A Survey on Routing Protocols in Wireless Sensor Network

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***Abstract*—In wireless sensor networks (WSNs), the deployment of massive numbers of small, inexpensive, low energy sensor nodes are random in nature. Therefore energy consumption reduction is very important. Wireless Sensor Networks with hundred to thousand of sensor nodes can gather information from unattendant environment transmit the gathered information to the specific user depending on the user end application. Information transmitted from one node to another node using different routing protocols. So routing protocol has now become one of the hot research in wireless sensor networks. In this paper we present a survey of state-of-the-art routing protocols in WSNs along with architecture of the wireless sensor network. Further we categorize routing protocols according to some factors and summarize on their mode of operation. At the end, we go through a comparative study on these protocols.**

***Keywords*—wireless, sensor, data collector, protocols, networking, base station**

I. INTRODUCTION

A wireless sensor network (WSN) consist of large number of heterogeneous sesnsor devices spread over enormous field. These sensor nodes are of low-power multi-functioning operating in an unattended environment, having capabilities of sesing, computations and communications. The basic components of node are sensor unit, ADC(analog to digital converter), CPU(central processing unit), power unit and communication unit[1]. In a wireless sensor network (WSN), a large number of wireless sensors are randomly distributed to gather environmental condition data of an area, such as humidity, temperature, pressure, solar radiation and concentration of carbon dioxide[2]. These wireless information collectors either uses guided or unguided medium for the delivery of their data to a Base Station (BS). The nodes with large amount of energy can only communicate to the BS. Base station can communicate with the user either directly or through the existing wired network. The topology of sensor networks are dynamic in nature. The topology of WSNs can be vary from star network to latest wireless mesh network.

A structure of WSN is shown in figure 1. One of the main issues in WSNs is how to prolong the overall network lifetime with limited energy source. There are various types of routing techniques which individually has a vital role in prolonging the lifetime of the network. Routing techniques are required for sending data between sensor nodes and the base stations for communication.

There are different types of routing protocols are proposed for WSNs. These protocols can be classified as proactive, reactive and hybrid based on their mode of function and type of target applications. Mainly the above classification of protocols based on route discovery. In proactive protocol it establish the route before they actually needed. In this protocol node senses the environment then gather the information and then delivers the gathered information to the BS through predetermined route. LEACH[3](Low Energy Adaptive Clustering hierarchy) utilizes this type of protocol. In case of reactive protocol it find the route only when they are needed. TEEN[4](Threshold Sensitive Energy Efficient Network) is an example of reactive protocol. Hybrid protocol incorporates both proactive and reactive concepts. It first evaluates all the routes and then improve the route at the time of routing. APTEEN[5](Adaptive Periodic TEEN) protocol employs hybrid protocol.

Further depending on the participating style of nodes, the classification of routing protocol as direct communication , flat and clustering protocols. In direct communication node can send their data directly to BS. This protocol applied in case of very large network. And having a very much chances that the energy of sensor nodes may be drained out quickly. Its scalability is very small. SPIN[6] fall under the category of these protocol. In case of Flat protocols the responsibility of all the nodes are equal. In case if any node wants to transmit their data then it first search the valid route to the BS and then transmits the data. Nodes around the base station may drain out of their energy quickly. Its scalability is medium. Example: Rumour routing. In case of clustering WSNs are divided into different cluster and

each cluster having its own cluster head. All the nodes sends their data to their cluster head and then cluster head aggregates the data and delivers the data to the BS directly. Example: TEEN.

More imporatantly, depending on the network structure routing protocols can be classified as Hierarchical, Data centric and location based. Hierarchical routing is usually done to perform energy efficient routing. Hierarchical routing protocols have proven to be effective in network topology management, energy minimization, data aggregation and so on.
Examples: LEACH, TEEN, APTEEN. Data centric protocols are query based protocol l that is used for the elimination of much more redundant transmission. In this protocol the BS send queries related to some particular area for information and then waits for the node acknowledgement regarding that particular information. Since data is requested through queries, so each and every data has its own attributes with some specifications. SPIN is the first data centric protocol. In location based routing[7] nodes rely on location information. For getting the locations of nodes GPS(Global positioning System) is used. With the help of location information optimal path can be generated without using flooding technique. GEAR is an example of location based routing protocol.

The Present review paper gives the existing elaborate detail about the role of different routing protocols and the main concern of this survey is to examine the energy efficiency of these routing protocols.

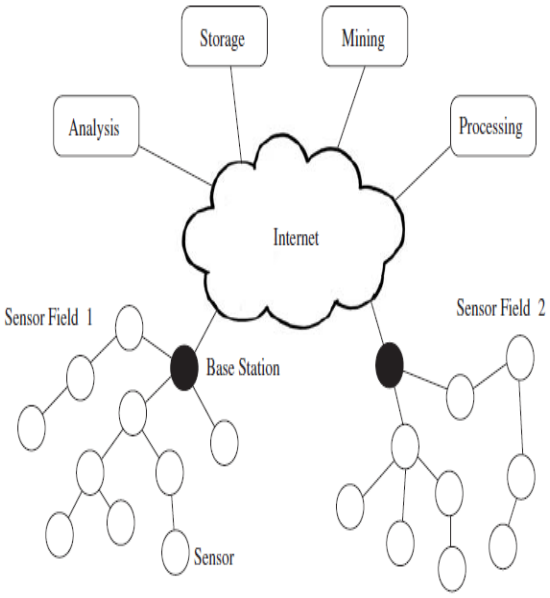


Fig 1. Wireless Sensor Network

II. EXISTING ROUTING PROTOCOLS

A. LEACH (Low Energy Adaptive Clustering Hierarchy)

LEACH[3] is the first and most popular energy-efficient hierarchical clustering algorithm for WSNs that was proposed for reducing power consumption. LEACH randomly selects few sensor nodes as cluster heads and rotates this task to evenly distributes the energy load among the sensors in the network. In order to reduce the amount of information delivered to the BS , Cluster head aggregates all the information received from the nodes in the respective cluster. LEACH protocol uses TDMA technique for dividing the time between different nodes for sharing their data in particular cluster. Each cluster communicates using different CDMA codes to reduce interference from nodes belonging to other clusters. Clustering LEACH is shown in figure 2.

LEACH divides the total operation into two rounds- each round is consisting of two phases: Set-up phase and steady phase. In set-up phase formation of cluster and selection of cluster head for each cluster takes place. During the set-up phase CH is selected from the nodes at a time with certain probability. In this each node generates a random number between 0 to 1. If this random value is less than a threshold value, the node becomes a CH for the current round. The Threshold value is calculated based on the equation.

$$T(n) = \frac{p}{1-p}\left[r \bmod \left(\frac{1}{p}\right)\right], n \epsilon G$$

$$=0, \text{otherwise}$$

Where p is the percentage of nodes that are CHs, r is the current round and G is the set of nodes that have not served as cluster heads in the past 1/p rounds. In steady state phase data transfers take place between nodes and cluster head. CH use TDMA technique to divide the time between different nodes for sharing information. When the cluster head gets data from its cluster, it aggregates the data and send the compressed data to BS. Since BS is far away from the CH, so it requires abundance of energy for transmitting the data. It only effects the node which are CH so therefore the selection of a CH depend on the remaining energy of node i.e. residual energy. After a certain time the network again goes back into the set-up phase and enter another round of selecting new CHs. More the residual energy more will be the probability of the node to be cluster head.

Although LEACH is able to prolong the network lifetime , there are still number of issues about the assumptions used in this protocol. LEACH assumes that all nodes can transmit with enough power to reach the BS. It also assumes that each node has computational power to support different MAC protocols along with that nodes located to each other have correlated data. More importantly this protocol uses dynamic clustering which brings extra overhead(head changes, advertisements, etc.,) which may diminish the gain in energy consumption.

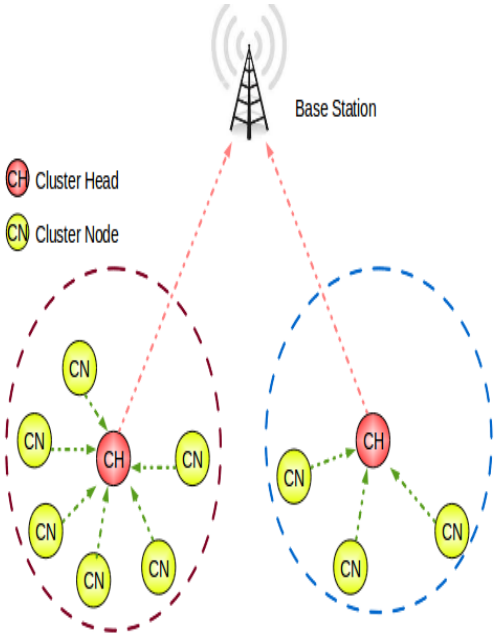


Fig2. Clustering in LEACH

B. *TEEN (Threshold sensitive Energy Efficient Sensor Network)*

TEEN[4] is cluster based hierarchical routing protocol designed to be responsive to sudden changes in the sensed attribute such as temperature. It is mainly used for time- critical applications. In TEEN, sensor nodes continuously sense the medium, but the data transmission is done less frequently. Network consist of simple nodes, first-level cluster heads and second-level cluster heads. First –level cluster heads are formed far away from the BS whereas the Second-level cluster head are formed near to the BS.

A CH sensors sends two type of data to its members one is hard threshold, which is the threshold value of sensed attribute, and a other one is soft threshold, which is small change in the value of sensed attribute that triggers the node to switch on its transmitter and transmit. The node will be going to transmit the data only if the following condition satisfies:

1) The current value of the sensed attribute is greater than hard threshold
2) The current value of the sensed attribute differs from the sense value by an amount equal to or greater than the soft threshold.

The main drawback of TEEN protocol is that if the thresholds are not received, the nodes will never communicate, and the end user will not get any data from the network at all.

C. *APTEEN(Adaptive Threshold TEEN)*

APTEEN[5] is the improved version of TEEN. It combines both proactive and reactive policies. APTEEN is hybrid protocol that changes the periodicity and threshold values used in TEEN protocol according to user needs and application type. It reacts to time critical events along with capturing of periodic data collection. CHs broadcast all parameters similar to TEEN protocol to all nodes but in additional with count time(CT). So in each round parameters broadcast to all nodes are as follows:

- Attributes: a set of physical parameters desired by specific user
- Thresholds: consist of Hard threshold and soft threshold
- Schedule: a schedule assign to each node using TDMA technique
- Count time: the maximum time between two successive reports sent by a node

The node continuously senses the environment and transmit the data if the value of the sensed data is beyond hard threshold. Once a node senses the data value beyond hard threshold , it transmits the data only when the value of that attribute changes by an amount equal to or greater than soft threshold. If node unable to send data for time equal to count time interval then it force to sense and retransmit data. By changing the values of threshold and count time interval energy consumption can be controlled which in turn offers a lot of flexibility. The main drawback of this scheme is the additional complexity required to implement the threshold functions and count time.

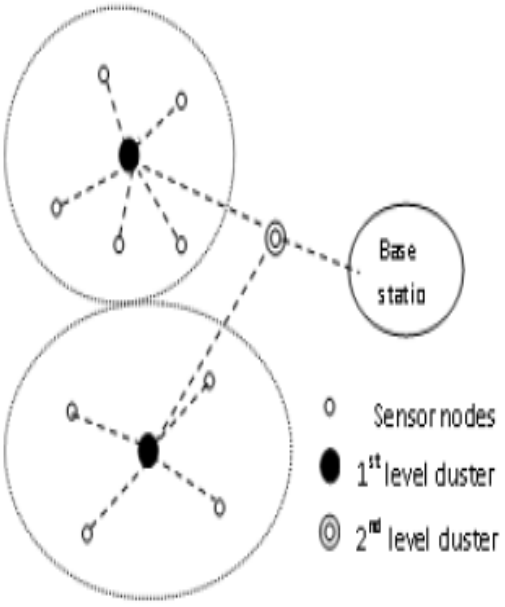


Fig 3. Hierarchical clustering in TEEN and APTEEN

D. *PEGASIS (Power efficient Gathering Sensor Information System)*

PEGASIS[8] is optimal chain based- protocol which is the improvement of LEACH[3] protocol. The idea behind this protocol is to prolong the lifetime of the network such that node need only communicate with their closest neighbours, and further they take turns in

communicating with the BS. When the round of all the nodes communicationg with BS coming to end, then again new round starts. This in turn reduces the power required to transmit the data because the power draining is spreaded uniformly throughout the nodes. In PEGASIS, instead of forming multiple clusters PEGASIS forms chains from sensor nodes such that every node receives and transmits from its closest neighbours and out of that only one node is selected to transmit the information to Base Station(Sink) as shown in Figure 4. Greedy algorithm is used for making chain among all the nodes. In order to locate the closest neighbor node in PEGASIS, each node uses signal strength to discover the distance to all neighbouring nodes and then balance the signal strength such that only one node can be heard. The chain in PEGASIS is like that all the nodes in the chain are closest to each other and form a path to the BS. Any of the node can be selected out of the nodes that participated in the chain to deliver the aggregate data of all participated nodes to base station. That node is known as LEADER node.

PEGASIS overcomes the drawback of LEACH by eliminating the overhead of dynamic cluster information, minimizes the sum of distances and limits the number of transmission. Although it helps in overcoming the clustering overhead, PEGASIS still requires dynamic topology adjustment as in order to know for node where to route its data, sensor node needs to know about the energy status of its neighbours. Such kind of topology also introduces significant overhead. Most importantly, PEGASIS assumes that each sensor node uses direct communication with the base station. It also assume that each node have got complete database of the location of all the other nodes participating in the network. In addition, PEGASIS assume that all the sensor nodes have same level of energy and are likely to die at same time.

E. SPIN(Sensor Protocols for Information via Negotiation)

SPIN[9],[10] is the data centric routing protocol which falls under the category of Adaptive protocols that uses data negotiation and resource-adaptive as its algorithms. It assumes that all the nodes in the network will act as potential base stations along with the assumption that nodes in close proximity have similar data. Nodes that uses SPIN as their protocol for routing their data they uses high-level name to completely describe their gathered sense data that is also known as Meta-data and perform metadata negotiation before transmitting any data. This ensures that no duplicate data sent throughout the network. The semantics of meta-data depends upon application and not mentioned in SPIN. Since all the nodes assumed as base stations in the SPIN, so all information is broadcasted to all the nodes in the network.

SPIN is three way handshaking protocol. Its uses three types of messages, ADV, REQ, and DATA to communicate. ADV is used to advertise new data, REQ is used to request data, and DATA is the information itself desired by user. It has following steps to start communicating. Data Communication is shown in figure 5. Firstly, it broadcast an ADV message containing meta-data. If a neighboring node is interested in the data, it send a REQ message for the DATA and DATA is sent to the neighbor node. The neighbor sensor nodes that get data repeats same process with their neighbouring nodes. As a result, the wide sensor area will receive a copy of the data. The concept of Meta-Data negotiation eradicate the traditional problem of flooding and thus it achieves energy efficiency.The SPIN protocol includes many other protocols. The major two protocols are SPIN-1 and SPIN -2. They include negotiation as an important part before transmitting data in order to ensure that only useful information will be transferred. Each data collector has its own resource manager that keeps track of resource consumption. The SPIN-1 is three way handshaking protocol, as described above. SPIN-2 is an extension of SPIN-1 protocol it enhances the features of SPIN-1 by introducing a new concept known as threshold-based resource awareness mechanism in addition to negotiation. When the energy in the node is more than enough, SPIN-2 protocol communicates using 3-stage protocol of SPIN-1. One of the advantages of SPIN is that topological changes are localized since each node need know only its single-hop neighbours. Although SPIN provides much energy savings than flooding, and meta-data negotiation almost halves the redundant data but still SPIN's data advertisement mechanism cannot guarantee reliable transmission of data.

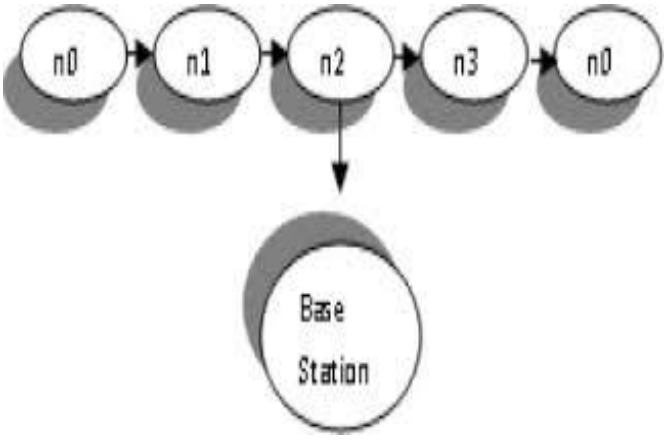
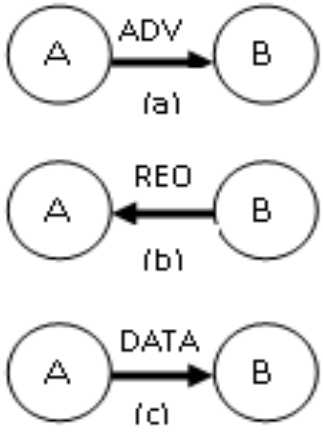


Fig 4. Chaining in PEGASIS



a. Node A sends ADV message to Node B
b. Node B sends REQ messahe to Node A
c. Node A sends DATA to Node B

Fig 5. Data transmission in SPIN

F. DD (Directed Diffusion)

Directed diffusion[10] is data-centric data dissemination and application-aware protocol that all the information generated by sensor nodes is named by attribute-value pairs. In order to prolong the network lifetime and saving network energy, the DD model of data centric routing combine the data coming from different sources by eradicating redundancy and minimizing the number of transmissions. Directed diffusion comprises of four elements: interests, data messages, gradients and reinforcements. An interest that describes a task. Data messages are named using attribute value pair. A gradient denotes data rate as well as the direction of event and reinforcement selects a optimal path out of number of paths. In DD, sink node(base station) periodically broadcasts an interest message to its neighbours. The interest is diffused through the network hop-by-hop. After receiving interest by each sensor node , all the nodes establishes a gradient toward the sink node(base station), which is a reply link toward the neighbor from which the interest was received. After interest fit gradients, informations passes through multiple paths but out of that paths only the best paths are reinforced to prevent further flooding according to a local rule. In order to reduce the communication cost, the intermediate node aggregate their data depending on the data message. Since interests are not reliably transmitted so the base station periodically refreshes and resends the interest when it starts to receive data from the source. Directed Diffusion protocols are application-oriented and hence in order to save energy it can go with likelihood path by performing caching and processing data in the network. However, it also suffers from some drawbacks. Firstly, Time Synchronization is required for data aggregation which is not very simple in WSN. Secondly, the cost of sensor node is increased when this protocol is associated with the overhead involved in recording information.

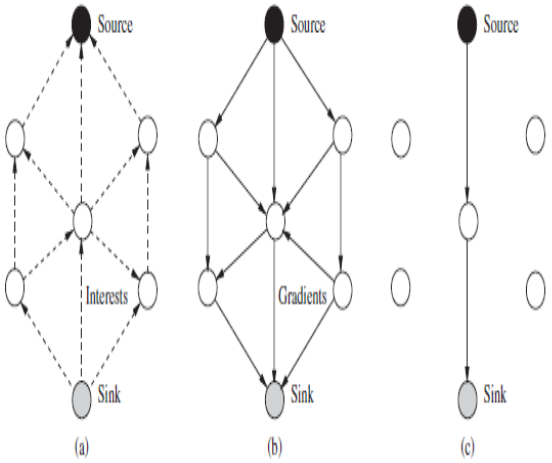
G. GEAR(Geographic and Energy-Aware Routing)

GEAR[11] is an example of a geocasting protocol, where packets are forwarded to all nodes inside a clear and exact target region. It falls under the category of location based routing protocols in which the sensor network need location information of all the sensor nodes to calculate the distance between any two nodes. GEAR protocol uses GIS(Geographic information system) in order to locate the position of sensor nodes. As stated by GEAR protocol that each node in GEAR keeps an estimated cost and a learning cost of reaching the destination through its neighbours. The estimated cost is the mixture of residual energy and distance to destination. The learned cost is the modification of estimated cost that accounts for routing around holes in the network. When node unable to find any closer neighbor towards the target region, then a hole occurs. This protocol follows two phases:

Phase-I: This phase is responsible for forwarding the packets towards target region. In this phase after receiving a packet a data collector searches for a neighbor which is closer to the target region than itself. If there are more than one nearer neighbor to the target region then it will be going to select as next hop.

Phase-II: This phase is responsible for forwarding the packets inside the region. If the packet has reached inside the region then it is diffused in that region by either recursive geographic forwarding or restricted flooding.

GEAR not only helps in reducing energy consumption but also performs better in terms of packet delivery.



a. Interest propagation
b. Initial gradients set up
c. Data delivery

Figure 6. Direct Diffusion Protocol

III. COMPARISON OF ROUTING PROTOCOLS

Now we compare the above routing protocols in accordance with a performance depending on different parameters.

Protocols	Mobility	Position awareness	Localiz-ation	Scalability	Multipath	Classification	Data Aggregation	QOS	Negoti-ation
LEACH[3]	Fixed BS	No	Yes	Good	No	Clustering	No	No	No
TEEN[4]	Fixed BS	No	Yes	Good	No	Clustering	Yes	No	No
APTEEN[5]	Fixed BS	No	Yes	Good	No	Hybrid	Yes	No	No
PEGASIS[8]	Fixed BS	No	Yes	Good	No	Reactive	Yes	No	No
SPIN[9],[10]	Possible	No	No	Limited	Yes	Flat	Yes	No	Yes
DD[10]	Limited	No	Yes	Limited	Yes	Flat	Yes	No	Yes
GEAR[11]	Limited	No	No	Limited	No	Location	No	No	No

IV. CONCLUSION

In recent years, Routing in sensor networks has enchanted a lot of attention and introduced unique challenges match up to long-established data routing in wired networks. Routing protocol in wireless sensor networks as one key technologies that has been a hot area of research. In this paper we mainly direct our attention on the energy efficient protocols that have been developed for WSNs. So in our project work we have gone through the necessary things that is important for survey of routing techniques in WSNs. In our paper firstly we have gone through the classification of routing protocols namely proactive, reactive and hybrid on the basis of their mode of function and type of target application. Further , there classifications has done according to participating style of nodes as direct communication, flat and clustering protocols. More importantly again depending on the network structure these are grouped as Hierarchical, Data Centric and Location Based. In our paper, we have gone through the seven routing protocols that plays a vital role in energy efficiency. These protocols are LEACH, TEEN, APTEEN, PEGASIS, SPIN, DD, and GEAR. Because the applications of wireless sensor network everywhere so it is difficult to say that there is routing protocol suitable for all the applications. As our study reveals that in future refinement of any of the above routing protocols in such way that refined protocol plays a vital role in minimizing more energy for the entire system.

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