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Increasing Performance of Cooperative Opportunistic Routing in MANET using Spatial Reuse

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***Abstract:* Mobile Ad Network is a self-configuring infrastructure less network of wireless communication. Opportunistic routing is a recent technique that achieves high throughput in the face of lossy wireless links. The current opportunistic routing protocol, ExOR, ties the MAC with routing, imposing a strict schedule on routers' access to the medium. The main concept of cooperative communications is to make use of the broadcast nature of the wireless medium. In this paper, we are improving the performance of cooperative opportunistic routing in MANET using spatial reuse. Here MORE is used instead of ExOR, since ExOR ties the MAC with routing, adding a strict schedule on routers' access to the medium. It randomly mixes the packets before forwarding them. This randomness ensures routers that hear the same transmission do no forward the same packets. Thus, MORE has no needs special scheduler to coordinate routers and can run directly on top of 802.11.**

Keywords: Corman, ExOR, MANET, MORE, PSR.

1. Introduction

A Mobile Ad hoc Network is a self-configuring infrastructure less network. These mobile devices connected by wireless communication network, in which nodes that are not direct transmission range of each other will require to forward data to other nodes. The main challenge of building the MANET, each device has to continuously maintain the information for routing the traffic properly. The network layer has got the most attention when working on MANET; as a result plenty of routing protocols in such a network with differing objectives and for various specific needs have been proposed [1]. There are two main operations at the network layer, *i.e.*, data forwarding and routing, are different concepts. Data forwarding means how packets are taken from one link and put on another. Routing explains how to follow path from the source node to the destination.

Routing protocols in Mobile ad hoc network can be categorized using an array of criteria. The most basic difference between this is the timing of routing information exchange. On one hand, a protocol may require that nodes in the network should maintain valid routes to all destinations all the time called as proactive routing protocols. And, on other hand, if nodes in the network do not always maintain routing information, when a node receives data from the upper layer for a given destination, it must first find out how to reach the destination, such approach is called reactive routing protocols.

Opportunistic routing has recently emerged as a mechanism for obtaining high throughput even when links are lossy [2][3]. Traditional routing chooses the next hop before transmitting a packet; but, when link quality is poor, the probability the chosen next hop receives the packet is low. In opposite to, opportunistic routing allows *any* node that overhears the transmission and is closer to the destination to participate in forwarding the packet. Opportunistic routing, however, introduces a difficult challenge. Multiple nodes may hear a packet broadcast and unnecessarily forward the same packet. ExOR [4] deals with this issue by tying the MAC to the routing, imposing a strict scheduler on routers' access to the medium. The scheduler goes in rounds. Forwarders transmit in order, and only one forwarder is allowed to transmit at any given time. The others listen to learn which packets were overheard by each node. Although the medium access scheduler delivers opportunistic throughput gains, it does so at the cost of losing some of the desirable features of the current 802.11 MAC. In particular, the scheduler prevents the forwarders from exploiting spatial reuse, even when multiple packets can be simultaneously received by their corresponding receivers.

Research on co-operative communication at the link layer and above had been little until ExOR [4]. ExOR is the main work in wireless networking and it is an elegant way to utilize the broadcasting nature of wireless links to achieve cooperative communication at the link layer and network layers of static multihop wireless networks. Here, we further broaden the scenarios that the idea behind ExOR can be used, called as Cooperative Opportunistic Routing in Mobile Ad hoc Networks (CORMAN) [5].

As compare to ExOR's highly structured scheduler, in this paper we address above challenge with randomness and no scheduler. For this purpose have taken use of MORE [3], MAC-independent Opportunistic Routing & Encoding. MORE randomly joins packets before forwarding them. This makes sure that routers that hear the same transmission do not forward the same packet. Indeed, the possibility that such randomly coded packets are the same is proven to be exponentially low. As a result, MORE does not require a special scheduler; it runs directly on top of 802.11.

2. Literature Survey

The use of the broadcasting nature of wireless channels at the link layer and above has a relatively recent history when compared to the efforts at the physical layer. Chlamtac I et al [6], describes about, a mobile ad hoc network (MANET), sometimes called a mobile mesh network, and is a self-configuring network of mobile devices connected by wireless links. The Ad hoc networks are a new wireless networking paradigm for mobile hosts. Unlike traditional mobile wireless networks, ad hoc networks do not rely on any fixed infrastructure. Instead, hosts rely on each other to keep the network connected. Larsson [7] proposes an innovative handshake technique, called Selection Diversity Forwarding (SDF), to implement downstream forwarder selection in a multihop wireless network, where multiple paths are provided by the routing module. In this case, a sender in the network can dynamically choose from a set of usable downstream neighbors that present high transient link quality. ExOR is solution for that. ExOR is a cross- layer explorative opportunistic data forwarding technique in multi-hop wireless networks by Biswas and Morris. It fuses the MAC and network layers so that the MAC layer can determine the actual next-hop forwarder after transmission depending on the transient channel conditions at all eligible downstream nodes. Leontiadis and Mascolo and Yang et al. [8] suggest using position information for routing in mobile multi-hop wireless networks. Therefore it is supposed that each and every node in a network is mindful of all other node position in the network. MORE improves ExOR to further increase the spatial channel reuse in a single flow via intra flow network coding [9] to reach destination from the source.

3. Basic Motivating Example

MORE's design builds on the theory of network coding [9][10][11]. In this section, we are explain two study examples to explain the intuition underlying our approach and illustrate the synergy between opportunistic routing and network coding.

The Unicast Case: Consider the case in Figure 1 [3]. Traditional routing predetermines the path before transmission. It sends traffic along the path "*src→R→dest*", which has the highest delivery probability. But, we know wireless is a broadcast medium. When a node transmits, there is always a chance that a node closer than the chosen next hop to the destination overhears the packet. For example, assume the source sends 2 packets, p_1 and p_2. The next hop, R, receives both, and the destination happens to overhear p_1. It would be a waste to have node R forward p_1 again to the destination. This observation has been noted in [2] and used to develop ExOR, an opportunistic routing protocol for mesh wireless networks. ExOR, however, requires node coordination, which is more difficult in larger networks. Consider again the example in the previous paragraph. R should forward only packet p_2 because the first packet has already been received by the destination; but, without consulting with the destination, R has no way of knowing which packet to transmit. The problem becomes harder in larger networks, where many nodes hear a transmitted packet. Opportunistic routing allows these nodes to participate in forwarding the heard packets. Without coordination, however, multiple nodes may unnecessarily forward the same packets, creating spurious transmissions. To deal with this issue, ExOR [4] imposes a special scheduler on top of 802.11. The scheduler goes in rounds and reserves the medium for a single forwarder at any one time. The rest of the nodes listen to learn the packets overheard by each node. Due to this strict schedule, nodes farther away from the destination (which could potentially have transmitted at the same time as nodes close to the destination due to spatial reuse), cannot, since they have to wait for the nodes close to the destination to finish transmitting. Hence the scheduler has the side effect of preventing a flow from exploiting spatial reuse.

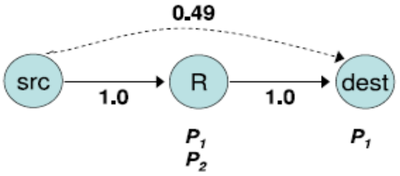

Figure 1—Unicast Example. The source sends 2 packets. The destination overhears p_1, while R receives both. R needs to forward just one packet but, without node-coordination, it may forward p_1, which is already known to the destination. With network coding, however, R does not need to know which packet the destination misses. R just sends the sum of the 2 packets $p_1 + p_2$. This coded packet allows the destination to retrieve the packet it misses independently of its identity. Once the destination receives the whole transfer (p_1 and p_2), it acks the transfer causing R to stop transmitting.

Network coding offers a good solution to the above problem. In our example, the destination has overheard one of the transmitted packets, p_1, but node R is unaware of this fortunate reception. With network coding, node R naturally forwards linear combinations of the received packets. For example, R can send the sum $p_1 + p_2$. The destination retrieves the packet p_2 it misses by subtracting from the sum and acknowledges the whole transfer. Thus, R need not know which packet the destination has overheard. Indeed, the above works if R sends any random linear combination of the two packets instead of the sum. Thus, one can generalize the above approach. The source broadcasts its packets. Routers create random linear combinations of the packets they hear (i.e., $c_1p_1 + . . . + c_np_n$, where c_i is a random coefficient). The destination sends an ack along the reverse path once it receives the whole transfer. This approach does not require node coordination and preserves spatial reuse.

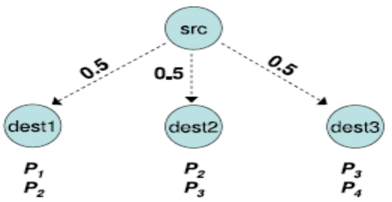

Figure 2—Multicast Example. Instead of retransmitting all four packets, the source can transmit two linear combinations, e.g., $p_1 + p_2 + p_3 + p_4$ and $p_1 + 2p_2 + 3p_3 + 4p_4$. These two coded packets allow all three destinations to retrieve the four original packets, saving the source 2 transmissions.

The Multicast Case: Our second example explains the synergy between network coding and multicast. In Figure 2, the source multicasts 4 packets to three destinations [3]. Wireless receptions at different nodes are known to be highly independent. Assume that each destination receives the packets indicated in the figure–i.e., the first destination receives p_1 and p_2, the second destination receives p_2 and p_3, and the last destination receives p_3 and p_4. Note that each of the four packets is lost by some destination. Without coding, the sender has to retransmit the union of all lost packets, i.e., the sender needs to retransmit all four packets. In contrast, with network coding, it is sufficient to transmit 2 randomly coded packets. For example, the sender may send $p'_1 = p_1 + p_2 + p_3 + p_4$ and $p'_2 = p_1 + 2p_2 + 3p_3 + 4p_4$. Despite the fact that they lost different packets, all three destinations can retrieve the four original packets using these two coded packets. For example, the first destination, which has received p'_1, p'_2 and p_1, p_2, retrieves all four original packets by inverting the matrix of coefficients, and multiplying it with the packets it received, as follows:

$$\begin{pmatrix} p_1 \\ p_2 \\ p_3 \\ p_4 \end{pmatrix} = \begin{pmatrix} 1 & 1 & 1 & 1 \\ 1 & 2 & 3 & 4 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{pmatrix}^{-1} \begin{pmatrix} p'_1 \\ p'_2 \\ p_1 \\ p_2 \end{pmatrix}$$

Thus, in this simple example, network coding has reduced the needed retransmissions from 4 packets to 2, improving the overall throughput.

4. Implementation Details

4.1 System Model

The proposed solution is the extension of CORMAN [5]. To achieve better performance we use spatial channel reuse in the existing system. The whole system has following modules. Out of which first three modules are in existing system and last three modules are in proposed system work s cooperatively with existing system. Figure (3) shows system architecture proposed system.

4.1.1 Proactive Source Routing

PSR runs at the background [12]. That's why; nodes periodically exchange network structure information. It joins after the number of iterations equal to the network diameter. Where each node has is having spanning tree of the network indicating the shortest path to all other nodes.

4.1.2 Large Scale Live Update

When data packets are received by and stored at forwarding node, the node has ability to how to forward them to the destination from the forwarder list carried by the packets. Since this node is closer to the destination than the source node. When node is having packets with this updated forwarder list are broadcast by the forwarder, then updating message about the network topology change propagates back to its upstream neighbor. The neighbors fit in the changes to the packets in its cache.

4.1.3 Small Scale Retransmission

A short forwarder list tries to move packets over long and possibly weak links. To increase the reliability of data forwarding between two listed forwarders, CORMAN allows the nodes which are not on the forwarder list but are situated between two listed forwarders to retransmit data packets if the downstream forwarder has not received these packets successfully. Because there may be multiple such nodes between a given pair of listed forwarders, CORMAN coordinates retransmission attempts among them extremely efficiently.

4.1.4 Source

The source splits up the file into batches of K packets, where K may vary from one batch to another. These K *uncoded* packets are called *native packets*. When the 802.11 MAC is ready to send, the source creates a random linear combination of the K native packets in the current batch and broadcasts the coded packet. In MORE, data packets are always coded. A *coded packet* is $P'_j = \sum_i C_{ji} P_i$, where the C_{ji}'s are random coefficients picked by the node, and the P_i's are native packets from the same batch. We call $C_j = (C_{j1}, \ldots, Cji, \ldots, C_{jK})$ the *code vector* of packet P'_j. Thus, the code vector describes how to generate the coded packet from the native packets.

The sender includes in the forwarder list nodes that are closer to the destination than itself, ordered according to their proximity to the destination. The sender keeps transmitting coded packets from the current batch until the batch is acknowledged by the destination, at which time, the sender proceeds to the next batch.

4.1.5 Forwarders

Nodes listen to all transmissions. When a node hears a packet, it checks whether it is in the packet's forwarder list. If so, the node checks whether the packet contains new information, in which case it is called an *innovative packet*. Technically speaking, a packet is innovative if it is linearly independent from the packets the node has previously received from this batch. Checking for independence can be done using simple algebra (Gaussian Elimination). The node ignores non-innovative packets, and stores the innovative packets it receives from the current batch.

If the node is in the forwarder list, the arrival of this new packet triggers the node to broadcast a coded packet. To do so the node creates a random linear combination of the coded packets it has heard from the same batch and broadcasts it. Note that a linear combination of coded packets is also a linear combination of the corresponding native packets. In particular, assume that the forwarder has heard coded packets of the form $P'' = \sum_i C_{ji} P_i$, where P_i is a native packet. It linearly combines these coded packets to create more coded packets as follows: $P'' = \sum_j r_j P'_j$, where r_j's are random numbers. The resulting coded packet P'' can be expressed in terms of the native packets as follows: $P'' = \sum_j (r_j = \sum_i C_{ji} P_i) = \sum_i (\sum_j r_j C_{ji}) P_i$; thus, it is a linear combination of the native packets themselves.

4.1.6 Destination

For each packet it receives, the destination checks whether the packet is innovative, i.e., it is linearly independent from previously received packets. The destination discards non-innovative packets because they do not contain new information. Once the destination receives K innovative packets, it decodes the whole batch (i.e., it obtains the native packets) using simple matrix inversion:

$$\begin{pmatrix} p_1 \\ \vdots \\ p_K \end{pmatrix} = \begin{pmatrix} c_{11} & \cdots & c_{1K} \\ \vdots & \ddots & \\ c_{K1} & \cdots & c_{KK} \end{pmatrix}^{-1} \begin{pmatrix} p'_1 \\ \vdots \\ p'_K \end{pmatrix}$$

Where, P_i is a native packet, and p'_i is a coded packet whose code vector is $C_i = C_{i1}, \ldots, C_{iK}$. As soon as the destination decodes the batch, it sends an acknowledgment to the source to allow it to move to the next batch. ACKs are sent using best path routing, which is possible because MORE uses standard 802.11 and co-exists with shortest path routing. ACKs are also given priority over data packets at every node.

4.2 Mathematical Model

Let we have N no of packets at source node that we have to send to the destination;

$N=\{N_1, N_2, N_3,\ldots\ldots, N_n\}$

These packets are divided into K batches, where K may vary from one batch to another. Initially, they are uncoded packets.

These *K uncoded* packets are called *native packets*.

When sender is ready sends the source creates a random linear combination of the *K* native packets in the current batch and broadcasts the coded packet.

Here, Data packets are always coded and coded packet is given by,

$P'_j = \sum_i C_{ji} P_i,$

Where the C_{ji}'s are random coefficients picked by the node and The P_i's are native packets from the same batch.

We call them,

$C_j = (C_{j1}, \ldots, C_{ji}, \ldots, C_{jK})$ the *code vector* of packet P'_j.

Thus, the code vector describes how to generate the coded packet from the native packets.

At Forwarders node, when node hears a packet, it checks whether it is in the packet's forwarder list. Assume that the forwarder has heard coded packets of the form

$P'' = \sum_i C_{ji} P_i$, Where P_i is a native packet.

It linearly combines these coded packets to create more coded packets as follows:

$P'' = \sum_j r_j P',$

Where r_j's are random numbers. The resulting coded packet P'' can be expressed in terms of the native packets as follows: $P'' = \sum_j (r_j = \sum_i C_{ji} P_i) = \sum_i (\sum_j r_j C_{ji}) P_i;$

If so, the node checks whether the packet contains new information, in which case it is called an *innovative packet*.

Every time packet is *innovative* or not checked and *non innovative* packets are discarded.

At destination, it checks whether the packet is innovative, i.e., it is linearly independent from previously received packets. Once the destination receives *K* innovative packets, it decodes the whole batch, and then simple matrix inversion original packets are recovered and pass to the destination.

$$\begin{pmatrix} p_1 \\ \vdots \\ p_K \end{pmatrix} = \begin{pmatrix} c_{11} & \cdots & c_{1K} \\ \vdots & \ddots & \\ c_{K1} & \cdots & c_{KK} \end{pmatrix}^{-1} \begin{pmatrix} p'_1 \\ \vdots \\ p'_K \end{pmatrix}$$

Where, P_i is a native packet, and p'_i is a coded packet whose code vector is $C_i = C_{i1}, \ldots, C_{iK}$. at the last destination decodes the batch and send acknowledgement back to sender to allow it, send next batch.

5. Expected Result Discussion

The results of new proposed technique improve the performance of CORMAN by using spatial channel reuse. MORE improves the throughput by 95%; MORE's throughput exceeds ExOR's mainly because of its ability to exploit spatial reuse. For multicast traffic, MORE's throughput gain increases with the number of destinations. For 2-4 destinations, MORE's throughput is 35-100% larger than ExOR's.

6. Conclusion and Future Works

In this paper, we have proposed better co-operative opportunistic routing in MANET by using spatial channel reusing. The ExOR is having highly structured scheduler, but implemented MORE is sits between network layer and above the 802.11 MAC and has no special scheduler. In the proposed system performance is improved with Opportunistic routing. For the future work we suggest working on overcoming the existing problems of CORMAN and present the next extended version of the same.

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