

An Approach to Improve the Quality of Service in DTN and Non-DTN based VANET

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Abstract

Nowadays, with attention to soar in the number of network users, it is necessary to find new approaches to revolutionize network operation. Vehicular ad-hoc networks are bound to play a pivotal role in communication, therefore raising the traffic in the network, using only WiFi is unlikely to address this problem. Vehicles could use SDN and other networks such as 4G as well as 5G to distribute traffic to different networks. Moreover, many approaches for handling different data types are inappropriate due to the lack of attention to the data separation idea. In this paper, we proposed a control scheme called Improve Quality of Service in DTN and Non-DTN (IQDN) which works based on vehicle communication infrastructure using SDN idea. IQDN separates data to Delay-Tolerant Data (DTD), and Delay-Intolerant Data (DID) where the former buffers in a vehicle till the vehicle enters an RSU range and sends DTD using IEEE 802.11p. DID packets are sent by cellular networks and LTE. To transmit DTD via IEEE 802.11p, the network capacity is evaluated by SDN. If that network has room to transmit the data, SDN sends a control message to inform the vehicle. Simulations show that sending data over RSU and LTE increases the throughput and decreases the congestion, so the quality of service improves.

Keywords: DTN; Vehicular communications; LTE; IEEE 802.11p; SDN.

1- Introduction

Dedicated Short Range Communication (DSRC) based on IEEE 802.11p is used by vehicle communication [1]. Vehicular Ad-hoc Network is a subset of Mobile Ad-hoc Network, which is attractive for researchers due to challenges, features as well as different applications [2]. With rising in the number of network users, we need new approaches for managing network traffic and satisfy QoS's requirements. Using networks like 4G beside IEEE 802.11p could increase the available bandwidth in the network. Using SDN also could decrease the needed processing power; consequently, it helps to decrease overhead in the network. Communications in VANET are divided into Vehicle-to-Vehicle (V2V) as well as Vehicle-to-Infrastructure (V2I). Vehicles of V2I communication could send/receive data both via the IEEE 802.11p protocol as well as the 3G/3.5G/4G cellular network [3]. Vehicles could communicate with the internet via WiFi as well as LTE and due to demand for fast internet it can be possible to propose the ways that enable vehicles to gain benefit from both infrastructures, so both WiFi and LTE offloading could be an appropriate response for improving

circumstances in VANET [5]. In [6] Huang and his colleagues used Handover Decision based on Software-Defined Network (OHD-SDN) for offloading from the cellular network to WiFi 802.11p. In this scheme, the main issue is IEEE 802.11p offloading and there are some defects and challenges: 1) The simulation in this scheme is different from the real scenario (urban or highway scenario). 2) There is no attention to the other aspects of quality of services such as Delay and Jitter. 3) With rising in the number of traffic by nodes, packet loss increases significantly. In our scheme, vehicles use LTE and IEEE 802.11p. Moreover, to make handoff decisions, we use the Software-Defined Network (SDN) [7]. We consider both Delay-Tolerant Data (DTD) and Delay-Intolerant Data (DID) in the network. Vehicles send and receive DID via 3G/3.5G/4G cellular network, while DTD is sent via RSUs and Wi-Fi 802.11p. Vehicles send control messages to SDN and give their information to it; therefore, the SDN controller is constantly being aware of the vehicles. A vehicle sends a connection request to the SDN controller before it reaches the RSU. The SDN controller calculates arriving time and distance to the RSU and sends them to the vehicle before entering the RSU range. So the vehicle knows its distance and its arrival time to the RSU. Afterward, the SDN controller decides whether that

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vehicle is allowed to send data through IEEE 802.11p or not. This decision depends on the IEEE 802.11p bandwidth. If there is no available bandwidth, the SDN controller does not grant permission to the vehicle to connect to the RSU, so the vehicle should wait for the next RSU. The simulation of our proposed scheme shows improvement in the quality of service in the network.

The paper is organized as follows: In the second section, we have a review of the related works. In the third section, we introduce the architecture of the network. In the fourth section, the pattern of sending delay tolerant data is introduced and in the fifth section, the simulation and evaluation of our proposed scheme in comparison to other schemes are stated.

2- Related Work

In [8], a routing plan to prevent congestion is presented. In this scheme, a part of vehicle routing is calculated and it makes a balance between user privacy and re-routing procedure. In [9], the authors present cellular networks as well as WiFi roaming decisions and AP selection based on IEEE 802.11u as well as the 3GPP network. It helps mobile nodes to decide roaming in the network at the right time. Also, authors in [10] provided a way to improve mobile data offloading. Authors in [11], [12] presented an offloading decision considering the availability of V2I capacity as well as QoS of V2V, the data volume, and the connection time between vehicles and RSUs. To manage the time and resources in heterogeneous vehicles, the authors in [13] used SDN, and they reduced the communication cost. In [14], authors with an opportunistic network approach, offer a way for stream offloading from the cellular network to WiFi. Park et al. [15] used SDN to present a centralized routing architecture to network traffic and also reduce packet loss. In [16], a resource allocation process has been introduced, including link scheduling and link bandwidth for short-term communication in VANET. In [17], the authors proposed a protocol that collects and distributes the data generated by the heterogeneous LTE and DSRC as well as the LTE offloading on the network. In [18], an approach has been introduced, in which, vehicles try to have the best connection choice in an urban environment and heterogeneous network, which aims to provide continuous access to services and reduce connection costs. Bravo et al. [19] provided an approach to offloading mobile data based on a virtualization layer in the communication protocol stack, as well as a routing protocol that combines topology and geography. This approach decreased overhead and delay in an urban environment and it increased data rate in the network. Authors in [20] presented an approach to guarantee the quality of service for mobile data and to balance between mobile data and QoS for vehicular cyber-physical systems

(VCPSs). In [21], a cheap approach has been proposed for offloading data from the cellular network to WiFi. In [22], the authors presented a plan for WiFi offloading as well as switching in cellular networks and WiFi. They aim to raise capacity, improve transmission rate, and decrease cost and energy consumption in the network. In [23], the authors implemented the VANET network predicting the WiFi offloading. Authors in [24], [25] presented an approach, where SDN is used for mobile data offloading and routing respectively in VANET. In [26], the authors presented a smart network, which evaluates massive data and helps vehicles to make appropriate decisions to access the network. In [27], the authors proposed an algorithm that helps vehicles to use 4G LTE and WiFi and make communication among vehicles and infrastructure. Bazzi et al. [28], used virtual RSUs to decrease exchange data in the network, consequently, the packet transmission rate to RSU is improved. In [29], the authors presented data offloading in a cellular network to stream data in VANET.

3- Network Architecture and Overview to the Scheme

In this section network configuration as well as the general idea of our scheme is proposed. As known LTE covers a wider area than RSUs, so it is possible to employ them for communication in VANET. As can be seen in Fig.1, vehicles are connected to cellular networks and RSU for transmitting their packets. Considering the quality of service, the vehicles transmit DID via LTE, while they buffer DTD until they can transmit them through RSU. Offloading from LTE to IEEE 802.11p raises these questions:

- 1) When and how we should make a decision?
- 2) How to inform vehicles about RSUs information?

To do this, we employed the SDN controller for calculations, and it is assumed that vehicles are equipped with GPS so they are always informed

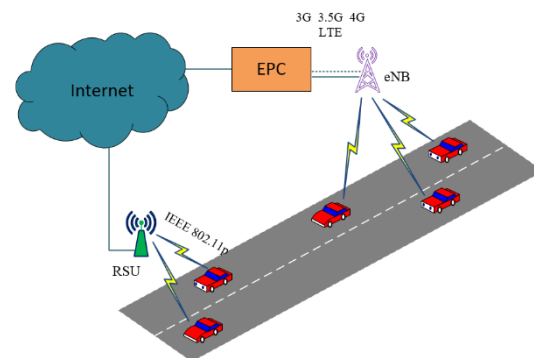


Fig. 1 Network Architecture

about their location. Furthermore, the vehicles send their location, direction, and speed to the SDN controller periodically. As a result, SDN has adequate information about vehicles and RSUs, and it evaluates the bandwidth of IEEE 802.11p network.

The vehicles usually transmit DID through LTE, however, for transmitting DTD, they initially send a request to the SDN for connecting to RSU. Consequently, the SDN sends a response to the vehicle, determining that the vehicle has permission to connect to RSU or not.

The request message includes vehicle demand to connect to IEEE 802.11p, its location, direction, and speed. Afterward, the vehicle waits for the response from SDN. Receiving a request from a vehicle, SDN calculates its arriving time to the nearest RSU and available IEEE 802.11p bandwidth. Consequently SDN makes two decisions:

- 1) If IEEE 802.11p has available bandwidths, the vehicle has permission to connect, so the vehicle could transmit its buffered packets via the RSU. Leaving the RSU covered area; the vehicle disconnects its link and sends a message containing RSU ID, the volume of transmitting data, and the RSU connection time to SDN.
- 2) If IEEE 802.11p has no available bandwidth, the SDN controller does not grant permission to the vehicle to connect to RSU. Therefore, the vehicle should buffer its DTD and waits for the next RSU.

A significant proportion of the data are DTD, where buffering them decreases traffic on the 3G/3.5G/4G LTE network.

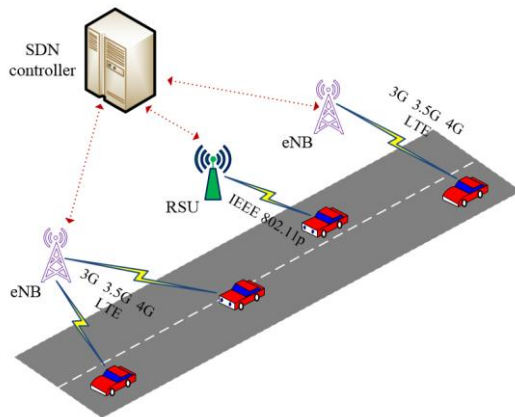


Fig. 2 Vehicles are connected to the SDN controller to exchange control messages

4- Process of Transmitting DTD

In this section, we introduce the SDN controller computations.

4-1- Arriving Time and Distance to the RSU Relation

Having periodic messages, the SDN controller could calculate the average speed of a vehicle:

$$V_{ave} = \frac{v_1 + v_2 + \dots + v_n}{n} \quad (1)$$

V_{ave} is the average vehicle speed. To calculate vehicle-RSU distance we consider the range of RSU's signal as a globe with the center of its antenna and the radius of its coverage range.

Vehicles move in two directions, so they are on a plate intersecting with the globe. If $O(x_0, y_0, z_0)$ is considered as the globe center, (2) shows the globe equation with a radius of r [30]:

$$(X - x_0)^2 + (Y - y_0)^2 + (Z - z_0)^2 = r^2 \quad (2)$$

Furthermore, if L-plate passes through point $A(x_2, y_2, z_2)$ and the vector $n(a, b, c)$ be perpendicular on that and consider the optional point $Q(x, y, z)$ on this plate, so Q is on the L-plate if and only if dimensions n and \overrightarrow{AQ} be perpendicular [30]. Therefore:

$$\begin{aligned} \overrightarrow{AQ} &= (x - x_2, y - y_2, z - z_2), n(a, b, c) \\ \rightarrow n \perp \overrightarrow{AQ} &\rightarrow n \cdot \overrightarrow{AQ} = 0 \end{aligned} \quad (3)$$

As a result equation L-plate which passes through a certain point such as $A(x_2, y_2, z_2)$ and is perpendicular to the inverse vector $n(a, b, c)$ has shown in (4) [30]:

$$a(x - x_2) + b(y - y_2) + c(z - z_2) = 0 \quad (4)$$

By expanding the plate equation as follows:

$$\begin{aligned} ax + by + cz &= ax_2 + by_2 + cz_2 \\ \xrightarrow{ax_2 + by_2 + cz_2 = w} &ax + by + cz = w \end{aligned} \quad (5)$$

We consider the road surface in xoy -plate and d as the height of RSU in the direction of the Z -axis, the intersection between the globe equation and plate equation is a circle [30].

Consider $O(x_0, y_0, z_0)$ as the center of the globe, and then a globe with the center of the RSU and its range is as follows:

$$(X - x_0)^2 + (Y - y_0)^2 + (Z - z_0)^2 = R^2 \quad (6)$$

Also, the plate equation is obtained as follows:

$$Z = d \quad (7)$$

With the intersection of (6) and (7) we have:

$$(X - x_0)^2 + (Y - y_0)^2 + (d - z_0)^2 = R^2 \quad (8)$$

In table-1 we can see the parameters that are used in equations.

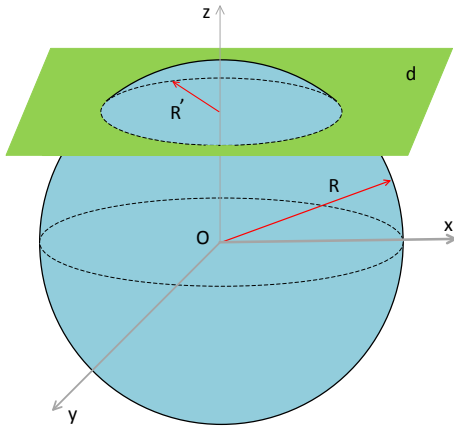


Fig. 3 A circle is obtained from the intersection of the plate and the globe

Table 1: parameters which are used

V_{ave}	Average vehicle speed
d'	Distance between center of the circle and vehicle crossing route
d	Height of RSU from road surface
R'	RSU range radius
$ M $	Distance to RSU range
T_v	Arriving time to RSU
C	Half of distance which RSU signal covers
T_m	Covering time by RSU

By expanding the equation (8) we have:

$$(X - x_0) + (Y - y_0) = R'^2 \quad (9)$$

Equation (9) is the circle of RSU coverage on the road, if $V(x_v, y_v)$ be the vehicle's location, we can calculate the distance between the vehicle and the center of the circle as follows:

$$|\vec{VO}| = \sqrt{(x_0 - x_v)^2 + (y_0 - y_v)^2} \quad (10)$$

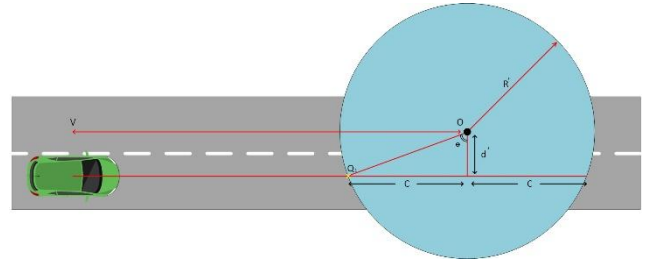


Fig. 4 Distance between the vehicle and RSU range

By subtracting R' (radius of RSU range) from $|\vec{VO}|$, the distance to RSU range is achieved and it is named as M .

$$|M| = \left| |\vec{VO}| - |R'| \right| \quad (11)$$

As it can be seen in Fig.4, and supposing that the vehicle moves in the X-axis direction, to calculate its arriving time to RSU range, M should be considered as well. We assume $Q_1(x_1, y_1)$ as the point of entering the vehicle to RSU range and T_v as its arriving time:

$$Q_1(x_1, y_1) = (x_v + |M|, y_v), T_v = \frac{|M|}{V_{ave}} \quad (12)$$

To calculate covering time by RSU signal, initially, d' should be considered:

$$|d'| = |y_0 - y_1| \quad (13)$$

With attention to $R \sin \theta = d'$ as well as $\tan \theta = \frac{C}{d'}$, we calculate θ and C . Therefore, $2C$ is the approximate distance in which the RSU signal covers the vehicle. T_m as

the covering time by RSU is the maximum time for the vehicle which can transmit packets via RSU.

$$T_m = \frac{2C}{V_{ave}} \quad (14)$$

4-2- IEEE 802.11p Capacity

IEEE 802.11p bandwidth is limited; therefore, all vehicles that need to transmit data should seek permission from the SDN controller. Suppose its bandwidth is 4Mbps, and four vehicles are connected to the RSU and they all are sending packets with the rate of 1Mbps. The SDN controller does not grant permission to the fifth vehicle due to the lack of available bandwidth. To do this, the SDN controller should constantly be aware of the network capacity to calculate the number of connected vehicles, as well as the number of their transmission rates. When a vehicle sends a request, the SDN controller at a duration time between request and arriving at RSU range calculates the volume of data that is transmitted. In the following equation, h_k is the volume of data that is sent by k th vehicle via RSU, and $F(i)$ is the sum of data that is sent by n vehicles.

$$F(i) = \sum_{k=1}^n h_k \quad (15)$$

Consider t_k as the connection time between k th vehicle and the RSU, therefore, $F(t)$ is the average of RSU connection time for n vehicle.

$$F(t) = \frac{1}{n} \sum_{k=1}^n t_k \quad (16)$$

IEEE 802.11p bandwidth capacity, which is called FG is determined by:

$$FG(i, t) = n \sum_{k=1}^n \frac{h_k}{t_k} \quad (17)$$

4-3- Communication Among Vehicles and SDN Controller

In this section, we express handoff decisions in the network. As we can see in the flowchart, initially the vehicle should send a request to the SDN controller. Afterward, the controller sends a message to the vehicle containing distance to RSU range, covering the time by RSU, and arriving time to RSU. Before entering the vehicle into RSU range, if IEEE 802.11p has available bandwidth, the SDN controller informs the vehicle and the handoff procedure from the cellular network to RSU will be done. Consequently, the vehicle transmits its packets via RSU and after exiting from RSU coverage, it switches back to the cellular network. The vehicle should send its RSU connection time as well as its packet quantity to the SDN controller.

SDN controller considers a threshold value for allocating bandwidth for the vehicles. If FG_{TH} be that threshold:

$$FG_{TH} = FG + 1 \quad (18)$$

Based on FG_{TH} , the SDN controller decides if the vehicle is allowed to connect to RSU or not. If FG_{TH} is less than

the IEEE 802.11p bandwidth, the SDN controller grants connection permit for the vehicle.

Receiving a request from a vehicle, the SDN controller makes many calculations which can be seen in Algorithm 1. Algorithm 2 shows how the SDN controller decides for a handoff between the cellular network and RSU.

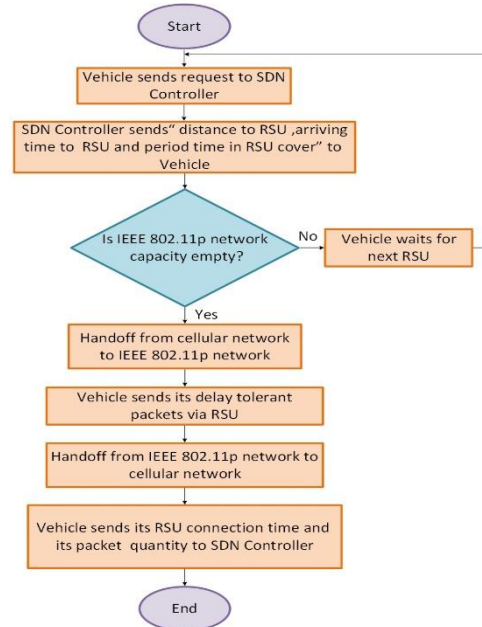


Fig. 5 The flowchart shows the handoff process from cellular network to RSU

Algorithm 1: Calculations before making handoff decisions

1. Send REQ to SDN for connection to RSU
2. Calculate RSU coverage: $(X - x_0) + (Y - y_0) = R^2$
3. Vehicle to RSU distance:
 $|\overline{VO}| = \sqrt{(x_0 - x_v)^2 + (y_0 - y_v)^2}$
4. Distance from vehicle to RSU signal: $|M| = \left| |\overline{VO}| - |R'| \right|$
5. Time which vehicle reaches to RSU signal: $T_v = \frac{|M|}{V_{ave}}$
6. Maximum vehicle remaining time in RSU coverage:
 $T_m = \frac{2C}{V_{ave}}$
7. SDN sends T_v, T_m and $|M|$ to vehicle
8. Return

Algorithm 2: Making decision for handoff from cellular network to RSU

1. SDN controller receives data from vehicles
2. Calculates $V(i), V(t)$ and $VC(i, t)$
3. Calculates FG_{TH} : $FG_{TH} = FG + 1$
4. if $FG_{TH} < IEEE802.11p$ Bandwidth
5. | Vehicle connect to RSU
6. else End

5- Simulation

As [31] and [32], we employed the NS-3 software and C++ program for simulation, and we investigate a VANET in a highway as our scenario using both LTE and IEEE 802.11p. The size of the area is considered 30*10000 square meters using 80 nodes with a speed of 20 m/s, also there were 20 nodes per kilometer, and followed them throughout the highway. We use two RSUs connected via a wired network. Each vehicle has a corresponding node to send and receive packets. LTE network has two ENodeB and is connected to the Internet. RSU range is 250 meters and all areas are covered by LTE. Vehicles generate two types of data: 1) DID which is transmitted with the rate of 64Kbps with 160 Byte packet sizes, 2) DTD which is transmitted with the rate of 1Mbps, and 1000Byte packet sizes, as a result, we considered a scenario with high congestion. Table.2 shows the simulation parameters. Furthermore, we executed the scenario 4 times and we consider the time of simulation 450 seconds, in which the last vehicle passes 10Km of the road.

Table 2: Simulation parameters

Parameter	Value
Road Size (m)	30*10000
Vehicle Speed (m/s)	20
Number of Vehicles (vehicle/Km)	20
RSU Range (m)	250
Number of RSUs	2
Packet Size (byte)	160/1000
Data Sending Rate	64 Kbps/ 1 Mbps
Cellular Network	LTE
RSU Bandwidth (Mbps)	6
Cellular Bandwidth (Mbps)	18
Simulation Time (s)	450
Number of Simulation	4

5-1- Simulation Result and Evaluation

For evaluating our scheme, we tried to evaluate all significant QoS parameters, IQDN is compared with OHD-SDN as well as Naive which are presented in [6]. Fig. 6 to Fig. 9 illustrate delay, jitter, packet loss, and throughput in three schemes respectively. It can be seen that our scheme has a significant decline in delay, jitter, and packet loss due to a decrease in traffic on LTE. Furthermore, our scheme has a higher throughput than the other two schemes. Fig.10 also shows the total data received at the destination which illustrates our scheme has more capacity rather than other schemes. After that, we compared DTD in the network. Fig. 12 shows packet

loss in the network, which decreased significantly, while Fig. 11 shows a significant improvement in throughput on the network. That is because both OHD-SDN and Naive transmit their packets via LTE at any time, and when a vehicle arrives in RSU range either transmit packets via RSU (Naive) or if the situation in IEEE 802.11p is not appropriate stay in LTE and transmit packets via the cellular network (OHD-SDN), so, many packets are lost in the network. In contrast, in IQDN vehicles buffer their packets to transmit those using high reliability and QoS guaranteed network.

Fig. 13 shows the volume of data received by nodes in the network. In our scheme destination nodes receives less data rather than other schemes, because the vehicles in the network have limited time for connecting to RSU so it is clear that lower data will be transmitted.

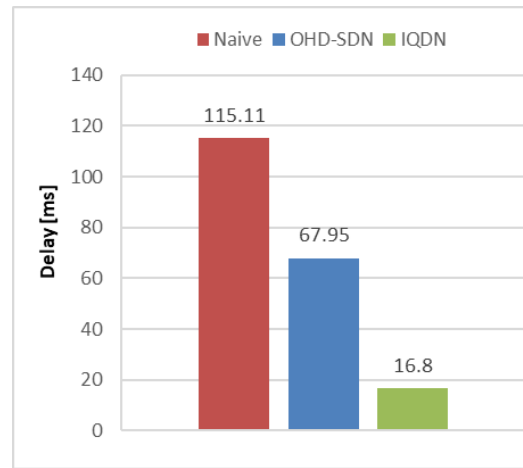


Fig. 6 Delay comparison in network

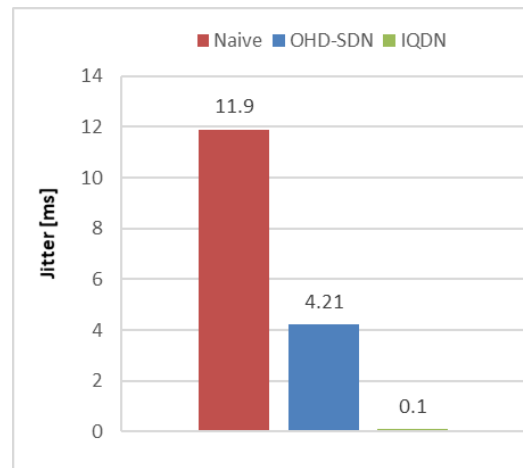


Fig. 7 Comparison of Jitter in network

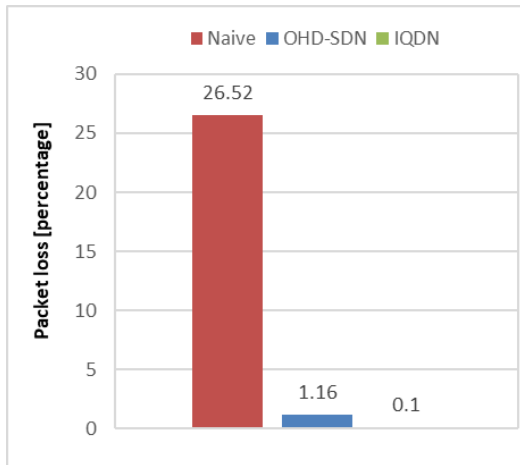


Fig. 8 Packet loss in network

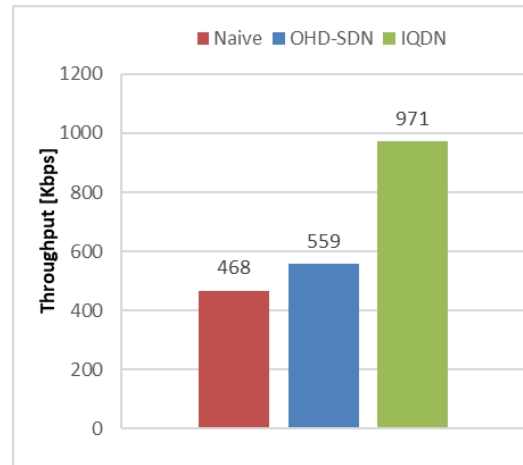


Fig. 11 Throughput in network

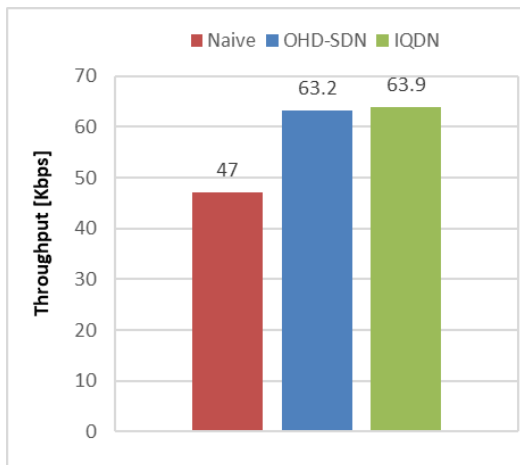


Fig. 9 Throughput in network

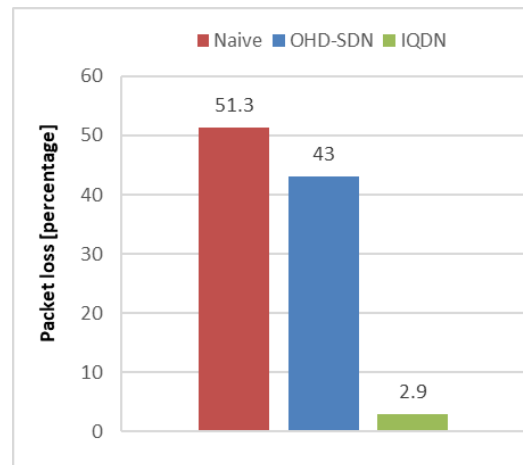


Fig. 12 Packet loss in network

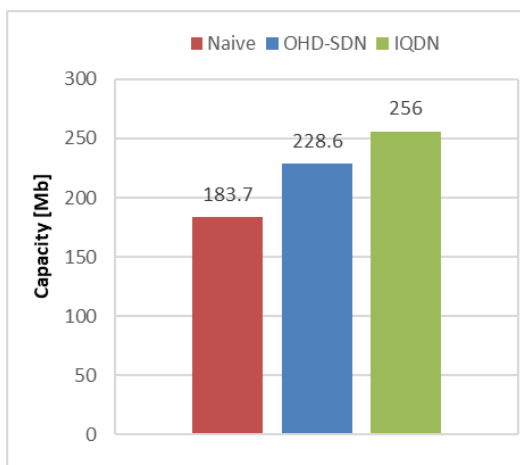


Fig. 10 Capacity in network

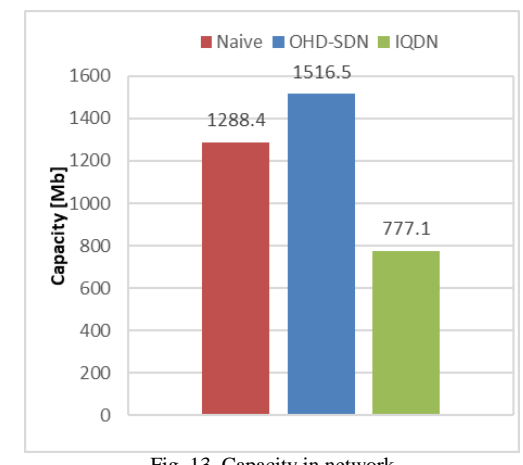


Fig. 13 Capacity in network

6- Conclusion

IQDN considered data into two categories, Delay-Intolerant Data (DID) as well as Delay-Tolerant Data (DTD) and treat them differently. It uses the SDN controller, LTE, and IEEE 802.11p to distribute traffic on the network. In this scheme, the vehicle sends DID just via LTE while DTD is sent through RSUs. For sending DTD via RSU, SDN evaluates capacity in IEEE 802.11p, then SDN decides to permit the vehicle to connect to RSU or not. IQDN with separate data in the network and using SDN for evaluating traffic in IEEE 802.11p can distribute traffic in the network efficiently. It also, decreases the traffic and improves the quality of service in the network. IQDN revolutionizes Jitter, Delay, Packet Loss, and Throughput in comparison with similar schemes. Using simple equations, IQDN grants permission for a vehicle to transmit its data to RSU or LTE. It showed higher protocol performance compared with two other schemes via simulation. For future work, the Epidemic protocol can be used for DTN so each vehicle sends its packet to another vehicle via V2V communication. It is expected to have high network capacity, with higher overhead in the network.

References

- [1] X. Wu, S. Subramanian, R. Guha, R. G. White, J. Li, K. W. Lu, A. Bucceri, and T. Zhang, "Vehicular Communications Using DSRC: Challenges, Enhancements, and Evolution," *IEEE Journal on Selected Areas in Communications*, VOL.31, pp. 399–408, 09 2013.
- [2] S. Al-Sultan, M. M. Al-Doori, A. H. Al-Bayatti, and H. Zedan, "A Comprehensive Survey on Vehicular Ad Hoc Network," *Journal of Network and Computer Applications*, VOL. 37, pp. 380–392, 01 2014.
- [3] P. Matzakos, J. Hrri, B. Villeforceix, and C. Bonnet, "An IPv6 Architecture for Cloud-to-Vehicle Smart Mobility Services over Heterogeneous Vehicular Networks," *Proceedings of 2014 International Conference on Connected Vehicles and Expo (ICCVE)*, pp. 767–772, Nov 2014.
- [4] N. Cheng, N. Lu, N. Zhang, X. S. Shen, and J. W. Mark, "Opportunistic WiFi Offloading in Vehicular Environment: A Queueing Analysis," *Proceedings of 2014 IEEE Global Communications Conference*, pp. 211–216, Dec 2014.
- [5] K. Lee, J. Lee, Y. Yi, I. Rhee, and S. Chong, "Mobile Data Offloading: How Much Can WiFi Deliver?" *IEEE/ACM Transactions on Networking*, VOL. 21, pp. 536–550, 04 2013.
- [6] S. Al-Sultan, M. M. Al-Doori, A. H. Al-Bayatti, H. Zedan, "Vehicle-to-Infrastructure (V2I) Offloading from Cellular Network to 802.11p Wi-Fi Network based on the Software-Defined Network (SDN) Architecture," *Vehicular communications*, VOL. 9, pp. 288–300, 07 2017.
- [7] D. Kreutz, F. M. V. Ramos, P. E. Verssimo, C. E. Rothenberg, S. Azodolmolky, and S. Uhlig, "Software-Defined Networking: A Comprehensive Survey," *Proceedings of the IEEE*, VOL. 103, NO. 1, pp. 14–76, Jan 2015.
- [8] J. Pan, I. S. Popa, and C. Borcea, "DIVERT: A Distributed Vehicular Traffic Re-Routing System for Congestion Avoidance," *IEEE Transactions on Mobile Computing*, VOL. 60, NO. 1, pp. 58–72, Jan. 1 2017.
- [9] N. Nguyen, M. Arifuzzaman, and T. Sato, "A Novel WLAN Roaming Decision and Selection Scheme for Mobile Data Offloading," *Journal of Electrical and Computer Engineering*, VOL. 2015, Article ID 324936, pp. 1–15, 2015.
- [10] A. Aijaz, H. Aghvami, and M. Amani, "A Survey on Mobile Data Offloading: Technical and Business Perspectives," *IEEE Wireless Communications*, VOL. 20, NO. 2, pp. 104–112, April 2013.
- [11] G. e. m. Zhioua, H. Labiod, N. Tabbane, and S. Tabbane, "A Traffic QoS Aware Approach for Cellular Infrastructure Offloading using VANETs," *Proceedings of the 22nd IEEE International Symposium of Quality of Service (IWQoS)*, pp. 278–283, May 2014.
- [12] G. E. M. Zhioua, H. Labiod, N. Tabbane, and S. Tabbane, "Cellular Content Download through A Vehicular Network: I2V Link Estimation," *Proceedings of the 81st IEEE Vehicular Technology Conference (VTC Spring)*, pp. 1–6, May 2015.
- [13] Z. He, D. Zhang, and J. Liang, "Cost-Efficient Sensory Data Transmission in Heterogeneous Software-Defined Vehicular Networks," *IEEE Sensors Journal*, VOL. 16, NO. 20, pp. 7342–7354, 10 2016.
- [14] D. Suh, H. Ko, and S. Pack, "Efficiency Analysis of WiFi Offloading Techniques," *IEEE Transactions on Vehicular Technology*, VOL. 65, NO. 5, pp. 3813–3817, 05 2016.
- [15] S. M. Park, S. Ju, and J. Lee, "Efficient Routing for Traffic Offloading in Software-Defined Network," *Procedia Computer Science*, VOL. 34, pp. 674–679, 2014.
- [16] J. Chen, B. Liu, L. Gui, F. Sun, and H. Zhou, "Engineering Link Utilization in Cellular Offloading Oriented VANETs," *Proceedings of 2015 IEEE Global Communications Conference (GLOBECOM)*, pp. 1–6, Dec 2015.
- [17] P. Salvo, I. Turcanu, F. Cuomo, A. Baiocchi, and I. Rubin, "Heterogeneous Cellular and DSRC Networking for Floating Car Data Collection in Urban Areas," *Vehicular Communications*, 2016.
- [18] A. Mabrouk, A. Kobbane, E. Sabir, J. Ben-Othman, and M. El Koutbi, "Meeting Always-Best-Connected Paradigm in Heterogeneous Vehicular Networks: A Graph Theory and A Signaling Game Analysis," *Vehicular Communications*, VOL. 5, pp. 1–8, 2016.
- [19] J. F. Bravo-Torres, J. V. Sains-Vzquez, M. Lopez-Nores, Y. Blanco-Fernandez, and J. J. Pazos-Arias, "Mobile Data Offloading in Urban VANETs on Top of A Virtualization Layer," *Proceedings of 2015 International Wireless Communications and Mobile Computing Conference (IWCMC)*, pp. 291–296, Aug 2015.
- [20] S. Wang, T. Lei, L. Zhang, C.-H. Hsu, and F. Yang, "Offloading Mobile Data Traffic for QoS-Aware Service Provision in Vehicular Cyber-Physical Systems," *Future Generation Computer Systems*, VOL. 61, pp. 118–127, 08 2016.
- [21] H. Park, Y. Jin, J. Yoon, and Y. Yi, "On The Economic Effects of User-Oriented Delayed Wi-Fi Offloading," *IEEE Transactions on Wireless Communications*, VOL. 15, NO. 4, pp. 2684–2697, 04 2016.

- [22] Y. He, M. Chen, B. Ge, and M. Guizani, "On WiFi Offloading in Heterogeneous Networks: Various Incentives and Trade-Off Strategies," *IEEE Communications Surveys Tutorials*, VOL. 18, NO. 4, pp. 2345–2385, Fourthquarter 2016.
- [23] N. Cheng, N. Lu, N. Zhang, X. Zhang, X. S. Shen, and J. W. Mark, "Opportunistic WiFi Offloading in Vehicular Environment: A Game-Theory Approach," *IEEE Transactions on Intelligent Transportation Systems*, VOL. 17, NO. 7, pp. 1944–1955, 07 2016.
- [24] J. Cho, B. Nguyen, A. Banerjee, R. Ricci, J. Van der Merwe, and K. Webb, "SMORE: Software-Defined Networking Mobile Offloading Architecture," *Proceedings of the 4th Workshop on All Things Cellular: Operations, Applications, and Challenges, AllThingsCellular '14*, (New York, NY, USA), pp. 21–26, ACM, 2014.
- [25] A. U. Khan and B. K. Ratha, "Time Series Prediction QoS Routing in Software-Defined Vehicular Ad-Hoc Network," *Proceedings of 2015 International Conference on Man and Machine Interfacing (MAMI)*, pp. 1–6, Dec 2015.
- [26] Y. Liu, X. Chen, C. Chen, and X. Guan, "Traffic Big Data Analysis Supporting Vehicular Network Access Recommendation," *Proceedings of 2016 IEEE International Conference on Communications (ICC)*, pp. 1–6, May 2016.
- [27] G. e. m. Zhioua, H. Labiod, N. Tabbane, and S. Tabbane, "VANET Inherent Capacity for Offloading Wireless Cellular Infrastructure: An Analytical Study," *Proceedings of the 6th International Conference on New Technologies, Mobility and Security (NTMS)*, pp. 1–5, March 2014.
- [28] A. Bazzi, B. M. Masini, A. Zanella, and G. Pasolini, "Virtual Road Side Units for Geo-Routing in VANETs," *Proceedings of 2014 International Conference on Connected Vehicles and Expo (ICCVE)*, pp. 234–239, Nov 2014.
- [29] G. el Mouna Zhioua, J. Zhang, H. Labiod, N. Tabbane, and S. Tabbane, "VOPP: A VANET Offloading Potential Prediction Model," *Proceedings of 2014 IEEE Wireless Communications and Networking Conference (WCNC)*, pp. 2408–2413, April 2014.
- [30] G. Thomas, R. Finney. *Calculus and Analytic Geometric*: Addison-Wesley, 1988.
- [31] R. Fernandes and M. Ferreira, "Scalable VANET Simulations with NS-3," *Proceedings of the 75th IEEE Vehicular Technology Conference (VTC Spring)*, pp. 1–5, May 2012.
- [32] H. Arbabi and M.C. Weigle, "HIGHWAY MOBILITY AND VEHICULAR AD-HOC NETWORKS IN NS-3," *Proceedings of the 2010 Winter Simulation Conference*, pp. 5-8 Dec. 2010.

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