Dominating Sets: Sensor Networks

Prachi Shivhare, Sriraman Sridharan, Tushar Deshpande

Abstract—*In this paper we study the use of dominating sets in sensor networks. We explain the idea of dominating sets and its use in wireless sensor networks environment. To substantiate the idea of dominating sets in sensor networks, we present the results of a set of nodes with their dominating sets.*

General Terms: *Dominating Sets, Energy efficiency, Performance*

Keywords:Dominating sets, adHoc Networks, Sensor Networks

1 Introduction

Advances in digital electronics and wireless communications have enabled the development of low-power, lowcost, multi−functional sensor devices. These devices gather process and communicate information about their environments. A large number of devices collaborate using wireless network and an asymmetric, many-to-one data flow, this communication constitute a sensor network. The sensor nodes usually send their data to a monitoring station which it-self is a node. If all the nodes communicated directly with the monitoring station, the communication load will drain the networks power resources. Therefore the sensors operate in a self-organized, decentralized manner that maintains the best connectivity as long as possible. Sensor networks generally deploy nodes densely, using hundreds or thousands of sensors placed mostly at random either very near or inside the phenomenon to be studied. The nodes are static and carry less battery and processing power efficiently.

As a sensors battery is not replaceable its energy becomes the most important system resource. The best method for conserving energy is to put the sensors to sleep when they are not in use. At the same time the network must maintain its functionality through a connected sub-network that lets the monitoring station communicate with any of the networks active sensors. Each sensors monitoring area can be approximated as a disk around it. We further assume that each sensor can measure or observe the physical parameter or event in its own monitoring area and can use radio-frequency technology to communicate with other sensors in its vicinity. The solutions we present here also assume that a sensors monitoring area is the area in which nodes can receive communication from a transmitting node

2 History

Hedetniemi and Laskar [3] in 1990 worked on the domination problem wich was studied from the 1950s onwards, but the rate of research on domination significantly increased in the mid-1970s. Garey, Michael R. and Johnson, David S. published a book on 'Computers and Intractability: A Guide to the Theory of NP-Completeness' in the year 1979.[4] From then, research has picked up pace.In the year 2000, Jie Wu and Hailan Li, in proceedings of 2000 international conference of parallel processing presented a paper on 'Domination and Its Applications in Ad Hoc Wireless Networks with Unidirectional Links', in 2004 Jean Carle ,David Simplot-Ryl's paper on 'Energy-Efficient Area

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Monitoring for Sensor Networks [5] published in the IEEE Computer Society and Bolla, J.A. Huynh, D.T.'s paper on Adapting connected d−hop dominating sets to topology changes in wireless ad hoc networks [6] at 2006 IEEE International Performance Computing and Communications Conference were some milestones in the area of using dominating sets in sensor networks.

3 APPLICATIONS

3.1 Social Networks

Social networking has been developed significantly in the recent years as the mode of communication. Dominating sets play an important role in analysing the real-world social network data through simulation process. Used to relate to groups of social causes like smoking, drinking, drug abuse etc. An undirected graph $G = (V, E, C)$ denotes the online social network as, friendship in social networks is usually bidirectional. In the graph G, a person is the vertex, an edge E represents the friendship and C is the compartment which defines the group people belong to.[7](Figure 1)

3.2 Mobile AdHoc Networks

A Mobile Ad-Hoc Network (MANET) is a self-configurable infrastructureless network connecting the mobile devices in wireless mode. The dominating set has been commonly used for routing and broadcasting the information to the mobile devices in mobile ad-hoc networks [1]. The Dominating Set is used as the backbone

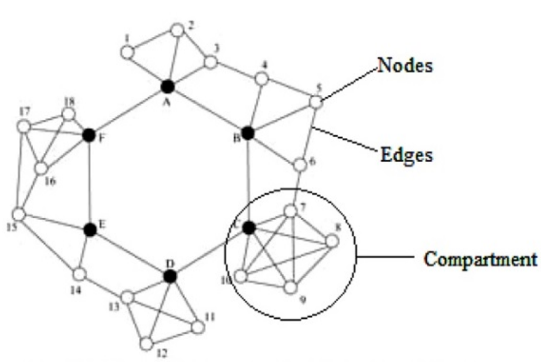

Fig. 1. Application 1

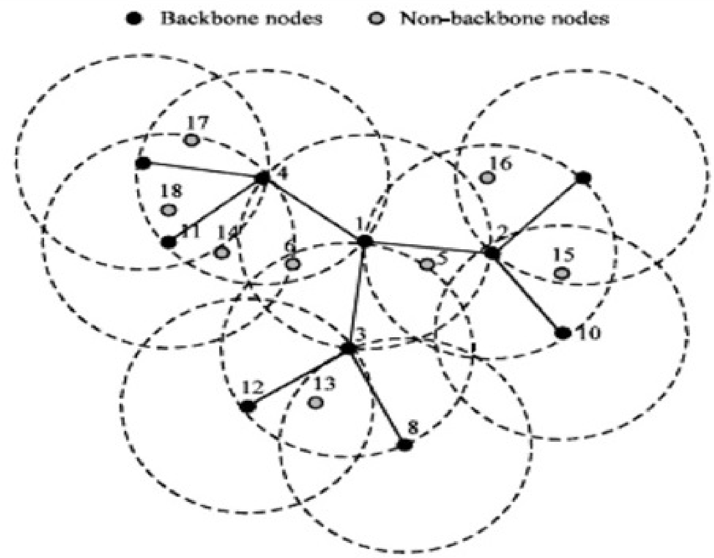

Fig. 2. Application 2

for Mobile Ad-Hoc Networks to provide them with various communication primes such as routing, broadcasting etc [2].The construction of such a virtual backbone is very important and it is used in the approximation by a minimum dominating set with a graph as shown in the (Figure 2)

4 ALGORITHM

We have developed a version of this algorithm for generating dominating sets, that minimizes the power consumption which in−turn maximizes the network lifetime. It can be divided into three modules as follows:

Algorithm 1 Decrement Power

procedure $decrementing_power(ArrayList < Node > graph, List < Integer > domList)$
    SET new_graph to graph
    For each(element in graph)
    if dominating set list contains this element **then**
        Remove the node from new_graph
        SUBTRACT life of node by DEC_LIFE_BY
        Add the node to new_graph again
    End For
return new_graph

Algorithm 2 Generating Dominating Sets

procedure GENERATEDOMINATINGSETS (ARRAYLIST< $Node$ > GRAPH)
  For each(Node)
  Get node with index i
  if (dominating list does not contain i) **then**
    if (dominating list does not contain all the adjacent nodes of i) **then**
      if (secondhop() does not return TRUE) **then**
        if (node still has power) **then**
          Add the node to the dominating set list
  End For
  Display dominating set list
  Set new_graph to Call $decrementing\_power$
  For each(Node)
  if (Node power is 0) **then**
    Increment Dead nodes by 1
  End For
  if $(Deadnodes <= NUMBER\_OF\_NODES)$ **then**
    $Call\ generateDominatingSets\ with\ new\_graph$

Algorithm 3 Second Hop

procedure $secondhop(Nodenode, ArrayList < Node > graph, List < Integer > domList)$
  Set adjList to adjacency list of node
  Set flag to true
  For each(element in adjList)
  Set $adj\_adjList$ to the adjacency list of each adjacent element
  For each(element in $adj\_adjList$)
  if dominating set list contains element of $adj\_adjList$ **then**
    Set flag to TRUE
return FLAG
    if there exists no such element **then**
      Set flag to FALSE
  End For
  End For
return FLAG

5 Example Implementation

```
L1.public class Node {
L2.     private int index;
L3.     private int life;
L4.     private List<Integer> adj;
        adj = new ArrayList<Integer >();
L5.}
```

The class Node represent a node in the Adhoc network. The node class object will contain information about node it represent in the graph. Each node will have index that indicates the identity of the node in network, life indicates the power of the node and adj will have adjacency list of each node.

```
L1.public class GraphGenerator {
L2.private static final int LIFE;
L3.LIFE= 10;
L4.public static final int NUMBER_OF_NODES;
L5.NUMBER_OF_NODES = 10;
L6.private static ArrayList<Node> graph;
L7.graph = new ArrayList<Node>();
L8.public static void generateGraph();
L9.}
```

The $GraphGenerator.java$ contains function generates a random graph. Constants like LIFE and $NUMBER\_OF\_NODES$ are used to generate graph with nodes equals $NUMBER\_OF\_NODES$ and each node at the start will have equal power which is defined as $LIFE$. The function that generates graph $i.e.$ generateGraph() will create graph as ArrayList of objects of Node. Each object is initialized and added to the ArrayList. The degree and the adjacency list of each node is created randomly. The adjacency list of a node will have the list of node in which it has previously appeared and the random nodes having greater index will be added to satisfy the degree of the node. No node is added to the node adjacency list if the node has already reached its degree or the it already contains the nodes after it.

```
public class DominatingSets
{
int count = 0;
public static final int DEC_LIFE_BY = 2;
public void generateDominatingSets
(ArrayList<Node>);
public boolean secondhop
(Node,ArrayList<Node>,List<Integer >);
public ArrayList<Node> decrementing_power
(ArrayList<Node>,List<Integer >);
}
```

For generating Dominating Sets generateDominatingSets() function is called which is defined in DominatingSets.java. This function take the random graph generated as input and generates a dominating set. A node index is added to dominating set List if the node is not already in the dominating set list or if the dominating set list does not contains all the elements of adjacency list.

Additional it also checks for the second hop condition which is given by function $secondhop()$. It takes graph, dominating list and the current node as inputs and returns true or false. If the dominating set list contains the node which is adjacent to the adjacent node of the current node the second hop condition is true and the will not be added to the dominating list. If the second hop condition is false then it check if the node has power. If it has power it is added to the Dominating Set List. After generating the a dominating set list the function calls function $decrementing_power$. The function $decrementing\_power$ will take dominating set list and the graph as input. This function removes the node from graph, decrements the power/life of the nodes in dominating set list by a constant DEC_LIFE_BY and the add it to the graph $ArrayList$ again. This new graph $ArrayList$ is returned to the function $generateDominatingSets()$. The function $generateDominatingSets()$ then checks for number of dead nodes in the network if it is less than number of nodes it call itself i.e. function $generateDominatingSets()$ with the new graph as input to generate dominating list again. When the number of dead nodes in graph becomes equal to the number of nodes in network the function $generateDominatingSets()$ terminates.

5.1 Observations

In our implementation we have generated all the possible sets from a random graph and mapped it to the possible dominating sets in the spanning tree. While doing this we used the algorithm given the reference paper [9] which optimally covers the area for the sensor network and efficiently uses power of each node to maximize the life of the whole network.It runs at the complexity $O(n^2)$.

6 Conclusion

In this paper we have extended the uses of dominating set in to sensor networks with reference to the paper 'Energy-efficient area monitoring for sensor networks' [8] We have implemented algorithms used in the above paper to find out the domination of a set in the given group of nodes and how energy can be optimally consumed to run all the nodes to maximum time.

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