Heterogeneous networking in C-ITS

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ABSTRACT

Cooperative Systems are part of the Smart Cities solutions and the essential part of the cooperative systems represents guaranteed quality of information exchange both between VANET members (V2V) as well as between VANET and Infrastructure (V2I). This article presents proposal of multiplatform routing protocol designed for combination of two most widely accepted mobile technologies. Properties of proposed protocol are in VANET communication simulation compared with selection of mostly discussed routing protocols designed for VANET conditions.

Keywords: Cooperative systems, VANET, routing protocols, simulation.

1. INTRODUCTION

C-ITS (Cooperative Intelligent transport systems) represent one of key essentials of the smart cities/planet solutions. An important benefit of such systems is to increase the efficiency and security of transport as a whole. According to a study [4] there could be possible to eliminate up to 60 percent of the consequences of traffic accidents, which are most often caused by not enough skilled or not enough concentrated drivers. Such drivers are not able appropriately react on the dynamically developing road conditions caused between others also by improper behavior of other drivers. Improvement of transport systems security and efficiency is dependent on additional information sharing about road and traffic condition.
Infrastructure and police authorities have been continuously collecting a considerable amount of information about traffic conditions, road stage, police controls, accidents etc., However, such mass information is only partially available to drivers e.g. via radio services or intelligent navigation systems. Coverage is, however, limited on certain roads and even critical information might easily need several seconds to be delivered to driver.

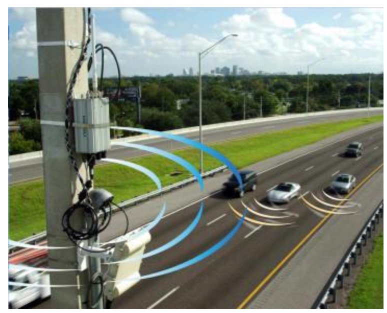

Fig. 1. Example of cooperative systems

In order to improve road safety and traffic efficiency services a standardized telecommunication solutions for direct communication between vehicles (V2V), as well as between vehicles and roadside infrastructure (V2I), must be standardized, widely adopted and massively unconditionally implemented.
Vehicles in C-ITS solutions use to be clustered in the dynamically developing VANETs (Vehicle Ad hock Networks) and required performance of C-ITS solutions induce prerequisites on guaranteed quality of information exchange both between VANET members (V2V) as well as between VANET and Infrastructure (V2I). Cooperative principles in VANETs compel preferably M2M (machine to machine) communication, however, HMI (Human-machine interface) type of communication, i.e. information exchange between driver and vehicle and via vehicle also with C-ITS cannot be underestimated. Even though fully automated driving (autonomous vehicles) reached remarkable progress, massive integration of autonomous vehicles in real transport traffic will not come soon namely due to existing legal issues. However, in all consequent steps of C-ITS implementations specific information exchange in VANETs conditions will play always key role and itis crucial for C-ITS future development to identify appropriate telecommunication strategy being able to meet all key C-ITS requirements.
In order to improve road safety and traffic efficiency services on the path towards automated driving it is clear that standardized technologies for direct communication between vehicles (V2V), as well as between vehicles and roadside

infrastructure (V2I) must be on the national level selected, adopted, and widely implemented. Even though low latency technologies are already available and their availability can provide guaranty on service availability as long as the communication partners are within a certain communication range, their sensitive and effective adoption to the specific conditions of dynamically developing VANET applications has been still urgently needed.

2. THE DIFFERENT APPROACHES TO ROUTING IN COOPERATIVE NETWORKS

Existing Protocols

There is a large number of different protocols applicable within VANET networks, i.e. ad hock networks with dynamically developing topology. Such networking must properly discovery of proper paths, effectively maintain set of routes and properly react on sudden changes in network topology. The significant group of routing protocols represent topology based routing protocols with either proactive or reactive routing approach. Another routing protocols based on position, cluster routing etc. Follows brief introduction of basic protocols:

DSDV (Destination Sequence Distance Vector):

It works on the principle of knowledge of vector distance path between source and destination. DSDV sends two types of packets - a full listing and incremental. The full listing packets sent all routing information, while the incremental packet is sent only in case of changes, thereby achieves a reduction in network load. Unfortunately incremental type of packets still increase the network overhead, because these packets are sent very frequently that for larger networks, this protocol unusable, however, in networks with a small number of nodes this protocol can be effective enough. DSVS protocol is not standardized and no commercially applied.

AODV (Ad Hoc On-demand Distance Vector)

It is a combination of protocols Dynamic Source Routing (DSR) and the Destination Sequence Distance Vector (DSDV). This protocol is designed for networks with large numbers of nodes and supports multiple gateways. Routing Hop-by-Hop and sequence number AODV adopted from DSDV. Maintenance process of the route takes from DSR, specifically protocol sends RREQ (Route Request) message to all its neighbors with a request to connect to the target node. If it is not within radio range of the neighbors, the neighbors redistributes the RREQ request further their neighbors. The message carries a sequence number, which prevents the formation of loops, and when the target node is found, it is answered with RREP (Route Reply) message with the number of jumps. Confirmation is sent to all nodes so that all nodes add another route to a node in own routing table.

GPSR (Greedy Perimeter Stateless Routing)

GPSR protocol is one of the best examples of protocols based on the principle of routing based on location. It uses information about the destination from the nearest neighbor in order to forward the packet. This method is also known as the "greedy forwarding". Each node in GPSR has information on its physical location and position of neighbors. This information about the positions of individual nodes allow better routing and provide information about the targets. Neighboring nodes can also help in routing decision for packets without topology information.

The current approaches to the routing

Currently there are different approaches to this topic. There are efforts to invent complex protocols, which will resolve the shortcomings of the already available approaches. Some of possible approaches follow:

Improvements in the formation of clusters

Routing in VANET networks are improved by better clustering [14] [15]. The formation of clusters is solved, for example, by an ant colony, which is a meta-heuristic technique, inspired by the behavior of ants and their search for food, which seeks an approximate solution of combinatorial problems [18] [19].

More efficient use of vehicle position

Another approach applies better utilization of the vehicles position for more efficient data dissemination [16]. In this paper, partial modifications of existing protocols were proposed and via simulations verification of author findings were presented.

Utilization of traffic information

Another approach is the utilization of the current traffic information to optimize spreading packet over networks. Packets are preferably routed to the directions with higher traffic density for achieving increased coverage area. [17].

Others

There are available specific approaches to the protocols. E.g. addition of a new type of message about the throughput of individual connections [22] or about the content of transmitted information [20], and the modification of priorities and queuing protocols [21]. Another interesting modification is the use of fuzzy logic to determine the suitability of each vehicle wireless connections for forwarding data [23].

3. SPECIFICATION OF METRICS AND OTHER PARAMETERS FOR SIMULATION

Our approach lies on simulation of protocols behavior applied in specific traffic situations.

Simulation of routing protocols depends on available protocols library configurable from the viewpoint of intended simulation. Simulation scenarios represents specific parameters configuration used by the simulation programs.

In case of traffic simulation, the main concern is concentrated on traffic impact on data mobility. Whole set of parameters represent substantial list of input variables for the simulation model. The output of qualitative parameters as response on set input conditions (for a particular routing protocol and the remaining adjustment simulation environment) represents basis for mutual comparison, finding the critical values and for subsequent optimization.

Our simulation is based on combination of simulators SUMO and ns-2 structured in accordance to figure. 2.

Input parameters of simulation are parameters of

- tested protocol,
- network simulator (NS-2) and
- transport simulator (SUMO).

In the particular testing scenario (in defined traffic conditions) parameters of the tested protocol (assuming compatibility of parameters of individual tested protocols) are consequently set and representative results of the various protocols are so obtained.

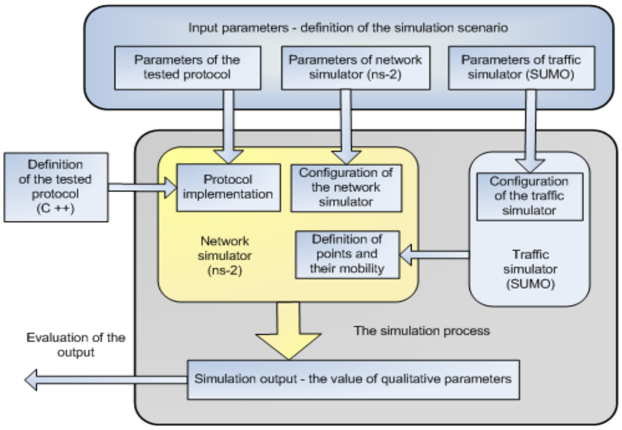

Fig. 2 Process for a particular application of simulator SUMO

For the correct definition of the traffic simulator parameters is important to set an extensive number of parameters, however the for the subsequent processing the only very limited number of parameters like e.g. traffic density in specific area can be modified to simulate different types of traffic situations.
For evaluation reasons subset of widely accepted performative parameters was selected to enable evaluation of the properties of the individual tested protocol. Some parameters were not reachable due to limits of the applied simulation software. Based on the analysis were adopted following five representative performance parameters: (i) Latency, (ii) Throughput, (iii) The success rate of delivery, (iv) The number of hops and (v) Utilization of the available capacity.

4. SIMULATION AND EVALUATION OF BASIC ROUTING PROTOCOLS

As part of the methodology was compiled uniform testing scenario that tests the routing protocols in different circumstances; in various environments (city, highway, a combination of highway and local roads, different densities of vehicles) and with different network simulator (channel type, etc.). Essential thing is that for each tested routing protocol are used the same test scenario parameters, thereby maximally ensuring mutual metric for subsequent comparison.

Aggregation of outputs

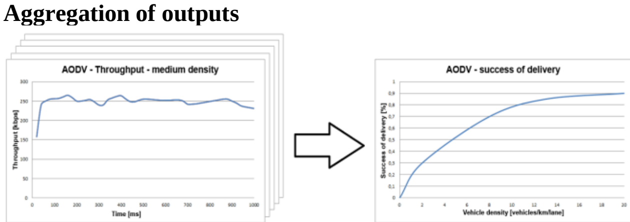

Fig. 3 Data aggregation

Based on the test scenario for each tested protocol are generated five output files describing all the events that occurred during each partial simulation. These data are than aggregated in a single file. For each monitored parameter thereby arises a graph where the vertical axis is the value of the monitored parameter and the horizontal axis is the density of vehicles according to the set mobility of simulation due to aggregation instead of the time course of the parameter. The above principle is illustrated on the figure. 3.

Quantification and display of results

Aggregated data already provide an overview of the protocol using progression of individual observed parameters. However, goal is to be able mutually compare the results of simulations of different protocols that have different characteristics, and some performance indicators can also acquire different non-standardized values is appropriate to quantify the results. This step is suitable in terms of the parameters that are defined specifically (e.g. security) and allows comparison seemingly incomparable values.
Quantification process applies classification tables that determine which values belong in which group. Classification tables must be for each communication technology separately, for each specific configuration of simulation parameters and within the same classification table are available values for different performance parameters. Creating these classification tables requires knowledge of various system parameters and performance indicators.

Summary evaluation of protocol

For final results presentation we decided to use “radar chart” form, which at first glance provides information about the values of individual parameters of simulated protocols. Radar chart aggregated graph has defined a fixed structure and therefore it is possible to compare the graphs of different protocols and their settings between each other. The individual rays of the graph represent the monitored variables and on these rays are then plotted the converted values of classification.
In response to this radar chart was introduced (see figure 10) a comprehensive evaluation of the protocol as a content of area defined by the values of various parameters on this chart.
Evaluation is as follows:

$$S = \sum_{i=1}^{n} \frac{x_i \cdot x_{i+1} \cdot \sin\frac{360°}{n}}{2} , \qquad (1)$$

where $x_{n+1} = x_1$ and variables are
S … the area chart (evaluation)
n … number of vertices in the graph (number of variables)
x … variable value

wherein in the case where it is used five performance parameters can be the evaluation expressed as follows

$$S = \sum_{i=1}^{5} \frac{x_i \cdot x_{i+1} \cdot \sin 72°}{2} , \qquad (2)$$

where $x_6 = x_1$.

Such comprehensive evaluation offers a quick overview of the quality of the routing protocol on the basis of applied performance parameters, where everyone has equal weight. In the case that different parameters have different weights, it would be necessary to choose a different approach and comprehensive evaluation determined using the preferences of the individual parameters.

5. DESIGN OF OPTIMIZED SOLUTION OF ROUTING PROTOCOL

Our solution was motivated by the capacity constraints of WAVE / DSRC technology and provides a multiplatform combination of WAVE / DSRC technology and LTE.
The proposed solution uses the location information of individual clients (vehicles obtained from the GNSS system. Clients on regular basis process and distribute a report about the status update (RASU) which contains address, current timestamp, GNSS position and a list of neighbors and their parameters. RASU is distributed by client to its neighboring clients. For LTE RASU message can be delivered (multicast) to all members of shared eNodeB. If D2D service is available in future, RASU report is distributed to neighbors like in DSRC mode. Besides direct communication it is also important connection with the routing server, which is located in a secure Intranet or VPN within the wider network. The server processes all RASU messages from all clients and has an overview of the current position and status of routing tables of the individual clients.
Clients then in the case of an incoming message has implemented a two-tier system of finding a suitable target for forwarding messages. Firstly, the table of neighbors is checked. This RASU report table is continuously updated by RASU information including those of the closest neighbors of neighbor (2 hops are supported). Consequently, if the destination is not among these close neighbors to find, client via LTE sends request to the routing server to create a path to their destination. Routing server provides based on the current state of the positions of individual clients and information about the quality of connection the optimal route (shortest path method with regard to the values of delay of each connection) and information on this path distribute to participants. New record is stored in the routing tables of the participants and the data are ready to be sent.
This brief description is on the figure 4 of architecture of the proposed solution.
Proposed solution stress these basic principles:

- In case communication has local character, it can apply routing information on neighboring clients up to the level of two hops.
- Other routing relies on the central authority, which has an overall view of the situation and individual requests authority replied by routing information sent back to clients.
- The solution be modified based on evaluation of the latency value between individual clients on the network.

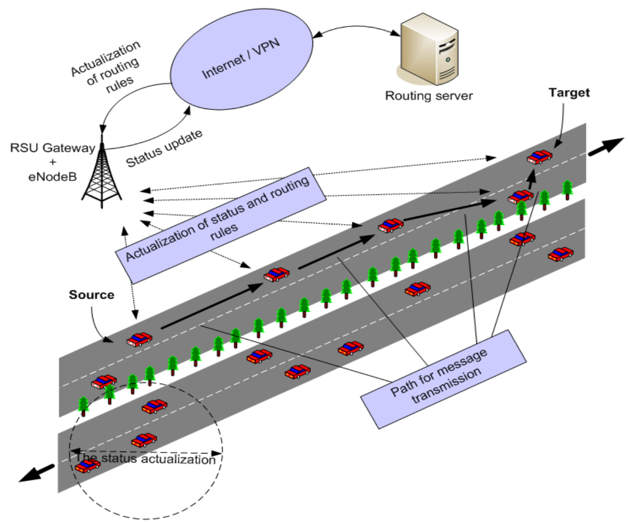

Fig. 4 Architecture of the proposed solution

6. RESULTS OF SIMULATION

Simulation of all protocols were carried out according to defined methodology, referred test scenarios and predefined variable parameters for each of the protocols. The following are outputs in the form of graphs of individual observed parameters and summary radar chart. Are displayed all of the tested protocols, including the optimized design of the WAVE-LTE at once for easier comparison.

The latency parameter

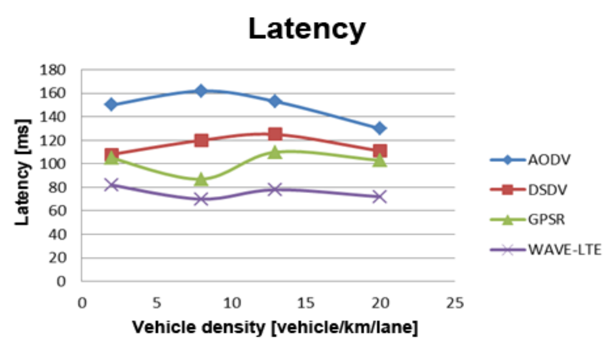

Fig. 5 Latency

We received positive results in case of latency parameter. The progression is similar to GPSR protocol, but the actual values are lower. This is achieved thanks to the fact that requests to update the routing rules are sent only if the destination is outside the neighborhood and achievable thanks to assistance from the infrastructure that determines the optimal route.

The throughput parameter
Throughput parameter in the proposed solution achieves higher values than the other tested protocols. It corresponds most closely to GPSR protocol, but its value exceeds by about 10%.

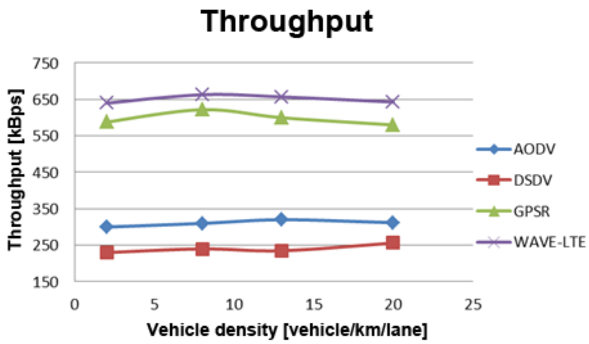

Fig. 6 Throughput

The parameter of successful rate of delivery
The proposed solution is in terms of the measured values of the parameter successful rate of delivery almost identical as the AODV protocol, other protocols have lower values.

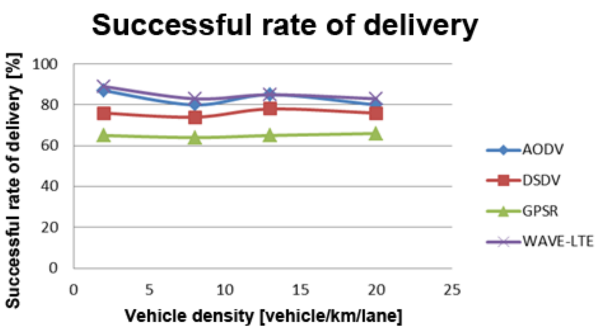

Fig. 7 Successful rate of delivery

The parameter of number of hops

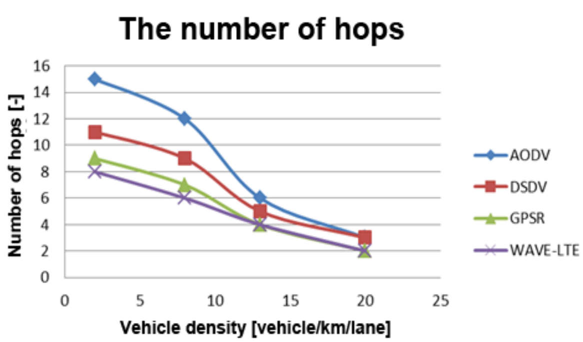

Fig. 8 No. of hops

Parameter of number of hops at the proposed solutions are ranked in the first position. Its values are in part identical to parameter GPSR and the remaining part are on one hop lower and therefore better.

The parameter of utilization of the available capacity
In the proposed solution, the measured values of utilization of the available capacity are 1-2% lower than GPSR protocol

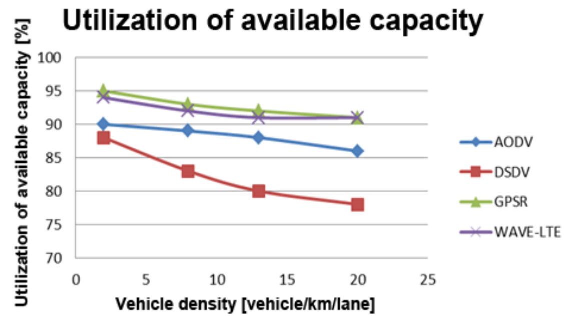

Fig. 9 Utilization of available capacity

In the proposed solution, the measured values of utilization of the available capacity are 1-2% lower than GPSR protocol

Comprehensive evaluation of protocol parameters

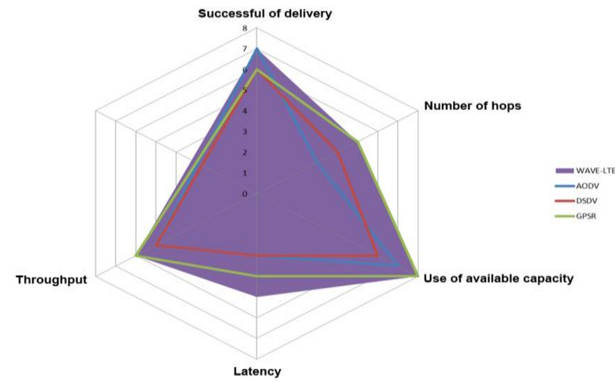

Fig. 10 Comprehensive evaluation

The final summary radar chart on figure 10 displays all of the tested protocols using the edges and the proposed solution is shown as a background area, which stand out the differences between the proposed solution and other protocols.
The numerical comprehensive evaluation of summary provided by the equation (2) is shown in the table 1, together with previous data for comparison.

Protocol	AODV	DSDV	GPSR	WAVE-LTE
Comprehensive evaluation	**53,7**	**52,8**	**77,0**	**88,9**

Table 1

The proposed solution WAVE-LTE is ranked by number 88.9, which exceeds other values and in terms of comprehensive evaluation of parameter is in the first position.

5. CONCLUSION

The draft of the protocol assume hybrid solution of combining approaches and possibilities of technologies WAVE / DSRC 5.9 and LTE. Protocol takes account besides a standard architecture WAVE / DSRC 5.9 also LTE architecture. Integration of LTE technology into solutions a VANET networks is in our view in the mid-term inevitable, anyhow and even current development of LTE technology strongly stress this direction. Using simulation engine designed for VANET type of communication we compared proposed protocol with selection of existing protocols. In most of key performance parameters proposed solution achieves better values, only in the parameter of use of available final assessment the proposed protocol received by almost 12 points more than the second protocol (GPSR) which converted to a percentage represents approximately 6% better result.

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