Reliable Data Delivery Mechanisms for Highly Dynamic Mobile Ad Hoc Networks

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Abstract: ***Most existing ad hoc routing protocols are susceptible to node mobility, especially for large-scale networks. The additional latency incurred by local route recovery is greatly reduced and the duplicate relaying caused by packet reroute is also decreased. This paper proposes a Location Based Opportunistic Routing Protocol (LOR)and Void Handling Based on Virtual Destination (VHVD) scheme to addresses the problem of delivering data packets for highly dynamic mobile ad hoc networks in a reliable and timely manner. This protocol 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. Simulation results on NS2 verified the effectiveness of the proposed protocol with improvement in throughput by 28%.***

Keywords: MANET, Geographic Routing, GPSR, AOMDV, LOR

1. Introduction

A mobile ad hoc network (MANET) is a collection of wireless mobile nodes that dynamically establishes the network in the absence of fixed infrastructure. One of the distinctive features of MANET is, each node must be able to act as a router to find out the optimal path to forward a packet. As nodes may be mobile, entering and leaving the network, the topology of the network will change continuously. MANETs provide an emerging technology for civilian and military applications. Since the medium of the communication is wireless, only limited bandwidth is available. Another important constraint is energy due to the mobility of the nodes in nature.

MANETs have gained a great deal of attention because of its significant advantages brought about by multi-hop, infrastructure-less transmission. However, due to dynamic network topology the reliable data delivery in network, especially in challenged environments with high mobility remains an issue. We propose the new structure which takes advantage of the broadcast nature of network. By utilizing intermediate nodes as air-backup, communication is maintained without being interrupted. There will be many candidates' nodes among the network, if the best candidate 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 [1].

Geographic routing (GR) [3] 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 [4]. No end-to-end routes need to be maintained, leading to GR's high efficiency and scalability. However, GR is very sensitive to the inaccuracy of location information [5]. 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 [6] (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.

In fact, due to the broadcast nature of the wireless medium, a single packet transmission will lead to multiple reception. 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 [7]. Recently, location-aided opportunistic routing has been proposed 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, a novel GPS based Location-based Opportunistic Routing (LOR) protocol is proposed. In this 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 multi paths are exploited on the fly on a per packet basis, leading to LOR's excellent robustness.

n 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.

The rest of this paper is organized as follows. Section II reviews the GPSR and AOMDV protocols. and in Section III describes the proposed Location based Opportunistic Routing Protocol and the Related work. The comparative study of the protocols is described by simulations in Section IV and finally Section V concludes the paper.

2. Literature Review

A. Geographic routing

Geographic routing (location/position-based routing) for communication in ad-hoc wireless networks has recently received increased attention, especially in the energy saving area . In geographic routing, each node has knowledge of its own geographic information either via Global Positioning System (GPS) or network localization algorithms, and broadcasts its location information to other nodes periodically. The next relay node is selected only based on the location of the source node, its neighbors and its ultimate destination (contained in the data packet). Therefore, geographic routing is generally considered to be scalable and applicable to large networks.

B. Greedy Perimeter Stateless Routing(GPSR)

GPSR protocol [8] is the earliest geographical routing protocols for ad hoc networks which can also be used for WSN environment. The GPSR adapts a greedy forwarding strategy and perimeter forwarding strategy to route messages. It makes uses of a neighborhood beacon that sends a node's identity and its position. However, instead of sending this beacon periodically and add to the network congestion, GPSR piggybacks the neighborhood beacon on every message that is sent or forwarded by the node. Every node in GPSR has a neighborhood table of its own. Whenever a message needs to be sent, the GPSR tries to find a node that is closer to the destination than itself and forwards the message to that node. However, this method fails for topologies that do not have a uniform distribution of nodes or contain voids. Hence, the GPSR adapts to this situation by introducing the concept of perimeter routing utilizing the right-hand graph traversal rule. Every packet transmitted in GPSR has a fixed number of retransmits [1, 8]. This information is given to the node by the medium access (MAC) layer that is required to be compliant to the IEEE 802.11 standard. This may render the GPSR protocol unusable in its normal form for WSN. The GPSR does not elucidate more on the action taken in case a message is unable to be transmitted even in perimeter mode. Finally GPSR disallows the use of periodic broadcast of the neighborhood beacons and piggybacks these beacons on the messages sent by each node. As a strong geographical routing protocol GPSR is allowing nodes to send packets to a particular location and holding a promise in providing routing support in WSN. Many recent research works in WSN are building applications using GPSR protocol. However, GPSR is not originally designed for sensor networks, several problems are required to be fixed before it is applied in sensor networks

C. AOMDV

AOMDV shares several characteristics with AODV. It is based on the distance vector concept and uses hop-by-hop routing approach. Moreover, AOMDV also finds routes on demand using a route discovery procedure. The main difference lies in the number of routes found in each route discovery. In AOMDV, RREQ propagation from the source towards the destination establishes multiple reverse paths both at intermediate nodes as well as the destination. Multiple RREPs traverse these reverse paths back to form multiple forward paths to the destination at the source and intermediate nodes. Note that AOMDV also provides intermediate nodes with alternate paths as they are found to be useful in reducing route discovery frequency. The core of the AOMDV protocol lies in ensuring that multiple paths discovered are loop-free and disjoint, and in efficiently finding such paths using a flood-based route discovery. AOMDV route update rules, applied locally at each node, play a key role in maintaining loop-freedom and disjointness properties [9].

D. Problem statement

Mostly ad hoc routing protocols are susceptible to node mobility, especially for large-scale networks. One of the main reasons is due to the pre-determination 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. Pre-determination of an end-to-end route will be constructed before data transmission also no guarantee the data will send to destination. Without knowing location requires more time and energy to discovery and recovery the route to send data. So, there is a need for routing protocol which take advantage of location information is required for high amount of data delivery in highly dynamic mobile ad hoc networks.

3. Location Based Opportunistic Routing Protocol (LOR)

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 [6]. 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 multi hop 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 [5]. 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 LOR, we use similar scheme as the MAC multicast mode described in . 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).

A. Void Handling Based on Virtual Destination (VHVD)

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. 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.

A fundamental issue in void handling is when and how to switch back to normal greedy forwarding.. After a packet has been forwarded to route around, the communication void for more than two hops (including two hops), the forwarder will check whether there is any potential candidate that is able to switch back. If yes, that node will be selected as the next hop, but the mode is still void handling. Only if the receiver finds that its own location is nearer to the real destination than the void node and it gets at least one neighbor that makes positive progress towards the real destination, it will change the forwarding mode back to normal greedy forwarding.

In VDVH, if a trigger node finds that there are forwarding candidates in both directions, the data flow will be split into two where the two directions will be tried simultaneously for a possible route around the communication void. In order to reduce unnecessary duplication, two control messages are introduced, namely, path acknowledgment and reverse suppression. If a forwarding candidate receives a packet that is being delivered or has been delivered in void handling mode, it will record a reverse entry. Once the packet reaches the destination, a path acknowledgment will be sent along the reverse path to inform the trigger node. Then, the trigger node will give up trying the other direction. For the same flow, the path acknowledgment will be periodically sent (not on per-packet basis; otherwise, there will be too many control messages). If there is another trigger node upstream, the path acknowledgment will be further delivered to that node, and so on. On the other hand, if a packet that is forwarded in void handling mode cannot go any further or the number of hops traversed exceeds a certain threshold but it is still being delivered in void handling mode, a DISRUPT control packet will be sent back to the trigger node as reverse suppression. Once the trigger node receives the message, it will stop trying that direction.

B. Related work

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. Existing multipath routing protocols are broadly classified into the following three types: 1) using alternate paths as backup .2) packet replication along multiple path and 3) split, multipath delivery, and reconstruction using some coding techniques. However, as discussed, it may be difficult to find suitable number of independent paths. More importantly, in the face of high node mobility, all paths may be broken with considerably high probability due to constantly changing topology, especially when the end-to-end path length is long, making multipath routing still incapable of providing satisfactory performance.

In recent years, wireless broadcast is widely exploited to improve the performance of wireless communication. The concept of opportunistic forwarding, which was used to increase the network throughput [7], also shows its great power in enhancing the reliability of data delivery. In the context of infrastructure networks, by using opportunistic overhearing, the connectivity between the mobile node and base station (BS) can be significantly improved. In, an opportunistic retransmission protocol PRO is proposed to cope with the unreliable wireless channel. Implemented at the link layer, PRO leverages on the path loss information Receiver Signal Strength Indicator (RSSI) to select and prioritize relay nodes. By assigning the higher priority relay a smaller contention window size, the node that has higher packet delivery ratio to the destination will be preferred in relaying.. BSs that overhear a packet but not its acknowledgment probabilistically relay the packet to the intended next hop. With the help of auxiliary BSs, the new protocol performs much better than those schemes with only one BS participating in the communication even if advanced link prediction and handover methods are involved. However, due to the lack of strict coordination between BSs, false positives and false negatives exist. While the aforementioned two schemes deal with the issues in WLANs, which concentrate on the robust routing in mobile wireless sensor networks. In the proposed RRP, traditional ad hoc routing mechanism is used to discover an intended path while the nodes nearby act as guard nodes. Leveraging on a modified 802.11 MAC, guard nodes relay the packet with prioritized back off time when the intended node fails. If the failure time exceeds a certain threshold, the guard node who has recently accomplished the forwarding will become the new intended node. A potential problem is that such substitution scheme may lead to suboptimal paths. Unlike RRP, our protocol uses location information to guide the data flow and can always archive near optimal path. On the other hand, our scheme focuses on the route discovery from the perspective of network layer and no such complex MAC modification is necessary. Forwarding candidates are coordinated using the candidate list and no contention would happen. By limiting the forwarding area, duplication can also be well controlled.

4. Simulation and Results

To evaluate the performance of POR, we simulate the algorithm in a variety of mobile network topologies in NS-2.34 and compare it with AOMDV and GPSR. The common parameters utilized in the simulations are listed in Table 1.

Table 1: Simulation Parameters

Parameter	*Value*
MAC Protocol	IEEE 802.11
Propagation Model	Two-ray ground
Transmission Range	200m
Mobility Model	Random Way Point
Traffic Type	Constant Bit Rate
Packet Size	256 bytes
No. of Nodes	100
Simulation Time	300 Sec

The improved random way point without pausing is used to model nodes' mobility. The minimum node speed is set to 1 m/s and we vary the maximum speed to change the mobility degree of the network. The following metrics are used for performance comparison:

Packet delivery ratio: The ratio of the number of data packets received at the destination(s) to the number of data packets sent by the source(s).

From Fig.1, it is clear that the PDR of the LOR is better w.r.t GPSR and AOMDV. Also PDR decreases when the number of nodes increases.

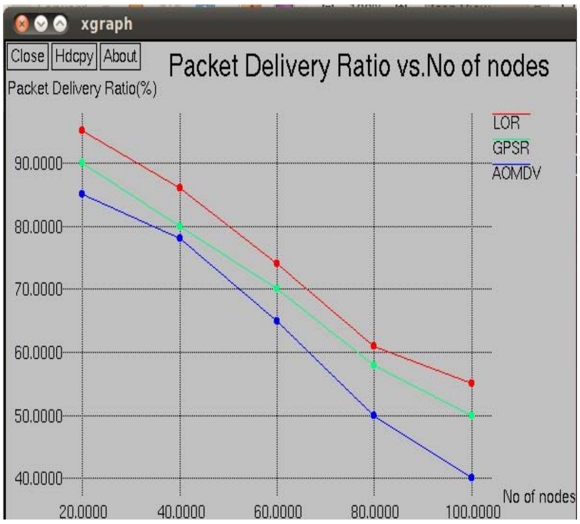

Figure 1: PDR Comparison Graph

Throughput: is the average rate of successful message delivery over a communication channel. Fig 2 shows the increase in throughput when the number of participating node increases.

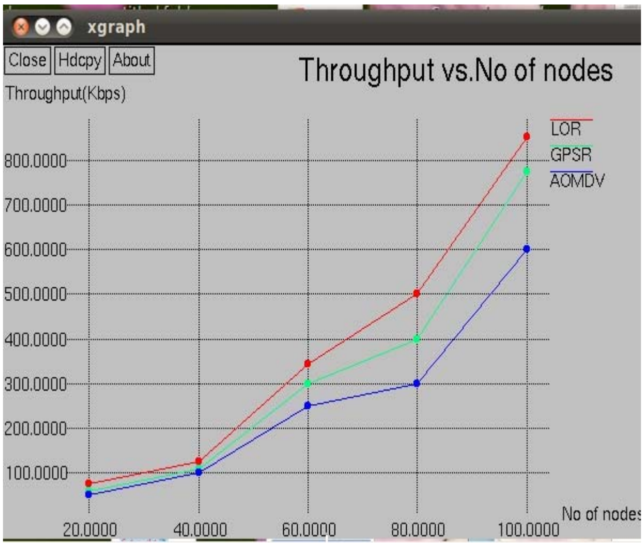

Figure 2: Throughput Comparison Graph

End-to-end delay: The average and the median end-to end delay are evaluated, together with the cumulative distribution function of the delay

End to End Delay will increases as amount of participating node increases. LOR has lower delay compared with others as shown in Fig.3

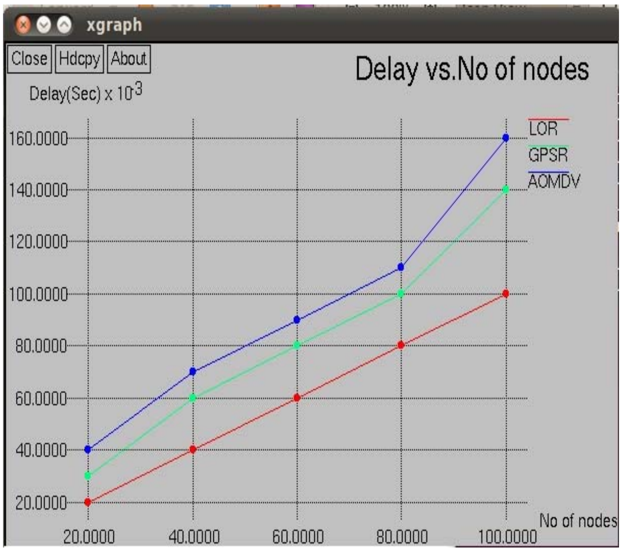

Figure 3: End t End Delay Comparison Graph

5. Conclusion

In this paper, we proposed a location based opportunistic routing protocol and void handling mechanism based on virtual destination, to solve 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. 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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