ISSN:0975-9646

Network Coding Based Virtual Backbone for Wireless Sensor Network

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Abstract— Wireless sensor networks are densely deployed having limited recourses where a small change in resource management adds high value to overall network. Topology control and network coding are such techniques, which can prolong network lifetime on reducing radio interference, ensuring network connectivity, coverage, increases network throughput and capacity. In this paper, we discuss about combining Network Coding(NC) with the Virtual Backbone (VB)- based broadcasting and propose an scheme, named NCVB, that shows a minimized Connected Dominating Set and limits total packet transmission over the constructed VB with the help of NC.

Keywords— Wireless Sensor Network, Topology Control, Network Coding.

I. INTRODUCTION

WSN nodes generally deployed in hostile region thus battery replacement becomes impractical and hence Energy becomes major challenge. A typical alkaline battery, for example, provides about 50 watt-hours of energy; this may translate to less than a month of continuous operation for each node in full active mode [6]. Transmitting and receiving power at particular node and interference at wireless link are two major issues, which consumes nearly 7/10 of total energy of sensor nodes [9], so it is strictly required to limit transmission power at node by managing transmitting range and to reduce interference by managing transmission capacity [6]. The term topology control coined to resolve such issues whereas network coding increase capacity and throughput and thus helps in reducing interference. Rest of article organized as follows, section 2 covers various topology control mechanism , network coding covered in section 3, section 4 covers related work, section 5 covers proposed algorithm and finally section 6 conclude the topic.

II. TOPOLOGY CONTROL MECHANISM

Topology control is a technique, used to enhance network capacity at network level and transmission power at node level [6]. The basic goal of Topology control is better utilization of network resources by reducing size of network either using node reduction or edge reduction. Where nodes are minimized using algorithms, which select a pair of nodes, these nodes, are used to forward packet to other nodes whereas edge reduction means selecting a dedicated path in such a way that it should contain a minimized edge set between source to destination and thus minimizes interference at wireless link. Based on structure Topology control categorized in three parts as shown in Figure 1. Flat network considers all nodes of same type and data is forwarded using multi hop short distance instead of single hop long distance. It is simple and robust but the structure does not have central management, it adopts self-organize cooperate algorithm to form network. The major disadvantage of flat network structure is that they are not expendable, complexity of algorithm increases with network size, whereas we know sensor networks are dense in nature. Large number of such node makes it infeasible to assign a global identifier to each node due to this reason data centric routing considered where the base station (sink) sends queries to certain regions and waits for data from the sensors located in the selected regions.

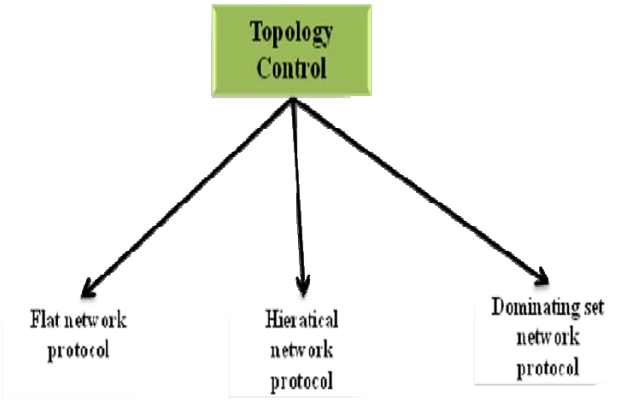

Figure 1. Topology Control Hierarchy [7]

Cluster network considers heterogeneous nodes and thus provides relaxation over flat network. Heterogeneity comes from hardware or from functionality. Here nodes divided in cluster head, gateways and cluster nodes. Topology control assigns functionality to each member node and decides which node will declare its own role in the cluster. Dynamic topology periodically adjust role of nodes, which is putted as cluster maintenance. Cluster based network faces many challenges like selecting optimal frequency, ensuring connectivity and computing optimal cluster size. Dominating set network describes about protocols, which chooses nodes to create backbone in order to perform routing related task. A backbone is chosen such that all nodes, which are in backbone known as dominating set and theses nodes work to forward non local data, other nodes connect themselves with any one of nearest dominating node and communicate using

this node itself. A topology constructed based on this idea and is fully connected is known as connected dominating set. However, the approach is better than other two types of network but complexity is to create minimal dominating set, which should preserve connectivity [5].

III. NETWORK CODING

Network coding in particular network is a data processing technique that exploits the characterststics of wireless medium in order to increase the capacity, throughput, fairness and node management of the network. Ahlswede et al. first coined it in 2000, which attracted much attention in coding field. It allowed sensor nodes to code the incoming data with appropriate coding method like XOR or linear operation instead of simply store and forward the data packet to achieve maximum transmission capacity and energy efficiency. Increasing throughput and reliability in network decreases network communication traffic and hence enhances energy consumption. Where to increase throughput Network coding allows the forwarding sensor node to compress N packet into single one and transmits the packet into single transmission whereas ancient method like store and forward technique takes N transmission to transmit N single packets separately. Hence, network coding saves a lot of energy by increasing throughput. Network coding achieves reliability by using intra flow network coding. In this method, nodes need not to learn which packet has to send to which node instead node simply broadcast the coded packet to all neighbor so that they may collect missing packet by decoding it and hence reduces communication traffic [2][3][4].

IV. RELATED WORK

An Energy-aware Virtual Backbone Tree (EVBT) proposed in [1] for the energy efficient communication in WSN. The overhead for constructing the EVBT is low, the data delivery along the tree saves a lot of energy, and the nodes in EVBT are at the high energy level. Algorithm assumes that sensors are equipped with GPS device and hence system becomes costly. In 2007, T. Acharya, which is our base paper, enhanced above work and proposed distributed EVBT [11] for WSN, it chooses only nodes with adequate energy levels as the member of the virtual backbone and used depth first search algorithm to construct Backbone. S. katti proposed network-coding scheme- COPE [8] that proved that CDS increases coding opportunity compared to other topology control schemes. S. Wang et. al., 2011, proposed Network coding based Connected Dominating Set (NCDS) [10] protocol, which constructs CDS over Ad-hoc network and implement Network coding to gain energy efficiency.

V. PROPOSED ALGORITHM

In this phase, Network Coding based Virtual Backbone (NCVB) algorithm is described. A Virtual Backbone (VB) is essentially a Connected Dominating Set (CDS). Sensors, which do not belong to Virtual Backbone, are termed as leaf node. Every node in the network has a VB node as its one hop neighbor. In this algorithm initially all node will be in Node_not_define state and after construction of topology their state will change to Dominator (nodes which belong to VB) and Dominatee (node which does not belong to VB) when they will receive the related message. See Figure 2.

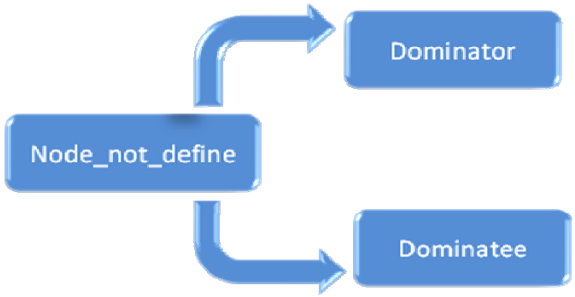

Figure 2. Transformation Diagram of State

A. *Preliminary work*

TABLE I
SYMBOL DEFINITIONS

N	One-hop Neighbor list of a node
N(N)	Two-hop reachable neighbors of a node
P	Packet transmitted by a Dominatee node
P'	Packet transmitted by a Dominator node
BS	Base Station (Sink node)
S_{id}	Senders address

B. *Construction of Virtual Backbone (VB)*

Step I. At first nodes in the network broadcast the Hello message to its neighbor. After collecting the hello message, every node creates a list N of its one-hop neighbor.

Step II. Each node will broadcast its N to its neighbor. On receiving, this broadcast node will collect two-hop neighbor information calculating [senders (N) - receivers (N)] and update its N (N) corresponding to sender's entry.

Step III. Initialize the values of variables and base station as a Dominator:

Dominator = 1;

Dominatee = -1;

Count = 1;

BS -> 1;

Step IV. Dominator will select node for next level Dominator and will broadcast a Dominator message, in case if there exist more than one node having same criteria than all node will be selected to next level Dominator:

For all N (1 to N (i))

Select i such that having MAXIMUM N (N) in it in case of tie select all ids.

End for

Dominator ({i_{id}}, {N (i) - i_{id}})

Step V. Receiver will check if receiver's id and iid matches than this node will change its state to Dominator otherwise state will changed to Dominatee. Each node will update its routing table by assigning Dominator nodes id as its parent.

If (massage = Domintor && $Node_{id}$ = iid)

{

$Node_i$ -> 1;

N ($Node_i$) – {(Ni)- i_{id}};

Count++;

Parent - > S_{id}

}

Else

{

Nodei -> -1;

Parent - > S_{id}

}

Step VI. Step VI and V will iterate until the completion of topology. At the end of step VI a minimized VB will be constructed.

C. Network Coding over VB

In this phase, we describe how to use network coding in VB-based broadcasting. Similar to MCDS [10] our algorithm implements Network Coding over VB nodes. The corresponding packet-processing algorithm is shown in Algorithm 1. In (line 1) of algorithm VB node checks if the packet is coming from Dominatee. For each node in VB, it tries to see whether it can get any coding opportunity to encode the packet with the remaining packets in the output queue that it needs to forward (line 3). If yes, it will encode the packets together and sends the coded packet in one transmission (line 5). If not, the VB node will buffer the packet for a fix constant time and will search for more coding opportunity (line 9-10) if the buffer time exceed the fix time than node sends the packet immediately (line 11). If the packet is from Dominator node than this packet will not be encoded and forwarded immediately (line 15) reason behind the concept is that if Dominator node will encode the packet coming from lower Dominators than this may create overhead as it passes towards Base Station (BS).

We desire to encode as many packets as possible in the range of a Dominator. For simplicity, we use simple linear operation to implement concept of network coding as shown in Algorithm 2. Whenever having an opportunity to transmit, the node picks the first packet P in the output queue and for remaining packets q {q: q €P} it simply adds the packets in linear way so that they can be extracted based on the fixed length of data packet. Numbers of packet encoded in algorithm bounded by node Degree so computational overhead for the procedure is insignificant.

Algorithm1. Processpkt ()

```
1. If (RecvPkt (p) == P)
2.     {
3.       k= EncodePkt ();
4.      if (k!= 1)
5.            sendCodedPkt ();
6.      else
7.          {
8.            do {
9.                  bufferPkt (p, timer);
10.               } while (buffertime (p) < timer)
11.           sendPacket (p);
12.         }
13.       }
14.  Else
15.       sendPacket (p');
```

Algorithm2. EncodePkt ()

```
//Pick packet p at the head of output queue
1.  k =1;
2. for all remaining pkt q in output queue
3.      {
4.       p' = p +q;
5.      k++;
6.      }
7. return (p', k);
```

VI. CONCLUSION

In this paper, a simple and efficient algorithm for constructing a Network Coding based Virtual Backbone (NCVB) being proposed for wireless sensor networks with the goal of improving packet transmission and energy gain in the network. To do so, main idea is to apply Network Coding on VB based broadcasting. On one hand, VB based broadcasting is efficient topology in terms of topology construction and energy efficiency. VB provides a common path for information flow, which increases the coding opportunity. Network Coding thus reduces total number of transmission and makes it more efficient. In the future, we will simulate the NCVB algorithm to check the proposed algorithm and will prove that total number of transmissions over a VB can be reduced to thrice (as calculated mathematically).

REFERENCES

[1] B. Zhou, A. Marshall and T.H. Lee, "An Energy-Aware Virtual Backbone Tree for Wireless Sensor Networks", Global Telecommunication Conference, IEEE Globecom, PP.162- 166, November 28- December 2, 2005.

[2] C. Fragouli, D. Katabi, A. Markopoulou and H. Rahul "Wireless Network Coding: Opportunities & Challenges", Milcom, 2009.

[3] J. Luo, T. Qin and J. Lui, "An Energy Saving Scheme Based on Network Coding in WSN" , IEEE - International Conference on Communications and Mobile Computing, PP. 229-233, 2010.

[4] L. Wang, G. Zhang, C. Ma and X. Fan, "Application Research on Network Coding in WSN" , Fifth International Conference on Internet Computing for Science and Engineering, IEEE, PP 162-166, 2010.

[5] N. K. Ray, "Analysis of Topology Control Algorithms in Ad hoc and Sensor Networks", Proceedings of International conference on Challenges and Application of Mathematics In Science and Technology (CAMIST), PP. 562-571, 2010.

[6] P. Santi, "Topology Control in Wireless Ad Hoc and Sensor Networks", John Wiley & Sons, Ltd, 2005.

[7] S. Jardosh, "A Survey: Topology Control For Wireless Sensor Networks", IEEE-International Conference on Signal processing, Communications and Networking, Madras Institute of Technology, Anna University Chennai India, PP. 422-427, January 4-6, 2008.

[8] S. Katti, H. Rahul, W. Hu, D. Katabi, M. Medard and J. Crowcroft, "XORs in the Air: Practicle Wireless Network Coding", ACM SIGCOMM, September 2006.

[9] S. Pete, K. Bo-Cheng, C. Lai, D. D. Hwang, "Reducing radio Energy consumption of key management protocols for wireless sensor networks", ACM 1-58113-929-2/04/0008, PP. 351 – 356, August 9-11, 2004.

[10] S. Wang, A. Vasilakos, H. Jiang and X. Ma, "Energy Efficient Broadcasting Using Network Coding Aware Protocol in Wireless Ad hoc Network", Communication(ICC), IEEE International Conference, PP. 1-5,June 5-9, 2011.

[11] T. Acharya, S. Chattopadhyay, R. Roy "Energy-Aware Virtual Backbone Tree for Efficient Routing in Wireless Sensor Networks", Third International Conference on Networking and Services (ICNS), IEEE , Athens, June 19-25, 2007.