster nodes and reliably deliver data. The main functions of routing protocols are: Identify node address according to data attribute, Send detected data to sink node, eliminate redundancy by merging data, thereby reducing bandwidth power and power consumption. Quality of routing protocols depends upon the amount of data successfully received by base-station from sensors nodes deployed in the network region. Consequently many protocols have been proposed in order to minimize the energy of these sensor nodes. These routing protocols can be classified according to the network structure, protocol operation, resource utilization, or routing algorithms. According to network we have three types of routing protocols. 1) Flat Routing Protocols, 2) Hierarchical Routing Protocols, and 3) Location-based Routing Protocols[6][7].

4. HIERARICAL ROUTING(HR)

Hierarchical routing protocols also known as cluster-based routing. The concept of hierarchical routing is also utilized to perform energy efficient routing in WSNs. In a single-tier network, the gateway overload with the increase in sensors density. Such overload might cause latency in communication[2]. To overcome this additional

load and to be able to cover a large area of interest without degrading the service, networking clustering is used in some routing approaches. Hierarchical routing is mainly two-layer routing where one layer is used to select cluster heads and the other layer is used for routing. The basic idea is as follow: At level 0, every node belongs to its own cluster. Neighboring single clusters are logically grouped into level-1 clusters, which, in turn, are grouped into level-2 clusters, and so on until there is one or a few top-level clusters that cover the whole network. As a result, at every level of the hierarchy, each node belongs to exactly one cluster[11].The main aim of hierarchical routing is to efficiently maintain the energy consumption of sensor nodes by involving them in multi-hop communication within a particular cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the sink. There are many hierarchical routing based protocols, LEACH (Low Energy Adaptive Clustering Hierarchy) is one of the basic energy efficient hierarchical routing protocol. Other HR based protocols are PEGASIS,TEEN,APTEEN,EEHC,HEED.LEACH(Low Energy Adaptive Clustering Hierarchy)LEACH is a protocol based on clustering hierarchy architecture. In this protocol, nodes are organized into different clusters each of which has a cluster-head and each cluster-head fuses data from its members before transmitting them to the base station. Sensors elect themselves to be local cluster-heads at any given time with a certain probability[6][8]. In order to avoid cluster-heads dissipating too much power, cluster-head election and network rebuilding run periodically. And LEACH is built on the following two assumptions: 1) the base station is fixed and is far from the sensors; 2) All nodes in the network are homogeneous and energy-constrained. The operation of LEACH is broken up into two phases, where each phase begins with a set-up phase, when the clusters are organized, followed by a steady-state phase, when data transfers to the base station occur[5][7][8].

Setup Phase: In setup phase, each node will choose a random value between 0&1. If the chosen value is less than the threshold $T(n)$, the node will act as the cluster-head else it become simple node. Threshold $T(n)$ is determined by the equation:[8]

$$T(n) = \begin{cases} \frac{p}{1-p \cdot (r \bmod \frac{1}{p})} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases}$$

Here r-current round

p- the desired percentage for becoming CH

G-Collection of nodes that in the last $1/p$ rounds have not been elected as a CH

After electing CHs, every CH announces all sensor nodes in the network that it is the new CH. When each node receives the announcement, it chooses its desired cluster to join based on the signal strength of the announcement from the CHs to it. So, the sensor nodes inform their appropriate CH to join it. Based on the number of nodes in the cluster, the cluster-head node creates a TDMA schedule telling each node when it can transmit[8].

eady Phase: In steady state phase, the data sent from nodes such as data fusion& aggregation is processed by the cluster head nodes and transmitted to sinks i.e., data is transferred to the base station.

This protocol lets the data transmission phase last for a fixed period, then move to the new round of cluster head election. In order to decrease the overhead of set-up phase, the time length of each round should be increased. Since these are only a few CH it only affects a small number of nodes mainly a CH drains the battery of the node. In order to avoid this, we spread this energy over multiple nodes, also the CH nodes are not fixed, and rather their position is self-elected at different time intervals. Thus the LEACH protocol improves the energy efficiency[7][8].

PEGASIS(Power-Efficient Gathering in Sensor Information Systems) is a chain-based protocol developed from LEACH, and it is based on the idea that node farthest away from the base station firstly send a testing signal to find the nearest neighbor sensor as its next-hop node in the chain. This next-hop node searches its next-hop node in the same way and this procedure is repeated until the whole chain is built. Nodes in the chain act as a leader in turn to send data to the base station, so it balances the energy consumption in the network. By this way, all nodes only need minimum energy to send data packets, as they only communicate with the adjacent nodes[5][6][8]. Every node except the end nodes in the chain fuses its neighbor's data with its own and forwards to its other neighbor. The data packets finally reach the leader, and the leader will send them to the base station.

A Hierarchical-PEGASIS is an extension to PEGASIS, which aims at decreasing the delay for packets during transmission to the base station and proposes a solution to the data gathering problem by considering (energy*delay) metric. In order to reduce the delay in PEGASIS, simultaneous transmissions of data messages are followed. To avoid collisions and possible signal interference among the sensors, two approaches have been investigated. The first approach incorporates signal coding, e.g. CDMA. In the second approach only spatially separated nodes are allowed to transmit at the same time[2].

EEHC(Energy Efficient Hierarchical Clustering) is LEACH based protocol. It is a distributed, k-hop hierarchical clustering algorithm aiming at the maximization of the network lifetime. Initially, each sensor node is elected as a CH with probability “p” and announces its election to the neighboring nodes within its communication range. The above CHs are now called the “volunteer” CHs. Next, all the nodes that are within “k”-hops distance from a “volunteer” CH, are supposed to receive the election message either directly or through intermediate forwarding. Consequently, any node that receives such CH election message and is not itself a CH, becomes a member of the closest cluster and a number of ‘forced’ CHs are elected from nodes that are neither CHs nor belong to a cluster. Specifically, if the election messages do not reach a node within a preset time interval t, the node becomes a “forced” CH assuming that it is not within k hops of all volunteer CHs.[9]

HEED(Hybrid Energy-Efficient Distributed Clustering) is a hierarchical, distributed, clustering scheme in which a single-hop communication pattern is retained within each cluster, whereas multi-hop communication is allowed among CHs and the BS. The CH nodes are chosen based on two basic parameters: 1) Residual Energy and 2) Intra-Cluster communication cost[9][10].

The residual energy of each node is used to probabilistically choose the initial set of cluster heads. This parameter is commonly used in many other clustering schemes. Intra-Cluster Communication Cost is used by nodes to determine the cluster to join. This is especially useful if a given node falls within the range of more than one cluster head. In HEED it is important to identify what the range of a node is in terms of its power levels as a given node will have multiple discrete transmission power levels. The power level used by a node for intra-cluster announcements and during clustering is referred to as cluster power level[9][10].

TEEN(Threshold sensitive Energy Efficient sensor Network protocol) is a hierarchical and data centric protocol designed for time-critical applications, for sudden response to some attributes, first it goes through cluster formation.[2] After the clusters are formed, the cluster head broadcasts two thresholds to the nodes: 1) Soft threshold(ST) and 2) Hard Threshold(HT)

Soft Threshold is a small change in the value of the sensed attribute which triggers the node to switch on its transmitter and transmit. It stimulates the node to switch on its transmitter and report the sensed data. Hard threshold is the minimum possible value of an attribute to trigger a sensor node to switch on its transmitter and transmit to the cluster head. A node will report data only when the sensed value is beyond the HT or the change in the value is greater than the ST. However, TEEN cannot be applied for sensor networks where periodic sensor readings should be delivered to the Sink there is always a possibility that the sink may not be able to distinguish dead nodes from alive ones. Another limitation of the protocol is that the message propagation is accomplished by CHs only. If CHs are not in each other’s transmission radius, the messages will be lost[2][5][10].

APTEEN(The Adaptive Threshold sensitive Energy Efficient sensor Network protocol) is an extension to TEEN and aims at both capturing periodic data collections and reacting to time-critical events. The architecture is same as in TEEN. When the base station forms the clusters, the cluster heads broadcast the attributes, the threshold values, and the transmission schedule to all nodes. Cluster heads also perform data aggregation in order to save energy. APTEEN supports three different query types: historical, to analyze past data values; one-time, to take a snapshot view of the network; and persistent to monitor an event for a period of time[2][8].

5. LIMITATIONS OF HR

HR is cluster based routing technology, Although it has advantages like Data aggregation, Low Local power consumption, Low Signaling but also have some disadvantages which makes its protocols an open issue for further improvement. LEACH serviceable the randomized rotation of cluster heads to evenly distribute the energy load, As cluster heads are placed randomly, some non-cluster head nodes may have no cluster head at communication range. As a result, these nodes are disconnected from the network although physically exists there. The main drawback of HEED protocol is that it is based on the assumption that nodes do their communication through transmission power: low power levels are used for intra-cluster communication, higher levels for inter-cluster communication. This cause HEED to be little impractical in use. TEEN and APTEEN construct a multi-hop hierarchy, in which data is relayed by several cluster heads before arriving to the sink [5][7]. The main problem of TEEN and APTEEN is the overhead and complexity associated with forming clusters at multiple levels. Some other limitations associated with HR are: 1) Nodes are considered static 2) High cost scalability 3) Homogenous distribution of nodes in clusters 4) More Hardware required 5) Medium Hotspot.

6. CONCLUSION AND FUTURE SCOPE

One of the main challenges in the design of routing protocols for WSNs is energy efficiency due to the limited energy resources of sensors. The energy consumption of the sensors is dominated by data transmission. Therefore, routing protocols designed for WSNs should be as energy efficient as possible to prolong the lifetime of individual sensors, and hence the network lifetime. Protocols discussed have some limitations and some main limitations are highlighted. Based on these limitations, there is further need of improvement in LEACH protocol as compared to PEGASIS and TEEN/APTEEN protocols. Energy dissipation and network lifetime of LEACH Protocol is poor, so there is lot of a future scope to improve LEACH protocol and much research work can be done further. There are many open issues in WSN regarding improvement of routing algorithms of LEACH, PEGASIS, TEEN/APTEEN.

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