International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-1 Issue-6, August 2012

Power of Network Stochasticity

Parimal Kumar Giri, Akshaya Kumar Behera

Abstract—Network coding protocol that allows intermediate nodes, not only to XORs packets together, but also to broadcast coded packets. The COPE system architecture is implementing between IP and MAC layers, which identifies coding opportunities and benefits from them by forwarding multiple packets in a single transmission using XORs. Our work is based on the theory of network coding, which allows the routers to mix the information content in the packets before forwarding them. Prior work on network coding is mainly theoretical and focuses on multicast traffic.

Index Terms— Coded packets; Network coding; COPE; Opportunistic listening; Opportunistic coding

I. INTRODUCTION

A. Network Coding

Network stochasticity comprises basic introduction to the network coding. Research on network coding started with a pioneering in [1]. One of the initial network coding systems, COPE for different types of networks, introduced in [2, 3]. It is a basic network architecture which allows Opportunistic listening and Opportunistic coding.

In [4]–[8] for prior work on network coding is a new transmission paradigm that proved its strength in optimizing the usage of network resources. Network coding can significantly improve the efficiency of network protocols by requiring intermediate nodes to mix packets before forwarding them to receiving nodes.

B. COPE system

COPE is a new broadcast based coding architecture for unicasts in wireless mesh networks that employs opportunistic network coding to improve total throughput. Researchers proposed new coded wireless network systems based on the idea of COPE. Dong et al. [9] proposed loop coding, which allows receivers to temporarily store coded packets for future decoding. Omiwade et al. [10] proposed BFLY, a localized network coding protocol that allows intermediate nodes not only to XOR packets together (as in COPE), but also to forward coded packets. Chaporkar et al. [11] presented a joint network coding and scheduling schemes to optimize network throughput.

The concept behind network coding is that instead of transmitting packets separately and independently, a sender transmits a linear combination of k packets, where k is the number of packets. After receiving k packets with all linearly independent coefficients, the receiver can then decode and recover the contents of the original packet. Network coding is beneficial when packets are transmitted through multiple paths; more specifically, nodes receive packets from multiple intermediate nodes. Since all packets are coded to contain a linear combination of k packets, the receivers can then decode and recover the original content from any of k linearly independent packets.

The rest of this paper is organized as follows. In section II we discuss the basic idea of COPE. Section III basically COPE's different techniques, section IV introduce design principle and section V provide pseudo broadcast nature and VI introduce architecture of COPE. Finally concluding section and future scope is in section VII and VIII.

II. BASIC IDEA OF COPE

In this section we represent the working procedure of COPE. To give the readers to feel for how COPE works, we start with a fairly simple scenario in Figure 1. Here network coding is allowed in the router R, after R has received the two packets from Alice and Bob, it can XORs the two packets together and broadcast this new packet. When Alice and Bob receive the XOR-ed packet, they can obtain each other's packet by XOR-ing again with their own packet. In this way, we utilize the broadcast nature of the medium and save one transmission, which can be used to send additional data, and increasing the optimum network throughput with larger bandwidth saving [2, 3].

COPE exploits the shared nature of the wireless medium which broadcasts each packet in a small neighborhood around its path [2]. Each node stores the overheard packets for a short time. It also tells its neighbors which packets it has heard by annotating the packets it sends. When a node transmits a packet, it uses its knowledge of what its neighbors have heard to perform opportunistic coding; the node XORs multiple packets and transmits them as a single packet if each intended next hop has enough information to decode the encoded packet.

In wireless, routing protocols compute the delivery probability and assigns each link as weight equal to 1/(delivery probability) between every pair of nodes and use it to identify good paths. These weights are broadcast to all nodes in the network and used by a link-state routing protocol to compute shortest paths.

A. COPE Design

COPE employs network coding. Our work is based on the theory of network coding, which allows the routers to mix the information content in the packets before forwarding them. Prior work on network coding is mainly theoretical and focuses on multicast traffic [2].

In [2, 3], authors proposed prior work on network coding in three main ways:

Manuscript published on 30 August 2012.
***** Correspondence Author (s)
Parimal Kumar Giri*, Department of Computer Science and Engineering APEX Institute of Technology & Management Bhubaneswar, India.
Akshaya Kumar Behera, Department of Computer Science and Engineering APEX Institute of Technology & Management Bhubaneswar, India.

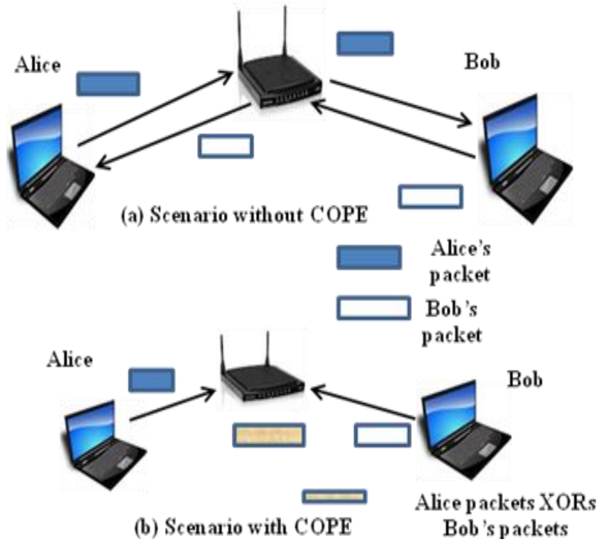

Figure 1. A simplified illustration of network coding, showing how network coding saves bandwidth consumption. It shows Alice and Bob to exchange a pair of packets using 3 transmissions instead of 4.

- The paper presents the first system architecture for wireless network coding. It articulates a full fledged design that integrates seamlessly into the current network stack, works with both TCP and UDP flows, and runs real applications.
- The implementation is deployed on a 20-node wireless test bed, creating the first deployment of network coding in a wireless network.
- They study the performance of COPE, and reveal its interactions with the wireless channel, routing, and higher layer protocols.

B. Packet Coding

In [2], authors suggested that, to build the coding scheme, we have to make a few design decisions. First, we design our coding scheme around the principle of never delaying packets. When the wireless channel is available, the node takes the packet at the head of its output queue, checks which other packets in the queue may be encoded with this packet, XORs those packets together, and broadcasts the XOR-ed version. Second, COPE gives preference to XOR-ing packets of similar lengths, because XOR-ing small packets with larger ones reduces throughput.

We only need to consider packets headed to different next hops. It therefore maintains two virtual queues per neighbor; one for small packets and another for large packets. Searching for appropriate packets to code is efficient due to the maintenance of virtual queues. Depending on the size, it looks at the appropriate virtual queues.

Another concern is packet reordering. We would like to limit reordering packets from the same flow because TCP mistakes it as a congestion signal. Thus, we always consider packets according to their order in the output queue

C. Packet Decoding

Packet decoding is simple. Each node maintains a Packet Pool, in which it keeps a copy of each native packet it has received or sent out. The packets are stored in a hash table keyed on packet id and the table is garbage collected every few seconds.

III. COPE TECHNIQUES

There are three types of COPE Techniques.

A. Opportunistic Listening

Wireless is a broadcast medium, creating many opportunities for nodes to overhear packets when they are equipped with Omni-directional antennae. COPE sets the nodes in promiscuous mode, makes them snoop on all communications over the wireless medium and store the overheard packets for a limited period time T (the default value is T = 0.5s).

In addition, each node broadcasts reception reports to tell its neighbors which packets it has stored. Reception reports are sent by annotating the data packets the node transmits.

B. Opportunistic Coding

A node may have multiple options, but it should aim to maximize the number of native packets delivered in a single transmission, while ensuring that each intended next hop has enough information to decode its native packet.

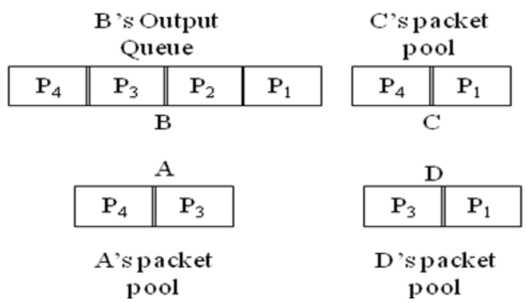

Figure 2. B can code packets it wants to send

In Fig. 2 node B has four packets in its output queue p1, p2, p3 and p4. Its neighbours have overheard some of these packets. Fig. 3 shows the next hop of each packet in B's queue. When the MAC permits B to transmit, B takes packet p1 from the head of the queue. Assuming that B knows which packets each neighbor has, it has a few coding options as shown in Fig. 3.

It could send $p_1 \oplus p_2$. Since node C has p_2 is store, it could XOR p_1 with $p_1 \oplus p_2$ to obtain the native packet sent to it, i.e., p_2.

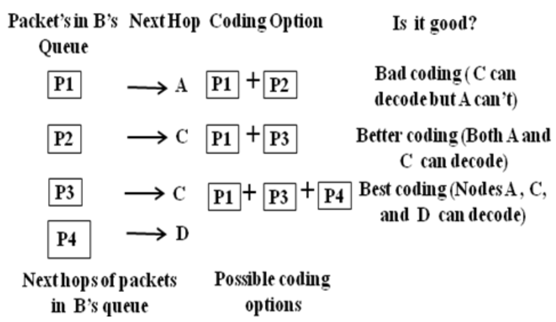

Figure 3. Next hops of packets in B's queue

However, node A does not have p_2, and so cannot decode the XOR-ed packet. Thus, sending $p_1 \oplus p_2$ would be a bad coding decision for B, because only one neighbor can benefit from this transmission. The second option in Figure 3 shows a better coding decision for B.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

Sending $p_1 \oplus p_2$ would allow both neighbors C and A to decode and obtain their intended packets from a single transmission. Yet the best coding decision for B would be to send $p_1 \oplus p_2 \oplus p_4$, which would allow all three neighbors to receive their respective packets all at once.

The coding algorithm should ensure that all next hops of an encoded packet can decode their corresponding native packets. This can be achieved using the following simple rule:

To transmit n packets, $p_1, p_2, ..., p_n$, to n next hops, $r_1, ..., r_m$, a node can XOR the n packets together only if each next hop r_i has all (n–1) packets p_j for j = i. This rule ensures that each next hop can decode the XOR-ed version to extract its native packet. Whenever a node has a chance to transmit a packet, it chooses the largest n that satisfies the above rule to maximize the benefit of coding.

C. Learning Neighbor State

As explained earlier, each node announces to its neighbors the packets it stores in reception reports. However, at times of severe congestion, reception reports may get lost in collisions, while at times of light traffic, they may arrive too late, after the node has already made a suboptimal coding decision [13, 14]. Therefore, a node cannot rely solely on reception reports, and may need to guess whether a neighbor has a particular packet.

IV. COPE'S GAINS

A. XOR-ing GAIN

In [2,3], defined the coding gain as the ratio of the number of transmissions required by the current non-coding approach, to the minimum number of transmissions used by COPE to deliver the same set of packets. As per the Alice-and-Bob experiment, COPE reduces the number of transmissions from 4 to 3, thus producing a coding gain of 4/3=1.33.

B. Coding + MAC GAIN

The Coding+MAC gain is best explained using the Alice-and-Bob scenario. Because it tries to be fair, the MAC divides the bandwidth equally between the 3 contending nodes: Alice, Bob, and the router.

COPE allows the bottleneck router to XOR pairs of packets and drain them twice as fast, doubling the throughput of this network. Thus, the Coding+MAC gain of the Alice-and-Bob topology is 2 [2, 3]. For topologies with a single bottleneck, like the Alice-and-Bob's, the Coding+MAC gain is the ratio of the bottleneck's draining rate with COPE to its draining rate without COPE [12,13].

V. PSEUDO BROADCASTS

In [14], 802.11 MAC has two modes: unicast and pseudo broadcast. Since COPE broadcasts encoded packets to their next hops, the natural approach would be to use broadcast. Unfortunately, this does not work because of two reasons: poor reliability and lack of back off. In standard 802.11 unicast mode, packets are immediately ack-ed by their intended next hops. The 802.11 protocol ensures reliability by retransmitting the packet at the MAC layer for a fixed number of times until a synchronous acknowledgement is received [15, 16].

As all packets are sent using 802.11 unicast, the MAC can detect collisions and back off properly [15].Encoded packets require all next hops to acknowledge the receipt of the associated native packet for two reasons. First, encoded packets are headed to multiple next hops, but the sender gets synchronous MAC-layer acks only from the next hop that is set as the link layer destination of the packet.

COPE resolves the problem using local retransmissions. In this process the sender expects the next-hops of an XOR-ed packet to decode the XOR-ed packet and it obtain their native packet, and ack it. If any of the native packets is not ack-ed within a certain interval, the packet is retransmitted and potentially encoded with another set of native packets.

VI. ARCHITECTURE OF COPE

COPE adds special packet headers and alters the control flow of the router to code and decode packets. On the sending side, whenever the MAC signals an opportunity to send, the node takes the packet at the head of its output queue and hands it to the coding module. If the node can encode multiple native packets in a single XOR-ed version, it has to schedule asynchronous retransmissions. Either way, before the packet can leave the node, pending reception reports and acks are added.

On the receiving side, when a packet arrives, the node extracts any acks sent by this neighbor to the node. It also extracts all reception reports and updates its view of what packets its neighbor stores. Further processing depends on whether the packet is intended for the node. If the node is not a next hop for the packet, the packet is stored in the Packet Pool. If the node is a next hop, it then checks if the packet is encoded. If it is, the node tries to decode by XOR-ing the encoded packet with the native packets it stores in its Packet Pool [17].

After decoding it acks this reception to the previous shop and stores the decoded packet in the Packet Pool. The node checks if it is the ultimate destination of the packet, if so it hands the packet off to the higher layers of the network stack. If the node is an intermediate hop, it pushes the packet to the output queue. If the received packet is not encoded, the packet is simply stored in the Packet Pool and processed in the same fashion as a decoded packet.

VII. DISCUSSION AND CONCLUSION

Finally, we would like to comment on the scope of COPE. The present design targets stationary wireless mesh networks, where the nodes are not resource-constrained. More generally, COPE can be used in multi-hop wireless networks that satisfy the following.

A. Memory

COPE's nodes need to store recently heard packets for future decoding. Only packets in flight are used in coding & there is no need to store packets that have already reached their destination.

B. Power requirements

COPE does not optimize power usage and assumes the nodes are not energy limited.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

VIII. FUTURE SCOPE

COPE would allow cellular relays to use the bandwidth more efficiently. This scheme can be extended to make full usage of the ideas embedded in COPE. We believe that COPE is an important step forward in our understanding of the potential of wireless networks [18] because it presents a new orthogonal axis that can be manipulated to extract more throughputs. Thus, COPE can be integrated with forwarding, routing, and reliable delivery.

Here we discussed the concept of static networks. But, in many wireless networks, conditions change for network coding in dynamic environments may lead to dynamic programming approaches that naturally extend the static optimization techniques. In [19] indicate that some predictive information regarding movement or traffic trends, adjust our optimization to account in balanced fashion for both current and future network states and demands have discussed.

In future the COPE routing technique will implement on speckled network and Biogeography Based Optimization (BBO) for optimum network throughput to join network coding and scheduling schemes.

REFERENCES

[1] R. Ahlswede, N. Cai, S.-Y. R. Li, and R. W. Yeung, "Network information flow," IEEE Trans. Inf. Theory, vol. 46, no. 4, pp. 1204–1216, July 2000.

[2] S. Katti, H. Rahul, W. Hu, D. Katabi, M. Medard, and J. Crowcroft, "Xors in the air: practical wireless network coding," in Proc. ACM SIGCOMM '06,September 11-15,2006,Pisa,Italy.

[3] S. Katti, D. Katabi, W. Hu, H. Rahul, and M. Medard, "The importance of being opportunistic: practical network coding for wireless environments," in Proc. October 2005 [Annual Allerton 43rd Conf. on Communication Control and Computing].

[4] P. A. Chou, Y. Wu, and K. Jain," Practical network coding," In Proc. of Allerton, Monticello, IL, USA, September 2003.

[5] Y.Wu, P. A. Chou, and S. Y. Kung," Information Exchange in Wireless Networks with Network Coding and Physical-layer Broadcast ," MSR-TR-2004-78.

[6] T. Ho and R. Koetter.,"Online incremental network coding for multiple unicasts," In DIMACS Working Group on Network Coding, 2005.

[7] D. S. J. De Couto, D. Aguayo, J. Bicket, and R. Morris," A high-throughput pathmetric for multi-hop wireless routing," In ACM MobiCom '03, San Diego,California, September 2003.

[8] S. Deb, M. Effros, T. Ho, D. R. Karger, R. Koetter, D. S.Lun., M. Medard, and N. Ratnakar," Network coding for wireless applications: A brief tutorial," In Proc. of IWWAN,London, UK, May 2005.

[9] Q. Dong, J. Wu, W. Hu, and J. Crowcroft, "Practical network coding in wireless networks," in Proc. the 13th Annual International Conference on Mobile Computing and Networking (MobiCom '07), Sept. 2007.

[10] S. Omiwade, R. Zheng, and C. Hua, "Practical localized network coding in wireless mesh networks," in Proc. 5th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks (SECON '08), June 2008.

[11] P. Chaporkar and A. Proutiere, "Adaptive network coding and scheduling for maximizing throughput in wireless networks," in Proc. the 13th Annual International Conference on Mobile Computing and Networking (MobiCom '07), Sept. 2007.

[12] C. Gkantsidis and P. Rodriguez," Network coding for large scale content distribution," In Proc. of INFOCOM, Miami,USA, March 2005.

[13] Fang Zhao, and M. Medard,"On analyzing and improving COPE performance," Information Theory and Applications Workshop (ITA), 2010.pp. 1-6. ©2010 Institute of Electrical and Electronics Engineers.

[14] S. Sengupta, S. Rayanchu, and S. Banerjee, "An analysis of wireless network coding for unicast sessions: the case for coding-aware routing,"in Proc. IEEE Infocom, May 2007.

[15] C. cheng Chen, E. Seo, H. Kim, and H. Luo," Self-learning collision avoidance for wireless networks," In Proceedings of IEEE INFOCOM, 2006.

[16] D. Aguayo, J. Bicket, S. Biswas, G. Judd, and R. Morris, "Link-level measurements from an 802.11b mesh network," In ACM SIGCOMM, 2004.

[17] D. S. Lun, M. M´ edard, R. Koetter, and M. Effros," Further results on coding for eliable communication over packet networks," In IEEE International Symposium on Information Theory, (ISIT 05), 2005.

[18] J. Le, J. Lui, and D. M. Chiu, "How many packets can we encode? – an analysis of practical wireless network coding," in Proc. IEEE Infocom, April 2008.

[19] D. S. Lun, N. Ratnakar, M. M´edard, R. Koetter, D. R. Karger, T. Ho, and E. Ahmed, "Minimum-cost multicast over coded packet networks,"submitted to IEEE Trans. Inform. Theory.

Parimal Kumar Giri is an Assistant Professor Department of Computer Science & Engineering at Apex Institute of Technology & Management, Bhubaneswar, India. He received his M.Tech degree from utkal University, Bhubaneswar in 2002 and pursuing Ph. D in Computer Science at F. M. University, Vyasa Vihar, India. His research interests include Computer Networks, Soft Computing, Cryptography and Networks Security.

Akshaya Kumar Behera is an Assistant Professor Department of Computer Science & Engineering at Apex Institute of Technology & Management, Bhubaneswar, India. Previously he worked at Mahindra Satyam as Sr. Project Manager at Hyderabad. He received his M.Tech degree from Indian School of Mines, Dhanbad in 1998. His research interests include Computer Networks, Computer Architecture, Cryptography and Networks Security.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)