Dominating Set Based Topology control for Life-time Maximization in Wireless Sensor Networks

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***Abstract* - An important issue in wireless sensor networks is to prolong networks life time. Sensors are hard to recharge, since it is battery powered. A set of active sensors are chosen to provide better coverage which perform sensing and data transferring. In this work, the Connected Dominating Set (CDS) has been recommended to serve as a virtual backbone which provides coverage and connectivity. This algorithm will also reduce routing overhead and improve the network life time with energy efficient routing.**

Index Terms— Wireless sensor networks, Connected Dominating Set, Coverage and Connectivity, residual energy.

I. INTRODUCTION

A Wireless sensor network consists of a large number of sensor nodes that are densely deployed. These nodes are able to perform sensing as well as processing and are additionally capable of communicating with each other. Sensors collect the data and transmit to sink node using hop-by-hop communication. Sensor nodes are used in different applications. The military applications include surveillance and monitoring, guidance systems of intelligent missiles. Sensors are also used in environmental application habitat exploration of animals, forest fire and flood detection.

An important issue in WSNs is energy management, battery power and better coverage. One of the issues is density control. A subset of sensor nodes operates in the active mode, to conserve energy. The two requirements are: (1) coverage: The area that can be monitored by a set of sensors. (2) Connectivity: Sensor nodes collect the information and relay back to data sinks or controllers.

Topology control is an iterative process. Topology control is used by wireless ad hoc and sensor networks. Many centralized and distributed algorithms ensure topology control. The main aim of topology control is to save energy, to reduce interference between nodes, extend lifetime of the networks. Topology control involves two mechanisms: Topology construction and Topology Maintenance.

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The connectivity framework requires a set of active sensors to be connected all the time. This condition is significantly necessary for the communication between sensors and the sink in operation such as data reporting, query propagating, and forwarding of control messages.

A Connected Dominating Set (CDS) based localized mechanism is proposed to provide fault tolerant topology control. Initially, a basic backbone (CDS) is constructed. CDS is an energy-efficient mechanism which constructs a connected backbone in order to provide both coverage and connectivity.

The rest of the paper is categorized as follows. We discuss previous works on related topics in Section II. Section III describes CDS backbone selection algorithm in detail. Section IV provides the simulation results include CDS size, energy consumption, and delay for coverage and connectivity mechanism. Section V finally concludes the paper.

II. RELATED WORKS

Hakki Bagci, et al [1] proposed a Disjoint Path Vector (DPV) Algorithm. DPV are guaranteed to satisfy k-vertex super node connectivity. This algorithm finds the shortest path and then to transmit the data. The total power consumption is minimized.

Mohamed Younis, et al [2] discussed a cone-based distributed topology-control (CBTC) algorithm.They have focused on network topology management techniques for tolerating/handling node failure in WSNs. They have identified the reactive and proactive methods to ensure the network connectivity and to prolong networks lifetime.

Jie Wu, et al [3] proposed a simple and efficient distributed algorithm for calculating connected dominating set in ad hoc wireless networks, where connections of nodes are determined by geographical distances of nodes. This algorithm prolongs the life span of each node and balance the energy consumption in the network.

Khaled M. Alzoubiet al [4] explained a minimum connected dominating set (MCDS). MCDS for the unit-disk-graph is constructed with a *constant* approximation ratio, and *linear* time and *linear* message complexity. This algorithm is fully localized, and does not depend on the spanning tree. The message length is $O(\log n)$ bits.

Ivan Stojmenovic et al [5] proposed a localized dominating set algorithm to significantly reduce or eliminate the communication overhead of a broadcasting task. Also this algorithm maintains the positions of neighboring nodes. Existing dominating sets are improved by using node degrees instead of their ids as primary keys.

Jamil A. Shaikh et al [6] proposed new metrics for source-independent localized dominating set, based on combinations of node degrees and remaining energy levels, for deciding activity status. Also they proposed CDS scheme to prolong network life while preserving connectivity.

Fei Dai et al [7] proposed simple and efficient localized algorithm that can quickly determine a CDS in ad hoc networks. The efficiency of dominating-set based routing mainly depends on the overhead, introduced in the formation of the dominating set and the size of the dominating set. A localized formation of a connected dominating set called marking process and dominating-set-based routing. The dominant pruning rule to reduce the size of the dominating set.

Lu Ruana et al [8] described a connected dominating set is a subset of vertices. Every vertex is either in the subset or adjacent to a vertex in the subset and the sub graph induced by the subset is connected. A minimum connected dominating set is such a vertex subset with minimum cardinality. It represents a new one-step greedy approximation with performance ratio ln δ+ 2 where δis the maximum degree in the input graph. The interesting aspect is that the greedy potential function of this algorithm is not sub-modular.

Zheng Gengzhong, et al [9] proposed a topology control techniques.To provide energy efficient control topology structure of sensor networks, the common approaches are to adjust the transmission power of sensors and to dynamically schedule sensor's cycle.

Masoumeh Haghpanahi et al [10] proposed a new notation of connectivity called path-implement ability. It represents the ability of sensor nodes to relay traffic along a given direction field. Also they proposed a point MAC and routing protocol to forward traffic along the flow field.

IV. PROPOSED WORK

In wireless sensor network where the source node sense and send the data to sink node. Sensors are equipped with one or more sensing components. In our paper, a connected dominating set (CDS) based localized mechanism is used to provide coverage and connectivity.

A Dominating Set based Topology control algorithm for Wireless Sensor Networks is designed. Initially, it generates topology for wireless sensor nodes. Backbone node is selected based on node id, node degree and residual energy. To construct the backbone topology, such that a set of active sensors are chosen to work alternatively to serve different types of data, the global connectivity requirements can be achieved.

This algorithm analyzes the performance of nodes and getting better results. Also it provides energy conserved connectivity and coverage, it also maximized the nodes Lifetime.

1. Background

1.1 Dominating Set

Consider G = (V, E) is a subset D of V such that every vertex not in D is joined to at least one member of D by some edge. Domination number γ (G) is the number of vertices in a smallest dominating set for G.

1.2 Connected Dominating set

In a given graph, subset of nodes such that it forms a dominating set in the graph and the sub graph induced is connected. Involves two properties,

- Any node in D can reach any other node in D by a path that stays entirely within D. That is, D induces a connected sub graph of G.
- Every vertex in G either belongs to D or is adjacent to a vertex in D. It implies that D is a dominating set of G.

2. Topology Control

The fundament problem in Wireless Sensor Network is Topology control. It is of great importance for prolonged lifetime, increasing the efficiency of routing protocol, ensuring the quality of connectivity and coverage and increasing the network services. Also it is used to maintain network connectivity while improving energy efficiency and increasing network capacity.

2.1. Network Coverage

Coverage is a method for evaluating the QoS of Wireless Sensor Networks. The most important factor of coverage is network sensing capability of physical world. Coverage in wireless sensor networks is defined as a measure of how well and for how long the sensors are able to observe the physical space.

2.2. Network Connectivity

Network connectivity is the process of connecting various parts of a network to one another. WSNs is a large scale network, sensory data need to be sent to sink through hop by hop communication. This requires topology control to prove the connectivity of network.

2.3. Network Lifetime

An important issue in wireless sensor networks is to prolong networks life time. Sensors are hard to recharge them, since it is battery powered. Network lifetime depends on the objective of an application. The common definition includes the time until the first or last node in the network depletes its energy and the time until the node is disconnected from the case station.

2.1.1 Minimum CDS Backbone Selection

In the beginning, an initial CDS backbone is selected so that the sensed data can be propagated to the sink along the backbone. These sensors provide coverage and connectivity.

Each sensor *u* has associated the following fields: time *t (u)*, a priority *p (u)*, *status (u), CDS (u),* and role label *r (u)*. The time data structure describes the amount of time that *u* has to be active. Sensor priority *p (u)* is defined as a 2-tuple *p (u) = (E (u), D (u))*, where *E (u)* is the node *u*'s residual energy and *D (u)* is the node *u*'s degree. A node with higher residual energy has higher priority. If the residual energy of two nodes is same, then the node degrees are used to determine the priority.

The *status* field can either be active or not. The field *CDS (u)* can be TRUE or FALSE, depending on whether node *u* is currently in the backbone CDS or not. The field *r* keeps information about the role of a sensor, whether the node is active for serving the connectivity. Sensors collect *h*-hop neighborhood information by exchanging *Hello* messages.

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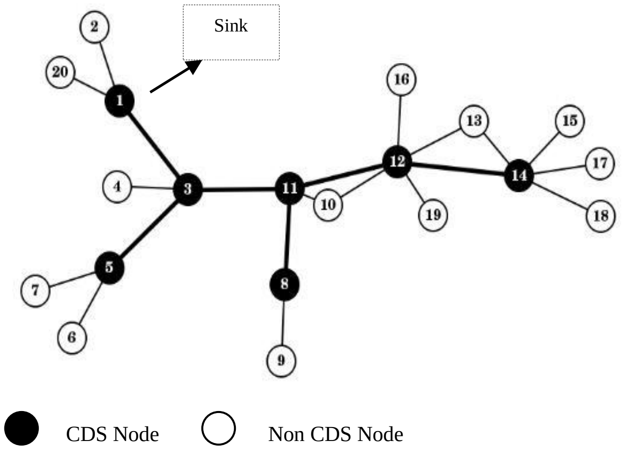

Fig. 1 Connected Dominating Set

Algorithm for Minimum CDS Backbone Selection

//Initialization
Each sensor '*u*' has following fields:
Time *t (u) =0*; //amount of time '*u*' is active
Node Degree *D (u)*;
Energy *E (u)*;
Priority *p (u)* = *(E (u), D (u))*;
CDS (u) =FALSE; // sensor '*u*' is not in CDS
role *r (u)* =NULL; // sensor '*u*' is in CDS or not

Status (u) =active; // all nodes are initially active

//Backbone Selection
for each sensor '*u*' ***do***
Compute energy *E (u)* and Node Degree *D (u)*
Priority *p (u)* = (Higher energy, Node Degree);
for time interval '*T*' on each sensor '*u*' ***do***
(a) Exchange '*Hello* message' within its range among its neighbors;
(b)***for*** sensors '*u*' and '*v*' compute energy ***do***
if ('*u*' has higher energy) ***then***
Sensor '*u*' is in CDS; // sensor '*u*' is in active
end if
if (sensors '*u*' and '*v*' has same energy)
and (compare Node Degree of '*u*' and '*v*') ***then***
Sensor '*u*' is in CDS (active); // *D (u)>D (v)*
else
Sensor '*v*' is in CDS; // '*u*' is in sleep state
end if
end for
end for
end for

V. PERFORMANCE ANALYSIS

In this section we evaluate the performance of dominating set based topology control algorithm to maximize the network lifetime. We study the average number of active sensors, energy consumption and delay. Sensors are randomly deployed in an area of 600m × 600m. The network setup is shown in the following Fig.2,

Transmission Range	: 100m
Sensing Range	: 20m
Bandwidth	: 2Mbps
Initial Energy Model	: Battery
Initial Battery Power	: 1000Joules
Communication Model	: Bi-Directional
TC Protocol	: MCDS
Routing Protocol	: Simple Forwarding
Sensor & Data Protocol	: Simple S&D Protocol
Interval	: 5.0Seconds
Number of Nodes	: 50,100,150,200,250

Fig. 2 Network Setup

Fig. 3 descibes the number of active nodes (i.e) number of nodes present in CDS backbone, coverage, and connectivity of the network.

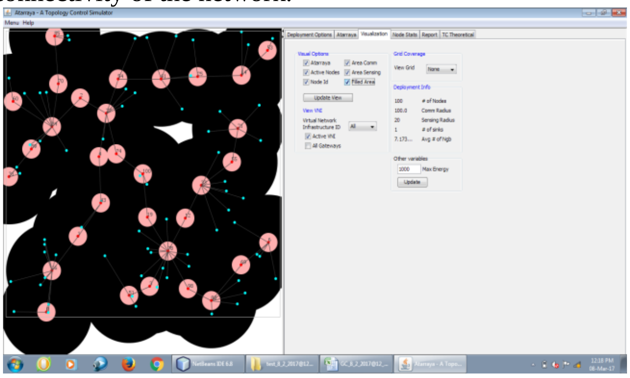

Fig. 3 Network Topology

Fig. 4 represents the variation of active nodes as compared to the total number of nodes. It shows that the topology control algorithm chooses fewer number of active sensors for sensing and data relying tasks. This CDS backbone ensures network coverage and connectivity.

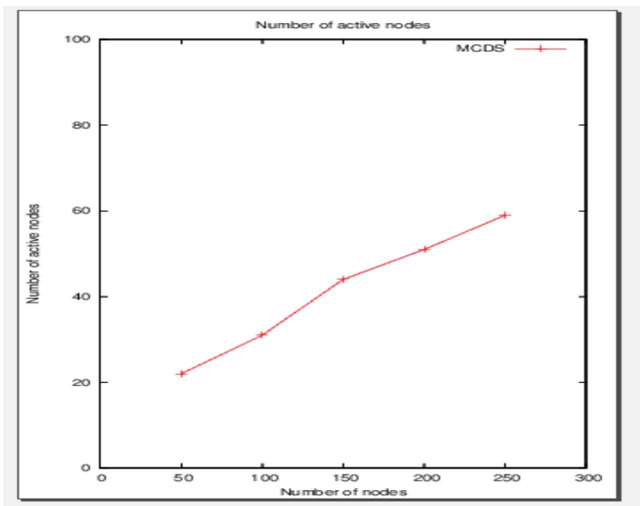

Fig. 4 Average Number of Active Sensors

Fig. 5 shows that the dominating set based topology control algorithm consumes less energy for building a topology, since it also has the lowest number of messages sent. It can be observed that the MCDS algorithm is developed to ensure energy consumption. Also less energy is wasted on control messages since most of the sensors do not take part in the data communication and as a result less energy is consumed. The simulation result shows that the algorithm is more energy efficient.

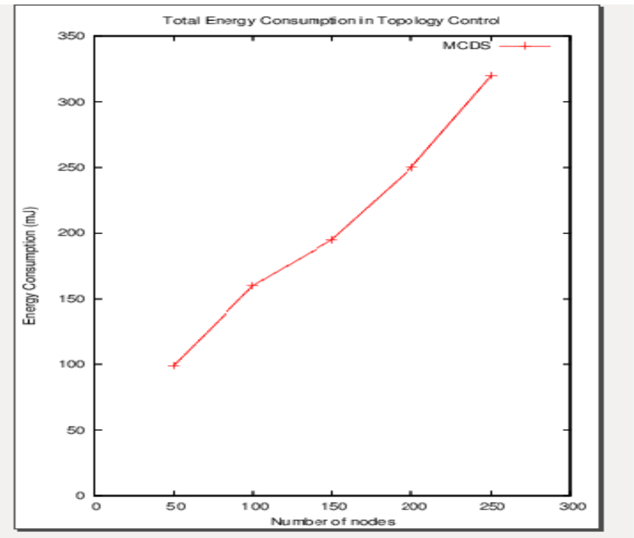

Fig. 5 Total Energy Consumption

Fig. 6 shows that the number of packets sent in order to achieve the topology construction. MCDS algorithm transmits packets (2197 packets) for the topology with a total of 250 nodes.

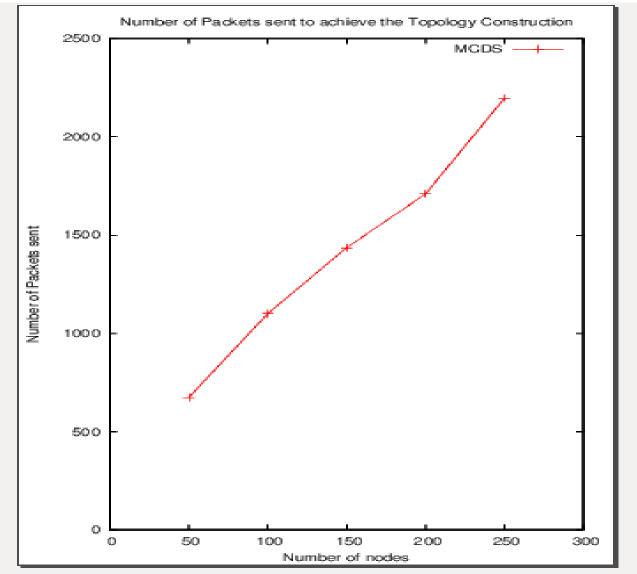

Fig. 6 Number of Packets sent to achieve topology construction

VI. CONCLUSION

Thus, topology control entails changing the node parameter in order to develop a network topology that would ensure the lowest energy consumption and the highest throughput within the network. A MCDS based localized mechanism is proposed. The minimum CDS backbone selection algorithm constructs topology with reduced size and although the algorithm is designed for optimal energy consumption. The coverage and global connectivity requirements are met. MCDS is energy efficient; it provides coverage, connectivity and prolong the network lifetime.

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