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An Efficient Location-based Opportunistic Routing with Virtual Destiny-based Void Handling Scheme for Mobile Ad-Hoc Networks

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Abstract* — This paper addresses the problem of delivering data packets for highly dynamic mobile ad hoc networks in a reliable and timely manner. Most existing ad hoc routing protocols are susceptible to node mobility, especially for large-scale networks. Driven by this issue, we propose an efficient Location-based Opportunistic Routing (LOR) 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 Destiny-based Void Handling (VDVH) scheme is further proposed to work together with LOR. Both theoretical analysis and simulation results show that LOR achieves excellent performance even under high node mobility with acceptable overhead and the new void handling scheme also works well.

***Keywords* — Location-based Opportunistic Routing, local route recovery, Virtual Destiny-based Void Handling.**

I. Introduction

Mobile ad- hoc networks (MANETs) have gained a great deal of attention because of its significant advantages brought about by multihop, infrastructure-less transmission. However, due to the error prone wireless channel and the dynamic network topology, reliable data delivery in MANETs, especially in challenged environments with high mobility remains an issue. Traditional topology-based MANET routing protocols (e.g., DSDV, AODV, DSR [1]) 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. Geographic routing (GR) [2] uses location information to forward data packets, in a hop-by-hop routing fashion. Greedy forwarding is used to select next hop forwarder with the largest positive progress toward the destination while void handling mechanism is triggered to route around communication voids [3]. No end-to-end routes need to be maintained, leading to GR's high efficiency and scalability. However, GPSR is very sensitive to the inaccuracy of location information [4]. In the operation of greedy forwarding, the neighbor which is relatively far away from the sender is chosen as the next hop. If the node moves out of the sender's coverage area, the transmission will fail. In GPSR [5] (a very famous geographic routing protocol), the MAC-layer failure feedback is used to offer the packet another chance to reroute. However, our simulation reveals that it is still incapable of keeping up with the performance when node mobility increases. 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 by 802.11.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 Destiny-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 [6][7]. The overhead of LOR with focus on buffer usage and bandwidth consumption due to forwarding candidates' duplicate relaying is also discussed. Through analysis, we conclude that due to the selection of forwarding area and the properly designed duplication limitation scheme, LOR's performance gain can be achieved at little overhead cost. . Finally, we evaluate the performance of LOR through extensive simulations and verify that LOR achieves excellent performance in the face of high node mobility while the overhead is acceptable. The rest of this paper is organized as follows: we present the protocol design of LOR and complementary mechanisms in Section II. VDVH is depicted in Section III.

II. Location-Based Opportunistic Routing

The design of LOR 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 as in could be realized using many kinds of location service In our scenario, some efficient and reliable way is also available[8]. 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 in [9][10]. The basic routing scenario of LOR can be simply illustrated in Fig. 1.

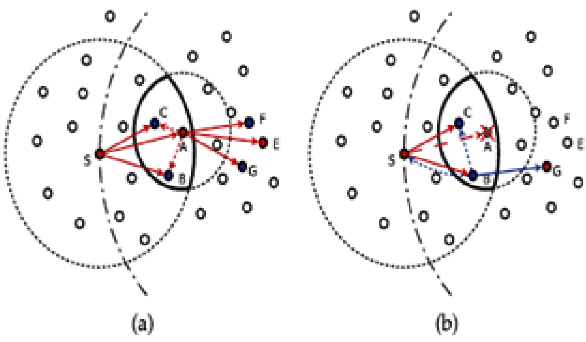

Fig.1.The basic routing scenario of LOR

Forwarding Table in LOR

TABLE 1

(src_ip, dst_ip)	next_hop	candidate_list
(N1, N11)	N4	N5, N6
(N2, N12)	N7	N8, N5
...	...	...

Every node maintains a forwarding table for the packets of each flow (identified as source-destination pair) that it has sent or forwarded. Before calculating a new forwarder list, it looks up the forwarding table, an example is illustrated in Table 1, to check if a valid item for that destination is still available. The forwarding table is constructed during data packet transmissions and its maintenance is much easier than a routing table. It can be seen as a trade-off between efficiency and scalability.

III. VIRTUAL DESTINY-BASED VOID HANDLING

In order to enhance the robustness of LOR in the network where nodes are not uniformly distributed and large holes may exist, a complementary void handling mechanism based on virtual destination is proposed. 3.1 Trigger Node The first question is at which node should packet forwarding switch from greedy mode to void handling mode. In many existing geographic routing protocols, the mode change happens at the void node, e.g., Node B in Fig. 3. Then, Path 1 (A-B-E-_ _ _) and/or Path 2 (A-B-C-F-_ _ _) (in some cases, only Path 1 is available if Node C is outside Node B's transmission range) can be used to route around the communication hole. From Fig. 3, it is obvious that Path 3 (A-C-F-_ _ _) is better than Path 2. If the mode switch is done at Node A, Path 3 will be tried instead of Path 2 while Path 1 still gets the chance to be used. A message called void warning, which is actually the data packet returned from Node B to Node A with some flag set in the packet header, is introduced to trigger the void handling mode. As soon as the void warning is received, Node A (referred to as trigger node) will switch the packet delivery from greedy mode to void handling mode and rechoose better next hops to forward the packet. Of course, if the void node happens to be the source node, packet forwarding mode will be set as void handling at that node without other choice (i.e., in this case, the source node is the trigger node).

Virtual Destiny

To handle communication voids, almost all existing mechanisms try to find a route around. During the void handling process, the advantage of greedy forwarding cannot be achieved as the path that is used to go around the hole is usually not optimal (e.g., with more hops compared to the possible optimal path). More importantly, the robustness of multicast-style routing cannot be exploited. In order to enable opportunistic forwarding in void handling, which means even in dealing with voids, we can still transmit the packet in an opportunistic routing like fashion, virtual destination is introduced, as the temporary target that the packets are forwarded to. Virtual destinations are located at the circumference with the trigger node as center (Fig. 4), but the radius of the circle is set as a value that is large enough (e.g., the network diameter). They are used to guide the direction of packet delivery during void handling. Compared to the real destination D, a virtual destination (e.g., D0 left and D0 right) has a certain degree of offset simulation) in Fig. 2. With the help of the virtual destination.

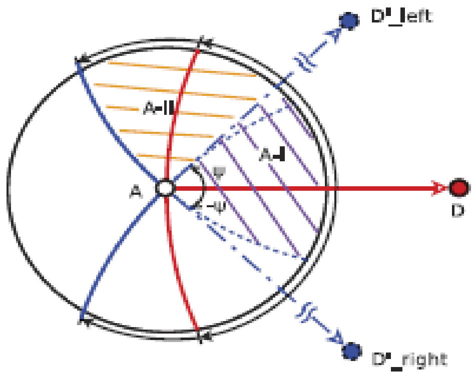

Fig.2.Forwarding area is extended with virtual destination

Forwarding area is significantly extended. Strictly speaking, our mechanism cannot handle all kinds of communication voids, since not all the neighbors of the current node are covered. However, for most situations, it is effective. For those communication holes with very strange shape, a reposition scheme has been proposed to smooth the edge of the hole. Given the work that has been done in, VDVH thus still has the potential to deal with all kinds of communication voids.

IV. ANALYSIS

In this section, theoretical analysis on the robustness of LOR will be conducted. The overhead inclusive of memory consumption and duplicate relaying will also be discussed. Since our focus lies on the effect of node mobility, an ideal wireless channel is assumed in the following part and the unit disc graph model will be used by default: a link between two nodes exists if and only if the distance between them is less than a certain threshold. When two nodes are located inside each others' coverage range (R), bidirectional data transmission between them can be achieved without failure. Robustness versus Mobility Owing to node mobility, it is impossible that the location information of a node's neighbors which is maintained through beacon exchange is always up to date. Here, we only consider the forwarding failure caused by node mobility while the effect of the unreliable wireless link has not be taken into consideration. We believe that in the light traffic case with retransmission scheme implemented in the MAC layer, node mobility should be the main factor resulting in the packet forwarding failure.

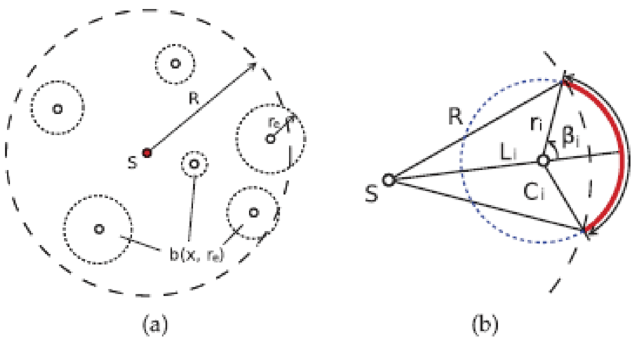

Fig.3. (a) Network model. (b) Out of range caused by node's movement.

4.2 ENHANCEMENT

To enhance a system's robustness, the most straightforward method is to provide some degree of redundancy. According to the degree of redundancy, existing robust routing protocols for MANETs can be classified into two categories. One uses the end-to-end redundancy, e.g., multipath routing, while the other leverages on the hop-by-hop redundancy which takes advantage of the broadcast nature of wireless medium and transmits the packets in an opportunistic or cooperative way. Our scheme falls into the second category. Multipath routing, which is typically proposed to increase the reliability of data transmission in wireless ad hoc networks, allows the establishment of multiple paths between the source and the destination.

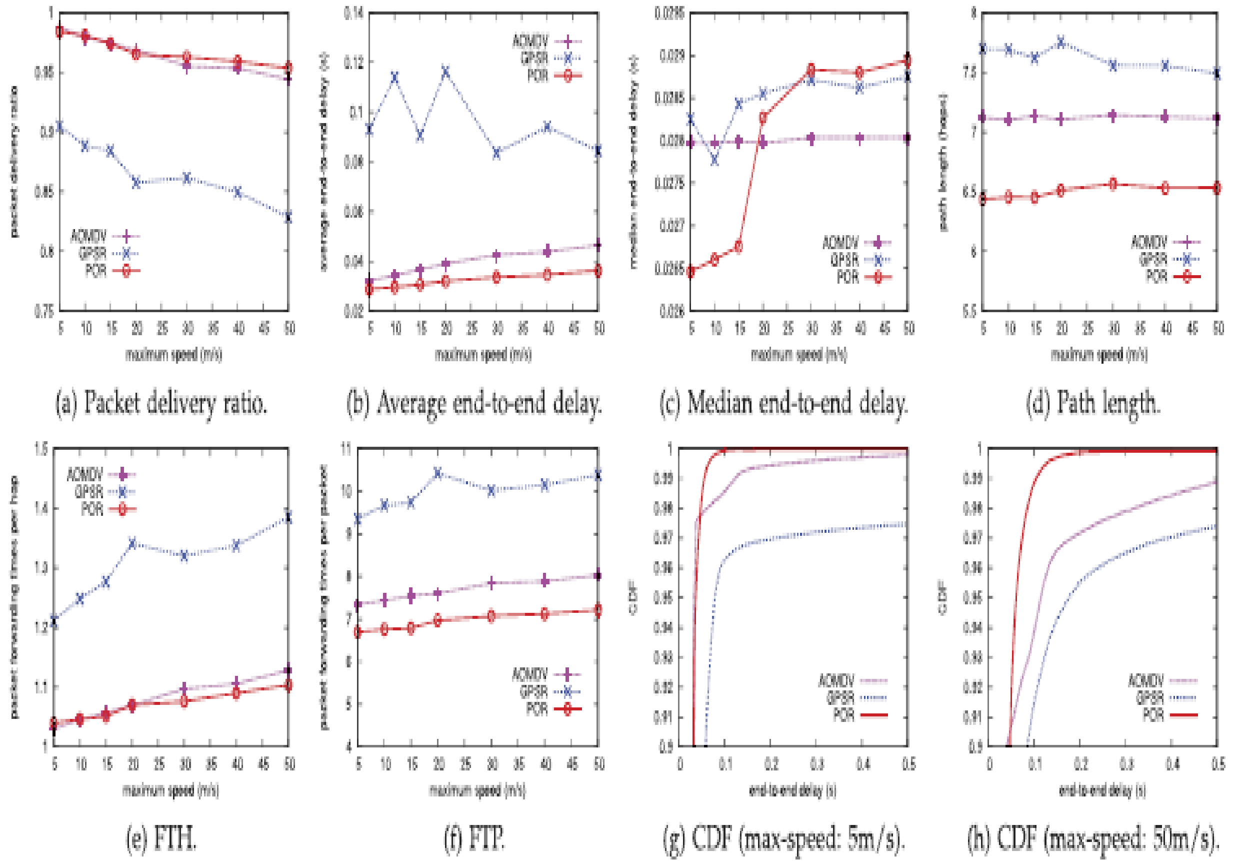

Fig.4. Simulation results: with communication hole.

V. Conclusion

In this paper, we address the problem of reliable data delivery in highly dynamic mobile ad hoc networks. 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 LOR 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 LOR: high packet delivery ratio is achieved while the delay and duplication are the lowest.

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Authors Profile

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