Improving energy efficiency in wireless sensor networks using Clustering

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1. Aim

To propose a protocol to improve energy efficiency in wireless sensor networks using clustering.

2. Introduction and Related Work

2.1 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.

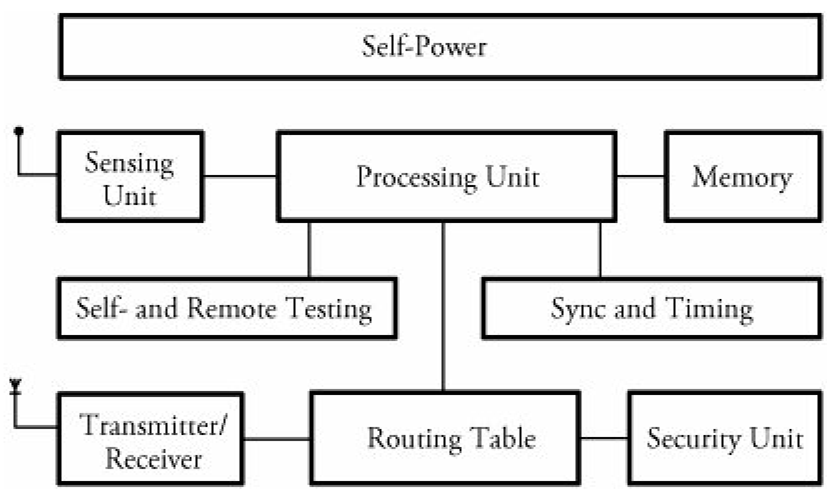

Fig. 1 Structure of a Wireless sensor node

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. 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.

2.1.1 Components involved in clustered wireless sensor network

Following figure shows a clustered wireless sensor network.

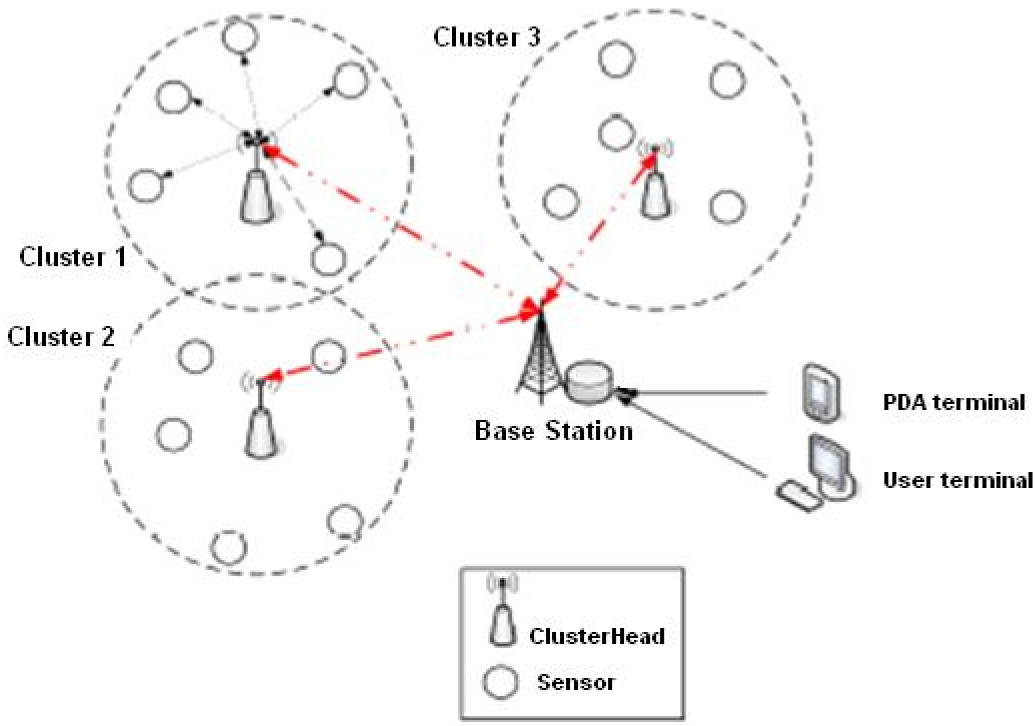

Fig. 2 . Clustered wireless sensor network .

- **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.

2.1.2 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.

2.1.3 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 . 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.

2.1.4 Clustering Attributes

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

2.1.4.1 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 multi-hop CH to CH communication route from every CH to the base-station.

2.1.4.2 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.

2.2 Related Work

In paper [1] ,Heinzelman et al. discuss a **low-energy adaptive clustering hierarchy** (**LEACH**) protocol, the first clustering based protocol. It minimizes the overall energy usage by organizing the nodes into clusters. Each cluster contains a specifically designated node called cluster head. The cluster head selected among the sensor nodes by rotation based on their residual energies receives the data from its cluster members and transmits it to the sink. In this protocol, the network energy is used efficiently because only the cluster heads spend their energies in transmitting the data.

In paper [2] ,an improved version of LEACH, called as **power efficient gathering in sensor information systems (PEGASIS)** protocol, is discussed wherein a node sends data to another node forming chains rather than clusters and the node in a chain nearest to the sink sends the data to the sink.

In paper [3] , Fahmy et al. discuss a **Hybrid energy efficient distributed(HEED)** clustering approach .The cluster head selection process in the HEED protocol uses two parameters: residual energy as primary parameter and intra-cluster communication cost as the secondary parameter. The primary parameter probabilistically selects an initial set of cluster heads and the secondary parameter is used to break tie among them. A tie occurs when a node falls within the range of more than one cluster heads. The cluster range is determined by the power level used for inter-cluster communication during clustering. Initially, the percentage of cluster heads in HEED are predetermined, C prob (say 5 %), assuming that an optimal percentage cannot be computed a priori. The cluster heads' probability C prob is used to limit the initial cluster heads.It sets the probability of making a node as a cluster head, CH prob ,

$$CHprob = Cprob * (Eresidual \div Emax)$$

where Eresidual and Emax are residual and maximum energies of the concerned node,respectively.

Paper [4] discuss **energy efficient clustering scheme (EECS)** protocol in which the cluster heads are selected in two phases based on the residual energy. In first phase, called head election phase, a fixed number of nodes are elected that compete for cluster heads based on their residual energies. In second phase, called as cluster formation phase, the cluster heads are chosen among the elected nodes in such a way that the load gets balanced.

Manjeshwar et al. [5] discuss a **threshold sensitive energy efficient sensor network (TEEN)** protocol. It is based on a hierarchical grouping of nodes in which all cluster heads do not send data to the sink, but to the cluster heads nearer to the sink; thus,reducing the energy consumption.

The TEEN protocol has been extended in [6] and the resultant protocol is called as **adaptive threshold sensitive energy efficient sensor network (APTEEN)** protocol. The APTEEN is meant for capturing data periodic and time-critical events unlike TEEN that is meant only for time-critical events. The main drawbacks of the TEEN and APTEEN protocols are overhead and complexity of forming clusters in multiple levels, implementing threshold-based functions, and dealing with attribute based naming of queries.

3. Hardware Specification

Laptop

Memory : 3.9 GiB

Processor : Intel® Core™ i3-2350M CPU @ 2.30GHz × 4

Graphics : Intel® Sandybridge Mobile x86/MMX/SSE2

Disk : 146.3 GB

4. Software Specification

Tools and Language : Matlab

5. Applications

- Habitat and Ecosystem Monitoring
- Seismic Monitoring
- Civil Structural Health Monitoring
- Monitoring Groundwater Contamination
- Rapid Emergency Response
- Industrial Process Monitoring
- Perimeter Security and Surveillance

6. References

[1]W.R. Heinzelman, A.P. Chandrakasan, and H. Balakrishnan,Energy efficient communication protocol for wireless microsensor networks, in Proceedings of the 33rd Hawaaian International Conference on System Sciences, January 2000.

[2]Lindsey, S., & Raghavendra, C. S. , PEGASIS: Power efficient gathering in sensor information systems. In Proceedings of the IEEE aerospace conference, Big Sky, Montana, March 2002.

[3]Younis O., Fahmy S., HEED: a hybrid, energy-efficient, distributed clustering approach for ad-hoc sensor networks IEEE Transactions on Mobile Computing, 2004.

[4]Kumar, D., Aseri, T. C., & Patel, R. B., EEHC: Energy efficient heterogeneous clustered scheme for WSNs. Computer Communications, 32, 662–667, 2009.

[5]Manjeshwar, A., & Agarwal, D. P., TEEN: A routing protocol for enhanced efficiency in WSNs.In 1st International workshop on parallel and distributed computing issues in wireless networks and mobile computing, April 2001.

[6]Manjeshwar, A., & Agarwal, D. P.,APTEEN: A hybrid protocol for efficient routing and comprehensive information retrieval in WSNs. In Parallel and distributed processing symposium,IPDPS. (pp. 195–202), 2002.