International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:9, No:6, 2015

A Survey on Opportunistic Routing in Mobile Ad Hoc Networks

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***Abstract*—**Opportunistic Routing (OR) increases the transmission reliability and network throughput. Traditional routing protocols preselects one or more predetermined nodes before transmission starts and uses a predetermined neighbor to forward a packet in each hop. The opportunistic routing overcomes the drawback of unreliable wireless transmission by broadcasting one transmission can be overheard by manifold neighbors. The first cooperation-optimal protocol for Multirate OR (COMO) used to achieve social efficiency and prevent the selfish behavior of the nodes. The novel link-correlation-aware OR improves the performance by exploiting the miscellaneous low correlated forward links. Context aware Adaptive OR (CAOR) uses active suppression mechanism to reduce packet duplication. The Context-aware OR (COR) can provide efficient routing in mobile networks. By using Cooperative Opportunistic Routing in Mobile Ad hoc Networks (CORMAN), the problem of opportunistic data transfer can be tackled. While comparing to all the protocols, COMO is the best as it achieves social efficiency and prevents the selfish behavior of the nodes.

***Keywords*—**CAOR, COMO, COR, CORMAN, MANET, Opportunistic Routing, Reliability, Throughput.

I. Introduction

MANET can be defined as a system of autonomous mobile nodes that communicate over wireless links without any preinstalled infrastructure. A Mobile Ad hoc Network is a collection of independent mobile nodes that can communicate to each other via radio waves. The mobile nodes that are in radio range of each other can directly communicate, whereas others need the aid of intermediate nodes to route their packets. Each of the nodes has a wireless interface to communicate with each other. These networks are fully distributed, and they can work at any place without the help of any fixed infrastructure as access points or base stations as given by [4].

Fig. 1 illustrates that, node 1 and node 3 are not within range of each other; however, the node 2 can be used to forward packets between node 1 and node 2. The node 2 will act as a router and these three nodes together form an ad-hoc network. Similarly, [2] presents the key to the function of all ad hoc networks. It is the performance of the route discovery protocol in use. Route discovery protocols for ad hoc networks differ considerably from route discovery protocols used in conventional fixed networks.

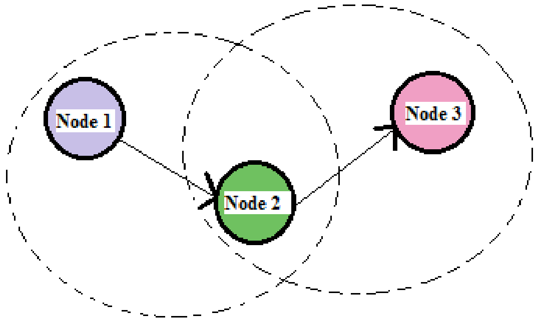

Fig. 1 Node Communication [4]

The performance of routing is given as in [5]: Routing is crucial in wireless ad hoc as well as sensor networks. The tasks of routing include route selection and packet forwarding. Route selection is to select one or more routes connecting a pair of nodes. Packet forwarding makes a one-hop decision on which neighbor should be chosen for forwarding a packet along the selected routes. The benefits and characteristics of OR is given by [1]: Opportunistic Routing benefits from the broadcast characteristic of wireless mediums to improve network performance. The basic function of OR is its ability to overhear the transmitted packet and to coordinate among relaying nodes. In OR, a candidate set is a potential group of nodes that is selected as the next-hop forwarders. Hence, each node in OR can use different potential paths to send packets toward the destination. Any of the candidates of a node that have received the transmitted packet may forward it. The decision of choosing the next forwarder is made by coordination between candidates that have successfully received the transmitted packet. The example for OR is given in [3]: E.g., only the one that is closest to the destination will perform the forwarding while the rest will simply drop the packet even they have successfully received it. As a result, opportunistic routing can take advantage of the potentially numerous, yet unreliable wireless links in the network when they actually deliver. In contrast, traditional routing in wireless networks only targets a packet to the preselected next-hop forwarder, which is the node on a preselected path towards the destination of the packet. In OR, the transmission reliability and network throughput can be increased by using a dynamic relay node to forward the packet.

The Opportunistic Routing is classified as: Forwarder Set Selection, Metrics for Prioritization, Forwarder Candidate's

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Coordination, Deterministic or Probabilistic forwarder selection, Location or Topology-based as given by [5] in Fig. 2.

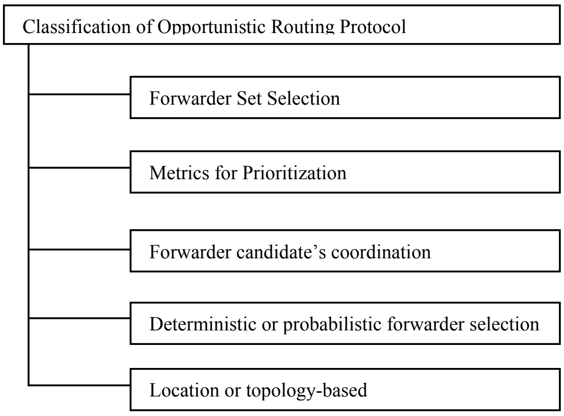

Fig. 2 Classification of Opportunistic Routing Protocol

II. Opportunistic Routing Protocols

A. CORMAN

CORMAN [6] used light weight proactive source routing protocol. It enables each node to have a complete knowledge of how to route data to all other nodes in the network at any time. When a flow of data is forwarded towards their destination, the information of the route carried by the nodes can be attuned by intermediate forwarders. CORMAN has two objectives:

1. It does not rely on external information sources to broaden the applicability of ExOR to mobile multi-hop wireless networks
2. It incurs a smaller overhead than ExOR as it includes shorter forwarder lists in data packets.

The challenges are:

1. Overhead in route calculation
2. Forwarder list adaptation
3. Robustness against link quality variation.

There are three components to overcome the challenges:

1. Proactive source routing (PSR)
2. Large-scale live update
3. Small-scale retransmission.

In PSR, each node will have the spanning tree to indicate the shortest path to all other nodes. In large-scale live update, when the forwarding node receives the data packets, it may have several views to forward that packet to the destination from the forwarder list carried by the packets. If the forwarder node is closer to the destination than the source node, it means that the forwarder node has more updated routing information. In this case, the forwarder node updates the part of the forwarder list and sends to the destination. The small-scale retransmission increases the reliability of data forwarding between two listed forwarders by allowing the nodes that are not on the forwarder list but are situated between these two listed forwarders to retransmit data packets if the downstream forwarder has not received these packets successfully. By the use of these three components, the problem of opportunistic data transfer can be tackled.

B. COR

Opportunistic routing employs a list of candidates to improve reliability. The major drawback in conventional list-based OR is that only the listed nodes should compete for relaying and packet duplication. They choose next hop based on the candidate list, created before the data transmission. By using this, OR cannot provide the best reliability in mobile environment. This drawback is overcome by COR. It is based on Beacon-Less Routing protocol (BLR). COR [7] allows all the qualified nodes to participate in the packet forwarding. It simultaneously uses context information such as link quality, geographic progress, and residual energy of nodes to make routing decisions. It exploits the relative mobility of nodes to improve the performance. Whenever the source needs to send a packet to the destination, it will broadcast the packet. It includes the location of both source and destination. By using this information, the neighbor nodes which receive the packet can check whether they are close to the destination (or) not. If they are close to the destination, they start a local timer based on Dynamic Forwarding Delay (DFD) and they acts as relaying candidate. DFD is calculated based on link quality, progress and energy. All the nodes compute DFD and the node with shortest DFD becomes the relay and forwards the packet. The other nodes will drop the packet on overhearing this relay. The forwarded packet should be re-broadcasted as a passive acknowledgement to inform the sender which node is selected as a forwarder. Then, the sender node will be aware of its next hop and starts transmitting to the chosen forwarder. The destination should notify its neighbors by re-broadcasting a message with sequence number of the received packet to avoid the packet duplication.

C. CAOR

CAOR [8] uses the Analytic Hierarchy Process (AHP) theory to adjust the weight of context information that is based on their instantaneous values to adapt the protocol behavior at runtime. AHP is an essential multi-criteria decision making solution. It decomposes a complex problem into simpler sub-problems. It considers a set of criteria, and generates a weight for each evaluation criterion according to the pair wise comparison of the criteria. CAOR uses the active suppression mechanism to control the duplicate transmissions. It has three parts:

1. DFD-based forwarder selection exploits manifold context information to choose a forwarder
2. Exploration of AHP to dynamically adapt the context information weight according to their real-time values
3. Duplicate transmission is reduced by lightweight active suppression mechanism.

The next-hop selection by AHP is shown in Fig. 3. Every candidate constructs its own comparison matrix according to their instantaneous values by comparing the importance of all context-pairs. While constructing the comparison matrix, AHP uses a consistency ratio (CR) to represent the deviation. As there is no centralized coordinator to indicate explicitly which neighbor will be the forwarder, manifold receivers may forward the packets due to the hidden terminal problem. It leads to packet duplication.

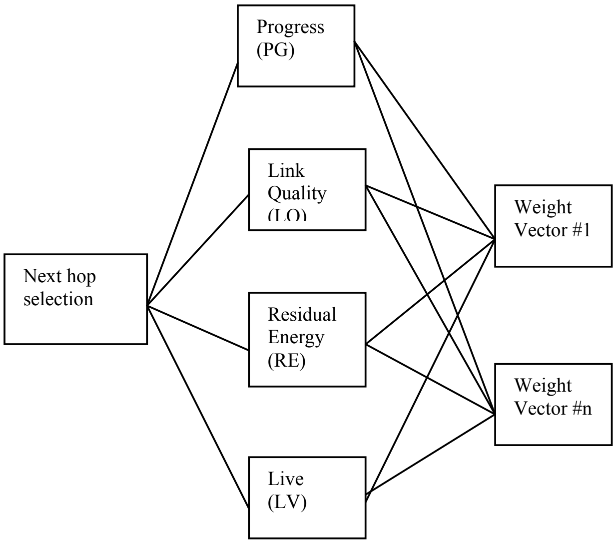

Fig. 3 AHP hierarchy for next-hop selection in CAOR

Two mechanisms are used to reduce packet duplication:

1. Reducing Duplicates at Intermediate Nodes
2. Reducing Duplicates at the Destination

The overhead of context manipulation and AHP calculation is tolerable, since it includes neither prediction/estimation operation nor routing table maintenance. With the ability of self-adaptivity and duplicate reduction, CAOR outperforms other opportunistic routing protocols.

D. Link Correlation

In wireless networks, because of the broadcast nature when a sender transmits a packet, the packet reaches to manifold receivers. In link correlation [9], the correlations are dependent. In OR, only the node with highest priority forwards the packet to the next hop. The sender selects the subset of nodes as forwarders and the priority will be assigned. When the sender transmits a packet to the next-hop, it includes an ordered candidate forwarder set in its header. When manifold nodes receive a packet, each node should respond with an acknowledgement. Candidates defer their ACKs according to their priorities to avoid the feedback implosion.

Fig. 4 illustrates that, if node X fails to receive a packet, candidate Y may receive the packet. Similarly, if Y loses the packet as well, Z may probably receive it. The nodes with diverse low correlated link are selected as forwarder candidates to improve the performance of OR.

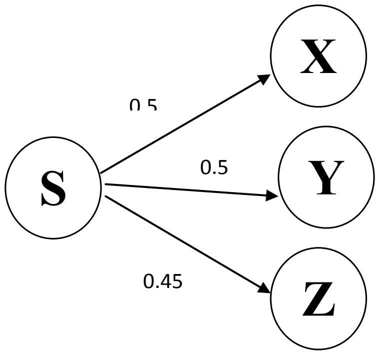

Fig. 4 Link Correlation

E. COMO

The first Cooperation-Optimal protocol for Multirate Opportunistic routing and forwarding [10] achieves the social efficiency. The probe messages are incorporated with a cryptographic component to measure the link loss probability. When session starts from source to destination, the source node, and the intermediate node sends the probe message. Each intermediate node and the destination node report the received probe messages to the source node. From this probe messages, the source node calculates the link loss probabilities. By comparing the two types of node behavior such as following and deviating, we can identify the selfish behavior of the nodes. In following, each node will follow the protocol. In deviating, the selfish node may send the incorrect number of probe messages or it will report only the part of probe messages while measuring the link loss probability.

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

PROTOCOL	FEATURES	PERFORMANCE METRICS	PARAMETRIC ANALYSIS	DRAWBACKS
CORMAN	Proactive Source Routing	Packet Delay Ratio, Delay and Delay Jitter	Outperforms than ExOR	Opportunistic data transfer
COR	Beaconless-based Geographic Routing	Packet Delivery Ratio	40 % throughput higher than traditional routing	It does not provide reliability
CAOR	List-based opportunistic routing	Packet Delivery Ratio, Packet duplicates, Average end-to-end delay	It reduces packet duplication	Packet duplication
LINK CORRELATION	Link probing protocol	Computational cost, Communication cost	Number of transmissions reduced by 38 % than traditional routing	More computations needed for maintaining topological information
COMO	Multirate opportunistic routing	Node utility and End-to-end throughput	Achieves social efficiency	Selfish behavior of nodes

III. CONCLUSION

The analysis of opportunistic routing protocol has been done. Opportunistic routing increases the reliability and throughput by using the source routing protocol. By comparing these protocols, COMO outperforms the other opportunistic routing protocol. It achieves the social efficiency and prevents the selfish behavior of the nodes.

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