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CORMAN Using Delivery Predictability Metric

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Abstract – The variation of link quality of wireless channels has been a challenging issue in data communications. The same broadcast transmission may be observed differently, and usually independently, by receivers at different geographic locations. The combination of link-quality variation along with the broadcasting nature of wireless channels has revealed a new direction in the research of the wireless networking namely, cooperative communication. We also consider the issue of routing in intermittently coupled networks. In such like networks there is no guarantee that a fully connected path between the source and the destination exists at any time, rendering traditional routing protocols unable to deliver messages between the hosts. Here, in this article, we tackle the problem of opportunistic data transfer in mobile ad hoc networks and able to deliver more messages with lower communication overhead. Solution is called Cooperative Opportunistic Routing in Mobile Ad hoc Networks (CORMAN) using delivery predictability metric. It helps not to transfer message to every nodes in range, but to the most likely node. Also other nodes helps the process by transferring the missing message.

Index Terms – MANET, Routing, Opportunistic, Delivery predictability, Summary Vector.

1. INTRODUCTION

Mobile ad hoc network is a form of decentralized network [6]. The network is an ad hoc because it does not rely on an already existing infrastructure, such as routers in wired networks or access points in managed wireless networks. Instead of each node participates in routing by forwarding data for other nodes, so the determination of which node to forward data is made dynamically based on the network connectivity. Each and every node will be able to communicate directly with any other node that dwell within its transmission range. For communicating with the nodes that dwell beyond this range, the node needs to seek help from the intermediate nodes to relay the messages hop by hop. 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.

While working on mobile ad hoc networks the network layer has received the peak attention compared to other layers. As a result, the abundant routing protocols in such a network with differing objectives as well as for various specific needs have been proposed. In fact, the two most prominent operations at the network layer, i.e., data forwarding and routing, are distinct ideas [7]. Data forwarding regulates how the corresponding packets are taken from one link and put on another. Routing determines which path to follow by a data packet from the source node to the destination. The latter essentially provides the former with control input.

One of the most basic requirements for traditional networking, which also holds for ad hoc networking, is that there must exist a fully connected path between communication endpoints for communication to be possible. There are however a number of scenarios where this is not the case. E.g. satellite communication, military and disaster recovery operations, sensor networking and monitoring.

In wireless networks, when a packet is transmitted through a physical channel, that packet can be detected by all other nodes inside the transmission range on that channel. For the most part of the research history, overhearing a packet not intended for the receiving node had been considered as completely negative, i.e., interference [5].

Thus, the goal of research in wireless networking was to build wireless links as good as the wired ones. Unfortunately, this ignores the inherent nature of broadcasting of wireless communication links. For mobile ad hoc networks to truly succeed beyond labs and test beds, we must break-in and utilize its broadcasting nature instead of fighting it. Cooperative communication is an effective approach to achieving such a goal.

So to enable communication, messages may have to be buffered for a long time by intermediate nodes, and the mobility of those nodes must be abused to bring messages closer to their destination by exchanging messages between nodes as they meet. This protocol works by doing pair-wise information exchange of messages within the nodes as they get contact with each other to ultimately deliver messages to their destination.

Major goals are highlighted as follows:

- To efficiently distribute messages through partially connected ad hoc networks in a probabilistic fashion,
- To minimize the amount of resources consumed during delivering any single message, and

- To maximize the percentage of messages that are finally delivered to their destination.

2. RELATED WORK

The exploitation of the broadcasting nature of wireless channels at the link layer and above has a fairly recent history compared to the efforts at the physical layer. Larsson [4] suggests an innovative handshake technique, called Selection Diversity Forwarding (SDF), which implement downstream forwarder selection in a multi hop wireless network, where multiple paths are given by the routing module. A sender in the network can dynamically select from a set of functional downstream neighbors that provide high transient link quality. Such a handshake is the first opportunistic exploitation of link quality deviation at the link and network layers in multi hop wireless networks. The synchronization in SDF is somewhat costly and its overhead needs to be considerably reduced for it to be more practical.

ExOR [3] is a solution to that. It is an explorative cross layer opportunistic data forwarding method in multi-hop wireless networks by Biswas and Morris. It fuses the Medium Access Control (MAC) and network layers so that the Medium Access Control layer can decide the actual next-hop forwarder after transmission depending on the transient channel settings at all eligible downstream nodes. Nodes are allowed to overhear all packets transmitted in the channel, whether proposed for it or not.

A multitude of forwarders can possibly forward a packet as long as it is encompassed on the forwarder list carried by the packet. Thus, if a packet is received by a listed forwarder closer to the destination with a good reception state, this long-haul transmission should be used. Else, shorter and thus more robust transmissions can always be used to promise reliable progress. The challenge is to ensure that exactly one of the listed forwarders should spread the packet that is likely to be the nearby to the destination at the same time. This is addressed by prioritized scheduling between the listed forwarders according to their priority specified in the forwarder list.

3. PORPOSED MODELLING

CORMAN [1], the novel cooperative opportunistic scheme in MANET operates by forwarding data in batch wise manner. The data flow of packets are divided into batches. The packets with in the same batch holds the same forwarder list as they leave the source node. The design of system includes the following two modules.

3.1 Small-scale retransmission

Nodes always retransmit the data packets if the other node has not yet received these packets successfully. To enhance the reliability of packet transmission within two consecutive listed forwarders, we employ the mechanism of small-scale retransmission which operates at the time granularity of a fragment and space granularity of a single link.

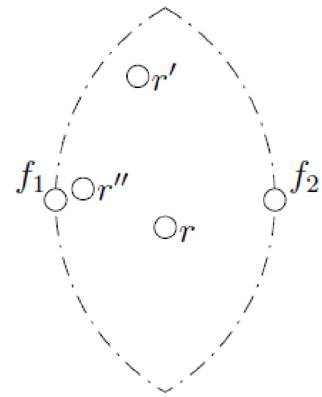

Fig 1. Retransmission region

Consider a given batch of packet transfer and suppose that two consecutive forwarders on this batch list are f_1 and f_2, in that order, as in Fig 1, and that a node r is located somewhere between f_1 and f_2. After f_2 has transmitted its fragment of packets, by comparing the packets transmitted by f_1 to those by f_2, node r knows which packets f_2 has missed.

Intermediate nodes usually buffer messages even if there is no path to the destination available at the moment. An index of these messages is kept by the nodes, called a summary vector and when two nodes meet they exchange those summary vectors. After this exchange, each node can conclude if the other node has some message that was previously unseen to this node. In this particular case, the node requests the messages from the other node. So even if the nodes in between is not in the actual routing, it helps in ensuring complete transmission of the messages.

This means that as long as buffer space is available, messages will spread as fast as possible i.e. like some disease spread through the network as nodes meet and infect each other. So each node may be doing a small scale retransmission, but each small transmission concludes in receiving the 100 percent messages to the destination.

A short forwarder list forces packets to be forwarded over long and possibly weak links. In case if a packet of message missed means we retransmit the packet from last sending node not from the source, since then the packet delay will be reduced.

3.2. Large Scale Live Update

If a node visits same location several times, it is likely that the node will visit that location again. To accomplish this, we establish a probabilistic metric called delivery predictability, $P(a,b) \in [0,1]$, at every node a for each known destination b.

This indicates how likely this node will be able to deliver a message to that destination. When two nodes meet, they exchange the summary vectors which also contain the delivery predictability information stored along with the nodes [2]. This information is then used to update the internal delivery predictability vector.

3.3. Delivery predictability calculation

The calculation of the delivery predictabilities includes three parts. The first thing to do is to update the metric whenever a node is encountered, so that nodes that are often encountered have a high delivery predictability. This calculation is shown in equation 1, where $Pinit \in [0,1]$ is an initialization constant.

$$P(a,b) = P(a,b)old + 1 - P(a,b)old * Pinit \longrightarrow (1)$$

If a pair of nodes does not encounter each other in a while, they are less likely to be good forwarders of messages to each other, thus the delivery predictability values must age, being reduced in the process. The aging equation is shown in equation 2, where $\gamma \epsilon [0,1)$ the aging constant, and k is the number of time units that have elapsed since the last time the metric was aged. The time unit used can differ, and should be defined based on the application and the expected delays in the targeted network.

$$P(a,b) = P(a,b)old * \gamma^k \longrightarrow (2)$$

The delivery predictability also has a transitive property that is based on the observation that if node A frequently encounters node B, and node B frequently encounters node C, then node C probably is a good node to forward messages destined for node A to. Equation 3 shows how this transitivity affects the delivery predictability, where $\beta \varepsilon [0,1]$ is a scaling constant that decides how large should be the impact the transitivity should have on the delivery predictability.

$$P(a,c) = P(a,c)_{old} + (1 - P(a,c)_{old}) * P(a,b) * p(b,c) * \beta \longrightarrow (3)$$

Depending on the movements of nodes the predictions are made, it is vital that the mobility models we use here are realistic. One mobility model that has been commonly used in evaluation of ad hoc routing protocols is the random way-point mobility model [19]. In this model, nodes randomly choose a destination and then a speed to reach the destination point. Upon arriving at the destination, the node pause for a while and then chooses for a new destination. Thus, it is desirable to model the mobility in a better way to better reflect reality because normal users do not run around completely or randomly, but rather have some set some goals with their movements.

3.4. Forwarding strategies

In traditional routing protocols, choosing a destination for a message to forward is usually a simple task. The message is sent to a neighbor node which has the path to the destination with the least cost (usually the shortest path). Normally the message is only sent to a single node since the reliability of paths is comparatively high. When a message arrives at a node, and no path available for that node to reach the destination, so the node have to buffer the message and upon encountering with another node, the decision must be made on whether or not to transfer a particular message.

Furthermore, it may also be sensible to forward a message to multiple nodes to increase the probability that a message is delivered to its destination without any fail. Select a fixed threshold and only give a message to nodes that have a delivery predictability over that threshold for the destination of the message. On the other hand, when encountering a node with a low delivery predictability, it is not certain that a node with a higher metric will be encountered within a reasonable time [2].

Distributing a message to a large number of nodes will of course increase the probability of delivering a message to its destination, but in return, more system resources will be exhausted. On the other hand, giving a message only to a few nodes (maybe even just a single node) will use little system resources, but the probability of delivering a message is probably lower, and the experienced delay is high.

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. Since this node is closer to the destination than the source node, such difference usually means that the forwarding node has more updated routing information. In this case, the forwarding node forwards the message to other node by looking the updated value of Delivery predictability according to its own knowledge. Such an update procedure is significantly faster than the rate at which a proactive routing protocol disseminates routing information.

4. CONCLUSION

This paper deals with intermittently connected networks, an area where a more innovative applications are viable, expecting for an exciting future if the underlying mechanisms are present.

Here we have opportunistic routing with two different modules. 1) Small-scale retransmission where the nodes can retransmit data packets if the other node has not yet received these packets successfully and 2) Large scale live update where nodes uses delivery predictability metric for data forwarding. When nodes meet, a metric called Delivery predictability is updated. Based on the updated live values, the route is determined. All of these explicitly utilize the broadcasting nature of wireless channels and are achieved through efficient cooperation among participating nodes within the network.

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