Towards Optimal Data Delivery in Highly Mobile Wireless Ad Hoc Networks

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***Abstract*—Opportunistic routing overcomes most of the issues and challenges faced by traditional topology based routing protocols in highly mobile ad hoc networks. Opportunistic routing alleviates the impact of poor transmission links in wireless networks by making use of the broadcast nature of the wireless medium and path diversity. In opportunistic routing a list of candidate nodes are selected and prioritized using a metric calculated dynamically from the network. When a data packet is transmitted, the candidate nodes coordinate and select one best forwarder to forward the data packet towards the destination. This opportunistic forwarding strategy continues till the packet reaches the destination. In recent times a number of opportunistic routing protocols have been proposed for mobile ad hoc networks. The packet delivery rate of most of these protocols decreases with increased mobility in the network. In this research paper we propose a method Optimal Data Delivery Routing (ODDR) that uses the help of intermediate nodes as back up nodes in data forwarding to achieve approximate 100% data delivery in highly mobile ad hoc networks. Simulation results show that our method achieves the highest data delivery compared to the latest opportunistic protocols in highly dynamic**

Keywords- Mobile ad hoc networks, Data delivery, Opportunistic routing, Packet delivery ratio, Routing protocols.

I. INTRODUCTION

Mobile ad hoc networks are a collection of wireless devices that can configure by itself to form self sustainable networks. They can be deployed in various environments without the help of any infrastructure. Mobile ad hoc networks do not have any centralized control. All the devices in the network take part in the routing process of data packets. Every device is free to enter and leave the network at any point of time. This keeps the topology of the network dynamic throughout. The wireless devices in the network may be mobile phones, laptops, tablets etc. These unique features of mobile ad hoc networks have enabled researchers to use them in a variety of applications ranging from battlefield communications [1-2] to disaster recovery operations [3]. The popularity of ad hoc networks are rising day by day and they are currently used in setting up conferences, organizational networks and providing internet to rural areas [4].

Modern ad hoc networks have raised a number of challenges to the research community. Constantly increasing mobility of wireless devices has been the prime area of research. Conventional protocols such as DSR [5], DSDV [6], AODV [7] and TORA [8-9] that depend on predetermined routes to the destination does not perform well with mobile ad hoc networks [10-12]. As the speed of wireless devices increases in the network, more and more data packets get dropped in the network leading to increased delay and congestion [13-14]. Moreover using these protocols, the data delivery in the network comes down drastically with increased mobility. Opportunistic routing protocols [15-20] have been introduced to tackle these problems in the networks.

II. OPPORTUNISTIC ROUTING

Opportunistic routing protocols utilize the broadcasting property of the wireless channel to increase the number of devices retransmitting a data packet [21-22]. When a device wants to send a data packet to the destination it broadcasts the data packet into the network. Neighboring devices within its transmission range receives the data packet. Using the value of metrics like ETX [20] and Packet Advancement [3] calculated dynamically from the network, these neighboring devices are given priorities. These devices then coordinate with each other and select the best priority device to forward the data packet. The best priority device then forwards the data packet and this opportunistic forwarding strategy continues till the data packet reaches the target device.

The concept of opportunistic routing was given by Extremely Opportunistic Routing Protocol (ExOR) [20] protocol in 2005. This protocol effectively utilized the broadcasting property of the wireless channel and exploited the multiple transmission opportunities existed in ad hoc networks. But the major drawback with this protocol was the usage of link state style topology database to calculate the ETX metric for assigning priority to the forwarding candidates. It was difficult to manage the network with increasing speed of the devices and periodic measurements of the metrics also became tough with ExOR protocol. In order to improve the performance, the Economy [23] protocol was proposed. The primary objective of the protocol was to improve the efficiency of opportunistic routing by reducing the number of duplicate transmissions in the network. But the modification that was made in opportunistic routing lead to considerable overhead in this protocol. Simple Opportunistic Adaptive Routing Protocol (SOAR) [21] protocol used the same features of the ExOR protocol with batch mechanism but was unable to improve on the performance in the network. To reduce the load on the network the Fixed Point Opportunistic Routing (FPOR) [24] protocol was proposed that used encounter probabilities to generate the candidate list for the nodes in the network. But this protocol was not able to handle high mobility in the network. The Opportunistic Flooding [25] protocol introduced for error prone links also couldn't handle high mobility in the network. Some other opportunistic routing protocols like Interference-Limited Opportunistic Relaying (ILOR) [26] and Simple, Practical, Effective Opportunistic Routing (SPOR) [27], used the channel propagation attributes for computing the relay candidate set. But again these protocols assumed that the value of the metrics remained constant throughout a data transmission which is never true in extremely dynamic ad hoc networks. A new category of opportunistic protocols used the location information of the devices in the network for routing the data packet. Geographic Opportunistic Routing (GOR) [28] was one of the earliest protocols in this category that used a much more efficient timer based coordination scheme. Although network throughput was increased with this protocol, there was considerable duplicate transmission between the mobile devices. Directed Transmission Routing Protocol (DTRP) [29] was proposed for improved data transmission within sensor networks. DTRP treated the transmitting probabilities of the data packet at every device in a different way and this enabled the protocol to prioritize the forwarding of data packets. But DTRP used the beacon packets to get the hop count values that reduced the available energy with the devices. Recently a number of optimised opportunistic routing protocols were proposed that used graph theory and other mathematical methods to optimise the candidate relay set. One such protocol Localized Opportunistic Routing (LOR) [30] segregates the entire topology of the network into smaller topologies using graph theory. But even LOR could not guarantee high data delivery in the network and the performance degrades with increased mobility in the network.

As the number of wireless devices are growing exponentially every day, it is very important for opportunistic protocols to deal with the issues of high mobility and scalability. Moreover many applications of ad hoc networks like communication between rescue officers in disaster recovery operations requires high data delivery rate. In this research paper we examine the possibilities in which an optimal data delivery could be achieved using opportunistic routing. Using lower priority nodes as backup, our method Optimal Data Delivery Routing (ODDR) shows that near to 100% data delivery can be obtained in fast changing ad hoc networks. Simulations are carried out with the proposed method to measure the data delivery rate in various mobility scenarios. The performance of ODDR is then compared with the latest opportunistic routing protocols.

III. Optimal Data Delivery Routing (ODDR)

In this section we examine the possibilities of optimal data delivery in extremely dynamic ad hoc networks with opportunistic routing. The working of the proposed method, Optimal Data Delivery Routing (ODDR) is very simple. When a wireless device wants to transmit a data packet to another device, it broadcasts the data packet into the network. All the neighboring devices within its transmission range receive the packet using MAC interception[26]. These neighboring devices constitute our potential forwarding devices. We then calculate the distance of each potential forwarding device to the destination device. The device that is nearest to the destination device is given the top priority followed by the other devices in the respective order of nearness to the destination. The top priority device is then selected to forward the data packet. If the top priority device does not forward the data packet within a particular time, the next priority device in the list forwards the data packet. Hence data forwarding is assured as long as there is one device in the potential forwarder list and high data delivery rate is achieved.

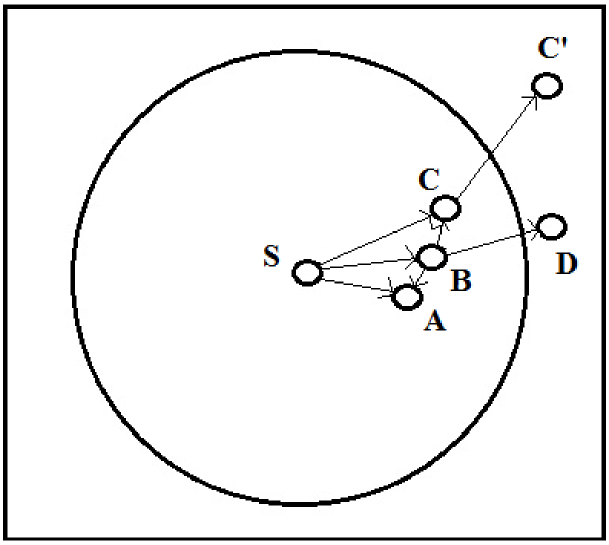

Figure 1. Working of ODDR

Figure 1 shows the working of ODDR. Here wireless device S wants to send data to another device D in the network. Device S broadcasts the data packet into the network, which is received by devices A, B, C which are in its transmission range. These devices are added into the potential forwarder list for device S. Now the distance of each of these devices to the destination is calculated and the list is sorted as C, B, A.

Device C that is nearest to the destination is selected as the best forwarder device to forward the data packet. In normal conditions device C forwards the data packet to the destination. But here device C moves away from the current location and is unable to forward the data packet. Device B waits for a particular time and if it does not receive a copy of the data packet, it assumes that device C has moved out of the transmission range. So device B which is the second priority candidate forwards the data packet to the destination D. Device C also receives a copy of the data packet and understands that a higher priority device have already forwarded the data packet. So device C drops the data packet, thus avoiding duplicate transmissions. In this way packet retransmission occurs as long as there is at least one device in the potential forwarder list and using this method optimal data delivery in extremely mobile networks could be achieved.

Algorithm for Priority List Generation

Let Source Node be S and Destination node be D
Let NN.list be the list of all neighboring nodes of S.
Let T_R be the Transmission Range of I_N
Let T be Timer for retransmission by back up nodes
When a data packet reaches an intermediate node I_N

1. Begin
2. Identify all the neighboring nodes of I_N and add it to a list NN.list
3. Calculate the distance from each node in NN.list to the destination node D
4. Sort the List in increasing order of distance to destination.
5. Assign highest priority to the first node in the list.
6. Select the node with highest priority to forward the data packet.
7. Check if any other nodes are in the transmission range $T_{R.}$ If Yes add them to NN.list
8. Check if any nodes in NN.list are not in the transmission range $T_{R.}$ and remove them from the list.
9. End

Algorithm for Data Forwarding

When a data packet reaches an intermediate node I_N

1. Begin
2. Check if I_N is marked as the highest priority node in the data packet. If yes go to step 3.Else go to step 4
3. Forward the data packet.
4. Wait for retransmission time T
5. If packet is received within T go to step 6,else go to step 3
6. Discard the packet and update the list
7. End

Protocol	Type	Metric Used	Coordination Method	Issues and Demerits
ExOR	Link state OR	ETX	Timer and Acknowledgement	Periodic ETX measurement is very difficult in highly dynamic ad hoc networks
Economy	Link state OR	ETX	Token	Very high overhead in communication
SOAR	Link state OR	ETX	Timer	Periodic ETX measurement is very difficult in highly dynamic ad hoc networks
FPOR	Probabilistic OR	Delay	Timer	Less reliable in dynamic networks
Opportunistic Flooding	Probabilistic OR	Delay	Overhearing	Performance degrades with increase in mobility of wireless devices in the network
ILOR	Probabilistic OR	SNR	Contention Based	Less reliable in dynamic networks
SPOR	Probabilistic OR	PDR	Overhearing	Less reliable in dynamic networks
GOR	Geographic OR	Geo-distance	Overhearing	Duplicate packet retransmissions in highly mobile ad hoc networks
DTRP	Probabilistic OR	Hop count	Timer	Very high overhead in communication
LOR	Optimization OR	Link quality	Overhearing	Very high overhead in communication
ODDR	Geographic OR	Geo-distance	Timer	Buffer occupancy

IV. PERFORMANCE EVALUATION

The performance of the ODDR is assessed using simulations in network simulator-2 [32-33]. Different ad hoc topologies are generated in simulation scenarios. We carry out simulations with 100 nodes distributed uniformly in the network of 500m×400m. Constant Bit Rate traffic is generated between the sender and receiver nodes. Random Waypoint model [34] is used for movement of the nodes. The mobility of the devices is varied in the network and the corresponding Packet Delivery Ratio is measured. Packet Delivery Ratio gives the ratio of the number of data packets successfully delivered at the destination to the number of data packets send by the source device. Table 2 show the packet delivery ratio when the speeds of nodes are varied from 0 to 10 m/s. Figure 2 shows the packet delivery ratio of the network when the mobility of nodes are varied from 0 to 40 m/s.

Table 2. Packet Delivery Ratio

Speed of the Mobile Devices (m/s)	Packet Delivery Ratio
0	0.9992
2	0.9991
4	0.9991
6	0.9987
8	0.9985
10	0.9985

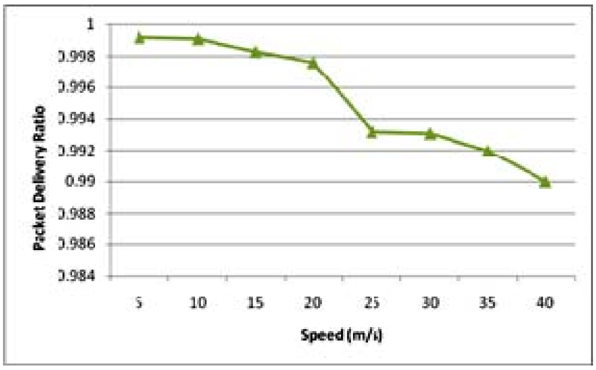

Figure 2. Packet Delivery Ratio vs Speed (ODDR)

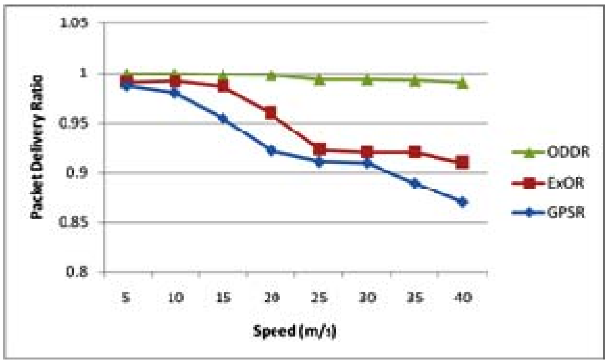

Figure 3. Packet Delivery Ratio vs Speed (Comparison)

The figure clearly shows that our proposed method ODDR achieves a packet delivery ratio near to 1. This proves that almost all the packets that are send by the source device are delivered successfully at the destination. Figure 3 shows the comparison of Packet Delivery Ratio of ODDR with GPSR [35] and ExOR protocols. The graph clearly shows that the ODDR maintains a very high delivery rate even in high mobility environments compared to the other two protocols. This high data delivery rate is achieved because of the data forwarding by the backup nodes in the network. Data forwarding till the destination is assured as long as there is one device in the potential forwarder list. Table 1 shows the issues and challenges experienced by the various opportunistic routing protocols in highly mobile ad hoc networks. Most of the protocols suffer from serious performance degradations, duplicate transmissions and increased overhead in highly dynamic networks. But as ODDR uses geo-distance as the metric and retransmission timer as the coordination method along with the backup nodes, it gives very high performance in highly mobile ad hoc networks with very less communication overhead.

V. CONCLUSIONS

In this research paper we examined the possibilities of achieving optimal data delivery in extremely mobile ad hoc networks with opportunistic routing. We initially discussed the problems and challenges faced by the existing opportunistic protocols in fast changing ad hoc networks. We then discussed the proposed method Optimal Data Delivery Routing (ODDR) in detail. ODDR prioritized the potential forwarding nodes based on their nearness to the destination and selected the node that is nearest to the destination as the highest priority node. This node is selected to forward the data packet to the destination. Due to mobility if this node moves away from transmission range, based on a set timer, the next priority node is selected to forward the data packet. So data delivery is guaranteed as long as there is one node in the potential forwarder list. Simulation results showed that the proposed method achieved very high data delivery in extremely mobile ad hoc networks.

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