An Improved technology to increase the delivery ratio using Position based Opportunistic Petal Routing Protocol (POPR) in MANET

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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 topology based ad hoc routing protocols are susceptible to node mobility, especially for large-scale networks. The main reason is due to the predetermination of an end-to-end route before data transmission in existing routing protocols. A novel Position-based Opportunistic Petal Routing protocol (POPR) is proposed which takes advantage of the stateless property of geographic routing and broadcast nature of wireless medium. A Virtual destination based Void handling (VDVH) scheme is further proposed in order to improve the performance of POPR even when the node mobility is high. Performance is evaluated based on the metrics such as packet delivery ratio, End-to-end delay, FTP, FTH, Path length.**

***Keywords*— GPSR, MANET, Opportunistic forwarding, Petal routing.**

I. INTRODUCTION

Mobile Ad-hoc network is a collection of mobile nodes connected via wireless links without using any pre existing network infrastructure or centralized administration [1]. The term "Ad-hoc" implies can take different forms and can be standalone, mobile or networked [18] [20]. The nodes in the network can free to move randomly and organize themselves arbitrarily. Thus the topology of the network may change rapidly and unpredictably.

Traditional topology based MANET routing protocols (like AODV, DSR, DSDV etc.,) are quite susceptible to node mobility [2]. The main reason is due to the predetermination of an end-to-end route before data transmission. In order to transmit the data from source to the destination the route is fixed. Owing to constantly and even fast changing network topology it is very difficult to maintain a deterministic route. If there is an increase in node mobility, the discovery and recovery procedures are time and energy consuming. Once any path breaks, the data transmission will be lost or can be delayed for a long time. Fig 1 shows an example of mobile ad hoc network.

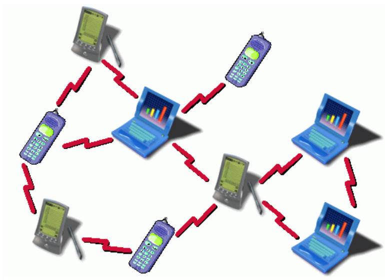


Fig 1: A Typical Mobile Ad hoc network

Geographic routing (GR) [3] that uses node location to address the nodes and forwards the packets by using the location information of the nodes in a hop-by-hop routing fashion, in which Greedy forwarding is one of the techniques which is being used to select next hop forwarder with the largest positive progress toward the destination while void handling mechanism is the other one which is triggered to route around communication voids [4]. Leading to GR's high efficiency and scalability because there is no End-to-end routes that needs to be maintained. If the node moves out of the sender's coverage area the transmission will fail. However, GR is very sensitive to the inaccuracy of location information.

In fact, due to the broadcast nature of the wireless medium, a single packet it will lead to multiple reception [5]. 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 [6].

In this paper, a novel Position-based Opportunistic petal routing (POPR) protocol [7] is proposed, which takes advantage of both the stateless property of geographic routing and the broadcast nature of wireless medium 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, its neighboring candidates will take turn to forward the packet according to a locally formed order. In this way, the data transmission will not be interrupted as long as one of the candidates succeeds in forwarding and receiving the packet.

The main contributions of this paper can be summarized as follows:

- ✓ Proposed a position based opportunistic petal routing protocol (POPR).
- ✓ Proposed a Virtual Destination based Void Handling (VDVH) scheme to improve the performance of POPR in case of communication voids.
- ✓ Finally, the performance of POPR has been evaluated through extensive simulations and it has been proved that POPR achieves excellent performance in the face of high node mobility.

II. POSITION BASED OPPORTUNISTIC PETAL ROUTING

A. *Overview*

The design of POPR is based on geographic routing and broadcast nature of wireless medium. 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.

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. At each hop of transmission, the node that transmits the packet checks the neighbor list whether the destination is within its transmission range or not. If yes, the packet will be directly forwarded to the destination else it simply discards the packet. To deal with such an issue, additional check for the destination node is introduced. 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 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 (sr_ip, se_no) where sr_ip is the IP address of the source node and se_no is the corresponding sequence number. Every node maintains a monotonically increasing sequence number, and an ID_Cache to record the ID (sr_ip, se_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 period.

When a node sends or forwards a packet, it selects the next hop forwarder as well as the forwarding candidates among its neighbors. One of the key points of POPR is that when an intermediate node receives a packet with the same ID (i.e., same source address and sequence number), it means a better forwarder has already taken over the function. Hence, it will drop that packet from its packet list. Besides maintaining the packet list, we also check the interface queue. We do this because when the packet arrives at the routing layer, the same packet might have already been sent down to the lower layers by the current node. With additional inspection of the interface queue, we further decrease the duplicate packets appearing in the wireless channel.

B. *Robust Multipath Routing*

Here, we present a robust on-demand routing scheme for wireless ad hoc networks that we call Petal routing. This routing technique utilizes the broadcast nature of wireless networks to combine multiple transmissions [8]. The basic idea is, given a source and a destination, the concept of flooding takes place to carry out the data transmission from source to the destination. The flooding is constrained with in an area and that we call a petal. The shape of flooding area is modeled as a petal, as shown in Fig 2; here the two ends of the petal in which they converge are at the source and the destination. Since the underlying protocol is flooding, the individual node does not need any prior information about their neighbors or maintain any end-to-end paths. Such protocol that does not need any information about their neighborhood is called beaconless protocol. In order to determine the location of the intermediate node which is located within the petal or outside the petal a parameter called a petal parameter is used. The concept of flooding is determined by the reliability metric, and can be defined on per transmission basis. This technique can also be enhanced by reducing the number of transmissions within the petal.

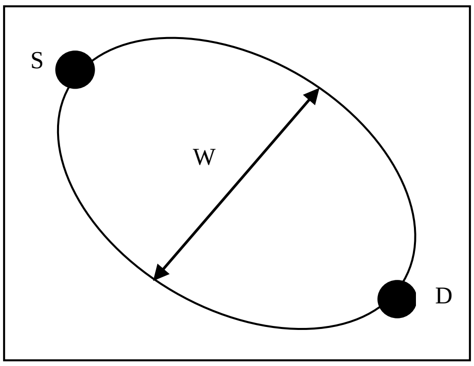


Fig 2: Visualization of a Petal

C. *Assumptions*

In order to minimize the number of individual transmissions in the network, the petal routing uses the methodology of location of the nodes, which determines whether it will take part in certain transmission or not. It is assumed that a node always knows its current location. In addition to that source is also expected to know the location of the destination. Other than the source (which knows the location of the destination), no other node in the network knows the location of any other nodes, other than itself. In addition, each node in the network need not maintain any route to any other nodes, or need not know who their neighbors are. The (x, y) coordinates of the node is in the form: (longitude, latitude). The routing protocol is designed in such a way that the addressing is done by using location of the coordinates. A node's latitude and longitude uniquely identifies it. In other words, the geographic location of a node is its address. The source always sends a packet to a location and not to any IP address.

We assume that the network is reasonably dense, with regard to the nodal density in the network. This is pertinent, because we use multipath routing technique. The routing will fail if there is no path exists within the area of the petal. In case of a sparsely populated network, the approach can be used in combination with table driven approach to store neighborhood information, which can be used in calculating the optimal width of the petal. In a densely populated wireless network, collisions are an important concern and that can lead to poor performance.

Node locations are obtained from a positioning system, such as GPS. In our basic implementation, we assume that the location obtained from the GPS is precise enough for our calculations and also that the nodes in the network are capable of unidirectional transmission. There are no special requirements on directional transmission for petal routing. In addition to that, we assume that all nodes in the network need to be roughly identical and have similar transmission range.

D. *Petal Routing*

When a source transmits a packet it encapsulates the payload with petal headers. We define a petal packet, called petalgram. The structure of petalgram is shown IN Fig: 2.1

ID	Sloc	Dloc	Tloc	W	payload

Fig: 2.1 structure of a petalgram

The headers in a petalgram are as follows.

- Packet ID (ID): a number that uniquely identifies a packet.
- Source Location (Sloc): co-ordinates of the source.
- Destination Location (Dloc): co-ordinates of the destination.
- Transmitter Location (Tloc): location co-ordinates of the node that is transmitting (or transmitted) the packet.
- Petal Parameter (W): This parameter specifies the width of the petal.

Algorithm 1: Schedule or drop packet

Obtain current node location as Ploc
if Ploc = Dloc then
Destination has received packet.
exit
else if Ploc is inside petal
else
This packet was already transmitted by this node so
drop packet.
exit
end if
end if

III. VIRTUAL DESTINATION BASED VOID HANDLING (VDVH)

In order to enhance the robustness of POPR in the network where nodes are not uniformly distributed and large holes may exist, a complementary void handling mechanism based on virtual destination[8][9] is proposed.

A. *Trigger Node*

In many existing geographic routing protocols, the change of mode happens at the void node, e.g., Node B in Fig. 3 [8]. 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(A-B-C-F-….). 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 re choose better next hops to forward the packet.

B. *Virtual Destination*

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.

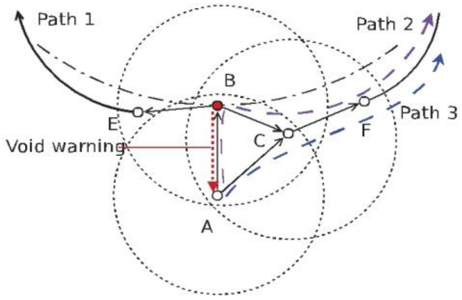


Fig 3: Potential paths around the void

C. *Path Acknowledgment and Disrupt Message*

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 acknowledgement 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 acknowledgement will be sent along the reverse path to inform the trigger node. Then, the trigger node will give up trying the other direction.

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 in that direction.

IV. SIMULATION DESIGN

Simulation has been done with pause time 0.0ms, which is considered as by default value. We implemented the Random waypoint mobility model for the random motion of the nodes. Traffic type between the nodes is CBR (Constant Bit Rate) with packet size of 256-bytes and packet-sending rate is 4 packets per second. The common parameters utilized in the simulation are listed in Table 1.

Table 1 Simulation parameters

Parameter	Value
Mac protocol	IEEE 802.11
Propagation model	Two-ray ground
Transmission range	250m
Mobility model	Random way point
Number of nodes	100
Simulation time	500sec
Traffic type	Constant bit rate(CBR)

V. PERFORMANCE EVALUATION

To evaluate the performance of POPR, the algorithm has been simulated in a variety of mobile network topologies in NS-2[11] [19] and compared with AODV (Ad hoc On-Demand Distance Vector), GPSR (Greedy perimeter stateless routing) and POR (Position Based Opportunistic Routing).

AODV (Ad hoc On-Demand Distance Vector) [12] is a reactive routing protocol. It minimizes the number of broadcasts by creating routes based on demand. When any source node wants to send a packet to a destination, it broadcasts a route request (RREQ) packet. The neighboring nodes in turn broadcast the packet to their neighbors and the process continues until the packet reaches the destination. During the process of forwarding the route request, intermediate nodes record the address of the neighbor from which the first copy of the broadcast packet is received. This record is stored in their route tables, which helps for establishing a reverse path [13]. If additional copies of the same RREQ are later received, these packets are discarded. The reply is sent using the reverse path.

GPSR (Greedy Perimeter Stateless Routing) [14] is a responsive and efficient routing protocol for mobile ad hoc networks. Unlike established routing algorithms before, which use graph theoretic notions of shortest paths and transitive reach ability to find routes, GPSR exploits the correspondence between geographic position and connectivity in a wireless network, by using the positions of nodes to make packet forwarding decisions. GPSR uses greedy forwarding to forward packets to nodes that are always progressively closer to the destination. In regions of the network where such a greedy path does not exist (i.e., the only path requires that one move temporarily farther away from the destination), GPSR recovers by forwarding in perimeter mode, in which a packet traverses successively closer faces of a planar sub graph of the full radio network connectivity graph, until reaching a node closer to the destination, where greedy forwarding resumes.

POR (Position Based Opportunistic Routing) [15] is a position based routing protocol which uses the location of the mobile nodes in the network to forward the packet from source to the destination. The nodes are assumed to be aware of their own location and the positions of their direct neighbors. In normal situation without link break, the packet is directly forwarded by the next hop node. In case if any intermediate node fails to forward the packet its neighboring node with highest priority will forward the packet [16]. The nodes which are near to the destination that nodes are considered as the highest priority. Only the nodes located in the forwarding area [17] would get the chance to be backup nodes. The forwarding area is determined by the sender and the next hop node. A node located in the forwarding area should satisfy the two conditions: 1) It makes positive progress toward the destination; and 2) Its distance to the next node should not exceed half of its transmission range.

The following metrics are used for performance comparison.

A. Packet Delivery Ratio: The ratio of the number of data packets received at the destination to the number of data packets sent by the source.
Packet delivery ratio = ∑ Number of packets receive / ∑ number of packet send
The greater the value of packet delivery ratio means the better performance of the protocol.

B. End-to-end Delay: The average time taken by a data packet to arrive in the destination. It also includes the delay caused by route discovery process and the queue in data packet transmission. Only the data packets that successfully delivered to destinations that counted.
End-to-end Delay = ∑ (arrive time-send time) / ∑ number of connections.
The lower the value of end to end delay means the better performance of the protocol.

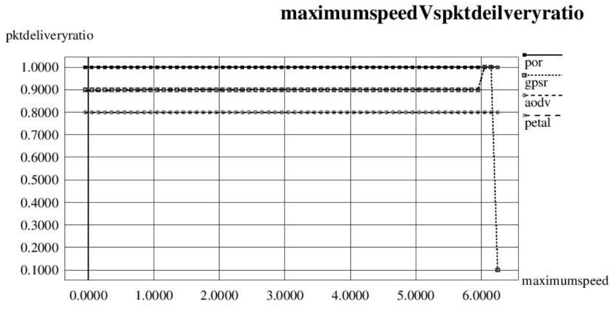
C. Packet forwarding times per packet (FTP): The average number of times a packet is being forwarded to deliver a data from the source to destination.

D. Packet forwarding times per hop (FTH): The average number of times a packet is being forwarded to deliver a data packet over each hop.

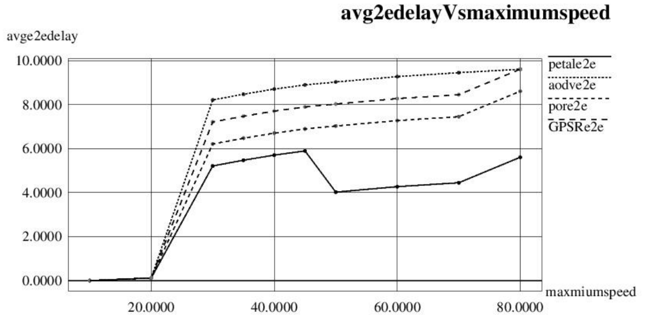
E. Path length: The average end-to-end path length (number of hops) for successful packet delivery.

VI. RESULTS AND ANALYSIS

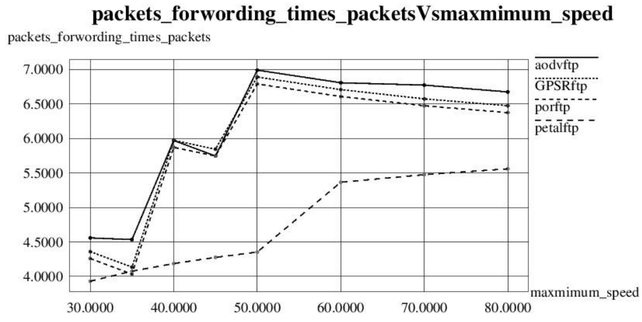
Experimental simulation results of AODV, GPSR, POR and POPR routing protocols which are obtained using NS-2.34 Simulator.



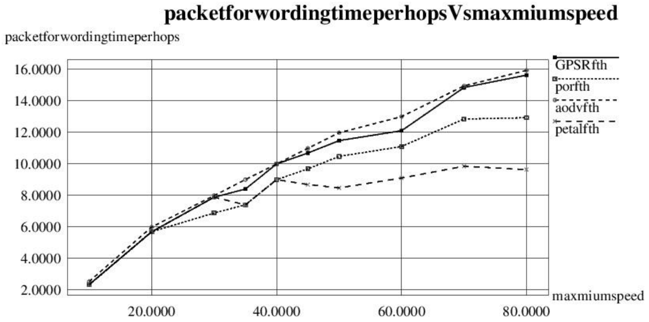
a) Packet delivery ratio



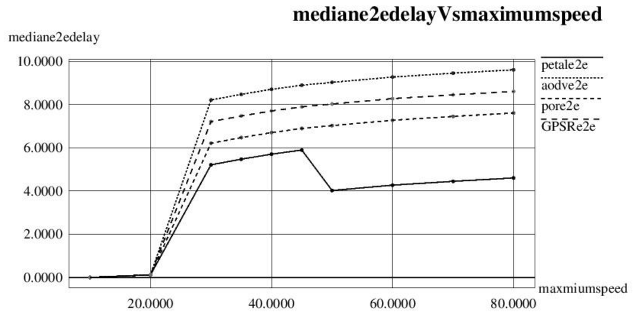
b) Average End-to-end delay



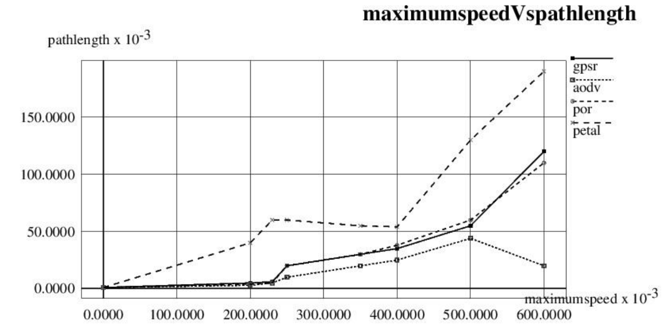
c) Packet forwarding times per packet (FTP)



d) Packet forwarding times per hop (FTH)



e) Median End-to-end delay



f) Path length

Fig: 6 Simulation results

Fig: 6 show the simulations results of POPR. POPR performs well than other three protocols and it remains consistent in Packet Delivery Ratio as it supports high level of mobility as well as large number of nodes and also it achieves and delivers as many as packets with extremely low delay. GPSR seems to be better than AODV when the node mobility is not so high but fails to keep the performance when the node mobility exceeds certain threshold.

VII. CONCLUSION

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. Proposed a novel MANET position based opportunistic petal routing protocol (POPR) which takes the advantage of stateless property of geographic routing and broadcast nature of wireless medium. The information is sent through multiple source destination paths so that even if one path fails, the destination has a higher probability of receiving the information via the other path. In order to improve the performance of POPR in case of communication voids, a virtual destination based void handling technique (VDVH) is also proposed. By temporarily adjusting the direction of data flow, the advantage of greedy forwarding is achieved. Evaluated the performance of POPR through extensive simulation using NS-2 simulator and it achieves excellent performance in high packet delivery ratio while the delay and the duplication are the lowest even when node mobility is high.

VIII. DISCUSSIONS

Multipath routing [8] which is used to increase the reliability of data transmission in wireless ad hoc networks, allows the establishment of multiple paths between the source and the destination. To make network communication more reliable, this work can also be extended by reducing the number of transmissions in the petal area. So the redundancy of duplicate relaying can further get reduced.

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