Heterogeneous ITS Architecture for Manned and Unmanned Cars in Suburban Areas

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***Abstract*—Vehicle-to-Everything (V2X) technology plays a critical role in maintaining road safety, avoiding accidents and controlling traffic flow. As self driving cars are expected to take over the roads, this paper discusses the intermediate phase in which manned and unmanned cars coexist. A heterogeneous network architecture that simultaneously serves manned and unmanned cars' different requirements in a suburban area is proposed and simulated using Riverbed Modeler. The feasibility of this architecture is examined in three different scenarios: Normal operation, congestion in both directions and Road Side Units (RSU) failure. In normal operation mode, traffic data is sent through Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure/Infrastructure-to-Vehicle (V2I/I2V or to RSU) using IEEE 802.11p and infotainment information is communicated as V2I/I2V using Long Term Evolution (LTE). A special case is highlighted and tested, in which congestion is in both directions. In such situation, data needs to be relayed to the nearest RSU using multi-hop communication. A fault-tolerant model is also proposed and analyzed in case of failure of RSU. The performance metrics are end-to-end delay, LTE response time, handover delay and packet loss ratio. The architecture proves its suitability by satisfying traffic control real time application requirements.**

Keywords—LTE, IEEE 802.11p, V2V, V2I/I2V, Heterogeneous networks, Riverbed Modeler.

I. Introduction

Vehicle-to-Everything communication (V2X) includes Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure/Infrastructure-to-Vehicle (V2I/I2V) communications. V2I/I2V is the wireless exchange between vehicles and the infrastructure for traffic management and avoidance of bottlenecks, whereas V2V is when a vehicle communicates to nearby vehicles exchanging messages for safety enhancements [1]. The standard protocol for vehicular networks is IEEE 802.11p. However, a lot of researches advocate the usage of LTE in vehicular networks [2-10].

In the emerging world of the wireless Internet of Things (IoT), where every single object would be connected through a network with all its surroundings, the concept of V2X communications stands as one of this world's most critical applications. This would enable the automotive world into further creativity, where different vehicles would be operated autonomously [11].

Recently, an emerging computing scheme known as fog or edge computing was introduced to decrease latency over the communication network [12, 13]. This computation model offloads processing happening in the cloud and moves it to the network edge [12]. In addition to fog computing, dew computing is introduced to further lower the traffic load on networks [14].

Several proposed architectures introduced and analyzed the use of Road Side Units (RSUs) to serve as fog elements or as communication points of attachment positioned in safety critical locations, and the communication protocols used were mainly IEEE 802.11p, Wi-Fi and LTE [4, 15, 16]. Usually, applications supported by V2I include traffic safety and infotainment services such as video streaming, web browsing, e-mail and VoIP [2-11, 15-18].

To introduce self driving cars in streets, automotive companies have done intensive research in the area of autonomous vehicles. Several car manufacturers and technology companies, notably Google, Chevrolet, BMW and Tesla cars use cameras and sensors in order to gather information about its surrounding, to move and avoid obstacles on the road [19-23].

In this paper, a scenario is proposed where manned and unmanned vehicles coexist. This positions the research as a step further from what is currently proposed in the literature; being the enhancement of driving experience for manned cars. A heterogeneous model of communication is proposed where V2V and V2I/I2V (RSU) communication use IEEE 802.11p protocol, while V2I/I2V uses LTE. Fault-Tolerance of the system is also studied in case of RSU failure. Congestion in both directions is also studied. In such scenario, data needs to be communicated to the nearest RSU using multi-hop scheme. Secured communication is out of scope of this research.

The rest of this paper is organized as follows. Section II describes the related work and explains the technologies used and their suitability. The proposed model architecture

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is presented in Section III. In Sections IV, V and VI, the V2V, V2I/I2V and infotainment using LTE aspects of the proposed work are discussed and simulated using Riverbed Modeler and the results are shown. Section VII introduces a case study for congested roads between two RSUs. Finally, the paper is concluded in Section VIII.

II. RELATED WORK

This section highlights previous studies on the computational hierarchy including dew, fog and cloud, as well as vehicular networking protocols such as LTE and IEEE 802.11.

References [12-14, 18, 24] proposed a hierarchical model for computation in vehicular networks. The dew computing level that receives raw data, is followed by a fog computational level and finally a cloud server [14]. A car gathers information about the surrounding from two main sources; the sensors embedded in the car [18] and V2V communication [25]. The sensors generate a huge volume of data that cannot be passed directly to the infrastructure [14, 24]. Hence, a dew computing level is introduced. The dew computing level is a small embedded processor in the car that generates reports from the gathered information [14]. This data is then passed to the fog level. It is argued that fog computing provides low latency for time critical applications [13]. Reference [12] proposed that Road Side Units (RSUs) could serve as fog elements. Dew is expected to be more beneficial than higher computational levels as it is closer to the end devices, i.e., the car because the reports generated at the dew level reduce the burden on the infrastructure [14].

The current issues of self-driving cars include the range of road coverage, which tends to be less than 80m relying on camera-based object detection algorithms, and less than 200m relying on Radars and Lidars [18]. A downside of relying solely on sensors and cameras is that the gathered information about the road is limited to the vehicle’s approach [18]. This implies that there is no information shared with other surrounding vehicles. This limits the vehicle’s coverage to its line of sight, hindering the idea of grasping full information about the road [18]. Hence, some obstacles or other vehicles within the road would be left hidden or unrecognized within the vehicle's proximity.

Therefore, the second source of data is V2X communications, which is superior to relying on sensors only [18]. V2X communication would extend that range of coverage to beyond 200m of road detection [18]. In [25], DSRC and on-board sensors improve the root mean square error (RMSE) in road estimation at 200m from the vehicle by about 65% (compared to cameras and sensors). The likelihood of the street estimation error to be superior to half of a lane width is 98.7% with strategy proposed in [25] while it is just 48% with the previously described techniques.

Extensive research evaluated the performance of IEEE 802.11p as a standard for ad hoc V2V communications [17, 26]. The evaluation was done on 50 nodes in the streets of Paris using Riverbed Modeler [17]. The results support that the routing protocol does not make a huge difference. To achieve the best performance possible, a maximum of two-hop routes is maintained [17]. Another research on V2V in [26] proposes an intersection management algorithm. The algorithm was tested in seven different traffic conditions showing around 11% to 26% improvement in the waiting time; however, results vary depending on the traffic condition [26].

Another discussed technology for V2V is LTE; however, as the network gets easily congested it could not handle V2V applications [24]. Similarly, reference [7] emphasizes that the high rate of V2V messages, which is typically every 100ms, cannot be supported by LTE networks.

To build V2I communication architecture, references [15, 16] use IEEE 802.11 communication protocol and RSUs. RSUs perform some processing to calculate the current traveling time and broadcast messages to other cars [16]. When using IEEE 802.11p, simulation results showed a general decrease in traveling time and fuel consumption [16]. Due to the high cost of deploying RSUs, it is believed in [4] that RSUs should be positioned in locations where safety is eminent. Whereas in [15], an integrated traffic enforcement system is introduced to log traffic tolling and report traffic violations via Wi-Fi. Their proposed model involves positioning Wi-Fi access points at intersections to communicate with equipped vehicles. Simulation results proved that all violations were reported promptly [15].

Another communication scheme used for V2I/I2V communications is LTE. Reference [3] examined the performance of such a network, where vehicular and infotainment data are transmitted over LTE using different scheduling strategies. Results showed that for small coverage areas LTE is not efficient. Similarly, reference [5] used LTE for V2I/I2V traffic control and infotainment and showed the feasibility of this architecture. Reference [4] proved that LTE has long coverage range and high throughput for infotainment services.

A comparative study was conducted between IEEE 802.11p and LTE in [2] in order to evaluate their suitability in different vehicular applications. The paper’s primary focus was on investigating the performance according to metrics such as delay, reliability, scalability and mobility support of both communication standards in the context of suitability for different vehicular applications. It was concluded that LTE is suitable for most vehicular applications and satisfies most of the vehicular requirements. On the other hand, LTE demonstrated a tendency for high delay as the load increases on the network. While IEEE 802.11p offers acceptable performance for sparse network topologies with limited mobility support [2].

Heterogeneous and hybrid models were discussed by [4, 6, 8, 10]. Reference [8] presented a hybrid communication scheme using LTE and IEEE 802.11p in an urban environment for vehicular networks. Simulation results concluded that the deployed heterogeneous network of IEEE 802.11p-LTE demonstrated superior performance especially in scenarios with high vehicle density and speed. References [4, 10] concluded that the LTE for V2I/I2V and DSRC for V2V should be implemented together as they complement each other.

Reference [6] proposed a heterogeneous architecture using 802.11 and LTE. Gateway vehicles are enabled to communicate through LTE for V2I/I2V and IEEE 802.11g for V2V. This ensured that few cars send to the infrastructure, hence reducing the load on the network. Performance metrics proved the feasibility of this architecture.

III. Model Description

The proposed heterogeneous vehicular network serves two different vehicle types: manned and unmanned. The network is modeled in an un-crowded suburban environment. To be able to give vehicles full information about the traffic, on-board sensors gather raw traffic data, and the vehicle communicates its status through V2V. V2V communication is used by vehicles to exchange messages with the surrounding vehicles about its own trajectory, speed and position through a simple broadcast message using User Datagram Protocol (UDP). The required packet size is chosen to meet the benchmark of the unmanned vehicle communication. This is to ensure that all necessary information about the vehicle's surroundings is available. V2V communication uses the standardized protocol IEEE 802.11p.

Also, the model combines two communication protocols for V2I/I2V communication: IEEE 802.11p and LTE. For traffic control data (ITS traffic), V2I/I2V uses IEEE 802.11p protocol to exchange traffic information, which includes congested areas and accidents locations. This information is exchanged between RSUs and vehicles at the intersections. While, LTE in normal operating conditions provides infotainment services to enhance the user experience and enjoyment. However, if the RSU network fails, LTE network will communicate both traffic control and infotainment data to ensure no degradation in the users' experience.

The computational hierarchy in this model is available through the computation done on three different levels: dew, fog, and cloud. Vehicles receive raw traffic data from on-board sensors and through V2V communication. This raw data is processed on-board; therefore, the vehicles are considered to be the dew computing level. On a higher computational level, the presence of the RSUs introduces the fog level. In addition, the central node through which all the RSUs are connected is the highest level of computation called the cloud. This hierarchy ensures supporting low latency, position awareness, mobility support, high node density, real-time applications, heterogeneity, broadness of geo-distribution of the network, which is required by connected vehicles in the proposed model [13].

As shown in Fig. 1, between any two RSUs, an uncovered area exists. This distribution of RSUs is chosen to minimize the cost of installation of the units keeping one RSU at each intersection [27]. In case of traffic congestion on both sides of the road within the blind area between two RSUs, traffic information about the congestion should be sent to the central network of the city. This is communicated through a hybrid communication scheme, where vehicles in the congested area pass traffic information to the RSUs through multi-hops between the vehicles (V2V) to reach to the nearest RSU (V2I).

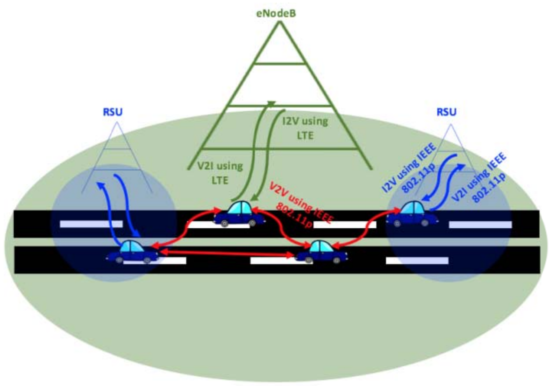

Fig. 1. Model Description

The performance metrics for the simulated models (when relevant) are:

- Packet Loss Ratio (PLR) is defined as the ratio of the number of lost packets to the total number of packets sent.
- LTE Response time is defined as time from sending a request to receiving a response.
- End-to-end delay is defined as the time a packet takes to be received from the transmitting node.
- Handover delay is defined as the time a moving node takes to disconnect from a source eNodeB and establish another connection with a target eNodeB.

The following sections IV to VI will introduce each model: V2V, V2I/I2V and LTE for V2I/I2V infotainment and the fault-tolerant scheme respectively, together with its simulation results.

IV. IEEE 802.11p for V2V

In the V2V communication scheme, a street that has two unobstructed lanes in two different directions, is simulated using Riverbed Modeler [28]. It encloses four cars, two in each direction. Every vehicle communicates with the other three vehicles using IEEE 802.11p. Fig. 2 illustrates the V2V model. Simulation parameters are presented in Table I.

Moreover, the cars communicate using UDP to ensure fast communication between the vehicles.

Simulations were run to study different system performance metrics: end-to-end delay and packet loss ratio. The results showed that the vehicles were fully connected during their communication range. The communication exhibited no packet loss as long as the vehicles were within range. End-to-end delay results are tabulated in Table II, when all four cars are connected. The results show that end-to-end delay is below 150ms as the standards require [29]. However, when only two cars are connected to each other, the end-to-end delay remains constant at 0.288ms. All results are based on a 95% confidence analysis. It is important to mention that these results will be further investigated to accommodate for surrounding interference on the communication channel in section VI.

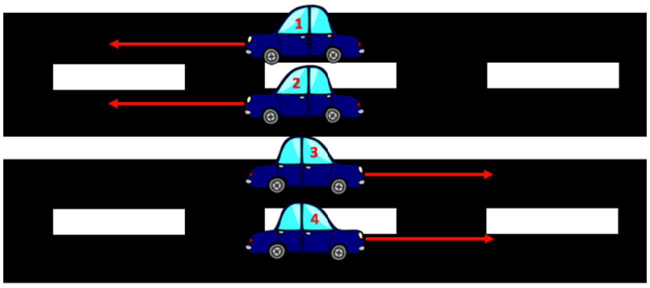

Fig. 2. The V2V Simulation Model

TABLE I. SIMULATION PARAMETERS FOR V2V

Parameter	*Value*
Transmit Power (mW)	11
Packet Reception-Power Threshold (dBm)	–95
Packet Size (B)	300 [1]
Inter-arrival Packet Time (ms)	100 [1]
Vehicle Speed (Km/h)	60

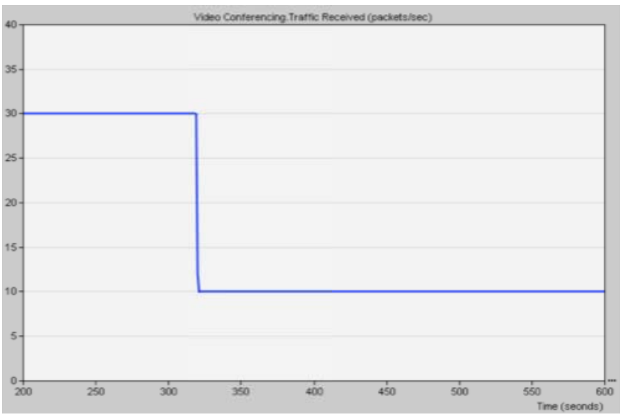

Fig. 3. Traffic Received by Vehicles in V2V communication

TABLE II. END-TO-END DELAY FOR V2V (IN MS)

Car	*Confidence Bound*
1 and 2	[1.02; 0.628]
1 and 3	[1.39; 0.987]
1 and 4	[1.25; 0.880]
2 and 3	[1.41; 0.896]
2 and 4	[1.16; 0.789]
3 and 4	[1.13; 0.745]

In Fig. 3, the x-axis is the simulation time in seconds and the y-axis is the traffic received in packets/second. For the first part of the graph, all cars are within communication range. After the instant 320s, each set of cars moving in one direction is far apart from the other set (recall Fig. 2). Since, each car sends to all 3 others in the model, the load decreases by one third when they become out of range.

V. IEEE 802.11P FOR V2I/I2V

RSUs are used for mobile nodes (MN) communication with infrastructure. These MN cars exchange traffic information with the Central Node (CN). MNs include both types of cars: unmanned (autonomous) and manned vehicles. RSUs are positioned at intersections and communicate with each other on the backbone using Point-to-point protocol (PPP). IEEE 802.11p is used for V2I/I2V communication. The model includes four roaming vehicles traveling with different trajectories and crossing various RSUs. To model the background interference produced by the V2V traffic, two stationary nodes are located within the coverage area of each RSU with equivalent payload communication. Also, background interference due to moving vehicles within the same RSU is modeled.

In order to examine system performance at different speeds, different scenarios are simulated for MN moving at 33 and 60Km/h [30].

RSU radius based on Riverbed simulations is 122m in conformance with [15]. Within this radius, RSU and MN exchange information without data loss. Simulation parameters are detailed in Table III.

TABLE III. SIMULATION PARAMETERS FOR V2I

Parameter	*Value for MN*	*Value for RSU*
Transmit Power (mW)	1	1.5
Packet Reception-Power Threshold (dBm)	–80 [15]	–80 [15]
Packet Size (KB)	1	1
Inter-arrival Packet Time for 60Km/h (s)	120	120
Inter-arrival Packet Time for 33Km/h (s)	219	219
Channel Number	11	11

TABLE IV. END-TO-END DELAY FOR INTERFERENCE FREE MODEL (IN MS)

Speed	*Confidence Bound at MN*	*Confidence Bound at CN*
33Km/h	[3.71; 4.81]	[1.59; 1.76]
60Km/h	[4.77; 8.13]	[2.05; 5.21]

TABLE V. END-TO-END DELAY FOR INTERFERENCE MODEL WITH V2V AND BACKGROUND COMMUNICATION (IN MS)

Speed	*Confidence Bound at MN*	*Confidence Bound at CN*
33Km/h	[3.84; 4.83]	[5.55; 8.53]
60Km/h	[6.75; 10.7]	[3.83; 7.15]

Riverbed simulation scenarios were tested to evaluate the system performance: MN roaming in the system at 33 and 60Km/h, without interference. To study the interference effect on the model of section IV, V2V and surrounding V2I/I2V interference are injected. Results for the interference free model as well as for the interference model are tabulated in Table IV and V respectively. These results are based on a 95% confidence analysis.

VI. LTE FOR V2I/I2V INFOTAINMENT

The proposed system architecture requires modeling a bi-directional road where eNodeBs are to be deployed in a linear manner as shown in Fig. 4. This linear distribution of eNodeBs provides full coverage for the simulated road. It is assumed that the same scenario applies to the whole suburban area, where eNodeBs are distributed all over the city. The infotainment traffic is sent over LTE network, serving users in moving cars with infotainment services such as web browsing and video.

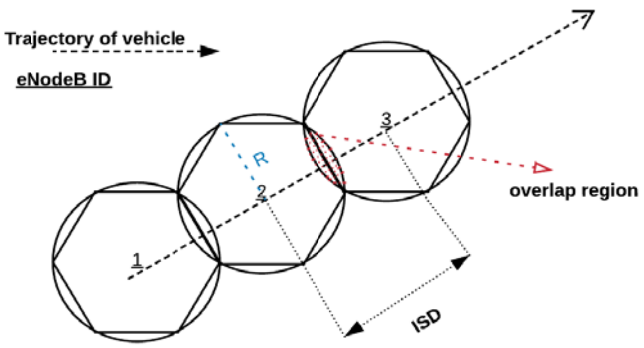

Fig. 4. LTE Cell deployment

During normal operation of the system, only infotainment traffic is sent over the network. However, if RSUs fail, or faults occur in the central controller, two types of traffic will be sent over LTE: ITS control data and infotainment traffic data.

A. Network Model

The proposed model consists of three cells arranged in a linear manner. Each cell is modeled having a hexagonal honey-cell layout where each cell is covered by a single eNodeB. The cell layout, radius, Inter-site distance (ISD), eNodeB ID, and trajectory of one vehicle are shown in Fig 4. Four vehicles are modeled moving in a straight line between the three cells with a speed of 60Km/h. The vehicles are modeled under "ITU Vehicular Environment" path loss model and "Vehicular B" model for multipath [5] using Riverbed Modeler.

Two simulation scenarios are studied: LTE carrying infotainment traffic only, and LTE carrying extra traffic for traffic control data. The first scenario is simulating normal operation condition, while the second one is the fault-tolerant model in case of RSU failure. Both scenarios are subjected to extra background traffic simulating interference on the communication channel.

In the simulations of the proposed system, infotainment traffic is simulated by sending 1Mbit/s that is a video streaming of a Youtube 480p video [5]. While ITS payload is simulated by 1KB with 120s Inter Packet Time (as per Table III). The background traffic is assuming the presence of 10 users communicating with each eNodeB.

The performance evaluation metrics are: packet loss ratio, LTE response time and handover delay.

The path loss between the eNodeB and the UE is

$$L(dB) = P_t - P_r \quad (1)$$

where P_t is the transmitted power by the eNodeB (40 dBm) and P_r is the received power at the UE (−106dBm).

In a vehicular environment, the transmission path loss (L) is given in dB by the following equation [31].

$$L = [40(1 - 4 \times 10^{-3} \Delta h_b)] \log R - 18 \log \Delta h_b + 21 \log f + 80 \quad (2)$$

where f is the carrier frequency in MHz, R is the distance in Km from the eNodeB to the UE and Δh_b is the height difference between the BS antenna and the average building rooftop height. Δh_b =4m considering an average four storey building. Using equation (1) and equation (2) and the simulations parameters described in Table VI, the theoretical cell radius (R) is 1.6Km [31].

The ISD is defined as the distance between the centers of two adjacent eNodeBs. The ISD in an LTE network is chosen in a way that optimizes the performance of the system in terms of handover delay, packet loss ratio during handover. For an omnidirectional eNodeB, the ISD is calculated as follows [5].

$$ISD = \sqrt{3}R \quad (3)$$

where R is the cell radius.

Based on equation (3) the calculated cell radius, the ISD is found to be equal to 2.77Km.

TABLE VI. SIMULATION PARAMETERS

eNodeB	
Parameter	***Value [5]***
Transmit power (W)	10
Antenna gain (dBi)	18
MIMO	2x2
Bandwidth (MHz)	10
Frequency band (GHz)	1.8
Rx Sensitivity (dBi)	-123
Duplexing technique	FDD
Antenna height (m)	4
UE	
Parameter	***Value [5]***
Transmit power (W)	0.2
Antenna gain (dBi)	0
MIMO	1x2
Rx Sensitivity (dBi)	-106
Shadow fading standard deviation (dB)	4

Regarding spectrum allocation, Band 3 has been selected for LTE network with 10 MHz bandwidth. Band 3 provides a unique combination of capacity and coverage. Apart from capacity and coverage, its frequency band is far from IEEE 802.11p band frequency which is 5.9GHz. Also, Band 3 is the mostly commonly used band in the world especially in Europe and Asia [32].

B. Results and Analysis

Using Riverbed Modeler, the eNodeB cell radius was found to be 1.54Km. Therefore, the obtained cell radius is within 3.75% error of the calculated cell radius obtained analytically from equation (1). The ISD is chosen to be 2.67Km according equation (3), keeping the overlap distance to be 206m.

For evaluating system performance, the aforementioned evaluation metrics, which are PLR, handover delay and response time have been analyzed using Riverbed Modeler and compared to communication requirements mentioned in the literature to ensure quality of service. A 95% confidence analysis was performed for all results. Table VII shows the results when the system is fault free: only infotainment traffic is communicated. Table VIII shows the results when ITS traffic is loaded to the LTE communication network.

For PLR in video streaming services, the benchmark is to be lower than 2% [33, 34]. Response time for traffic control data and for video streaming should be below 150ms and 100-500ms respectively while handover delay should remain below 65ms [34, 35].

TABLE VII. NORMAL OPERATION

Infotainment (Video)	
Evaluation Metric	***Confidence Bound***
PLR (%)	[1.03; 1.43]
Handover Delay (ms)	[14.4; 17.5]
Response Time (ms)	[15.3; 15.6]

TABLE VIII. FAULT-TOLERANT OPERATION

Infotainment (Video) + ITS	
Evaluation Metric	***Confidence Bound***
Handover Delay (ms)	[13.9; 16.4]
Infotainment	
PLR (%)	[1.03;1.22]
Response Time (ms)	[14.3; 14.5]
ITS	
PLR (%)	[0; 0]
Response Time (ms)	[15.0; 16.5]

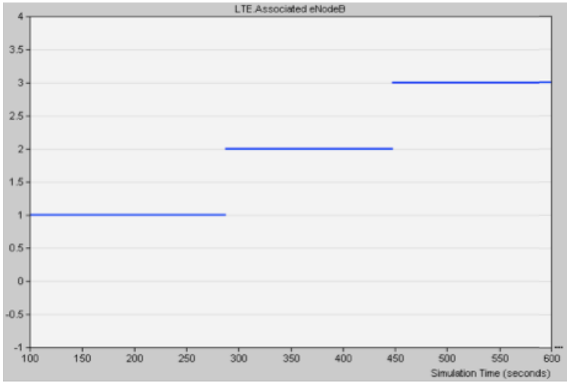

Fig. 5. The Associated eNodeB with the UE

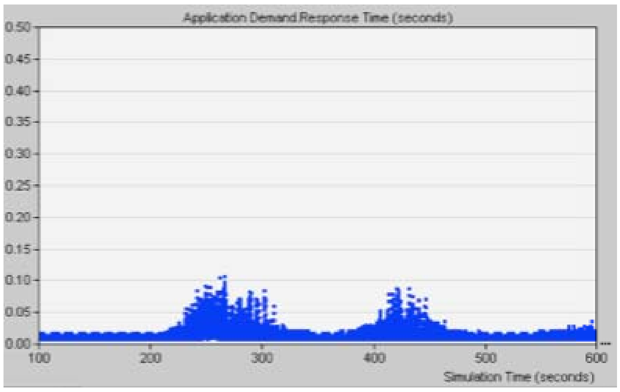

Fig. 6. Response Time in Normal Operation

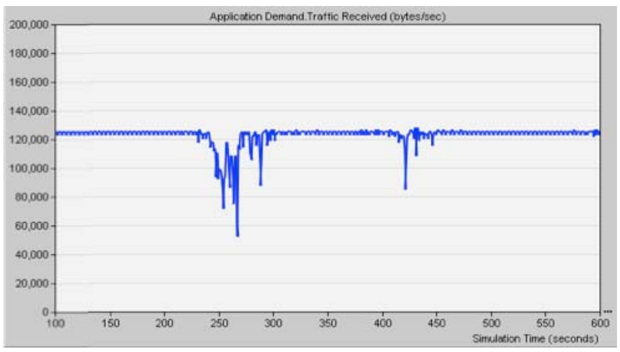

Fig. 7. Infotainment Traffic Received in Normal Operation

Results of Table VII and Table VIII assure that PLR, handover delay and LTE response time meet these benchmarks.

Fig. 5 to Fig. 7 show the Riverbed graphs verifying the system performance through associated eNodeB, response time and traffic received at one car in fault free scenario. The x-axis in Fig. 5 to Fig 7 is the simulation time in seconds. In Fig. 5, Fig. 6 and Fig. 7, the y-axes are: the associated eNodeB, LTE response time in seconds and traffic received in bytes per seconds respectively.

VII. Blind Region Coverage Model

In the special case of road congestion in both directions, there is a need to provide connectivity for cars in the blind region between RSUs, which is approximately 1.76Km. Hence, studying the performance metrics of the V2V/V2I hybrid relay scheme shown in Fig. 8 is crucial to the proposed system. When two way roads get congested in both directions, in a region not covered by any RSU, traffic information would be missing. This will lead to inaccurate journey time estimation and wrong decisions by vehicles.

In Fig. 8, traffic congestion happens in the worst case scenario which is in the centre between two RSUs. Using a widely used routing protocol such as Ad-hoc On-Demand Distance Vector (AODV) or Destination Sequence Distance Vector Routing (DSDV) [36], the best route to transfer traffic information to the RSU is chosen. Based on this route, the power of the V2V antenna is adjusted to compromise between transmission power and delay to transfer information to the central network. Assuming the number of hops advised by a given routing protocol is three to reach the nearest RSU, the transmit power of the congested vehicle is increased to be 18mW on the dedicated channel.

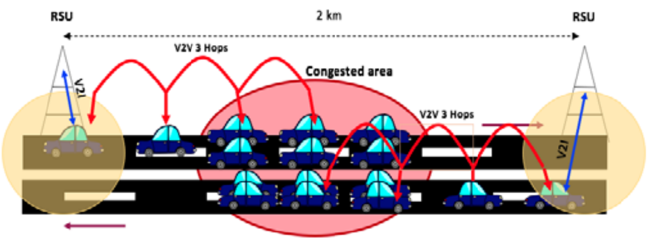

Fig. 8. V2V-V2I Hybrid Relay Scheme

Table IX shows the results for the simulated scenario based on a 95% confidence analysis. The performance metric is the end-to-end delay. Since the data is communicated based on multi-hops, the total end-to-end delay is calculated by accumulating end-to-end delay at each hop added to the final stage of V2I (RSU).

TABLE IX. V2V-V2I Hybrid Scheme Performance Metrics

Delay for Exchanging ITS Control Data in ms	
Communication Direction	***Confidence Interval***
I2V-V2V	[3.952; 6.658]
V2V-V2I	[4.091; 6.803]

VIII. Conclusions

In this paper, a heterogeneous network architecture for serving manned and unmanned cars in a suburban area is proposed. This research goes ahead of what is commonly proposed in the literature, which is focusing on enhancing driving experience for manned cars. The architecture has been simulated using Riverbed Modeler to test its feasibility by measuring the performance metrics: packet loss ratio, LTE response time, end-to-end delay and handover delay. The architecture consists of three main communication schemes: V2V using IEEE 802.11p, V2I/I2V using IEEE 802.11p (to RSU) and LTE (to mobile network) for infotainment services. Fault-tolerance was also proposed to solve the problem in case of RSU failure. In this case, V2I RSU traffic will be shifted to V2I LTE. In this situation, LTE will carry traffic management data as well as infotainment load. Another important scenario was evaluated: the case of congestion in both directions. In this model, a V2V/V2I hybrid scheme will be in place to relay information in the blind region between RSUs. This mechanism uses multi-hop to transfer traffic information to the nearest RSU. This is because the RSUs coverage is not continuous. All presented results in all simulated scenarios are based on 95% confidence analysis. These results are in-line with the stated benchmarks. Security issues related to data communication is out of scope of the presented study.

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