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Clustering Protocols in Wireless Sensor Network: A Review

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Abstract - The research conducted in Wireless Sensor Networks (WSN) in last few years witnessed the popularity of this domain among the researchers. There are various issues in WSN such as energy consumption, route optimization, lifetime enhancements, etc. that are required to resolve. The clustering approach is developed to resolve the issue of energy consumption in network. But the cluster selection is most tedious task to perform. Thus, various cluster head selection strategies have been developed by different authors. This study provides an analysis over the sensor networks and various strategies that can be used for creating an energy efficient network by modifying the cluster head selection criteria.

Key Words: Sensor Network, Cluster Head Selection, LEACH, TEEN, APTEEN.

1. INTRODUCTION

The Wireless sensor network (WSN) can be described as group of sensors which when implemented in the sensor field they work to monitor the particular parameters of the environment. After measuring these parameters the relevant information was collected. The WSN is newly emerged technology that had large scale application like protection of infrastructure, industrial sensing, monitoring the parameters of environment, context–aware computing etc. In the Wireless Sensor Networks (WSNs) the communication between the nodes is done in wireless form. In the large areas various numbers of users are present; for example mobile users. So the towers in the particular area that are behaving as the sensors are referred as node in WSNs. Therefore the transmission of data from one node to another can be carried out through air medium. In this transmission network various numbers of nodes are used in which one node is used as source while other node is used as destination. In wireless sensor networks any topology can be used varying from star network to improved multi-hop wireless mesh network. Different propagation techniques can be used for data transmission either routing of data or flooding.

To select the cluster head in wireless sensor networks different protocols are used. In WSNs large number of nodes is present and all the nodes have ability to sense, communicate and compute. The term 'Routing' may be described as the technique of determining the route for transmission of data. All the nodes in the network can transmit and receive the data directly with each other by using the external mobile sink. The idea of Mobile sink was come into existence to remove the drawback of static sink. By using the mobile sink, the energy consumption in the network reduced and therefore it working life time increased. In this the cluster heads (CHs) are selected by using the weight values. In addition to this the idea of event driven is implemented that will further increase the lifetime of the network by minimizing the consumption of energy. Routing strategies are required for transferring data between the sensor nodes and the base station. Routing in WSN is different than traditional IP network routing because it exhibits a number of unique characteristics such as it is unrealistic to build a global addressing scheme for a large number of sensor nodes, secondly as opposed to regular correspondence systems all utilization of sensor systems require the stream of detected information from numerous sources to a specific BS. Different routing techniques are proposed for remote sensor network and these conventions can be classified as per different parameters. The similar information received by the neighboring sensor nodes can be received by the base station (BS) and this reduces the efficiency of network. In order to remove this data redundancy and to transform the network in optimum way in terms of energy, data aggregation and fusion of sensor have been highlighted. Various routing paradigm with different ideas have been suggested by different researchers on order to make the optimum network in terms of energy. The cluster based routing paradigm is an optimum idea in which sensor nodes are grouped in order to create a cluster. In all the clusters one head is selected and which is referred as Cluster head (CH).

2. CLUSTERING PROTOCOLS

In past few years the use of WSNs have been increased and simultaneously the problems related to the energy constrained also raised because we have limited amount of energy stored in the battery. As the working of nodes totally dependent on the amount of energy therefore it is not an easy task to recharge and replace the battery unit. If any node in the network stop operating then it leads to failure of the whole network.

Clustering protocols specify the topology of the hierarchical non overlapping clusters of sensor nodes. A robust clustering technique is essential for self-organizing sensor networks. An efficient clustering protocol ensures the creation of clusters with almost the same radius and cluster heads that are best positioned in the clusters. Since every

node in a clustered network is connected to a cluster head, route discovery among cluster heads is sufficient to establish a feasible route in the network. For a large sensor network, clustering can simplify multihop route discovery and limit the number of transmissions compared to a flat, nonclustered network.

This section provides a brief explanation to the cluster head selection techniques or protocols with respect to the used cluster head selection criteria. Routing protocols for Wireless Sensor Network are as follows:

a. LEACH
b. PEGASIS
c. TEEN
d. APTEEN

a. LEACH

LEACH (Low-Energy Adaptive Clustering Hierarchy) is an adaptive technique and can automatically organize itself in the network. If for the full system lifetime cluster head is fixed, then it can be commonly seen that cluster head would die quickly because of selection of unlucky sensors and this will lead to halt of useful lifetime of nodes in those clusters.

This technique is introduced to obtain the energy efficient networks by uniformly distributing the load among all the nodes in the network. The communication of data in LEACH paradigm exist between sensor node and cluster head. The cluster head receives the information from member nodes in the cluster and then further transmit it to the sink node. After forming the cluster now it is required t choose the cluster head on the basis of probabilistic equation. When the cluster head is selected then the next stage will execute in which the gathered information is transmitted to the base station (BS) and this stage is also known as steady state. With the help of second stage the maximum overhead of whole network will reduces. The data transmission to the base station takes place by using the TDMA technique and depends upon the cluster head and also number of member nodes. It's not possible to implement it on large scale networks. The LEACH protocol have tendency to organize itself automatically and also it is adaptive in nature. With the help of LEACH protocol the cluster heads are rotated within the cluster so that the energy will be uniformly distributed within the cluster. Two assumptions are made before implementing the LEACH protocol and that are as follow:

1. BS is located at a farther distance from the nodes and also the BS is static in nature.

2. All the nodes in the network are similar and have limited amount of energy storage unit.

b. PEGASIS

PEGASIS (Power-Efficient Gathering In Sensor Information System) this technique is introduced to resolve the issues related to gathering of information. These problems are faced by the ordinary techniques. The transmission of data from the sensor node to base station takes place in this technique by transmission of gathered information to the nearest sensor nodes and finally processed to the BS. All the nodes in the sensor network contain equal load therefore it can be said that this technique implements uniform distribution of loads among various nodes. While transmission of data the sensor nodes form the chain in the network therefore the sensor nodes in the network are randomly placed. Base station is responsible for computation of the chain formed and after that the information is disseminated among sensors in the network. This protocol utilize greedy paradigm to form the chain among sensor nodes. The chain is formed on the basis of knowledge the sensor nodes contain. PEGASIS protocol is comparatively better than the ordinary protocols such as LEACH. The PEGASIS technique can eliminate the overhead of network to forming the dynamic clusters. As in PEGASIS technique there is no need to form the dynamic clusters therefore the count of transmission reduced in it. One more advantage associate with it is that this technique can also be implemented over the large scale networks because it requires only one transmission from the nodes to the BS in one round. This protocol executes fusion of data within the chain but it is not executed at the termination of the chain. Some assumptions are made before implementing the PEGASIS protocol as follow:

- Sensor nodes in the network contain all the data about the network.
- All the sensor nodes in the network are fixed in nature.
- Each sensor node contains the information about the position of all the other nodes in the network.

c. TEEN

Threshold sensitive Energy Efficient Network protocol is an improved form of ordinary LEACH protocol. TEEN protocol was introduced for temperature sensing networks. Major disadvantages of TEEN protocol are: it can be deployed over the large scale network containing large number of sensor nodes, large amount of energy is consumed, and the clusters formed by this protocol are unbalanced in nature. Reason behind the unbalanced cluster is that the CHs are randomly selected. By implementing TEEN protocol there is no increment in the lifespan of the wireless sensor networks as the cluster heads are not selected on the basis of residual energy of nodes. Drawbacks of TEEN are as below:

• It elects the CH randomly before the occurring of an event in the network. It allows the sensor nodes to establish communication out of the region which leads to the excess energy consumption and unbalanced clustering in a network.
• It comprised of single hop communication among CH and BS.

d. APTEEN

Adaptive Threshold-sensitive Energy Efficient Network protocol is developed based on LEACH with CH being selected in random. During the forming of clusters, it will generate random numbers ranging from 0 to 1 compared with a threshold, $T(n)$. The node is made as a CH for the current round, should the generated value $< T(n)$; otherwise, the node remains as a cluster member (CM). The threshold $T(n)$ can be expressed by Equation:

$$T(n) = \frac{p}{1 - p * \left(r \bmod \frac{1}{p}\right)}; \quad \text{if } n \in G$$

0 ; Otherwise

Where p is the elected probability of the MCHs among all the nodes, r is the number of current round, and G is the collections of the nodes that have not yet been selected as MCH nodes during the previous 1/p rounds.

Once CH is determined, it declares itself selected as the CH in this round and broadcasts the attribute, hard threshold (HT), soft threshold (ST), and count time (CT) parameters. Each node may acquire messages from one or more MCH and will choose its participation in the cluster which has the strongest received signal. After cluster formation, CM starts sensing continuously. When the value exceeds HT, sensed value (SV) is stored in an internal variable and the data is transmitted to CH according to TDMA schedule assigned for it. And then, CM node keeps on sensing. The sensed value will be stored and transmitted again only if the sensed value exceeds HT, and meanwhile, the variations of sensed value in the transmitter and receiver exceed the ST. In addition, as CT is surpassed, the sensed value does not exceed threshold value which causes no sensed data, the nodes are forced to transmit data to CH. CT is the maximal time interval between two reports sent successively by a node. Since data transmission appears periodic, the sensed values of nodes are transmitted frequently to CH. Reasonable selection on threshold values and CT can reduce the energy consumption.

A reactive network protocol called APTEEN is Adaptive periodic threshold sensitive energy efficient sensor network protocol. Hybrid Networks combine the best features of proactive and reactive networks, while minimizing their drawbacks. Nodes in such a network transmit data periodically at relatively longer intervals while at the same time transmitting data when the sensed value goes beyond its threshold. Thus, the sensor energy is used very efficiently by reducing the number of transmissions of noncritical data. The user can change the periodicity, threshold value(s) and the parameter to be sensed in different regions. This network can emulate either the proactive or the reactive network by suitably changing the periodicity or threshold values. Thus, this network can be used in any type of application by suitably setting the various parameters. However, this flexibility and versatility does increase the complexity at the sensor. Here a new protocol APTEEN (Adaptive Periodic Threshold-sensitive Energy Efficient sensor Network Protocol) is introduced for hybrid networks. There are applications in which the user wants time critical data and also wants to query the network for analysis of conditions other than collecting time critical data. In other words, the user might need a network that reacts immediately to time critical situations and gives an overall picture of the network at periodic intervals, so that it is able to answer analysis queries. None of the above sensor networks can do both jobs satisfactorily since they have their own limitations. APTEEN is able to combine the best features of proactive and reactive networks while minimizing their limitations to create a new type of network called a hybrid network. In this network, the nodes not only send data periodically, they also respond to sudden changes in attribute values. In this way it works as a proactive protocol as well as reactive protocol. This uses the same model as the TEEN protocols with the following changes. In APTEEN, once the CHs are decided, the following events take place in each cluster period. The CH first broadcasts the following parameter.

Thresholds: This parameter consists of a HT and a ST. HT is a value of an attribute beyond which a node can be triggered to transmit data. ST is a small change in the value of an attribute that can trigger a node to transmit.

Schedule: This is a TDMA schedule, assigning a slot to each node.

Count time: This is the maximum time period between two successive reports sent by a node. It can be a multiple of the TDMA schedule length, and it introduces the proactive component in the protocol. Data values exceeding the threshold value are referred to as critical data. The nodes sense their environment continuously. However, only those nodes that sense a data value at or beyond the hard threshold transmit. The exception to this rule is that if a node does not send data for a time period equal to the count time, it is forced to sense and transmit the data, irrespective to the sensed value of the attribute. Hence, a TDMA schedule is used and each node in the cluster is assigned a transmitter slot. The main features of the scheme are as follow:

1) By sending periodic data, it gives the user a complete picture of the network, like a proactive scheme. It also senses data continuously and response immediately to drastic changes, making it

responsive to time critical situations. Thus it behaves as a reactive network.

2) It offers a lot of flexibility by allowing the users to set the count time interval and the threshold values for the attributes.
3) Changing the count time as well as the threshold values can control energy consumption and can support proactive and reactive behavior in a sensor network.

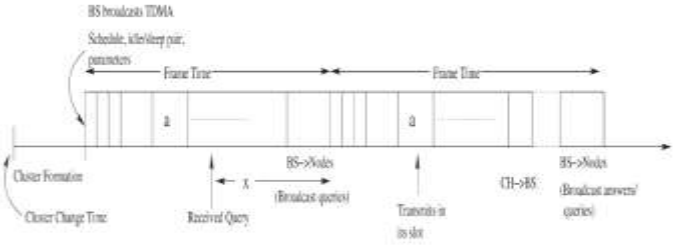

Fig- 1 : Time Line for enhanced APTEEN for Query Handling

The idle nodes in addition to the above behavior, also have to handle queries, as shown in Figure. After cluster formation, BS broadcasts those queries which it can't handle, to the idle nodes. So, the idle nodes have two additional responsibilities.

1. The idle nodes listen continuously for queries. If a node receives a query in the current frame, then it waits till its slot in the next frame and transmits the query to its CH.

2. If the nodes satisfy any of the queries received from the BS, they transmit the sensed data to the BS (through the CHs). A study of other systems which use TDMA led us to realize that, to overcome synchronization problems, the data (queries) for a node should be handled in the frame after the one in which they arrive. The node can transmit the query to its CH in its current slot and so on. Otherwise, the node has to wait till its next slot to transmit the query.

When the load increases, it is possible that a query arrives even before the node has transmitted the previous query. It is most unlikely that a sensor network with energy restricted nodes will be made to operate in a situation where, at any instant, there are as many queries as there are nodes or a single node will be queried more than once in one frame time which is approximately a fraction of a second, in this case. Even if the query frequency is greater than the frame time, more than one node receives the query broadcast by a user. So, there is enough redundancy in the system to handle such loads. But, in the worst case scenario, we would like to make the system as robust as possible so that it is capable of handling heavy load situations. We make use of the buffer available at each node to hold new queries when the old ones are still being processed. The queries are dequeued on a first come first served (FCFS) basis. So, if a node is already handling a query when another query arrives, it is enqueued and handled as soon as the current query is dealt with.

Therefore, no query is dropped, but the delay for some queries increases. The delay for answering the queries depends directly on the frame time, which in turn depends on the maximum number of nodes in a cluster. Since the BS forms the clusters, the nodes are distributed evenly in all clusters while minimizing the transmission distance within a cluster.

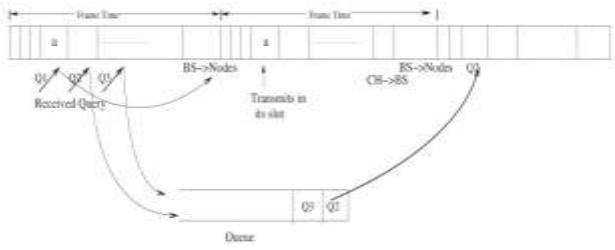

Fig- 2 : System Model

Hence, the frame size is also expected to vary according to a normal distribution. We initially considered a fixed frame size to simplify the model. To start with, we consider a situation where all nodes form only one cluster and hence, the frame-size is a constant and is given by Frame Time = no. of sleep nodes * sleep slot + no. of idle nodes * idle slot + (CH -> BS) slot + (BS -> nodes) slot.

Described above is mainly based on hierarchical routing protocol which relevant to applications and difficulty of wireless sensor, the protocol is difficult to say which is more superior. Based on the performance requirements above, here the comparison of the routing protocols described in the text shown in Table 1.

Table 1: Comparison of Routing Protocols

	LEACH	PEAGSIS	TEEN	APTEEN
Energy Conservation	Very Good	Very Good	Very Good	Very Good
Network Life Time	Good	Very Good	Very Good	Better
Data Based	No	Yes	Yes	Yes
Location Based	No	No	No	No
Robustness	Better	Better	Better	Better
Scalability	Good	Good	Good	Good
Security	No	No	No	No

3. LITERATURE REVIEW

The TEEN protocol send the value of sensed parameter to the base station, when there is sudden and significant change in the threshold value of that parameter higher than or equal to the set threshold, then sensor node switch on its transmitter to send the required information to the base station. APTEEN is the enhance version of TEEN protocol, it send the sensed periodical data at regular time interval and it can be used in both application either proactive or reactive. APTEEN has a disadvantage over TEEN that it consumes more energy than TEEN because it sends the sensed data periodically. This protocol have four parameters i.e.- hard threshold, soft threshold, current value and the count time. APTEEN has one more parameter than the TEEN which is count time. Count time is a counter which is a time duration after which the node sends the sensed value to the CH whether it reaches the threshold or not. In this way it gives the solution for real time applications but at the cost of more energy dissipation [1] .

It is observed that it is one of the hierarchical clustering protocol in which hierarchy of sensor nodes is present. In this protocol data is accumulated from sensor nodes and transmitted from cluster head of first level to cluster head of next level and so on until it reaches to the Base station. TEEN executes its function on the basis of a threshold value. It is an enhancement of TEEN protocol in order to overcome its drawbacks. It uses the same concept of TEEN to reduce energy dissipation. This protocol provides a time critical information as well as constant transmission of sensed data to user. It works on the combination rule from both the LEACH and TEEN protocol. Its efficiency is between the two protocols as it performs the function of both the protocol [2].

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. It allows the user to set threshold values and also a count time interval. If a node does not send data for a time period equal to the count time, it is forced to sense and retransmit the data thus maintaining energy consumption. Since it is a hybrid protocol, it can emulate a proactive network or a reactive network depending on the count time and threshold value. It has the disadvantage that additional complexity is required to implement the threshold function and count time features [5].

It is a basic routing protocol of hierarchical clustered multihop routing protocol. TEEN protocol in WSN assume a trusted environment where all sensor nodes cooperate each other without any attacks. There are routing protocol groups based on their mode of functioning and the type of target application in WSNs: proactive and reactive routing protocols. In proactive routing protocol, once the cluster heads (CHs) are decided after cluster exchanging, the CH node creates a TDMA schedule and assigns each node a time slot when it can transmit. After setup phase, cluster members sense the phenomena and transmit the data to the CH. The CH aggregates this data and sends aggregated data to the higher level CH, or the BS depends on the network hierarchy. Low-Energy Adaptive Clustering Hierarchy (LEACH) is a good example of a proactive routing protocol with some small differences. TEEN protocol: node-to-CH, CH-to-BS, and CH-to-CH communication [8].

The LEACH and PEGASIS protocols hold up applications where information from sensor nodes is rarely transmitted to the sink. Therefore, the information pleased from multiple nodes is decreased throughout aggregation method. Though, these protocols may not be reactive to event-based applications, where information is generated only when assured events take place. The TEEN protocol aims to give event-based release in the network. APTEEN protocol is the addition protocol of the TEEN protocol, which correct the parameters issued through the cluster head, which can change associated parameters according to the requests of users, together with a set of physical attributes uttered that users expect to get; hard and soft threshold; operation mode (TDMA); counting time (CT), the mainly time period represented successful data communication of a node. APTEEN moreover used superior TDMA scheduling thus allocating a specific slot for transmission for preventing data redundancies [12].

TEEN is based on a hierarchical grouping where closer nodes form clusters and this process goes on the second level until the BS (sink) is reached. TEEN is a clustering communication protocol that targets a reactive network and enables CHs to impose a constraint on when the sensor should report their sensed data. After clusters are formed, the CH broadcasts two thresholds to the nodes namely Hard threshold (HT), and Soft threshold (ST). The architecture of APTEEN is same as in TEEN, which uses the concept hierarchical clustering for energy efficient communication between source sensors and the sink. APTEEN guarantees lower energy dissipation and helps in ensuring a large number of sensors alive. When the base station forms the clusters, the CHs broadcasts the attributes, the hard and soft threshold values, and TDMA transmission schedule to all nodes, and a maximum time interval between two successive reports sent to a sensor, called count time (TC) [15].

In modified APTEEN, focus is on increasing the energy efficiency of the sensor network by modifying the cluster head selection in APTEEN. New clusters are formed and cluster head are selected by using the random number generation system in clustering. However, during the simulation of the environment in APTEEN, it is observed that with the passage of time nodes starts to be dead because of power shortage [18].

The "APTEEN" is an expansion of "TEEN" and goals at both taking episodic data gatherings and replying to time-critical

events. As soon as the BS formulates the clusters, the C.H transmits the features, the values of threshold and schedule of transmission to all nodes. After that, the C.H performs information accumulation, which has as a consequence to preserve power. The main advantage of "APTEEN" in contrast to "TEEN", is that nodes utilize a smaller amount power. On the other hand, the primary disadvantages of APTEEN are the complication and that it results in lengthier deferment times [22].

4. CONCLUSION

The clustering routing protocols are the basic need for an energy efficient cluster head selection in a wireless sensor networks. This paper presents a double cluster heads Adaptive Threshold-sensitive Energy Efficient Network based on ant colony (ADCAPTEEN) and a Multiple Adaptive Threshold-sensitive Energy Efficient Network based on ant colony (AMAPTEEN) in wireless sensor networks (WSN). Two proposed protocols modify traditional $T(n)$, and MCH and CH are selected by considering the residual energy of nodes. Making the choice of MCH and CH is more reasonable. Forming multipath using ant colony, AMAPTEEN reduces energy consumption, improves node survival rate, and extends life cycle of network.

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