IMPROVING MESSAGE DELIVERY IN VEHICULAR AD-HOC NETWORKS

Nnamdi Anyameluhor
Evtim Peytchev
Javad Akhlaghinia
Department of Computer Science
Nottingham Trent University
Clifton Lane, NG11 8NS, Nottingham, United Kingdom
E-mail: Nnamdi.Anyameluhor, Evtim.Peytchev, Javad.Akhlaghinia {@ntu.ac.uk}

KEYWORDS

Framework, Model, Vehicular Ad-hoc NETworks, VANET, Wireless Communication, Network Simulation.

ABSTRACT

Road traffic information has been a primary source for traffic management, user services and other systems that enable road congestion prevention and control; however, road traffic information has not been adequately exploited as a part of the design for wireless communication network. In vehicular ad-hoc networks, the protocol design must consider the dynamic nature of the topology and the probability of available alternate routes for wireless routing. The information provided by either the road itself or the activities on the road can help to void common issues such as broadcast storms, hidden node problems and lost data caused by an increase in road traffic density or sparse road traffic respectively. Routing protocols must therefore be able to dynamically adjust to the current road traffic information. In order to improve message delivery in vehicular ad-hoc networks, this project proposes a collaborative process of utilizing real time road traffic information and route knowledge to enhance routing decisions in order to maximize packet delivery ratio and reduce delays in transmission.

INTRODUCTION

Intelligent Transportation Systems has become an important field because of the growth of wireless networking technologies and devices as well as the increase of transportation vehicles. However, vehicular ad-hoc network is still an emerging technology aided by number of research and issued standards, which still requires some further work to attain the level at which it could provide its all promises. Vehicular ad-hoc networks are wireless networks that can be formed with or without infrastructure, comprised of vehicles with wireless capabilities in a self-organizing manner. Traffic management, road safety aid, entertainment, and user targeted services (Morsink et al. 2002, Wischhof et al. 2003) are among the uses of vehicular ad-hoc networks.

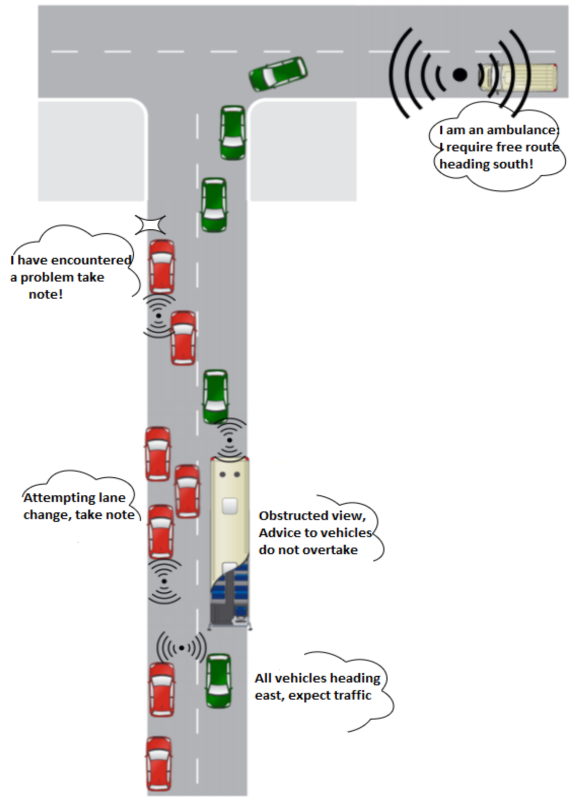

Fig 1: VANET in operation

Message delivery in vehicular ad-hoc networks is affected by factors such as the speed and mobility of the vehicles, i.e. topological fluctuation, as well as the number of participating vehicles in an area, i.e. vehicular density. These factors impose serious and unique challenges on researchers in order to design encompassing solutions capable of handling various possible scenarios. Models to be designed must consider the unique characteristics of vehicular networks as well as issues that may arise, such as broadcast storms where transmission attempts surpass the available bandwidth due to a high vehicular density. The result of a broadcast storm will be network congestion and added delays caused by packet collisions. On the other hand, very low vehicular density results in sparse networks that might not be suitable enough to guarantee message delivery

Proceedings 31st European Conference on Modelling and Simulation ©ECMS Zita Zoltay Paprika, Péter Horák, Kata Váradi, Péter Tamás Zwierczyk, Ágnes Vidovics-Dancs, János Péter Rádics (Editors)
ISBN: 978-0-9932440-4-9/ ISBN: 978-0-9932440-5-6 (CD)

from one point to another. In this paper, a Framework for Improving Message Delivery in VANETs (FIMDEV) is proposed and discussed. The aim of the framework and model is to assist message delivery from one location to another by using current road traffic information as it relates to the wireless network condition of that area. Among the aims of the framework includes low delays and some level of guarantee regardless of the routing protocol used in the dissemination process. FIMDEV, in conjunction with directed propagation will ensure messages avoid congested routes on their way to their destination. It also employs the use of furthest node reachable as well as the use of established traffic routes where applicable. The rest of this paper is organized as follows; section II discusses some work relevant in this area, section III describes the framework, section IV discusses the performance through evaluation and results and section V concludes the paper and provides possible future work.

II RELATED WORK

Message dissemination in vehicular ad-hoc networks is conducted either through the spread of one-hop messages, e.g. the ones spread periodically by neighbouring vehicles to share relevant updates such as travel data or cluster formation data and are not sent to other vehicles further than a hop away. Message dissemination is also handled through multi-hops, in this case messages such as the spread of safety related messages or value added services may need to transverse beyond the area of origin and will therefore need to travel beyond one hop radius in the wireless network. The IEEE 1609.4 standard based on the 802.11p specifies multichannel operations at the 5.9 GHz band. This band is divided into Control Channels, and Service Channels ready for safety and non-safety applications. One-hop safety messages using this standard are generated periodically at a typical rate of 10 Hz in VANETs to provide updated information about traffic conditions while multi-hop transmissions rely on smart routing protocols for efficient message delivery. J Park and Y Lim proposed RSMB, Reliable and Swift Message Broadcast Method for vehicular ad-hoc networks. In this model, the authors use duplicates of the same message to increase the probability of that message transmitting to the next relay on its way to its final destination. The next relay was selected in such a way as to transverse the network quickly. Although the duplication of messages can increase the chances of vehicles' reception and it is done selectively, it is unclear how scalable the model is under real scenarios. This model showed good results in its evaluation. Fogue et al. in (Fouge et al., 2012) showed that the use of roadmaps in an innovative way that could help in improving message delivery. The protocol called enhanced Message Dissemination for Roadmaps, eMDR builds upon a prior protocol called enhanced Street Broadcast Reduction (Martinez F. J. et al., 2010) which also used information from maps and GPS to alert vehicles within the vehicular network. The eSBR protocol works by choosing the farthest vehicle from the sender on the map, this method works well when all routes are not congested and the aim is to spread the message as far as possible. In the case of eMDR extra controls are put in place to avoid retransmissions by preventing vehicles from broadcasts, allowing only the node closest to the center of a junction to retransmit any message. Multi-hop vehicular broadcast, MHVB (Osafune et al., 2006) was proposed as a flooding solution for vehicular ad-hoc networks to efficiently disseminate safety application information, such as the positions and the velocities of the vehicles within a small geographical area of up to 300m while achieving maximum delays of up to 0.5s. It is presented as a flooding protocol with two main algorithms which are; (i) a Congestion Detection algorithm which reduces unnecessary packets due to vehicular congested traffic by limiting packet spread and (ii) Backfire algorithm which efficiently disseminates the messages through the network by selecting the right receiver node based on the distance from the original node. Adaptive Traffic Beacon (ATB) by Sommer C. et al. (2011), presented a message dissemination protocol which uses two main metrics to adjust the rate at which beacons are transmitted. The metrics are; channel quality and kind of message to be sent. From results shown, the protocol compares well to pure flooding broadcasts, albeit done at a slower rate. It has a knowledge database with important information shared through the use of previously described adaptive beaconing technique in order to maintain a congestion free network. In Cross Layer Broadcast Protocol, CLBP (Bi et al., 2010) the same principles of using knowledge of the channel condition, geographic position, and speed of the car to improve message dissemination in vehicular ad-hoc networks. However, in this protocol, they employ the use of Broadcast Request to Send and Broadcast Clear To Send techniques which may add to the time taken to setup a connection and perform transmissions. This protocol may fail if used in a more rapidly evolving mobility scenario which the authors did not test. Some researchers (Burns et al, Burgess et al, Y Li and E Peytchev) have suggested the use of vehicles such as buses with more permanent routine as agents of message dissemination with the argument that buses are fairly frequent and therefore a reliable way to share data in vehicular network. This works very well for areas with a frequent bus network. Trajectory based forwarding (Tian et al, Niculescu and B. Nath) show that by understanding the road through which the vehicles travel, delivery of messages can be improved upon. Here messages are forwarded greedily along a pre-defined trajectory.

III FRAMEWORK DESCRIPTION

Framework for Improved Message Delivery (FIMDEV) is a dynamic framework that works by comparing current road traffic information against stored values of that road under similar road traffic conditions. In the proposed framework, the vehicles are supplied with information about the current road traffic data by using which they make decisions. Research on how to gather such data have been conducted by (Gamati et al. 2011). In this research, however, we have assumed that current road traffic information is provided by the city's transport authorities which is collected from inductor loops along various points of the road. The figure below shows the structure of the framework.

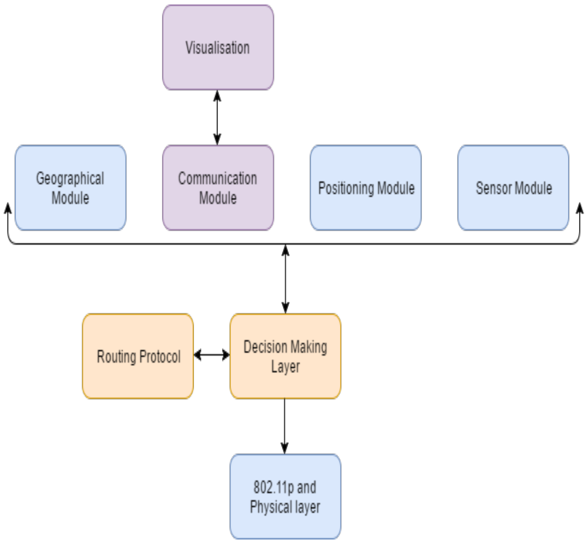

Figure 2 Proposed Framework

The framework consists of various modules representing different data sources such as geographic, communication, position and sensor data. While geographic data can be retrieved from digital maps, positioning will be done by using information from any global navigation satellite system available to the vehicle. Gathering of sensor data has been discussed previously (Gamatti et al. 2011).

Sensor Module

Data from speed sensors for example will play a vital role in ensuring accuracy of information (Tripp-Barba et al., 2014). For this research project, the sensor data is important in order to maintain validation or corroborate the traffic conditions reported by other vehicles; sensor data at this stage are simulated information such as the speed of the vehicle.

Positioning Module

The position of the vehicles along the route is a very important factor as it allows algorithms to differentiate between reachable and unreachable nodes. As will be seen below, if a path is to be determined between two points then those points' locations must be identified in relation to the area under consideration. In (Sun et al., 2000) the authors proposed and implemented a protocol called TRADE which uses the information obtained from Global Positioning System in order to categorise the neighbouring vehicles, by doing this, the protocol is able to accurately detect the furthest reachable node within the neighbouring list. Though the use of positioning is widely accepted, the use of Global Positioning System as the default choice is a bit of a stretch because of the level of accuracy available for use in the public domain. In terms of experimental simulation, pure dependence on a god-like accuracy of positions is faulty, as this will ultimately prove impossible to achieve in real world scenarios. In this research project, the proposal is that the most suitable Global Navigation Satellite System to use will be the Galileo system that offers higher accuracy to within a meter (Steigenberger, 2017).

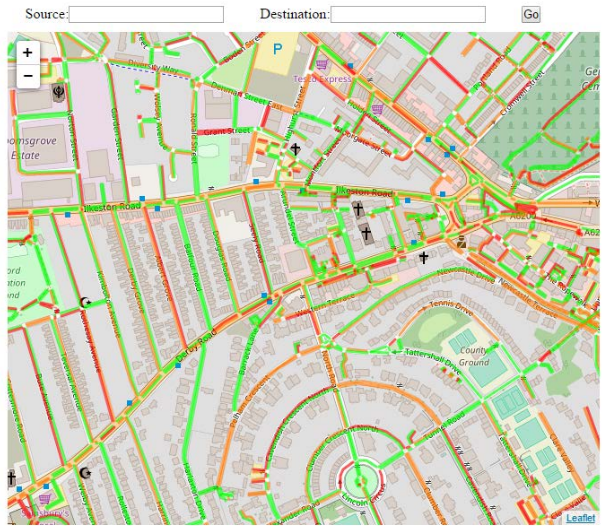

Figure 3: Visualisation of the communication map

Communication Module

This module contains information about the wireless network condition of the area in question, it is a wireless network condition map of the area as visualised in figure 3. It is a collection of data obtained by running experiments offline under various conditions and recording the data. In order to achieve the aim of this research, it is crucial to determine the wireless communication condition of the network of each road with various combinations of traffic elements. That is, capturing the level of wireless network condition when the state of vehicles in this scenario are altered by changing the number of participants and their average speeds. These data can then be used as a reference when comparing against current wireless network communication levels based on current traffic data. These factors have been chosen after careful consideration of the factors that have considerable effect on the potential outcome of any VANET communication.

The experiments conducted consists of a series of simulations on each of the City's roads under consideration, the metrics considered as outcomes include the packet delivery ratio and average end to end delay. This method of analysing and storing values is inspired by application of similar methods used in SatNavs where each road and landmark is digitised for future use. If each road's wireless network situation is known beforehand then it allows for some adjustment to how messages are moved about those roads.

Packet delivery ratio is the ratio of the number of packets received by the destination to the number of packets sent, it is a uniquely important factor as it represents how efficient a wireless network is; high values indicates a good network (Shobana M., Karthik S., 2013).

In order to classify each road as good average or bad, we varied number of vehicles and speeds for each road simulated and recorded the results of those experiments. Next the results are identified as:
Good, where packet delivery ratio is ≥ .75 and ≤ 1
Average, where packet delivery ratio is ≥ 0.5 and ≤ 0.74
Poor, where packet delivery ratio is ≥ 0 and ≤ 0.49

Together these values are called communication network values (cnv) which are then stored for each road against its corresponding number of vehicles and speed in a database

Geographical Module
Several researches have shown digital geographic map of areas to be useful tools in implementing vehicular network designs. The map of an area can provide road information critical in directing messages along the right path, or used in implementing conditional routing at junctions etc. For example, the authors in (Xiang et al., 2013) proposed a map based protocol called GeoSVR aimed at solving local maximum and sparse connectivity problems in VANETs thereby increasing packet delivery ratio. It works by locating the nodes on a digital map and calculating the optimum path by using a shortest path greedy algorithm. Similarly, for FIMDEV to function, sections of the area under consideration will be represented as a weighted graph, with junctions, intersections and roundabouts represented as vertices (nodes) in the graph while the roads represent the edges of the graph. These edges will all have weights which represent the current wireless communication condition values of each road which will be compared to stored values for each road as described in the previous section. Paths between two locations can then be found using Dijkstra's algorithm as follows;

Algorithm 1 Communication Path Finder Using Dijkstra

```
Require: Weighted Graph G, roads = edges, junctions etc = vertexes (v)
Require: Source node s
Ensure: Path between two points in G satisfying the wireless network value
    constraint
for all v ∈ V[G] do
    cnv[v] ← +∞
    previous path[v] ← undefined
end for
cnv[s] ← 0
S ← empty set
Q ← V[G]
loop
    Q is not an empty set
    u ← Extract_Min(Q)
    S ← S ∪ {u}
    for all edge (u, v) outgoing from u do
        if cnv[u] + w(u, v) < cnv[v] then
            cnv[v] ← cnv[u] + w(u, v)
            previous[v] := u
        end if
    end for
end loop
```

Algorithm 1: Framework Algorithm

i. All nodes are initially set to infinity with the exception of the starting position which is given a value of zero. That is, the communication network values between the starting point and every other point is regarded as infinity.
ii. All nodes are regarded as temporary with the exception of the starting node, in order to indicate what nodes have been "visited".
iii. The starting node begins the process by being marked as active.
iv. Calculation of the ability to reach all neighbour nodes from the active node by summing up its value with the weights of the edges.
v. If such a calculated path of a node is smaller than the current one, update the value and set the current node as the previous node.
vi. Next the node with the minimal temporary value is marked as active.
vii. Steps 4 to 6 are repeated till all nodes examined.

At the end of the algorithm, a path that has the best communication network ability between the source and intended destination is found and this information is forwarded to the decision layer in order to forward the intended message.

Decision Layer
The decision making is one based on trajectory forwarding (Niculescu and Nath, 2003) which is a method that directs messages closer to its destination by selecting a node in a specific direction. It is a forwarding strategy based on iterations of the algorithm on each node while considering each node as the source node until the message arrives its destination. Trajectory Based Forwarding is favourable in this case because it uses similar data already found in FIMDEV, hence it is easier to implement.

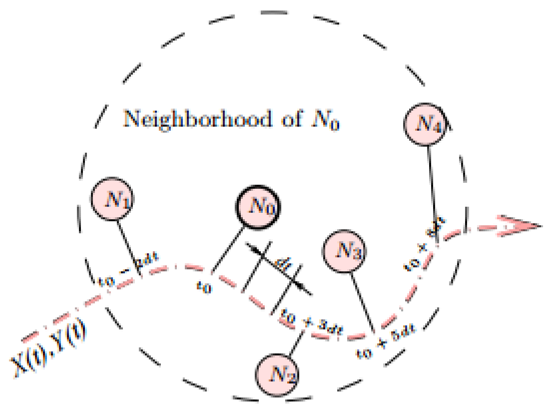

Figure 4: Trajectory Forwarding Strategy (Niculescu and Nath, 2003)

In trajectory based forwarding messages follow a trajectory established at the source, but each successive node takes a greedy decision to infer the next hop based on local position information from a Global Navigation Satellite System such as GPS. If the trajectory is expressed as a coordinate X(t), Y (t) then the equation for routing along a line with slope α passing through the source with coordinates x_1, y_1 would be described by $X(t) = x_1 + t\cos(\alpha)$; $Y(t) = y_1 + t\sin(\alpha)$ respectively. Where α, x_1, y_1 are constants, and the t describes euclidean distance traveled along the line. More information on this can be found in (Finn, 1987) (Niculescu and Nath, 2003).

IV RESULTS AND EVALUATION

The proposed framework was tested on Network Simulator, NS-3 and evaluated in comparison to Ad-hoc On Demand Vector Routing (AODV) protocol (Perkins et al. 2003). All experiments were done following IEEE 802.11p standard. The scenario tested was an Open Street Map (OSM) extract of the Nottingham City Centre that was prepared using mobility patterns from Simulation of Urban Mobility (SUMO). The results shown here for each evaluation represents a mean of 20 executions.

Parameter	**Value**
Simulation Scenario	Nottingham City Center
Frequency Band	5.9 GHz
MAC Protocol	802.11p
Node Density	Varied
Node Speed	Varied
Interface Type	Queue
Range	250m
Propagation Model	Two-Ray Ground

Table 1: Simulation Parameters

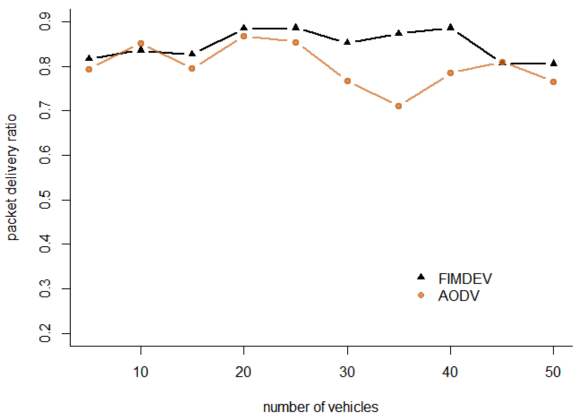

Figure 4 PDR results at speed 10m/h

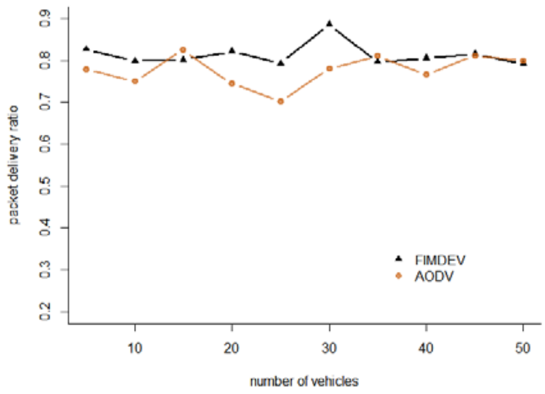

Figure 5 PDR results at speed 20m/h

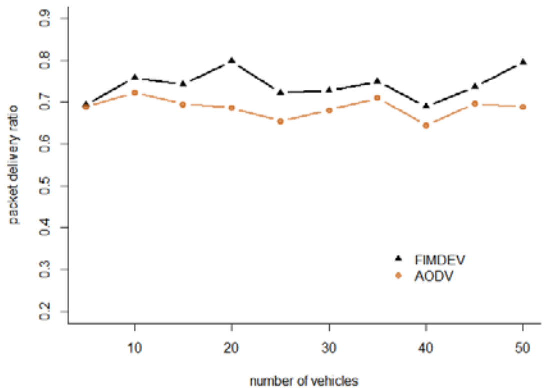

Figure 6 PDR results at speed 30m/h

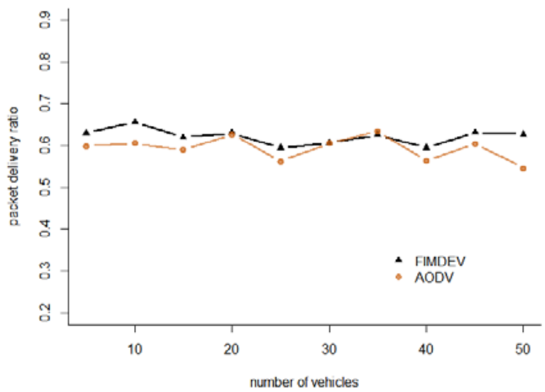

Figure 7 PDR results at speed 40m/h

The graphs show FIMDEV provides improvement in terms of the packet delivery ratio at various speeds and number of vehicles. The speeds are representative of the average speeds within the Nottingham city center. The strength of FIMDEV is its ability of nodes to quickly utilize current road traffic condition as a yardstick to determine what its premeasured wireless communication condition is and therefore find alternate routes where possible. Nodes wanting to transmit messages compare the current traffic condition (i.e. number of vehicles on the route and speed) against the corresponding values in the stored database. Two areas where FIMDEV performs better than AODV is when the vehicles travel at high speeds and situations where there are a lot of vehicles in the network as previous experiments have shown that high speeds and high vehicle congestion inhibits efficient message dissemination (Hafeez et al. 2013).

V CONCLUSION

The goal of the framework is to provide a system through which vehicles can make more intelligent decisions about how to transmit messages in a vehicular ad-hoc network. It can be noted from the evaluation of the work that the model compares favourably against pure flooding and AODV. The explanation for this is that the vehicles should not only apply suppression for reducing multiple broadcasts when the network is perceived to be congested through a comparison of the current traffic condition and recorded corresponding wireless network values in the communication database. Vehicles can therefore use selective path forwarding to push messages towards less congested routes by using a modified greedy path algorithm while applying directed forwarding strategy to ensure messages follow the specified path. The aim of the research can be said to have been attained, being to describe a novel way of using road traffic information to make intelligent decisions related to message distribution in a vehicular ad-hoc network.

Storing values in a database is acceptable for small areas but it is not entirely scalable, that is, as the size of the network increases the amount of data to search through increases.

Hence in future work, we will consider using strategies like Farthest-in-Future Optimal Caching to store the communication data to reduce the amount of obsolete data the algorithm needs to go through.

REFERENCES

Bi Y., L.X. Cai, X. Shen, and H. Zhao. 2010. “A cross-layer broadcast protocol for multi-hop emergency message dissemination in inter-vehicle communication,” in Proceedings of the IEEE International Conference on Communications (ICC ’10), pp.1–5, Cape Town, South Africa

Burns B., O. Brock, and B. Levine. 2005. “MV Routing and Capacity Building in Disruption Tolerant Networks,” in InfoCom.

Burgess J., B. Gallagher, D. Jensen, and B. N. Levine. 2006. “Maxprop: Routing for vehicle-based disruption-tolerant networking,” in InfoCom.

Crovella, L. Feeney, D. Rubenstein, and Raghavan S. 2010. Eds., vol. 6091 of Lecture Notes in Computer Science, pp. 265–276, Springer, Berlin, Germany.

Finn G. 1987. “Routing and addressing problems in large metropolitan-scale internetworks.” in Technical Report ISI Research Report ISI/RR-87-180, University of Southern California.

Fogue M., Garrido P., Martinez, F.J., Cano J., Calafate, C. T. and Manzoni, P. 2012. “Evaluating the impact of a novel message dissemination scheme for vehicular networks using real maps”, Transportation Research Part C: Emerging Technologies, vol. 25, pp. 61–80.

Fogue M., Garrido P., Martinez, F.J., Cano J., Calafate, C. T. and Manzoni. 2010. “Evaluating the impact of a novel warning message dissemination scheme for VANETs using real city maps” in NETWORKING 2010: 9th International IFIPTC 6 Networking Conference.

Hafeez, K.A., Zhao, L., Ma, B. and Mark, J.W., 2013. "Performance analysis and enhancement of the DSRC for VANET's safety applications." in IEEE Transactions on Vehicular Technology, 62(7), pp.3069-3083.

Morsink, P., Cseh, C., Gietelink, O. and Miglietta, M. 2002. “Design of an application for communication-based longitudinal control in the CarTALK project.” in IT Solutions for Safety and Security in Intelligent Transport (e-Safety).

Niculescu, D. and Nath, B. 2003. “Trajectory Based Forwarding and Its Applications.” in MobiCom'03.

Perkins, C., Belding-Royer, E., Das, S. et al. 2003. “Rfc 3561-ad hoc on-demand distance vector (aodv) routing”, Internet RFCs pp. 1–38.

Shobana M. and Karthik S. 2013. “A Performance Analysis and Comparison of various Routing Protocols in MANET” in proc. International Conference on Pattern Recognition, Informatics and Mobile Engineering (PRIME), pp 391-392.

Sommer C., Tonguz O.K., and Dressler F. 2011. “Traffic information systems: efficient message dissemination via adaptive beaconing” in IEEE Communications Magazine, vol. 49, no. 5, pp. 173–179.

Steigenberger, Peter. 2017. “Accuracy of Current and Future Satellite Navigation Systems”. Habilitation, Technische Universität München.

Sun, M.T., Feng, W.C., Lai, T.H., Yamada, K., Okada, H. and Fujimura, K. 2000. “GPS-based message broadcast for adaptive inter-vehicle communications” In Vehicular Technology Conference, 2000. IEEE-VTS Fall VTC 2000. 52nd (Vol. 6, pp. 2685-2692).

Tian J., Han L., Rothermel K., and Cseh C. 2003. “Spatially Aware Packet Routing for Mobile Ad Hoc Inter-Vehicle Radio Networks,” in Proc. of the IEEE 6th Intl. Conf. on Intelligent Transportation Systems (ITSC).

Tripp-Barba, C., Urquiza-Aguiar, L., Igartua, M.A., Rebollo-Monedero, D., de la Cruz Llopis, L.J., Mezher, A.M. and Aguilar-Calderón, J.A., 2014. “A multimetric, map-aware routing protocol for VANETs in urban areas” in Sensors, 14(2), pp.2199-2224.

Wischhof, L., Ebner, A., Rohling, H., Lott, M. and Hafmann, R., 2003. “Adaptive Broadcast for Travel and Traffic Information Distribution Based on Inter-Vehicle Communication” in IEEE IV'2003.

Yong Xiang, Zheng Liu, Ruilin Liu, Weizhen Sun, Wei Wang. 2013. “GeoSVR: A map-based stateless VANET routing” in Ad Hoc Networks, Volume 11, Issue 7, Pages 2125-2135, ISSN 1570-8705.

Ziliaskopoulos, A.K. and Zhang, J. 2003. A Zero Public Infrastructure Vehicle Based Traffic Information System. in TRB 2003 Annual Meeting.

AUTHOR BIOGRAPHIES

DR. EVTIM PEYTCHEV is Reader in Wireless, Mobile and Pervasive Computing in the school of Science and Technology at Nottingham Trent University, UK. He is leading the Intelligent Simulation, Modelling and Networking Research Group, which consists of 5 lecturers, 3 Research Fellows and 6 research students. He is the Module Leader for Systems Software; and Wireless and Mobile Communications. He is a participant in various European projects such as MODUM and he also teaches modules Software Design and Implementation; Mobile Networking; Enterprise Computing; and Computer Architecture at the university.

Dr. JAVAD AKHLAGHINIA is an experienced research scientist in intelligent transportation systems, embedded technologies, machine learning and intelligent environments. He has been working as a research fellow in EC funded European projects such as REMOURBAN at Nottingham Trent University, MODUM and ARUM at the University of Manchester.

NNAMDI ANYAMELUHOR is a post graduate researcher in the field of vehicular networks and wireless communications at the Nottingham Trent University with a first degree in Electrical and Electronic Engineering, MSc in Cybernetics and Communication Engineering from the Nottingham Trent University, United Kingdom.