An Experimental Comparison of Dynamic Routing Protocols in Mobile Networks

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Abstract: The paper deals with the research of dynamic attributes of routing protocols in the vehicle's movement simulation in urban environment. Simulation environment allows to modify the volume of the transmitted data, transmission speed, failures' character and intensity. The research was performed for OLSR and B.A.T.M.A.N. protocols. The obtained results permit to formulate optimal conditions for using these protocols on the vehicle's board.

1 INTRODUCTION

Application of wireless protocols for data transmission in vehicles considerably widens information interaction of all traffic parties, from vehicle manufactures to passengers (Zaborovski et al., 2013). Nowadays they help to solve tasks of traffic control, to monitor the vehicle conditions, to prevent accidents, to provide aid in emergency cases, to offer entertainment activities to passengers, and to plan transportation process (Glazunov et al., 2013b). This results in a considerable change in the volume and frequency of transmitted data.

Currently, it is possible to set a multi-protocol unit (MPU) aboard the vehicle. It supports an arbitral number of data transfer protocols and ensures high reliability of message transfer between the vehicle and the access point. A stationary transmitter of LTE, DSRC network or mobile one — for mesh-network (Chakraborty and Nandi, 2013) is an access point. To transmit data the vehicle makes a stable connection with the nearest access point within 100 to 800 meters. Constant replacement of one access point by another one occurs during the motion and in some time intervals the connection can fail.

Besides, structural features of buildings distort the standard picture of signal propagation in the air, which also has an impact on connection stability. In this situation the task of reliability research of data transfer for each type through different technologies of wireless connection is of special priority (Glazunov et al., 2013a).

This paper deals with two technologies: LTE and Mesh as they are most common among mobile clients. The objects of the research are B.A.T.M.A.N. (Pereira et al., 2012) and OLSR (Laouiti et al., 2008) dynamic routing protocols since they are directly oriented at use in dynamic mobile networks.

2 RELATED WORK

There have been several studies about the performance of different routing protocols in wireless mesh networks (Murray et al., 2010), (Abolhasan et al., 2009) and (Kulla et al., 2012). In these papers authors compare the performance in terms of transport layer protocols in Ad-Hoc networks. They analyze the following terms: overhead, latency, data transfer speed.

In the paper (Murray et al., 2010) and (Abolhasan et al., 2009) authors compare OLSR and B.A.T.M.A.N. routing protocols by average file and ICMP requests set transfer time within experimental Wi-Fi networks. They are using only 802.11a technology in experiments.

In the paper (Kulla et al., 2012) authors test and verify the quality of message delivery and network loading by OLSR, B.A.T.M.A.N. and DSR protocols in buildings.

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In this paper OLSR and B.A.T.M.A.N were selected based on above mentioned studies. However our paper considers the changed task that replaces the homogeneous network by heterogeneous Wi-Fi(802.11bg) + Mesh(802.11s) networks. Multiprotocol node will be alternative means of data transmission over wireless local area networks. In dynamic routing protocols instead of transport protocols the user's high-level protocols are taken for the most adequate estimation of the user's actual scenarios.

3 ANALYSIS OF RESEARCH PARAMETERS

Data Volume Analysis
In modern intelligent transport systems (Zaborovskiy et al., 2013) the following scenarios of data transfer (see Table 1) are realized between mobile clients (Vilhan and Hudec, 2013). Limited volume of data and frequency renewal are selected for each scenario.

Table 1: Limited data volume.

Data Transfer Scenario	Limited Volume, KBytes	Event frequency
Messaging of weather conditions, of pavement conditions, current changes in traffic network	10–100	event-trigger
Gathering and displaying of location data of other vehicles	$10–10^3$	constant
Autosave of the vehicle's motion tracks with video record of key motion points during motion or by request	$10–10^3$	constant
Accidents messaging	10–100	event-trigger
Distant upload of new software	$10^3–10^5$	occasional
Audio and video consultation on the vehicle technical conditions	$10^3–10^5$	occasional
Telecommunication environment for passengers (media content)	$10^4–10^5$	constant
Messaging on technical checkup or urgent repair	$100–10^3$	event-trigger
Distant control of the vehicle's units	$10–10^3$	event-trigger

The files' volume ranges from 10KB to 100MB. For example, the amount of data for:

- information messages, such as eCall, geoinformation, service messages, are less than 10K;
- text documents, e-mails and hyperlink files range from 10 to 100K;
- files of media-content graphic data or software update range from 1M to 10M;
- audio and video files, user software and program data updates range from 10M to 100M;

Therefore, 10KB, 100KB, 1MB, 10MB, 100MB are typical data volumes, which will be used in experiments.

Channel Analysis
Factual speed of data transfer via communication channels essentially differs from maximum declared for a technology in question. In practice it is limited by:

- service providers;
- network hardware settings;
- software settings of server infrastructure;

Besides, the transfer speed at a specific point depends on the channel loading that has a random character and depends on clients' activity. Loading variation of the LTE channel causes the user's uncertainty about current speed of access to files and services. To reduce the time of information exchange it is necessary to have alternative ways of file delivery and service access via a chain of retranslators.

The following technologies of access through connection channels are chosen for this research:

- LTE provides connection with the cloud environment and file access services.
- Mesh provides alternative opportunity of interaction between mobile clients and connection with the cloud environment via retranslators.

Analysis of Routing Protocols
OLSR and B.A.T.M.A.N. protocols are mainly used in mobile networks with high dynamics network topology changes. For example these protocols currently used in urban mesh-networks with Wi-Fi technology. These networks consist of more than 1000 nodes and now is used in Greece, Italy, Germany and other European countries. In these networks mobile users used as a mobile routers. At the moment, there are applications for smartphones for the Android operating system supporting B.A.T.M.A.N. protocol (Jayasooriya et al., 2013). For example the mobile smartphone application is described in the article (Jayasooriya et al., 2013) presents functions for accessing web-content (multimedia) and reduce download global data networks. Another important example of use of protocols OLSR and B.A.T.M.A.N. is information networks in vehicles (VANET). Such networks are now being actively investigated and modeled in order to further the development of infrastructure and dynamic stationary transmitters in mobile networks, the development of intelligent transport systems (ITS).

The research considers two dynamic routing protocols: OLSR and B.A.T.M.A.N. They are developed for mobile networks and permit to find routes of data transfer after the network reconfiguration. Realizations of two classes of protocols are considered: B.A.T.M.A.N. is a protocol based on calculation of distance vector while OLSR is based on channel condition analysis. There are differences between them: OLSR builds a complete route to the recipient whereas B.A.T.M.A.N. calculates a distance vector and chooses next transition on this basis (Klein et al., 2012). It allows to measure time difference when files of different size are transferred at different speeds with or without interference.

Data transfer between the server and the client is performed by means of layer protocols application: ftp and http (Zaborovsky et al., 2009). These are standard protocols available in many web-applications and are used to receive hypertext, media, and graphic data.

Interference Analysis

Local technologies in the connection of mobile clients regulate two modes of connection function:

Stable connection — the vehicle is immovable and is connected to a mobile local network, e.g. via Wi-Fi.

Unstable connection — the vehicle is moving from one access point to another. In this case, intervals of connection failure occurs. Time of connection failure can be simulated on the basis of reciprocal positions of immovable access points and mobile retranslators, e.g., via mesh.

To study the features of the second mode of local technologies functions, a simulation testbed, that provides time registration of the chosen volume data interchange, was assembled.

4 THE EXPERIMENT

Stand Hardware and Software Configuration

The testbed is a hardware-software complex implementing interaction of multi-protocol unit (MPU) prototypes with a load simulator for LTE, Mesh, and Wi-Fi. Structural chart of testbed's hardware are shown in Fig. 1.

To implement the scenario the testbed is set as follows: it consists of two MPU blocks, a load simulator, and a Wi-Fi access point. The load simulator provides mobile network clients with access to files. Each MPU block provides operation with two interfaces — Mesh and Wi-Fi or Mesh and LTE which allows to transfer data in different directions using different technologies. MPU-1 acts as a client that connects to the load simulator. MPU-2 is designed for the retranslator that connects MPU-1 and the load simulator. The logic chart of the testbed connection for the scenario realization is shown in Fig. 2

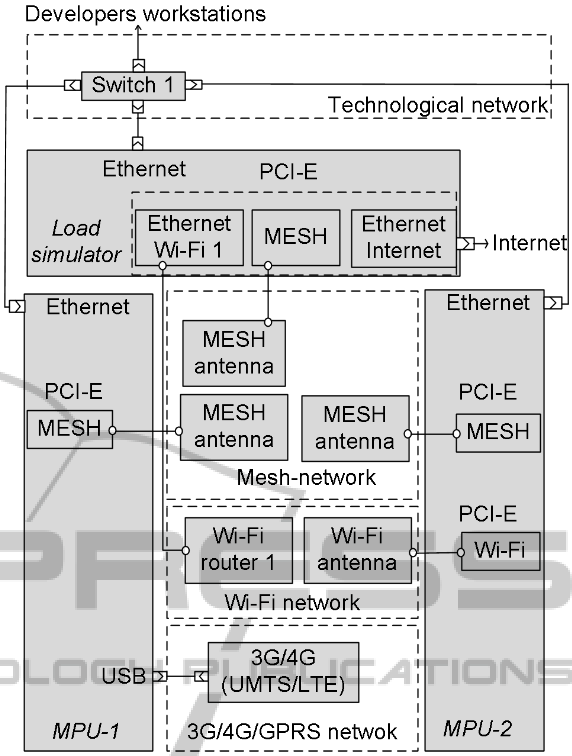

Figure 1: Structural chart of hardware configuration.

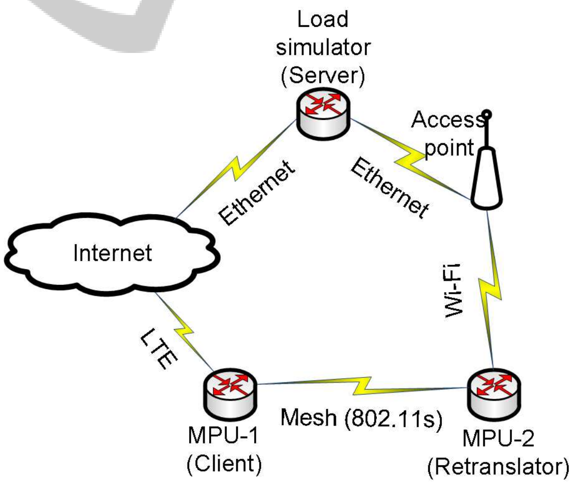

Figure 2: The logical chart of the testbed connection of the system and client software update scenario.

The applied technologies for MPU-1 connection, realizing the client's functions, and the load simulator, acting as a server, and MPU-2, functioning as the retranslator between MPU-1 and the load simulator, are shown on the chart.

Software architecture shown in Fig. 3 is implemented to realize scenarios of mobile clients motion, data transfer stream management, interference simulation, routing protocols choice, communication channels feature setting.

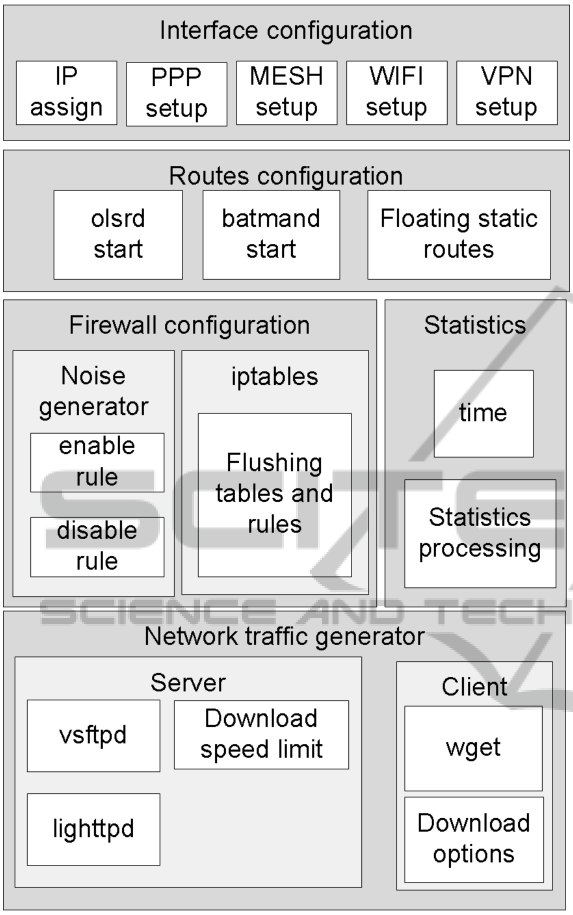

Figure 3: Software architecture.

The testbed's software consists of five modules.

Network interface module. It sets up IP-addresses, VPN connection, internal and external interfaces of points.

Routing module. It configures parameters of dynamic routing protocols, adds floating static routes, start services (daemons) of dynamic routing protocols.

Network traffic generation module. It starts file services (daemons), in this research being FTP, HTTP and MQTT (Hunkeler et al., 2008) protocols. It starts FTP, HTTP and MQTT for clients to download files of chosen size, with files previously generated in back end.

Firewall module. It makes interference on channel level at certain points of time that prevent distribution of routes and data in a chosen communication channel. This module is used by generator module to create a mobile chart of the point movement.

Statistics modules. It records file download time with consideration of reconnection time after connection failure. Besides, the module turns on data aggregation facilities to calculate numerical characteristics for graphic dependencies construction.

Core software includes:

- Linux Debian 7.4/Kernel 3.2.0-4.
- HTTP Server: Lighttpd 1.4.31
- FTP Server: Vsftpd 2.3.5
- MQTT 3.1 broker/client: Mosquitto 0.15-2
- OLSR protocol implementation: olsrd 0.6.2
- B.A.T.M.A.N. protocol implementation: batmand debian-0.3.2-12 (compatibility version 5)
- FTP/HTTP Client: wget 1.13.4.
- Network filter: iptables 1.4.14.

Experiment Procedure

The developed procedure includes the following stages:

1. Interface set-up (IP-address, VPN connection, mesh-network).
2. Firewall set-up.
3. Set of dynamic routing protocol.
4. Selection of mesh channel function mode.
5. Set of application layer protocols.
6. Selection of message file size.
7. Selection of server response speed.
8. Selection of amount of iterations (10000).

Time of file transfer is measured.

The Experiment

Experimental research was carried out in order to determine file transfer time with application of OLSR and B.A.T.M.A.N routing protocols under conditions of interference corresponding to the vehicle's movement in the urban.

Let us simulate a situation when the vehicle that has a LTE dedicated channel periodically connects to a mesh-network that has a high-speed gate in Internet. The vehicle downloads files of user software updates and program data.

To simulate the process of file download from the server to the client we chose FTP, HTTP or MQTT protocols as the most available for this application. Two alternative channels, LTE and Mesh, for data receiving were used in the experiment.

Mesh-network channel as more speedy was chosen as a priority direction of file download.

In-out parameters of experiments are given in Table 2.

Table 2: Experiments initial data.

Parameter	Value
Routing protocol	OLSR, B.A.T.M.A.N
File size	10KB, 100KB, 1MB, 10MB, 100MB
Server download speed limit	128Kbit/s, 1024Kbit/s, 11Mbit/s(Unlimited)
File download protocol	FTP, HTTP, MQTT

Fixed Parameters

- OLSR parameters: Hello Interval — 1.0; HelloValidityTime — 3.0; LinkQualityFishEye — 1.
- B.A.T.M.A.N. parameters: OGM Interval — 1.0.
- Ftp, http download parametrs (wget): Network timeout — 2; Waitretry — 1; Tries — 0 (unlimited); Retry-Connrefused — yes.
- ftp server parameters (vsftpd): anon_max_rate — 6750000, 128000, 16000.
- http server parameters (lighttpd): server.kbytes-per-second — 6750, 128, 16.

During the experiment finite time of file transfer for FTP, HTTP and MQTT protocols is measured. Mesh-network interference chart during the vehicle movement on the highway is shown in Fig. 4. MQTT used as a publish-subscribe based "light weight" messaging protocol for use on top of the TCP/IP protocol. MQTT as ftp and http uses as a transport layer protocol — TCP. It corresponds to the vehicle movement between cross-roads at speed of 60 kmh. The simulation is introduced by interchange of time intervals with stable and unstable connection. One cycle is equal to 60 sec which corresponds to one kilometer of the highway.

The first interval of a short-time connection failure of 1 sec illustrates the situation of reconnection to a new access point. Next 7 seconds the vehicle is moving within the range of new access point functioning, then the signal from all neighbors will fails, which can be compared with driving in a tunnel or driving in a territory without 802.11s technology coverage. After that a zone with stable connection with several varieties of network access appears which lasts 15 seconds (250 meters). Further on, a short-time connection failure occurs for a shorter period of time (3 sec). Finally, a complete simulation cycle is repeated.

This operation model corresponds to the operational mode of dynamic routing protocol and data transfer under conditions of increased instability of network topology.

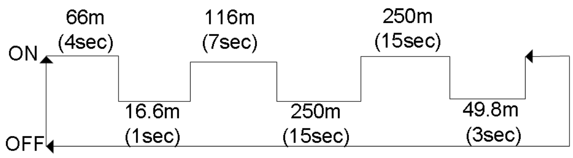

Figure 4: Chart of noise into mesh-network.

Table 3 shows experimental values of file download time in mesh-network for different values of server response speed. These values can be considered as the best ones as they were received under ideal conditions without interference and failures in communication channel operation.

Table 3: Experimental values of file download time in mesh-network without noise.

File size, KBytes	Download Speed Limit, Kbit/s		
	11000	1024	128
10	0.17	0.17	0.39
100	0.23	0.67	3.70
10^3	0.91	8.20	43.49
10^4	6.63	80.26	432.28
10^5	64.37	801.09	4320.94

During the investigation 3 experiment series for each speed were performed, with each series amounting to 400 measurements. Figures 5, 6 and 7 show graphic presentation of results of these experiments findings.

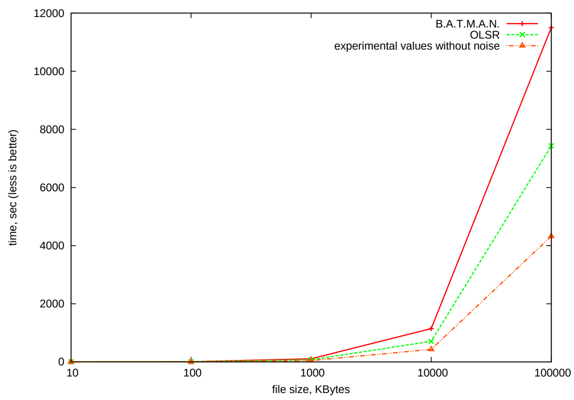

Figure 5: Dependency of file transfer time on size for B.A.T.M.A.N and OLSR protocols at 128 Kbit/s speed (first series).

Results of the first series demonstrate dynamics of data transfer at low speed (128 Kbit/s). Such speed is typical of bulk data transfer that includes information about traffic network and other clients. The chart presents dependency of data transfer time via http-protocol on file size with the application of B.A.T.M.A.N and OLSR dynamic routing protocols and ideal transfer version via mesh-network without interference produced by traffic route. The experiment proved better performance of OLSR dynamic routing protocol in comparison with B.A.T.M.A.N. in bulk data transfer (over 10 MB); gain in transfer speed amounts up to 35%. It is connected with the fact that the amount of interference during the file download rises proportionally to the file size and transfer speed. In this case, therefore, it is necessary to switch as soon as possible to alternative transfer channel without waiting for main transfer channel recovery as standstill time will substantially influence the data transfer volume. B.A.T.M.A.N. protocol, on the contrary, waits for channel recovery via main channel without deleting the route from routing table.

It was also found out in the experiment that http-protocol proves to be a better application layer protocol at low speed data transfer (128 Kbit/s) for big files (over 10 MB). It manifested lower transfer time by 10 to 30% because http-protocol uses fewer executive instructions that should be performed before the file download. In case of connection failure (interference) and file download the protocol should repeat these instructions.

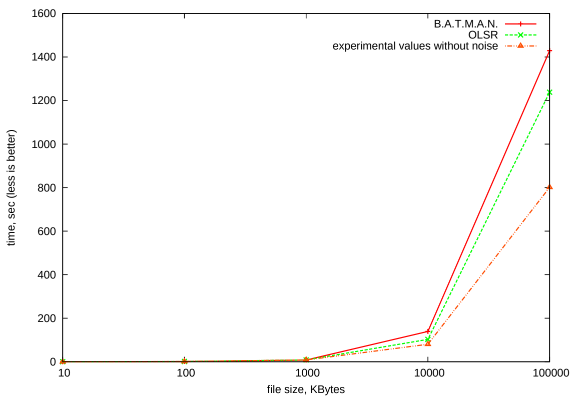

Figure 6: Dependency of file transfer time on size for B.A.T.M.A.N and OLSR protocols at 1024 Kbit/s speed (second series).

Results of the second series demonstrate dynamics of data transfer at mean speed (1024 Kbit/s). Such speed is typical of bulk data transfer including web-traffic, online-conferences. The chart presents dependency of data transfer time via http-protocol on file size with the application of B.A.T.M.A.N and OLSR dynamic routing protocols and ideal transfer version via mesh-network without interference produced by traffic route. The experiment proved better performance of OLSR dynamic routing protocol in comparison with B.A.T.M.A.N. in bulk data transfer (over 10 MB); gain in speed transfer makes up to 20%. It is connected with the fact that amount of interference during file download is rising proportionally to the file size and transfer speed.

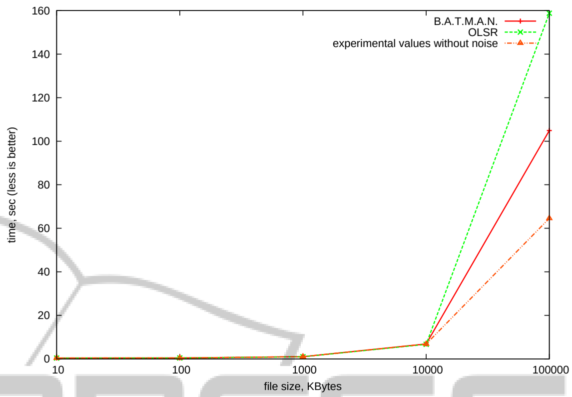

Figure 7: Dependency of file transfer time on size for B.A.T.M.A.N and OLSR protocols at 11 Mbit/s speed (third series).

The results of the third series demonstrate dynamics of data transfer at maximum speed (ca. 11 Mbit/s). Such speed is typical of bulk data transfer including multimedia and program update. The chart presents dependency of data transfer time via http-protocol on file size with the application of B.A.T.M.A.N and OLSR dynamic routing protocols and ideal transfer version via mesh-network without interference produced by traffic route. The experiment proved better performance of B.A.T.M.A.N. dynamic routing protocol in comparison with OLSR in bulk data transfer (over 10 MB); gain in speed transfer makes up to 50%. It is connected with the fact that the protocol is oriented at recovery connections (frequent failure with same-route recovery). Hence, the route in question is not deleted from routing table (even if the neighboring one is lost) but resumes being active. It means that during interference time the data transfer route is not rebuild and it does not require additional time to re-calculate the route when the connection re-establishes as it occurs with OLSR protocol.

The results of three series of experiments demonstrate that small data packets independent on a chosen dynamic routing protocol take shorter time for delivery even at low speed communication channels or server limitations on data transfer. It allows to organize eCall emergency messaging or gathering vehicle's statistics applying the current network infrastructure.

5 CONCLUSION

The research resulted in assessment of different dynamic routing protocol applicability in conditions of the vehicle movement in urban environment for different data volumes. OLSR dynamic routing protocol proved to be the best at low speed (128 Kbit/s) for file transfer of over 10MB, with the difference of file download time making up to 35%. HTTP-protocol is a recommended application layer protocol to transfer data at low speed with transfer time shorter by 10 to 30%. OLSR protocol also proves the best at middle speed (1024 Kbit/s) and for files over 10 MB; the gain in file download speed is up to 20%.

B.A.T.M.A.N dynamic routing protocol is preferable at high speed data transfer (11 Mbit/s); the gain in file download speed amounts to 50%. It can be concluded according to the experimental results that B.A.T.M.A.N is less preferable for frequently changing network topology. It is more oriented at connections recovery (frequent failure with same route recovery) and is worth applying at high speed data transfer.

According to the study it can be concluded that the protocol B.A.T.M.A.N. performs better in situations where the cars move in organized groups. These conditions, frequent disconnects do not immediately rebuild the network topology and data transmission quickly restored when the neighbors are again within sight of the transmitter. OLSR shows a good performance when used in an urban environment, in a situation where the available set of routes for data transfer, and it is unlikely that the driver returns to the network recently vacated. Thus, it is necessary, depending on the driving conditions, switch between the dynamic routing protocols, or the simultaneous use both dynamic routing protocols. Alternate use of two routing protocols will increase the amount of traffic the service transmitted via the communication channels (increase the load on the mesh-network).

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REFERENCES

Abolhasan, M., Hagelstein, B., and Wang (2009). Real-world performance of current proactive multi-hop mesh protocols. *Communications, 2009. APCC 2009. 15th Asia-Pacific Conference on*, pages 44–47.

Chakraborty, S. and Nandi, S. (2013). Ieee 802.11s mesh backbone for vehicular communication: Fairness and throughput. *Vehicular Technology, IEEE Transactions on*, 62(5):2193–2203.

Glazunov, V., Kurochkin, L., Kurochkin, M., and Popov, S. (2013a). Instrumental environment of multi-protocol cloud-oriented vehicular mesh network. In Ferrier, J.-L., Gusikhin, O. Y., Madani, K., and Sasiadek, J. Z., editors, *ICINCO (1)*, pages 568–574. SciTePress.

Glazunov, V., Kurochkin, L., Kurochkin, M., Popov, S., and Timofeev, D. (2013b). Road traffic efficiency and safety improvements trends. In Ferrier, J.-L., Gusikhin, O. Y., Madani, K., and Sasiadek, J. Z., editors, *ICINCO (2)*, pages 439–446. SciTePress.

Hunkeler, U., Truong, H. L., and Stanford-Clark, A. (2008). Mqtt-s; a publish/subscribe protocol for wireless sensor networks. In *Communication Systems Software and Middleware and Workshops, 2008. COMSWARE 2008. 3rd International Conference on*, pages 791–798.

Jayasooriya, I., Nallaperuma, T., Herath, U., Ranasinghe, S., Liyanage, M., Tennekoon, R., and Rupasinghe, L. (2013). Decentralized peer to peer web caching for mobile ad hoc networks (icache). In *Computer Science Education (ICCSE), 2013 8th International Conference on*, pages 218–223.

Klein, A., Braun, L., and Oehlmann, F. (2012). Performance study of the better approach to mobile adhoc networking (b.a.t.m.a.n.) protocol in the context of asymmetric links. In *World of Wireless, Mobile and Multimedia Networks (WoWMoM), 2012 IEEE International Symposium on a*, pages 1–7.

Kulla, E., Hiyama, M., Ikeda, M., and Barolli, L. (2012). Performance comparison of olsr and batman routing protocols by a manet testbed in stairs environment. *Comput. Math. Appl.*, 63(2):339–349.

Laouiti, A., Muhlethaler, P., Sayah, F., and Toor, Y. (2008). Quantitative evaluation of the cost of routing protocol olsr in a vehicle ad hoc network (vanet). In *Vehicular Technology Conference, 2008. VTC Spring 2008. IEEE*, pages 2986–2990.

Murray, D., Dixon, M., and Koziniec, T. (2010). An experimental comparison of routing protocols in multi hop ad hoc networks. In *Telecommunication Networks and Applications Conference (ATNAC), 2010 Australasian*, pages 159–164.

Pereira, A., Pharris, P., Oursler, J., and Lauf, A. (2012). Distributed aerial reconnaissance ad-hoc networking protocol. In *MILITARY COMMUNICATIONS CONFERENCE, 2012 - MILCOM 2012*, pages 1–6.

Vilhan, P. and Hudec, L. (2013). Building public key infrastructure for manet with help of b.a.t.m.a.n. advanced. In *Modelling Symposium (EMS), 2013 European*, pages 566–571.

Zaborovski, V. S., Chuvatov, M., Gusikhin, O. Y., Makkiya, A., and Hatton, D. (2013). Heterogeneous multiprotocol vehicle controls systems in cloud computing environment. In Ferrier, J.-L., Gusikhin, O. Y., Madani, K., and Sasiadek, J. Z., editors, *ICINCO (1)*, pages 555–561. SciTePress.

Zaborovskiy, V., Lukashin, A., Popov, S., and Vostrov, A. (2013). Adage mobile services for its infrastructure. In *ITS Telecommunications (ITST), 2013 13th International Conference on*, pages 127–132.

Zaborovsky, V., Gorodetsky, A., and Muljukha, V. (2009). Internet performance: Tcp in stochastic network environment. *1st International Conference on Evolving Internet, INTERNET 2009*, pages 21–26. cited By (since 1996)0.