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The POR Protocol: Tying Data To Geographic Locations In Mobile Disconnected Networks

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ABSTRACT

We propose an efficient Position-based Opportunistic Routing (POR) protocol which takes advantage of the stateless property of geographic routing and the broadcast nature of wireless medium. When a data packet is sent out, some of the neighbor nodes that have overheard the transmission will serve as forwarding candidates, and take turn to forward the packet if it is not relayed by the specific best forwarder within a certain period of time. By utilizing such in-the-air backup, communication is maintained without being interrupted. The additional latency incurred by local route recovery is greatly reduced and the duplicate relaying caused by packet reroute is also decreased. In the case of communication hole, a Virtual Destination-based Void Handling (VDVH) scheme is further proposed to work together with POR. we take inspiration from real life solutions. Suppose if we lost/found an item, a common practice is to post a note around the area where it was lost/ found, and later we refer back to the same location to check for further updates. Similarly, in the anytime-anywhere mobile sensing era, information is commonly tagged with location, thus encouraging location-based queries. To facilitate such queries, we advocate building "directories" around locations of interest by having nearby mobiles carry the data generated around these locations.

Index Terms- Geographic locations, POR, routing, VDVH.

1 INTRODUCTION

Reliable data delivery in MANETs, especially in challenged environments with high mobility remains an issue. Traditional topology-based MANET routing protocols are quite susceptible to node mobility. One of the main reasons is due to the predetermination of an end-to-end route before data transmission. Owing to the constantly and even fast changing network topology, it is very difficult to maintain a deterministic route. The discovery and recovery procedures are also time and energy consuming. Once the path breaks, data packets will get lost or be delayed for a long time until the reconstruction of the route, causing transmission interruption.

In fact, due to the broadcast nature of the wireless medium, a single packet transmission will lead to multiple receptions. If such transmission is used as backup, the robustness of the routing protocol can be significantly enhanced. The concept of such multicast-like routing strategy has already been demonstrated in opportunistic routing. However, most of them use link-state style topology database to select and prioritize the forwarding candidates. In order to acquire the inter node loss rates, periodic network-wide measurement is required, which is impractical for mobile environment. As mentioned in [9], the batching used in these protocols also tends to delay packets and is not preferred for many delay sensitive applications. Recently, location-aided opportunistic routing has been proposed [10] which directly uses location information to guide packet forwarding. However, just like the other opportunistic routing protocols, it is still designed for static mesh networks and focuses on network throughput while the robustness brought upon by opportunistic forwarding has not been well exploited.

In this paper, we study protocols that retain Geocache around the anchor location through inter vehicle communication. Specifically, we address two major challenges:

1) Returning the Geocache to the anchor location with high probability if the carrier of the Geocache becomes temporarily disconnected;
2) Minimizing the communication overhead for retaining the Geocache near an anchor location.

The boomerang protocol addresses these challenges by using a trajectory-based approach. It increases the successful return probability of the Geocache even in temporary disconnected scenarios. While the boomerang protocol is inspired by delay-tolerant geographic routing, it is unique in recording a node's trajectory as the node is moving away from the anchor location and using this trajectory as a guidance to carry back the Geocache. Further, to reduce communication overhead, instead of each node sending the Geocache over the wireless link as soon as it was received, we have the node keep the Geocache until it drives off the original trajectory. Thus, it exploits an important characteristic of vehicular networks, which is: vehicles move on well-defined and usually bidirectional paths. We will show through analysis and simulations how this characteristic impacts the performance. In connected networks, the increased return probability allows significantly reduced communication overhead by purposefully allowing a node to briefly carry the information away from the anchor location before returning it, instead of constantly keeping the Geocache at the anchor location.

A novel Position-based Opportunistic Routing (POR) protocol is proposed, in which several forwarding candidates cache the packet that has been received using MAC interception. If the best forwarder does not forward the packet in certain time slots, suboptimal candidates will take turn to forward the packet according to a locally formed order. In this way, as long as one of the candidates succeeds in receiving and forwarding the packet, the data transmission will not be interrupted. Potential multipaths are exploited on the fly on a perpacket basis, leading to POR's excellent robustness.

2 RELATED WORKS

2.1 Mobile sensor networks

Recent works in mobile sensor networks exploit mobility when it is not feasible to build a dense network of fixed sensors. Notably, Zebranet [1] places sensors on zebras to collect valuable zoology data. In under water sensor network [13], mobile nodes are robots that collect data from regions of interest. Several projects target specifically at vehicular sensing. CarTel [2], for example, is a comprehensive distributed mobile computing system used to collect, process, and visualize data from sensors located on mobile units. It aims at exploring in-network computing on individual mobile units, as we do, but it does not use intervehicle communication, which in our project, is a main focus to enable distributed aggregation of sensor readings from multiple cars. Another vehicular sensor network.

2.2 MAC interception

We leverage on the broadcast nature of 802.11 MAC: all nodes within the coverage of the sender would receive the signal. However, its RTS/CTS/DATA/ACK mechanism is only designed for unicast. It simply sends out data for all broadcast packets with CSMA. Therefore, packet loss due to collisions would dominate the performance of multicast-like routing protocols. Here, we did some alteration on the packet transmission scenario. In the network layer, we just send the packet via unicast, to the best node which is elected by greedy forwarding as the next hop. In this way, we make full utilization of the collision avoidance supported by 802.11 MAC. While on the receiver side, we do some modification of the MAC-layer address filter: even when the data packet's next hop is not the receiver, it is also delivered to the upper layer but with some hint set in the packet header indicating that this packet is overheard. It is then further processed by POR. Hence, the benefit of both broadcast and unicast (MAC support) can be achieved.

2.3 MAC Callback

When the MAC layer fails to forward a packet, the function implemented in POR— MAC_callback will be executed. The item in the forwarding table corresponding to that destination will be deleted and the next hop node in the neighbor list will also be removed. If the transmission of the same packet by a forwarding candidate is overheard, then the packet will be dropped without reforwarding again; otherwise, it will be given a second chance to reroute. The packets with the same next hop in the interface queue which is located between the routing layer and MAC layer will also be pulled back for rerouting. As the location information of the neighbors is updated periodically, some items might become obsolete very quickly especially for nodes with high mobility. This scheme introduces a timely update which enables more packets to be delivered.

3 OUR WORK

The main challenge for implementing the boomerang protocol lies in the choice of a new carrier node at each handoff, especially if the first handoff occurs somewhere far away from the anchor location. The data may have traveled along a rather complicated route before the current carrier looks for a new carrier. In this case, a single carrier node may not be sufficient to bring back the data; instead, nodes B, C, and D all needed to be involved in this returning process. Efficiently choosing a set of suitable carriers is thus the key to the success of the boomerang protocol. A set of poorly selected carriers may incur a long delay in bringing back the data (note that the data may lose its value after a long delay). The task of choosing appropriate carrier nodes is particularly daunting because at each handoff, neither the current carrier nor the nodes within the hand off range have knowledge beyond their current velocity and location, and the traversed trajectory.

Another challenge is the handoff criteria. When to hand off is a tricky issue, especially at the first time. The first handoff can greatly impact the handoff frequency (and thus communication overhead) and return probability of the Geocache. Recognizing the importance of this problem. The rest of the handoffs are easier to decide. In this paper, we propose a trajectory-based carrier selection approach and compare it to a baseline shortest distance-based selection scheme.

We propose a position-based opportunistic routing mechanism which can be deployed without complex modification to MAC protocol and achieve multiple reception without losing the benefit of collision avoidance provided. The concept of in-the-air backup significantly enhances the robustness of the routing protocol and reduces the latency and duplicate forwarding caused by local route repair.

In the case of communication hole, we propose a Virtual Destination-based Void Handling (VDVH) scheme in which the advantages of greedy forwarding (e.g., large progress per hop) and opportunistic routing can still be achieved while handling communication voids. We analyze the effect of node mobility on packet delivery and explain the improvement brought about by the participation of forwarding candidates. The overhead of POR with focus on buffer usage and bandwidth consumption due to forwarding candidates' duplicate relaying is also discussed.

3.1 POR Algorithm

The design of POR is based on geographic routing and opportunistic forwarding. The nodes are assumed to be aware of their own location and the positions of their direct neighbors. Neighborhood location information can be exchanged using one-hop beacon or piggyback in the data packet's header. While for the position of the destination, we assume that a location registration and lookup service which maps node addresses to locations is available just. It could be realized using many kinds of location service. In our scenario, some efficient and reliable way is also available. For example, the location of the destination could be transmitted by low bit rate but long range radios, which can be implemented as periodic beacon, as well as by replies when requested by the source.

When a source node wants to transmit a packet, it gets the location of the destination first and then attaches it to the packet header. Due to the destination node's movement, the multihop path may diverge from the true location of the final destination and a packet would be dropped even if it has already been delivered into the neighborhood of the destination. To deal with such issue, additional check for the destination node is introduced. At each hop, the node that forwards the packet will check its neighbor list to see whether the destination is within its transmission range. If yes, the packet will be directly forwarded to the destination, similar to the destination location prediction scheme described. By performing such identification check before greedy forwarding based on location information, the effect of the path divergence can be very much alleviated.

In conventional opportunistic forwarding, to have a packet received by multiple candidates, either IP broadcast or an integration of routing and MAC protocol is adopted. The former is susceptible to MAC collision because of the lack of collision avoidance support for broadcast packet in current 802.11, while the latter requires complex coordination and is not easy to be implemented. In POR, we use similar scheme as the MAC multicast mode described. The packet is transmitted as unicast (the best forwarder which makes the largest positive progress toward the destination is set as the next hop) in IP layer and multiple reception is achieved using MAC interception.

The use of RTS/CTS/DATA/ACK significantly reduces the collision and all the nodes within the transmission range of the sender can eavesdrop on the packet successfully with higher probability due to medium reservation. As the data packets are transmitted in a multicast-like form, each of them is identified with a unique tuple (src_ip, seq_no) where src_ip is the IP address of the source node and seq_no is the corresponding sequence number. Every node maintains a monotonically increasing sequence number, and an ID_Cache to record the ID (src_ip, seq_no) of the packets that have been recently received. If a packet with the same ID is received again, it will be discarded. Otherwise, it will be forwarded at once if the receiver is the next hop, or cached in a Packet List if it is received by a forwarding candidate, or dropped if the receiver is not specified. The packet in the Packet List will be sent out after waiting for a certain number of time slots or discarded if the same packet is received again during the waiting period (this implicitly means a better forwarder has already carried out the task).

4 CONCLUSIONS

Constantly changing network topology makes conventional ad hoc routing protocols incapable of providing satisfactory performance. In the face of frequent link break due to node mobility, substantial data packets would either get lost, or experience long latency before restoration of connectivity. Inspired by opportunistic routing, we propose a novel MANET routing protocol POR which takes advantage of the stateless property of geographic routing and broadcast nature of wireless medium. Besides selecting the next hop, several forwarding candidates are also explicitly specified in case of link break. Leveraging on such natural backup in the air, broken route can be recovered in a timely manner. The efficacy of the involvement of forwarding candidates against node mobility, as well as the overhead due to opportunistic forwarding is analyzed. Through simulation, we further confirm the effectiveness and efficiency of POR: high packet delivery ratio is achieved while the delay and duplication are the lowest. On the other hand, inherited from geographic routing, the problem of communication void is also investigated. To work with the multicast forwarding style, a virtual destination-based void handling scheme is proposed. By temporarily adjusting the direction of data flow, the advantage of greedy forwarding as well as the robustness brought about by opportunistic routing can still be achieved when handling communication voids. Traditional void handling method performs poorly in mobile environments while VDVH works quite well.

We have presented the trajectory-based boomerang protocol to periodically make available data at certain geographic locations in a highly mobile vehicular network. The boomerang protocol returns the Geocache through nodes traveling toward the anchor location. To increase the probability of successful return, it records a node's trajectory while moving away from the anchor location then select nodes to return the Geocache based on the trajectory (RevTraj). We compared this scheme with a

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shortest distance georouting scheme MaxProgress, and demonstrated that our scheme significantly outperforms its counterpart in realistic traffic simulation, with a return probability improvement of up to 70 percent. We also extend the boomerang protocol to satisfy more stringent anchoring requirements, such as returning the Geocache within specified time limits. This is achieved through adapting the initial handoff time based on the return time history.

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