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On the Development of a Cluster-Based Cooperative Network with Directional Antennas at Trans-Receivers Using Connected Dominating Set in WANET

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Abstract - The sensors can be grouped into clusters and the mini sensors use a high energy to communicate with each other. Every cluster is equipped with a source node which acts as the central gateway for that cluster. In this paper we treat the communication among the smart nodes in the ad hoc mode where we propose to minimize the energy conservation of the nodes by increasing the cooperativeness. Directional antenna doesn't overhear the nodes outside its own arc of coverage and allows simultaneous communication without interference. This additionally helps to reduce power depletion of nodes. First layer of the sensor networks is the infrastructure layer and there is no back-bone for these networks. In this paper, we propose a frame-work model for cluster based cooperative networks and we measure the network lifetime and survivability as the performance evaluation metrics of the proposed model.

Keywords - ad hoc, cluster, connected dominating set,co-operative network, directional system, sensor technology & networks, transmission energy.

1. Introduction

The latest development in the field of miniature sensing technologies and their application in ad hoc communication has increased the horizon for further developments. These sensing devices are generally equipped with processing and communication technology capabilities. The signaling device uses different types of directionaling systems such as directional, Omni-directional antennas. The device checks the ambient environmental condition, converts and transforms them into electrical signals. Those signals again send to other devices or sensors by using these contents. The sensors sends the collected data via a radio transmission or a wave form data signals to its commend center or the sink directly through the data concentration centre. The potential of collaboration among sensor in data gathering and processing and the co-operation and management of the sensing activity and data flow to the sink. This is well facilitated for such collaborative distributed sensing can be formed among the sensors in the ad hoc manner. The directional system in the ad hoc network helps to minimize the overhead of energy conservation, cooperativeness and co-ordination and processing of the data in the smart dusts.

A battery-operated sensor cannot be kept active all the time since this will deplete its energy resources quickly. The sensor should be notified on when exactly to turn on its circuitry for performing various functions like sensing, transmitting and receiving data. This is done at the MAC layer by a TDMA scheme, in which each sensor is allotted a time slot for performing its duties [1, 2]. The sensor turns off its circuitry when its time slot has passed to conserve energy. The energy consumed for transmitting data increases with the distance between the communicating parties. Thus, the sensors that are located at longer distances from the gateway or command center will die out more quickly than those at shorter distances. Instead of having the longer distances sensors transmitting directly to the gateway, certain sensors in between can be used as the forwarding agents. Transmitting data over these much shorter distances leads to substantial power savings at sensors. This approach is at the routing layer, and uses connected dominating set in power constrained trans-receivers in the wireless ad-hoc network. This is an approach for minimizing energy consumption of the nodes and to increase the network life time.

In the further parts of the paper, section 2 we next describe preliminaries on connected dominating set. Section3 describes the related work. We present our proposed algorithm in section 4, clustering method in section-5, application of CDS method to clusters in section-6. Simulation results are used to evaluate the model in Section 7. Finally Section 8 concludes the paper.

2 Preliminaries

An ad-hoc network can be presented by a unit disk graph where every vertex (host node) is associated with a disk connected at this vertex with the same radius (transmitter range) [3]. Two vertices are neighbors if and only if they are covered by each others arc. For example, both vertices v and w in Fig-1 are neighbors of vertex u because they are covered by the arc of u. we consider an Ad-hoc network, where all links (edges)

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are unidirectional due to the disparity of energy levels of hosts. Therefore a general Ad-hoc wireless sensor network can be considered as a directed graph with a high percentage of bidirectional links.

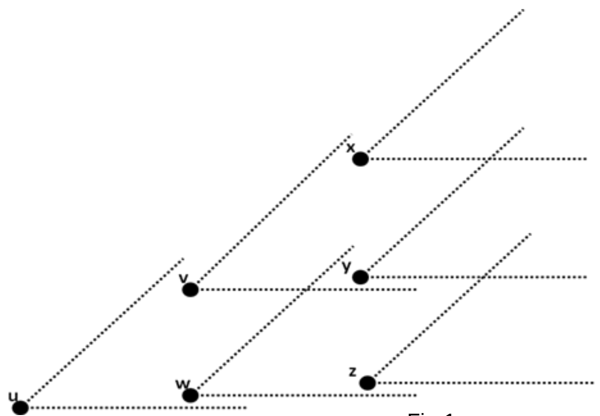

Fig-1

A Connected Dominating Set (CDS),were proposed to reduce the routing overhead and enhance scalability [4]. In dominating set, every vertex in the graph is either in the set or adjacent to a vertex in the set. Vertices in dominating set are also called gateways while vertices that are outside a dominating set are called non-gateways. Among CDS based routing protocols, only gateways need to keep routing information in a proactive approach and the search space is reduced to the dominating set in a reactive approach[5].

Finding a minimum connected dominating set is NP-complete for most graphs. Wu and Li proposed a simple and efficient approach called marking process for undirected graph & absorbent for directed graphs that can quickly determine a CDS .Specifically, each host is marked if it has two unconnected neighbors. It is shown that collectively these hosts achieve a desired global objective - a set of marked hosts forms a small CDS. Based on the marking process, vertices u and w in Figure 1 are marked and they form a dominating set in their network. The CDS derived from the marking process is further reduced by applying two dominant pruning rules.

According to dominant pruning rule 1 - a marked host can unmark itself if its neighbor set is covered by another marked host; that is if all its neighbors are connected with each other via another gateway, it can relinquish its responsibility as a gateway. In Figure 1, either u or w can be unmarked (but not both). According to dominant pruning rule 2, a marked host can unmark itself if its neighborhood is covered by two other directly connected marked host. The marking process 1 and 2 are purely localized algorithm where the marker of host depends on topology of small vicinity only [5].

We propose a connected dominating and a clustering algorithm in the MAC layer that can increase the life time and survivability of the wireless sensor network.

3. Related Work

Wu, J. and Dai, F. [5] marking process uses a constant number of rounds to determine a CDS. This approach can be applied to Ad-hoc sensor networks with bidirectional link only. The mesh scheme [6] designates a subset of border members as gateways so that there is exactly one virtual link between two neighboring clusters. Das et al.[7]proposed an algorithm using spine to identify a sub-network that forms a minimum CDS (MCDS). This algorithm finds a CDS by growing a tree T starting a vertex with the maximum vertex degree, and adding a new vertex to T according to its effective degree (number of neighbors that are not neighbors of T).

In this paper, we introduce a model to develop an infrastructure for wireless ad-hoc network at the trans-receivers in directional systems. Our algorithm consists of 2 phases: First, we cluster sensor nodes using clustering algorithm and then we implement the CDS algorithm to intra clusters.

4. Our Proposed Model

We propose a way to make an infrastructure for co-operative wireless ad-hoc network with connected dominating set and in addition to a clustering method for trans-receiver nodes. The wireless sensor nodes are densely deployed in the space. Therefore, if we can cluster them considering their gateways (cluster head), the network life time and survivability increases [2, 10]. The sensor network is divided into separate regions known as clusters. A cluster is nothing but a gateway and a set of trans-receivers that communicate with that gateway. Dividing a network into clusters has the advantage that since there are fewer sensor nodes in a cluster, the computation of routes is much faster. The number of clusters in the network is equal to the number of gateways, since there is one gateway for each cluster. After clustering the network we use the CDS finding method. In the simulation, we show that the network lifetime and packet overhead are managed till an acceptance optimal level. We use the packet drop probability as the performance metrics parameter.

5 Clustering method

The main objective of our approach is to cluster sensors in the ad-hoc network efficiently around few high-energy gateway nodes. The clustering method is responsible for dividing the whole network topology into clusters. The method takes the set of sensor nodes and gateways, and partitions them such that there is one gateway and a subset of the set of nodes in each cluster. Clustering enables network scalability to large number of sensors and extends the life of the network by allowing the sensors to conserve energy through communication with closer nodes and by balancing the load among the gateway nodes. Gateways associate cost to communicate with each sensor in the network.

Clusters are formed based on the cost of communication and the load on the gateways. Network setup is performed in two stages; 'Registering' and 'Clustering'. In the Registering phase, gateways discover the nodes that are located within their communication range. Gateways broadcast a message indicating the start of clustering. We assume that receivers of sensors are open through out the clustering process. Each gateway starts the clustering at a different instance of time in order to avoid collisions. In reply the sensors also broadcast a

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message with their maximum transmission power indicating their location and energy reserve in this message. Each node discovered in this phase is included in a range set per gateway. Registering a sensor network is the processing of establishing inter-node links and forming an overall network topology. Registering typically consists of two phases:

Find Node: unless the nodes are manually placed, nodes are not aware of their peers and thus should at least discover their neighbors.

Topology Setup: Based on the established links among neighboring nodes, a network topology should be established to allow for data gathering.

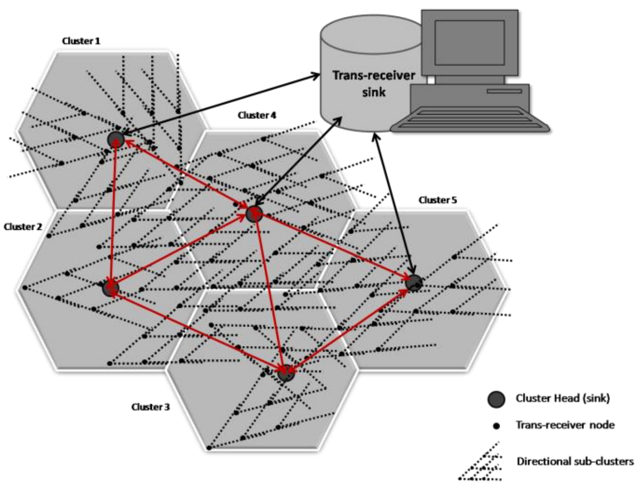

Fig -2

In the clustering phase, gateways calculate the cost of communication with each node in the range set. This information is then exchanged between all the gateways. After receiving the data from all the other gateways each gateway start clustering nodes based on the communication cost and the current load on its cluster. Than the formed clusters finds out the different directional sub-clusters present in the cluster sink (gateway) of the cluster. When the clustering is over, all the sensors are informed about the ID of the cluster they belong to. Since gateways share the common information during clustering, each sensor belongs to only one cluster. For inter-cluster communication all the traffic is routed through the gateways. The clustering method may use a number of metrics to determine how to form clusters[10]:

1. Physical distance of a sensor node from the sensor. In this case, the sensor node determines the nearest gateway and reports to that gateway.
2. Equal number of sensors in each cluster. This ensures that each gateway has equal routing overhead.
3. Redundancy assurance. A sensor may determine that there exists more than one gateway within transmission range. It chooses one gateway and joins that cluster, and keeps the others as backups. Thus, this method may change the cluster formation due to factors such as gateway failure.

As shown in Fig-2, at first, sensor nodes are clustered into sub-clusters, clusters and then the CDS method is applied to the clustered network. The method that has been used in our approach uses the proximity based metrics. Thus, each sensor node chooses the nearest gateway and joins that cluster. As shown in Fig - 2, all sensors find their Euclidian distance from the gateways and join them. After clustering sensor nodes in clusters with cluster head or gateways, the CDS finding method is used in each cluster.

6 CDS Method

A co-operative ad-hoc wireless network with unidirectional links can be represented by a simple directed graph G = (V,E), where

V is a set of vertices (hosts)

E is a set of directed edges (unidirectional links)

A directed edge directed from u to v is denoted by an ordered pair (u,v). A directed graph G is strongly connected if for any two vertices u & v, a(u,v)- path, i.e. ,a path connecting u to v, exists. If (u,v) is an edge in G, we say that u dominates v, & v is the absorbent of u. The dominating neighbor set Dn(u) of vertex is defined as

$$Dn(u) = \{w: (w, u)\ E\} \qquad (1)$$

The absorbent neighbor set An(u) of vertex u is defined as

$$An(u) = \{v: (u, v)\ E\} \qquad (2)$$

& N(u) represents the neighbor set of vertex u:

$$N(u) = Dn(u) \ \ U \ \ An(u) \qquad (3)$$

Considering the above marking rules, the marking process is as below:

Method1: Marking Process [6]

1. Each u periodically exchanges its neighbor set Dn(u) & An(u) with all its neighbors.
2. u sets its marker to T(marked) if there exist two neighbors v & w of u such that (w,v) belongs to E, & (u,v) belongs to E & (w,v) does not belong to E.

Initially vertices are unmarked. They exchange their open neighborhood information with their one-hop neighbors. Therefore each node knows all of its two-hop neighbors. The marking process uses the following simple rule: any vertex having two unconnected neighbors is marked as a dominator.

The set of marked vertices form a connected dominating set, with lots of redundant nodes. Two pruning rules are provided to post-process the dominating set, based on the neighborhood subset coverage. A node u can be taken out from S, the CDS, if there exists a node v with higher ID such that the closed neighbor set of u is a subset of the closed

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neighbor set of v. For the same reason, a node u will be deleted from S when two of its connected neighbor in S with higher IDs can cover all u's neighbors. This idea is also extended to directed graph. Due to differences in transmission ranges of wireless networks, some links in Ad-hoc wireless network may be unidirectional. In order to apply this to a directed graph like sensor network model, neighboring vertices of a certain node are classified into a dominating neighbor set & an absorbent neighbor sets in terms of the directions of the connected edges.

7 Simulations

For simulating the clustering of sensor nodes in the network, we make a network with below entities: Sensor nodes, Gateways, Clusters, directional sub-clusters, Packets, Packet Queues, Targets, User interface Events, Event Queues. Our metrics are the energy consumption per node, the average energy consumption within overall network, and network lifetime [7]. The average energy consumption for a uniformly 7-cluster network is less than 55uj, as shown in Fig-3.

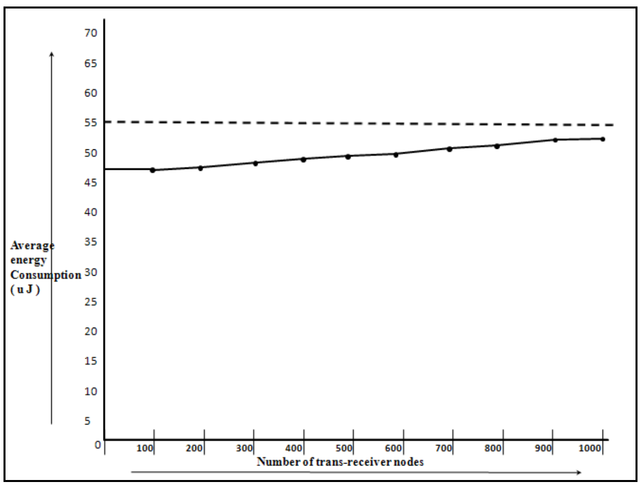

Fig - 3: The average energy consumed by trans-receivers in a network with 7 clusters.

In Fig-4, we can see that less than 34 % of the sensors consumed more than 55uj. The density of cluster sinks and directional sub-clusters can be increased to reduce the average energy consumption.

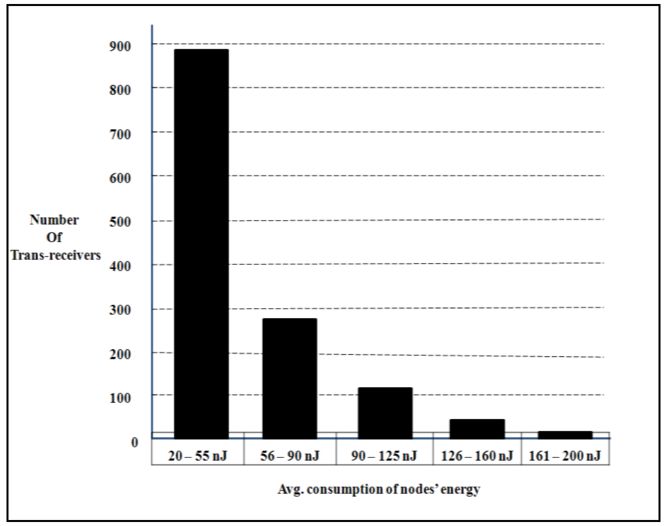

Fig - 4:Distribution of sensor energy consumption with our approach

For the other half resultant we apply the Connected Dominating Set algorithm used by Ji and Dai in [2] and Azarderakhsh, Jahangir and Keshtgary in [8]to simulate the connected dominating set reduction in co-operative directional Ad-hoc wireless sensor networks and we extend it by adding the clustering method to it. To generate a random Ad-hoc network, n hosts are randomly placed in a restricted 100*100 (meter) area. The transmitter range R is adjusted according to the average vertex degree d to produce (nd/2) links in the corresponding unit disk graph. All of these links are treated as bidirectional. Networks that cannot form a strongly connected graph are discarded. For each combination of parameters (n, d and p), the simulations repeated 300-800 times until the confidence interval is sufficiency small(+/-1% for the confidence level of 87%).

8 Conclusions and Future Work

In this paper we presented a new technique for implementing the clustering and efficient routing scheme for co-operative ad-hoc network with the directional antenna system based on the framework model using the concept of connected dominating sets of graph theory. In general, it is difficult to devise algorithms for such chaotic unpredictable environments. With the presented abstract framework model we measure the network energy consumption as an important parameter to evaluate network lifetime. This is a new technique which introduces increasing the network lifetime by increasing the cooperation among the nodes by efficient clustering.

In our simulation, we can measure other parameters like increasing the capacity as a network survivability metrics for our future work. We will also focus on evaluating survivability of the ad-hoc sensor networks considering capacity and network lifetime parameters. However, it still cannot root up some concerns (i.e., applying it to variety of layers as to improve overall system throughput and system reliability) worth further investigation in the future research

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work.

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