A Comparative Study of Novel Opportunistic Routing Protocols in Mobile Ad Hoc Networks

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Abstract—Opportunistic routing is used, where the network has the features like dynamic topology changes and intermittent network connectivity. In Delay tolerant network or Disruption tolerant network opportunistic forwarding technique is widely used. The key idea of opportunistic routing is selecting forwarding nodes to forward data packets and coordination among these nodes to avoid duplicate transmissions. This paper gives the analysis of pros and cons of various opportunistic routing techniques used in MANET.

Keywords—Expected Transmission Count (ETX), Opportunistic routing, Proactive Source Routing (PSR), throughput.

I. INTRODUCTION

THE mobile ad hoc network is a type of wireless ad hoc network. MANET doesn't require base station and doesn't rely on pre existing infrastructure. So, mobile ad hoc networks are self configuring networks. The characteristics of MANET are dynamic topology, network partitions and constrained resources. Due to this, there are many issues while designing routing protocol for MANET. The issues such as error prone channel state, hidden and exposed terminal problem, bandwidth constrained, and variable capacity links and energy constrained operations are found. For efficient data transmission and to improvise throughput and avoid retransmissions in MANET, various opportunistic routing techniques were used. Opportunistic routing is mainly used for delay tolerant networks or disruption tolerant networks. The classification of opportunistic networks is shown in Fig. 1.

Delay tolerant network is a type of opportunistic networks. Opportunistic networks are prone to frequent disconnections and communication delays and it uses store-carry-forwarding paradigm to forward data from source to destination. The routing protocol used for opportunistic networks are different from opportunistic forwarding used in MANET. The protocols used for opportunistic networks are epidemic, prophet etc. The opportunistic routing in MANET is used to fully utilize the broadcast nature of wireless medium and to improve transmission reliability.

The challenges in designing and implementing opportunistic routing in MANET are given by [7]. The first issue is selection of forwarding candidates. Selecting the size

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and the specific nodes of the set of forwarding nodes is critical in opportunistic routing. Selecting the most appropriate nodes to forward will increase the system throughput and reduce the latency and choosing the right size of the forwarding nodes will increase the network utilization and decrease the network overhead. The coordination overhead among the candidate nodes should be minimum. The second issue is the prioritization of the candidates. The priority is given according to the closeness of the destination. The third issue is when relays should forward packets. In the DTNs, forwarding the received packets right away may not be the best solution due to imperfect coordination among candidate relays and packet losses, which may cause multiple duplicate transmissions of the same packet. The fourth issue is how to combine packets (e.g., with network coding) in opportunistic routing.

The categorization of opportunistic forwarding are MAC decoupled, MAC coupled, dissemination based, content based, local knowledge only and an end to end knowledge overlay as given by [4]. The categorization is shown in Fig. 2.

II. OPPORTUNISTIC ROUTING PROTOCOLS

A. ExOR

ExOR [1] is an integration of routing and MAC protocol, and it takes some of the advantages of cooperative diversity. In cooperative diversity, the data forwarded by broadcast transmission through multiple relays, then the destination chooses the best of multiple relayed signals. But this scheme requires additional radio channel for each relay. To avoid using of additional channel and to use the existing channel, ExOR transmits the data by using a single node for each packet.

The MAC/Routing or Link/Network layer routing technique uses standard radio hardware to achieve high throughput than traditional routing. The reason for throughput improvement is, there will be more independent chances of receiving and forwarding the packet in each transmission. Another reason in ExOR throughput improvement is, if the data transmission falls unexpectedly short/far, then the nodes make use of it. For example, in the below figure the source node S and destination node D are separated by some set of nodes.

In traditional routing, the traffic is forwarded in pre determined path. The path is S-N3-N5-D is shown in Fig. 3. When the source transmits the data packet, if it falls before N3 and if it falls after N5, in both the cases traditional routing doesn't use this opportunity. ExOR works in both the cases to avoid unnecessary retransmissions as well as interference and improves network capacity as well as throughput.
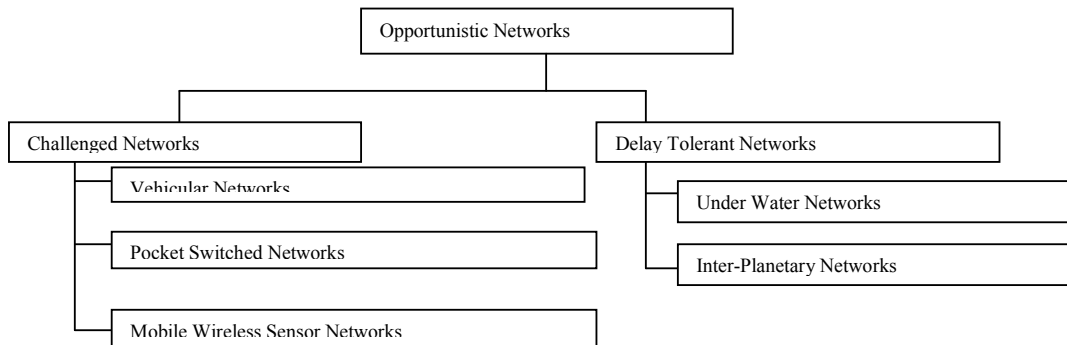
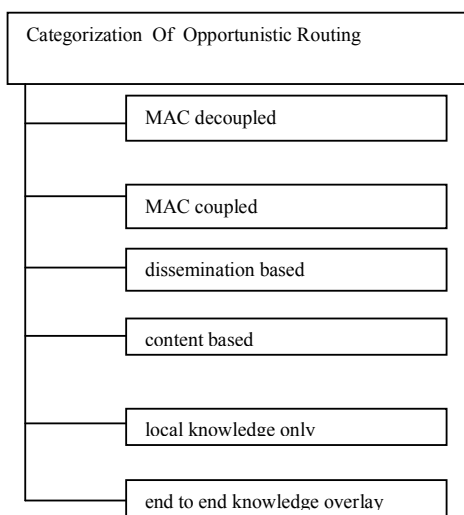Fig. 1 Categories of opportunistic networks

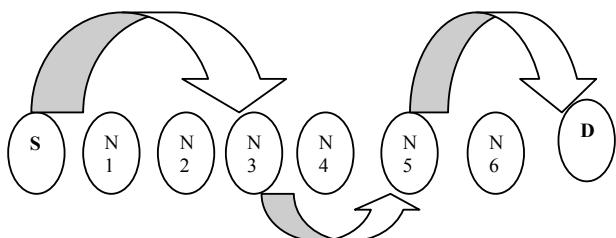Fig. 2 Categories of opportunistic routing

Fig. 3 Utilization of wireless medium in opportunistic routing

In ExOR, the packets are grouped to form batches. The node broadcast the batches to the neighboring nodes and then the node runs a protocol to find a subset of nodes to forward the data packets available in batches. In the broadcasted data packet, header consists of batch id, forwarder list, packet number and batch size. The forwarder list consist list of forwarders and their priority. Priority is assigned to the forwarder according to the number of hops and retransmissions needed to transmit the packets to destination, and it uses the metric for calculation. It is similar to Expected Transmission Count(ETX), the difference is ExOR considers only forwarding delivery probability. After assigning priority, the highest priority node broadcasts the batches to the neighboring node, in that batch map which is included in each data packet. The Batch Map indicates that, the sender's best option of highest priority node receives each packet. Other than higher priority nodes, forwards the data packet which was not acknowledged in the batch map of higher priority node.

In ExOR, 90% of batch data packets are transmitted by ExOR and the remaining 10% of packets are transmitted by traditional routing.

ExOR increases throughput by 35% than traditional routing. But there are some challenges in designing ExOR protocol. Initially, the batch size or group size have to be determined, it is complicated in ExOR. To avoid using batch SOAR is introduced. ExOR doesn't use spatial reuse and it doesn't extend for multicasting. Hence MORE is introduced to obtain these functionalities.

B.MORE

MORE [3] is a MAC independent Opportunistic Routing and Encoding protocol. ExOR ties MAC and routing, this restricts the access of medium and its leads to underutilization of the wireless medium. ExOR doesn't extend for multicasting. To overcome these disadvantages of ExOR, MORE is introduced. MORE uses intra-flow network coding. It doesn't use strict schedule on medium access and it is supports for multicasting.

C.SOAR

SOAR [2] is a source opportunistic Adaptive Routing and proactive link state routing. The following optimization has been done in SOAR for better performance in large range topologies and in traffic demands. By considering the present network topology, link quality and traffic, SOAR uses adaptive rate control to determine sending rate to minimize overhead and retransmissions. The forwarding node selection is an important task in opportunistic routing. The better forwarding nodes coordination improves throughput. In SOAR, the forwarding nodes are selected by priority timer based. The SOAR performs as follows:

1. Determining Adaptive Transmission Path:

In SOAR, the forwarding nodes selection depends upon default path. Default Path is predicted by using ETX metric. The ETX metric calculated by the number of hops needed to transmit a data to destination. In the pool of path, the default

path is selected which is having minimum ETX. The constraint has been given for selecting forwarding nodes from the default path is given by [2]:

a) The forwarding node's ETX to the destination is lower than the node's ETX (in default path) to the destination.
b) The forwarding node's ETX to default path node is within a threshold.
c) Each forwarding node is close to at least one node on the default path (i.e., with ETX below a threshold).
d) The ETX of a link between any pair of forwarding nodes is within a threshold.

Forwarding nodes assigned with priority and uses forwarding timer for each packet transmission to avoid duplicate transmissions and retransmissions. Local recovery is used in SOAR, other than forwarding nodes used as backup, it transmits data if the data doesn't reach destination. SOAR uses rate control, sending rate adapts with path capability to transmit the data to destination and it uses end to end acknowledgement. SOAR uses priority based forwarding timers to do scheduling and uses ETX metric to assign priority. But SOAR doesn't use batches as like EXOR, because it needs more computations.

D. POR

POR[5] is a Position based Opportunistic routing uses opportunistic forwarding along with location information, to utilize the broadcast nature of wireless medium. POR uses MAC dependent opportunistic routing technique. In POR, the forwarding nodes or candidate nodes selected based upon location of the nodes, which is nearer to destination. This property improves the robustness and scalability of POR. The modifications are done in MAC layer to support unicast and multicast transmissions. These MAC interruptions take the advantages of collision avoidance supported by 802.11. If the packet doesn't forward in a certain time, mac_callback function is called to reroute the packet. Interface queue is maintained in between the logical link layer and MAC layer to avoid duplicate transmissions. In POR, every node maintains local information. Every node consists of neighbor list, ID record, forwarding table, packet list and packet buffer. Forwarding table is constructed by local information provided by neighbor list and it consists of destination ip, forwarder list and forwarder number. When a node receives packet, if it needs some time to forward that packet then it is added in packet list. By using forwarder list in each node, the node determines the candidate node to forward the packets. Packet buffer is used to cache the packets, if the node doesn't find the forwarder. POR gives more throughputs and the drawback is it needs more computational resources and buffer space.

E. SCaTR

SCaTR[6] is a combination of On-demand and opportunistic routing. On demand routing protocols consider the unique features of MANET such as dynamic topology, limited battery life, but it doesn't consider the intermitted connectivity, which leads to arbitrarily long lived partitions. Space Content Adaptive Time routing is introduced for robust data delivery in arbitrarily long lived partitions. If the direct route exist between source and destination, it works as traditional on demand routing, else ScaTR will performs, by using past connectivity information. SCaTR consists of four phases for its implementation. The phases are contact table maintenance, route discovery, route selection and proxy rediscovery.

In route discovery, PREQ (proxy request) and PREP (proxy response) messages were used. These messages are used to route traffic to destination through proxies. Proxies are nodes which is closer to destination that buffered the messages transmitted from the source node. Proxy nodes are selected by content adaptive contact tables. Contact tables are similar to traditional routing tables, uses time dependent and space dependent routing metrics. Route selection is based on contact tables, and it also considers the metric buffer space. The messages are replicated only once to avoid inconsistency.

SCaTR increases delivery ratio with lower signaling overhead in an arbitrarily long lived partitions by comparing to on demand routing and opportunistic technique.

F. PSR:

In opportunistic routing, the candidate (or) forwarding nodes has to be selected initially. For selection of forwarding nodes, strong source routing capability is needed. To provide strong source routing capability, a lightweight proactive source routing is proposed. In PSR[8], every nodes consists the topological information in the Breadth First Spanning Tree structure. To construct an effective BFST in each node, three processes have been done. They are periodic route update, neighborhood trimming and streamlined differential updates. The route update operation in PSR done iteratively and distributed among with all the nodes in the network. The neighboring nodes receive BFST with latest information, the nodes updates its own BFST. The updated BFST is exchanged with its neighbors iteratively. If the node doesn't participate in network connectivity, it should be removed because of the loss of node. This process is called neighborhood trimming. The following ways are used to detect the loss nodes.

1) There is no route update message from that node periodically.
2) The data transmission to that node has been failed.

Streamlined differential update process is used to reduce overhead. The objective of this process is to reduce the size of BFST broadcasted to the neighbor's periodically. This can be done by compact tree representation and by shortening the differential update messages.

The features of PSR are proactive source routing, loop free routing and extremely small routing overhead. PSR outperforms than traditional routing protocols such as DSDV, OLSR, LS and DSR.

TABLE I
COMPARATIVE ANALYSIS OF OPPORTUNISTIC ROUTING PROTOCOLS IN MOBILE AD HOC NETWORKS

Protocol	Main features of protocols	Performance metric	Parametric analysis	Drawbacks
ExOR	Mac coupled opportunistic forwarding	Throughput	55% Throughput higher than traditional routing.	It uses strict medium access so it doesn't supports multicasting.
MORE	Mac decoupled opportunistic routing	Throughput.	35% Throughput higher than ExOR.	Implementing network coding is complicated.
SOAR	Dissemination based(Broadcast data packets at fixed PHY data rate)	Throughput	Outperforms than ExOR.	Improper rate control in source node leads to inefficiency.
POR	Location based opportunistic forwarding. (mac interception)	Packet delivery ratio	Delivers high packet delivery ratio in critical environments.	It requires more computational resources.
SCATR	On demand opportunistic routing	Packet delivery ratio	Increases throughput with lower signalling overhead.	It needs accurate past topological information.
PSR	Proactive opportunistic routing	Packet delivery ratio	It provides loop free routing with lower communication overhead	More computations needed for maintaining topological information

III. CONCLUSION

The analysis of opportunistic routing protocols has been done. In this ExOR, MORE, SOAR and PSR are proactive link state routing protocol and ScaTR uses an on demand opportunistic routing. Opportunistic routing achieves high throughput and improve performance when it uses source routing. By comparing these protocols PSR outperforms the other opportunistic routing protocols hence it uses source routing. The throughput achievement of PSR is due to its loop free and source routing features and PSR reduces the communication overhead by comparing to baseline protocols such as Link State, Destination Sequenced Distance vector protocols, Dynamic Source routing and Optimized Link State routing.

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