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Eliminating Redundant Relaying of Data Packets for Efficient Opportunistic Routing in Dynamic Wireless AD HOC Networks

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Abstract: Number of wireless devices connected via ad hoc networks has been growing exponentially over these years with increased mobility and resource usage. Routing of data packets from the source to the destination device has been a major issue in dynamic wireless networks. Traditional topology based routing protocols suffer from increased mobility in the network and cannot guarantee the expected quality of service. To overcome this issue a new class of highly flexible routing protocols were proposed that opportunistically forward the data packets from one node to the other based on current channel characteristics and mobility. These opportunistic routing protocols utilize the broadcasting nature of the wireless medium to achieve high data delivery in dynamic ad hoc networks. But this high data delivery comes at a cost of increased redundant packets and duplicate data forwarding in the network. Limited research has been done in increasing the efficiency of opportunistic routing protocols in highly dynamic networks. This study aims to improve the efficiency of opportunistic routing protocols in highly dynamic ad hoc networks by eliminating redundant data forwarding at the mobile wireless devices. The proposed method helps to control relaying of data packets at each node in the network on a per packet basis using information piggybacked on each packet. Simulation results show that the proposed method reduces duplicate data forwarding considerably in the network leading to higher efficiency in opportunistic routing.

Key word: Ad hoc networks, data forwarding, opportunistic routing, redundant packets, wireless devices

INTRODUCTION

Mobile ad hoc networks are a collection of devices like mobile phones and laptops that can dynamically form a wireless network without the use of any infrastructure or centralized control. The network does not have any centralized control and every device in the network is given equal importance. Every device in the network acts as a router and a host and plays equal role in routing the data packets from the source to the destination device. Most of the devices continuously move from one place to another and thus the topology of the network remain dynamic. Due to its numerous advantages, mobile ad hoc networks are increasingly being used in wide range of applications like battlefield communication (Leiner *et al*., 1996), organizational networks (Chakchouk, 2015), disaster recovery operations (Menon *et al*., 2016). The numbers of wireless devices connected to these networks are increasing at a very high rate and the networks are becoming much bigger each day. With increased mobility of devices in the network, routing of data packets from the source to the destination has become a great challenge. Random and unpredictable movement of the wireless devices has made these networks highly dynamic. Traditional topology based protocols like DSR (Maltz, 1996), DSDV (Perkins and Bhagwat, 1994), DSR (Perkins and Royer in 1994) and TORA (Park *et al*., 1998) depend on end to end pre-determined routes for data delivery which is not possible in these highly dynamic environments. So the performance of these protocols comes down with increased mobility in the network (Menon *et al*., 2013a, b; Menon and Prathap, 2016, 2013a, b). Recently a new class of routing protocols has been proposed that would opportunistically forward the data packets from one node to the other based on current channel characteristics and mobility. These opportunistic routing protocols (Biswas and Morris 2005; Conan *et al*., 2008; Fang *et al*., 2011; Bhorkar *et al*., 2012; RameshKumar and Anithaa, 2016; Li *et al*., 2013; Menon *et al*., 2016) utilize the broadcasting nature of the wireless medium to achieve high data delivery in dynamic ad hoc networks. They select one best forwarder from the neighboring node list based on some metrics like Expected Transmission Count (Biswas and Morris, 2005), Packet Advancement (Menon *et al*., 2016). The main advantage is that the metric values for selecting the best forwarder node is obtained dynamically from the network and that would be unique for each data packet. While analyzing

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the working of the major opportunistic protocols it was found that redundant data packets generated by broadcasting and duplicate relaying of these packets at each device were the major reasons of transmission inefficiency in the network.

Very few research study have focused on improving the transmission efficiency of opportunistic routing protocols in highly dynamic ad hoc networks. In this study we modify the latest opportunistic routing scheme that is currently used in ad hoc networks to improve the transmission efficiency in the network. The proposed method helps to control relaying of data packets at each node in the network on a per packet basis using information piggybacked on each packet and eliminates duplicate data forwarding at the mobile devices for better efficiency in opportunistic routing. Only the nodes that reply with an acknowledgement are considered for forwarding the data packet. Among the nodes that reply with the acknowledgement, the node that is nearest to the destination is selected for forwarding. All the remaining nodes do not act on the data packet.

Literature review: A number of opportunistic routing algorithms have been proposed over these years for better quality of service in the network. Some of these algorithms (Biswas and Morris 2005), use the value of expected transmission count to figure out the best path for the data packet from each node to its neighboring node. Periodic network wide measurements are required for this method, which is often infeasible in highly dynamic networks. Algorithms (Conan *et al*., 2008; RameshKumar and Anithaa, 2016; Fang *et al*., 2011; Bhorkar *et al*., 2012; Li *et al*., 2013;) focus on improving the data delivery rate in the network by broadcasting the data packet to all the neighboring nodes. Although these methods improve the data delivery rate in the network, large number of duplicate data forwarding takes place. None of the works have focused on improving the transmission efficiency of opportunistic routing protocols by reducing the redundant relaying of data packets by the wireless devices in the network.

MATERIALS AND METHODS

The proposed method controls the relaying of data packets by every mobile device in the network and thus helps in eliminating duplicate forwarding of data packets. Figure 1 illustrates the working of the proposed method. Let us consider a wireless mobile ad hoc network with 5 nodes S, A, B, C and D. We assume that all the devices are highly mobile and they move randomly in the network. Here source node S wants to send data packets to the destination node D. We assume that each node is aware of its position and the position of its direct neighbours (Karp and Kung, 2000). Position information can be obtained through GPS. Using the opportunistic routing strategy, we generate a priority list of forwarders based on their nearness to the destination device. So our list would be C, B, A in the descending order of their priority. We piggyback a new field in the data packet header which is shown in Table 1. The initial sequence values (sequence numbers) for nodes A, B, C would be 0 in data packet P1. Using the broadcasting property of the wireless network, device S broadcasts the data packet P1 intended for the destination device D. The source node S receives acknowledgement for data packet P1 from node A only. This may be caused due to mobility of nodes B and C. Also node A does not forward the data packet immediately and it waits for subsequent packets. Now the source node modifies the sequence value of node A to 1 in the special field and piggybacks it to packet P2 and broadcasts the data packet. The data packet P2 is received by all the three nodes. Node A forwards the data packet P1 as soon as it receives the data packet P2 with sequence value 1(1 is the sequence number of data packet P1).The major advantage is that nodes A, C does not forward the data packet because the sequence value for those nodes in data packet P2 is 0 and thus we eliminate duplicate forwarding of data packets by these nodes. Now source node S receives acknowledgements from all the three nodes for packet P2. Source node modifies the sequence value table and gives value 2 for node C which is the node that is nearest to the destination among the three. This value is piggybacked in packet P3. Node C forwards the data packet P2 as soon as it receives packet P3 with value 2. This technique only the best forwarder node forwards data packet thus, eliminate duplicate forwarding of data packets at the other devices in the network.

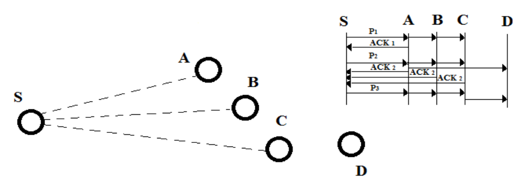

Fig. 1: Working of the proposed method

Table 1: Sequence values

Packet P1 (Initial value)		Packet P2		Packet P3node	
Node	Sequence value	Node	Sequence value	Node	Sequence value
A	0	A	1	A	1
B	0	B	0	B	0
C	0	C	0	C	2

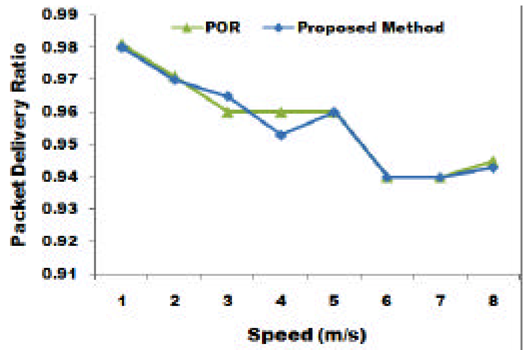

Fig. 2: Packet delivery ratio vs speed

Table 2: Simulation parameters

Parameter	Values
MAC protocol	IEEE 802.11
Number of nodes	100
Mobility model	Random way point
Packet size	512 Bytes
Transmission range	250 m
Simulation time	600 s
Network dimension	1000×1000 m
Traffic	Constant bit rate

RESULTS AND DISCUSSION

We use simulations in Network Simulator-2 to evaluate the performance of our method. About 100 nodes are distributed uniformly in the network and the sender and receiver nodes are placed at the two ends. Mobility is introduced in the network with random way point mobility model (Yoon *et al*., 2003). We generate constant bit rate traffic from the source to the destination. We vary the speed of mobile nodes from 0-40 m sec^{-1} and measure the corresponding performance in the network. Table 2 shows the parameters used in simulation. We use two metrics packet delivery ratio and packet forwarding times per hop to measure the performance of the proposed method. Packet delivery ratio measures the delivery rate of data packets in the network and packet forwarding times per hop measures the number of times the packet is forwarded from the routing layer to the application layer which helps in measuring duplicate forwarding at the wireless nodes.

Figure 2 shows the packet delivery ratio of the proposed routing method with increasing mobility of nodes. The performance of the proposed method is compared with the latest POR (RameshKumar and Anithaa, 2016) protocol. We use POR protocol for comparison because this method gives high data delivery rate among all the existing opportunistic routing protocols in dynamic networks. We can see that our proposed method gives data delivery rate similar to POR in dynamic ad hoc networks. Our main focus is in Fig. 3 which shows the variation in packet forwarding times per hop with increasing mobility of nodes in the network. This value

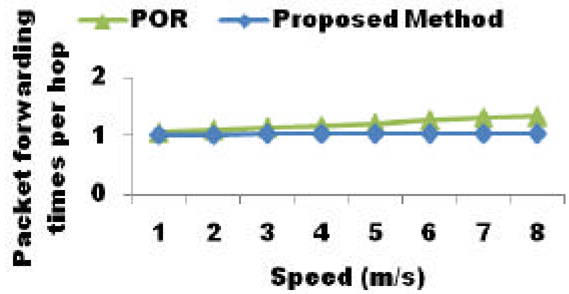

Fig. 3: Packet forwarding times per hop vs speed

indicates the level of duplicate forwarding happening in the network. We can see that our proposed method have a less value compared to POR protocol. Also the value of packet forwarding times per hop for the proposed method is close to 1 which means that the packet is only forwarded once by each hop and there is no redundant data relaying at the devices. This confirms the efficiency of the proposed method in highly dynamic ad hoc networks.

CONCLUSION

In this research study we proposed a method to improve the efficiency of opportunistic routing protocols by eliminating redundant data forwarding at the intermediate devices in highly dynamic ad hoc networks. Initially we discussed the issues with traditional routing protocols in dynamic ad hoc networks and also the advantage brought by broadcasting and opportunistic forwarding. These opportunistic routing protocols utilize the broadcasting nature of the wireless medium to achieve high data delivery in dynamic ad hoc networks. But this high data delivery comes at a cost of increased redundant packets and duplicate data forwarding in the network. The proposed method helps to control relaying of data packets at each node in the network on a per packet basis using information piggybacked on each packet. Simulation results showed that the proposed method reduces duplicate data forwarding considerably in the network leading to higher efficiency in opportunistic routing.

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