International Journal of Scientific & Engineering Research, Volume 4, Issue 7, July-2013 1563
ISSN 2229-5518

A Distributed Topology Control Technique for Low Interference and Load Balancing of Energy Utilization in Wireless Sensor Networks

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Abstract— Topology control has one of the foremost goal is the reduction of interference. Low interference is often claimed to be a consequence of sparseness or low node degree of the constructed topologies. Topology control plays an important role the design of wireless ad hoc and sensor networks; with the Topology control it is possible to construct the networks that have desirable characteristics such as sparser connectivity, lower transmission power and connectivity and smaller node degree. In this paper a new Load balancing algorithm for energy utilization is proposed and this algorithm improves energy utilization in Distributed Topology control Techniques as well as reduces the interference in Wireless Sensor Networks.

Index Terms— Wireless sensor networks, Topology control, Graph theory, Load balancing, Interference, Distributed topology.

1 INTRODUCTION

Topology Control is a technique which is used to increase crease network capacity and to reduce energy consumption in ad hoc network. The goal of Topology Control protocol is
to reduce the transmission power level used by network nodes,with the constraint of preserving some fundamental properties(typically connectivity) of the communication graph. Decreasing the nodes transmission power with respect to the maximum level potentially has two effects:1)reducing the nodes energy consumption, and 2) increasing the spatial reuse, with a positive overall effect on network capacity. Due to the limited availability of both energy and capacity in ad hoc networks, topology control is considered to be a fundamental building block of forthcoming wireless networks.

Wireless solutions have benefits in industrial applications such as enhanced physically mobility, reduced danger of breaking cables, less hassle with connectors and ease of upgrading. WSNs can be deployed in unpleasant, inaccessible or hazardous environments which are impractical with traditional wired networks such as in the bearings of motors or inside the inside of whirring motors [1]. In addition to this, the collaborative naure of WSNs brings about flexibility, self-organization, self-configuration, inharant intelligent processing capability, and enables rapid deployment. The data collected by sensor nodes is sent wirelessly to to a sink node that analyses yhe data from each sensor node. Notifications of any possible problems can then be sent to the plant personal or instructions can be relayed back to the sensor nodes to activate on board actuators in a certain way if equipped [1]. In sensor networks nodes are equipped with sensor measuring certain physical values such as humidity, brightness, temparature, acceleration or vibration therefore sensor networks can be considered as a speciliztion of ad hoc networks. Usully, the sensor nodes are designed to report measured information to a data sink node. Wireless sensor networks (WSNs) are expected to dominate industrial and environmental sensing networks to replace the current wired architecture not only to reduce cost but also to increase flexibility, scalability, and interoperability [3]. WSN plays a vital role in crating a highly reliable and self healing industrial system that rapidly responds to real-time events with appropriate actions [5].

Although the potential advantages of applying Topology Control techniques in ad hoc networks are two-fold, the current literarature on topology control has focused ettention solely on energy consumption, trying to minimize the “energy cost” of the the generated(connected) network topology[11]. Networks of sensors exist in many industrial applications providing the ability to monitor and control environment in real time. Most of the sensor networks, however are wired and as a result they they are costly to install and maintain. To lower the system and infrastructure cost wireless solutions can be used. Among the most comman scenarios foe sensor networks are environment monitoring tasks, for instance to warn of imminent natural disasters or for the the purpose of biological or other scientific observations. Since ad hoc and sensor network nodes are generally assumed to be autonomous and operate for considerable period of time, in the case of sensor networks up to several years, energy utilization is one of the central issues in this research context[11].

In a very general sense, tpology control in wireless ad hoc and sensor networks can be considered the task of,given a network connectivity graph, computing a subgraph with specifis desired properties, such as connectivity, short stretches,sparsity, low interference, or low node degree. Sometimes also the construction of node clusters and dominating sets of nodes is considered topology control [14]. To choose the transmitter power for each packet in a distribution fashion at each node is the power control problem in wireless sensor network. This problem is complex and mostly affects on operation of network. The transmitter power affects on quality of the signal received at the receiver. Power control determines the magnitude of the interefernce it creates for the other receivers as well as this power control affects on energy consumption in wireless sensor networks.

From all the above introductory part it comes to know energy efficiency and low interference are the most important factors in the wireless sensor networks. For energy efficiency and low interference there is a algorithm called as SBYaoGG algorithm which is discussed in related work. This algorithm gives very good results in the form of energy efficiency and low interefernce. But this algorithm does not tell about energy loads in each node. There is a unbalanced energy load distribution among all the nodes. But for better utilization of energy over the whole wireless sensor network, the energy loads of the each node should be balanced. For this here in this paper new load balancing algorithm is proposed which is discussed in section three. And results of both this algoriths are discussed in results section.

2 RELATED WORK

2.1 TOPOLOGY CONTROL

2.1.1 Taxonomy

There are several different approaches to topology control and it is possible to organize them into a coherent taxonomy. This approaches are distinguished on the basis of that control transmitter power and those that impose a hierechy in the network. Hierarchical approaches change the logical structure of the network in terms of node adjancies and may be broken down into approaches that use clustering and those that use dominating sets.

The power control approaches act on the transmission power of nodes using several different techniques. The first distinction to make a power control approaches are between homogeneous and heterogeneous approaches. Homogeneous topology control is the easier of the two in which nodes are assumed to use the same transmitting power and the problem of topology control becomes in essence one of finding the value of the transmitter range that satisfies a certain network wide property.

In heterogeneous topology control nodes are allowed to select different individual transmitting powers up to certain maximum that they can support which means that they will have different transmitting ranges. This form of topology control can split into three categories according to the type of information that is used to generate the topology. These three categories are location based, direction based, and neighbor based. In location based approaches exact node locations are known and are either used by a centralized authority to calculate a set of transmitting range assignements which optimize a certain measure or are exchanged between nodes to create an approximately optimal topology in a distribution fashion. In direction based approaches, nodes are assumed to not know their positions but can estimate the relative direction to each of their neighbors. Finally, in neighbor-based approaches the only knowledge nodes have of their neighbors is the neighbors IDs and the IDs are ordered according to some criterion when performing topology control.

2.1.2 Quality Measures

Different approaches to topology control will produce different results. for a collection of nodes V let G denote the graph on for which there is an edge from node u to node v only if u can directly reach to v. it is desirable to judge the usefulness of a topology T returned by a topology control algorithm and compare it with results from other algorithm. In order to do this, some metrics and measures are required which include connectivity, energy efficiency, throughput, and robustness to mobility [1].

1) Connectivity: if there is a multichip path between 'u' and 'v' in G, then there should also be a path in 'T'. This is a basic requirement for a topology control algorithm, that it should not disconnect a connected graph.

2) Energy Efficiency: The energy consumed for a transmission between u and v is a polynomial function of the distance between u and v. two common notations of enrgy efficiency are the energy stretch factor and the hop stretch factor. The energy stretch factor is the worst increase in energy used to deliver a packet between any pair of nodes and along with a minimum energy path between the original graph and the topology controlled graph. The hop stretch is similar except that focus is on path length as opposed to energy consumption. Formally

Energy stretch factor = max E_T (u, v)/E_G (u, v)

Where E_G (u, v) is the energy consumed along the most energy efficient path in graph G. Likewise

Hop stretch factor= max$|(u, v)_T| / |(u, v)_G|$

Where (u, v) is the shortest path in graph G and |(u, v)| is its length.

3) Node Degree: In order to to better evaluate the performance of the topology control technique in terms of interference, a distinction is made between the physical and logical node degree. The physical node degree refers to the number of neighbor nodes that are within the transmitter range of given node. The logical node degree refers to the number of neighbor nodes that a given node is linked to.

4) Simplicity and Maintainability: It is desirable for a a topology to be a simple and easy to maintain and objective measures that can be used to evaluate these objective goals are the number of edges in and the maximum node degree (number of neighbors) of any node in G. It is desirable also for the algorithm used to have little overhead in terms of computation and communication requirements.

5) Throughput: It is desirable for the network topology to have a high throughput, where it is possible to sustain a comparable amount of traffic as the original network topology. Several throughput measures can be used [15] one of which is the bit-meter which is defined in terms of the bit distance product. A network transports one bit-meter when it one bit is transported a distance of one meter. The throughput of the network then

6) Roburstness to Mobility: The mobility of nodes causes neighborhood relationships to change in the original graph and some other nodes will have to change their distributed topology. A roburst topology should only require a small number of these adaptions and avoids the effects of reorganization due to lacal node movement affecting the entire network. A measure of roburstness is the adaptability [15] which is the maximum number of nodes that need to change their topology information as result of the movement of the node. Adaptability depends on the size of the transmission neighborhood of the mobile node and the relative location of the nodes. Roburstness to mobility is an issue in industrial applications such as product tracking and material tracking.

2.2 SMART BOUNDARY YAO GABRIEL GRAPH (SBYAOGG)

A. Aim of the algorithm:

1. Enhances energy efficiency.
2. Reduce radio interference in wireless sensor networks.

ISSN 2229-5518

B. Objective of the project:

Topology control plays an important role in the design of wireless ad hoc networks that have desirable characteristics such as sparser connectivity, lower transmission power, and and a smaller node degree. In this algorithm, a new distributed topology control technique is presented that enhances energy efficiency and reduces radio radio interference in wireless sensor networks. Each node in the network makes local decisions about its transmission power and the culmination of these local decisions produces a network topology that preserves the global connectivity. Central to this topology control technique is the novel Smart Boundary Yao Gabriel Graph (SBYaoGG) and optimizations ensure that all links in the network are symmetric and energy efficient.

There are two design objectives in developing in the envisaged topology control technique for WSNs. The first objective is that it should been energy efficient and the second is that it should have low interference. Performance measures are used to determine how well these objectives are meeting.

C. Requirements:

To meet the design objectives, the routing sub graph produced by the topology control technique from the original graph had to meet certain requirements. A number of requirements are as follows:

1. Constant power stretch factor, i.e. the graph should be power spanner of graph G.
2. Linear number of edges, i.e. the graph must be sparse.
3. Easy computation in a distributed and localized way.

In addition to this, the sub graph had to be:

1. Connected with high probability if the original graph is connected.
2. Planner, meaning that no two edges in the graph cross each other. This will enable some localized routing algorithms.

D. Process:

The topology is generated by first computing the Gabriel graph from the Unit Disk Graph (UDG) at the maximum transmitter power and then computes the Yao graph on the reduced topology to produce the final topology. By computing the Gabriel graph from the UDG some of the requirements for the final topology should meet.

1. The graph produced should be planner.
2. The graph should has a linear number of edges.

After computing the Yao graph from the Gabriel graph some other requirements for the final topology should meet.

1. The graph should be connected. This is because both the Gabriel graph and Yao graph are connected if the original graph is connected.
2. The graph should be a power spanner of the original UDG. This is because both the Yao graph and the Gabriel graph are power spnners.

The procedure employed to reduce interference are as follows:

1. Prune the edges of the Gabriel graph using the Yao graph.
2. Use large regions in omputing the Yao graph.
3. Select the axes of the cones for each region of the Yao graph
4. Reduce the transmitter power of each node to the lowest level so that it allows it to reach its furthest neighbor in the final topology.

3 LOAD BALANCING FOR ENERGY UTILIZATION ALGORITHM

This algorithm is using to make topology in energy efficient state. Here we are checking the energy load in each state node has equal energy load then do nothing otherwise reduce the energy from the the nodes which are using high energy and allocate this energy to the nodes which are using less energy.

The Load balancing for energy utilization algorithm is given below:

1. The node discovers its neighbor nodes by broadcasting at maximum power.
2. Unit Disk Graph (UDG) is calculated by using Waxman Algorithm.
3. Apply SBYaoGG.
4. Chech energy load in each state node.
   1. If each state node has equal energy load then do nothing.
   2. Otherwise reduce the energy from the nodes which are using high energy and allocate the energy to the nodes which are using less energy.

Here we are considering the state nodes with high degree are using high energy and the state nodes with less degree are using less energy.

Finally, results of load balancing algorithm are compared with resukts of the SBYaoGG in terms of energy utilization and interference.

4 RESULTS

For results discussion here first consider the wireless sensor network of 100 nodes. Then first decide number of groups or region boundaries in which network should be breakable as well as calculate the number of state nodes at this stage. Here state nodes are nothing but the nodes which are in position to send data to other nodes. These state nodes are calculated randomly. Then draw the Unit Disk Graph (UDG) from this number of nodes and region boundaries by using Waxman Algorithm. After UDG creation apply the SBYaoGG algorithm on it. And then finally apply the load balancing algorithm on it and compare both the results.

For results just take an example of wireless sensor network consist of 100 nodes and here suppose number of groups or region boundaries are 10. Then the number of state nodes is 3 in which one is root node. Then SBYaoGG looks like:

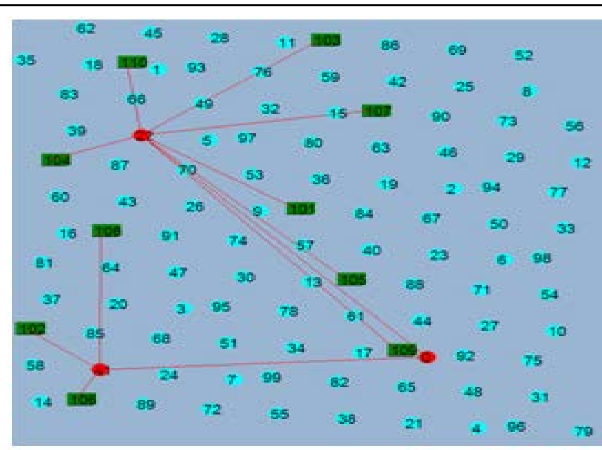

Fig. 1 SBYaoGG

Here in this graph number of state nodes are 3 and that are 0(root node), 22 and 41. From this graph it can be noticed that node 22 are having 7 load and 41 are having 3 loads. From this it comes to know that all state nodes are not in the balanced state that is some state nodes are having high energy load and some are having less energy load. So here what happens in the network this low energy load nodes are using the same energy as the high energy load nodes. So in this situation utilization of energy is unbalanced.
Here apply load balancing algorithm. After applying this algorithm the state nodes are the same as initial state nodes in SBYaoGG. Here only energy loads are balanced among all the state nodes.
The final graph will look like as follows:

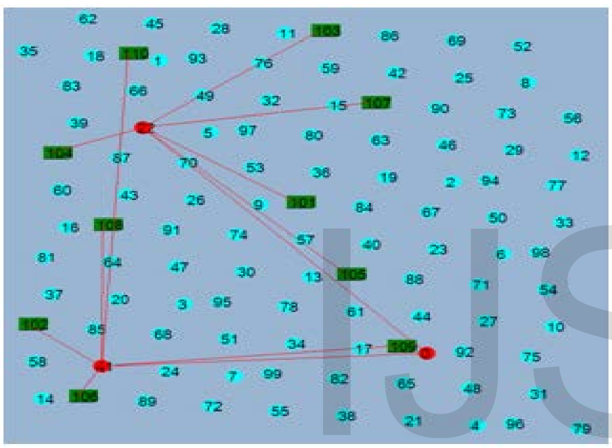

Fig. 2 Load balanced graph

From figure 2 it is clear that state node 22 and 41 are having same energy load 5. In this way it is possible to balance the energy load among all the state nodes. So that utilization of energy is balanced through whole wireless sensor network.

5 MATHEMATICAL MODEL FOR PROPOSED ALGORITHM

Set Theory-

G is the graph G= (V, E)
Where,
V is main set of nodes (vertices) like v1, v2, v3…
V= {v1, v2, v3…} of Graph G

E is main set of edges like e1, e2, e3 …
E= {e1, e2, e3…}

Waxman Algorithm-
In this application Waxman algorithm is used to define the probability of an edge between node u and v as:

P (u, v) = 10*alpha*Math.Exp (-1.0*(distance/(beta*L)));

Where distance is Euclidean distance between the node u and v and L is the maximum distance between two freely selected nodes. An increase in the parameter alpha effects in the increase in the number of edges in the graph, while a decrease of parameter beta increases the ratio of the long edges against the short ones.

Energy Management-
Here load balancing algorithm is used for the energy management between nodes-
Suppose SBYaoGG graph Gyg (v, e) has vertices (nodes) (v1, v2, v3… vn)
And corresponding consumed energy (e1, e2, e3… en)
Total consumed energy including all vertices-

$$E = \sum_{z=1}^{n} en \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Then efficient consumed energy should be in each vertices-

$$Ee = Et/n \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Here this is assumed that energy of a vertex is equal to the degree of each vertex. So in order tomake the graph in efficient energy state, check the node degree of each vertex, remove the exceeded nodes from higher node degree vertex and add the node with less node degree. Here node degree of particular node is the number of nodes which are directly connected to that node.

6 CONCLUSION

In this research, a topology control technique for low intereferense and load balancing for energy utilization in wireless sensor networks was developed in the form of load balancing algorithm. The load load balancing algorithm is a variation of the SBYaoGG. In this technique we first computed SBYaoGG results in terms of energy efficiency and interference and then tried to to improve energy utilization and lower interference by using load balancing algorithm. This new load balancing algorithm gives the very good results in terms of utilization of energy and low intereference in wireless sensor network. The results are shown in figure 1 and figure 2.

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