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Experimental Evaluation of Routing Protocols for Vehicular Ad-hoc Networks Using GNU Radio and USRP

Atsuro Furumori
Toyohashi
University of Technology

Yuichi Miyaji
Toyohashi
University of Technology

Hideyuki Uehara
Toyohashi
University of Technology

Takashi Ohira
Toyohashi
University of Technology

***Abstract*—Vehicular Ad-hoc Networks (VANET) is attracting notice as one of Intelligent Transportation Systems (ITS) technology. It is important to evaluate various communication protocols for VANET in a field operational test. Because channel environment of VANET is highly variable on time and location. Most of field operational tests of VANET are conducted on single hop topology and measuring channel characteristics. In this paper, we evaluate the routing protocols for VANET in multi-hop topology by using Software Defined Radio (SDR) technology. Ad-hoc On-demand Distance Vector[1] (AODV) and Direction Oriented Routing Protocol[2] (DORP) are chosen to be implemented. AODV has been already implemented and we conducted measurement experiments. The result of experiments validated that AODV was implemented correctly and usable for field operational tests. Experiments of DORP will be completed in the near future.**

I. Introduction

Inter Vehicle Communication (IVC) is general technology expected for safe driving, traffic management and infotainment applications. There are a lot of proposals of application based on IVC. Channel condition and network topology of IVC are highly variable on time and location due to high mobility and speed of vehicles. However, most of VANET simulators are using highly abstracted channel model and moving model. Thus it is important to evaluate protocols using IVC by field operational tests. There are a number of literatures about protocols based on IVC, although most of those protocols are evaluated only on VANET simulators and very few on field operational tests. Furthermore, most of field operational tests are experimented with single hop environment despite a lot of VANET applications are using multi hop network. In order to realize protocols using multi hop network, routing protocols are necessary to resolve how to transport packets from a source to a destination. Hence, we will implement routing protocols by using SDR and conduct a field operational test. In order to implement routing protocols, we use GNU Radio and Universal Software Radio Peripheral (USRP), which are software development toolkit and radio device respectively.

II. Routing Protocols

Routing protocols decide a path for delivering packets from a source to a destination which cannot communicate directly each other. Routing protocols used in mobile ad-hoc network (MANET) are roughly divided into two types: a reactive type and a proactive type. Difference of these two types is timing of building a route. The reactive type builds the route when a source node needs to send packets to a desired destination. On the other hand, the proactive type builds the routes to the possible destinations beforehand and update at all times. Therefore, the reactive type is tolerant of change of network topology and the proactive type achieves low delay. Thus, the reactive type is suitable for VANET because, as told above, network topology of VANET is highly variable.

A. Ad-hoc On-demand Distance Vector

AODV is the routing protocol representative of reactive type. In this protocol, a node which wants to send packets to a destination and does not know a route to the destination floods route request (RREQ) packet to the whole network. RREQ packet contains destination address and source address. When the destination node receives the RREQ packet, it makes and sends route reply (RREP) packet by unicast. AODV uses Expanding Ring Search (ERS) when building the route. ERS is a technique to reduce redundant packet and use bandwidth effectively. On ERS, at first, time to live (TTL) value of RREQ packet is set to small value and source node floods the RREQ packet. If the source node does not receive RREP packet in specific time, it increments TTL value and re-floods the RREQ packet. The source node repeats the increment and re-flood process until TTL reaches the threshold value and then, finally, floods the RREQ packet to all area of network. Routing table consists of destination address and next hop address. When a node attempts to send a packet, the node looks up the routing table and transmits the packet to the next hop node. Routing table will be updated by using the information obtained from received packets.

B. Direction Oriented Routing Protocol

DORP is a routing protocol dedicated to VANET. This protocol assumes that vehicles have two directional antennas mounted on front and rear side and supposes that direction of arrival packet is available. Similar to AODV, a source node which does not know a route to the destination node floods the direction request (DREQ) packet to front and back. When a destination node receives DREQ packet, it makes and sends the direction reply (DREP) packet by unicast. Every node has two tables: neighbor table and direction table. Neighbor table consists of node address, direction of the node and Received Signal Strength Indication (RSSI) of signal from the node. A node is able to communicate directly with the nodes listed in its own neighbor table. Direction table consists of destination address and direction of destination node. If destination is in neighbor table, node sends the packet directly. Otherwise, if destination is in direction table, node sends the packet to relay node. Relay node is selected from neighbor table entry which has same direction to destination and median RSSI.

III. Software Defined Radio

SDR is a technology that processes radio communication sequence by software. It is easy to implement protocols of any layer by coding and executing the programs. In this study, we employed GNU Radio and USRP which are software development toolkit and radio device, respectively.

A. GNU Radio

GNU Radio is an open source software development toolkit that provides signal processing blocks to implement software radios. Each signal processing component (modulation, filter, encoding etc.) is divided into the blocks and users can easily build wireless communication systems by connecting these blocks.

B. USRP

USRP is a radio device that is specialized for SDR and suitable for GNU Radio. USRP consists of mother board and daughter board. Mother board provides clock generation, DAC, ADC and host interface. Daughter board provides filtering, AGC and up/down-conversion.

IV. Experiments

We implemented AODV by using GNU Radio and USRP and conducted measurement experiments and a route building experiment of AODV. Measured characteristics are the route discovery time (RDT) and the round trip time (RTT) after building a route. RDT is a time from start to end of building a route. RTT is a time between sending a packet to the destination and receiving reply packet from the destination. The route building experiment is conducted to ensure that the implemented AODV builds a route correctly. Experimental setup is stated in Table I. Fig. 1 is the photo of experimental environment and Fig. 2 shows network topology of measurement experiments. Each node is separated 1.5[m] and can communicate with only next nodes. All of experiments are conducted in an anechoic chamber. In order to reduce the influence of laptop computers, we put microwave absorbers between USRP and the computers. Fig. 3 shows network topology of the route building experiment. In the experiment, the node S builds a route to the node D. AODV selects a route that has least number of hops. Thus, in this experiment, the route 1 should be selected as the route between the node S and the node D.

Results of the measurement experiments are stated in Fig. 4. The result of RDT is not in proportion to number of hops

TABLE I
Experimental setup

Software	GNU Radio 3.3.0
Hardware	USRP2
Number of nodes	2 for 7
MAC protocol	CSMA/CA with RTS/CTS
Modulation	GMSK
Bitrate	1.0Mbps
Frequency	5.11GHz

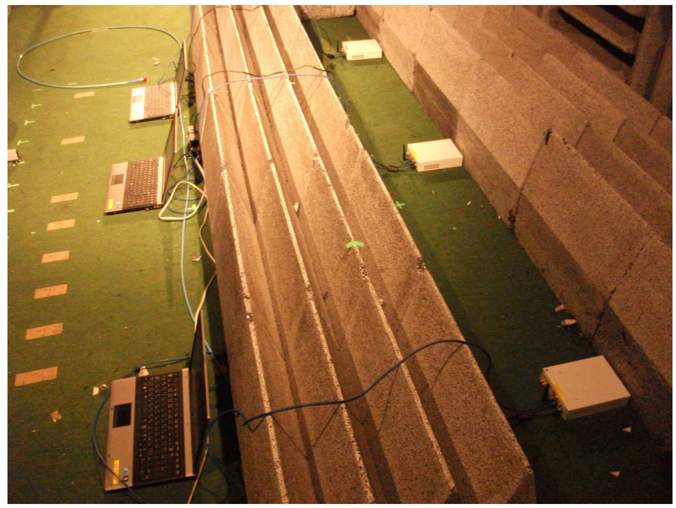

Fig. 1. Experimental environment

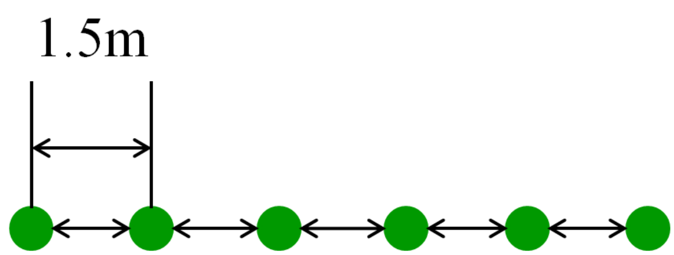

Fig. 2. Network topology of the characteristics measurement experiments

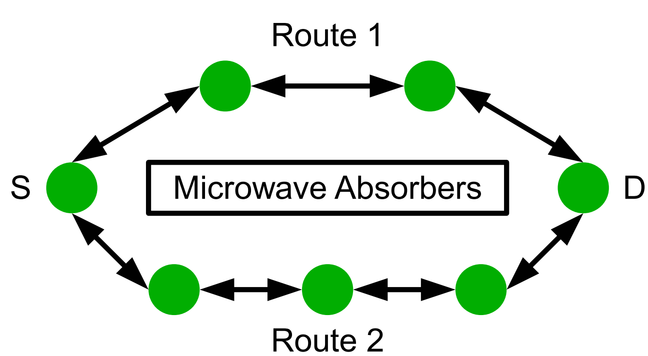

Fig. 3. Network topology of the route building experiment

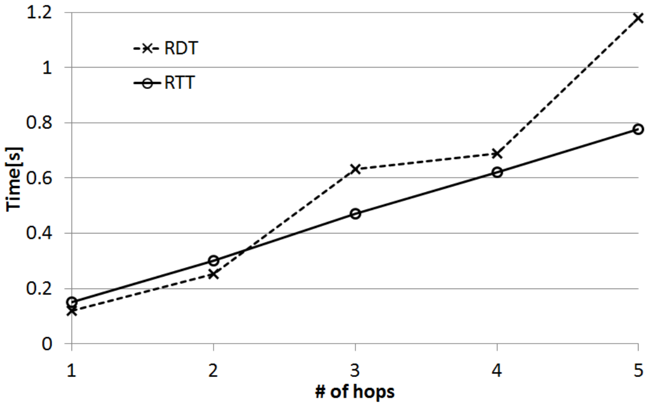

Fig. 4. Experimental results of RTT and RDT

linearly. This comes from the waiting time of ERS. In ERS, there is waiting time between each RREQ flooding to wait for RREP. This waiting time makes result of RDT nonlinear. The result of RTT is in proportion to number of hops. Packets simply go and return in line topology, thus this is appropriate result. In one and two hops topology, RDT is lower than RTT. This because RDT uses broadcast to send RREQ where RTT uses unicast in all of the communications. Overhead of RTS/CTS handshake makes this difference. We analyzed logs of the route building experiment and confirmed that the route 1 was selected as the route between the node S and the node D.

V. Conclusion

We implemented AODV by using GNU Radio and USRP and conducted measurement experiments. Result of experiments showed that implemented AODV behaved correctly. Now we are going on the implementation of DORP, and then we will conduct field operational tests and show effects of real environment.

References

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