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Comparative Study of Network Coding Techniques in Wireless Network

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Abstract: Wireless network is now an interesting area of research. In this paper we are giving a comparative study of COPE and DCAR the two main network coding systems in wireless network; both give high throughput gain in wireless network. COPE mix packets from different sources to increase information content of each transmission. It takes into advantage the broadcast nature of wireless network. COPE is the first practical wireless network coding system. DCAR, the first distributed coding-aware routing mechanism can be seen as a variant of COPE. It in co-operate the features of COPE plus some extra features. This paper give the similarities, variations, advantages and disadvantages of both COPE and DCAR.

Keywords: network coding, ETX, CRM, routing

I. Introduction

Recently there has been a breakthrough in the field of communication in computer networks .Researchers made numerous studies to improve throughput, efficient bandwidth usage, less delay etc both in wired and wireless network techniques. But the channel interference in network is still a bottleneck in network communication. So a new method called network coding [1] is evolved.

The basic idea of network coding can be demonstrated using the Alice-and-Bob scenario [2] in Figure 1, where Alice wants to send packet P1 to Bob and Bob wants to send packet P2 to Alice. They rely on a relay in the middle to exchange packets. In the terminology of network coding, a non encoded original packet (such as P1 and P2) is referred to as a native packet. Network coding is about what packet(s) should the relay transmit, in order for the native packets to be obtained by their intended receiver(s).

Encode at relay The relay XORs P1 and P2 together (with padding if necessary) and broadcasts P1⊕P2, which we refer to as an *XOR packet*. Decode at receiver(s)**.**Upon receiving P1 ⊕ P2, Alice can decode P2 by P2 = P1 ⊕ (P1 ⊕ P2). Similarly, Bob can decode P1 by P1 = (P1 ⊕ P2) ⊕ P2. Thus, in order to relay P1 and P2 to their intended receiver, the relay only needs to transmit one packet (i.e., the XOR packet) instead of two (i.e., P1 and P2).

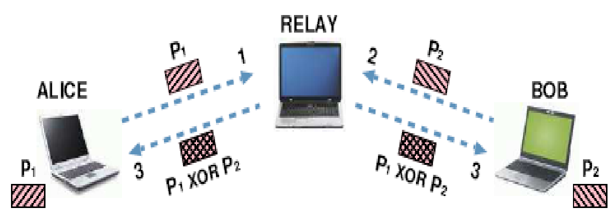

Fig.1: the basic alice and bob scenario with network coding

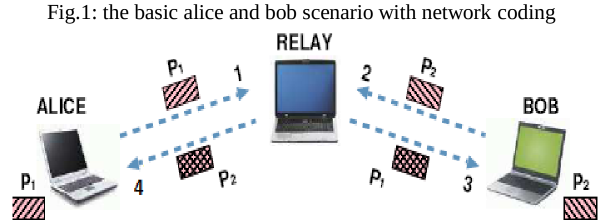

Fig.2: the basic alice and bob scenario without network coding

In conventional communication alice and bob sent P1 and p2 to relay and relay will send P1 and P2 independently to bob and alice. Fig.2 explains this scenario.

From this it is clear that the number of transmissions is reduced from 4 to 3 by using network coding in alice and bob scenario.

Now most advancement in network coding is done in the area of wireless network. So we are concentrating on wireless network here. Here we are discussing COPE and DCAR, network coding systems in wireless network. Latter is just proposed and the former is implemented

This paper is structured as follows: In section II we explains about COPE and section III contains DCAR.

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Section IV includes the comparative study. Section IV will conclude this paper.

II. COPE

COPE is the first practical network coding system for multihop wireless networks. Fig. 3 shows the basic scenarios of how COPE works. In Fig. 1a, there are five wireless nodes. Suppose node 1 wants to send a packet P1 to node 2 and this packet needs to be relayed by node C; and node 3 wants to send another packet P2 to node 4 Wherein node C also needs to relay this packet. The dashed arrows 1 ⇢ 4 and 3 ⇢ 2 indicate that 4, 2 are within the transmission ranges of 1, 3, respectively. Under this scenario, nodes 4 and 2 can perform "opportunistic overhearing": when 1(3) transmits P1 (P2) to node C, node 4 (2) can overhear the transmission. When node C forwards the packets, it only needs to broadcast one packet (P1 ⊕ P2) to both 4 and 2. Since 4 and 2 have already overheard the necessary packets, they can carry out the decoding by performing P2⊕ (P1⊕ P2) or P1⊕ (P1⊕ P2), respectively, thereby obtaining the intended packet. In this case, it is easy to see that there is a reduction in bandwidth consumption because node C can use network coding to reduce one transmission. It is interesting to point out that network coding can also be used when there is no opportunistic overhearing, and this scenario is illustrated in Fig. 3b. In this case, the source node 1 (2) needs to send a packet P1 (P2) to its destination node 2 (1). Since each source is also a destination node, it has the necessary packets for decoding upon receiving the encoded packet P1 ⊕ P2. Again, instead of four transmissions when network coding is not used, one only needs three transmissions and thereby reducing the bandwidth consumption.

So we can conclude that, COPE takes advantage of the "broadcast nature" of the wireless channel to perform "opportunistic overhearing" and "encoded broadcast" so that the number of necessary transmissions can be reduced.

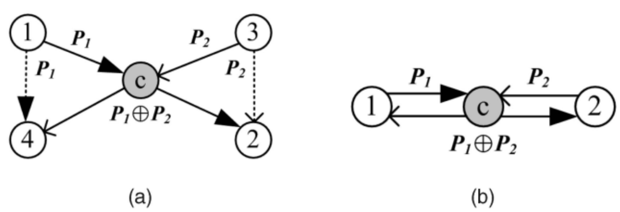

Figure. 3: Basic coding scenarios in COPE. (a) Coding scenario with opportunistic overhearing. (b) Coding scenario without opportunistic overhearing [5].

However, COPE has two fundamental limitations which we illustrate as follows: The first limitation is that whether network coding is possible (or we called the "coding opportunity") is crucially dependent on traffic pattern. In other words, network coding is possible only when there exists certain "coding structure" that is similar to the ones shown in Fig. 3. In COPE, network coding functions as a separate layer from the MAC and network layers. If one uses the shortest path routing, or some recently proposed ETX-like routing [8], [9], the potential coding opportunity may be significantly reduced. To illustrate, consider the example in Fig. 4 where there are two flows to be routed. Without consideration on potential coding opportunities, the disjoint paths shown in Fig. 4a may very likely be chosen. On the other hand, if we use a coding-aware routing decision as shown in Fig. 4b, node 3 has the opportunity to perform network coding. In this example, coding-aware routing will result in a higher end-to-end throughput for both flows if we employ network coding. But we know that in COPE, coding possibility is checked in already established paths. As in fig. 4a if route 1→3→2 and2→4→1 are already fixed no routing is possible. From this we can conclude that, in COPE coding opportunity depends on the routing protocols used.

The second limitation of COPE is that it limits the entire coding structure within a two-hop region. To illustrate, consider the example as depicted in Fig. 3a. COPE assumes that the transmitters for opportunistic overhearing (i.e., nodes 1 and 3) are the one-hop predecessors of node C, and that the intended receivers (i.e., nodes 4 and 2) are the one hop successors of node C. These assumptions may unnecessarily eliminate coding opportunities in a wireless network with flows that traverse longer than two hops.

COPE provides a general scheme for inter-session wireless network coding. It applies to any topology and an arbitrary number of bursty flows whose duration is not known a priori, and that arrive and leave dynamically. In contrast, prior work on inter-session network coding either focuses on duplex flows [6] or assumes known flow patterns with steady rates and ideal scheduling [7].

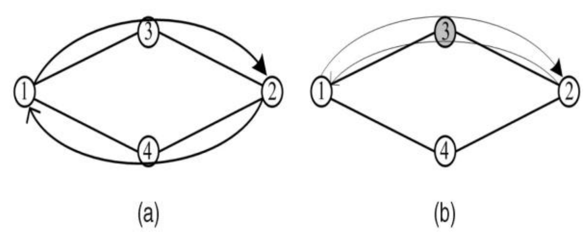

Fig. 4. Example: effect of routing decision on the potential coding opportunity.(a) Routing without coding consideration. (b) Routing with coding consideration at node 3 [5].

For a mesh network connected to the Internet via an access point, the throughput improvement observed with COPE varies depending on the ratio between total download and upload traffic traversing the access point, and ranges from 5% to 70%.

From the above scenarios the working of COPE can be given as follows:

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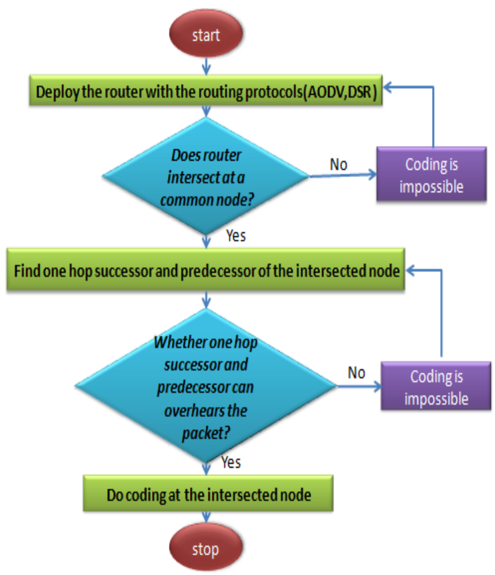

Fig 5. Working of COPE

III. DCAR

To overcome the limitations of COPE researchers proposed DCAR[5] which combine "coding + routing". Let us now describe how this happens in DCAR. Here detection of coding opportunity is based coding conditions. It can be given as follows:
For simplicity consider two flows say F1 and F2 intersect at an arbitrary node c. Then the coding condition can be given as

1. There exists d1 € D(c,F1) such that d1 € N(s2), s2 € U(c,F2), or d1 € U(c,F2).
2. There exists d2 € D(c,F2) such that d2 € N(s1), s1 € U(c,F1),or d2 €U(c,F1).

Where N(s2) denote the set of all one hop neighbors of s2.U(c,F2) denote the upstream nodes of c in the flow F2. D(c, F2) denote the downstream nodes of c in the flow F2.

Note that when we detect a path with coding opportunity (and we call this the coding-possible path), we do not impose the requirement that the new flow has to take this path as its routing outcome, instead, we have another module which will evaluate the benefit of each path and to make the final path selection.

For each node a in a wireless network, it maintains a list of all its one-hop neighbors and the packet loss probabilities of all its outgoing links. These information can be collected by periodically sending probing messages as in [10], or by estimating the loss probability based on previously transmitted traffic. When a new flow arrives to the wireless network, the source node of this new flow activates the coding + routing discovery process which has the following steps:

Step 1.The source node s initiates the route discovery. It broadcasting the Route Request (RREQ) message. The RREQ contains the informations such as One-hop neighbors of the source node. The threshold value can be predefined by the network designers or operators. Let's take that the threshold value greater than 0.7 will be sufficient.

Step 2.when an intermediate node say node c receives RREQ, it first checks whether the RREQ has already traversed through itself. If so, node discards the RREQ to prevent loop; otherwise, performs the following:

- Temporally storing the RREQ, which contains the "who-can-overhear" information for the new path. In other words, node c stores the list of overhearing nodes that can perform "opportunistic overhearing" when the upstream nodes transmit.

TABLE I

COMPRISON OF COPE & DCAR

COPE	**DCAR**
Coding structure is limited within two-hop region	Can detect coding opportunity on the entire path
Coding opportunity depends on established routes	Inco-operate coding within routing

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Routing metric involved	Code-aware routing metric involved
Depends on traffic pattern	Applies to any traffic pattern
No need of coding condition	Uses the some coding condition
Use ETX as the routing metric	Use CRM as the routing metric
Network coding act as a separate layer between MAC and network layers	Network coding done within the network layer
Coding opportunity depends on routing protocol	Independent of routing protocol
No module is needed to select between code possible and code impossible paths	An extra module is needed to select between code passible and code impossible path

- Updating the "who-can-overhear" information. Node c appends its high-quality neighbors into the RREQ such that the list gradually enlarges when the RREQ travels through the network.
- Rebroadcasting the updated RREQ to discover remaining path to the destination node.

Step 3.destination replies with the Route Reply (RREP) message using the reverse path back to the source node as soon as the RREQ reaches the destination node. RREP

contains the "path" information and it is send as a unicast message.

Step 4. Upon receiving an RREP, an intermediate node, say node c, compares the upstream path contained in the RREP with the paths in its temporally stored RREQs. If there is a match, then it has obtained both the "path" and "who-can overhear" information for the new path. Each node also maintains the "path" and "who-can-overhear" information for all the existing flows relayed by itself. Given these information, node c can check whether the new flow can be encoded with some existing flow(s) using the coding condition. If there is coding opportunity, node c marks its link as "coding-possible" in the RREP.

Step 5. When the RREP(s) return to the source node, a routing decision is made based on the potential coding opportunities and the benefit of each available paths , and the source node begins to send data packets on the selected path.

Step 6. When the first data packet reaches an intermediate node, say node c, it stores the "who-can-overhear" and "path" information for the selected path, while discarding other temporally stored information.

IV. COMPARATIVE STUDY

COPE has a static coding structure and DCAR has a dynamic coding opportunity which is the main difference between COPE and DCAR

As a result of the studies done, it has found that the COPE and DCAR has the characteristics shown in Table I.

V. CONCLUSION

Network coding is a promising method to improve the performance of wireless network. The first practical network coding method introduced for wireless network is COPE. COPE give a simple architecture to implement network coding in wireless network. Coding in COPE can occur in

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two hop region only. In order to shadow COPE's disadvantage DCAR, a new architecture is proposed which have wider coding region than COPE. DCAR in co-operate coding within routing decision. Still researches in network coding are improving to increase the throughput of wireless network.

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