Simulation of Routing Protocols for Emergency Vehicle Warning Application in VANETs

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Abstract. *Vehicular ad hoc networks (VANETs) can present a great benefit for road transport safety, effficiency and environmental impact. One of the applications that can utilize the VANETs to increase the traffic safety is an Emergency Vehicle Warning Application. For the application to leverage its potential, it is vital to find appropriate forwarding scheme to allow reliable and timely communication. In this paper, computer modelling using realistic VANET simulation stack is used to evaluate the end-to-end delay characteristics of common ad hoc routing protocols. After the evaluation of protocols' characteristics, we aim to propose the most suitable forwarding mechanism to support the Emergency Vehicle Warning Application.*

Keywords

VANET, simulation, routing protocols, vehicular application.

1. Introduction

Vehicular Ad hoc Networks (VANETs) are one of the key technologies of Intelligent Transportation Systems (ITS). Based on a communication between radio transceiver equipped vehicles and intelligent roadside infrastructure, they can provide critical information for both drivers and autonomous vehicles. These data can be used to prevent vehicle collisions, increase driver´s awareness of road and traffic conditions, or plan the route to the destination in a most environmentally friendly manner.

The communication between the network nodes can be carried out simply by a broadcasting or multicasting. In some cases, however, the targeting of the message to a specific host can be beneficial for the ease of the information interpretation. Let´s assume an application, which provides a warning information about approaching emergency vehicle to ensure a fluent emergency vehicle transit. This information is relevant mostly to the vehicles in front of the emergency vehicle which are travelling the same route. More specifically, if the vehicles are on a road with multiple driving lanes, the information can be targeted to specific vehicles and make them change their lane to the rightmost one in order to free the left lane/lanes for the emergency vehicle.

To compare the performance of the broadcast and the unicast approaches in VANETs, a simulation model was built using OMNeT++ and SUMO simulators with Veins simulation framework.

2. Simulation Tools

With the growing attention on vehicular networks, several tools for vehicular network simulations were introduced. Some of them are reviewed in [1].

Vehicular networks differ from the conventional ad hoc networks mainly by their high mobility. In order to make their simulation as realistic as possible, several computer modeling tools have to be used in conjunction. For our simulations following modeling stack was used:

- OMNeT++ discrete event network simulator
- Simulation of Urban Mobility (SUMO) traffic simulator
- Veins and Artery simulation frameworks
- custom built stochastic traffic flow generator for SUMO

OMNeT++ network simulator is used to obtain the network performance parameters like end-to-end (E2E) delay, average number of hops for a specific protocol, as well as for implementing the whole communication stack.

The SUMO traffic simulator provides the mobility for the nodes modeled in OMNeT++. SUMO uses realistic maps exported from the Openstreetmap project. From the map, road network is extracted and converted using the SUMO's netconvert tool to XML format readable by SUMO. The exported road network is then used as a base for modeling a vehicle traffic flows. Actual traffic flows are modeled based on data obtained by a traffic survey for the Traffic General Plan of the City of Žilina. By this approach, a highly realistic vehicle mobility traces are obtained. [2-5]

Simulation frameworks provide compatibility with IEEE WAVE (Veins) and ETSI ITS G5 (Artery) communication standards for vehicular networks. But one of their biggest advantages is the fact that they implement the Traffic Control Interface (TraCI) API. TraCI provides a real-time bi-directional coupling of the OMNeT++ and the SUMO via TCP socket. This way, the traffic simulator can be controlled from the network simulator and vice versa. This enables modeling of realistic simulation scerasios, for example to change the vehicle's trajectory based on a content of a message it received. [6]

3. Routing in VANETs

Currently, there are five approaches to routing in VANET networks. These approaches can be seen in the Fig.1.

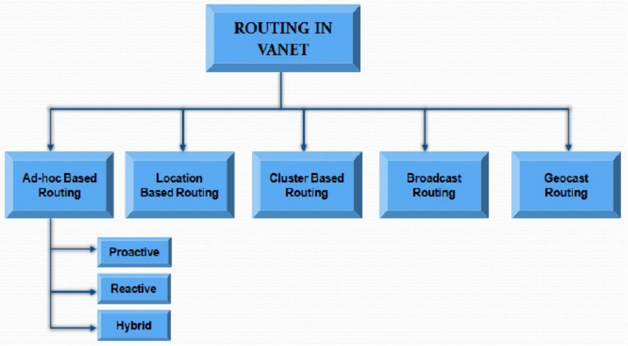

Fig. 1. Routing in VANETs [7]

3.1 Ad-hoc Based Routing (Topology Based Routing)

Some of the routing protocols developed for MANETs and other ad-hoc networks can be used in VANETs with some modifications [7]. This family of protocols can be divided into three groups according to the way in which they maintain their routing tables.

3.1.1 Proactive protocols

Proactive protocols maintain full routing table with all of the routing information to all known networks. All networks are periodically monitored and updated and the node has immediate access to the routing information. Every node maintains its own, complete routing table. If the topology of the network is changed, the information about all of the changes is distributed to the whole network. This ensures that all the nodes have complete knowledge about the topology of the network. Advantages of the proactive routing approach include minimum delay when establishing the connection between nodes, possibility of real-time communication. The proactive protocols provide better quality of service (QoS), as routes are allways up-to-date and immediately available so the end-to-end delay in such a network can be minimized. [8] However, in the case of large-scale networks, or networks with high mobility, signalization packets can overload the network, consuming large portion of available bandwidth, which cannot be utilized to transmit useful data.

3.1.2 Reactive protocols

To minimize the signalization traffic in the network, new family of protocols was developed. Reactive protocols do not maintain complete routing information to all of the available networks. When a node wants to communicate with a distant network, a route discovery process is performed by sending a Route Request (RREQ) packet. If the neighboring node knows the route to the destination, it generates the Route Reply (RREP) packet which is then sent back to the source node using Backward learning method. Otherwise, the neighboring node will rebroadcast the RREQ [8]. This approach can significantly reduce the energy consumption and signalization load, however, it adds a variable delay to the network.

3.1.3 Hybrid protocols

Hybrid routing protocols are a combination of proactive and reactive protocols. They try to utilize advantages of both the families. An example of a hybrid protocol can be the Zone Routing Protocol (ZRP), which uses proactive routing in a zone defined by a certain number of hops. Outside of this zone it uses the reactive routing approach.

3.2 Location Based Routing

Location based routing protocols utilize the coordinates of individual nodes to optimize routing. To use these protocols, it is assumed that each node knows its precise geographical position obtained from a GPS receiver or other source. [9] Each node contains information about the source, destination and neighboring nodes.

3.2.1 Greedy Perimeter Stateless Routing (GPSR)

The GPSR was introduced in 2000 by Karp and Kung [10]. The routing algorithm uses positions of neighboring nodes and the destination node to forward the packet from the source to the destination. It makes forwarding decisions based only on the information about neighboring nodes. The node forwards packets to the neighboring node which is geographically closest to the packet´s destination. If the node cannot find any next hop that is closer to the destination than itself (often referred to as the local maximum problem), the algorithm recovers by routing along the perimeter of the region, using the right-hand rule for traversing the graph. [10] [11]

One of the biggest disadvantages of the GPSR protocol when used in VANETs is that its performance drops significantly when there are obstacles present, rendering it not suitable to use in the urban environments. [11]

3.2.2 Geographic Source Routing (GSR)

The GSR protocol uses street map of the city and location of the source and the destination node to calculate the progression of the key nodes, through which the packet should be forwarded in order to reach its destination. The optimal path is calculated using the Dijkstra´s shortest path algorithm. Between the junction nodes, packets are forwarded using greedy forwarding – node chooses the next hop that is geographically closest to the next junction. When the junction of the path is reached, the greedy forwarding algorithm is applied again to reach the next key node. The process repeats until the packet finally reaches its destination.

3.2.3 Anchor-based Street and Traffic Aware Routing (A - STAR)

This protocol was specifically designed for the inter-vehicular communication systems in an urban environment. Like the GSR protocol, it calculates the list of junctions a packet must traverse in order to reach the destination. To overcome the problem of highly fragile connections in a VANETs and issues caused by an uneven density of the nodes, the protocol uses actual traffic information including number of public transport lines and traffic density to calculate high-connectivity path to the destination. Using this approach, the packets are delivered using streets with higher density of vehicles, which ensures higher connectivity among nodes and less frequent connection breakdowns. [9] [12] [13]

Streets of the map are weighted according to the traffic density, while assigned weight of the street is inversely proportional to the traffic density on the street. After the streets of the map are weighted, an anchor path is computed using Dijkstra´s least-weight path algorithm. Packets then traverse the calculated anchors to reach their destination. [9] [12] [13]

3.3 Cluster Based Routing

Cluster is a group of nodes that can directly communicate to each other without disconnection. An example of clustering can be seen in the Fig.2. To coordinate the communication, a cluster head is selected by the nodes according to the so called suitability value. A vehicle which has higher number of stable neighbors, closer speed to average speed of its stable neighbors and maintains closer distance to its stable neighbors has higher priority to become a cluster head. [14] The vehicles within the cluster can communicate directly. Communication between clusters is performed via cluster heads. [9]

Position data received by the periodic messages (Cooperative Awareness Messages - CAMs) are used to build neighborhood relationships between vehicles in the cluster. To transmit periodic messages, vehicles use the control channel (CCH). To perform all intra-cluster communication tasks and to define the cluster radius, one service channel (SCH) is used.

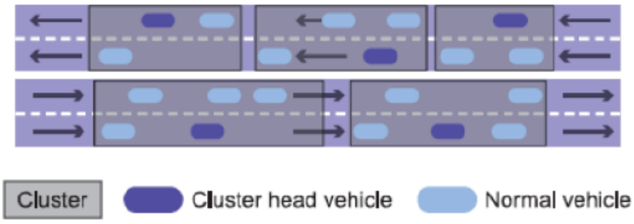

Fig. 2. An example of cluster-based topology [9]

3.4 Geocast Based Routing

Geocast routing can be understood as a multicasting based on the knowledge of geographical location of the nodes. A single source node forwards data to the destination area which is called Zone of Relevance (ZOR). In order to prevent flooding of the geocast message a forwarding area called a Zone of Forwarding (ZOF) is used to confine the message forwarding until it reaches the ZOR. [14]

4. Frame Structure

Frame structure used in simulations can be seen in Fig.3. At the MAC layer, the frame consists of header, payload and a trailer. At the physical layer, preamble and signal are added. Transmissions were carried out using the default 6 Mbit/s data rate according to [16]. The preamble field consists of 12 OFDM symbols with total duration of 32 µs. The signal field is one OFDM symbol with duration 8 µs [17].

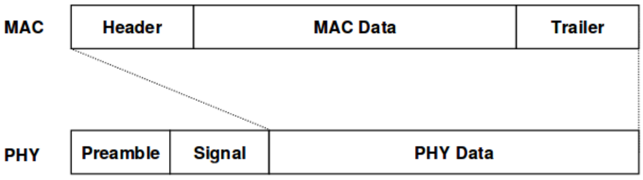

Fig. 3. Frame structure used in simulations

Frame duration can be calculated according to the equation (1).

$$td=\frac{Pl}{DR}+Lp+Ls+Dp+Hc[s] \tag{1}$$

where td is the frame duration in seconds, Pl is the packet length in bits, DR is used datarate in bits per second, Lp is preamble duration, Ls signal duration, Dp propagation delay and Hc is clock hold-on.

Parameters can be found in the Table.1.

Packet length	Preamble [μs]	Signal [μs]	Propagation delay [μs]	Clock hold-on [μs]
300 bytes	32	8	6	50

Tab. 1. Frame duration parameters.

5. Results

As can be seen in figures 4 and 5, the end-to-end delay significantly increases with growing number of next hops. This increase seems to be more significant in the case of AODV protocol, however, the GPSR protocol is unable to find route to the destination at extremely low signal-to-noise ratio. Here the AODV protocol outperforms the GPSR as can be seen in figures 4 and 5.

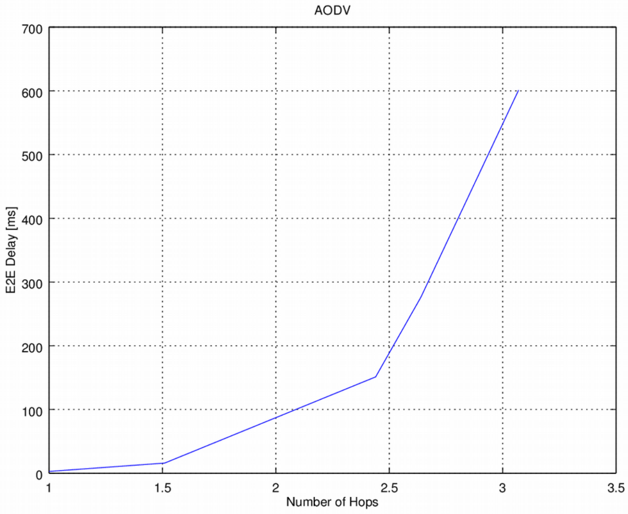

Fig. 4. End-to-End delay for AODV protocol.

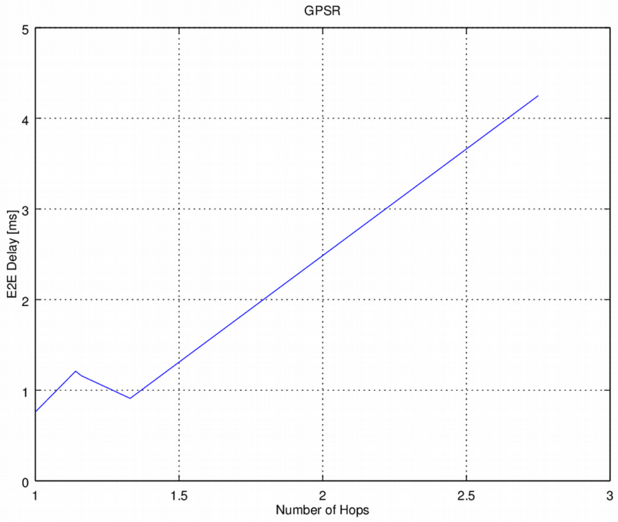

Fig. 5. End-to-End delay for GPSR protocol.

6. Conclusion and Further Work

End-to-End delay of two ad-hoc routing protocols was examined by a simulation of transmissions of a real VANET application in a realistic traffic scenario.

From the simulation results we can conclude that it is very difficult to use a single routing protocol in various scenarios. One of the studied protocols (AODV) achieved much higher average end-to-end delay, but it also was able to support the communication ina case of very low signal-to-noise ratios. The GPSR protocol, on the other hand, showed opposite behavior. Average end-to-end delay in this case was much (100x) lower, however, the protocol was unable to establish the route in complicated communication environment.

In our next research, we would like to similarly examine the behavior of DYMO and ETSI GeoNet protocols. Based on these results we would like to propose the most suitable routing scheme for an emergency vehicle warning application for VANETs which is currently being developed.

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References

[1] PETROV, T., DADO, M., AMBROSCH, K.E. Computer Modelling of Cooperative Intelligent Transportation Systems in Procedia Engineering, Volume 192, Elsevier, pp. 683-688, 2017

[2] VARGA, A., HORNIG, R. An Overview of the OMNeT++ Simulation Environment in Proceedings of the 1st international conference on Simulation tools and techniques for communications, networks and systems & workshops, Article No.: 60, 2008

[3] SUMO User Documentation [online], http://sumo.dlr.de/wiki/SUMO_User_Documentation

[4] Veins: The open source vehicular network simulation framework [online], http://veins.car2x.org/documentation/modules/

[5] Územný general dopravy Mesta Žilina [online], http://enviroportal.sk/sk/eia/detail/uzemny-generel-dopravy-mesta-zilina

[6] RIEBL, R., GÜNTHER, H-J., FACCHI, C., WOLF, L. Artery: Extending Veins for VANET applications in International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS), 2015, IEEE, pp. 450-456

[7] REHMAN, S., ARIF KHAN, M., ZIA, T.A., ZHENG, L. Vehicular Ad-Hoc Networks (VANETs) - An Overview and Challenges in Journal of Wireless Networking and Communications 2013, 3, pp. 29-38

[8] JAYAKUMAR, G., GOPINATH, G. Ad Hoc Mobile Wireless Networks Routing Protocols – A Review in Journal of Computer Science 3, 2007, pp. 574-582

[9] SROTYR, M., LOKAJ, Z., ZELINKA, T. Advanced VANET routing design in Proceedings of the Smart Cities Symposium Prague (SCSP), IEEE, 2015

[10] KARP, B., KUNG, H.T. GPSR: Greedy Perimeter Stateless Routing for Wireless Networks, 2000

[11] LIU, J., WAN, J., WANG, Q., DENG P., ZHOU, K., QIAO, Y. A survey on position-based routing for vehicular ad hoc networks in Telecommunication Systems 62, Springer, 2016, pp. 15-30

[12] KARIMI, R., ITHNIN, N., RAZAK, A., NAJAFZADEH, S. Non DTN Geographic Routing Protocols for Vehicular Ad Hoc Networks. in International Journal of Computer Science Issues, Vol. 8, Issue 5, No 3, September 2011, pp. 86-91

[13] SEET, B., LIU, G., LEE, B., FOH, C., WONG, K. A-STAR: A Mobile Ad Hoc Routing Strategy for Metropolis Vehicular Communications, Networking 2004, Volume 3042, Springer, 2004, pp. 989-999

[14] PRASAD, M.H., KOWSALYA, P. Performance Enhancement of VANETs Using Cluster Based Routing in International Journal of Innovative Research in Science, Engineering and Technology, Vol. 3, Issue 5, May 2014, pp. 12296-12302

[15] ALLAL, S., BOUDJIT, S. Geocast Routing Protocols for VANETs: Survey and Guidelines in Proceedings of the 2012 Sixth International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing, IEEE: 2012, pp. 323-328

[16] ETSI EN 302 663, Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band

[17] ETSI TR 102 861, STDMA recommended parameters and settings for cooperative ITS; Access Layer Part – 2.

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Tibor PETROV was born in Plovdiv, Bulgaria in 1990. In 2015 he finished MSc at the University of Žilina, Faculty of Electrical Engineering, Department of Telecommunications and Multimedia. Currently he studies doctoral degree at the same department. His research activities include wireless networks and cooperative technologies in the Intelligent Transportation Systems (ITS) environment.