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A Review on Cluster Head Selection Algorithms for Wireless Sensor Networks

[1*]S. Tamilselvi, [2]S. Rizwana

[1]Department of Computer Science, Erode Arts and Science College, Erode
[2]Department of Computer Science [SF], Erode Arts and Science College, Erode

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Abstract—Energy-efficient cluster head selection algorithms are significant in Wireless Sensor Networks (WSN) to improve the lifetime of the networks. Various cluster head selection algorithms were designed in WSN to enhance the network lifetime. The tiny sensor nodes are grouped to form a cluster and clustering is an important technique in WSN. The selection of cluster heads greatly affects the throughput of the network. Still, it is a challenging task. Different approaches and algorithms have been proposed for the efficient CH selection in WSNs. In this paper, a brief survey is made about the various CH selection algorithms in the recent scenario. The advantages and disadvantages of the most important algorithms are highlighted.

Keywords – Wireless Sensor Network (WSN), Cluster Head (CH), Energy Efficient, Network Lifetime, Throughput

I. INTRODUCTION

Wireless Sensor Networks (WSN) [1] consists of numerous autonomous sensor devices that are capable of communicating with each other. These sensor devices are deployed in real-world applications to sense information about the environment. The energy of these sensor nodes is limited, so the data collected from the environment is directly sent to the Base Station (BS). Smart sensor nodes composed of low power devices equipped with one or more sensors, a processor, a power supply, a memory, a radio, and an actuator. The sensors communicate over a short distance through a common medium to accomplish a common task.

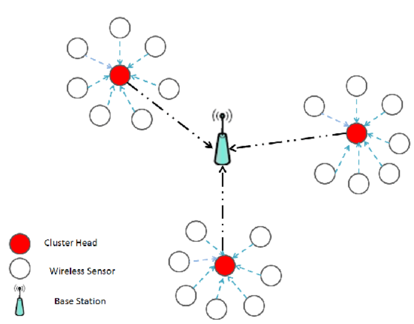

Fig. 1. The architecture of Wireless Sensor Network

WSN consists of two different types of nodes as shown in Figure 1, (i) Sensor Nodes, (ii) Base Station. The sensor nodes sense the physical or environmental conditions such as sound, pressure, humidity, temperature and collectively pass the data through the network to the BS.

This paper is organized into four different sections. In the first section, various types of WSNs are discussed. The second section is about applications of WSN. The third section discussed how clustering is done in WSN and a review of various cluster head selection algorithms is discussed in the fourth section.

II. TYPES OF WSNs

Depending on the environments, WSNs can be classified as,

(i) Terrestrial WSNs
This type of WSNs can communicate with the base stations efficiently and it consists of hundreds of sensor nodes that are deployed either in a structured or unstructured manner.

(ii) Underground WSNs
This type of WSNs is more expensive than the terrestrial WSNs in terms of deployment and maintenance. It consists of many sensor nodes that are buried in the ground to monitor underground conditions.

(iii) Underwater WSNs
This network consists of sensor nodes that are deployed under water. Here, autonomous underwater vehicles are used for gathering data from these sensor nodes.

(iv) Multimedia WSNs
Multimedia WSNs enable tracking and monitoring of events through multimedia such as images, video, and audio. It

consists of low-cost sensor nodes equipped with cameras and microphones.

(v) Mobile WSNs
Mobile WSNs consists of sensor nodes that can be moved on their own and it can interact with the physical environment.

III. APPLICATIONS OF WSNs

(i) Environmental Monitoring
Some of the parameters that are gathered are barometric pressure, ambient temperature, atmospheric humidity, wind speed, wind direction, rainfall and underground water level[2]. A group of sensors is installed in forests to prevent natural disasters such as forest fire and landslides.

(ii) Healthcare Monitoring
Healthcare monitoring systems highly concentrate on the utilization of remote sensor systems for the advancements in the medicinal services. Some of the applications include body position measurement, location of persons and overall monitoring of patients in hospitals and at home.

(iii) Crop Monitoring
WSN technology can be applied in agriculture and farming to improve its production and enhance the agricultural yield standard. Sensors can be implemented in remote agricultural areas to monitor the crops. Some of the parameters that can be monitored through WSN are soil water tension, depth of water and system capacity, etc[3].

(iv) Military Applications
WSNs are self-organized and it can be deployed rapidly. So, they are useful in military operations for sensing the friendly or hostile motions. Various attacks such as chemical, biological and nuclear attacks can be detected through sensor nodes.

IV. CLUSTERING IN WSNs

Clustering is the process of dividing the network, where sensor nodes are organized into different groups called clusters. In each cluster, one sensor node is elected as Cluster Head (CH) and then allows the sensor nodes to join it.

The CH collects the data from all other sensor nodes in the cluster and transmits the aggregated data to the Base Station (BS). The clustering methods can prolong the network lifetime, residual energy consumption and provide scalability of the network[4].

The operations in clustering protocols are divided into four phases[5]:

- Information Collection
- CH Selection
- Cluster Formation
- Data Transmission

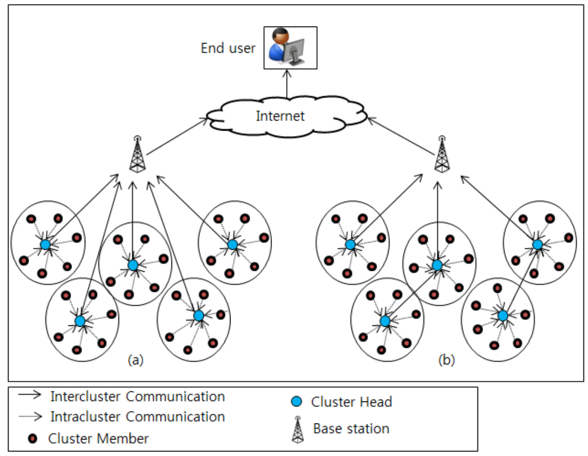

Fig. 2. Clustering in WSN

Hierarchical routing is an efficient way to reduce the energy consumption within a cluster, performs data aggregation and fusion to reduce the number of transmitted messages to the BS.

V. CLUSTER HEAD SELECTION ALGORITHMS

Sensor nodes are grouped into clusters controlled by the base station. The major issue in WSNs is the consumption of more amount of energy, therefore most of the existing schemes are focused on the energy efficiency of the nodes.

A classic energy-efficient communication protocol named LEACH[6] is introduced, where data is aggregated and sent to the BS through hierarchical clustering. It lowers the energy consumption of the network by forming the clusters. Each cluster has CH, aggregate and compresses the data and forwards to the BS. The threshold value is used to select the CH at each round.

In[7], an efficient approach to enhance the LEACH is proposed. Based on the threshold value, the CH node for each cluster is selected at each round. To avoid unwanted data transmission, a modified TDMA schedule is introduced in which the cluster with a small number of sensor nodes goes into sleep mode to balance the energy consumption which increases the network lifetime.

CHRA[8], a clustering routing algorithm for heterogeneous wireless sensor networks is proposed to balance the energy and network lifetime for heterogeneous WSNs. Sensor nodes are deployed optimally and CH is selected at each round.

Based on the redundant nodes and energy heterogeneity, the dynamic cluster head selection method[9] is proposed to reduce energy consumption and extend network lifetime.

The CH is selected in two different methods, (i) Based on Perceived Probability (ii) Based on Survival time estimation. This avoids the overlapping coverage problem and unbalances energy consumption.

The reservation-based CH selection algorithm is proposed in [10]. Here, the reservation phase is added to the beginning of the network configurations. Each node sends the R-matrix in the network and finally, a comprehensive matrix called Total Matrix is generated which shows the CH node for R rounds. Initially, it consumes more amount of energy due to the reservation phase. Later, the consumption of energy is reduced.

The tentative selection of CH by the energy-based timer is proposed in [11], selects final cluster head based on node degree, competition range and residual energy. The dual sink is used in this algorithm to enhance the lifetime of the network.

In [12], the cluster head is selected based on the residual energy. This algorithm considers the initial energy, residual energy and an optimum value of CHs to select the next group of CHS.

Delay and energy consumption of heterogeneous WSNs are reduced through a threshold based CH selection algorithm [13]. Here, CH is selected by computing the expected distance from the sensor node to the Base Station. Thus, it results in faster data dissemination.

In some distributed clustering algorithms, nodes tend to become isolated nodes from their CHs which results in higher energy consumption. Regional Energy Aware Clustering with Isolated Nodes (REAC-IN)[14] proposes a weight-based CH selection algorithm solves the problem of node isolation and improves the lifetime and stability of the network.

To enhance the overall performance of the network by selecting the appropriate CHs and forming balanced clusters, Cluster Chain Weight Metrics (CCWM)[15] approach is discussed. Network lifetime is improved and the time to first node death is increased.

Energy Aware Cluster Head Selection algorithm[16] minimizes the energy consumption and enhances network lifetime. Frequent re-clustering is avoided to select CH and the energy consumption of the nodes within the same cluster is minimized and thus it increases the network lifetime.

Firefly with Cyclic Randomization (FCR)[17] technique selects CHs based on the distance between the nodes and to the BS. Time delay is reduced by doing so and the rate of transmission of data packets is increased.

Another bio-inspired approach called firefly algorithm[18] is proposed for the selection of CHs. This algorithm selects the optimal CH node among all nodes in the network. Through energy consumption, packet drop ratio and the end to end delay of the nodes, CH is decided using the fitness function. Once the CH is elected, all the nodes are grouped with the CH.

Another approach for the selection of CH based on the Particle Swarm Optimization (PSO) is proposed in [19]. This algorithm reduces the cost of locating an optimal position for the head nodes in a cluster. Residual energy, intra-cluster distance, node degree and headcount of the probable cluster heads are the parameters considered for the selection of CHs. Network lifetime, energy consumption and an average number of packets communicated to the BS are enhanced.

Based on Particle Swarm Optimization (PSO), another approach is proposed in [20]. Energy Efficient Cluster Head Selection algorithm based on PSO called PSO-ECHS is developed with an efficient scheme of particle encoding and fitness function. The weight function is derived for the formation of clusters based on the intra-cluster distance, sink distance and residual energy.

Various optimizations of LEACH algorithms are investigated in [21], CHs are selected based on the probability to enhance the traditional LEACH and it is done by using W-LEACH and MAP. To prolong the network lifetime, the probability of CH among sensor nodes is balanced and the energy distribution is equally consumed.

In [22], CH selection is based on Artificial Bee Colony (ABC) optimization. Fitness function is derived based on the remaining energy of the sensors, the distance between cluster elements and distance from the sink station. As a result, total energy consumption is reduced when the BS is placed at the center of the sensor network.

A novel approach [23] by combining energy-awareness and load-balancing in heterogeneous WSNs is proposed to achieve the even distribution of the energy among all the nodes which ensure improved network performance. This paper implements a stable election protocol (SEP) and load balancing protocol (LEACH) to achieve efficient energy consumption.

Fault links between nodes in cluster based wireless sensor nodes is detected using the residual energy and optimum CH distance by using the non-linear equations. Verification is done by establishing the virtual link between the sensor nodes[24].

Table 1. Comparison of EDERP, REAC-IN, EEAOC, Modified LEACH, R-LEACH and DCHSM

SCHEME	PARAMETERS	MERITS	LIMITATIONS
EDERP	Throughput, Packet Delivery Ratio(PDR)	Node Classification Residual energy based CH selection increases the faster data dissemination	Network lifetime is not considered Distance to the BS is not calculated
REAC-IN	Residual Energy, Number of alive nodes, Number of data received, Average Lifetime	Weight-based CH selection Reduces the energy consumption of isolated nodes	Isolated nodes consume more energy while sending the data to previous CH nodes.
EEAOC	Number of alive nodes, Average Residual Energy	Suitable for continuous monitoring applications (Works dynamically) Hybrid data reporting strategy reduces the consumption of energy	Stationary sink nodes First node death(FND) between LEACH and EEAOC is very low
Modified LEACH	Number of Cluster heads, Network Lifetime, Number of Packets at Base Station, Energy Consumption	Energy is balanced among all the clusters Clusters with a small number of nodes go to sleep mode which reduces the energy consumption of the network.	High priority data cannot be sent when the node goes to sleep state Not suitable for heterogeneous networks
R-LEACH	Network Lifetime, Number of packets transferred to Base Station, Residual Energy, Throughput	Time to the FND and LND increases when compared to LEACH Controls the energy dissipation for extending the lifetime of the network	Not suitable for the network with mobile nodes
DCHSM	Node Lifetime, Number of active nodes, Average Residual energy of nodes	Filters the redundant information during transmission Two-stage CH selection extends the network lifetime	Heterogeneity of the mobile nodes can be extended

VI. CONCLUSION

Clustering and cluster head selection is one of the key research issues in the Wireless Sensor Network. In this paper, different CH selection algorithms are discussed in the present scenario. Most of the present CH selection mechanism focuses on reducing energy consumption by considering the residual energy of the sensor nodes. Throughput is an important aspect that is ignored in most of the proposed mechanisms. In the future, the selection of CH can be improved by using fuzzy algorithms and bio algorithms.

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