Energy Efficient balanced Cluster Size Solution to Extend Lifetime of Wireless Sensor Networks

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Abstract: ***Grouping sensor nodes into clusters has been widely adopted by the research community to achieve high energy efficiency and prolong network lifetime in large scale WSN environments. Clustering algorithms are considered as energy efficient approach for resource constraint wireless sensor networks. Traditional clustering algorithms results cluster formation with uneven clusters that make network load unbalanced. In this paper, a clustering algorithm is designed to identify this problem and it results balanced cluster size solution by considering thresholds for cluster formation. Simulation results indicate that current solution can offer a better network lifetime with reduction in node death rate in comparison with existing approaches.***

Keywords: WSN, Clustering Algorithm, Energy efficiency, Network Lifetime, Node Death Rate

1. Introduction

In many important WSN applications the sensor nodes are frequently deployed randomly in the area of interest. Moreover, taking into consideration the entire area that has to be covered, the little interval of the battery energy of sensor nodes and possibility of damaged nodes during deployment, huge amount of sensor nodes are to be expected. Wireless sensor networks (WSNs) are composed of many inexpensive power-constrained wireless sensor nodes, which detect and monitor physical parameters around them through self-organization. Utilizing clustering algorithms to form a hierarchical network topology is a common method of implementing network management and data aggregation in WSNs. If the remaining energy of nodes follows the arbitrary distribution, we can define a load-balanced clustering algorithm for WSNs based on their distance, making it unlike from the previous clustering algorithms. A wireless sensor network consists of sensor nodes placed over a geographical area for monitor physical phenomenon like temperature, humidity, vibrations and so on. Typically, a sensor node is a small device that includes three basic components (1) a sensing subsystem for data gaining from the physical surrounding environment (2) a processing subsystem for local data processing and storage, and (3) a wireless communication subsystem for data transmission. In addition, a power source supplies the energy required by the device to perform the programmed task. This power source often consists of a battery with inadequate energy resources. In addition, it could be impossible or difficult to recharge the battery, because nodes may be deployed in a aggressive or unpractical environment. On the other hand, the sensor network should have a battery life long enough to fulfill the application requirements. But it is difficult to recharge batteries in such crucial environment so different energy conservation strategies have to be taken into account. Following figure shows different components of sensor nodes.

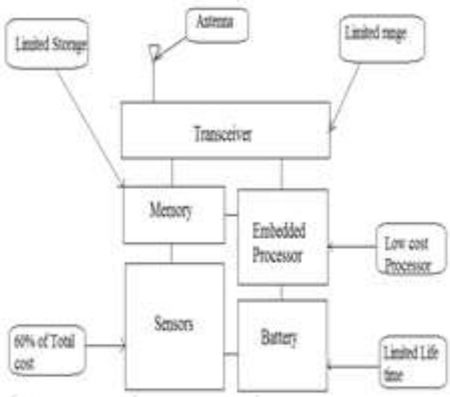

Figure: Various components of a sensor node

Sensor nodes can be useful for continuous sensing, event detection, event ID, location sensing, and local control of actuators. The concept of sensing data and wireless connection of these nodes promises many new application areas. We classify the applications into military, environment, health, home and other commercial areas. Wireless sensor network is an important part of the military communications, control, command, and surveillance. Rapid deployment, self organized characteristics of sensor nodes make them promising sensing technique. Some environmental applications of sensor networks involves tracking moving birds, animals, small insects also monitoring environmental conditions. Some of the health applications for sensor networks are integrated patient monitoring; diagnostics; drug administration in hospitals etc. home applications include vacuum cleaner, micro-wave ovens, refrigerators, and VCRs. These sensor nodes inside the electronic devices can interact with each other and with the exterior network via the Internet or Satellite. They allow end users to administer home devices locally and remotely more easily.

Naturally, grouping sensor nodes into clusters has been widely adopted by the research community to satisfy the above scalability objective and prolong network lifetime in large scale WSN environments. In hierarchical network structure each cluster has a leader, which is also called the cluster head (CH) and usually performs the special tasks referred (fusion and aggregation), and several common sensor nodes (SN) as members. Clustering algorithm [3], [4] is an energy efficient approach for wireless sensor networks to extend network lifetime. Decrease in communication distance, TDMA schedule and data aggregation/fusion [5] are the important key factor in clustering algorithm to minimize energy consumption of nodes.

In this paper, a clustering approach is proposed to address this problem and it provides balanced clusters by considering thresholds for cluster formation. Simulation results show that proposed solution can offer a better network lifetime with reduction in node death rate in comparison of the traditional approaches. Balanced cluster size solution approach has been defined to have extended network lifetime. In the proposed solution, a threshold has been set for number of nodes in clusters ($Th_{cluster}$) at the time of initial cluster formation, whereas a distance threshold ($Th_{distance}$) has been set for un-clustered nodes to join cluster. WSN is formed by hundreds or thousands of nodes that communicate with each other and pass data along from one to another and compulsorily connected to at least one base station.

2. Related Work

2.1 Problem Statement

G. Anastasi, M. Conti, M. Di Francesco, and A. Passarella [2] say that, generally data transmission is very costly in terms of energy use, while data processing consumes considerably less. Energy required to transmit single bit of information is same as that processing multiple operations in typical sensor node. The energy using up of the sensing subsystem depends on the specific sensor type. In many cases it is minor with respect to the energy consumed by the processing and, above all, the communication subsystems. In other cases, the energy expenses for data sensing may be comparable to, or even greater than, the energy required for data transmission. In general, energy-saving techniques focus on two subsystems: the networking subsystem (i.e., energy organization is taken into account in the operation of each single node, as well as in the design of networking protocols), and the sensing subsystem (i.e., techniques are used to reduce the amount or occurrence of energy-costly samples). The lifetime of a sensor network can be increased by jointly applying different techniques. For example, energy efficient protocols are aimed at minimizing the energy consumption during network actions. However, a huge amount of energy is consumed by node components (CPU, radio, etc.) even if they are idle. Power management schemes are thus used for switching off node components that are not temporarily needed. Energy efficient data acquisition and Mobility-based energy conservation schemes methods has been discussed in [2]. As mobility- based energy conservation schemes are relatively new in the field of wireless sensor networks, many aspects need to be studied with more care and attention.

In many real applications, however, have shown the power use of the sensor is comparable to, or even greater than, the power needed by the radio. In addition, the sampling phase may need a long time especially if we compare it to the time needed for transportation so that the energy consumption of the sensor itself can be very high as well. We think that the field of energy conservation targeted to data acquisition has not been fully explored yet, so that there is scope for developing convenient techniques to reduce the energy consumption of the sensors.

Very basically clustering can be classified in to three categories centralized, distributed and hybrid clustering methodologies. Centralized clustering is the one in which, a centralized architecture is used in the clustering process i.e. a fixed CH and the other nodes in the cluster act as member nodes [12], [13]. Distributed clustering is one in which, there is no permanent central CH and this keeps on changing from node to node based on some parameters, for example residual energy [14]. Hybrid clustering is one which is formed as the resulting combination of both the above mentioned mechanisms [15]. If a centralized architecture is used in a WSN and the central node fails, the entire network will fall down and hence there is no assurance for reliability in centralized clustering mechanism. Therefore, the reliability of a WSN can be improved by using distributed architecture. Distributed architecture is used in WSNs for some specific reasons like sensor nodes prone to failure, better collection of data and provide backup in case of failure of the central node. Also, nodes sensing and forwarding the redundant information can be minimized. Since there in no central body to allocate the resources, they have to be self-organized. Focusing on these projected advantages of distributed algorithms over centralized algorithms, one of the distributed clustering algorithms is described as follows with their parameters.

A. A. Abbasi and M. Younis [3] explain that, In LEACH, the network being divided into clusters and CHs which are purely distributed in manner and the randomly selected CHs collect the information from the nodes which are coming under its cluster. LEACH protocol involves four main steps for each round: (1) Advertisement phase, (2) cluster set-up phase, (3) schedule creation and (4) data transmission. In the first step that is the advertisement phase includes that it issues notification to nodes coming under it to become cluster member in its cluster. The nodes will be accepting the offer based on received signal strength (RSS). In the cluster set-up phase the nodes will be contacting to their selected CHs. In schedule creation step, as the CH receives response from the nodes it have to make a TDMA scheme and send back to its cluster members to intimate them when they have to pass the information to it. In the data transmission step, the data collected by the individual sensors will be given to the CH during their time intervals. The main restriction here is that, radio of particular node will be turned off after data transmission. Here in LEACH protocol, multi-cluster interference problem was solved by using unique CDMA codes for each cluster. The energy drain is prevented for the same sensor nodes which have been elected as the cluster leader using randomization, for each time CH would be changed. The CH is in charge for collecting data from the cluster members and fusing it. Finally each CH will be forwarding the merged data to the base station. When compared with the preceding protocols, LEACH has shown a considerable development mainly in terms of energy-efficiency. Though LEACH protocol is much more energy efficient when compared with its predecessors, the main drawback in this approach is the random selection of CH. In the worst case the CH nodes may not be evenly distributed among the nodes and it will have its effect on the data gathering. Therefore cluster head selection criteria in LEACH is not proper so balanced cluster with efficient cluster head selection depending on threshold is given in current paper.

In most of existing clustering algorithms, there are equal number of nodes in each cluster and all further processing of these algorithms heavily depends on this assumption [6], [7]. Clusters of small and large size exist at the same time making network load unbalanced and hence decreasing the network lifetime. In existing methods Data transmission phase is divided into frames are further divided into time slots. At the end of each frame, cluster head sends aggregated data to base station. So, length of frame depends upon number of nodes in a cluster. At the end of each frame, cluster head sends aggregated data to base station. So, length of frame depends upon number of nodes in a cluster. Further, head of small sized cluster consumes more energy because it sends data more times to the base station compared to head of large cluster. So, proposed clustering solution generates clusters of same size to have advantage of cluster processing for well node balanced network.

2.2 Proposed clustering algorithm

To design an optimum WSN we must minimize energy consumption and hence extend the network lifetime are major challenges. The identified challenge of increasing lifetime of WSN network can be resolved in future using proposed clustering method. Proposed solution performs operation in rounds and nodes are selected as cluster head in a round per probabilistic approach which ensures that each node is selected as cluster head once in an epoch of $1/P_{opt}$ rounds.

In proposed clustering algorithm, Selected cluster heads broadcast status message to network. cluster formation is carried in two phases: (1) Initial cluster formation and (2) Rescue phase. In initial cluster formation phase, $Th_{cluster}$ indicates no of member nodes in each cluster. Because of distributed and random nature, cluster head is selected in each round is different. So for each round different $Th_{cluster}$ has to be calculated. $Th_{cluster}$ is calculator for each round. If there are N active nodes in network, then

$$Th_{cluster} = N/X$$

Node joins nearest cluster head, If selected cluster head has member nodes less than $Th_{cluster}$, then node joins that cluster head otherwise it waits for the rescue phase. In rescue phase, un-clustered node joins best possible cluster head, if head is at distance less than $Th_{distance}$ from un-clustered node and also has the member nodes less than $Th_{cluster}$ then un-clustered node will join that cluster. Cluster heads are selected on the basis of probabilistic approach. Each node select a random number between 0 and 1. A threshold, T(n), is calculated which depends upon optimal cluster head probability (Popt) and current round (r).

$$T(n) = \begin{cases} \dfrac{P_{opt}}{1-P_{opt} * \left(rmod \frac{1}{P_{opt}}\right)} & \text{if } n \in G \\ 0 & \end{cases}$$

Where G is the set of nodes that are not selected as cluster head in last $1/P_{opt}$ rounds. If selected number is less than threshold calculated then that node is selected as cluster head. Once cluster has been set, node wakes up to send data to cluster head as time slot arrives otherwise remain in sleep state. Proposed solution can be used in large number of applications where energy of wireless sensor networks is very necessary.

3. Conclusion

Clustering approach presented in this paper has cluster threshold set to define number of cluster members and distance threshold for un- clustered nodes. Balanced cluster size clustering approach has been proposed to have prolonged network lifetime. Because of balanced cluster size formation limitation of uneven cluster nodes has been removed. So having same size of clusters, it increases lifetime sensor nodes.

Simulation results show that proposed solution can offer a better network lifetime with reduction in node death rate in comparison of the traditional approaches. Energy consumption of nodes throughout network is more uniform in proposed approach so first node death appears later than LEACH.

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