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A Review on Cluster Based Architecture in Wireless Sensor Networks

Devi Raveendran¹, Dr.Bindu V.R ²

M.Tech Student, School of Computer Sciences, Mahatma Gandhi University, Kerala, India¹

Associate Professor, School of Computer Sciences, Mahatma Gandhi University, Kerala, India²

ABSTRACT: A computational nodes which are also known as WSNs are compact in size and inexpensive, measures local environmental conditions or other parameters, for appropriate processing it forwards all the information to central point. It senses the environment and can communicate with neighbouring nodes. WSNs support a wide range of useful applications. Drastic changes in the area of WSN due to recent technological advancements, leads to broad range of applications in variety of fields including environmental applications, medical monitoring, home security, surveillance, military applications, air traffic control, industrial and manufacturing automation and so on. In a hierarchical architecture, nodes with highest energy can be used to process and send the information, while nodes with low energy can be used for sensing the data. Hierarchical routing algorithm LEACH efficiently lowers energy consumption within a cluster, performing data aggregation in order to decrease the number of transmitted messages to the sink, thereby improving overall system scalability, network lifetime, and energy efficiency.

KEYWORDS: Clustering, CH, Wireless Sensor Network, LEACH, Network Lifetime.

I. INTRODUCTION

Wireless sensor networks consist of a number of sensing nodes which are distributed in a wide area. Energy dissipation is a major factor in WSNs during communication among the nodes. Energy should be saved, so that the batteries do not get depleted or drained quickly as these are not easily replaceable in applications such as surveillance. Clustering approaches prolong the network lifetime with the load balanced network. When Wireless Sensor Networks are deployed mainly for military and health applications, there is a high need of secure communication among sensor nodes. There are different techniques to secure network data transmissions, but due to power constraints of WSN, group key based mechanism is the most preferred one. Hence to implement scalable energy efficient secure group communication, the best approach would be hierarchical based like Clustering.

In most of the WSN designs based on clustering, Base Station is the central point of contact to the outside world and in case of its failure; it may lead to total disconnection in the communication. So in order to provide better fault tolerant immediate action, a new BS at some other physical location will have to take the charge. This may lead to a total change in the hierarchical network topology, which in turn leads to re-clustering the entire network and in turn formation of new security keys. Hence in such situations, we need a clustering algorithm which will perform the minimum re-clustering with minimum energy consumption and minimum execution time.

WSN consists of a large number of sensor nodes, moreover these sensor nodes run on non rechargeable batteries. So to serve the objective of fault-tolerance, load balancing and network connectivity, grouping of nodes is required. Clustering is a process of dividing sensor nodes into groups on the basis of various parameters, and selecting a group leader from each group. The groups are called clusters and group leaders are called Cluster Heads (CHs) of the clusters. Parameters for forming the clusters include distance between cluster head and its member, intracluster communication cost, residual energy of sensor nodes, location of node with respect to BS etc.

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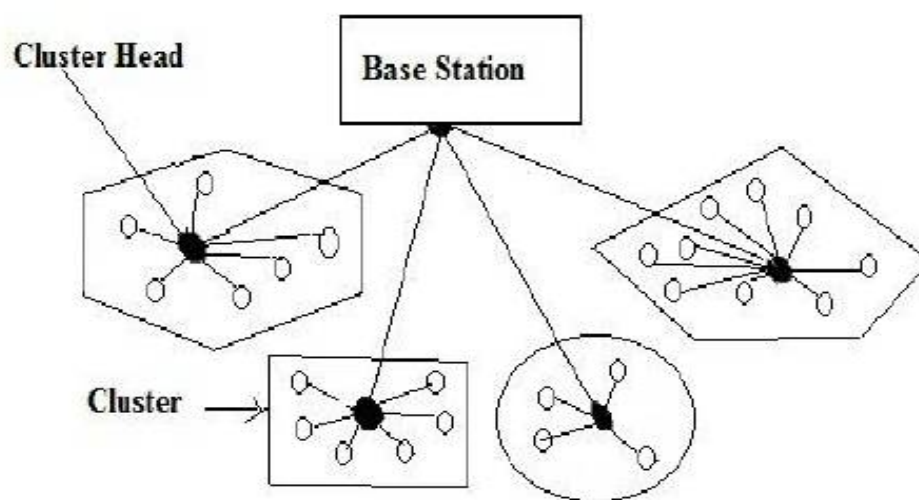


Fig. 1. Clustering in WSN

II. APPLICATIONS OF WIRELESS SENSOR NETWORK

Applications of sensor networks are divided into two basic categories[3].

- Category 1 WSN
- Category 2 WSN

Category 1 WSNs are networks in which end devices are permitted to be more than one radio hop away from a routing or forwarding node . The forwarding node is a wireless router that supports dynamic routing.wireless routers are often connected over wireless links. The important characterizations are,

- Sensor nodes can support communications on behalf of other sensor nodes by acting as repeaters.
- The forwarding node supports dynamic routing and provides more than one physical link to the remaining nodes in the network that are physically and logically present.
- The radio links are measured in thousands of meters,and These are complex and meshy wireless systems.The forwarding node can support data processing or reduction on behalf of the sensor nodes[3].

Category 2 WSNs are networks in which Point-to-point or multipoint-to-point systems generally with single-hop radio connectivity to WNs, supports static routing over the wireless network,typically, there will be only one route from the WNs to the forwarding nodes. C2WSNs are networks in which end devices (sensors) are one radio hop away from a forwarding node[3] . The important characterizations are,

- Sensor nodes do not support communications on behalf of any other sensor nodes.
- The forwarding node supports only static routing to the terrestrial network, and/or only one physical link to the terrestrial network is present.
- The radio link is measured in hundreds of meters.
- The forwarding node does not support data processing or reduction on behalf of the sensor nodes.

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Applications of category 1 wsn are : Commercial building control, Environmental and agricultural wireless sensors Home automation, including alarms , National security applications: chemical, biological, radiological, and nuclear wireless sensors, Industrial monitoring and control, Metropolitan operations (Example traffic, automatic tolls, fire, etc .) Military sensors, Process control, Wireless automated meter reading and load management.

Applications of category 2 wsn are : Home control, building automation, industrial automation, medical applications, lighting controls, automatic meter reading, wireless smoke and CO detectors etc falls under this category.

WSNs support a broad spectrum of applications, ranging from environmental sensing to vehicle tracking, from perimeter security to inventory management, and from habitat monitoring to battlefield management. WSNs may be deployed outdoors in large sensor fields to detect and control the forest fires, to detect and track enemy vehicles, or to support environmental monitoring, including precision agriculture. With WSNs one can monitor and control factories, offices, homes, vehicles, cities, the ambiance, and the environment. For example, one can detect structural faults in ships, aircraft, and buildings; public-assembly locations can be equipped to detect toxins and to trace the source of the contamination. Volcanic eruption, earthquake detection, and tsunami alerting applications that generally require WNs deployed in remote, even difficult-to-reach locations can be useful environmental monitoring systems[3].

III. PERFORMANCE OF WIRELESS SENSOR NETWORKS

The performance of wireless sensor networks is based on the following factors.

- **Latency:** Latency is defined by time taken by a node to sense, or monitor and communicate the activity. Sensor nodes collect information, process it and send it to the destination. Latency in a network is calculated based on these activities as well as amount of time a sensor takes to forward the data in heavy load traffic or in a low density network.
- **Scalability:** Scalability is an important factor in wireless sensor networks. A network area, changes depending upon the user requirements. All the nodes in the network area must be scalable or able to adjust themselves to the changes in the network structure depending upon the user [5][6].
- **Energy Awareness :** Every node uses some energy for activities like monitoring, computation, storage and transmission. A node in the network should be aware of amount of energy required to perform a new task that is submitted, the amount of energy that is dissipated can vary from high, moderate to low depending upon the type of operations and activities.
- **Processing Time of node :** It defines the time taken by the node in the network to execute all the operations beginning with monitoring the event, processing the data or storing data within the buffers and transmitting or receiving it over the network.
- **Transmission Scheme:** Sensor nodes which collect the data transmit it to the sink or the base station either using the flat or in multi hop routing schemes[8].
- **Network Power Utilized:** All the sensor nodes in the network use a certain amount of network power which helps them to perform certain activities like sensing or processing or even forming groups within the network area. The amount of energy or power utilized by the sensor nodes or a group of sensors within the network is known as network power usage[6].

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IV. CLUSTERING IN WIRELESS SENSOR NETWORKS

Clustering in wireless sensor network is one of the design methods which is used to manage energy consumption efficiently by grouping the sensor nodes into clusters which provides network scalability, resource sharing and efficient use of constrained resources that gives network topology stability and energy saving attributes. Each group of sensors has a node that serve as cluster head which is used to aggregate data from all the sensors of the same cluster and then transmit it to the base station. So it reduces the number of communication messages needed to transmit it to the base station which affect the energy consumption and reduce the overall rate of energy consumption[4].

A. LEACH ROUTING PROTOCOL IN WIRELESS SENSOR NETWORK

Low-energy adaptive clustering hierarchy (LEACH) is a routing algorithm designed to collect and deliver data to the data sink, typically a base station[3]. Three main objectives of LEACH are, Improved Network lifetime, reduced energy consumption by each sensor nodes in the network, reduced number of communication messages with the use of data aggregation technique. LEACH adopts a hierarchical approach to achieve these objectives. Heirarchial approach organize the network into a set of clusters, each cluster consists of a cluster head. The first main task of a cluster head is to collect the data from the member nodes of the cluster. The data gathered are aggregated by the cluster head to remove redundancy among correlated values. The second main task of cluster head is to transmit the aggregated data values to the base station, which is achieved over a single hop. For transmission, the cluster head's third main task is to create a TDMA-based schedule wherby each node of the cluster is assigned a time slot[5].

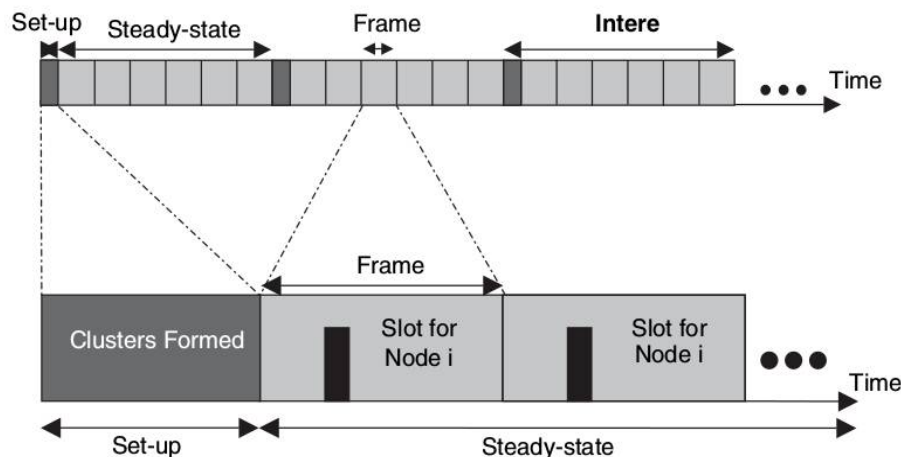


Fig. 2. Operations of LEACH protocol [3]

The function of LEACH is divided into rounds and are organized into two distinct phases as illustrated in the figure 2. The setup phase consists of CH selection and cluster formation followed by steady-state phase in which selected CH does data collection, aggregation, and delivery to base station. To minimize the protocol overhead, the duration of the setup phase is assumed to be relatively shorter than the steady-state phase[3].

Cluster head selection round begins at the starting of setup phase. Among the sensor nodes, the CH is selected randomly which uniformly distributes the energy consumption. To decide sensor nodes if its turn to become a CH, a node, n , generates a random number, v , between 0 and 1. It then compares it with CH selection threshold, $T(n)$ which is designed to ensure with high probability that a pre-determined fraction of nodes, P , is elected as CH for each round. Threshold also ensures that nodes which served in past $1/P$ rounds are not selected as CH in the current node[5][7]. To meet up these necessities, the threshold of a contending node n is articulated as follows:

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$$T(n) = \begin{cases} 0 & \text{if } n \notin G \\ \frac{P}{1 - P(r \bmod (1/P))} & \forall n \in G \end{cases}$$

where G represents the set of nodes that have not been elected to become cluster heads in the last $1/P$ rounds, and r indicates the current round. P is the cluster head probability, which is a pre-determined value[5].

Every node that was selected to become cluster head advertises its new role to rest of the network. Upon receiving the advertisement, rest of the nodes picks a cluster to join. The decision may be based on received signal strength of CH broadcast message, among other factors. The nodes then inform their selected cluster head of their wish to become a member of the cluster. Once the cluster is formed, cluster head creates and spreads a TDMA-based schedule to assign a time slot to each of its cluster member. To reduce inter cluster interference each CH selects a CDMA code, which is then disperse to all cluster members. The completion of setup phase activate beginning of the steady-state phase. During this phase, nodes collect information and use their allocated slots to transmit to the cluster head the data collected. This data collection is performed periodically[7].

B. Merits and Demerits of LEACH algorithm

Benefits of LEACH are, the cluster heads aggregates the whole data which lead to reduce the traffic in the entire network. As there is a single hop routing from nodes to cluster head considerable amount of energy is saved. It increases the lifetime of the sensor network. In this, location information of the nodes to create the cluster is not required. LEACH is completely distributed as it does not need any control information from the base station as well as no global knowledge of the network is required. Besides the benefits, there are some drawbacks such as, LEACH does not give any idea about the number of cluster heads in the network. One of the biggest demerit of LEACH is that when due to any reason Cluster head dies, the cluster will become useless because the data gathered by the cluster nodes would never reach its destination that is base station.

V. CONCLUSION

The lifetime and reliability of the network can be enhanced by clustering techniques in wireless sensor networks. A survey on wireless sensor networks and Hierarchical clustering algorithm LEACH was conducted in this paper and in future, it is expected that an improved LEACH algorithm can be developed, that considers node's remaining energy level in the selection of cluster heads for extending network lifetime by setting a threshold value with which energy consumption in sensor nodes can be minimized.

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