LTE SCHEDULER ALGORITHMS FOR VANET TRAFFIC IN SMART CITY

Khadija Raissi and Bechir Ben Gouissem

University of Tunis El Manar, Communications Systems Laboratory Sys'Com, National Engineering School of Tunis, BP 37, Le Belvedere1002, Tunis, Tunisia

ABSTRACT

A new concept such as smart city was introduced in the last years where the Intelligent Transportation system (ITS) plays a critical role to provide road safety and manage Vehicular Ad Hoc Networks (VANETs) traffic. Nevertheless, VANETs have significant constraints like nodes high mobility, intermittent connectivity, variable network density and heterogeneity. However, the different types of traffic, the different Quality of Service requirements, the need to exchange mobile data, multi-services and data diversity leads mainly to load and time constraints in this specific and stringent type of networks. The main characteristic of this kind of networks is the very changing topology that poses supplementary constraints and makes achieving QoS constraints a very challenging task. In VANET network the vehicle generated traffic will be transferred to the data center from road side unit to the base station by using Long Term Evolution (LTE) in an urban area. Despite LTE has a larger system capacity and it provides a higher transmission speed, the network performance is affected by the implemented scheduling algorithm. In this context, we study the efficiency of LTE scheduler algorithms such as Proportional Fairness, Round Robin, Priority Set Scheduler, Maximum Throughput Scheduler and Throughput to Average Scheduler and Blind Equal Throughput mainly at the road side unit using Network Simulator 3(NS3) to determinate the most suitable scheduler for VANET traffic. Results demonstrate that the round robin algorithm is more effective for volumetric VANET traffic in terms of throughput, delay, packet loss rate and fairness.

KEYWORDS

VANET, Schedulers, Smart city, VMASC, LTE, NS3

1. INTRODUCTION

Today, the number of vehicles increases rapidly which causes an increase in the road traffic congestion and accidents. Indeed, with the rapid development of wireless technologies, 25 billion of “objects” will be used as connected things to achieve a safer and a more comfortable experience. In other words, different types of traffic can be exchanged easily between vehicles and infrastructures using heterogeneous emerging wireless technologies [1] such as DSRC /WAVE, 3G cellular systems, long term evolution (LTE), LTE Advanced, IEEE 802.11p, and IEEE 802.16e to make pertinent and accurate decision. However, to support the different Quality of Service (QoS) requirements and the increase of mobile data usage, the wireless resource must be used in the best way to serve multiple users and increase the data rate.

As well-known, Vehicular Ad hoc Networks (VANETS) [2] is different from other kinds of networks. Moreover, the high mobility of nodes makes the links between the vehicles too dynamic and unstable during the transmission. This explains the hugely variant topology of vehicular networks related to the high speed of cars. Also the mobility of vehicles is related to the behaviour of drivers and their responses to different and complex encountered obstacles or

DOI: 10.5121/ijcnc.2020.12104

situations like accidents and traffic jams. In some emergency situations like a car crash, messages should be transferred and received on time to save a man's life and to be careful on the road. Diverse routing protocols have been designed to improve the efficiency of transport systems, to offer the driver the required information and the best visibility of the road scene.

So these protocols are designed to provide optimal paths with low cost between network nodes and to deal with the highly dynamic topology. Furthermore, VANET environment includes two types of communication such as Vehicle-to-infrastructure (V2I) and Vehicle-to-vehicle (V2V) in which vehicles communicate with each other's and with Road Side Unit(RSU) to manage and control generated traffic. Therefore, VANET aims to offer an efficient wireless connection between mobile vehicles to increase the road safety and give traffic information.

In this paper, we evaluate LTE scheduling algorithm performance in VANET traffic context in an urban zone. Many publishing works studied VANET networks in a highway [3] and the other part of works studied mainly routing protocols for VANET networks in an urban zone. Furthermore, VANET traffic is very stringent traffic that imposes a specific treatment to optimize his transmission. For that, our study is focalized to evaluate the LTE scheduler algorithms focusing on the channel condition to assign resources blocks to User Equipment as medium range support. A new concept has recently appeared as smart cities [4-5] that include intelligent traffic management, where VANET is the most important area in the Intelligent Transportation System (ITS) [6]. There are several mobility models used in the simulations of vehicular networks[7]. In the case of our architecture VMASC routing protocol [8]is used for inter-vehicles communication utilizing realistic mobility traces of a Simulation of Urban Mobility (SUMO) [9] tool.

Gathered VANET traffic will be transferred to the base station using LTE technology as a medium range support. Mainly, at the road side scheduling algorithms are very important to serve multiple users and to manage different types of traffic. For this purpose, we study the efficiency of schedulers; Proportional Fairness(PF), Round Robin(RR), Priority Set Scheduler(PS), Maximum Throughput Scheduler (MT), Throughput to Average Scheduler (TTA) and Blind Equal Throughput (BET) to determinate the most suitable scheduling algorithm to support VANET traffic.

The rest of the paper is organized as follows; we discuss related work in section II and then we give an overview of the Simulation Network Architecture in section III. Section IV includes scheduling algorithms in NS-3 whereas Routing in VANET is described, in section V. Simulation Results of VANET Traffic is analyzed and discussed in section VI and finally, we conclude the paper.

2. RELATED WORK

Our research aims to define a smart city network architecture precisely its application using VANET networks. In this optic, we engaged a study of VANET network in an urban zone where the major parts of papers studied VANET networks in the highway. To the best of our knowledge, there is no paper studied the performance of LTE schedulers in the context of VANET traffic in the urban zone despite his specific patterns and stringent applications constraints.

For example, Mahesha et .al [10] studied the performance of LTE scheduling algorithms (RR, PF, MT, BET) in vehicular and pedestrian mobility during handover. In this work, scheduling algorithms are evaluated in a multi cell network in a case of delay and throughput. Simulation results demonstrate that the RR algorithm achieves the least delay and higher system throughput than PF, MT, and BET.

In[11]various scheduling algorithms such as PF, RR, PSS (Priority Set Scheduler) and CQA(Channel-QoS Aware) are simulate during real-time application. PF and PSS provide similar results. However, the CQA scheduler performs better than other schedulers considering packet loss ratio, fairness index, delay, and throughput.

Marinčić et .al [12]used Vienna LTE-A System Level Simulator to evaluate the following schedulers in LTE systems: Best CQI, Round Robin, Proportional Fair, MaxMin and Resource Fair. Results show that the highest peak throughput and average spectral efficiency are gained by the Best CQI scheduler. Whereas the MaxMin algorithm achieves higher fairness and edge throughput of the user equipment.

Authors in [13] implemented a new scheduling algorithm named NewQueue, which is based on the existing DropTail Algorithm to reduce jitter and delay and to increase throughput. Then they evaluate these two schedulers by considering different metrics such as jitter, delay and throughput. From the simulation results, the proposed scheduler performs better than the DropTail Algorithm by considering the previous metrics.

3. Scheduling Algorithms in NS3

In this section, we present a state of the art of scheduling algorithms[14-16] proposed for Long Term Evolution (LTE) implemented in ns3 simulator.

Proportional Fairness(PF): The PF algorithm is used in the case of non-real-time traffic without considering the packet delay. During the resource allocation process, it schedules firstly user which has a good channel quality to increase the overall throughput of the system. The goal of this algorithm is to balance data rate fairness and throughput among all the user equipments (UEs). In this algorithm, the users with the relative best channel condition will be served. But the probability for scheduling users far from the responsible node for managing resource scheduling is low and it can cause starvation.

Round Robin(RR): RR scheduling is a classic strategy for allocating radio resources, it divides all the available resources to active traffic flows by following the same quantum of time without any priority. Therefore, RR is simple and easy to implement; its purpose is to treat the fairness problem between users to offer great fairness results without considering channel conditions into account. However, the algorithm ignores the reported instantaneous signal to noise ratio(SNR) values when performing the allocation process. The major advantage of this algorithm is to achieve a good spectral efficiency since it allocates resources to the node at the edge of the cell. Nevertheless, for different types of traffic (real-time traffic, voice over IP, video, non-real time traffic) RR can degrade system performance significantly.

Maximum Throughput Scheduler (MT): This scheduler takes into account the impact of channel condition to assign users with good channel quality. Therefore, it maximizes system throughput without considering fairness. It assigns each resource block (RB) to the user that can achieve the maximum data rate in the current transmission time interval (TTI). However, users with poor CQI values may suffer from starvation, low throughput and a large packet delay. MT cannot guarantee QoS because it is unable to support mixed type traffic flows which can cause growing in packet loss ratio when the cell edge nodes not served.

Priority Set Scheduler(PS): PS in NS3 works by using the time domain (TD) and frequency domain (FD) packet scheduler as one scheduler to provide fairness to the UEs. The aim of TD scheduler is to use priority to serve UEs contrary to PF and RR algorithms by selecting the UE with non empty radio link control RLC buffer. However, the FD scheduler defines the specified target bit rate (TBR) to control the fairness among the UE concerning a QoS requirement.

Throughput to Average Scheduler (TTA): TTA is a QoS aware scheduler implemented only in frequency domain (FD), unlike another algorithm due to the achievable rate of the particular resource block group (RBG). Thus, it tries to divide the available resources using the priority metrics to perform averaging of resources between all users. The rationale behind this algorithm is to guarantee the trade-off between efficiency and fairness since it is a combination of MT and PF.

Blind Equal Throughput (BET): BET scheduler is channel unaware, unlike MT and TTA schedulers. It uses CQI in the scheduling process and it does not consider the channel condition for resource allocation. This algorithm aims to give an equal chance for all users, as well as fair resource allocation to achieve similar data rates in every TTI. Unlike MT, BET tries to provide equal throughput among all the users associated with the same eNodeB. It allocates more resources to the users with lower average throughput in the past compared to the users with higher average throughput. This implies that BET achieves throughput fairness with a significant loss of the overall resource utilization. Also it performs similarly to the RR scheduler when users meet similar CQI.

4. NETWORK ARCHITECTURE

VANET architecture includes mobile nodes and roadside unit entities (RSU) attached to infrastructure to network generated traffic to the data center. Hence, IEEE 802.11p is integrated as radio interfaces in vehicles and Long Term Evolution (LTE) technology is used as a link between RSU and base station (eNodeB) to increase communication range.

The explosion of different types of traffic such as Internet, Email, multimedia with several Quality of Service requirements leads to the development of LTE introduced by the Third Generation Partnership Project (3GPP)[17]. Nevertheless, LTE is a flat architecture that responds to a rapid increase in traffic to guarantee a greater capacity and higher data rates in the networks. Contrary to the existing third-generation architecture, the LTE network has a reduced number of equipment to minimize delay and increase system performance.

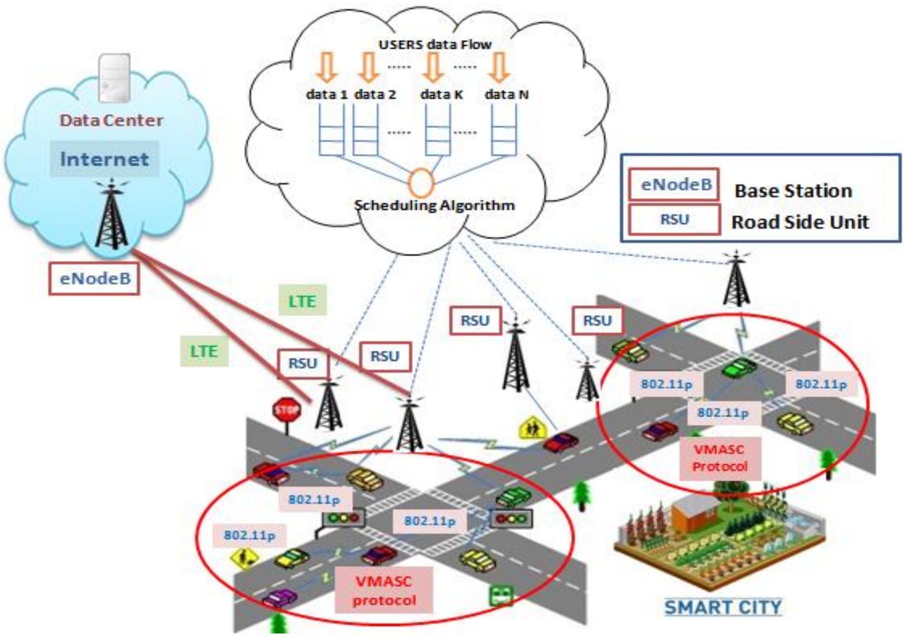

Figure 1. Network Architecture

As an example, we take an urban VANETs as shown in Figure.1 which presents the network architecture of a smart city based on LTE technology used in the interaction between RSU and eNodeB which is responsible for transmitting the network traffic to the data center. This network consists of a great number of mobile nodes communicating with each other's and with stationary nodes named RSU by the use of short range wireless technologies 802.11p.

Hence, we use the VMASC protocol for inter vehicle communication and LTE for transferring the gathered VANET traffic from RSU to the eNodeB in an urban scenario. Thereby, different scheduling algorithms are used in the specific case of VANET traffic to allocate the available radio resources to connect nodes.

5. ROUTING IN VANET

Several routing algorithms play a critically key role in improving the road safety part of Vehicular Ad Hoc Networks. Thus, the high speed of vehicles, the large volume of traffic, the sporadic connectivity and the dynamic topology make the management of VANET network very difficult. From these vulnerabilities, many routing protocols [18] have been proposed to support VANET traffic characteristics.

These protocols try to support changes in the dynamic topology, computation resources limitation, number of links, the PDR, the throughput and the bandwidth. With the emergence of this latter, many researchers have developed several routing protocols. There are several criteria for designing and classifying routing protocols in ad hoc networks: How is routing information exchanged? When and how are routes computed?

Researchers have proposed various routing protocols to facilitate network management such as position based routing protocols, proactive protocols, topology based routing protocols, cluster based routing protocols...

The ad hoc vehicle network suffers from discontinuous connectivity and limited capacity. The VANET cluster protocol provides solutions to these problems. This approach is well suited to the VANET due to the dynamics of vehicular traffic leading to the nodes groups formation in intersections or convoys on a highway. Therefore, when the network size becomes larger and the mobility is high, its management becomes more difficult.

In our work [19], we compared different routing schemes namely AODV(Ad hoc On-demand Distance Vector Routing), DSR(Dynamic Source Routing), OLSR(Optimized Link State Routing), DSDV(Destination Sequenced Distance Vector) and VMASC in terms of packet delivery ratio and throughput. Results shows that VMASC is more advantageous than others protocols in different volumetric traffic scenarios especially in a suburban section of Ariana governorate, Tunisia. This is because VMASC decreases the number of cluster head changes and increases the multi-hop clusters stability in wireless networks. It calculates the least mobility between the current node and their neighbours. It uses the notion of aggregated mobility to choose Cluster Heads(CHs) that select other CHs to forward packets. All nodes in a cluster can communicate with the CHs in a number of hops. By creating clusters of vehicles, the VMASC can maintain the link stability and ensure rapid data transmission, so we can control management functions and resource sharing in VANETs which are highly dynamic.

Thus, we are going to use the VMASC protocol for inter vehicle communication and LTE for transferring the traffic from RSU to the eNodeB in order to determinate the most suitable scheduler for VANET traffic in an urban scenario.

6. RESULTS OF VANET TRAFFIC AND DISCUSSION

In our simulation network architecture, N vehicles communicate with each other's and with the infrastructure in an area of 3000 x 4000 m in a suburban section of Ariana, Tunisia. We use the Simulation of Urban Mobility (SUMO) tool to simulate realistic mobility traces to compare the performance of scheduling algorithms with various speed and vehicle density effects. Hence, we use a routing protocol such as VMASC protocol and a short range wireless technology 802.11p between vehicles and between vehicles and RSU. Also, LTE technology is used in the interaction between RSU and eNodeB to transmit gathered network traffic to the data center.

6.1. Parameter Settings

In this part, we study the performance of scheduling algorithms such as RR, PF, PS, TTA, MT and BET scheduler in terms of throughput, delay, packet loss ratio and fairness index in a function of the number of vehicles. Throughput is denoted as the sum of successful packets sent from the base station to the nodes however packet loss ratio is caused by the transmission errors. Delay is the total time that is consumed by packets to be transmitted from source to destination. In scheduling algorithm, Fairness index is defined as a performance metric to allocate fairly the system resource between nodes. These parameters are critical factors in LTE scheduling algorithms performance. Table I lists the parameters used in the simulation scenario.

Table 1. Simulation Parameters.

Parameters	**Values**
Number of vehicles	10, 20, 40, 60, 80, 100, 150, 200
Vehicles speed	10 km/h, 50 km/h, 100 km/h
Topology size	3000 x 4000 m
Simulation time	1000 s
Interval between two transmitted packets	0,5 s
Routing Protocol	VMASC
Data packet size	1024 bytes
MAC protocols	IEEE 802.11p
Scheduler	RR, PF, PS, TTA, MT, BET

In a vehicular environment, nodes use VMASC protocol to communicate the VANET traffic in an area of 3000 x 4000 m. The comparison is performed by considering a fixed packet size of 1024 bytes since it has a considerable impact on packet transmission. Also, we take into account the impact of various speed set to 10 km/h, 50 km/h or 100 km/h to analyze packet loss ratio.

6.2. Simulation Results and Analysis

In our study, we aim to evaluate QoS metrics in the context of ITS application for smart-city. To this purpose, we choose to implement the architecture network in NS3 coupled with SUMO “Simulation of Urban Mobility”. Different scenarios in the urban zone are proposed to evaluate various QoS metrics like throughput, latency time, reliability and fairness for different vehicle speed and different vehicles number.

The first simulation scenario is dedicated to evaluate throughput metric for different vehicles number and average speed of 50km/h and different LTE scheduling algorithms.

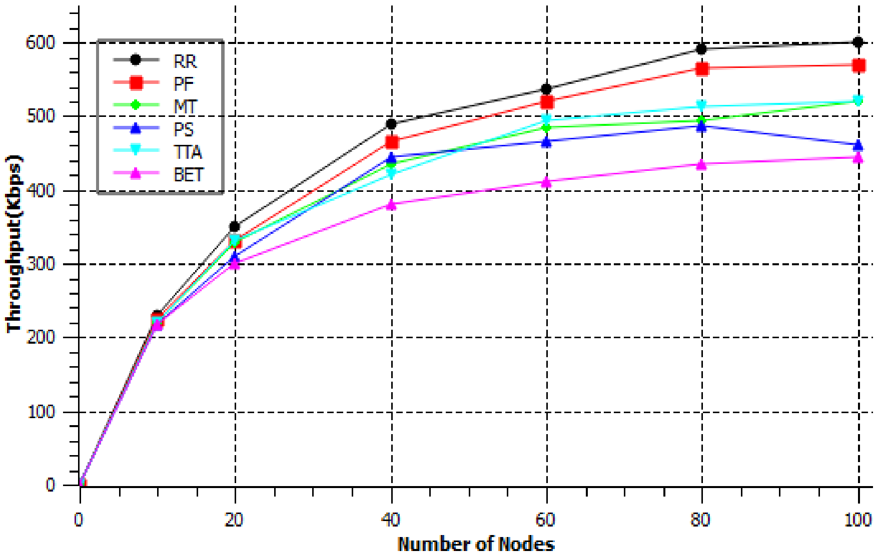

Figure 2. VANET traffic throughput performance of various Scheduling Algorithms

In Figure. 2 we notice that schedulers present the same behaviour until 10 nodes when vehicles move at a speed of 50 km/h. The curve of the RR scheduler went up to reach the higher throughput value compared to other algorithms by increasing nodes number to reach 600kbps. Since the algorithm ignores the channel condition values of the node when performing the allocation process.

However, PF throughput is less than RR and better than others since the average channel condition over time is low. Then it aims to provide all users at least a minimal level of service while at the same time it tries to maximize total throughput to balance between throughput and fairness among all the users. On the other hand, the BET scheduler has shown the lowest in throughput in the fact it allocates more resources to the users with lower average throughput in the past compared to the users with higher average throughput. These results permit us to conclude that the RR scheduler gives the best throughput against other simulated schedulers.
In the second simulation scenario, we studied the delay parameter for different vehicles number and 50km/h average speed.

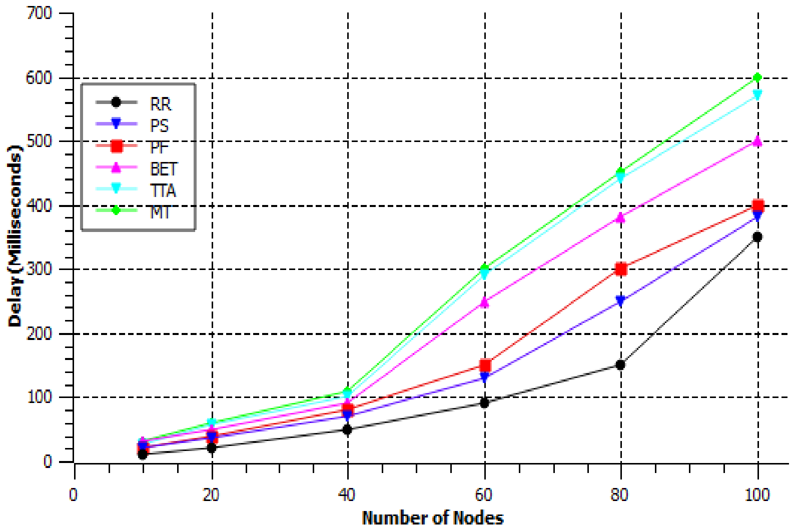

Figure 3. VANET traffic Delay of various Scheduling Algorithms

From the plots in Figure.3, it is observed that delay for VANET traffic in RR scheduler achieves the least delay compared to the rest of schedulers due to the channel-unaware scheduling feature. This means that the real time traffic can be transmitted in a short amount of time. MT, TTA and BET schedulers have the highest delay (600 milliseconds) when the number of the vehicles equal to 100 nodes. The impacts of varying packet loss ratio (PLR) defines the total of number for packet loss during the transmission of the packets. After 80 nodes per VMASC cluster delay increases rapidly mainly for RR scheduler so we can conclude that optimal cluster size will be 80 nodes per cluster to achieve the trade-off between cluster size and transmission delay.

The third scenario presented in figure 4 (a-b-c) permits to study the PLR "packet loss ratio" for different node number and different scheduler in varying vehicle speed from 10km/h to 100km/h. these plots demonstrate that the PLR parameter is very sensitive to node speed.

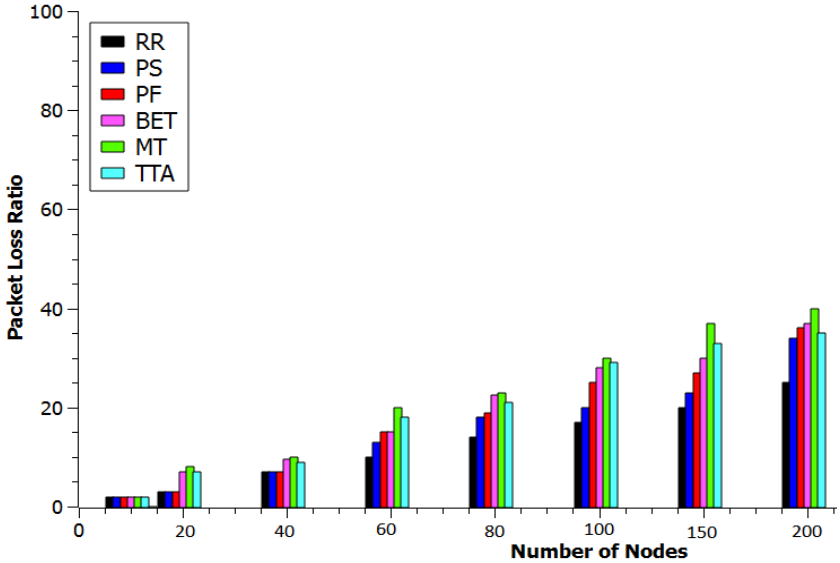

Figure 4(a). Packet Loss Ratio Vs Number of Nodes, 10 km/h

In the case where the nodes speed equal to 10 km/h, Figure. 4 (a), RR scheduler has less PLR because it provides an equal share of packet transmission time to each user to meet the fairness. Furthermore, PS scheduler has a significant loss rate than RR since it controls fairness by defining a specified target bit rate (TBR). Whereas the MT algorithm has the highest PLR value for providing maximum throughput without considering fairness among nodes and without taking into account the impact of channel condition.

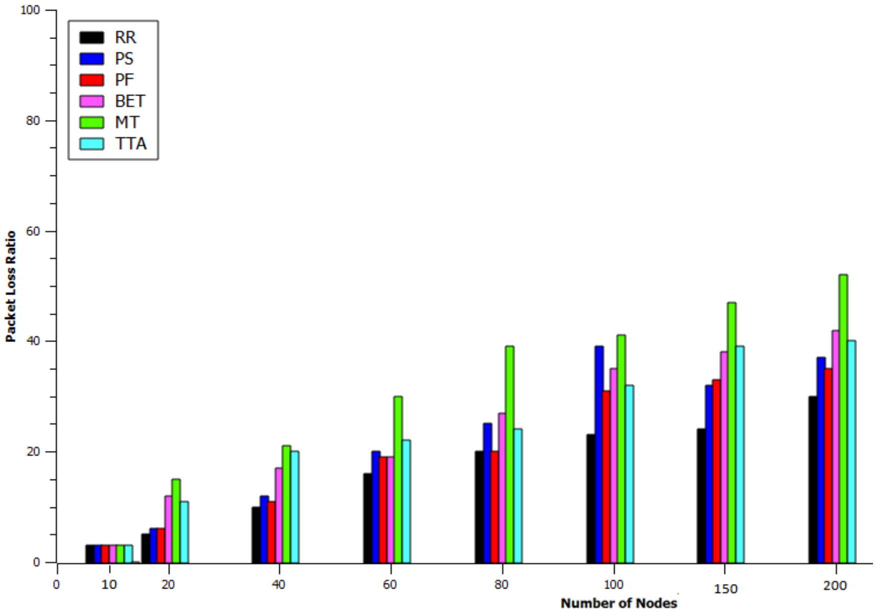

Figure 4(b). Packet Loss Ratio Vs Number of Nodes, 50 km/h

In Figure. 4 (b) all schedulers have an increased PLR when vehicle speed is set to 50 km/h. The difference between these schedulers starts to be shown when the number of nodes exceeds 10. Even for 40 nodes, RR drops about 10%of the packets regardless of the good spectral efficiency while this value exceeds 20% for the remaining examined schedulers. We note a significant loss of traffic in the case of the scheduler MT when executing more than 60 nodes. This is because the nodes with poor CQI values may suffer from starvation which can cause growing in packet loss ratio when the cell edge nodes not served.

The figure below represents the PLR when speed is set to 100 km/h to evaluate system performance at high speed.

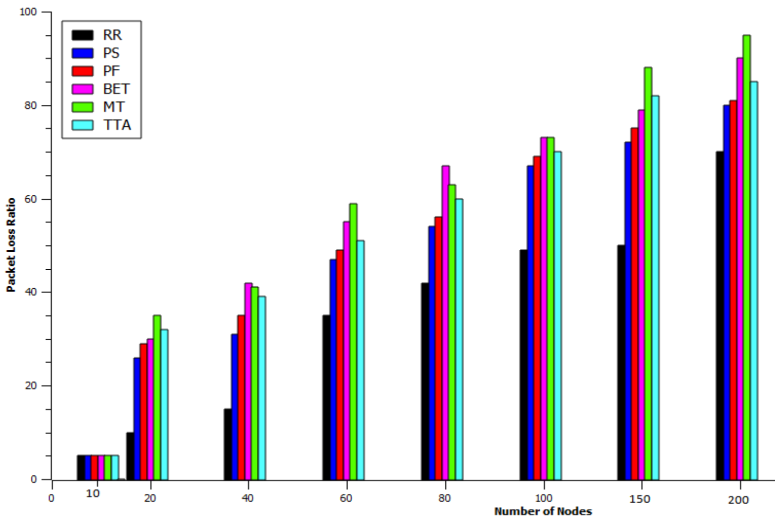

Figure 4(c). Packet Loss Ratio Vs Number of Nodes, 100 km/h

Therefore, the PLR for MT scheduler reaches 95 %, nearly 90% for the BET scheduler and more than 80 % of the packets for PS, PF and TTA when the number of nodes is set to 200. Whereas the RR is lower for all schedulers since it allocates resources to the node at the edge of the cell. Thus the high speed of nodes leads to degrade the system performance for all schedulers.

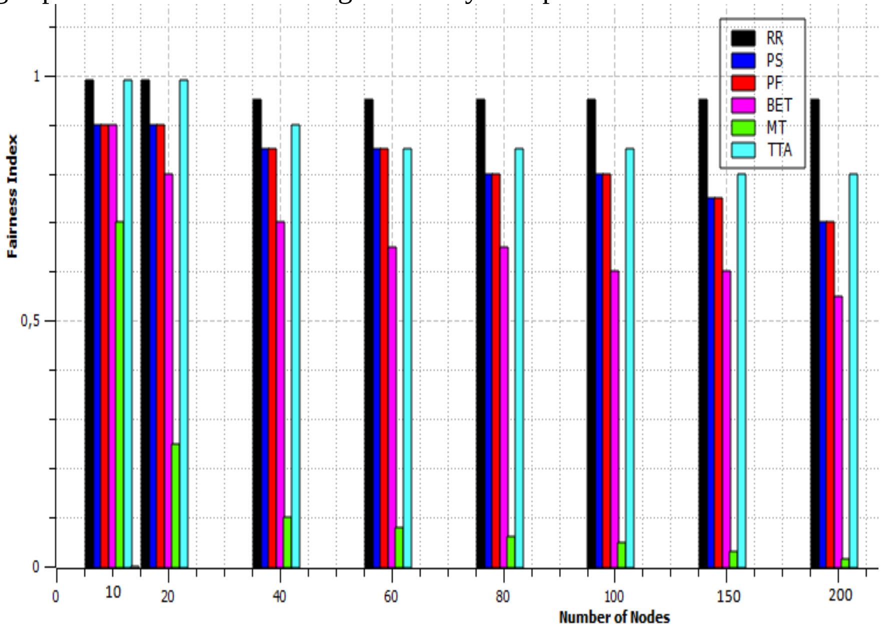

Figure 5. Fairness Index Vs Number of Nodes

The last scenario in our study is to evaluate the performance of several schedulers in terms of fairness index. The fairness index is a good parameter to judge the performance of the schedulers. It consists of resources sharing between nodes. The Histogram in Figure 5 demonstrates that the Round Robin scheduler achieves a significant fairness index value against number of nodes. Because it treats the fairness problem between users to offer great fairness results without considering channel conditions into account. Although the TTA scheduler tries to guarantee the trade-off between efficiency and fairness that's why it has a good fairness index value. The unfair resource allocation among PF, PS and BET is related to redundant allocation and resources starvation. Whereas the MT algorithm achieves the least value since it favours nodes close to the road side unit and it wastes a lot of resources.

The results of these simulations showed that the RR algorithm performs better than other algorithms such as MT, TTA, PF, PS and BET in terms of throughput, delays, packet loss ratio and fairness in an urban scenario.

7. Conclusion and Future Work

In this paper, we present performance evaluation results for LTE scheduler aiming to determinate the best schedulers that can manage VANET traffic.

In the network architecture, we use LTE technology as a medium-range support solution between RSU and eNodeB and VMASC routing protocol for inter vehicle communication and 802.11p as a MAC protocol. Then gathered VANET traffic will be transferred to the data center using LTE. Mainly, at the road side unit, we have evaluated the performance of scheduling algorithms such as RR, PF, PS, TTA, MT and BET to select the most suitable scheduler to serve multiple users and to manage different types of traffic. We conclude after scheduling algorithm evaluation that the round robin algorithm is the most suitable scheduler in terms of throughput, delay, packet loss rate and fairness. Finally, we achieve that the use of the VMASC protocol for inter-vehicle communication and round robin LTE scheduler at the RSU gives a good result in the overall wireless network scenarios.

As VANET network is multi-services with multi-type traffic, we think that a specific scheduler that can manage this traffic diversity and offer scheduling service that takes into account specific constraints of every traffic type can be a better solution for this kind of networks.

Hence in the future work, we will explore the development of a specifically tailored scheduling algorithm that manages very particular VANET traffic. we will develop a new scheduling algorithm that includes channel conditions for resource allocation, different level of fairness and speed of nodes to avoid starvation and to decrease packet loss ratio to optimize several performance metrics for VANET traffic.

REFERENCES

[1] STADLER, Christina, FLAMM, Xenia, GRUBER, Thomas, et al. Communication Characteristics of VANETs. 5th GI/ITG KuVSFachgespräch Inter-Vehicle Communication, 2017, p. 33.
[2] James R. Milne, Gregory Peter Carlsson, Frederick J. Zustak, “Vehicle Ad Hoc Network (VANET)”, related pending U.S. Appl. No. 15/149,562, filed May 9, 2016.
[3] Maratha, Barakat Pravin, Sheltami, Tarek R., et Shakshuki, ElhaPerformance Evaluation of Topology based Routing Protocols VANET Highway Scenario. International Journal of Distr Systems and Technologies (IJDST), 2017, vol. 8, no 1, p. 34-45.
[4] MENOUAR, Hamid, GUVENC, Ismail, AKKAYA, Kemal, et al. UAV-Enabled Intelligent Transportation Systems for the Smart City: Applications and Challenges. IEEE Communications Magazine, 2017, vol. 55, no 3, p. 22-28.
[5] SOLANO, Sandra Escamilla, CASADO, Paola Plaza, et UREBA, Sandra Flores. Smart Cities and Sustainable Development. A Case Study. In : Sustainable Smart Cities. Springer International Publishing, 2017. p. 65-77.
[6] KHATOUN, Rida et ZEADALLY, Sherali. Smart cities: concepts, architectures, research opportunities. Communications of the ACM, 2016, vol. 59, no 8, p. 46-57.
[7] Bahidja Boukenadil and Mohammed Feham: Importance of Realistic Mobility Models for Vanet Network Simulation. International Journal of Computer Networks & Communications (IJCNC), Vol.6, No.5, September 2014, p.175-182.
[8] UCAR, Seyhan, ERGEN, SinemColeri, et OZKASAP, Oznur. VMaSC: Vehicular multi-hop algorithm for stable clustering in vehicular ad hoc networks. In : Wireless Communications and Networking Conference (WCNC), 2013 IEEE. IEEE, 2013. p. 2381-2386.
[9] LIU, Weiwei, WANG, Xichen, ZHANG, Wenli, et al. Coordinative simulation with SUMO and NS3 for Vehicular Ad Hoc Networks. In : Communications (APCC), 2016 22nd Asia-Pacific Confewwrence on. IEEE, 2016. p. 337-341.
[10] Mahesha .S.N, C.Y. Gopinath, Hemanth Kumar .A.R, Eshwar.N.Kumar: Performance Study of LTE Scheduling Algorithms in Vehicular and Pedestrian Mobility. International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, May 2016, Vol. 5, Issue 5, p.3871-3876.
[11] AdiS.M.Y., KuokkweeWee, EeMaeA., Mohd.F.A.A: Performance Study of Channel-QoS Aware Scheduler in LTE Downlink Using NS3.Proceedings of the Seventh International Conference on Emerging Networks and Systems Intelligence, 2015, p.44-49.
[12] A. Marinčić, D. Šimunić: Performance Evaluation of Different Scheduling Algorithms in LTE Systems. In MIPRO 2016, May 30 - June 3, 2016, Opatija, Croatia, p. 595-600.
[13] Radhika R Kulkarni and P M Pujar. Implementation and Analysis of Scheduling Algorithms for LTE Network. International Journal of Computer Applications 171(4):27-31, August 2017.
[14] Samia Dardouri and, Ridha Bouallegue, “Comparative study of downlink packet scheduling for LTE networks,” Wireless Pers Commun (2015) 82:1405-1418, Springer Science+ Business Media, 2015.
[15] Salman a. AlQahtani, Mohammed Alhassany “Comparing Different LTE Scheduling Schemes”, 978-1-4673-2480-9/13- 2013 IEEE.

[16] Swetha, Mohan kumar N M , Devaraju J T , "Performance Evaluation of Round Robin and Proportional Fair Scheduling Algorithms for constant Bit Rate Traffic in LTE" International Journal of Computer Networks and Wireless Communications (IJCNWC), Vol, 3 (1), 2013.
[17] 3GPP, Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall Description: Stage 2 (Release 8), 3GPP TS 36.3000.
[18] Dixit, Mayank, Kumar, Rajesh, et Sagar, Anil Kumar. VANET: Architectures, research issues, routing protocols, and its applications. In: Computing, Communication and Automation (ICCCA), 2016 International Conference on. IEEE, 2016. p. 555-561.
[19] Khadija Raissi, Bechir Ben Gouissem: Comparative Networks for Smart City, Proceedings of the20th International Conference on Information and Communications Technologies(Paris, France), 2017, p. 1165–1170.

AUTHORS

Khadija Raissi received her National Engineering Diploma from the National School of Engi neering of Carthage in 2015 and presently pursuing her doctorate at the National School of Engineering of Tunis in Communications Systems Laboratory Sys'Com. Her areas of interest are communication networks and Routing protocols for wireless sensor networks.

Bechir Ben GOUISSEM was born in 1974 in Tunis, Tunisia. Received his M.Sc. in electronics (1998) and his Graduate degree in Communication Systems and Networks (2000) from Faculty of Science s of Tunis, Tunisia, and the postgraduate research degree in communication networks (2003) from National School of Engineering of Tunis, , and the PhD in the Department of Computer and Communication Technologies of National School of Engineering of Tunis in Tunis El Manar University of TUNISIA in 2009. His research interests are communication networks, wireless industrial networks, wireless MAC protocols for real-time and distributed applications, Routing protocols for Wireless sensor networks and Wireless Sensor and Actor Networks.