

TO-GO: TOpology-assist Geo-Opportunistic Routing in Urban Vehicular Grids

Kevin C. Lee, Uichin Lee, Mario Gerla

UCLA

Computer Science Department

Los Angeles, CA

{klee, ulee, gerla}@cs.ucla.edu

Abstract— Recently, the road topology information has been used to assist geo-routing, thereby improving the overall performance. However, unreliable wireless channel that is prevalent in urban vehicular grids due to obstacles and mobility is not well considered. The contribution of this poster is to account for the unreliable wireless channel by enhancing road topology assist geo-routing with opportunistic routing where opportunistic packet receptions due to channel errors are exploited to improve the performance.

Keywords-component; Geographic routing, opportunistic forwarding, contention-based forwarding

I. INTRODUCTION

Geo-routing has become one of the popular routing protocols in a *vehicular ad hoc network* (VANET) for two reasons. First, geo-routing is stateless, thus obviating the need of route discovery and maintenance procedures as in conventional on-demand and table-driven routing protocols, which is very costly in highly mobile vehicular environments such as VANETs. Second, with Navigation System/GPS devices getting cheaper and becoming a common add-on, it is becoming easier to support geo- routing.

In urban grids, it is known that conventional geo-routing protocols such as *Geographic Perimeter Stateless Routing* (GPSR) [1] may not work well due to the unique layout of road structure. Given this, Lochert et al. recognized a road segment as a road segment and proposed *Geographic Perimeter Coordinator Routing* (GPCR) [1], by incorporating the road topology in the geo-routing. The key distinction is that nodes in junctions (or intersections) decide to which junction a packet must be forwarded.

In our previous work, we proposed an enhancement to GPCR, called GPSRJ+ [5], by reducing the dependency on junction nodes, noting that not every packet must be forwarded to a junction node. A packet must be forwarded to a junction node only when it needs to make a left/right turn to the other road segments. In GPSRJ+, a forwarding node uses two-hop neighbor information to predict which road segment its potential next hop node will forward to. Knowing that there will be no turns, GPSRJ+ attempts to bypass a junction area. This simple prediction reduces hop counts and increases the packet delivery ratio.

However, these geo-routing protocols in urban grids do not consider the error-prone wireless channel due to multi-path fading and shadowing, which are prevalent in vehicular networks. Also, the assumption of a unit disc propagation model does not hold anymore. The main problem of previous approaches in this environment is that a packet will be more likely to be lost when it is forwarded to a node that is furthest from the sender.

This observation brings forth the concept of opportunistic routing [2,7]. In opportunistic routing, a sender can take advantage of random packet reception in its neighboring nodes due to the error-prone wireless channel. A key question is to decide at each node which neighbors should be potential relay nodes to reach a destination. ExOR and LCOR used ETX based table-driven methods to find such a set. In geo-routing, Shah et al. proposed to use a lens shape forwarding region that is the intersection between a circle centered at a forwarding node and that centered at the destination [6]. Contention-based forwarding algorithms (e.g., [4]), which are not originally designed for opportunistic routing, use a similar forwarding shape. Nodes in a forwarding region contend for packet forwarding based on a distance based timer. These geo-routing protocols, however, always use the radius between the forwarding node and destination in order to find the region and set the timer.

In this poster, we enhance GPSRJ+ with opportunistic forwarding. Unlike previous approaches where a forwarding region is defined between the current sender and the destination, we find a forwarding set between the current sender and the anchor node. It is then included in a packet, allowing nodes to contend for forwarding: each node sets a timer based on its distance to the anchor node. Preliminary finding has shown that the performance of TO-GO is as good as GPSRJ+ and better as packets get delivered opportunistically toward the destination in an unpredictable, lossy wireless medium. In summary, our main contribution is an enhanced geo-routing that improves the packet delivery ratio by incorporating junction prediction and opportunistic forwarding with a novel set selection algorithm.

II. TO-GO DESIGN

In TO-GO routing, a packet is marked for an anchor node, determined by the *Next-hop Prediction Algorithm* (NPA), and broadcasted. Nodes at or close to the anchor node will receive

the packet. Nodes that are in the set determined by the *Forwarding Set Selection (FSS)* set their timer based on their relative distance to the anchor. The closer the distance to the anchor, the sooner the timer goes off. Among those nodes who have received a packet, the node whose timer expires first becomes the next forwarding node. As the next node contends the channel successfully and broadcasts, the other contending nodes will cancel their timer, thus preventing redundant packet transmissions.

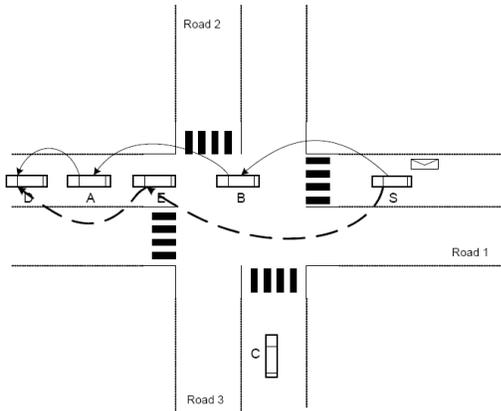


Figure 1: Dashed arrows are TO-GO and solid arrows are GPCR.

A. Next-hop Prediction Algorithm (NPA)

We use two-hop neighbor beacons as described in [5] to predict whether a node can bypass forwarding a packet to its junction neighbor whenever possible. In greedy mode, a node simply needs to know its junction neighbor's furthest nodes to predict the road segment that the packet will be forwarded to. If the furthest node is on the same road segment as the node's furthest node, the node simply forwards the packet to the furthest node. Otherwise, the node will forward the packet to its junction neighbor. In perimeter mode, the node knows the roads that its junction neighbor's neighbors are on, and this helps the node to determine which road its junction neighbor will forward the packet to based on the right-hand rule. If it is on the same road segment as the node's furthest node, the node can simply forward to the furthest node. Otherwise, the node will forward the packet to its junction neighbor. We refer readers to [5] for the detailed algorithm. Figure 1 shows the difference between TO-GO and GPCR.

B. Forwarding Set Selection (FSS)

Given that the next forwarding node, or the anchor node is determined, the current forwarding node finds a forwarding set. Since we do not assume a unit disk radio model (i.e., transmission range is not fixed), we utilize two-hop neighbor information to determine the set as follows. For each neighbor i , a node finds a set of nodes n_i that is i 's neighbors that can hear the node and the anchor node. The forwarding set is simply then the intersection of n_i 's. This allows all nodes in the forwarding set to hear one another. Thus, when a node wins the competition, other nodes can suppress their packet transmission. Note that the packet transmission, however, could also be lost, leading redundant packet transmission, but this can be suppressed later on. Also, the size of a packet can

be reduced by using a Bloom filter, a space efficient membership checking data structure.

C. Setting the Timer

Having found the forwarding set, we want a node close to the anchor node to become the next forwarder, and ideally, we want the anchor node to receive the packet. To this end, we set the timer T as follows: $T = C * \frac{dist(receiving\ node, anchor\ node)}{dist(receiving\ node, sending\ node)}$

C is a constant that varies with the transmission rate, the processing time, and the system throughput. Setting it too low results in incorrect selection of the next forwarding node. Setting it too high results in poor system throughput. T is proportional to the distance between the receiving node and the anchor node and inversely proportional to the distance between the receiving node and the sending node. Because it takes shorter time for nodes closer to the sending node to receive the broadcast than nodes further away, the closer nodes' timer should account for the shorter propagation delay so that all receiving nodes start the timer approximately at the same time.

D. Retransmission

For reliability, a node will retransmit the packet, if it does not overhear a packet forwarded by one of its forwarding set nodes. In our protocol, we limit a node to only retransmit three times before dropping the packet, but this number can be configured based on the channel conditions. The retransmission timer RT is set as follows:

$$RT = 2 \times PropDelay + T$$

The two propagation delays account for the time it takes for the broadcast to reach the desired node, either close to the anchor or at the anchor, and the time for the broadcast from such a node to come back. T is the upper bound approximation of the time it takes before the desired node's timer expires. The desired node, in the worst case, is at the same location as the retransmitting node. In that case, its timer is simply T .

REFERENCES

- [1] B. Karp and H. T. Kung, "GPSR: greedy perimeter stateless routing for wireless networks," in Proc. ACM/IEEE MOBICOM'00, Boston, Massachusetts, USA, 2000, pp. 243-254.
- [2] S. Biswas and R. Morris, "ExOR: Opportunistic routing in multi-hop wireless networks." In Proceedings of the ACM Symposium in Communications Architectures and Protocols (SIGCOMM), Philadelphia, USA, 2005.
- [3] C. Lochert, M. Mauve, H. Foussler, and H. Hartenstein, "Geographic routing in city scenarios," ACM SIGMOBILE, vol. 9, no. 1, pp. 69-72, 2005.
- [4] H. Füßler, J. Widmer, M. Käsemann, M. Mauve, and H. Hartenstein, "Contention-Based Forwarding for Mobile Ad-Hoc Networks," Elsevier's Ad Hoc Networks, vol. 1, no. 4, pp. 351-369, 2003.
- [5] K. C. Lee, J. Haerri, U. Lee, and M. Gerla, "Enhanced perimeter routing for geographic forwarding protocols in urban vehicular scenarios," Globecom Workshops, 2007 IEEE, pages 1-10, 26-30 Nov., 2007.
- [6] Shah, R.C., Wietholter, S., Wolisz, A., Rabaey, J.M., "When does opportunistic routing make sense?," Pervasive Computing and Communications Workshops, 8-12 March, 2005
- [7] H. Dubois-Ferriere, M. Grossglauser, and M. Vetterli, "Least-cost opportunistic routing." Technical Report LCAV-REPORT-2007-001, School of Computer and Communication Sciences, EPFL, 2007.