CLUSTERING BASED ENERGY EFFICIENT CONGESTION AWARE PROTOCOL FOR WIRELESS SENSOR NETWORKS

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Abstract

Wireless Sensor Networks (WSNs) have inherent and unique characteristics rather than traditional networks. They have many different constraints, such as computational power, storage capacity, energy supply and etc. Energy aware routing protocol is very important in WSN, but routing protocol which only considers energy has not efficient performance. Therefore considering other parameters beside energy efficiency is crucial for protocols efficiency. Depending on sensor network application, different parameters can be considered for its protocols. Congestion management can affect routing protocol performance. Cluster-based architectures are one of the most practical solutions in order to cope with the requirements of large-scale wireless sensor networks (WSN). Cluster-head election problem is one of the basic QoS require-ments of WSNs, yet this problem has not been sufficiently explored in the context of cluster-based sensor networks. Specifically, it is not known how to select the best candidates for the cluster head roles. In this paper, we investigate the cluster head election problem and congestion management problem. Specifically concentrating on applications where the energy of full network is the main requirement, and we propose a new approach to exploit efficiently the network energy, by reducing the energy consumed for cluster forming and reducing the congestion to provide the better efficiency for the high priority data.

Key words : Wireless Sensor Networks, Clustering Protocol, Congestion Aware, Energy Efficiency, Cluster-head selection, Information Routing

1.INTRODUCTION

Wireless Sensor Networks can offer unique benefits and versatility with respect to low-power and low-cost rapid deployment for many applications, which do not need human supervision. The nodes in WSNs are usu-ally battery operated sensing devices with limited en-ergy resources and replacing or replenishing the bat-teries is usually not an option. Thus energy efficiency is one of the most important issues and designing power-efficient protocols is critical for prolonging the lifetime. The latest developments in time critical, low cost, long battery life, and low data rate wireless ap-plications have led to work on WSNs. These WSNs have been considered for work in certain applications with limited power, reliable data transfer, short communication range, and reasonably low cost such as industrial monitoring and control, home automation and security, and automotive sensing applications[2]. Specific functions can be obtained through cooperation between these nodes: functions such as sensing, tracking, and alerting [3]. These functions make these wireless sen-sors very useful for monitoring natural phenomena, environmental changes, controlling security, estimating traffic flows, monitoring military application, and tracking friendly forces in the battlefields.

WSNs have inherent and unique characteristics compared with traditional networks [1,2]. These networks have many limitations such as computing power, storage space, communication range, energy supply and etc. Nodes have limited primary energy sources and in most of applications they are not rechargeable , therefore energy consumption is the most important factor in routing process for wireless sensor networks. Node's energy is consumed due to using sensors, processing informa-tion and communicating with other nodes. Communica-tions are the main element in energy consumption. Routing protocol directly affects communications volume; therefore energy aware routing protocols are very effective in decreasing energy consumption[4].

Routing protocols which only consider energy as their parameter are not efficient. In addition to energy effi-ciency, using other parameters makes routing protocol more efficient. For different applications, different pa-rameters should be considered. One of the most impor-tant parameter is congestion management. Congestion occurrence leads to increasing packet loss and network energy consumption. Congestion occurs for different reasons in wireless networks; first, due to limited storage capacity in relay nodes. When a node receives packets more than its capacity, congestion will be occurred. Second, due to inherent shared wireless link, congestion occurred for similar reasons in wireless sensor networks[5].

The methods to manage congestio in WSN is divided into two groups: congestion avoidance and congestion control. The former focuses on strategies to avoid congestion from happening and the latter works on removing con-gestion when it has occurred. In wireless sensor networks due to limitations in resources, avoiding congestion rather than controlling congestion is more reasonable.

2.RELATED WORK

In order to enhance the network lifetime by the period of a particular mission, network is partitioned into small clusters and each cluster is monitored and controlled by a node, called Cluster Head (CH). These cluster heads can communicate directly with the base station (BS). Other nodes send the data, sensed from the environment to these CHs. CHs first aggregate the data from the multiple sensor nodes, and then finally send it directly to the BS[6]. The clusterhead are selected following a distributed algorithm for each round. To avoid the congestion traffic is divided in to two traffic types are considered: high priority and low priority. It selects a special area in network called conzone. The nodes placed in conzone only forward high priority traffic and other network nodes forward other traffics. Reference [7] proposes two algorithms: CAR and MCAR. CAR is a network-layer solu-tion to provide differentiated service in congested sensor networks. CAR also prevents severe degradation of ser-vice to low priority data by utilizing uncongested parts of the network. MCAR is primarily a MAC-layer mecha-nism used in conjunction with routing to provide mobile and lightweight conzones to address sensor networks with mobile high priority data sources and/or bursty high priority traffic.

The proposed algorithm assumes that all nodes receive the messages broadcasted by the nodes selected as cluster heads. On one hand, if a node is not reachable by a cluster head it assumes that the number of clusters heads is insufficient, and elects them to be cluster head. The number of clusters and cluster head will be identified dynamically. The congestion of the network will differ from time to time. The routing in the network has been divided into Inter-cluster routing and intra-cluster routing.

3.PROPOSED PROTOCOL

The protocol divided into three phases **(i) network clustering (ii) Creating routing tree (iii) Data forwarding.** In network clustering phase, network nodes are partitioned into different clusters. During this phase cluster nodes information are delivered to cluster head. In creating routing tree phase, a limited routing tree will be created. During this phase a routing table is created for each of cluster nodes. In data trans-mission phase, packets are forwarded using relay nodes routing table. Rotuing table is updated whenever the node moves from the range of one cluster head to another head.

3.1Network Clustering

Network clustering is the process of partitioning the network nodes into various clusters. During the clus-tering phase, a cluster head also should be elected for each cluster. At the end of this phase, information about all of the cluster nodes is delivered to cluster head. Each node in cluster sends its own information to the sink di-rectly. It is important to know that, this phase is done once; therefore direct communication between cluster nodes and the cluster head is negligible[5].This clustering information is updated whenever the network node moves from the range of one cluster head to another.The routing table update is an event driven.

In our algorithm, Clustering Technique for Wireless Sensor Net-works (CTRWSN) is a self-organizing, dynamic clustering method that divides dynamically, the network on a number of a priori fixed clusters. Each cluster has one cluster-head. In this work, we use two-level heterogeneous networks, in which there are two types of sensor nodes: **the advanced nodes and normal nodes.** Based on the energy level of the nodes present. Let the E_0 initial energy of the normal nodes and, *f* the fraction of the advanced nodes, which own a times more energy than the normal ones. Thus there are f.N advanced nodes equipped with intial energy of (1+a) E_0 and (1-f)N normal nodes with initial energy E_0 [6].

$$E\ total = N(1-f)\,E_0 + Nf\,(1+a)\,E_0.$$

3.1.1.Setup Phase

Every transmission round, each node n uses the Formula

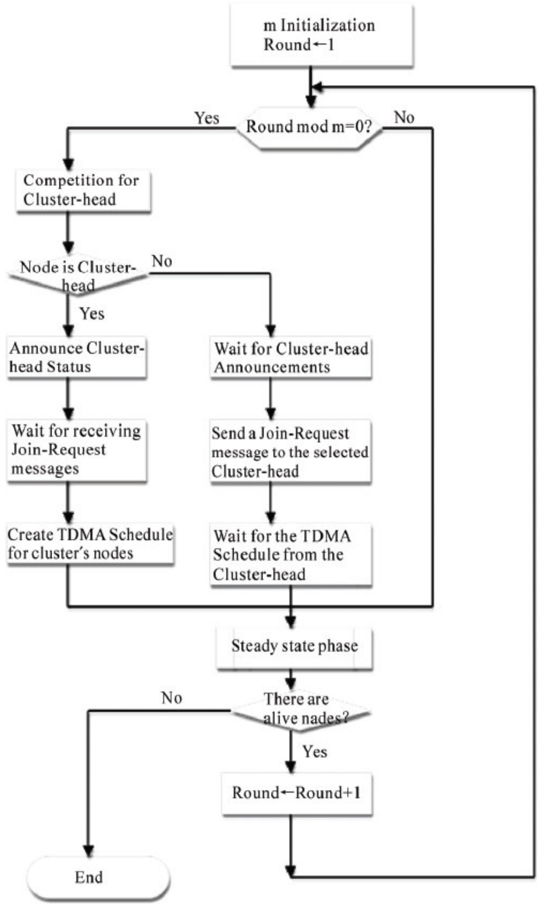
$$T(n) = \begin{cases} \dfrac{p_n}{\left(1 - p_n \cdot \left(r \bmod \left(\dfrac{1}{p_n}\right)\right)\right)} & \text{if } n \in G \\ 0 & \text{Otherwise} \end{cases}$$

to calculate the value and choose a random number between 0 and 1. If this chosen num-ber is less than the calculated threshold , the node becomes a clusterhead. The selected cluster heads broadcast an advertisement message to the network to declare themselves as cluster heads. Receiving this message, the not cluster head nodes belong to the clus-ter which the energy to join is minimum among all selected cluster-heads. The node can determine the needed energy to transmit to the cluster head based on the received signal strong.

Once the nodes decide to which cluster belong, they inform the cluster-head transmitting a join-request message to it, using CSMA/CA MAC protocol. A header, the node ID and the cluster-head ID, forms this message, which is a short one. This message size grants to reduce the time channel access and the transmission energy cost[7].

3.1.2. Steady-State Phase

Once the clusters are established, the nodes transmit their data messages towards the cluster-head. Within the cluster, the communication uses TDMA, as de-scribed in the set up phase. When the cluster-head re-ceives all the nodes data, it performs its compression, to form a new message that sent to the base station.



The network function is divided into cycles, each cycle lasts for m transmission rounds. Then, selected nodes for cluster-heads play this role for *m* consecutive transmission rounds. It is so difficult to determine analytically the pa-rameter *m*, because the nodes deployment is random and the cluster-heads position is also stochastic, then we determine this optimal value based on simulation[7].

3.2Creating Routing Tree Phase

In this phase, using information delivered to cluster node in the former phase. In a routing tree structure, for every cluster node a path to its cluster head is determined. Cluster head knows position of all nodes located in its cluster, and then in first step in this phase, cluster head evaluates link cost between every two nodes located in their communication range [9]. For determining link cost, proposed protocol uses

$$Cost_{ij} = \sum_{k=0}^{3} CF_k = c_0 \times \left(dist_{ij}\right)^L$$

$$+c_1 + c_2 + c_3 \times f\left(e_{ij}\right)$$

- CF_0 (Communication Cost) = where *c0* is a weight-ing constant and the parameter *L* depends on the en-vironment, and typically equals to 2. This factor re-flects the cost of the wireless transmission power, which is directly proportional to the distance raised to some power *L*. The closer a node to the destina-tion, the less its cost factor *CF0* and more attractive it is for routing.

- CF_1 (Energy stock) = this factor reflects the primary battery lifetime, which favors nodes with more en-ergy. The more energy the node contains, the better it is for routing. Applicable in networks which have heterogeneous nodes.

- CF_2 (Sensing-state cost) = where *c2* is a constant added when the node *j* is in a sensing state. This factor does not favor selecting sensing-enabled nodes to serve as relays. It's preferred not to over-load these nodes in order to keep functioning as long as possible.

- CF_3 (Error rate) = where *f* is a function of distance between nodes *i* and *j* and buffer size on node *j* (i.e. *distij* / *buffer _ size*). The links with high error rate will increase the cost function, thus will be avoided.

Cluster head using nodes' information, links cost and Dijkstra algorithm selects least cost route between every cluster node and cluster head. Using Dijkstra algorithm, route selected between every node and cluster head is optimum; and only one path is selected between each node and cluster head (only one optimal path is exist between each node and cluster head); therefore the set of all routes has a tree structure called routing tree. If a node uses selected least cost route for transmitting its traffic, network will consume least possible energy for its traffic. But, it is important to note here that, the least cost route is not always the best route.

Cluster head evaluates all of the cluster nodes and then chooses nodes that have children more than most number of children. For all of neighbors of each selected nodes, proposed protocol determines the following two parameters.

- Least cost route between node and sink (using one of its neighbors except former neighbor as next hop).

- Number of children of new selected next hop neighbor[8].

Then among the children of each node, the one which has a neighbor with fewer children than the most number of children and least cost route to sink will be selected. Then the selected child is modified and in future it will be the child of its new qualified neighbor. In some situa-tions, the child with appropriate conditions dose not exist, therefore exceptionally a node with children more than the most number of children is accepted. Here a routing tree with appropriate structure is ready to make for each cluster. But only cluster heads know the routes and rout-ing tree, because they made it by itself and other nodes do not participate in mentioned process.
After selecting the best route and determining the number of children for every node, cluster head creates a routing table for all cluster nodes. A special record in routing table is considered for its best route to cluster head. In addition to best route, many paths which have lower costs in comparison to other paths are also selected to create routing table. For each of selected paths, a record is considered in routing table. Routing table has following fields: ID, residual energy, number of children, cost and average queue length. After constructing routing table, cluster head directly sends each node routing table to it.

3.3 Data Transmission Phase

At the end of the former phase, all the nodes have a routing table. As mentioned before, the proposed routing protocol considers two traffic types: high priority and low priority. The main goal of this phase is to determine next hop for each arrival packet at each node. In the rest of this section, the routing process which is done in each node when it receives packets with different priorities is discussed.

When a node receives a high priority packet, it per-forms following steps:

1) If special record in node routing table is active, this record will be selected. Otherwise Step 2 will be done. (The only special record in node routing table belongs to least cost route)
2) Among the records which have average queue length lower than threshold β, the record with lowest cost field value will be selected. If all the records have aver-age queue length more than threshold β, Step 3 will be done.
3) Among the records, the one with the lowest cost field value will be selected.

Nodes' routing table should be updated periodically; otherwise they can not play their role effectively. When a node residual energy becomes less than threshold α, it broadcasts a message and informs its neighbors about its current condition. Neighbors receiving mentioned mes-sage, update the sender node's record in their routing table. Also the nodes should inform their neighbors about their average queue length.

To keep routing table update is necessary for proposed protocol. If routing table records not be updated, routing process can not be efficient, because its information is old. In other side, keeping routing table update is costly. For keeping routing table update, routing protocol should force nodes to send their current condition to its neigh- bors periodically.

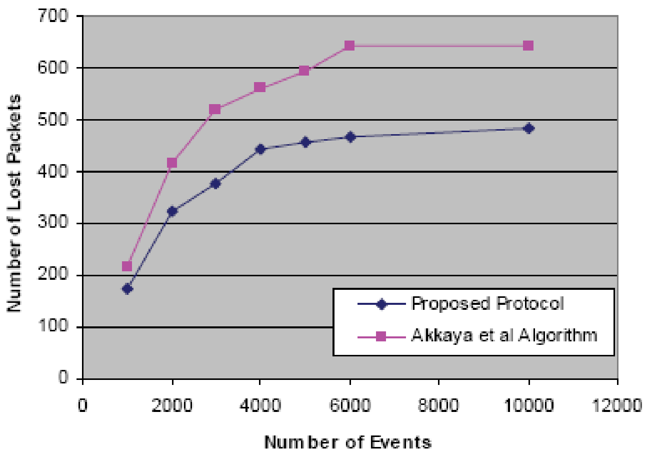
4.PERFORMANCE EVALUATION

Most of hierarchical routing protocols are composed of two main parts. The first part is routing intra clusters and the second part is routing inter clusters. The first part's role is more important. The number of cluster nodes in simulations is considered as to be between 29 and 99. The communication range is determined Based on number of nodes in cluster. consider almost a 40*40 square for each cluster.

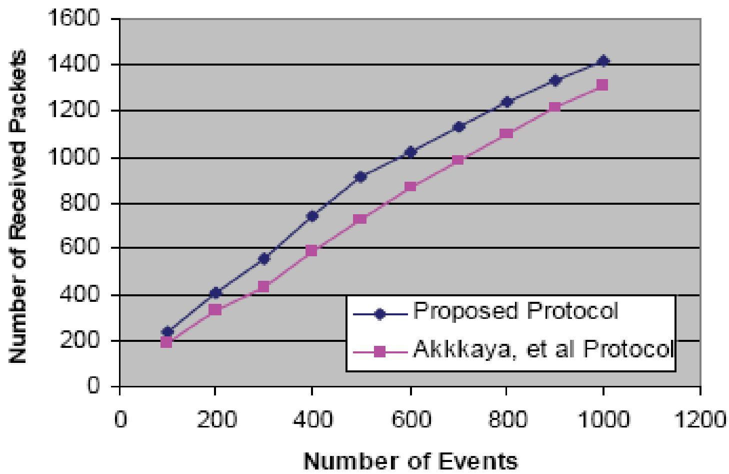
The main aim of the proposed algorithm is to reduce the congestion and power required for the routing the data by making the clusters.

It makes routing tree by considering the most number of children for its nodes. When the number of children in a routing tree is limited, traffic volumes which enter to the node are limited too. Therefore when an event is occurred, congestion occurrence probability will be decreased. Another parameter which affects the success in congestion management is the node's awareness about their neighbors average queue length. In this situation when nodes want to select the next hop for their data, they consider their neighbors average queue length as a parameter in decision making. The node with lower average queue length rather than other nodes has higher hope to be selected as next hop.

In the first graph, we evaluate the number of lost packets due to congestion for two protocols. The number of packet loss in two protocols for different numbers of events is presented.



Number of lost packets versus number of events

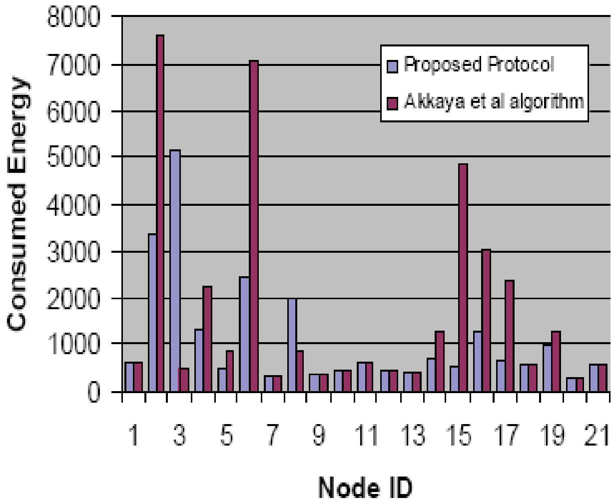


Number of received packets to cluster head versus number of events

Number of packets received to cluster head in this algorithm is always more than other protocols.It manages congestion; it tries to reduce packet loss in nodes which are located in paths between nodes and the cluster head. Lower packet loss leads to more success in delivering packets to cluster head. As mentioned in former sections, We consider two types of traffic. Network nodes service traffics based on their priority. Both of the protocols try to deliver the best possible services to high priority traffic besides de-liver suitable service to low priority traffic.

5.CONCLUSION

In this paper, we presented a new hierarchical energy efficient routing protocol for sensor networks which considers congestion management based on paper [8]. Routing protocol divides network into many clusters, then using Dijkstra algorithm constructs a routing tree for each cluster. In routing tree, most number of children for cluster nodes is determined. Proposed protocol man-ages congestion, using routing tree, node's neighbors average queue length and residual energy of nodes as parameters.



Consumed Energy in Nodes

The proposed algorithm allows a large stable network lifetime compared to the most known clustering algorithms in this area. As future work, we will reconsider the probability of becoming cluster-head, to extend yet the network lifetime. Proposed protocol considers only intra cluster routing; we are currently extending the protocol to perform routing inter clusters

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