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A Light weighted Opportunistic Source Routing Protocol for MANET

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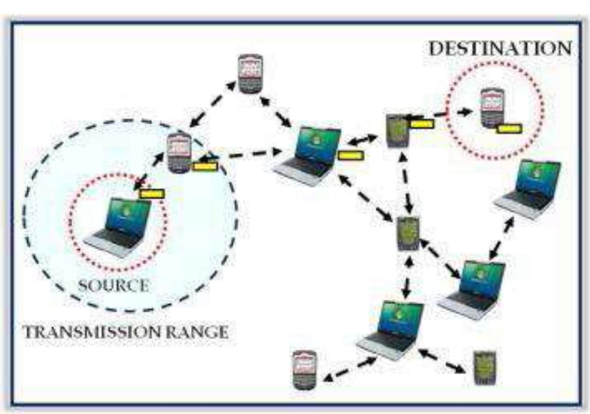
Abstract - **MANET is a self organized and self configurable network without existing infrastructure. It consists of several mobile wireless nodes. A routing protocol provides an efficient route between mobile nodes within the network. The discovery and maintenance of route should consume minimum overhead and bandwidth. Opportunistic data forwarding draws more and more attention in the research community of wireless network. However, as far as we know, all existing opportunistic data forwarding only use the nodes which are included in the forwarder list in the entire forwarding progress. In fact, even if a node is not a listed forwarder in the forwarder list, but it is on the direction from source node to destination node, and when it successfully overhears some packets by opportunity, the node actually can be utilized in the opportunistic data forwarding progress. In this paper, we propose a lightweight proactive source routing (PSR) protocol. PSR can maintain more network topology information than distance vector (DV) routing to facilitate source routing, and also has much smaller overhead than traditional DV-based protocol (DSDV)], link state (LS)-based routing [e.g., optimized link state routing (OLSR)], and reactive source routing [e.g., dynamic source routing (DSR)]. We analyze the solution of routing in MANET and evaluate its performance using Network Simulator-2 (NS-2) under different network parameters. Our NS2 simulation shows that that the overhead in PSR is only a fraction of the overhead of these baseline protocols, and PSR yields similar or better data transportation performance than these baseline protocols.**

Index Terms –mobile ad hoc networks (MANETs), opportunistic data forwarding, proactive routing, tree based routing, source routing, routing overhead control.

I. INTRODUCTION

Mobile ad-hoc network (MANET) is a wireless communication network that contains various mobile devices. These mobile devices form a network with each other without any existing infrastructure or any other kind of fixed stations. It is a self-configuring and self organized network of mobile devices. These devices can move in any direction. The links between these devices will be change frequently, due to their movement. In a dynamic environment of the wireless network, nodes are independent and their mobility causes frequent change of network connectivity. Nodes in such network can act as end points of data transmission as well as routers when the two end points are not in direct range of each other. In a decentralized network, a node is responsible to find the topology information and deliverance of data to the destination.



A mobile ad-hoc network (MANET) is a wireless communication network that can operate without existing infrastructure and support a number of mobile users. It is one of the general scopes of multi-hop wireless networking. Such networking paradigm originated from the needs in emergency operations, battlefield communications, search and rescue, and disaster relief operations[2]. The main challenges in this area of research include end-to-end data forwarding, communication link access control, network security and providing support for real-time multimedia streaming. Opportunistic data forwarding draws more and more attention in the research community of wireless network after the initial work ExOR was published[3]. In this paper, we extend the idea in ExOR and propose the local cooperative relay for opportunistic data forwarding. Contributions in our solution are highlighted as follows. _ Not only the nodes contained in the forwarder list, but also other nodes that are on the direction from source to destination will be used in the opportunistic data forwarding progress.

We provide here [4] a general classification and discussion of the possible routing approaches in opportunistic networks, we particularly focus on Mobile-Relay Forwarding (MRF). MRF assumes that there exist particular nodes (Mobile Relays) in the network that are exploited to collect messages from the source nodes, and to take messages (closer) to the destination. Routing approaches based on Mobile Relays (MRs) are very energy efficient because regular nodes are relieved of their routing workload, which is instead undertaken by MRs. Furthermore, this approach increases network scalability since the addition of extra nodes to the network does not imply an increment of routing complexity. This is particularly beneficial to scenarios that can potentially include a lot of (heterogeneous) devices like, for example, an urban environment.

We can distinguish the following three different components: regular nodes, MRs, and base stations. *Regular Nodes* (or simply nodes, for short) are the information sources and destinations. Depending on the specific application scenario, they may be fixed or mobile. For instance, in a sensor network nodes are typically stationary, while in a Mobile Ad Hoc Network (MANET) they are usually mobile. *Mobile Relays (MRs)* are specialized nodes that move throughout the network to collect datafrom source nodes and deliver it to the destination node or the Access Point. They can follow a fixed or variable trajectory, at constant or variable speed. Therefore, the time interval between successive visits of an MR to the same node may be predictable, variable in a bounded range, or completely random. The number of MRs in a network may vary depending on several factors such as, number of regular nodes, amount of traffic to manage, Quality of Service (QoS)
requirements, and costs.

The opportunistic routing protocols can improve the reliability of routing by making full use of the broadcast characteristics and assist in data transmission through additional backup links. In this paper[5],we propose a Link State aware Geographic Opportunistic routing protocol (LSGO) which exploits a combination of geographic location and the link state information as the routing metric. The LSGO aims to improve the reliability of data transmission in a highly dynamic environment, which selects the forwarders and prioritizes them based on the vehicle’s geographic location and the link’s quality. In this opportunistic routing protocols,
some take hop count as the routing metric, some pay more attention to the cost, some consider the distance to the destination to be the forwarding mechanism, and some care more about the energy. However, few of them take a combination of geographic location and the link state information into account. So, we proposed a Link State aware Geographic Opportunistic routing protocol (LSGO) which takes a combination of geographic location and the link state information as the forwarder selection mechanism. Firstly, we propose a candidate node set selection mechanism, which selects the forwarders based on the vehicle’s geographic location and the link’s quality. In our approach, the link’s quality is measured using the enhanced ETX metric. Secondly, we put forward a priority scheduling algorithm which prioritizes the forwarders by timer-based scheduling method. This routing protocol can greatly improve the packet delivery ratio, ensuring data transmission reliability under a highly dynamic environment. The protocol mainly includes three parts, namely, the estimation of link quality, candidate node set selection mechanism, and priority scheduling algorithm.

Routing protocols in MANETs are classified under two major fields of protocols: Proactive or table-driven and Reactive or on-demand. Some of reactive or on-demand protocols are Dynamic Source Routing (DSR), Ad-hoc On-demand Distance Vector Routing (AODV) and Ad-hoc On-demand Multipath Distance Vector Routing (AOMDV). These protocols employ a minimum-hop metric for choosing a route and do not consider energy. DSR is a simple and on-demand routing protocol for MANET. DSR uses source routes to control the forwarding of packets through the network [2]. AODV [3] is an on-demand routing protocol which is essentially a combination of DSR and DSDV. In AODV, a route is established only when it is required by a source node for transmitting data packets. AOMDV is an extension to the AODV protocol; it belongs to on demand and reactive routing protocol of ad-hoc wireless networks. The main goal is to compute multiple loop-free and link-disjoint paths between source and destination pair.The efficient node-energy utilization in mobile adhoc networks is an essential role. Death of node due to energy exhausted in ad hoc network lead s to the network partition and causes

Communication failure in the network. Since energy

is limited in wireless mobile ad hoc networks, designing energy aware routing protocols has become a main issue. The aim of these protocols is to reduce the energy consumption of the mobile nodes in the network in order to maximize the lifetime of the network. So, based on a reactive and multipath routing, we propose a new routing protocol and also consider transmission power of nodes and residual energy as energy metrics in order to maximize the network lifetime and to reduce energy consumption of mobile nodes.

In this paper, we propose a *lightweight opportunistic source routing (LOSR) protocol* to facilitate opportunistic data forwarding in MANETs. In LOSR, each node maintains a breadth-first search spanning tree of the network rooted at itself. This information is periodically exchanged among neighboring nodes for updated network topology information. Thus, LOSR allows a node to have full-path information to all other nodes in the network, although the communication cost is only linear to the number of the nodes. This allows it to support both source routing and conventional IP forwarding. When doing this, we try to reduce the routing overhead of LOSR as much as we can. Our simulation results indicate that LOSR has only a fraction of overhead of OLSR, DSDV, and DSR but still offers a similar or better data transportation capability compared with these protocols.

The rest of the paper is organized as follows: In Section 2, we will review the related work and introduce our motivation. Section 3 will present the details in the proposed LOSR scheme. The performance evaluations of the proposed scheme are presented in Section 4. Finally, Section 5 concludes the article.

II. RELATED WORK

In fact, many lightweight routing protocols had been proposed for the Internet to address its scalability issue, i.e., all of them are table driven. The path-finding algorithm (PFA) [11-6]is based on DVs and improves them by incorporating the predecessor of a destination in a routing update. Hence, the entire path to each node can be reconstructed by connecting the predecessors and destinations; therefore, the source node will have a tree topology rooted at itself. In the meantime, the link vector (LV) algorithm [12-7] reduces the overhead of LS algorithms to a great deal by only including links to be used in data forwarding in routing updates. The extreme case of LV, where only one link is included per destination, coincides with the PFA.

PFA and LV were both originally proposed for the Internet, but their ideas were later used to devise routing protocols in the MANET. The Wireless Routing Protocol (WRP) [13-8] was an early attempt to port the routing capabilities of LS routing protocols to MANETs. It is built on the same framework of the PFA for each node to use a tree to achieve loop-free routing. Although it is an innovative exploration in the research on MANETs, it has a rather high communication overhead due to the amount of information stored at and exchanged by the nodes. This is exacerbated by the same route update strategy as in the PFA, where routing updates are triggered by topology changes. Although this routing update strategy is reasonable for the PFA in the Internet, where the topology is relatively stable, this turns out to be fairly resource demanding in MANETs. (Our original intention was to include the WRP in the experimental comparison later in this paper, and we have implemented WRP in ns2. Unfortunately, our preliminary tests indicate that the changing topology in the MANET incurs an overwhelming amount of overhead, i.e., at least an order of magnitude higher than the other mainstream protocols. Thus, we do not include the simulation result of WRP as a baseline in our comparison.

The LOSR protocol proposed in this paper uses tree-based routing as in PFA and WRP. To make our PSR more suitable for the MANETs, we adopt a combined route update strategy that takes advantage of both “event-driven” and “timer-driven” approaches. Specifically, nodes would hold their broadcast after receiving a route update for a period of time. If more updates have been received in this window, all updates are consolidated before triggering one broadcast. The period of the update cycle is an important parameter in PSR. Furthermore, we go an extra mile to reduce its routing overhead. First, we interleave full dump and differential updates to strike the balance between efficient and robust network operation. Second, we package affected links into forests to avoid duplicating nodes in the data structure. Finally, to further reduce the size of differential update messages, each node tries to minimize the alteration of the routing tree that it maintains as the network changes its structure.

III. Design of Light Weight Opportunistic source Routing

Essentially, PSR provides every node with a breadth-first spanning tree (BFST) of the entire network rooted at itself. To do that, nodes periodically broadcast the tree structure to their best knowledge in each iteration. Based on the information collected from neighbors during the most recent iteration, a node can expand and refresh its knowledge about the network topology by constructing a deeper and more recent BFST. This knowledge will be distributed to its neighbors in the next round of operation (see Section III-A). On the other hand, when a neighbor is deemed lost, a procedure is triggered to remove its relevant information from the topology repository maintained by the detecting node (see Section III-B). Intuitively, PSR has about the same communication overhead as DV-based protocols. We go an extra mile to reduce the communication overhead incurred by PSR's routing agents. Details about this overhead reduction will be discussed in Section III-C.

A .Route Update

Due to its proactive nature, the update operation of PSR is iterative and distributed among all nodes in the network. At the beginning, node v is only aware of the existence of itself; therefore, there is only a single node in its BFST, which is root node v. By exchanging the BFSTs with the neighbors, it is able to construct a BFST within $N[v]$, i.e., the star graph centered at v, which is denoted Sv.

In each subsequent iteration, nodes exchange their spanning trees with their neighbors. Node v incorporates the most recent information from each neighbor to update its own BFST. It then broadcasts this tree to its neighbors at the end of the period. Formally, v has received the BFSTs from some of its neighbors. Including those from whom v has received updates in recent previous iterations, node v has a BFST, which is denoted Tu, cached for each neighbor $u \in N(v)$. Node v constructs a union graph, i.e.,

$$Gv = Sv \cup \_u{\in}N(v)\ (Tu - v). \qquad (1)$$

Here, we use $T - x$ to denote the operation of removing the subtree of T rooted at node x. As special cases, $T - x = T$ if x is not in T, and $T - x = \emptyset$ if x is the root of T. Then, node v calculates a BFST of Gv, which is denoted Tv, and places Tv in a routing packet to broadcast to its neighbors.

B. Neighborhood Trimming

The periodically broadcast routing messages in PSR also double as "hello" messages for a node to identify which other nodes are its neighbors. When a neighbor is deemed lost, its contribution to the network connectivity should be removed; this process is called neighbor trimming. Consider node v. The neighbor trimming procedure is triggered at v about neighbor u either by the following cases:

1) No routing update or data packet has been received from this neighbor for a given period of time.
2) A data transmission to node u has failed, as reported by the link layer.

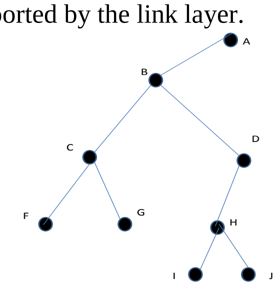


Fig 1 Binary tree

Node v responds by:
1) First, updating $N(v)$ with $N(v) - \{u\}$;
2) Then, constructing the union graph with the information of u removed, i.e.,

$$Gv = Sv \cup \_w \in N(v)(Tw - v) \quad \ldots\ldots(2)$$

3) Finally, computing BFST Tv.

Notice that Tv, which is thus calculated, is not broadcast immediately to avoid excessive messaging. With this updated BFST at v, it is able to avoid sending data packets via lost neighbors. Thus, multiple neighbor trimming procedures may be triggered within one period.

C. Streamlined Differential Update

The basic idea is to send the full update messages less frequently than shorter messages containing the difference between the current and previous knowledge of a node's routing module. Both the benefit of this approach and balancing between these two types of messages have been extensively studied in earlier proactive routing protocols.

In this paper, we further streamline the routing update in two new avenues. First, we use a compact tree representation in full-dump and differential update messages to halve the size of these messages. Second, every node attempts to maintain an updated BFST as the network changes so that the differential update messages are even shorter.

IV. . PERFORMANCE EVALUATION

We study the performance of LOSR using computer simulation with Network Simulator 2 version 2.34 (ns-2). We compare PSR against OLSR [7], DSDV [9], and DSR [8], which are three fundamentally different routing protocols in MANETs, with varying network densities and node mobility rates. We measure the data transportation capacity of these protocols supporting the Transmission Control Protocol (TCP) and the User Datagram Protocol (UDP) with different data flow deployment characteristics. Our tests show that the overhead of PSR is indeed only a fraction of that of the baseline protocols. Nevertheless, as it provides global routing information at such a small cost, PSR offers similar or even better data delivery performance.

We study the data transportation capabilities of these routing schemes and their overhead in doing so by loading the networks with TCP data flows.

We first study the performance of LOSR, OLSR, DSDV, and DSR in supporting 20 TCP flows in networks with different node densities. Specifically, with the default 250-m transmission range in ns-2, we deploy our 50-node network in a square space of varying side lengths that yield node densities of approximately 5, 6, 7, . . . , 12 neighbors per node. These nodes move following the random waypoint model with $v$max = 30 m/s.

We plot in Fig. 2 the per-node per-second routing overhead, i.e., the amount of routing information transmitted by the routing agents measured in B/node/s, of the four protocols when they transport a large number of TCP flows.

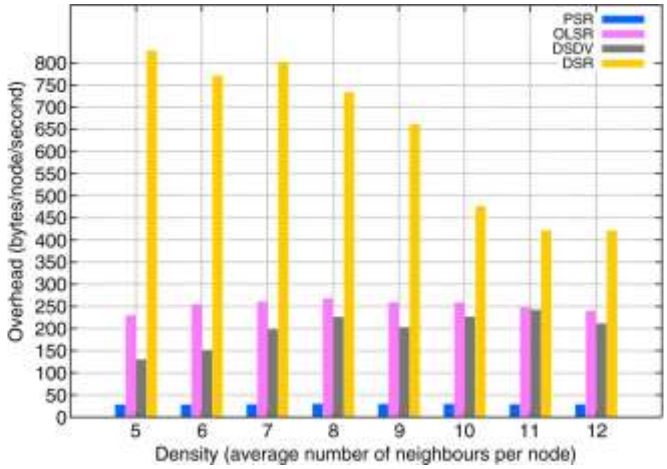


Fig. 2. Routing Overhead with velocity

This figure. 2 shows that the overhead of PSR (20 to 30) is just a fraction of that of OLSR and DSDV (140 to 260) and more than an order of magnitude smaller than DSR (420 to 830). The routing overhead of PSR, OLSR, and DSDV goes up gradually as the node density increases. This is a typical behavior of proactive routing protocols in MANETs. These protocols usually use a fixed-time interval to schedule route exchanges. While the number of routing messages transmitted in the network is always constant for a given network, the size of such message is determined by the node density. Note that when the node density is really high, e.g., around 10 and 12, the overhead of OLSR flattens out or even slightly decreases. This is a feature of OLSR when its multipoint relaying mechanism becomes more effective in removing duplicate broadcasts, In contrast, DSR, as a reactive routing protocol, incurs significantly higher overhead when transporting a large number of TCP flows because every source node needs to conduct its own route search. Here, the routing overhead of DSR decreases with the node density going up and the network diameter going down. This is because the number of hops to a destination is smaller in a denser network; therefore, the shorter and more robust routes break less frequently and do not need as many route searches.

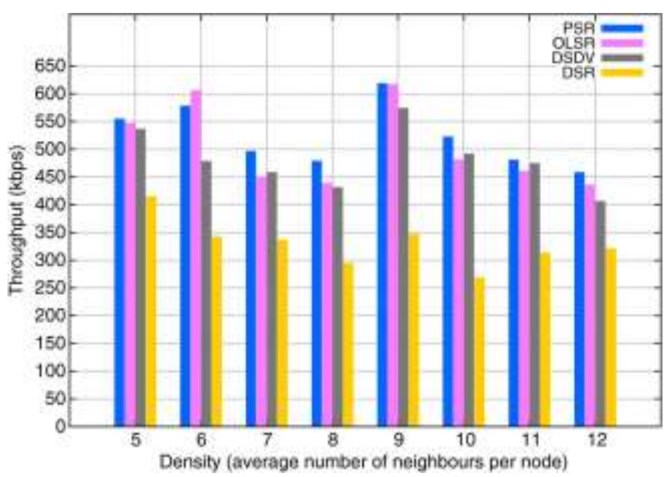
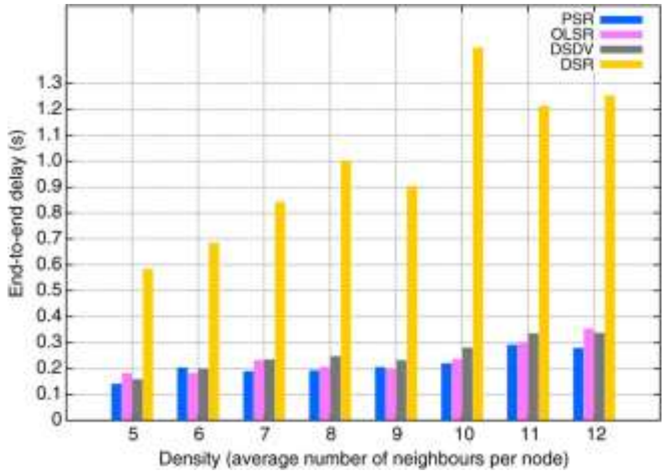


Fig. 3 TCP Threshold versus Density

Fig. 3 plots the TCP throughput of the four protocols for the same node density levels as before. The total throughput of the 20 TCP flows of PSR, OLSR, and DSDV is noticeably higher than that of DSR. In addition, while the TCP throughput of DSR decreases with node density, that for the other three are somewhat unaffected, hovering at around 500 kb/s. In most cases, PSR has the highest throughput because it needs to give up the least network resources for routing.



Next, we focus on the end-to-end delay of TCP flows to investigate how well these protocols support time-sensitive applications. Fig. 4 shows the delay measured for different node densities. As the density increases from 5 to 12 neighbors, the delay of DSR goes up from 0.58 to about 1.5 s, which is significantly higher than the typical value of 0.15 to 0.35 s for the other three protocols. This difference is caused by the initial route search when a TCP flow starts and by the subsequent searches triggered by route errors. As the network becomes denser, all protocols show an increasing trend in end to- end delay.

CONCLUSION

To generalize the milestone work of ExOR for it to function in such networks, we needed a LOSR proto col. Such a protocol should provide more topology information than DVs but must have significantly smaller overhead than LS routing protocols; even the MPR technique in OLSR would not suffice. Thus, we put forward a tree-based routing protocol, i.e., LOSR, which is inspired by the PFA and the WRP. Its routing overhead per time unit per node is on the order of the number of the nodes in the network as with DSDV, but each node has the full-path information to reach all other nodes. For it to have a very small footprint, LOSR's route messaging is designed to be very concise. First, it uses only one type of message, i.e., the periodic route update, both to exchange routing information and as hello beacon messages. Second, rather than packaging a set of discrete tree edges in the routing messages, we package a converted binary tree to reduce the size of the payload by about a half. Third, we interleave full-dump messages with differential updates so that, in relatively stable networks, the differential updates are much shorter than the full-dump messages. To further reduce the size of the differential updates, when a node maintains its routing tree as the network changes, it tries to minimize alteration of the tree. As a result, the routing overhead of LOSR is only a fraction or less compared with DSDV, OLSR, and DSR, as evidenced by our experiments.

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