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Clustering for Improving Lifetime of Wireless Sensor Network: A Survey

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ABSTRACT : *The Wireless Sensor Network (WSN) is becoming popular day by day due to its application in various fields like agriculture, environment monitoring, military etc. In such applications huge numbers of sensors are deployed in remote areas where human intervention is not possible. As the use of WSN is increasing, the demand in terms of reliability, scalability of sensor network has become a challenge. Reliability of wireless sensor network is deliberated as amount of time for which the sensor network is functioning. Clustering is one of the key techniques used to improve lifetime of wireless sensor network by reducing energy utilization. Clustering partitions sensor network into groups called as cluster, with high energy node acting as cluster head. This paper provides survey of various clustering algorithms highlighting their objectives and features.*

Keywords - *Clustering, Energy utilization, Lifetime, Reliability, Scalability*

I. INTRODUCTION

Recent advancement in technology have led to the development of low cost, battery operated tiny electromechanical devices called as sensors, which are capable of monitoring physical or environmental conditions, such as temperature, sound, pressure, etc. With upcoming technology innovations Wireless Sensor Network have become most interesting area of research. Wireless Sensor Network composed of sensor nodes deployed in the region of interest. Sensor nodes sense and detect events in the region and communicate data back to the Base Station (BS). The region of interest can be remote area or hostile environment where human intervention is not possible, hence the reliability of wireless sensor network is utmost important. To make sensor networks more reliable poses a great challenge to research community.

In wireless sensor network a typical sensor node is compact, tiny, and inexpensive normally operated by an attached power supply that is usually a non-rechargeable or non-replaceable battery. Sensor nodes have limited processing power, communication bandwidth, and storage space. Network lifetime is the key characteristics used for evaluating the performance of any sensor network [1]. A lifetime of the network is determined by residual energy of the system, hence main and most important challenge in WSN is the efficient use of energy resources. Maximizing network lifetime is most important design objectives for all the sensor networks that need to run for a long time. One of the key techniques in improving lifetime of wireless sensor network is clustering. Clustering partitions sensor network into groups called as cluster, with high energy node among the sensor nodes acting as master of the cluster called as cluster head. Sensor nodes in cluster gather data from the region of interest and communicate it to the cluster head. Cluster head gather and aggregate the data and send it back to the BS.

1.1 Components involved in clustered wireless sensor network

- **Sensor Node:** It is the core component of wireless sensor network. It has the capability of sensing, processing, routing, etc.
- **Cluster Head:** The Cluster head (CH) is considered as a leader for that specific cluster. And it is responsible for different activities carried out in the cluster, such as data aggregation, data transmission to base station, scheduling in the cluster, etc.
- **Base Station:** Base station is considered as a main data collection node for the entire sensor network. It is the bridge (via communication link) between the sensor network and the end user. Normally this node is considered as a node with no power constraints.
- **Cluster:** It is the organizational unit of the network, created to simplify the communication in the sensor network.

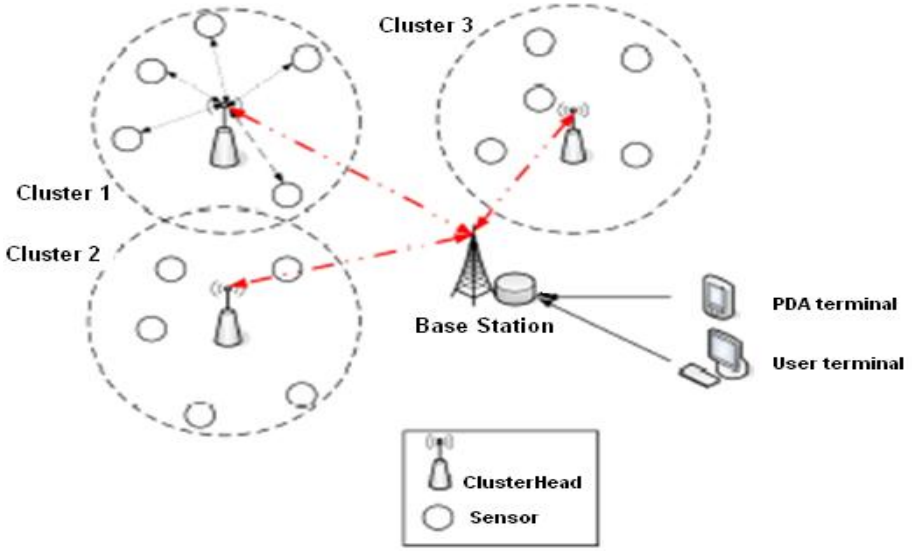

Fig. 1 Clustered Wireless Sensor Network [16]

Cluster structure can prolong the lifetime of the sensor network by making the cluster head aggregate data from the nodes in the cluster and send it to the base station. A randomly deployed sensor network requires a cluster formation protocol to partition the network into clusters. The cluster heads should also be selected. There are two approaches used in this process the leader first and the cluster first approach. In the leader first approach the cluster head is selected first and then cluster is formed. In the cluster first approach the cluster is formed first and then the cluster head is selected [2].

Some of the advantages of clustering are:

It reduces the size of the routing table stored at the individual nodes. The CH can extend the battery life of the individual sensors and the network. CH can perform data aggregation in its cluster and decrease the number of redundant packets. By scheduling the activities within the cluster CH can reduce the rate of energy.

1.2 Heterogeneity in Wireless Sensor Network

Wireless sensor networks can be homogeneous or heterogeneous, though in reality homogeneous sensor networks hardly exist. Heterogeneous sensor networks consists of large number of inexpensive nodes perform sensing, few nodes having comparatively more energy perform data filtering, fusion and transport. This leads to the research on heterogeneous networks where two or more types of nodes are considered. Heterogeneity in wireless sensor networks can be used to prolong the life time and reliability of the network. Heterogeneous sensor networks are very popular [3].

1.3 Heterogeneous Model for Wireless Sensor Networks

Heterogeneous Models for Wireless Sensor Networks varies based on the various resources. There are three common types of resource heterogeneity in sensor nodes: computational heterogeneity, link heterogeneity, and energy heterogeneity [4].

In computational heterogeneity the heterogeneous node has a more powerful microprocessor and more memory than the normal node. Using computational power, the heterogeneous nodes provide complex data processing and longer term storage.

In link heterogeneity the heterogeneous node has higher bandwidth and long distance network transceiver than the normal node. Link heterogeneity can provide a more reliable data transmission.

In energy heterogeneity the heterogeneous node is line powered, or its battery is replaceable. Among above three types of resource heterogeneity, the most important heterogeneity is the energy heterogeneity because both computational heterogeneity and link heterogeneity consumes more energy resource.

1.4 Objectives of Heterogeneous Clustering

1.4.1 Network lifetime enhancement

The energy consumed in forwarding a packet from the normal nodes to the sink in heterogeneous sensor networks will be much less than the energy consumed in homogeneous sensor networks. As the size of network increases, the difference in energy consumption between these two kinds of networks will be larger.

1.4.2 Improved response time

Computational heterogeneity can decrease the processing latency and link heterogeneity can decrease the waiting time, hence response time is decreased. [3]

1.4.3 Reliable data transmission:

With heterogeneous nodes, there will be fewer hops between normal sensor nodes and the sink. So the heterogeneous sensor network can get much higher end-to-end delivery rate than the homogeneous sensor network. [4]

1.5 Clustering Attributes

This section describes set of attributes based on which clustering algorithms can be classified [3].

1.5.1 Cluster properties

Quite often clustering schemes attempt to achieve some characteristics for the generated clusters. Such characteristics can be related to the internal structure of the cluster or how it relates to others.
The following are the relevant attributes:

- **Cluster count:** In some clustering approaches the set of CHs are fixed and thus the number of clusters. Random selection of CHs from the deployed sensor nodes usually gives variable number of clusters.
- **Stability:** Clustering scheme is termed as adaptive when the clusters count varies and the node's attachment changes in the due course. Otherwise, it is considered fixed as sensor nodes do not toggle among clusters and the number of clusters remains fixed throughout the network lifetime.
- **Intra-cluster topology:** In some clustering schemes there is a direct communication between a sensor node and its designated CH. However, when sensor's communication range is inadequate multi-hop sensor to CH connectivity is sometimes required.
- **Inter-CH connectivity:** When the CH does not have capability of long haul communication; the clustering scheme has to ensure the possibility of establishing a mutli-hop CH to CH communication route from every CH to the base-station.

1.5.2 Cluster-head capability

The chosen network model influences the clustering approach.
The following attributes of the CH node differentiates clustering schemes:

- **Mobility:** When a CH node is mobile, sensor's membership dynamically changes and the re-clustering would be continuously required. Whereas, immobile CH tends to give stable clusters and facilitate better intra- and inter-cluster communication.
- **Node types:** In some setups a subset of the deployed sensors are designated as CHs whereas in others CHs are equipped with significantly more computation and communication resources.
- **Role:** A CH can simply responsible for relaying the traffic from sensor nodes in cluster to the base station or can aggregate data collected from sensors. It can act as a sink or a base-station depending on the detected phenomena or targets.

II. RELATED WORK

Energy efficient communication protocol for wireless micro-sensor networks [1] describes LEACH (Low-Energy Adaptive Clustering Hierarchy), a first clustering-based algorithm that was proposed for reducing energy consumption. In this, cluster-heads are rotated randomly to evenly distribute the energy load among the sensor nodes in the network. Distribution of energy results in reduction of the energy dissipation and thereby improving life time of wireless sensor network. Direct communication is used by each cluster head to forward the data to the base station.

Sensor protocols for information via negotiation (SPIN) [13] is also improved the flooding algorithm, before transferring data, it only transmit data to needed neighbor nodes which using meta-data to reduce redundant information to save energy consumption.

U-LEACH, a routing protocol for prolonging lifetime of wireless sensor networks [6] is the extension of LEACH. LEACH select cluster heads randomly throughout the sensor network hence there is a possibility that the elected cluster heads will be concentrated in certain area of the sensor network. U-LEACH algorithm address this problem by using uniform distribution technique for selecting CHs and their corresponding clusters to prolong the lifetime of the network.

Distributed energy-efficient clustering [5] extends the basic scheme of LEACH by using residual energy. It selects cluster heads based on their residual energy and node degree. Sensor nodes join clusters such that communication cost is minimized. The approach exploits the availability of multiple transmission power levels at sensor nodes and operates in multi-hop networks, using an adaptive transmission power in the communication within the clusters.

A clustering-based routing protocol called base station controlled dynamic clustering protocol (BCDCP)[12], which utilizes a high energy base station to set up cluster heads and perform other energy-intensive tasks, can noticeably enhance the lifetime of a network.

Power efficient clustering protocol (PECP) [14] proposed an energy efficient heterogeneous clustered scheme for prolonging lifetime of wireless sensor networks. In order to improve the lifetime and performance of the network system, this paper reports on the development of an architecture that creates clusters based on zone and establishes connections between sensor nodes.

Energy efficient dynamic clustering protocol (EEDCP) [15] based on weight is proposed to prolong network lifetime and save energy. In the EEDCP, energy model is introduced to compute energy consumed virtual grid technology to construct the cluster and a long sleeping state to reduce energy consumption. Instead of voting it uses the value of weight to measure the size of residual energy, this results in significant reduction in the voting times and the number of transmitting information.

Energy efficient clustering scheme [8] for single-hop wireless sensor networks elects cluster heads with more residual energy in an autonomous manner through local radio communication. In this paper a novel distance-based method is discussed to balance the load among the cluster heads to improve network life time.
In load balanced clustering approach [9], weight is determined based on the distance between the head and the member and the residual energy to improve cluster member choice. It uses optimization threshold value for load balancing. The algorithm creates balanced cluster by load equalization to prolong network lifetime.

A multi-hop clustering algorithm for load balancing in wireless sensor networks [10] works on homogeneous wireless sensor network. It uses layered approach for intra cluster and inter-cluster communication.

Clustering and Load Balancing in Hybrid Sensor Network with mobile Cluster Nodes [11], has proposed an algorithm works on positioning of mobile cluster heads and balancing traffic load in sensor network that consists of static and mobile nodes. It states that location of the cluster head in the clustered network can affect network lifetime significantly and thus by moving cluster head to better location network load can be balanced and lifetime can be prolonged.

In [17], lifetime extension of wireless sensor network by selecting two cluster heads and hierarchical routing is proposed. This paper put forward use of two cluster heads in the data routing method from node to base station to prolong battery life of sensor nodes.

A novel cluster-based routing protocol ELCH (Extending Lifetime of Cluster Head) is proposed in [18]. It has self-configuration and hierarchal routing properties. In this method, the clusters in the network are equally distributed. This paper also suggest a novel clustering algorithm for sensor networks, which lets sensors vote for their neighbours in order to elect suitable cluster heads.

Most of the algorithms use random selection for selecting the cluster heads. Fault Tolerant Trajectory Clustering (FTTC) [19] algorithm proposed a technique for selecting the cluster heads based on traffic and rotates cluster head periodically. Algorithm enables sensor nodes to reduce data packets by data aggregation thus wireless communication cost is decreased by reduction of data packets, and extends the lifetime by reducing the energy consumption of the network.

In, On Life Time of Sensor Network [7], a general formula for the lifetime of wireless sensor networks is discussed. Using the formula a medium access control protocol has been proposed which exploits both the channel state information and the residual energy information of individual sensors. It tries to maximize the minimum residual energy across the network in each data collection.

SUMMARY

Title	Publication	Authors	Objective	Findings
Energy-Efficient Communication Protocol for Wireless Microsensor Networks (LEACH)	**IEEE(2000)**	**Heinzelman W, Chandrakasan A, Balakrishnan H**	**Save Energy**	**Distribution of energy among the sensor nodes results in reduction of the energy dissipation and improves life time.**
U-LEACH: A Routing Protocol for Prolonging Lifetime of Wireless Sensor Networks	**International Journal of Engineering Research and Applications (2012)**	**Nazia Majadi**	**Save Energy**	**Uniform distribution of cluster heads and their corresponding clusters to prolong the lifetime of the network.**

HEED: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks	**IEEE (2004)**	**Younis O., Fahmy S.**	**Save Energy**	**Selection of cluster heads based on their residual energy and node degree**
An Energy Efficient Clustering Scheme in Wireless Sensor Networks	**Ad Hoc & Sensor Wireless Networks(2006)**	**Mao YE, Chengfa LI, Guihai CHEN, Jie WU**	**Save Energy**	**A novel distance-based method is discussed to balance the load among the cluster heads to improve network life time.**
A Load Balancing Clustering Algorithm of WSN for Data Gathering	**IEEE(2011)**	**H. Zhang, L. Li, X. Yan, X. Li**	**Load Balancing**	**The algorithm creates balanced cluster by load equalization to prolong network lifetime.**
Multi-hop clustering Algo. For Load Balancing in WSN	**International Journal of SIMULATION**	**N. Israr , I. Awan**	**Load Balancing**	**Load balancing algorithm for homogeneous wireless sensor network using layered approach.**
Clustering & Load Balancing in Hybrid Sensor Network with mobile Cluster Heads	**Qshine(2006)**	**Ming Ma , Y. Yang**	**Load Balancing**	**Algorithm works on positioning of mobile cluster heads and balancing traffic load in sensor network to prolog network lifetime.**
A centralized energy-efficient routing protocol for wireless sensor networks	**IEEE (2005)**	**Muruganathan S D, Ma DCF, Bhasin PI, et al.**	**Save Energy**	**Utilizes a high energy base station to set up cluster heads and perform other energy-intensive tasks, to enhance the lifetime of a network.**
An Application-Specific Protocol Architecture for Wireless Microsensor Networks	**IEEE(2002)**	**Heinzelman W, Chandrakasan A, Balakrishnan H**	**Save Energy**	**Reduces transmission of redundant information to save energy.**
POWER EFFICIENT CLUSTERING PROTOCOL (PECP)-HETEREGENOUS WIRELESS SENSOR NETWORK	**International Journal of Wireless & Mobile Networks (2011)**	**S.Taruna , Kusum Jain, G.N. Purohit**	**Save Energy**	**Development of architecture to improve lifetime, that creates clusters based on zone and establishes connections between sensor nodes.**
A Novel Cluster-based Routing Protocol with Extending Lifetime for Wireless Sensor Networks	**IEEE(2008)**	**Jalil Jabari Lotf, Mehdi Nozad Bonab, Siavash Khorsandi**	**Save Energy**	**Extends life of cluster head, provides balanced cluster distribution to improve energy efficiency and network lifetime.**
A Fault Tolerant Trajectory Clustering (FTTC) for selecting cluster heads in Wireless Sensor Networks	**International Journal of Computational Intelligence Research (2008)**	**Hazarath Munaga, J. V. R. Murthy, N. B. Venkateswarlu**	**Fault Tolerance**	**Select the cluster heads based on traffic and rotates it periodically.**

III. CONCLUSION

In this paper, we have examined the current state of various proposed clustering algorithms with respect to energy requirements. A lifetime of the wireless sensor network is determined by residual energy of the system and hence energy is the valuable resource. The algorithms outlined in this paper offer a potential improvement over conventional algorithms. However there is still a long way to go and much work need to be done. Significant attention is required in defining clustering strategies yielding optimal clustering algorithm. An optimal clustering algorithm should take into consideration all the possibilities of reducing energy consumption, eliminate all the overhead of cluster head selection process as well as cluster member selection thereby prolonging lifetime of wireless sensor network.

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