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WIRELESS SENSOR NETWORKS: An Overview, Design goals &Issues, Routing Protocols, Applications

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***ABSTRACT*-Wireless Sensor Networks (WSNs) consist of numerous sensors which send sensed data to base station. Energy conservation is an important issue for sensor nodes as they have limited power.By using a clustering technique hierarchical routing protocols greatly minimize the energy consumed in collecting and disseminating data. In this paper we discuss overview,design goals, issuesand problem of routing in WSN based on route selection. The protocols discussed are LEACH which uses proactive routing, TEEN which uses reactive routing and concludes by a protocol for reactive homogeneous and heterogeneous WSNs, HEER (Hybrid Energy Efficient Reactive)protocol. In HEER, Cluster Head (CH) selection is based on theratio of residual energy of node and average energy of network.Moreover, to conserve more energy, we introduce Hard Threshold(HT) and Soft Threshold (ST) increasing the lifetime in heterogeneous WSNs, which is crucial for many applications**

***Index Terms*—Wireless, Sensor, Networks, Energy, Proactive, Reactive, Hybrid, Clusters**

I. INTRODUCTION

A wireless sensor network (WSN) consists of hundreds to thousands of low-power multi- functional sensor nodes, operating in an Unattended environment, functional sensor nodes, operating in an unattended environment, and having sensing, computation and communication capabilities. The basic components [5] of a node are a sensor unit, a communication unit. Sensor nodes are micro-electro-mechanical systems [5] (MEMS) that produce a measurable response to a change in some physical condition like temperature and pressure. Sensor nodes sense or measure physical data of the area to be monitored. The continual analog signal sensed by the sensors is digitized by an analog-to-digital converter and sent to controllers for further processing.Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth. The topology of the WSNs can vary from a simple star network to an advanced multi-hop wireless mesh network. The propagation technique between the hops of the network can be routing or flooding.

Wireless Sensor Networks (WSN's) are being widely used in monitoring various physical phenomena. WSN can be appliedvirtually in any environment which calls for monitoring before taking an appropriate action. WSNs find their application areas in disaster management, environment monitoring, facility management, intelligent homes, precision agriculture, logistics medicine and health care, military command and control, greenhouse monitoring, structural health monitoring.

Recent advances in wireless sensor networks have led researchers to research many protocols which are specially designed for the sensor networks which work under the limited resources available for sensor nodes.

APPLICATIONS OF WSN:

- Area monitoring
- Health care monitoring
- Air pollution monitoring
- Forest fire detection
- Landslide detection
- Water quality monitoring
- Natural disaster prevention
- Industrial monitoring*(*Machine health monitoring*)*
- Data logging
- Water/Waste water monitoring
- Structural Health Monitoring

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CLASSIFICATION:

Here a more general classification of routing techniques is presented [6]. Most of the routing techniques fall into one of the following categories. Routing techniques can be classified based on following:

- On the basis of Route Selection or path establishment [5,6]

1. Proactive protocols
2. Reactive protocols
3. Hybrid protocols

- On the basis of protocol Operation [5,6]

1. Negotiation based routing
2. Multipath routing protocols
3. Query based routing
4. QOS based routing
5. Coherent routing

- On the basis of Number of path [5,6]

1. Uni-path
2. Multi-path

The Paper has been organized as follows:
Section-2 "Design goals of WSNs" explains about the requirements of such a network section-3 "sensor network architecture and design issues" describes about the limitations of WSN's
section-4 "Routing Techniques"we have discussed about different energy efficient routing protocols based on route selection such as, the Proactive protocols which works on pre-determined routes e.g., taken LEACH,DEEN,the Reactive protocols such as TEEN and Finally the paper concludes by the Hybrid protocol HEER,protocol for reactive homogeneous and heterogeneous WSNs.

II. DESIGN GOALS OF WSN

The wireless sensor networks have its own limit that makes it differ from mobile adhoc networks and thus designing a wireless sensor network is very challenging. Firstly, generated data traffic has significant redundancy in it since multiple sensors may generate same data within the vicinity of a phenomenon. Secondly, sensor nodes might be deployed densely in the sensor networks. Unnecessary nodes should be turned off its radio while guaranteeing connectivity of the entire sensor field. Thirdly, sensor nodes are limited in power, processing capacities and memory. Those require careful resource management. Fourthly, sensor nodes may not have global identifications (IDs) [1].

- Scalability

Scalability is also critical factor. For a large scale sensor network, it is likely that localizing interactions through hierarchical and aggregation will be critical for ensure scalability

- Latency

The user is interested in knowing about the phenomena within a given delay. Therefore, it is important to receive the data in a timely manner.

III. SENSOR NETWORK ARCHITECTURE AND DESIGN ISSUES

In the following section we try to describe the architectural issues and challenges for WSNs[6].

- Node Distribution:

Node distribution in WSNs is either deterministic or self-organizing and application dependant.

- Network Dynamicity:

Most of the routing protocols assume that the sensor nodes and the base stations are fixed *i.e.*, they are static, but in the case of dynamic BS or nodes routes from one node to another must be reported periodically within the network so that all nodes can transmit data via the reported route depending on the application, the sensed event can be dynamic or static. For eg, in target detection/tracking applications, the event is dynamic, whereas forest monitoring for early fire prevention is an eg of a static event. Monitoring static events works in reactive mode where in dynamin events works in proactive mode.

- Energy efficiency:

The sensor nodes in WSNs have limited energy and they use their energy for computation, communication and sensing, so energy consumption is an important issue in WSNs.

- Data Transmission:

Data transmission in WSNs is application specific. It may be continuous or event driven or query-based or hybrid. In case of continuous data transmission, sensor nodes send data to the base station periodically. In event driven and query-based transmission they send data to the base station when some event occurs or a specific query is generated by the base station.

- Scalability:

A WSN consists of hundreds to thousands of sensor nodes. Routing protocols must be workable with this huge number of nodes *i.e.*, these protocols can be able to handle all of the functionalities of the sensor nodes so that the lifetime of the network can be stable.

- Data Fusion:

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Data fusion is a process of combining of data from different sources according to some function. This is achieved by signal processing methods. This technique is usedby some routing protocols for energy efficiency and data transfer optimization. Since sensor nodes get data from multiple nodes, similar packets may be fused generating redundant data. In data fusion or data aggregation process awareness is needed to avoid this redundant data.

IV. ROUTING TECHNIQUES

Routing techniques are required for sending data between sensor nodes and the base stations for communication. Protocols can be classified as proactive, reactive and hybrid based on their mode of functioning and type of target applications.

In a proactive protocol the nodes switch on their sensors and transmitters, sense the environment and transmit the data to a BS through the predefined route. The Low Energy Adaptive Clustering hierarchy protocol (LEACH) andDEEC [4] utilizes this type of protocol [1, 5].

In case of a reactive protocol if there are sudden changes in the sensed attribute beyond some pre-determined threshold value, the nodes immediately react. This type of protocol is used in time critical applications. The Threshold sensitive Energy Efficient sensor Network (TEEN) [3, 5] is an example of a reactive protocol.

Hybrid protocols like Adaptive Periodic TEEN (APTEEN) and HEER [3, 5] incorporate both proactive and reactive concepts. They first compute all routes and then improve the routes at the time of routing.

Comparison of proactive and reactive

Both proactive and reactive routing has specific advantages and disadvantages that make them suitable for certain types of scenarios.[6] Since proactive routing maintains information that is immediately available, the delay before sending a packet is minimal. On the contrary, reactive protocols must first determine the route, which may result in considerable delay if the information is not available in caches. Moreover, the reactive route search procedure may involve significant control traffic due to global flooding. This, together with the long setup delay, may make pure reactive routing less suitable for real-time traffic. However, the traffic amount can be reduced by employing route maintenance schemes.

LEACH (Low Energy Adaptive Clustering Hierarchy)

The Low energy adaptive clustering hierarchy (LEACH) uses the clustering scheme to distribute the energy consumption evenly over the network. LEACH attracted considerable attention due to its energy efficient, simplicity and load balancing properties. In LEACH, based on data collection, the WSN is divided into clusters and Cluster heads (CH) are elected randomly. The CH collects the data from the nodes within its cluster and sends the same it to the BS. All non-cluster head nodes transmit their data to their respective CH's, while the CH node receives data from all the cluster members, computes data aggregation, and transmits the aggregate data to the remote BS. The LEACH incorporates randomized rotation of the high-energy CH role among the nodes to avoid draining the battery of any one node in the network.

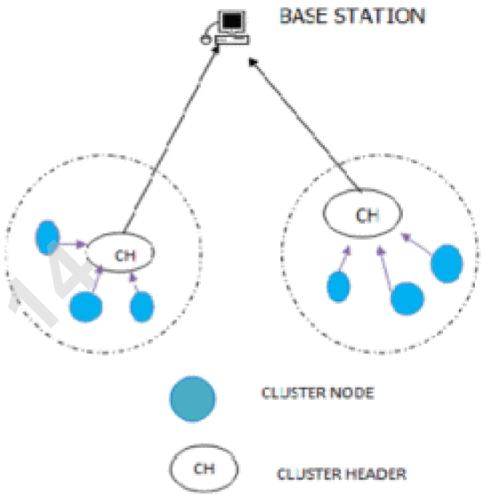

Fig. *1 Leach Protocol*

TEEN (Threshold sensitive Energy Efficient sensor Network)

TEEN [5] is a cluster based hierarchical routing protocol based on LEACH. This protocol is used

for time-critical applications. It has two assumptions [5]:The BS and the sensor nodes have same initial energy The BS can transmit data to all nodes in the network directly. In this protocol, nodes sense the medium continuously, but the data transmission is done less frequently. The network consists of simple nodes, first-level cluster heads and second-level cluster heads. TEEN uses LEACH's strategy to form cluster. First level CHs are formed away from the BS and second level cluster heads are formed near to the BS.A CH sends two types of data to its neighbours—one is the hard threshold (HT) and other is soft threshold (ST). In the hard threshold, the nodes transmit data if the sensed attribute is in the range of interest and thus it reduces the number of transmissions. On the other hand, in soft threshold mode, any small change in the value of the sensed attribute is transmitted. The nodes sense their environment continuously and store the sensed value for transmission.

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Thereafter the node transmits the sensed value if one of the following conditions satisfied:

a. Sensed value > hard threshold (HT).
b. Sensed value ~ hard threshold >= soft threshold (ST).
TEEN has the following drawbacks:

- A node may wait for their time slot for data transmission. Again time slot may be wasted if a node has no data for transmission. cluster heads always wait for data from nodes by keeping its transmitter on.

HEER (Hybrid Energy Efficient Reactive Protocol for Wireless Sensor Networks)

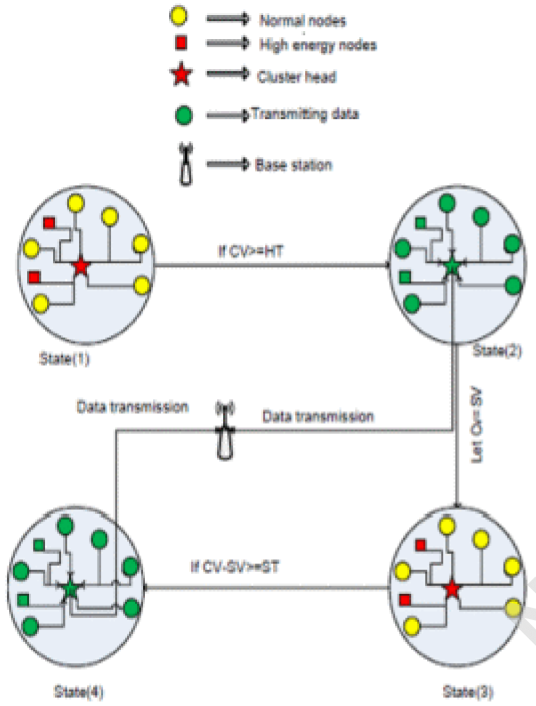

Fig. *2 HEER from data sensing to data transmission for a cluster*

In this section, we describe HEER [4], which improves the stable region for clustering hierarchy process for a reactive network in homogeneous and heterogeneous environment. We use the initial and residual energies of the nodes to become CH similar to that of DEEC. It does not require any global knowledge of energy at any election round. When cluster formation is done, the CH transmits two threshold values, i.e. *HT* and *ST*. The nodes sense their environment repeatedly and if a parameter from the attributes set reaches its *HT* value, the node switches on its transmitter and transmits data. The Current Value () on which first transmission occurs, is stored in an internal variable in the node called Sensed Value (*S*). This reduces the number of transmissions. Now the nodes will again transmit the data in the same cluster period when $CV - SV \geq ST$. That is, if *CV* differs from *SV* by an amount equal to or greater than *ST*, then it further reduces the number of transmissions.

Figure. 1 shows different states of a cluster i.e. from data sensing to data transmitting. Every node selects itself as a CH on the basis of its initial energy and residual energy. In State (1) a cluster is formed the node senses its environment continuously until the parameter (CV) reaches its HT value. When CV reaches HT value, the nodes become green as shown in the figure in State (2). The node then switches on its transmitter and sends the data to the CH. The CH aggregates and transmits data to base station. The CV on which first transmission occurs is stored in SV. The node, then again starts sensing its environment as shown in State (3) until the CV differs from SV by an amount equal to or greater than ST. When this condition becomes true, the node again switches on its transmitter and sends data to CH.The CH then transmits data to base station as shown in State (4) of figure. 1.

Important Features:
HEER performs best for time critical applications in both homogeneous and heterogeneous environment. It reduces the number of transmissions resulting in the reduction of energy consumption.It increase the stability period and network lifetime

V. CONCLUSION

In recent years, most of attention has been given on the energy factor of the sensor node as it is very crucial factor.According to various applications there are various routing techniques available with their features. Every routing technique has its some advantages and also some disadvantages. There is no single, best routing protocol that issuitable for all applications. Routing mechanism might differ depending on the application, network architecture and topologies. Energy efficiency, Scalability, Fault tolerance, quality of service, Application requirements are the main challenges that play important role in evolution of routing techniques. here, we present a hybrid reactive protocol of TEEN and DEEC. HEER minimizes the energy consumption by first distributing load to all high energy nodes and then on to low energy nodes. Like TEEN, it is well suited for time critical applications.

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