Power Minimization through Network Coding in WSN

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Abstract—**Wireless sensor networks have been attracting a great attention due to their wide range of potential applications. However, due to various limitations arising from their inexpensive nature, limited size, weight and ad hoc method of deployment, the power consumption is one of the major constraints in sensor networks. Moreover, it is well known that packet communication dominates the power consumption in wireless sensor network. Therefore, it is very desirable to reduce the amount of packet transmission as much as possible. Thus, recently researchers have been emphasizing on how wireless sensor networks can get benefits from network coding. Network coding can achieve this by improving network throughput. This paper studies network coding as power minimization technique, which is a new research area that may have interesting applications in practical networking systems. With network coding, intermediate nodes may send out packets that are linear combinations of previously received information. Thus network coding reduces the power consumption by minimizing the number of transmissions required to communicate a given amount of information across the network. This paper explains what is network coding and the benefits of network coding. Evaluation results indicate that the proposed solution is 35% more energy efficient than no-network coding solution while still meeting required lifetime constraints.**

***IndexTerms*—Wireless sensor network, network coding, power minimization.**

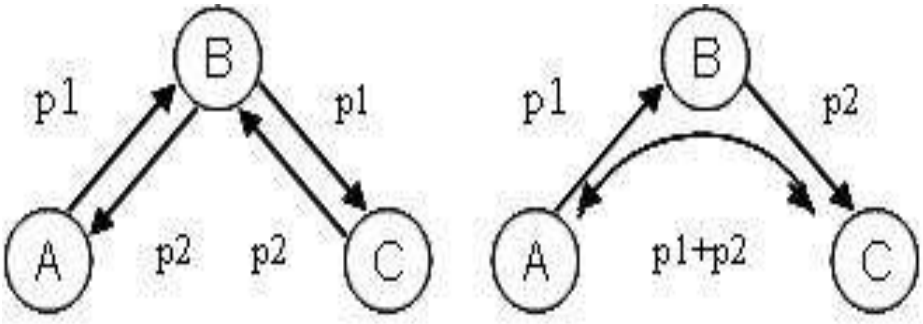
I. INTRODUCTION

Communication networks today share the same fundamental principle of operation. Whether it is packets over the Internet, or signals in a phone network, information is transported in the same way as cars share a highway or fluids share pipes. That is, independent data streams may share network resources, but the Information itself is separate. Routing, data storage, error control, and generally all network functions are based on this assumption. Network coding is a recent field in information theory that breaks with this assumption. Instead of simply for-warding data, nodes may recombine several input packets into one or several output packets. A promising generalization of routing is network coding. The potential advantages of network coding over routing include resource (e.g., bandwidth and power) efficiency, computational efficiency, and robustness to network dynamics. Network coding is also very well suited for environments where only partial or uncertain information is available for decision making. Similar to erasure coding, successful reception of information does not depend on receiving specific packet content but rather on receiving a sufficient number of independent packets. We will show that network coding, a technique originally introduced to maximize throughput, can be used as a technique to save energy by minimizing the number of transmissions needed to deliver a set of packets.

The rest of the paper is organized as follows. We first briefly describe network coding and its benefits in Section 2. Section 3describes the network coding applied for circular and grid networks. Power minimization using network coding in Section 4.Section 5 describes the improvement in lifetime. Finally, we conclude the paper in Section 6 , future work in Section 7 and references in Section 8.

II. NETWORK CODING AND ITS BENEFITS

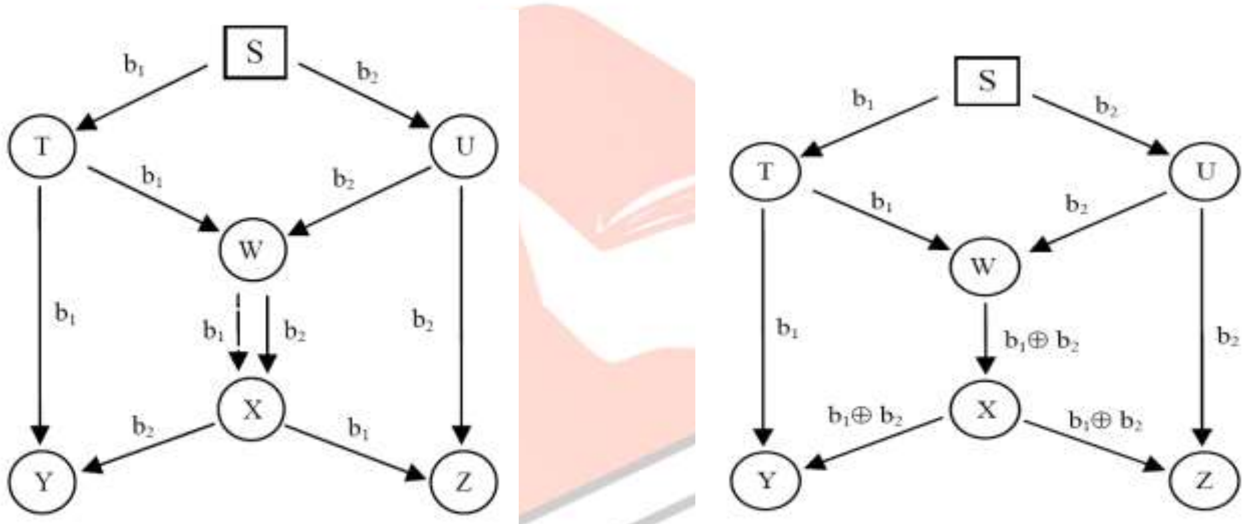
The basic idea of network coding is illustrated in Fig. 1where nodes A, B and C share the common wireless medium. Consider a scenario where nodes A and C has information to exchange. Due to the channel constraints only one node can transmit at any given time. Node A sends its packet (p1) to relay node B. Node B forwards this packet to node C. Similarly, node C sends its packet (p2) to node B which in turn forwards it to node A as shown in the Fig.1.This involves a total of four transmissions. Now consider the scenario where network coding is applied to reduce the number of transmissions.



[Fig. 1. (a) No coding (b) Network coding.]

Nodes A and C transmit packets to central node B sequentially (two transmissions). Node B, instead of directly forwarding each packet to its destination, XOR'sthe two packets and broadcasts the result as a single packet in the shared medium as shown in the figure. Both nodes A and C know their own packet (p1 and p2, respectively) that originated from them. They can therefore retrieve the unknown packet by XOR ing the known packet with broadcast packet.

For example, node A on receivingp1 $\oplus$ p2 performs the operation p1 $\oplus$(p1 $\oplus$ p2) to obtain p2.Similarly, node C retrieves packet p1.This entire process takes exactly three transmissions as opposed to four transmissions as discussed above. In a simplistic model this technique will result in 25% less energy consumption.



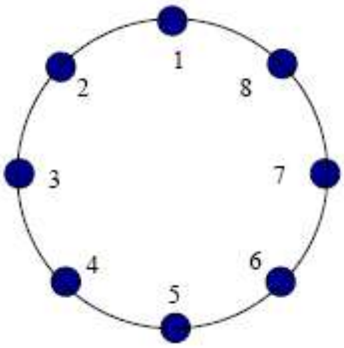
[Fig. 2. Multicasting over communication networka) Without network coding b) with network coding.]

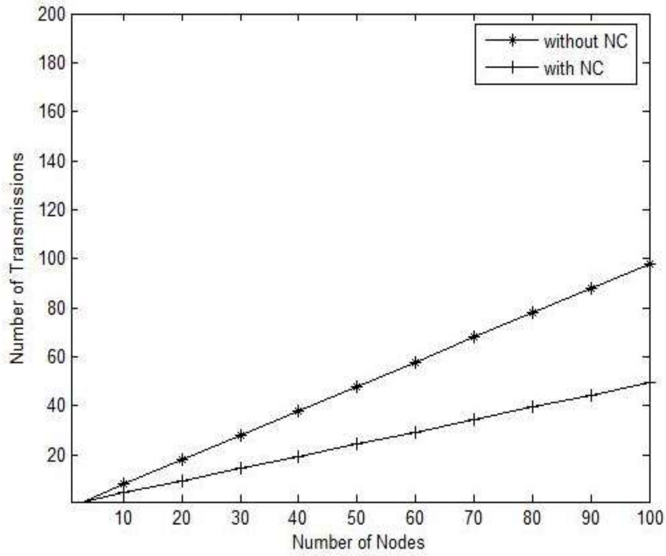
In Fig.2(a) every channel carries either the bit b1 or the bit b2 as indicated. Fig.2(b) depicts different way to multicast two bits from the source node S to Y and Z. In this way, all the 9 channels in the network are used exactly once. If the same communication objective is to be achieved simply by bit replication at theIntermediate nodes without coding, at least one channel in the network must be used twice so that the total number of channel usage would be at least 10. Thus, coding offers the potential advantage of minimizing both latency and energy consumption, and at the same time maximizing the bit rate.

III. NETWORK CODING APPLIED FOR CIRCULARAND GRID NETWORKS

a) CIRCULAR NETWORKS

Assume that each node can successfully broadcast information to its two neighbors as depicted in Fig.3(a)It has been analyzed earlier as in [3] that without network coding it needs n-2 transmissions and with network coding it needs only n-1/2 transmissions which is shown in the Fig.3(b).

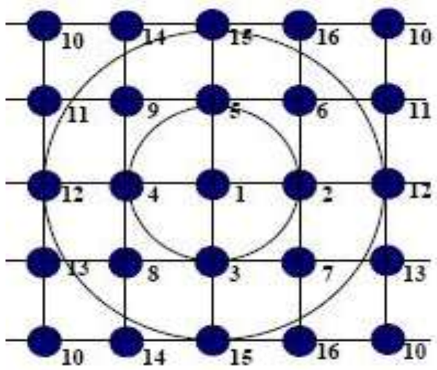


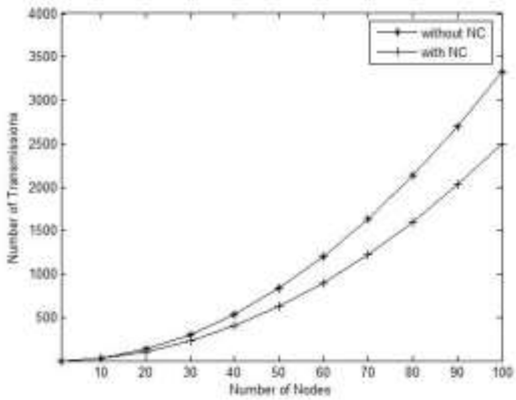


[Fig. 3(a) Circular Configuration.]
[Fig.3 (b) Average number of transmissions for various nodes in circular network with and without network coding as in [3].]

b) GRID NETWORKS

Consider a wireless ad-hoc network with n nodes. Let n =m2. Assume that every node is a source that wants to broadcast information to all n nodes. The nodes are placed on the vertices of a rectangular grid and each node can successfully broadcast information to its four nearest neighbors as shown in Fig .4(a).It has been analyzed earlier as in [3] that without network coding it needs n2/3 transmissions and with network coding it needs only n2/4 transmissions as shown in Fig .4(b).





[Fig. 4(a) Grid Network.]
[Fig. 4(b) Average number of transmissions forvarious nodes in grid network with and without network coding[3]]

IV. POWER MINIMIZATION USING NETWORK CODING

The average power consumed by the radio is modelled as in [6],

Pradio=Ntx[Ptx(Ton-tx+Tst)+Pout Ton-tx]+Nrx[Prx(Ton-rx+Tst)] (1)

where Ntx/rx is the average number of times per second that the transmitter/receiver is active; Ptx/rx is the power consumed by the transmitter/receiver; Pout is the output transmit power; Tst is the transceiver start up time; and Ton-tx/on-rx is the actual data transmitting/receiving time equal to L/R, where L is the packet length in bits and R is the data rate in bits per second.

V. IMPROVEMENT IN LIFETIME

The network life time has been referred to as the fraction of surviving nodes in the network. Every node in the network can be taken to have initial battery power Pbattery. For a given data rate Rb is the time taken to transmit one packet is L/Rb. So to transmit one packet the total amount of power required would be written as in [4],

$$P_{packet} = P_t . L / R_b(2) \qquad (2)$$

Since nodes transmit packets with average rate Pt average power depleted per second is Pt. Ppacket. So finally the total time taken for the battery power to be exhausted can be written as:

$$\tau = P_{battery} R_b / \lambda_\tau LP_t (3)(3)$$

where τ is the lifetime of the node in seconds, Rb is the data rate. L is the packet length which is taken as 1000bits. □□ is the packet arrival rate given as 0.5packet/second and Pt is the transmitted power.However if the node participates in network coding then the remaining power of that node after coding will be more than the node which does not participates in network coding. This justifies that whenever network coding is applied then it can reduce the power consumption of the node since the number of transmissions required is reduced and hence it improves the lifetime of the same node.

VI. CONCLUSION

In this paper we showed that network coding, a technique originallyintroduced to maximize throughput, can be used as a technique to save energy by minimizing the number of transmissions needed in a wireless network to deliver a packet. This work indicates that there is a potential for significant benefits, when deploying network coding over a practical wireless network environment.

VII. FUTURE WORK

In future researchers tend to devise the trade-off between selecting shortest paths where network coding can be used and network lifetime, which is adversely effected when aggressive use of this technique creates hot spots where nodes die quickly disconnecting the network. Though selecting shortest path is not considered in this paper which is more advantageous.

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