Impact of VANET-Based V2X Communication Using IEEE 802.11p on Reducing Vehicles Traveling Time in Realistic Large Scale Urban Area

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***Abstract*—Vehicle to Vehicle (V2V) or Car to Car and Vehicle to Infrastructure (I2V or V2I) communication are important components of the Intelligent Transportation Systems (ITS) architecture. One of the promising applications of ITS is calculating the estimated traveling time dynamically and showing drivers the fastest vehicular route to the destination, which has several benefits such as decreasing emissions, traffic congestion, fuel consumption, etc. This paper proposes a new method to find the fastest route from origin to destination by using the V2X (V2V or V2I) communication which provides real-time traffic information to drivers. This method, assigns a Current Traveling Time (CTT) for each street in a city which could help drivers to find the best route and also it could help real-time monitoring of the traffic of the streets. The contribution of this study is threefold: First, the mentioned novel methods are proposed. Second, impact of the method is investigated by using SUMO as a traffic simulator and also dynamic route planning with employing CTT for each street which are calculated with the proposed method. Third, mentioned scenario is simulated by using OMNET++ as a VANET (with IEEE 802.11p standard) with employing Veins framework. Veins framework is able to run OMNET++ and SUMO in parallel. Veins is developed in this paper by adding new modules to OMNET++ which aims to add numerous RoadSideUnits (RSUs) in the realistic traffic simulation. Moreover to control the traffic simulation, in this paper a new program written in Python capable to connect to SUMO has been developed. This program connects to SUMO and by considering every single vehicle movements simulate a microscopic traffic, also calculating the Current Traveling Time for streets and dynamic route planning for the cars. This program dynamically calculates the fastest route for the specific car.**

Keywords-component; Dynamic Route Planning; Intelligent Transportation Systems (ITSs); vehicle-to-vehicle communication (V2V); vehicle-to-infrastructure communications(V2I); VANET; OMNET++; SUMO; Veins; 802.11p.

I. INTRODUCTION

Increasing number of accidents and rising greenhouse emissions stemming from high traffic volumes, combined with traffic congestions, decrease the living quality in urban city areas in most countries. A very huge amount of resources such as time and fuel are wasted because of traffic congestion. For example, in the U.S. each driver spent an additional 38 hour in vehicle and wasted 19 gal of fuel because of traffic congestion in 2011 which leads to 818 $ congestion cost per auto commuter. This means, wasting 2.9 billion gallons and 121 billion dollars for congestion related costs just in U.S. in one year [1]. A comparison with 1982 (16 h, 8 gal) illustrates that the increasing congestions and traffic volume in cities, cause an increasing problem in urban life and transportation systems.

In order to relax traffic related problems in future, several approaches are proposed, but it is clear that extending the road network is not suitable to solve the traffic related problems in future due to the limitation of resource, places, etc. Thus, novel scenarios are required. For example, the Federal Highway Administration in the U.S. (FHWA) proposed and defined three general tactics to decrease traffic related problems [2]:

- Work on current capacity of roads and extend them, e.g. increasing the size and number of streets and highways.
- Extension of alternative transportation that require less resources, e.g. non-automotive transportation.
- More efficient using of current capacities of cities and roads.

To solve traffic related problems, one of the useful solutions is wireless communication technology which focuses on the third strategy. Vehicle to Vehicle (V2V) or Car to Car Communication (C2CC) and Vehicle to Infrastructure (I2V or V2I) communication based on wireless technology is developed in order to make vehicles capable to “communicate” to Road Side Units (RSU) and each other. V2V and V2I have several applications in Intelligent Transportation Systems (ITSs) to make transportation more efficient. This paper focuses on the real-time monitoring of the traffic of the streets and calculates the best route for the drivers using the on-line traffic status of the roads. This efficient method for selection of the routes decreases traveling time for each journey which can decrease the traffic congestion and save the resources. Calculating the best route, requires two types of data, first the current traffic information of the cities and roads are required, then, by using this information, calculation of the routes becomes possible.

This paper simulates a realistic large scale city with real traffic demand using a network simulator as a VANET scenario by employing SUMO[3], OMNET++ [4] and Veins[5]. Several research works have been reported in recent years to calculate the best route for drivers using different methods and algorithms; also VANET-based traffic status monitor, has been investigated earlier, and several methods have been proposed (see Section II), but to our knowledge, up to now, there is no realistic large scale simulation in real urban area using the V2X communication to monitor the traffic, also calculating the fastest route for drivers has been reported.

The rest of the paper is outlined as follows: Section II discusses the related work. Then Section III proposes a new method to calculate the current traveling time in a street by using V2X communication. Efficiency of the proposed method is investigated by SUMO as a traffic simulator in Section IV and results are discussed. In Section V, the mentioned scenario is simulated by using OMNET++ as a VANET (with IEEE 802.11p standard) with employing Veins framework in order to run OMNET++ and SUMO in parallel and simulating a realistic large scale V2X communication. Finally Section VI is devoted to the final conclusions and future work is proposed.

II. Related Work

The main focusing area in this paper can be categorized in two parts: the first, using wireless communication in new traffic schemes in future world and the second, computing fastest paths for drivers from their origins to destinations. Thus, two different types of related works are studied. Study on ITS and use of new wireless technology in ITS are currently hotspots in mobile communication research fields and numerous research works have been done in this field, so in order to find new admissible approaches and applications and avoid repetitive research, study on related work is vital in this field. Thus, this paper has a wide survey on related works and technologies. Recently, cameras, loop detectors and numerous sensors are implemented in most major cities. Centralized system structures are used in conventional transportation and transportation information systems which are defined as follows: information related to recent traffic volume has been transmitted to the Center of Traffic Information (TIC) by using sensors, loop detectors, etc. which are installed in or above the streets. Analysis about the current traffic situation is performed in the TIC, then the result information is transmitted via several possible approaches such as on-demand (via cellular systems, 3G, LTE or UMTS) or via Radio Data System (Traffic Messaging Channel) to the vehicles [6]. High delay and low details of traffic information are drawbacks of this method. Projects such as Mobile Millennium[7], Nericell [8], JamBayes [9], CarTel [10] and surface street estimation [11] are based on data collection from cars with using on-board GPS devices to monitor and analyse traffic situation.

On the other hand, in near future wireless communication technology will be soon sufficiently developed to enable V2V and V2I communication to collect real-time traffic related information. Thus, current and future approaches are likely to use V2V and V2I with conventional approaches in parallel to monitor the traffic and using this data in several applications such as finding the best routes for drivers, safety applications, etc. For example, in the IPERMOB project [12], IEEE 802.11p as a vehicular network is used in parallel with wireless sensor network and connected via IEEE 802.11h with 5 GHz wideband link to a centralized database. In Japan, VICS center [13], has provided real-time road traffic information about congestions. In this project, cars are connected to the RSUs and share streets and traffic information with them, and the RSUs analyse this information and broadcast them to surrounding cars. Some prior researches have been done (such as [14]) to monitor the roads traffic with investigating the number of cars on the streets and these numbers are used as measurements to identify congested streets. Calculating number of cars in the streets is not a simple task and in some case other tools (such as image processing) are compulsory. In some researches such as [15], [16] traveling times for cars in streets are used (which are measured by previous cars).

Up to now, projects and researches related to traffic monitoring have been shortly reviewed. In this part, related researches in finding the route for drivers will be explained. [6], has proposed a VANET-based Dynamic Route Planning (DRP) Guidance. Recently, Hara *et al*[17], have used two approaches in order to find the best route and DRP using real-time traffic data, one of them is extending the range of broadcasting to make traffic data available to farther cars and the other approach is duplicating the road segment data broadcasted with cars to increase the chance for others cars to get the information. More recently, [18] has presented five cost-effective and easy deployable traffic re-routing strategies for reducing traveling time for vehicular traffic guidance system. In [19], a DRP is presented based on future traveling time estimation and the route is periodically calculated from an origin to destination for cars based on online traffic information. [20], presented an approach based on DRP for cars with using latest recorded traveling time. Genetic algorithms are used for DRP in [21], and authors proposed an approach with estimating the future traveling time based on current collected traveling time. Sommer *et al* [22], used V2I communication to propose a new traffic information system for optimizing the route planning which provides information for cars about traffic congestions.[23], selected a limited urban network and investigated the impact of DRP on the traveling times. Several different levels of penetration rate are used for simulation. Simulations provided traveling time information to vehicles and the results show decreasing traffic congestion using this information. However, in this case the impact is worse when all the drivers use DRP than static route planning. Since the transportation network which is used in [23] is too small, there is no conclusion for optimum strategy.

Recently, some systems are reporting capabilities to forecast traffic congestion and also its duration (such as Microsoft Bing and Google Map) by traffic pattern using statistical predictive analysis. In addition, infrastructure based traffic related information are being used by other companies (such as TomTom or Google) in order to calculate the shortest path. However, these solutions not try to prevent congestions clearly (i.e., reactive solutions) and also another problem is that they provide same guidance for all cars on the streets at a certain moment [18].

One of the most important issues in intelligent transportation systems is finding the real-time traffic information of the roads. Also one of the most important applications of the ITS is providing the best routes (dynamic or static) for drivers. Presented researches and projects, have several drawbacks behind their features. Most of them, have not used real-time traffic data, and some of them have a huge delay in order to provide the data. This paper, presents a novel approach to find the real-time traffic information of the roads using V2I communication technology and using IEEE 802.11p standards. Then, employing such online information for computing the dynamic route planning and decreasing the traveling time for vehicles are investigated. The important features of this study are presenting a novel method for real-time traffic monitoring, realistic communication simulation, using a realistic large scale urban map and also using realistic traffic data which make the results realistic and reliable.

III. PROPOSED METHOD

Recently, many groups (standardization bodies, automobile manufacturers and academia) have been in the process of defining standards for vehicular applications and they are working together in order to develop VANET-based communication systems. DSRC (Dedicated Short Range Communication) is a wireless protocol which is specifically designed for automotive application. These protocols (DSRC) offer high rate data communication between a vehicle and a RSU (V2I or I2V) or between two vehicles (V2V). For Wireless Access in Vehicular Environments (WAVE) the DSRC standards include IEEE 1609.x family and IEEE 802.11p. DSRC groundwork is IEEE 802.11p, and higher layer standard is IEEE 1609. The MAC (Medium Access Control) and physical layer protocols are specified in IEEE 802.11p for single-channel operations. In addition, for multi-channel operations, a trial-use standard IEEE 1609.4 is specified on top of the IEEE 802.11p. Multi-channel operations are implemented by dividing the access time to two different channel with intervals of 50ms, Control and Service channel (CCH and SCH) [24]. In addition, V2I and V2V communication concepts rely upon broadcasting the information continuously by all RSUs and vehicles, which allow each vehicle to discover all the neighboring RSUs and vehicles in real time and also other information which are provided by RSUs. Information is broadcasted as periodic messages, known as beacons. In order to inform neighbors about the vehicle profile, beacons are broadcasted consecutively. Beacons contain information about vehicle profile such as position, acceleration, speed, next coordination, etc. VANETs structure are dynamically changing, therefore beacons need to be sent frequently. ITS, has defined numerous applications based on V2X and up to now, several different approaches are proposed in order to use V2X in real world. Almost all of them are similar in broadcasting beacons by vehicles, but there are several differences in location and application of RSUs. Communication approaches are also different.

This paper proposes a method using communication between RSU and vehicle via IEEE 802.11p to monitor the traffic information of the roads and also the traveling time in each street by employing the V2X communication. The proposed methods can be explained as follows:

- All road segments (streets, highways, etc.) have two main variables, Ideal Traveling Time (ITT) and Current Traveling Time (CTT). ITT is the required traveling time for a car to go through the street from the beginning point to the end point of road segments in ideal form, (when the road is empty and with the maximum allowed speed); and CTT is the same required time for a car to pass the road in real-time (with considering the other cars traffic, congestion, road construction etc.). Calculating the ITT is simple, by using the road segments lengths and maximum allowed speed on the road. This paper proposes using V2I in order to calculate CTT as follows:

- RSUs should be added in start and end of each street or each road segment (RSUs can be traffic lights or current RSU or new one). When a car comes to the street, at the start point of the street, corresponding RSU sends a message to the car. The message includes the current time and date (starting time for the car in this street, ST). The car holds this message and broadcasts it periodically till the car arrives to the end point of the road. In the end point, car sends the starting time (ST) to the corresponding RSU at the end point of street, when the car wants to leave the street. The RSU at the end point, calculates the traveling time for the mentioned car by subtracting the real time and the starting time for the mentioned car (ST).

- RSU at the end point of the street, assigns a CTT equal to the average traveling time for 5 recent cars in the street. The RSUs are broadcasting this CTT for the street and it could be available for all cars.

This simple approach, can be implemented in the future real world and calculate the real-time traffic data for all the streets in cities. Several aspects should be considered in this approach. This approach suggests expanding content of each beacon by two additional variables, ST and CTT and cars and RSUs broadcast the ST and CTT in addition to the other information. In addition, there are several methods in order to find real starting and ending times for the cars in the street, such as short range communication (for example using RFID tag), or calculating the distance from cars and RSU based on the received power etc. and many other methods.

Furthermore, to avoid broadcasting the wrong data, if the RSU does not receive data from cars or if time of the last received data is later than the ITT of the street, the RSU assumes that there is not any car on the road and assigns the CTT equal to ITT for that street. Also about the cars, the ST should be changed when a new ST message is received or the ST should be equal to zero when the cars start to travel. RSUs broadcast periodically the CTT of the street and also they are connected to each other and central station which can do analysis of the real traffic data and provide data to others. When a car decides to start a travel, it makes a connection to the nearest RSUs by sending and receiving beacons, and request the best route from origin to destination, based on current CTT for streets; (CTTs are calculated by RSUs and provided to traffic information center (TIC). RSUs can connect to the TIC, and collect the data from other RSUs including all streets' CTTs.). This approach, can be implemented in near future because nowadays most of the required technologies are available and the future ITS must be able to find the real-time and in detailed data and information of traffics in the cities. Also, RSUs can count the exact number of cars on each street, when all the cars broadcast the beacons.

In summary, the proposed method, assigns a CTT for each street which is used to provide real-time data of traffic on all streets. These data are used to find the best route for cars and manage the traffic. These CTT's are broadcasted periodically via RSUs and can be provided by other technologies such as cellular or via internet. CTTs can also be broadcast by cars by cars if it is necessary. For example if a traffic congestion happens on the specific street, then all cars can broadcast this CTT to inform others that such traffic congestion has happened by using multi-hop beaconing.

IV. Traffic Simulation

In order to do detailed analysis and investigation on the proposed method, two different simulation scenarios are reported in this paper. First, SUMO (traffic simulator) is employed to simulate the dynamic route planning by using CTT and effect of dynamic route planning is investigated in the ideal form without any wireless communication technique. Second, OMNET++ (Network Simulator) is used in order to simulate mentioned scenario in realistic wireless communication scheme.

A. Dynamic Route Planning

As mentioned earlier in section II, there are several approaches to find the best route and calculate the dynamic route for cars. Searching for a route is in essence a classic shortest path problem. Often classic algorithms are used to solve this problem, like Dijkstra [25] or A*. Also, for transportation networks, the "graph network model (GNM)" [26] is commonly deployed. GNM consist of several links and vertices. Road segment (or streets) shown by links and intersections are defined by vertices. In GNM, each link has one direction, meaning that for example if J and K are intersections which are connected to each other via a street, there are two different links to define the mentioned street, link JK which defines traffic flows from intersection J to intersection K direction and another one, link KJ which defines traffic flows from intersection K to intersection J direction. Also, each link has a weight (cost) which can be the traveling time, fuel consumption, etc. This paper, uses and improves the A* search algorithm from [6] for calculating and searching the best route. This A* search algorithm is a combination of uniform cost search and Greedy search and it is an optimal and complete search method [27]. A* algorithm considers sum of two functions, $g(n)$, the cost (value) to reach from starting node to current node (*node n*), and $h(n)$, cost (value) to reach from node $\boldsymbol{n}$ to goal node (estimated cost of the least-cost path from a node $\boldsymbol{n}$ to the goal node). Therefore, $f(n)$, the cost function for node $\boldsymbol{n}$ is estimated least-cost path from a given initial node to the goal node through $\boldsymbol{n}$. The process of A* algorithm can be explained as follows: The algorithm defines two different sets, Open and Close set. Starting with the initial node, the algorithm maintains *openset* as priority queue of nodes which should be traversed through.

The higher priority belongs to lower $f(x)$ for node x. At each step, the node which has lowest $f(x)$ is removed from the *openset* (priority queue) and is added to *closeset*, then, neighbors of node x are added to the *openset* and the $h(n)$, $g(n)$ and $f(n)$ values of these neighbors are updated accordingly. The final step of algorithm is reached when algorithm finds the goal node in the queue with lowest f in *openset* (or till *openset* gets empty). (It should also be noticed that, algorithm may pass the goal node several times if algorithm find that other nodes have lower f). The length of the shortest path is equal to f value of the goal node and the shortest route can be found by revising the traversed path. In [6], several cost functions such as traveling time, Class of road segment, Expiration time, Delay in intersections, Fuel Consumption and pollution are considered and assigned to the roads. This paper, improves the traveling time cost function using real traveling time (CTT). The following pseudocode summarizes the overall algorithm:

A* Algorithm Pseudo Code:

Define origin and destination intersection with position
Define *closeset*. (Set of street intersections already passed.)
Define *openset*. (Set of intersections in the queue to be passed, initially containing the start intersection)
Define g Value. (Traveling Time to reach from origin intersection to current intersection)
Define h Value. (Lowest estimated traveling time from current intersection to the destination)
Define f Value. (g+h)
    While *openset* Not Empty
    Add neighbor intersections of current one to *openset*
    Calculate f Value for all neighbors
    Sort intersections in *openset* by f value in ascending order
    Get first array from *openset* call intersection X
    Compare X and goal, if true exit loop
    Else
    Remove current intersection from *openset* and add to *closeset*
Expand all reachable intersections from X call Y
If Y is not included in *closeset,* call "Next X"
$f(Next\ X) = g(Next\ X) + h(Next\ X)$
Loop

B. Simulation in SUMO

In order to obtain realistic and reliable results, this paper uses the realistic traffic and map. For the traffic demand and network of roads and streets, a data set from [28] has been used. (Any traffic data for the cities can be used in this simulation by employing the proposed method and future work could focus on the effect of this method in different traffic pattern in major cities and countries such as US, Japan, etc. which are having different regulations and policies affecting the traffic). The realistic map of the city of Cologne, Germany, with real traffic demand have been presented in [28]. TAPAS-Cologne project has provided information related to travel of the vehicles and traffic behaviour in this dataset. German

Aerospace Center, Institute of Transportation Systems (ITS-DLR), provide TAPAS-Cologne project which determines realistic vehicle traffic and traffic related information in the city of Cologne. In addition, the streets network and realistic map of the Cologne is imported from OpenStreetMap(OSM)[29]. The mentioned dataset covers approximately an area of 400 km^2 around the city of Cologne with cars traffic for 24 hours, including 700.000 individual vehicle trips. These two datasets have been imported to SUMO. City of Cologne in SUMO is shown in Fig.1.

To control the traffic simulation, this study has developed a new program written in Python capable to connect to SUMO. This program can calculate the CTT for the streets and find the fastest route for the cars. The program weights the street based on the presented methods and calculates the best route using presented A* algorithm. SUMO is able to find the exact traveling time for the last car which has passed the street and this program uses this feature to calculate 5 recent cars' traveling time on each street and calculates the CTT for each street. If there is not any car on the route, the program assigns the CTT equal to ITT which is calculated considering the maximum allowed speed and street length. Moreover, several statistics related to traffic simulation are created such as fuel consumption, waiting time, traveling time, emissions for each car; or number of vehicles during simulation, total amount of vehicles emissions in streets during the simulation, fuel consumption, etc. for each street.

The developed program is started with requesting name of the car, origin and destination. First, by using mentioned route planning, and using CTT for streets, the best route (fastest route) from origin to destination is calculated and the car starts to move through the route. To have dynamic route planning, in each simulation step, the program calculates the current CTT for streets. Then, when a car arrives to an intersection, the program calculates "the best route" again, based on current CTT and if the "current best route" is different with the "current route" for the car, the program changes the car's route. These changes in routes happen until the car arrives to the destination.

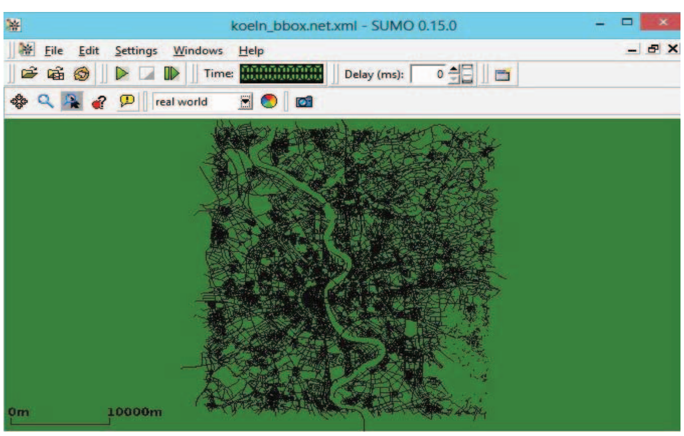

Figure 1. Cologne map in SUMO

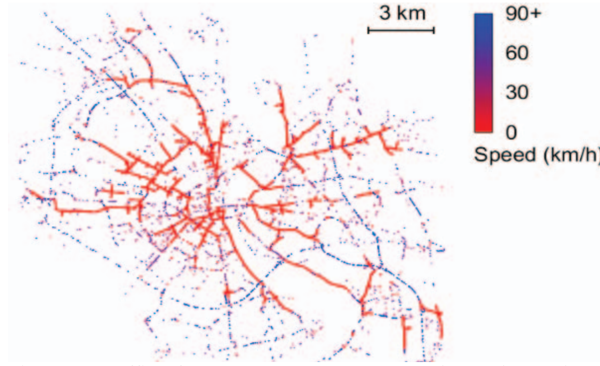

Figure 2. Traffic of cars at 7:00 a.m. TAPASCologne dataset in a 400 km^2 area centered on Cologne. Red vehicles are stopped and blue ones are moving. [28].

C. Simulation Scenario

In order to investigate the effect of the route changing, initially, real traffic demand of vehicles between 6 a.m. till 8 a.m. is considered and map of the city is divided into several zones. After that, based on the data provided in [28], different traffic densities are considered and based on the traffic status at 7:00 a.m., 20 different zones are selected (Fig.2). Then, an individual vehicle is added to each zone (with the origin and destination) and a traveling distance (approximately equal to 5km) is defined for all the mentioned 20 vehicles.

Three different simulations are done in order to observe the effect of dynamic route planning in the vehicles traveling time with using CTT:

a. At first, only mentioned 20 vehicles travel in the city of Cologne without any traffic lights or any other vehicles (Ideal Form). Then traveling time for 20 cars are obtained.

b. The real traffic of cars in Cologne with more than 250.000 individual cars and also with 20 mentioned vehicles traveling in city of cologne in this two hours (6 am till 8 am) are simulated in the second step. The traveling time for 20 vehicles are obtained in this simulation.

c. In the third simulation, the mentioned dynamic route planning using the developed program are employed to find the best route dynamically for the cars. Dynamic route changes for cars are done for all 20 cars during their journeys and the traveling times are obtained in this simulation.

D. Traffic Simulation Results

Mentioned simulations with three defined scenarios are done in SUMO. All required data is obtained. Figure.3 shows the traveling time for 20 vehicles ordered from low to high. Moreover, in order to obtain a better view of this method and illustrate the efficiency of using dynamic route planning, the fuel consumption and emitted CO_2 for cars are obtained (based on provided data from "Handbook Emission Factors for Road Transport (HBEFA) [30]" for typical personal car which are calculated with SUMO) and illustrated in Fig.4 and Fig.5.

It can be seen in Fig.3 changing the route for each car has a different effect in decreasing the traveling time. For example, for car's number 1-7 (in low traffic area) the average decrease of the traveling time is 41.12%, for car's No. 7-14 (medium traffic area) is 52.84% and for car's No. 14-20 (high traffic area) is 60.79%. In addition, about decreasing CO_2 and Fuel consumption, in almost all the cars, decreasing the traveling time reduces fuel consumption and CO_2 emissions (should be noticed that the fuel consumption and emissions are also a function of vehicle's instantaneous speed and acceleration levels). Figure.4 shows Fuel consumption diagram and illustrates the important fact that using DRP in low traffic area increases fuel consumption (the reasons could be changing speeds and accelerations for several time). But on average, using DRP decreases the fuel consumption. The average decrease in the fuel consumption in this simulation is 48.27%. It means that using this approach can save huge amount of money and resources. Compared to the presented other research works in the related work section (Section II) in DRP with communication technologies, using this method has the best effect in decreasing traveling time, fuel consumption and emissions. This method, could decrease traveling time in high traffic area on average about 60% and decrease fuel consumption on average about 50% which is because of real-time and online data provided by V2X communications.

I. VANET SIMULATION

Creating a wide and cheap wireless technology for sending and receiving information to connect vehicles to RSU and each other is the basic idea of the VANETs. The important features of VANET can explain as follows: VANET considers vehicles and RSUs as nodes in network; the network is highly dynamic and the nodes can move very fast, which means that changing the positions of the vehicles and density resulting in continuous changing topology of the network in VANET. As mentioned earlier, Veins framework are selected to simulation of VANET because of several features which are investigated in our previous studies [31][32][33]. SUMO and OMNET++ are integrated in Veins framework. At the start, traffic related information of the vehicles (such as start time and position, stop time and position, origin, destination, maps, traffic lights, etc.) is generated in SUMO and then, exported to the OMNET++. All vehicles are considered as nodes in the network simulator. If any changes occurs in SUMO, Veins changes the cars scenario in OMNE++ and vice versa. Veins is developed in this paper by adding new modules to OMNET++ which aims to add numerous RSUs in each intersection which are defined in SUMO and consider them as nodes as well. Simulation is done as a VANET with integrating OMNET++ and SUMO with Veins and by considering realistic traffic of Cologne (also with added 20 vehicle) and the developed new module. Every node is able to communicate using 802.11p standard. The main parameters for the network simulation which used in this paper are summarized in Table I. Simulation scenarios are done as follows: All vehicles and also all RSUs broadcast beacons periodically.

CTTs for each street are calculated as follows: if a RSU in the starting point of the street, receives a beacons from a car, then, if the distance between the RSU and vehicle is less than 5 meters (the car has entered to the street), the RSU saves the simulation time and the car ID. Then, if the RSU which is located at the end point of the street, receives a beacon from the same car, and the distance between the car and the RSU is less than 5 meters, the current simulation time is saved as ending time for the car in the mentioned street (the car leaves the street); and by using the saved starting and ending times, the traveling time for the cars in the street are calculated and CTT is equal to average of five recent cars which have traveled on the street. (In order to reduce the computing process and time, the streets and the RSUs which are located along the route of the cars are considered.

Figure 3. Traveling Time for 20 Vehicles, in three traffic simulation in SUMO: with and without traffic and Using Dynamic Route Planning.

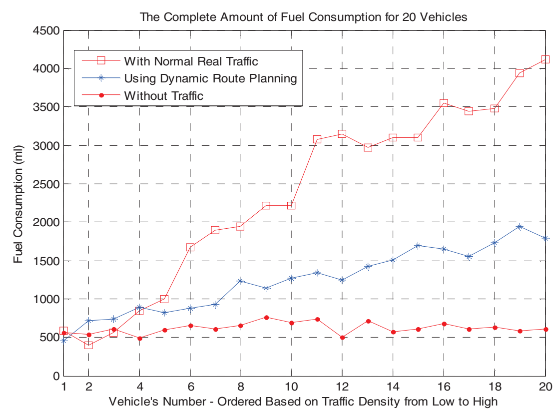

Figure 4. Total amount of fuel consumption of 20 vehicles during three different Simulation: with and without traffic and Using Dynamic Route Planning.

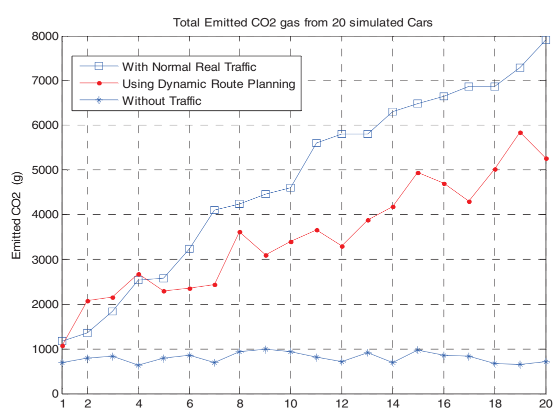

Figure 5. Total Emitted CO2 gas from each 20 simulated cars during travel from origin to destination, in three different simulation situations.

TABLE I. NETWORK SIMULATION PARAMETERS

Beacon size	400 Bytes		EIFS	188 µs
Beaconing Rate	10 Hz		CWmax	1023
Thermal Noise	-110 dBm		CWmin	15
Maximum Transmission Power	20 mW		Beacon delivery deadline	100 ms
Slot Duration	16 µs		AIFS	64µs
Header Length	24bit		Data rate	3 Mbit/s

One difficulty in large-scale simulation of VANET is "the time of simulation". For example for one hour simulation, OMNeT++ spends more than 100 hours in real time. Also the distances are calculated based on the position of the cars and RSUs which are provided by OMNET++ and SUMO.) Up to now, the simulation calculated and assigned the CTT for streets. All RSUs are broadcasting the CTT for streets which they are related to. Dynamic route planning for mentioned 20 cars is implemented as follows: at the start time of journey, the best routes are calculated based on current CTTs which are provided with OMNET++ simulation and the mentioned algorithm in previous section; and the best routes are sent to the SUMO to assign as cars routes. Similar to SUMO simulation, in OMNET++, in every simulation step, current CTTs are calculated. When a car gets close to the end point of the street, (RSU at the end of the street receives a beacon from the cars) a new best route is calculated based on current CTT and is sent to SUMO as new route. The simulations are done for 20 cars and traveling times are obtained for them.

A. VANET Simulation Result

The simulation with mentioned scenarios has been done and the traveling times for all 20 vehicles have been obtained. Figure.6 shows the traveling times for 20 vehicles which are collected by using V2I communication in order to calculate the CTT and best route with OMNET++. Also Fig.6 shows the data which was obtained in the previous sections using SUMO. In addition, Probability of Beacon Delivery (PBD) for 20 vehicles are calculated in order to analyse the accuracy of VANET simulation. PBD are calculated by considering all the lost beacons and received beacons during the journey for each vehicle from its origin to destination. Moreover, for each of the mentioned 20 vehicles, the difference between traveling time in SUMO and OMNET++ simulator are considered. Figure.7 shows PBD for 20 vehicles and also corresponding traveling time differences.

Figure.6 and Fig.7, illustrate the fact that the difference between traffic simulation result (ideal) and VANET simulation result (realistic) is quite small. Realistic results are collected from simulation with network simulator (OMNET++) by using the beaconing and IEEE 802.11p standard. Developed program is used SUMO to obtain the ideal form which considers the exact CTT (traveling time) and the exact position of the cars and RSUs for changing the routes. This Accurate and acceptable result has several reason, one of them is related to numerous broadcast

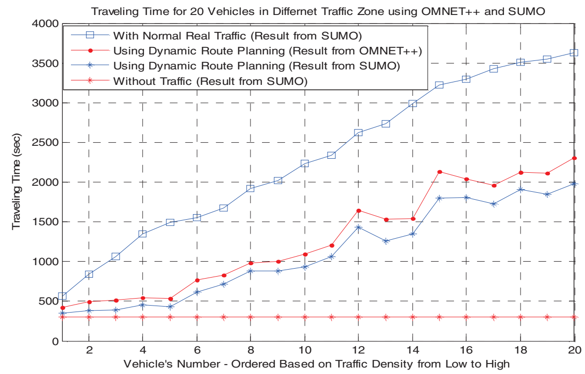

Figure 6. Traveling Time for 20 Vehicles, in three traffic simulation in SUMO: with and without traffic and Using Dynamic Route Planning in SUMO and also using V2I communication in OMNET++.

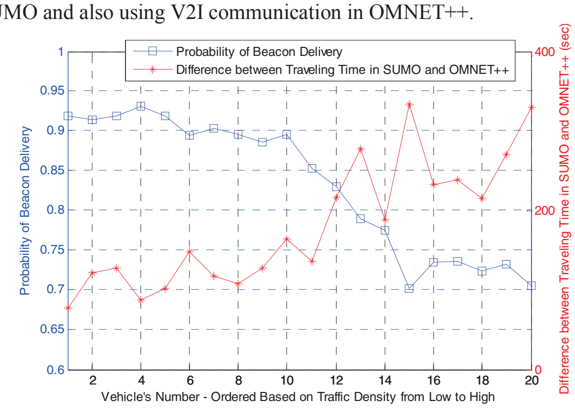

Figure 7. Probability of Beacon Delivery (PBD) and the difference between traveling times obtained from SUMO and OMNET++ simulator using DRP.

messages in beaconing scenario which aim to deliver the information to other vehicles and RSUs soon. This fact shows that V2V and V2I communication using IEEE 802.11p and employing DRP is capable to decrease the traveling time of the vehicles. In addition, Fig. 7 illustrate that with increasing the traffic density the PBD is decreased and also the cars traveling time is increased.

II. CONCLUSION AND FUTURE WORK

This paper proposes a new framework in order to calculate the fastest route for vehicles from origin to destination using V2X communication which provides real-time traffic information to drivers. This method, assigns a Current Traveling Time (CTT) for each street in a city which could help drivers to find the best route and also provides the on-line traffic data of the street (number of cars in roads segments). Then, effect of the method is investigated by using SUMO as a traffic simulator and Dynamic Route Planning (DRP). DRP is deploying the CTTs for streets which are calculated with the proposed method. Moreover to control the traffic simulation, this study is developed a new program written in Python capable to connect to SUMO. This program is connected to SUMO and by considering every single vehicle movements simulates a microscopic traffic, also able to calculate the Current Traveling Time for streets and dynamic route planning for the cars. This program dynamically calculates the fastest route for the specific car. Next, mentioned scenario is simulated as a VANET with IEEE 802.11p standard by integrating OMNET++ and SUMO with Veins framework. Veins is developed in this paper by added new modules to OMNET++ which aims to add numerous RoadSideUnits (RSUs) in the realistic traffic simulation. Several simulations are done with using SUMO, Veins and OMNET++. The results show that, proposed method, could decrease traveling time on average about 52% (and more than 60% in areas with high traffic) and decrease fuel consumption on average about 48% which is because of real-time and online data provided by V2X communications. Also traffic simulation and VANET simulation results have been compared and results show the high accuracy for IEEE 802.11p; and illustrate that V2X communication could be implemented in real world with using IEEE 802.11p standard which could save huge resources and helps to make roads more comfortable. Future work could include simulation of the traffic of the cities with other Dynamic Route Planning (DRP) approaches and also using network simulators and other wireless technologies such as LTE. In addition future work could focus on the effect of proposed method in different traffic patterns in major cities and countries such as US, Japan, etc. which have different regulations and policies affecting their traffic.

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