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Reducing Retransmission Delay in Mobile-ADHOC–Network (MANET)

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Abstract- The combination of link-quality variation with the broadcasting nature of wireless channels has revealed a direction in the research of wireless networking, namely, cooperative communication. Research on cooperative communication started to attract interests in the community at the physical layer but more recently its importance and usability have also been realized at upper layers of the network protocol stack. In this article, we tackle the problem of opportunistic data transfer in mobile ad hoc networks. Our solution is called Cooperative Opportunistic Routing in Mobile Ad hoc Networks (CORMAN). It is a pure network layer scheme that can be built atop off-the-shelf wireless networking equipment. Nodes in the network use a lightweight proactive source routing protocol to determine a list of intermediate nodes that the data packets should follow en route to the destination. Here, when a data packet is broadcast by an upstream node and has happened to be received by a downstream node further along the route, it continues its way from there and thus will arrive at the destination node sooner. This is achieved through cooperative data communication at the link and network layers. This work is a powerful extension to the pioneering work of ExOR. We test CORMAN and compare it to AODV, and observe significant performance improvement in varying mobile settings.

Index Terms- Cooperative communication, opportunistic proactive source routing, local retransmission, forwarder list update

I. Introduction

An mobile ad hoc network is a wireless communication network, where nodes that are not within direct transmission range of each other will require other nodes to forward data. It can operate without existing infrastructure, supports mobile users, and falls under the general scope of multi-hop wireless networking. Such a networking paradigm originated from the needs in battlefield communications, emergence operations, search and rescue, and disaster relief operations. Later, it found civilian applications such as community networks.A great deal of research results have been published since its early days in the 1980's [1]. The most salient research challenges in this area include end-to-end data transfer, link access control, security, and providing support for real-time multimedia streaming. The network layer has received the most attention when working on mobile ad hoc networks. As a result, abundant routing protocols in such a network with differing objectives and for various specific needs have been proposed [2]. In fact, the two most important operations at the network layer, i.e., data forwarding and routing, are distinct concepts. Data forwarding regulates how packets are taken from one link and put on another. Routing determines which path a data packet should follow from the source node to the destination. The latter essentially provides the former with control input. Although a large amount of efforts have been put in routing in ad hoc networks, in contrast, data forwarding follows pretty much the same paradigm as in IP forwarding in the Internet.IP forwarding was originally designed for multi-hop wired networks, where one packet transmission can only be received by nodes attached to the same cable. For the case of modern Ethernet, an IP packet is transmitted at one end of the Ethernet cable and received at the other. However, in wireless networks, when a packet is transmitted over a physical channel, it can be detected by all other nodes within the transmission range on that channel.

Research on cooperative commutation at the link layer and above had been little until ExOR [3]. ExOR is a milestone piece of work in this area and it is an elegant way to utilize the broadcasting nature of wireless links to achieve cooperative communication at the link and network layers of static multihop wireless networks. Here, we further extend the scenarios that the idea behind ExOR can be used, dubbed as Cooperative Opportunistic Routing in Mobile Ad hoc Networks (CORMAN). We test CORMAN using the Nakagami fading model in ns-2 and compare it to the well-understood AODV in an array of mobile network scenarios. The performance improvement of CORMAN that we have observed is substantial.Contributions in our solution are highlighted as follows.

- We use a lightweight proactive source routing protocol so that each node has complete knowledge of how to route data to all other nodes in the network at any time. When a flow of data packets are forwarded towards their destination, the route information carried by them can be adjusted by intermediate forwarders. Furthermore, as these packets are forwarded along the new route, such updated information is propagated upstream rapidly without any additional overhead. As a result, all upstream nodes learn about the new route at a rate much faster than via periodic route exchanges.
- We take opportunistic data forwarding to another level by allowing nodes that are not listed as intermediate forwarders to retransmit data if they believe certain packets are missing.

II. RELATED WORK

The utilization of the broadcasting nature of wireless channels at the link layer and above has a relatively recent historycompared to the efforts at the physical layer. Larsson [4]proposes an innovative handshake technique, called SelectionDiversity Forwarding (SDF), to implement downstreamforwarder selection in a multihop wireless network, where multiple paths are provided by the routing module. In thiscase, a sender in the network can dynamically choose from a set of usable downstream neighbors that present high transient link quality. For the sender to make the decision, the IEEE 802.11 Distributed Coordination Function (DCF)-based DATA/ACK handshake is enhanced. Such a handshake is the first opportunistic utilization of link quality variation in multihop wireless networks at the link and network layers. The coordination in SDF is somewhat expensive and its overhead needs to be significantly reduced for it to be more practical. ExOR [3] is an answer to that. It is an explorative crosslayer opportunistic data forwarding technique in multi-hop wireless networks by Biswas and Morris. It fuses the MAC (Medium Access Control) 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. Nodes are enabled to overhear all packets transmitted in the channel, whether intended for it or not. A multitude of forwarders can potentially forward a packet as long as it is included on the forwarder list carried by the packet. Thus, if a packet is heard by a listed forwarder closer to the destination with a good reception condition, this long-haul transmission should be utilized. Otherwise, shorter and thus more robust transmissions can always be used to guarantee reliable progress. The challenge is to ensure that exactly one of the listed forwarders should relay the packet that is likely to be the closest to the destination at the same time. This is addressed by prioritized scheduling among the listed forwarders according to their priority indicated in the forwarder list.

We adopt the following terms defined in ExOR to describe similar concepts in CORMAN:

• Batch size — number of packets in a batch. It has the same value for all packets in a given batch.

• Forwarder list size — number of forwarders on the forwarder list. It has the same value for all packets in a given batch.

• Packet number — index of the packet in the batch.

• Forwarder number — index of the forwarder on the forwarder list. It indicates which node on the list has just transmitted the data packet.

• Batch map — an array whose size equals the batch size. Each element of the map is indexed by the packet number, and its value is the forwarder number of the highest priority forwarder that this packet has reached.

• Fragment — a subset of packets in the current batch which are sent together from a given forwarder.

In ExOR, data packets are prepended with an ExOR header, which includes some of the above information. They arefurther prepended with an 802.11 DATA frame header before being broadcasted. For more details of the packet formats, the readers are referred to [3].

To generalize the idea behind ExOR to more different types of networks, such as mobile wireless networks, lightweightrouting algorithms with proactive source routing capabilities are preferred. Path Finding Algorithm (PFA) [9] was developed based on the distance vector algorithm, which incorporates the predecessor of a destination in a routing update.Hence, the entire path to a destination can be reconstructed by the source node. On the other hand, the Link Vector (LV) algorithm [10] reduces the overhead of link-state algorithms to a great deal by only including links to be used in data forwarding in routing updates. The extreme case of LV where only one link is included per destination coincides with PFA. While the two algorithms above were initially proposed to address the routing scalability issue in the Internet, the Wireless Routing Protocol (WRP) [11] attempts to apply the idea of PFA to mobile wireless networks. The update messages in WRP are event-driven and it requires reliable link-layer broadcast, which incurs a significant amount of overhead.

III. PROPOSED METHODOLOGY

This paper explores the possibility of using node information and neighbor list to improve performance of routing protocols for MANET fast transmission and reduce re-transmission delay. Proactive Source Routing is used to find the path and verifies the position of communicating nodes. In this we have three phases. They are:

- **a. Proactive Source Routing**
- **b. Large Scale Live update**
- **c. Small Scale Retransmission**

1.Proactive Source Routing — PSR runs in the background so that nodes periodically exchange network structure information. It converges after the number of iterations equal to the network diameter. At this point, each node has a spanning tree of the network indicating the shortest paths to all other nodes. PSR is inspired by path finding [9], [11] and link-vector [10] algorithms but is lighter weight. Technically, PSR can be used without CORMAN to support conventional IP forwarding.

2.Large-scale live update

When data packets are received by and stored at a forwarding node, the node may have a different view of 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, such discrepancy usually means that the forwarding node has more updated routing information. In this case, the forwarding node updates the part of the forwarder list in the packets from this point on towards the destination according to its own knowledge. When the packets with this updated forwarder list are broadcast by the forwarder, the update about the network topology change propagates back to its upstream neighbor. The neighbor incorporates the change to the packets in its cache. When these cached packets are broadcast later, the update is further propagated towards the source node. Such an update procedure is significantly faster than the rate at which a proactive routing protocol disseminates routing information.

3. Small-scale retransmission

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

IV. LARGE SCALE LIVE UPDATE

CORMAN generalizes the opportunistic data forwarding in ExOR to suit mobile wireless networks. That is, when a batch of packets are forwarded along the route towards the destination node, if an intermediate node is aware of a new route to the destination, it is able to use this new route to forward the packets that it has already received. There are a few implications of this. First, this new route will also be used to forward the subsequent packets of the same batch. Second, when packets are forwarded along the new route, such an updated forwarder list replaces the old list in the packets. By overhearing the forwarding of these packets, the upstream nodes can be notified of the new route and this information can propagate back to the source node quickly. Details of data forwarding and list update are described in this section with the help of Figure 1. In the figure, the source node v1 has a flow of data packets for destination node v10. According to its own routing module, v1 decides that the best route to v10 is v1v2v3v4v5v6v7v8v9v10; hence the forwarder list.

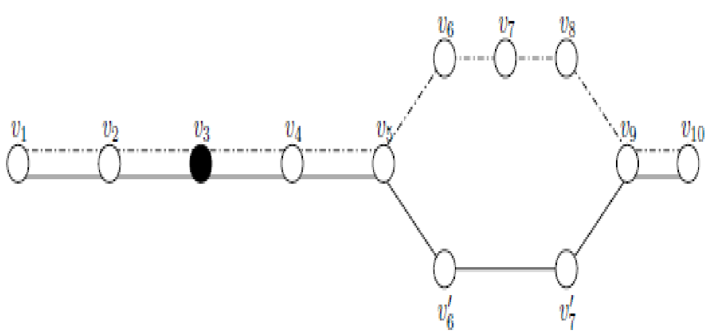

Figure :Route Update

We call such a node the frontier of the batch. At the beginning, the frontier is the source node. When the destination has received at least one packet of a batch, it has become the frontier of the batch. Recall that a fragment (Section II) is a subset of packets in the current batch which are transmitted in tandem by a given forwarder. Here, the frontier has cached its first fragment of packets. Suppose at this point, the frontier in Figure 1 is v3. When it is about to forward this fragment, if its routing module indicates there is a new route to the destination, e.g., v3v4v5v 6v 7v9v10, it replaces the segment of the original forwarder list from itself to the destination (i.e., v3v4v5v6v7v8v9v10) with this new route. That is, the forwarder list carried by these data packets are now v1v2v3v4v5v6v7v9v10. When the packets of the fragment are forwarded, they will be following the new route. In addition, upstream nodes can overhear these packets, and thus their new forwarder list. These nodes can update their own routing information and will incorporate such information when forwarding their fragments. This backtrack continues until the source is aware of the latest route information. We would like to bring up the following notes to the readers' attention.

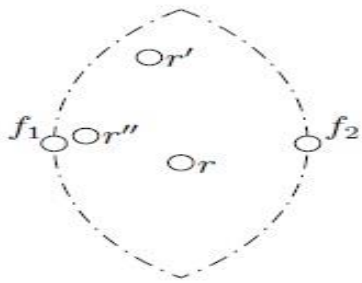

Figure 2:Retransmission region

V. SMALL SCALE RETRANSMISSION

To enhance the reliability of packet transmission between two consecutive listed forwarders, CORMAN employs the mechanism of small-scale retransmission. It operates at the time granularity of a fragment and space granularity of a single link. Consider a given batch of packet transfer and suppose that two consecutive forwarders on this batch's list are f1 and f2, in that order, as in Figure 2, and that a node r is located somewhere between f1 and f2. After f2 has transmitted its fragment of packets, by comparing the packets transmitted by f1 to those by f2, node r knows which packets f2 has missed. It is now eligible to retransmit these packets that are believed missing. If there are more than one such r in that area, such as r_ and r__, CORMAN guarantees at most one such node should retransmit. For r to be a retransmitter in this case, it must satisfy the following conditions:

- First, node r should be a neighbor of both f1 and f2.Node r can learn this by looking up its neighbor list.
- Second, the separation distance between f1 and f2, denoted d(f1, f2), should be greater than d(f1, r) and d(r, f2). That is, it must be within the region in Figure 2 enclosed by the dashed lines. The node separation distance can be estimated using the RSSI (Received Signal Strength Indicator) recorded when packets are received.
- Third, node r uses a scoring function F(d(f1, r), d(r, f2)) in the positive real domain to measure how "suitable" it is as a retransmitter for f1 and f2. F can be any function that favors a node close to the midpoint of the line segment between f1 and f2 but not too close to either one of them. In addition, node r is also able to calculate this suitability value for all other nodes satisfying the first two conditions. This is possible if node r is aware of the RSSI measurements of all links incident on a node in N(r). This can be realized simply by every node broadcasting the RSSI of all incident links periodically.This last condition ensures that node r

should have the best suitability score among those satisfying the first two conditions.

Suppose r decides that it is indeed the retransmitter between f1 and f2. It should retransmit the packets that f2 or anyhigher-priority node has missed. For us to keep track of the progression of data packets in the batch, each element of the batch map can have a value p ($0 \leq p \leq 2(l - 1)$), where l is the number of nodes in the forwarder list. We use the parity of p to distinguish if the corresponding node is a listed forwarder or not. That is, when it is even, p/2 is the offset of the node in the list that the corresponding packet has reached. When p is odd, the packet has reached the retransmitter between the $(p - 1)/2$-th and $(p + 1)/2$-th forwarders. Once node r has learned what packets should be retransmitted and what batch map they should carry, it retransmits them as if it were a listed forwarder.

VI. CONCLUSION

In this article, we have proposed CORMAN as an opportunistic routing scheme for mobile ad hoc networks. CORMAN is composed of three components. 1) PSR—a proactive source routing protocol, 2) large-scale live update of forwarder list, and 3) small-scale retransmission of missing packets. All of these explicitly utilize the broadcasting nature of wireless channels and are achieved via efficient cooperation among participating nodes in the network. Essentially, when packets of the same flow are forwarded, they can take different paths to the destination. Research based on CORMAN can be extended in the following interesting ways.

1) It would be informative to further test CORMAN. For example, we can compare CORMAN to ExOR and IP forwarding in static multi-hop networks with varying link quality to study their relative capabilities in data transfer. We will also test these data transfer techniques with multiple simultaneous flows are present to study how well they share the network resources. Through these tests, we will be able further optimize some parameters of CORMAN, such as the retry limit.

2) The coordination among multiple qualified small-scale retransmitters can be achieved with better measures than RSSI. In particular, if the "suitability" score is based on transient link quality rather than historical information, we will be able better utilize the receiver diversity. Apparently, this would require non-trivial coordination among these retransmitters, which could be challenging especially when we aim for zero extra overhead.

3) Nodes running CORMAN forward data packets in fragments. When the source and destination nodes are separated by many hops, it should allow nodes at different segment of the route to operate simultaneously. That is,a pipeline of data transportation could be achieved by better spatial channel reuse. The design of CORMAN can be further improved to address this explicitly. This may involve timing node backoff more precisely and tightly, or even devising a completely different coordination scheme

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