Efficient Scheme for Data Transfer Using XOR Network Coding

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Abstract— Compromised senders and pollution attacks are the key issues in designing and operating in any network either it is a wired or wireless (especially in applications like sensor networks, lossy wireless networks etc.) XOR network coding, an extension of Network coding is a new research area in information theory. It is a paradigm in which intermediate nodes are allowed to create new packets by combining (XORing) the incoming packets which provides the possibility to maximize network throughput and reduce number of transmissions. This paper explains the basic concept of network coding and XOR network coding, their applications and related challenges

Keywords— Network coding, XOR network coding, wireless sensor network, pollution attacks.

INTRODUCTION

Today's communication networks have the same operating principle as the data packets travelling over the internet, signals over the mobile network, vehicle share the traffic highways in which resources used are same but information is different to individual.

In classical approach, information stream can be sent by breaking in data packets in a store-And-forward manner in which intermediate nodes (router or relays) will duplicate the original message. With network coding (NC) intermediate nodes are allowed to combine incoming packets with the help of opportunistic coding. Network coding is a generalization of routing and well suited for the environments where the possibility of partial and uncertain information is high.

The remainder of paper is organized as follows: In section 2, we briefly describe the concept of XOR network coding and the related work done. In section 3, we describe applications of XOR network coding such as throughput gain, packet latency etc. In section 4, major issues and related approaches are described. In section 5 descriptions of various open challenges are given. In section 6, we presents conclusion of this paper.

I. OVERVIEW

A. XOR Network Coding

In XOR network coding, intermediate nodes are allowed to combine the incoming packets by applying the XOR operation not the linear combination. The basic idea of XOR network coding is illustrated in Fig 1 where nodes A,B and C share the common wireless medium as described by Ahlswede et al. [1]. Assume the capacity of network is 1 bit at a time. Due to capacity constraint, in fig 1(a) node A will transmit data packet p1 to B which in turn transmit to node C. Similarly, node C will transmit data packet p2 to B which in turn transmits p2 to node A. This whole process involves four transmissions.

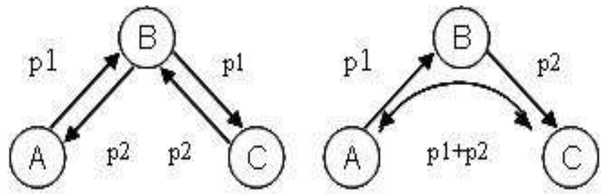

Fig. 1.(a) No coding (b) Network coding.

Now, consider fig1 (b) nodes A and C can transmit data packets p1 and p2 sequentially to node B which in turn combine two packets by XORing and transmit it on the shared medium. As, both nodes A and C know their own packets hence can easily detect another packet by XORing the known packet with broadcast packet. This whole process takes three transmissions. Number os transmissions used to send same amount of information is reduced resulting in 25% less energy consumption [2].

B. Related Work

Recently, network coding has gained much popularity as a potential way to increase the throughput in networking field. Zunnun and Sanjay [2], showed better performance in wired, wireless networks, multicast and broadcast protocols.

Network coding was first considered in the pioneering work by Alswede et al [1], which showed that a sender can communicate information to set of receivers at the broadcast capacity by using network coding resulting in capacity gain in wire line systems. Alswede's example which is generally considered as butterfly network is shown in fig2 is a multicast network from a single source to two destinations.

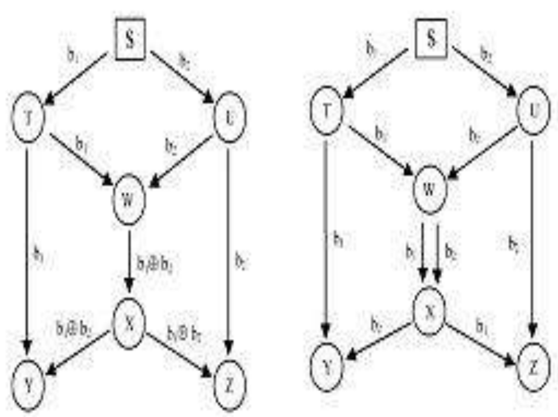

Fig..2 Multicast over communication network.

(a) Network coding (b) No coding

Source S, multicast two data bits b1 and b2 to nodes Y and Z by acyclic graph as shown in fig(2). In fig.2(b), one channel is used twice so that minimum usage at least 10. Now, in fig.2 (a) depicts network coding approach in which all the 9 channels are used exactly once. Later Li et al [3], showed that linear codes are sufficient for multicast traffic to achieve optimal throughput.

At the same time, Koetter and Medard [4] developed an algebraic framework and showed that coding and decoding can be done in polynomial time. Ho et al [5] used algebraic framework to present concept of random linear network coding, which makes network coding more practical especially in wireless networks.

Recently network coding has been applied to wireless networks and received a significant attention for research as means of improving network capacity and coping with unreliable wireless links [6]. Majid et al [7] presented reliability gain of network coding in lossy wireless networks. Work on improving throughput of wireless networks by using XOR network coding [8] showed a practical application and showed high benefits.

C. Grid Networks

Consider a wireless ad hoc network with n nodes. Each node is placed on the vertices of a rectangular grid. Suppose each node wants to broadcast the information to all other nodes. For this purpose, each node will transmit the information to their four neighbors as shown in fig 3.

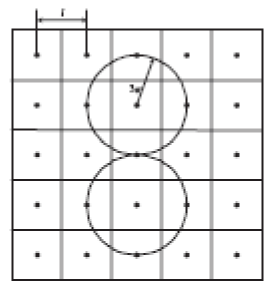

Fig 3 Square grid

II. APPLICATIONS

Main applications of network coding technique are in the area of content-distribution networks, peer-to-peer networks and wireless networks. Most of the work has been done to show the capacity gain and throughput but recently reliability gain is also a good consideration in research area [7].

A. Throughput

The capacity gain in wired and wireless networks has made a spark for researchers in multicast networks. Suppose we have X sources and Y receivers. Each source wants to send information to other at a given rate. All Y receivers are interested to receive the information and share the common resources. This, XOR network coding can help to make better throughput and to better sharing of resources.

Throughput gain [8] can be defined as:

$$Gain = \frac{T_w}{T_{wo}}$$

Where, T_w and T_{wo} are the throughput of network with and without network coding.

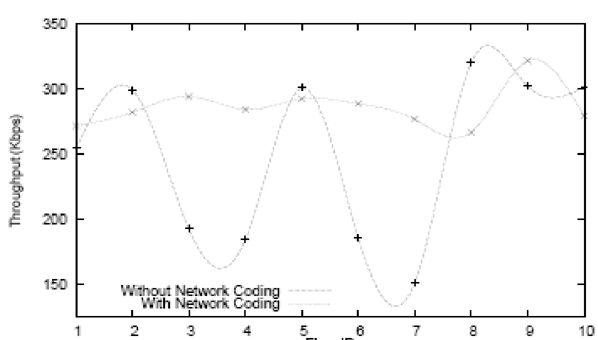

Fig.4 Throughput variations with and without network coding [8]

B. Mean Latency and standard Deviation

One of the important concerns of performance evaluation in XOR networks is mean packet latency that coding and decoding introduce. Amount of data to be aware of and processed by each node will increase with the increase of buffer size and producing high decoding delay. And also if buffer size is not sufficiently large the node will in information required to perform coding. Borislava et al. [9] presented packet latency aad standard deviation for XOR networks applied over 36 nodes. The results are shown in fig 5 for both butterfly ang grid networks (described in section 2).

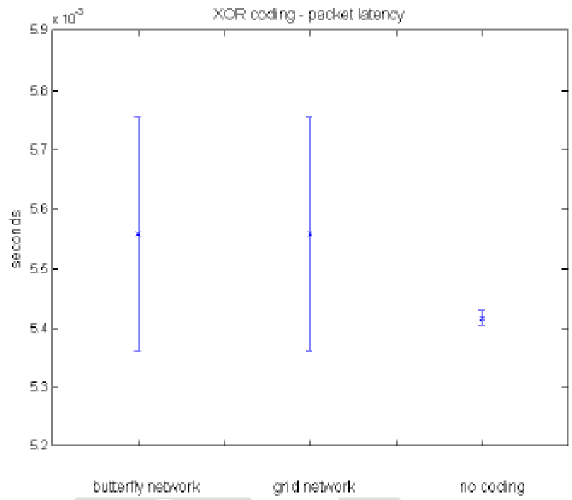

Fig.5 Mean latency and standard deviation for XOR coding (butterfly and grid networks) and no coding [9]

Mean latency and standard deviation is also dependent upon the channel parameters like data rate, delay etc. for fixed channel delay added by XOR coding decreases with increase in transmission rate [9] as shown in fig.6.

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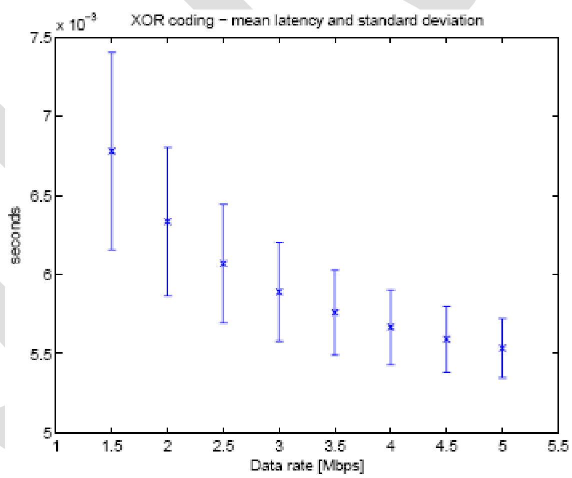

Fig.6 Mean latency and deviation for XOR coding over different data rates [9]

III. MAJOR ISSUES

In this paper we focus on challenges of XOR network coding in field of wireless networks.

A. Attacks

XOR network coding technique poses various new challenges in security system e.g. applications developed using this technique are vulnerable to *pollution attacks*
in which forged senders can pollute the data packets and also generate forged packets. These attacks not only prevent the sinks from recovering the source messages but also drain out the energy of forwarders. A more severe problem is pollution propagation on network. Therefore, polluted messages should be filtered as soon as possible.
Big threat of attacks is present in resource constrained networks such as wireless sensor networks, in which sensor nodes are equipped with limited computation capacity, restricted memory space, limited power resources etc.
Another challenge also appeared when sensor nodes are deployed in hostile environment like Military applications. In hostile environment, sensor nodes are vulnerable to be captured and compromised by the adversary one. Thus an adversary can inject false data in original stream resulting in *false data injection attacks.*

B. Approaches

Traditional approaches like RSA or MD5 based on hash functions are not suitable for network coding because encoding process carried out by each forwarder can destroy source's signatures.
Chrtos and Pablo introduced a cooperative security approach [10], in which users not only cooperate to distribute contents but to inform each other about malicious blocks also. Zhen et al. presented a signature based scheme [11] to detect and filter pollution attacks for applications using network coding. Ho et al. [12] proposed a simple polynomial hash function to detect pollution attacks. Jaggi et al. [13] presented polynomial time network coding algorithm for multicast network against pollution attacks.
These algorithms can be divided into two groups [14]: 1) Filtering the polluted messages at forwarders and sinks, such as [10]. [11]. 2) Filtering the polluted messages at sinks, such as [12], [13].
Several existing algorithms for filtering false data reports either cannot deal with the dynamic topology or have limited filtering capacity. Zhen and Yong [15] used Hiil Climbing approach to filter false data injection attacks in wireless sensor networks.

C. Approach for XOR network coding

The schemes described in part B can protect only normal network coding but none of them is able to secure XOR networks. Zhen et al. [14] presented an efficient scheme to secure XOR networks by using probabilistic pre key distribution and message authentication codes (MACs).

IV. OPEN CHALLENGES

Much work has been done on designing in various coding algorithms (for XOR network coding also) but most of them has not been practically implemented to show the real gain of net throughput of algorithms should be investigated.
In flooding mechanisms, draining out the particular packet after being flooded is a challenging issue. It is even more difficult in XOR networks where it can be a part of various encoded packets (unintentionally).
Also, work has been done by assuming that source will cooperate in network without being compromised. As [14] also assumed that forwarders can be compromised but sources can never be compromised. In future, work should be done to detect the compromised senders and protect network against them.

V. CONCLUSION

In this paper, we have presented a basic idea of network coding while focusing on XOR network coding. Applications of XOR networks are described on account of throughput, mean latency and standard deviation. In addition, major issues are open challenges are described.

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