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An Approach for Residual Energy Based Aggregator Selection for Data Aggregation in Wireless Sensor Networks

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Abstract. Wireless Sensor Networks (WSN) comprises an emerging technology which has received a significant attention from the research community. Tiny sensor nodes sometimes referred as “motes” are mini, low-cost devices with limited coverage having low power, smaller memory sizes and low bandwidth. WSN is an event-based system with one “sink” subscribing to specific data streams by expressing interest and queries. Since the amount of energy required to transmit even a bit of data is very high, and the energy of the nodes is limited, transmitting of data from all sources to sink becomes a great challenge. By using a technique termed as the in-network data aggregation, the inherent redundancy in raw data which is collected from the sensors can be eliminated. This paper focuses on the concept of clusters in WSN and defines an approach for selecting the aggregator among all the nodes. The cluster-based hierarchical architecture owns extraordinary performance on energy-saving. In WSN since energy of the nodes is limited, using one single node as aggregator is not feasible. WSN can choose its aggregators dynamically according to their residual power to optimize the total power consumption of the aggregation process. In this paper, the selection of aggregators based on their residual energy is proposed.

Keywords: WSN, Energy Efficiency, Data Aggregation, Aggregator Selection

1. Introduction

A WSN consists of inexpensive wireless nodes varying from hundreds to thousands in number, each having some degree of computational power and sensing capability that can operate in an unattended mode. However such systems suffer from band-width, energy and throughput constraints which limit the amount of information transferred from end-to-end. They are intended for a broad range of environmental sensing applications from vehicle tracking to habitat monitoring. Information gathering is the fundamental process performed by sensor nodes. Generally, information collected at the sensor nodes needs to be transmitted to a central base station for further processing, analysis, and visualization by the network users. For extracting the application specific information from the raw data, a process known as data aggregation is used. It is crucial for the network to support high incidence of in-network data aggregation for conserving energy for a longer network lifetime. The main requirements of wireless sensor network are to prolong the network lifetime and energy efficiency [1].

In WSN, energy conservation is a critical issue that has been addressed by substantial research works [2, 3]. The scheme of clustering of sensor nodes has been proven particularly energy efficient in sensor networks [4, 5]. The sensor nodes form clusters which have one cluster head and the rest are cluster members. Cluster heads (CHs) have the capability to process, filter and aggregate the data sent by sensors belonging to their cluster, thus reducing network load and alleviating the bandwidth [6]. This cluster head then send this data to the base station through single hop or multi-hop. Thus in clustered network data transmission is classified

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into two stages: intra-cluster communication and inter cluster communication. Usually the base station is usually located in the center of the experimental environment so that less power is consumed in data transmission from CHs to the base station. A multi hop inter-cluster communication mode is more energy efficient because of the limited capabilities and characteristics of wireless channel [7].

2. Data Aggregation

Data aggregation is a known technique addressed to alleviate the problems in WSN’s but are limited due to their lack of adaptation to dynamic network topologies and unpredictable traffic patterns . This scheme combines the data coming from the different sources and eliminates its redundancy and reduces the number of transmissions and thus saves energy. For this, aggregation points known as aggregators are introduced in the network. Aggregators are regular nodes that receive data from neighboring nodes, perform some kind of processing, and then forward the filtered data to the next hop and finally to the base station. This accumulation is important with respect to data analysis and also for obtaining a deeper understanding of the signals observed by the network. This reduces the total number of messages exchanged between nodes and saves some energy of the network.

3. Related Work

Li Qing et al. [8] have proposed and evaluated a new distributed energy efficient clustering scheme for heterogeneous wireless sensor networks, called as DEEC. They proposed that the cluster heads are elected by a probability based on the ratio between residual energy of each node and the average energy of the network.

Meelu R. et al. [9] proposed modification of DEEC and named it as Clustering Technique for Routing in Wireless Sensor Networks (CTRWSN). The operation of CTRWSN is broken up into rounds where each round consists of a clustering stage and distributed multi-hop routing stage. They have analyzed and compared the performance of the two cluster-based routing protocols viz. DEEC and CTWRSN for heterogeneous networks in terms of their network lifetime, energy consumption and the energy balancing. Through the simulation results they have demonstrated that the proposed algorithm shows good energy distribution and thus prolongs the network lifetime in comparison to DEEC routing protocol.

4. Cluster Based Architecture

4.1. The Cluster Formation

A cluster is a subset of the total set of sensors in a network which might have at least one cluster head capable of manipulating sensed data locally and then sending the gist of that to the base station. Grouping nodes into clusters is a good idea as it helps to divide the network into several separate but interrelated regions. It also helps for efficient routing within the network.

Figure 1.shows the organization of nodes in clusters and the way of communication from the nodes to the cluster heads and then to the sink in a multi hop manner

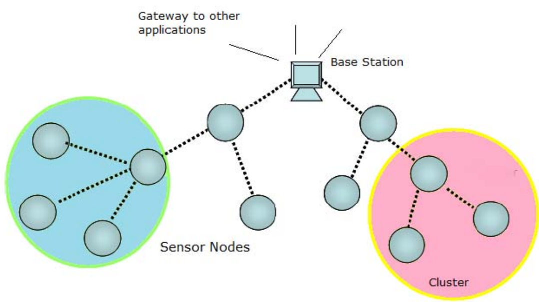

Fig 1 :Cluster- based Hierarchical Model

4.2. Energy in cluster-based architecture

The cluster-based hierarchical architecture owns extraordinary performance on energy-saving. All the sensor nodes, after deployed, are self-organized into clusters. In each cluster, there are a cluster head (CH) and no-cluster head nodes. The no-cluster head nodes collect and process data from the surrounding environment and then transmit the data to CH using wireless links. CHs may further process and send the data to base station (BS) which is used to communicate with the outside world. Because data aggregation and computation is performed locally in CHs to reduce the amount of transmitted data, thus the precious limited energy is saved.

However, being a cluster head node is much more energy intensive than being a non-cluster head node because it needs to do more energy consuming tasks. Once the cluster heads were chosen priori and never change throughout the network lifetime, these nodes will quickly die for running out of energy. Once the cluster head run out of energy, it is no longer operational, and all the nodes that belong to this cluster will lose communication ability. Hence the best technique has to be used for selection of aggregator in a cluster.

5. The Aggregator Election Phase

This section discusses the proposed approach for selection of the aggregator in a cluster. Here, one of the sensors will be elected as the cluster head based on energy efficiency of the nodes [8]. These cluster heads act as aggregation points. The clustering is based on the initial energy and residual energy and all nodes use these values to select the cluster heads. Residual energy as primary parameter and network topology features (e.g. node degree, distances to neighbors) are only used as secondary parameters to break tie between candidate cluster heads, as a metric for cluster selection to achieve power balancing [10]. The average energy of ith iteration is based on parameters such as the message size, the number of nodes, multi path energy, free space energy, energy dissipated over time , data aggregation cost expended in the cluster heads, the average distance between the cluster head and the base station, and the average distance between the cluster members and the cluster head[14].

Explanation

Clustering of nodes in the network is based on spatial and temporal characteristics of the wireless networks

5.1. Assumptions

1. Base station is denoted by S
2. Sensor nodes are denoted by $s_1, s_2, s_3 \ldots s_n$
3. Distance from the base station to the sensor nodes are $d_1, d_2, d_3 \ldots d_n$
4. Distance between any two sensors is negligible in computing.
5. Initially energies stored in sensor nodes are $e_1, e_2, e_3 \ldots e_n$.
6. Message size L

5.2. Computation of energies

The computation of energies due to spatial distribution of sensors and their use and dissipation of energy in lapse of time is as follows:

1. Energy consumption of sensor

Let (e*) be the energy consumption in the network in one round or iteration. This energy includes multi path energy, free space energy and the cost expended in data aggregation in the cluster heads.

Energy consumption (e*) in one round of signal transmission from a sensor to the base station S is proportional to two times of distance between them, say it is

$$e^* = k.2.d$$

where k is constant and computable by using initial conditions, If it is in two rounds of use then

$$2\, e^* = k.2^2.d$$

In general

$$m.\, e^* = 2^m.d.k , \qquad \text{for m rounds of use.}$$

Therefore, residual energy in one sensor after m rounds of use

$$E_{R(m)} = e - m.\, e^* = e - m.2^m.d.k \qquad (1)$$

Where e is the initial energy

If E_R is known then k can be computed in terms of known quantities i.e.

$$k = \frac{e - E_{R(m)}}{m.2^m.d}$$

If this constant k is same for all the sensors then

$$E_{R(total)} = \sum_{i=1}^{n} (e_i - m.2^m.d_i.k) \quad (2)$$

Eq.2 gives the total residual energies after the use of n sensors up to m rounds.

2. Time dependent dissipated energy

The time dependent dissipated energy can be computed by using the law of natural and physical decay phenomena in time t. Time dependent dissipated energy of one sensor in time t

$$e_{\mathbf{disp}}(t) = e(t_0).(\exp)^{-\lambda t} \quad (3)$$

where

$e_{disp}(t)$ = dissipated energy in lapse of time t

$e(t_0)$= energy at t=0

exp =e = 2.718 and λ is a constant which can be computed from initial conditions at 0 and t times.

Therefore, the total dissipated energy of n sensors in time t

$$= \sum_{i=1}^{n} e_i(t_0) . (\exp)^{-\lambda t} \quad (4)$$

3. Energy dissipated in sending message

The energy consumed by the network also depends on the message size. Let L be the message size that is to be transmitted.

Therefore, energy consumed in sending message size L is

$$e_i(L) = KL$$

where K is a constant The total dissipated energy of n sensors in the network in sending L

$$= \sum_{i=1}^{n} e_i(L) \quad (5)$$

Therefore, the total residual energy in n sensors after m rounds of their use and sending message size L ,and lapse of time t

$$E_{\mathbf{R(total)}} = \sum_{i=1}^{n} (e_i - m.2^m.d_i.k) - \sum_{i=1}^{n} e_i(t_0) . (\exp)^{-\lambda t} - \sum_{i=1}^{n} e_i(L) \quad (6)$$

After certain limiting values of m and t, beyond which the sensors may not be efficient to work, wireless sensor network may be clustered about a sensor node of high degree of expectation, called as cluster head.

5.3. Selection of Cluster Head

In the proposed approach, the sensor node with the maximum residual energy is selected as the cluster head. The residual energy of the node may be calculated by Eq.6.

Sensor of maximum $E_{R(total)}$ may be selected as cluster heads in the clustering process after each round thus saving energy of the previous aggregator.

6. Conclusion And Future Work

One of the major challenges in WSN is the conservation of energy. As the sensor nodes are limited in energy resources, techniques and approaches used for various functions of sensor nodes have to be optimized so that the consumption of energy is the minimum. In this paper an optimized approach for selection of an aggregator within a cluster is proposed. The overall energy consumption of a WSN needs to be reduced as to have longer network lifetime. In the proposed work, it can be seen that the node with the maximum residual energy can be selected as a cluster head. The proposed work fits best in a homogeneous network when the nodes have same energies at the time of deployment. This work can be extended to heterogeneous networks where nodes have variable energies.

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