Wireless Sensor Network and Hierarchical Routing Protocols: A Review

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***Abstract:*Wireless sensor network is a network formed by large number of sensor nodes which are randomly distributed in some regions. There is an issue of limited power supply of node and in fact battery of node is infeasible in replacement. The Life time of wireless sensor network is very much dependent on the life of each sensor node. As node does the task of sensing and forwarding the data to sink, this data forwarding has to be efficient to efficiently utilize the battery power of sensor node. Various researches have been done in finding the efficient routing scheme to efficiently route the data from sensor node to sink by aiming the minimization of the energy consumption of sensor nodes. In this paper we have surveyed and discussed the various routing protocols that aim to increase the life time of network**.

***Keywords*: - wireless sensor network (WSN), routing protocols, hot spot problem, cluster head, hierarchical routing**

1. INTRODUCTION

A wireless sensor network (WSN) consists of large number of nodes which are densely deployed to sense the environment surrounding to it. Each of these nodes collect data and after collection of data itforwards the data to sink. The network must possess self-organizing capabilities because the position of nodes is not predefined. One of the unique features of sensor networks is the cooperative effort of sensor nodes. Transmission of raw data is avoided with the use of data aggregation mechanism in sensor nodes [1].This paper is organized as follows: section 2 discuss the application of wireless sensor network. Section 3 presents the architecture of WSN node. In section 4 different deployment phase has been given. Section 5 and section 6 discuss about clustering and routing schemes. Section 7 compares various hierarchical routing protocols and paper ends with the conclusion in section 8 followed by reference listing.

2. APPLICATIONS OF WSN

Wireless sensor network are extensively used in different applications. There are various sensors being developed for effectively monitoring the environment. They include low sampling ratemagnetic, seismic, visual, thermal, acoustic, infrared and radar that can effectively monitor a wide variety of ambient condition like pressure, temperature, humidity etc [2]. Mainly Wireless sensors applications are categorized in environment, military,home, health and commercial areas.

2.1. Military applications

Wireless sensor networks are an integral partof military command, control, communications,computing, intelligence, surveillance, reconnaissanceand targeting (C4ISRT) systems.

2.2 Environment applications

Some environmental applications of sensor networks include tracking of the movements of small animals, birds and insects, monitoring of the environmental conditions that affect crops and livestock.

2.2.1.Forest fire detection: When sensor nodes are randomly deployed in forest they can relay the exact source of fire to end users so that further spread of fire can be avoided.

2.2.2.Flood detection[3]: ALERT system [4] is the example of flood detection deployed in the US. Various types of sensors deployed in theALERT system are rainfall, water level andweather sensors. These sensors provide informationto the centralized database system in a pre-definedway.

2.3. Health applications

Some of the health applications for sensor networks provide interfaces for the disabled;integrated patient monitoring; drug administration in hospitals; monitoring the movementsand internal processes of insects or other small animals; telemonitoring of human physiologicaldata and tracking and monitoring of the doctors and patients inside a hospital [5,6,7,8,9].

3. WIRELESS SENSOR NODE

There has been concerning issue in the selection process of hardware components for a wireless sensor node. It is basically decided by requirement of the application in context of size, cost and additional components that are to be employed. In some extreme cases, the size of an entire sensor node should be smaller than 1 cc, weight(considerably) should be less than 100 g, it should be substantiallycheaper than US$1, and power dissipation should be less than 100 mW [10,11].

3.1 Architecture of Wireless sensor node

The basic architecture of wireless sensor node is shown as below:-

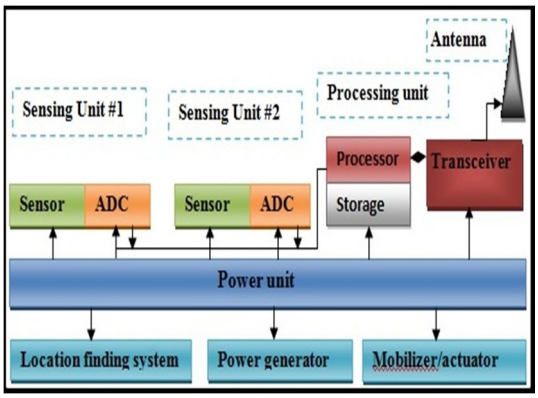

Fig 1 Architecture of Sensor Node[1]

A sensor node consists of four major components[1] as shown in Fig. 1: processingunit, sensing unit, power unit and transceiver unit. Other additional components are location finding system, mobilizer and power generator.

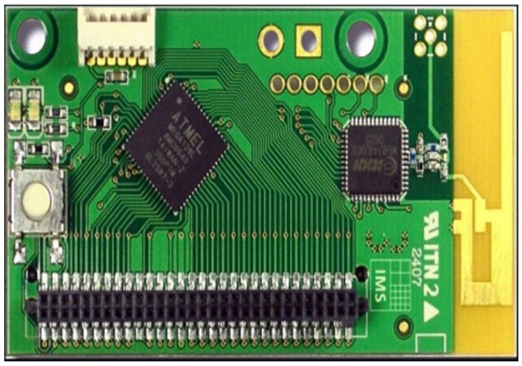

Fig 2 WSN node for agricultural application[12]

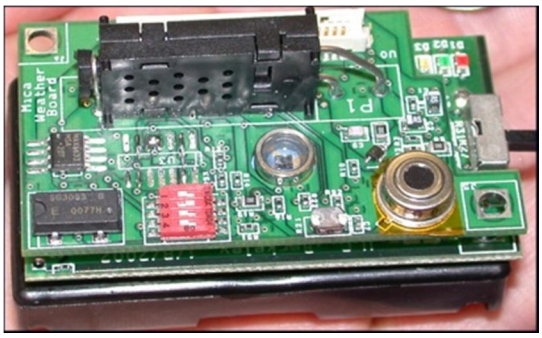

Fig 3 Mica WSN node for environmental application[13]

A mica wireless sensor node for environmental application has been shown in Fig 2 and for environment application it is shown in Fig 3.

Multiple Generations of Berkeley Motes are given in the table

TABLE: Multiple generations of Berkeley Motes

Model	Rene	Mica	Mica-2	Mica-Z
Date	1999	2002	2003	2004
CPU	4 MHz	4 MHz	4 MHz	4 MHz
Flash Memory	8 KB	128 KB	128 KB	128 KB
RAM	512 B	4 KB	4 KB	4 KB
Radio	10 Kbps	40 Kbps	76 Kbps	250 Kbps

Two subunits of sensing unit are sensorsand analog to digital converters (ADCs).

- ADC converts theanalog signals into digitalsignals and then they are fed into the processingunit.
- The main function of processing unit is that it allows the sensor node to collaborate with other nodes for performing the assigned task.
- A transceiver unit does the task of connecting the node to the network.
- The power is also an important component of WSN. Power units can be supported by a powerscavenging unit such as solar cells.

4. DEPLOYMENT PHASE

The dependence of node deployment is mainly on the application. The twomost important things thatare to be considered are the autonomy and adaptability[14].Autonomy specifies about the deployment of sensors in an unattended region or physically unreachable area, so they are required to operate with the minimum effortsfrom the sink or human administrators. Adaptability specifies the capability of wsn node to adapt according to environmental changesthat ittends to monitor, e.g. sensor may decrease their dutycycles in order to reduce the power consumption when there is not much considerable change in sensorreadings [15].

5. CLUSTER FORMATION

In order to make data aggregation more efficient in a network, nodes are partitioned into a number of small groups called clusters. In each cluster one sensor node is selected as cluster head which supervises the task of data collection from various nodes and thereby forwarding it further. This clustering scheme increases the life time of

network by avoiding unbalancing of energy load throughout the network[16].
The communication among clusters is categorized into two parts, single hop and multi hop communication.

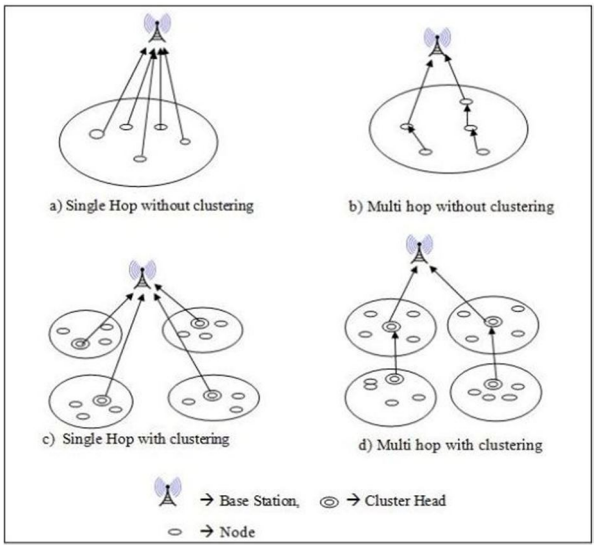

Fig.4. Single-Hop and Multi-Hop Communication [17]

5.1 Single Hop and Multi Hop cluster communication
In single hop cluster communication, cluster head transmit their data directly to base station. This is very much suitable approach for small networks. But to mitigate hot spot problem, clusters near the Base station are kept larger in size and those who are at distance they are to be smaller in size to preserve their energy to transmit directly to distant Base station[18].

Multi hop scheme is implemented for larger network for transmitting the data to Base station. In this inter cluster communication take place, and cluster head of each cluster forwards the data to neighboring cluster and thereby to Base Station.
In this the size of clusters nearer to Base Station are smaller in size and farther ones have large size so as former can preserve their energy for forwarding the data and hence in this way they mitigate hot spot problem. UCR(unequal cluster based routing protocol) is the first protocol to mitigate hot spot problem[19].

5.2 Cluster head selection
There are various algorithm developed for selection of cluster head. Some uses the criteria of establishing the threshold value with the equation (1)

$$T(n) = \begin{cases} P \div \left(1 - P\left[rmod\left(\frac{1}{p}\right)\right]\right), & n \epsilon G \\ 0, & others \end{cases} \quad (1)$$

Where, p is the percentage of cluster heads over all nodes in the network, r is the number of rounds of selection, and G is the set of nodes that are not selected in round 1/p[20].

Another efficient way of selection of cluster head is through calculating the average energy of all nodes and then residual energy is compared, if former is smaller only then that particular node can participate in cluster head competition. So for that a T value is determined which is given byequation (2).

$$T = E_{oi/} \left(\sum_{j=1}^{i-1} \left(E_{oj} \right) / n\text{-}1 \right) \quad (2)$$

Among them, Eoi indicates residual energy, n indicates the number of node within the scope of adjacent nodes,Eoj indicates the sum of other node's energy. If T > 1,node i is eligible to participate in the election of clusterbecause energy in node i is larger than average energy[21].
When a node is selected as cluster head it creates a Time Division Multiple Access Scheme (TDMA) and each node is assigned a time slot. In the steady state phase, it performs the task of collection of data from sensor nodes, aggregate data and then it sends it to base station[19].

6. ROUTING IN WSN

Routing in WSNs is a tricky task because of data source from multiple paths to single source, data redundancy and also because of energy and computation factors of the network [9]. The usual routing algorithms are not efficient when applied to WSNs. The performance of the existing routing algorithms for WSNs varies from application to application because of various demands of various applications.

6.1Challenges in routing:
There are various challenges[22] that can face the efficient routing, they are following:

- *Energy Consumption*: This is the most important parameter which decides the life time of sensor network. So while developing any routing protocol energy consumption has to be given the most priority. Routing in WSNs consumes energy for twomain causes:
  i. Neighborhood node discovery
  ii. Communication vs. computations
- *Scalability*: To improve the energy efficiency and decrease the load,routing protocols it must support scalability and in networkcombination[23].
- *Addressing*:Routing protocols that do not require unique IDs for each sensor node must be developed so as to decrease the overhead of routing.
- *Robustness*: It is really an important issue as it ensures the long life time of network even in case of any node failure.

- *Topology*: Routing protocols must provide topology flexibility and should be adaptive to dynamic changesof the network topology facilitated with sinkmobility and switching of the nodes between ON andOFF.

7. ROUTING PROTOCOL

The classification of routing protocols is done into two classes among which one is based on the network structure and other one is based on protocol operation. The classification of network structure is further done as flat network routing, hierarchal network routing and location based routing. The classification of protocol operation is done as negotiation based, multipath based, query based, coherent based and QoS based routing. We focus our survey on network structure and more specifically on hierarchical routing algorithms[22] which aims to increase the life time of network. Some of them are discussed with their advantages and disadvantages in the following table.

TABLE: Description, Advantages and Disadvantages of Hierarchical Protocol

Protocol	**Description(Hierarchical Protocols)**	**Advantages**	**Disadvantages**
Low-energy adaptive clustering hierarchy (LEACH)	In order to reduce power consumption in a network, Leach was the first energy-efficient hierarchical clustering algorithm for WSNs.It supports only single hop communication as it transmits data directly to base station. It uses the cluster based topology to increase the life time of network. LEACH is basically based on an aggregation technique that aggregates the useful data and forwards it to sink. The redundant data is removed with use of efficient aggregation technique and with the clustering approach routing and data dissemination are made more scalable and robust[23].Various improvement has been done to make LEACH more efficient.	• High Scalability • Very Good Life Time • Highly Energy Efficient • Veryless latency involved • Throughput is very high	LEACH assumes all nodes to be homogeneous which is practically not usual as heterogeneity in energy is the most common case. Single Hop Communication leadsto hot spot problem.
PEGASIS	Power-Efficient Gathering in Sensor Information Systems (PEGASIS) is an improved algorithm of the LEACH protocol. Unlike LEACH it avoids cluster formation and selection of one node is done to transmit data to sink rather than doing it by multiple nodes. So a chain is formed and only one node performs the task of transmission to the sink. PEGASIS uses a greedy approach and incase if there is any node failure than it bypass that node. So in each round node selection is done randomly thus reducing the per round energy consumption compared to LEACH [24].	Increase Life Time of network twice as compare to LEACH Decreases the number of transmission and reception by using data aggregation. Clustering overhead is avoided. Avoids so much clustering, Increases lifetime twice	It needs dynamical topology adjustment which causes significant overhead. It assumes every node to be of same energy which is not practically possible. Delay involved is concerning issue here.
TEEN	TEEN[25][26] is a clustering communication protocol. When clusters are formed, the CH broadcasts two thresholds to the sensor nodes namely (i) hard threshold (*HT*), and (ii) soft threshold(*ST*). Hard threshold gives the minimum value of an attribute after which sensor should turn on its transmitter to give information about sensed data to its CH. So transmission of data is made dependent on location of sensed attribute. When value is greater than Hard threshold, it will	Adjustment can be made in the value of hard and soft threshold values in order to control the number of packet transmissions. Suitable for time critical application	It is not suitable for applications whereperiodic reports are required.

	allow the node to transmit but it has to further check that if there is change in sensed attribute beyond the value of soft threshold. So in this way number of transmission are reduced.		
APTEEN	Adaptive Threshold sensitive Energy Efficient sensor Network protocol(APTEEN) performs both capturing periodic data collections and also reacting to the time-critical events [27].After the formation of cluster, CH broadcast the attributes, the threshold values, and the transmission schedule to all nodes and it also perform data aggregation. Three types of query are supported by APTEEN: historical, which analyze past data values; one-time, which take a snapshot view of the network and persistent which monitor an event for a period of time.	APTEEN guarantee lower energy dissipation and a larger number of sensor alive. The performance of APTEEN is between LEACH andTEEN in terms of energy dissipation andnetworklifetime.	Complexity is involved in forming clusters in multiple levels and also in implementation of threshold based function.
HEED	Hybrid, Energy-Efficient Distributed Clustering (HEED)[28][29]is implemented in multi-hop networks, with the use of an adaptive transmission power in the inter-clustering communication. There are four major goals for which HEED was proposed namely (i) prolonging the network lifetime by distribution of energy consumption, (ii) termination of the clustering process within a constant number of iterations, (iii) minimization of control overhead, and (iv) producing the well-distributed CHs and compact clusters.	Communication cost in minimized. Automatic updation of neighbor sets in multi hop environment by periodically transmitting and receiving messages.	It is not suitable for the needs of WSN.
ZECR	Zone-divided and energy balanced clustering routing protocol for WSN divides the network into different zone on the basis of the distance of the node from the base station. It has efficient approach for cluster head selection on the basis of average energy of the cluster. Various zones formed are given numbers on the basis of their distance from base station[30].	It is very much efficient in heterogeneous environment. There is no hot spot problem.	There is further scope of increasing the lifetime of network as data aggregation can be made still more efficient.

8. CONCLUSION

Due to scarce energy resources of sensors, the main challenge has been the energy efficiency of network. Even while manufacturing of sensor node and during its deployment the aim of least energy consumption holds its top priority. In this paper, we have overviewed the deployment phase, applications of WSNs and sensor node with its architecture. Then we have discussed the clustering approach that is being adopted to increase the life time of the network. After surveying various hierarchical routing protocols we have concluded that it is not possible to develop a precised routing protocol which has feasibility for all applications. Instead we have found that these routing protocols are developed based on the application like TEEN which is very much suitable for time critical application. Our future work will focus on the removing the shortcoming of these routing protocols and making them more energy efficient so as to increase the life time of network.

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