

A Survey On: Cluster Based Routing Protocols in Wireless Sensor Network

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ABSTRACT: This paper opinion the mechanisms by which sensors collect information from the physical world and convert it into the electronic alerts that are utilized in today's facts and control systems. In this paper, several fundamental key aspects of cluster based routing protocol are investigated. This paper review a variety of cluster based routing protocols used in wireless sensor networks. It summarizes types of cluster based routing protocols now a day used or being developed in remote sensing. It is expected that new types of cluster based routing protocol will be developed in future.

KEYWORDS: Text Wireless Sensor Networks, clustering protocols, WSN.

I. INTRODUCTION

A wireless sensor network is a collection of large number of sensor nodes and at least one base station. The sensor node is an autonomous small device that consists of mainly four units that are sensing, processing, communication, and power supply. These sensors are used to collect the information from the environment and pass it on to the base station [1]. A base station provides a connection to the wired world where the collected data is processed, analysed and presented to useful applications. Thus by implanting processing and communication inside the physical world, wireless sensor network (WSN) can be utilized as a device to scaffold genuine and virtual environment. A typical WSN deployed to collect data about an environment is shown in Fig 1. The major components of this network are sensor nodes, a base station and a sensor field.

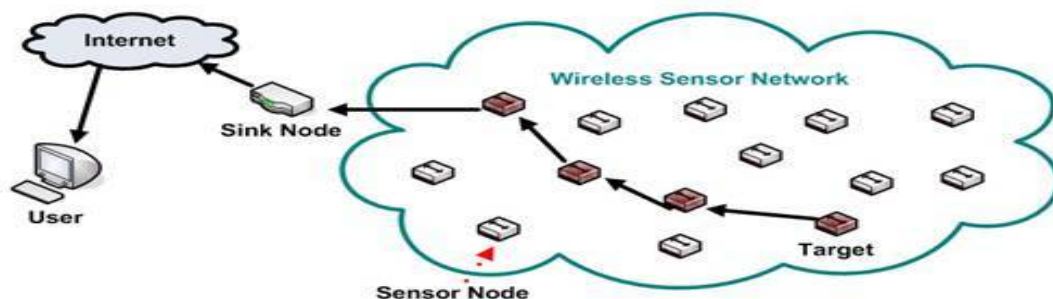


Fig 1: Working of Wireless Sensor Network

The nodes monitor the sensor field for the happening events. An event or phenomena of interest is the data generated by a monitored application. For example, an event may be the temperature, relative humidity and wind speed alert packets generated during a wildfire monitoring application. The operation of each node depends on the nature of these events. Once an event is detected, it is reported to a base station using multi-hop transmission links. After further analysing the data, the base station makes it available on the Internet, which the users can access; their computers or handheld devices provided they have privileges to do so. The nodes which sensed the events are known as source nodes while the nodes which process the data during its transit to a base station are known as intermediate nodes

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Some of the main features of wireless sensor networks are scalability, self-organization, self-healing, dense deployment, resource constrained, self configurable, application specific and data centric, low complexity, low cost and small size of nodes.

Scalability: The term scalability refers to the ability of a network to grow in terms of the number of nodes, without generating excessive overhead.

Self-organization: Self-organizing networks allow a new node to automatically join the network without the need for manual intervention.

Self-Healing: Self-Healing networks allow nodes to configure their link association and find alternatives pathways around failed or powered-downs nodes.

Dense node deployment: Sensor nodes are usually densely deployed in the field of interest.

Battery-powered sensor nodes: Sensor nodes are usually powered by the battery. In most situations, they are deployed in a harsh or hostile environment, where it is very difficult or even impossible to change or recharge the batteries.

Resource Constrained: Sensor nodes are highly deficient in energy, computation and storage capacities.

Self-Configurable: Sensor networks are usually deployed without careful planning and engineering. Once deployed, sensor nodes have to autonomously configure themselves into a communication network.

Application specific: Sensor networks are application specific. A network is usually designed and deployed for a specific application. The design requirements of a network change with its application.

Unreliable Sensor Nodes: Sensor nodes usually deployed in harsh or hostile environment and operate without attendance. They are prone to physical damages or failures.

Frequent Topology Change: Topology of these networks change frequently due to node failure, physical damage, nodes addition, energy depletion or channel fading.

No Global Identification: Due to large number of sensor nodes. It is usually not possible to build a global addressing scheme for the sensor networks because it would introduce a high network overhead for the maintenance of unique identification.

Many to one traffic pattern: In most of the applications of sensor networks, the data sensed by sensor nodes flow from multiple source sensor nodes to a particular sink node or base-station, exhibiting a many tone traffic pattern.

Low Cost: Even though there are many micro sensors replacing each macro sensor, due to reduced size, reliability and accuracy constraints on micro-sensor nodes, these nodes are much cheaper than their macro-sensor counterparts. Therefore, micro-sensor systems are less expensive than macro-sensor systems.

II. RELATED WORK

The cluster based routing is energy efficient method in which nodes those having high energies are arbitrarily selected for processing and sending data while nodes having low energies are used for sensing and sending information to the cluster heads(CHs) [5]. This property of cluster based routing contributes to the scalability, lifetime maximization, and energy minimization. The cluster-based routing protocols play a pivotal role in achieving application specific goals.

The popular cluster based routing protocols are LEACH, HEED, TEEN, APTEEN, PEGASIS, LEACH-VF, EECS, CCS, and TSC.

Low Energy Adaptive Clustering Hierarchy (LEACH): LEACH protocol is a typical representation of hierarchical routing protocol. It is a self-adaptive and self-organized. Leach protocol uses round as unit, each round is made up of cluster set-up stage and steady state storage for the purpose of reducing unnecessary energy cost. The steady-state phase duration is usually much longer than set-up phase duration. However, the first phase is more important, in which sensor nodes are allowed to elect themselves as cluster-head randomly, and then divided into clusters [2]. Each node that becomes the cluster head (CH) will create a TDMA schedule for the sensor nodes within the cluster. That allows the radio components of each non-CH-node to be turned off all times except during their transmit time. The advantages of the LEACH protocol are that its delivery delay of packets is very small and complexity of an algorithm is low. But Scalability and energy efficiency of the sensor node is very low.

Hybrid Energy Efficient Distributed (HEED): HEED (Hybrid Energy Efficient Distributed) protocol is the clustering protocol. It uses using residual energy as a primary parameter and topology features (e.g. node degree,

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distance to neighbours) are only used as secondary parameters to break a tie between candidate cluster heads, as a metric for cluster selection to achieve load balancing [10]. Advantage of the Hybrid Energy Efficient Distributed protocol is that it provides the cluster stability of the network is high. But the scalability, energy efficiency, load balancing, algorithm complexity of wireless sensor networks and delivery delay of the message is medium.

Threshold-Sensitive Energy Efficient Sensor Network (TEEN): The principle protocol created for responsive systems is TEEN (Threshold sensitive Energy Efficient sensor Network protocol). TEEN depends on group based various levelled approach and uses information-driven strategy. TEEN is occasion driven, a receptive protocol which is most appropriate for time basic application [12]. It transmits information in hard threshold and soft threshold values as it uses the information driven methodology in which information is essential and asked for in view of quality worth. The use of this protocol, for example, intrusion detection, explosion detection and so on. In TEEN protocol cluster head development procedure depends on LEACH (Low Energy Adaptive Clustering in Hierarchy). In TEEN protocol the energy efficiency and load balancing of the network are very good but the scalability of the network is low.

Adaptive Threshold-sensitive Energy Efficient Sensor Network Protocol (APTEEN): APTEEN is an extension to TEEN and its aims at both transmitting periodic data and reacting to time critical events. The structural design of APTEEN is similar to TEEN. In APTEEN firstly the cluster are formed by base station, now the cluster heads broadcast the attributes, the transmission schedule, count time and the threshold values to all nodes. All the nodes sense the environment continuously, if sensed value is equal to or beyond HT then transmission is permitted. If a node does not send data for a time interval equal to the CT, it must sense and transmit the data again. Cluster heads achieve data aggregation in APTEEN in order to save energy [7]. APTEEN protocol provides the better cluster stability of network but scalability and energy efficiency is not good. It's another benefit is that it has small delivery time of message between source to destination.

Power-Efficient Gathering In Sensor Information Systems (PEGASIS): An improved protocol called PEGASIS (Power-Efficient Gathering in Sensor Information Systems), which is near optimal for this data gathering application in sensor networks. The idea in PEGASIS is to form a chain among the sensor nodes so that each node will receive from and transmit to a close neighbour [11]. Gathered data moves from node to node, get fused, and eventually a designated node to the Base Station. Nodes take turns transmitting to the BS so that the average energy spent by each node per round is reduced. One of benefit of this protocol is that it has better energy efficiency but scalability and cluster stability is very low.

Energy Efficient Clustering Scheme (EECS): EECS (Energy Efficient Clustering Scheme) is suitable for periodic data gathering applications. It is an extension of LEACH and differs from LEACH in the cluster set-up stage. The main idea of EECS is to elect cluster heads with more residual energy. EECS divides the network into cluster and uses direct single-hop communication between the cluster head and base station [9]. EECS creates uniform cluster heads across the network. This protocol has moderate cluster stability, energy efficiency, load balancing and delivery delay. The scalability of network is low and complexity of the algorithm is very high.

Concentric Clustering Scheme (CCS): In CCS (Concentric Cluster Scheme), the sensor network field is divided into levels where each level is a concentric region. Each region in the field consists of nodes with the base station at the centre. All the nodes and the base station are fixed in the area. The topology of this network remains same. The base station sends the Hello packets and gets the location of all nodes. The nodes are checked for the energy higher than the threshold value. If the nodes greater than the threshold value, it is selected as co-ordinate nodes [8]. These nodes will send the location of itself to the base station acknowledgement. The base station sends the information regarding the respective co-ordinate Node to the specific region. All of the parameters of this protocol are not good.

Track-Sector Clustering (TSC): The TSC scheme is basically a hierarchical clustering scheme with one head node selected in each cluster. The TSC scheme uses tracks and sectors to form clusters. Therefore, a cluster is an area under curved strip formed by the intersection of a circular track and a triangular sector [13]. The formation of cluster using tracks and sectors reduces redundant data transmission in the network by breaking the long chain in the track into smaller chains. Also, it reduces the total distance for transmission of data from the nodes to their respective head nodes and then finally to the Base Station. All of the parameters of this protocol are moderate means that they are not very good or not very bad.

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III. CLASSIFICATION OF ROUTING PROTOCOLS IN WSN

In WSNs, the routing protocols are broadly classified into four categories, i.e., location-based, QoS-aware, data-centric and cluster-based hierarchical protocols [6].

Location based routing protocols: Location-based routing protocols require the location information of nodes to establish network communication. Location information enables the nodes to calculate the distance between them which in turn estimates their energy consumption. In the absence of a global addressing scheme, location information is utilized for energy-efficient data routing in these protocols. If the region of interest is known, using the particular location of the nodes, queries are directly transmitted to the region for data collection. Therefore, not only the energy consumption is minimized but the number of transmissions is also reduced significantly. Most of the location-based routing protocols were primarily designed for ad hoc networks and are suitable for static WSNs as well. However, these protocols are not suitable for those applications where mobile nodes are required.

QoS-aware routing protocols: QoS-aware routing protocols consider the end-to-end delay requirements among sensor nodes while establishing the paths for traffic flow. All the nodes are assumed to have the same reporting rate, i.e., the number of packets transmitted per unit time is similar for all nodes. As a result, these protocols may not work efficiently for heterogeneous sensor nodes. Also, some of them rely on traffic arrival time and adjustment of packet service rate which may increase energy consumption due to the delay associated with the processing of packets.

Data-centric routing protocols: In data-centric routing protocols, the base station transmits queries to sensor nodes in certain geographical regions and waits for their responses. The Query is a programming logic which has its own particular syntax and contains the specifications and requirements for data collection. Query-based data collection requires an attribute-based naming, i.e., the properties and features of data to be collected are specified. The use of queries significantly reduces the redundancy in captured data. Data-centric routing forms a single-tier network which can overload a gateway node within a dense deployment. Overloading a gateway node increases latency, deterioration in QoS and loss of critical events. Moreover, single-gateway architecture is not scalable and may not be suitable for a large scale WSN.

Cluster-based hierarchical routing protocols: To address these deficiencies, cluster-based hierarchical routing protocols were developed. These protocols partition a network into small clusters and nominate one node in each cluster as a cluster head to collect data from member nodes. The role of a cluster head changes in each round and the nodes take turn to become cluster heads for a uniform distribution of energy load. Among all the routing protocols, cluster-based hierarchical protocols are highly efficient in terms of data aggregation, energy consumption, collision avoidance, load balancing, and fault-tolerance and network lifetime. Unlike other protocols, a single cluster head node collects data from multiple nodes in order to eliminate redundancy in the gathered data. Data aggregation reduces the energy consumption of a network because the duplicate packets are eliminated. Each cluster head aggregates data within its cluster and transmits to a base station using a single-hop communication link. However, aggregating the data of member nodes is a resource-intensive operation. Therefore, the nodes take turn to become cluster heads in different rounds to balance the resource consumption. In other routing protocols, the data is aggregated by each node on its way toward a base station. As a result, the higher delay is incurred by the time the data reach a base station.

IV. CLUSTERING OBJECTIVE AND ADVANTAGES

In cluster-based routing protocols, intra-cluster and inter-cluster communication techniques are used to reduce the number of sensor nodes which perform the task of long-haul transmission to a base station. In intra-cluster communication, a single cluster head is responsible for collecting data which reduces the energy consumption within a cluster. In inter-cluster communication, one of the cluster heads is elected as a leader node which collects data from the remaining cluster heads, further aggregates it to improve its quality, and transmits to a base station. The use of intra-cluster and inter-cluster communication techniques for data aggregation and data transmission reduces collision to a greater extent. Fig. 2 shows the typical representation of cluster based routing protocols.

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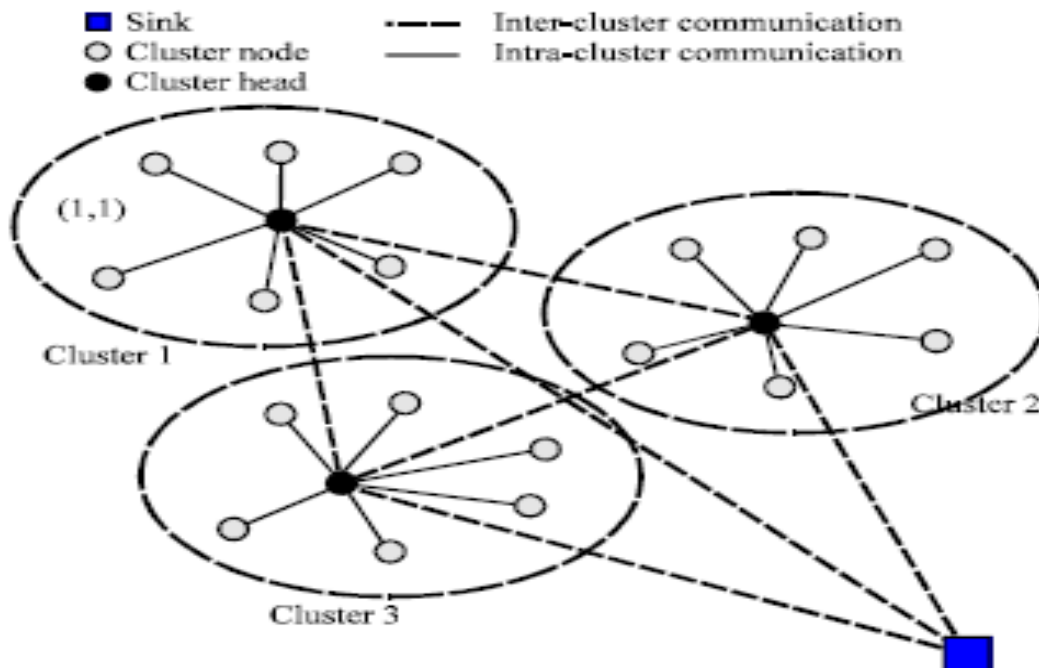


Fig 2: Clustering of Wireless Sensor Networks

Each cluster head allocates Time Division Multiple Access (TDMA) slots to member nodes within its cluster. The member nodes remain in sleep mode and periodically wake up to transmit their data to a cluster head using their allocated slots. The use of TDMA slots ensures that there is either minimal or no collision among the data packets of member nodes. Moreover, cluster heads are located at a distance far apart from each other which ensure that their transmissions have minimal chances of collision.

In contrast to flat routing schemes, cluster-based routing scheme is having the variety of advantages. Therefore, we summarize the advantages and objectives [9] of WSN clustering schemes are as follows:

More Scalability: Cluster-based routing scheme is more scalable as compare to flat topology. It is very easy to manage the events in the network.

Data Aggregation/Fusion: Data aggregation is the most popular method in which each cluster head perform the data aggregation, and sends it to the BS. It saves a significant amount of energy.

More Robustness: Cluster-based routing schemes should be dealt with any network changes, unpredictable failure, node mobility etc. Routing schemes only have to do with these changes within the individual cluster, in such a way robustness is achieved in the entire network.

Collision Avoidance: Sensor network is divided into clusters and communications among nodes involve two modes i.e. intra-cluster and inter-cluster, for the purpose of data gathering and data transmissions respectively.

Load Balancing: Load balancing is an essential requirement in WSNs, aiming to increase the network lifetime. In cluster creation, approximately equal distribution of sensor nodes is usually considered. Further, CHs performs the intra-cluster management. Generally, uniform clusters are adopted for increasing the network lifetime.

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V. COMPARISION OF CLUSTER BASED ROUTING SCHEMES

Table1. Summarizes the comparison between cluster-based routing schemes on the basis of scalability, cluster stability, energy efficiency, load balancing, algorithm complexity and delivery delay [4]. LEACH, TEEN, APTEEN and PEGASIS have similar features and fixed architecture in some extent [3].

Table1. Comparison of different Cluster-based Routing Schemes

Scheme Name	Scalability	Cluster Stability	Energy Efficiency	Load Balancing	Algorithm Complexity	Delivery Delay
LEACH	Very low	Moderate	Very low	Moderate	Low	Very small
HEED	Moderate	High	Moderate	Moderate	Moderate	Moderate
EECS	Low	Moderate	Moderate	Moderate	Very high	Moderate
TEEN	Low	Moderate	Very high	Good	High	Small
APTEEN	Low	High	Low	Moderate	Very high	Small
PEGASIS	Very low	Low	High	Moderate	High	Very large
CCS	Low	Low	Low	Very bad	Moderate	Large
TSC	Moderate	Moderate	Moderate	Bad	Moderate	Moderate

VI. RESEARCH CHALLENGES

Power: Energy of sensor is always been a challenge for WSNs designs. One of the ways to enhance the network lifetime is to design the energy efficient algorithms and hardware that uses power cleverly.

Hardware Cost: Minimizing the cost of wireless sensor is one of the most important challenges. Currently available sensors nodes are mostly prototypes of respect to these objectives. Low cost of sensor nodes may be available in recent and future progress in the fields of MEMS.

Security: Security is one of the most important challenges in WSNs. Large numbers of the attacks that are performed on WSN that place the false information by compromised nodes within the networks [1]. This is also a challenge to development of security scheme for the wireless sensor network related to constrained environment.

System Architecture: Research area of wireless sensor network is going on around the world but still there is a problem that there is no universal network architecture for the wireless sensor.

Real World Protocols: Protocols required to be developed for real world problems allowing the theoretical concepts and synthesizing original solutions into a complete system wide protocol for real world application.

Analytical and Practical Results: Now days, very few analytical results exists for WSNs. All new applications only get confidence when it is tested & analysed practically and results are compared with existing schemes.

VII. CONCLUSION

This paper has presented some of the traditional cluster based energy efficient routing protocols of wireless sensor networks and highlighted their clustering methods and their performance in terms of energy efficiency. A comparison has been done among these protocols and result is listed in the table 1.

As a future scope we can say that energy efficiency is one of the major design issues in wireless sensor networks. As most of the energy is consumed in communication than any other task so the need is to develop energy efficient

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routing protocols. Many of these protocols have been developed in the past few years but still improvements are required in routing protocols in terms of quality of service parameters.

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