Quality of Service Optimization in IoT Driven Intelligent Transportation System

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Abstract—**High mobility in intelligent transportation systems (ITS), especially vehicle to vehicle (V2V) communication, allows increasing coverage and quick assistance to the users and neighboring networks, but also degrades the performance of the entire system due to fluctuation in the wireless channel. How to obtain better quality of service (QoS) in terms of performance metrics during multimedia transmission in V2V over future generation networks (i.e., edge computing platforms) is very challenging due to the high mobility of vehicles and heterogeneity of future internet of things (IoT)-based edge computing networks. In this context, the paper contributes in three distinct ways: *(i)* to develop a QoS-aware, green, sustainable, reliable and available (QGSRA) algorithm to support multimedia transmission in V2V over future IoT driven edge computing networks; *(ii)* to implement a novel QoS optimization strategy in V2V during multimedia transmission over IoT-based edge computing platforms; *(iii)* to propose QoS metrics such as greenness (i.e., energy efficiency), sustainability (i.e., less battery charge consumption), reliability (i.e., less packet loss ratio), and availability (i.e., more coverage) to analyze the performance of V2V networks. Finally, the proposed QGSRA algorithm has been validated through extensive real-time data sets of vehicles to demonstrate how it outperforms conventional techniques making it a potential candidate for multimedia transmission in V2V over self-adaptive edge computing platforms**.

Index Terms—**IoT, Edge Computing, Intelligent Transportation System, QoS Optimization.**

I. Introduction

DUE to significant role and emerging importance of the intelligent transportation systems (ITS) with particular reference to the vehicle to vehicle (V2V) communication, every sector from industry to healthcare has been revolutionized. In the meantime the trend of multimedia content delivery inside vehicles has become the paradigm shift to highlight the every scene in a better way. On the one-hand, technological trends have enriched the lives of common citizen while on the other-hand quality of service (QoS) over smart cell phones and portable IoT devices in terms of multimedia contents, has been compromised due to high mobility of vehicles. In this context, the guarantee of a high QoS level to the users in vehicles, is still a critical challenge to be carefully tackled. In fact, due to the high mobility, the wireless link suffers of more fluctuation in the received signal indicator (RSSI) at base station (i.e., more packet loss ratio and less reliability), less greenness (i.e., high power drain), less sustainability (i.e., short battery lifetime), less availability (i.e., smaller coverage). In addition, because of resource constrained nature of portable devices at the edge of IoT-based computing networks, it is hard to satisfy the user requirements while watching the video content of the emergency patients in vehicles (i.e., ambulances). In fact, high mobility of vehicles in V2V communication impacts a lot the network performance (i.e., QoS) and user satisfaction/perception while exchanging critical and sensitive information. In the last few years, edge computing has entirely revolutionized the landscape of automotive industry, especially multimedia streaming in V2V communication while optimizing the QoS in terms of greenness, sustainability, reliability, and availability (i.e., high coverage) [1]. Furthermore, IoT-based battery-driven devices have significantly revolutionized the entire ITS platform; thus, it is necessary to optimize their power drain and battery lifetime during communication among users such as those in smart healthcare environments where physicians, medical and paramedical staff, nurses and patients are used to easily exchange the daily reports and relevant contents (i.e., dosage, food, exercise and precaution tips etc) [2]. However, dynamic nature of vehicles leads to more RSSI loss and power dissipation, hence shorter battery lifetime of IoT-based ITS by compromising the quality of the entire transportation system from both network and user perspective. For these reasons, today's V2V platforms must be equipped with state-of-the-art technological trends and tools to facilitate end users by optimizing the mobility, power drain and battery lifetime [3]. Although, the emerging edge computing networks are very promising to satisfy the networks and user's QoS requirements while transmitting multimedia content in V2V; however, a fair and intelligent resource allocation for the voluminous data amount of vehicles needs strategic pattern with state-of-the-art

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techniques to obtain high reliability and coverage, and low power and battery drains [4-5]. In-motion vehicular multimedia communication, on-board multimedia services in vehicles such as, navigation, video reporting, video gaming and entertainment, map images for proper vehicular guide are the key areas to get inspired to continue with the QoS optimization in V2V multimedia communication. Besides, to make an efficient and fair allocation of resources within the vehicular network communication scenarios, it is necessary to integrate future generation edge computing technologies to facilitate the users and drivers in convenient way. In particular, future networks intend to meet various criteria from both end-users and core network by entertaining in distinct applications, e.g., navigation and in-motion multimedia services to develop a green, sustainable, reliable and available platform [6]. Furthermore, edge computing can be used to support the high mobility/speed (i.e., 60-120km/h) with flexible, and scalable multimedia platform by transmitting large data rates over high bandwidth at any-time and anywhere. Finally, network performance in terms of QoS can be optimized by tuning the performance metrics (i.e., greenness, sustainability, reliability and availability) to increase the coverage and the capacity of the network in both urban and rural areas [7-8]. According to the presented vision and challenges, the main contribution of this article is three-fold.

- First, a QoS-aware Green, Sustainable, Reliable and Available (QGSRA) algorithm to support multimedia transmission in ITSs over future generation networks such as edge computing is presented.
- Second, a novel QoS optimization scheme in V2V multimedia transmission over edge computing is proposed.
- Third, several QoS metrics are proposed to analyze the performance of V2V networks.

The remaining of the article is organized as follows. Section II describes the novel QGSRA algorithm, the QoS optimization framework and a specific Use-Case for V2V communication over edge computing networks. Section III presents the experimental analysis of the proposed QGSRA algorithm in comparison with classical methods. Challenges and proposed solutions for future generation networks i.e., edge computing in V2V communication are discussed in section IV. Finally, section V draws the main conclusions and discusses future research directions.

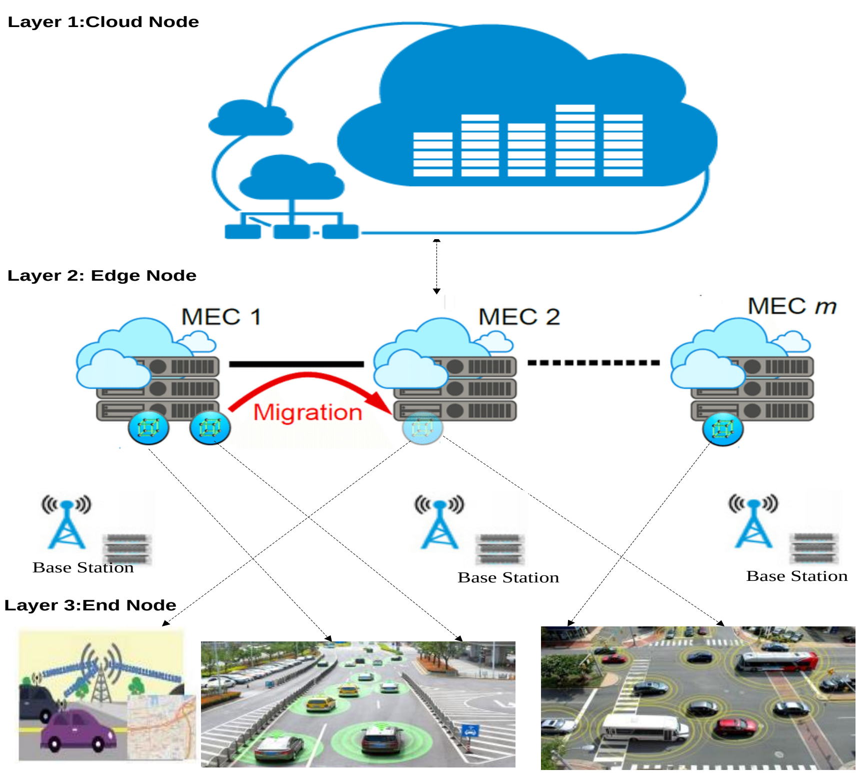


Fig. 1. Framework of Intelligent Transportation System

II. QoS-aware Green, Sustainable, Reliable and Available algorithm

Multimedia communication in V2V over edge computing platform is the emerging direction to present the clearer, nicer, bigger and better image of the emergency/critical event. Moreover, to manage the high mobility/dynamicity of the V2V platform, it is challenging to develop a green, sustainable, reliable and available (QGSRA) automotive system. To establish and understand the coordination between multimedia, V2V communications and edge computing, it is cornerstone to properly model the high mobility in vehicles. The key parameters E_{tot} , E_{stat} , E_{mov} , D_{c_opt} and $RSSI_{th}$ are the total energy, the energy drain of vehicles in static and moving states, the duty-cycle optimization and the RSSI threshold, respectively. For further details see the Figure. 2 (a) and 2 (b). There are various challenges in multimedia V2V communication over heterogeneous networks, but the followings are fundamental:

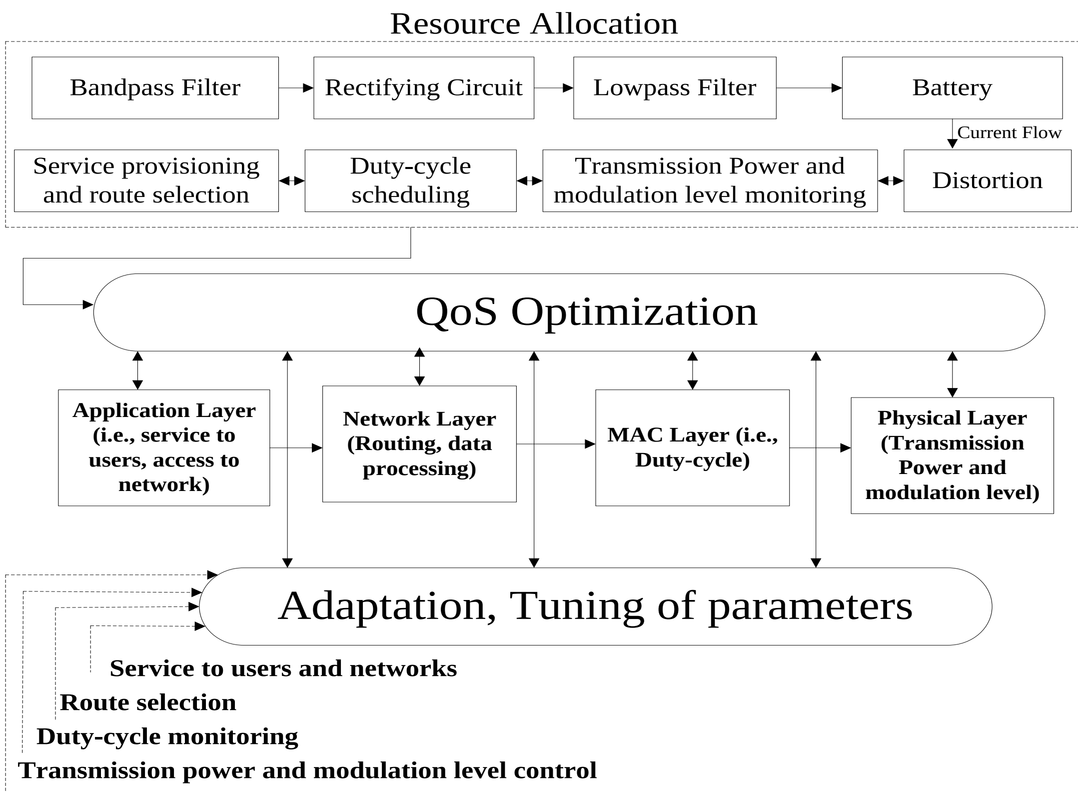


Fig. 2 (a). Proposed QoS-aware Green, Sustainable, Reliable and Available Algorithm.

Initialization:

Define: $TP, Dc, RSSI_{th}, d, b, LT, HT, R_s, W, \sigma, TP_{max}$

Set: $QoS_{i,j}(t) \quad \min_{\{Dc,TP,RSSI\}} \quad f(d, Dc, TP, RSSI_{th}), \ \forall i \in b, \ and \ j \in TP$

Event on $QoS(t)$ **do**

  for $i \leftarrow 1$ to b based on Table 1 **do**

    for $j \leftarrow 1$ to TP based on Table 1 **do**

      Compute $E_{total}(t) \leftarrow (E_{stat} + E_{mov} + E_{trans} = P_{stat} \times T_{stat} + P_{mov} \times T_{mov} + P_{trans} \times T_{trans})$

    end

  end

  if $(TP <= TP_{max} <= \sigma) \, \& \& \, (10m <= d <= 300m)$ based on Tables 1 and 2, then

    Compute $D_C \leftarrow (\frac{T_{mov}}{T_{total}} = \frac{\frac{W}{R_s \cdot b}}{T_{total}} = \frac{W}{R_s \cdot b \cdot T_{total}})$

  elseif $(LT <= RSSI_{th}(d) <= HT)$ based on Table 1 then

    update $TP \leftarrow TP \pm \sigma$

  else update $RSSI_{th} \leftarrow RSSI \pm b$

  end

end

Fig.2 (b). Pseudocode of the proposed QGSRA algorithm

Table 1. Description of the QGSRA parameters

Term and Explanation	Value	Term and Explanation	Value
Transmission Power (TP) in mW	{5,10,15,20}	Transmission rate (R_s)	6Mbps
Duty cycle (Dc) of vehicles	100%	Modulation level (b)	{32,64,128,256} QAM
Received Signal Strength Indicator (RSSI)	-87dBm	Total time (T_{total})	1560sec
Total power drain (P_{tot}) of vehicles	168W	Deviation in RSSI (σ)	7dB
Power consumed in stationary mode (P_{stat})	1.5W	RSSI threshold ($RSSI_{th}$)	-85dBm
Power consumed in moving mode (P_{mov})	188W	SINR threshold of Vehicles (ζ)	3-5dB
Power consumed during transmission (P_{trans})	214mW	Higher Threshold (HT) of RSSI	-83dBm
Career Frequency (fc) of vehicles	5.8GHz	Lower Threshold (LT) of RSSI	-88dBm
Time period of static/moving/transition mode (T_{stat}/T_{mov}/T_{trans})	0/10/30sec	Channel Bandwidth (*W*)	10 MHz
Average Distance (d) between vehicles	30m	QoS function (*f*)	*f*
TP_{max} in mW	25	*f* function for QoS optimization	{Dc,TP,RSSI,mobility}

1. QoS optimization in V2V during multimedia communication over edge computing platform by considering the high mobility of vehicles (i.e., fluctuation in wireless channel) and heterogeneity and resource constrained (i.e., high power and battery charge drains, high packet loss ratio and less coverage) nature of vehicular networks.
2. The development of the unique green (i.e., energy efficient), sustainable (i.e., battery-aware), reliable (i.e., less packet loss) and available (i.e., high coverage) framework/architecture by considering dynamic nature of the vehicles and the heterogeneous behavior of the emerging technologies. Furthermore, it is important to present a better insight of emergency/event-triggered situation in V2V communication in remote areas by understanding the importance of multimedia platforms.

It is reported by the research, industry personals and experts that by 2020 the number of connected vehicles in the automotive industries will be increased from 10% to the 90% [9-10], which is a quite significant portion of the transportation market. In the mean-time, there is an increasing demand of video and image transmission for better and clear social networking in the vehicles over edge computing platforms [11-12]. By considering these all demands, standards organizations such as federal communication commission (FCC), has reserved about 75 MHz bandwidth portion at 5.9 GHz frequency for the vehicular networks. So, a unique IoT driven edge computing framework, which comprises three key layers and well suited for V2V multimedia communication, is proposed in Figure 1. Cloud node in Layer 1 handles and monitors the services and tasks performed by the cloud. Edge node in Layer 2, which has several MECs (mobile edge computing) platforms, can manage and deliver the services from cloud node to the edge of the network to facilitate the users. End node in Layer 3, which is mostly related to the users/networks to get their requirements to be fulfilled. Most of the suggested methods in the previous works [11-12] faced the problem of wireless technology selection (i.e., channel, data rate, frequency, bandwidth, etc…) to guarantee an efficient and reliable communication. The main problem with the standard techniques is that these are not well suited for the V2V applications due to several reasons mostly related to high mobility, inconsistent coverage in rural areas, limited battery lifetime and power-constrained nature of end nodes. Moreover, there is no flexibility and dynamicity while dealing with the heterogeneous IoT enabled edge computing networks. Thus, to support such huge demand and importance of the QoS optimization during multimedia communication in V2V, the QGSRA is proposed to achieve green, sustainable, reliable and available V2V communication platform.

The proposed QGSRA algorithm comprises of three main blocks shown in Figure 2.(a): resource allocation, QoS optimization and adaptation & tuning of parameters. In the first block, resources (i.e., power, battery charge, packet reception rate and coverage with reasonable cost for V2V platform) are allocated efficiently because traditional methods are not able to address and less efficient to fulfill the requirements imposed by the multimedia V2V communication in IoT driven edge computing system. The second block of the proposed algorithm is based on four layers, i.e., Application, Networks, Medium Access Control (MAC) and Physical (PHY) integrating scheme and strategies such as application selection, routing/processing, vehicle node's duty cycle monitoring/scheduling and data rate/modulation level adaptation at application, network, MAC and PHY layers, respectively. Finally, the third block makes the right choices because it tunes/adapts the parameters according to the specific requirements of the vehicles during QoS optimization in V2V. Moreover, within this block, key factors such as service to users and networks with application layer, route selection to network layer, duty-cycle monitoring to MAC layer, and transmission power and modulation level control for the PHY layer are properly handled. Figure.2.(b) presents the pseudo code of the proposed QGRSA algorithm, which contains two main steps: step 1 computes the energy and duty-cycle at PHY and MAC layers respectively by optimizing the power drain and battery lifetime in IoT-based ITS. Step 2 calculates the reliability and coverage at network and application layers (i.e., vehicular networks) accordingly by minimizing the RSSI and packet loss. Finally, the overall QoS is optimized in vehicular networks by adapting the power drain and time of both active and sleep cycles. All the details on the used parameters are listed in Table 1.

III. Proposed Framework for V2V Communication

A. QoS optimization in multimedia V2V communication

This section presents the QoS optimization process during multimedia communication in V2V over edge computing networks. Due to high importance of the multimedia content and more information delivery in ITS environment, it is vital to develop efficient and effective frameworks.V2V communication architecture comprises the following key steps while optimizing the performance of the ITS:

- High definition multimedia content will be watched by passengers/users through large screen IoT-enabled portable devices in vehicles;
- QoS analysis tools are the key drivers to examine the user satisfaction level during multimedia communication in ITS;
- The quality of measured multimedia content is interpreted by V2V platform. It sets the standard platform of real-time vehicular environment;
- V2V data sets while transferring multimedia content have better network quality and user perception analysis indicators;
- Degraded and unsatisfactory performance of V2V will be improved by getting frequent updates from the multimedia server. Then final results will be obtained on the basis of network and user satisfaction and further modifications in V2V application.

As shown in Figure 3.(a), the injured patient's car from sender vehicle (i.e., source area) to emergency vehicle within the (destination area) transmits data to the portable devices such as smartphone in connection with vehicle monitoring. Then QoS is measured through the specific multimedia tool by statistically examining the V2V performance. Feedbacks are reported to the QoS management server that is constantly connected to the emergency vehicles.

B. Use-Case: vehicular communication in healthcare

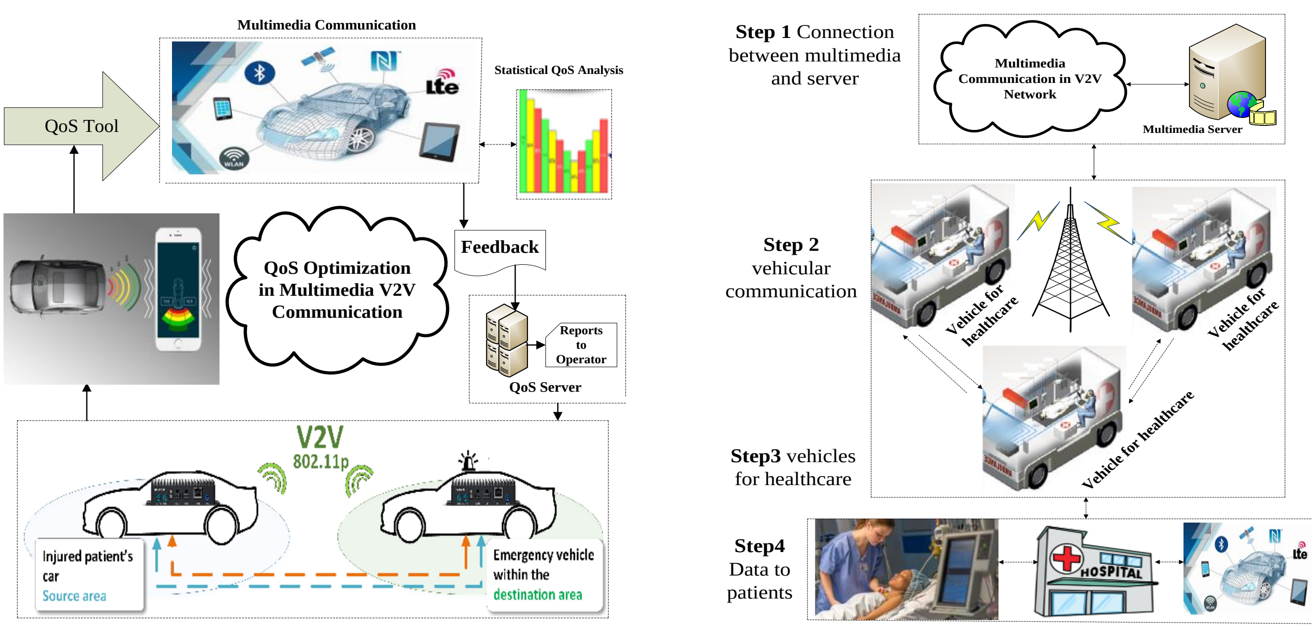
This section presents a specific use-case for performance analysis of V2V (i.e., ambulance to ambulance) over future technology driven networks i.e., IoT driven edge computing platforms for medical healthcare [15]. Figure 3.(b) shows the four parts of QoS optimization through IoT-based devices in ITS.

First, V2V data communication platform is accomplished in-line with multimedia server's requirements.

Second, data among vehicles is exchanged through different modes for instance, inter, intra and extra-vehicle. It is dire need to manage the sensitive and emergency events in the healthcare environment while considering ambulance as a high mobility vehicle.

Third, in healthcare vehicles for examples, ambulances, information is delivered/exchanged among several parties i.e., hospitals, medical theaters, centers, paramedic staff, patients and physicians on the basis of the service (i.e., normal or urgent). Thus, on the basis of these services, patients will be entertained and diagnosed by adopting their previous history, which is already stored, online recorded or examined with high quality tools.

Fourth, error-free data is transmitted to the patients through portable devices with better visualization, enhanced battery lifetime and energy level.



(a) (b)

Fig. 3. a) QoS optimization in V2V communication; b) Multimedia transmission in Vehicle to Vehicle communication.

Table 2. Experimental parameters

Parameter	Value	Parameter	Value
Experimental Tool	Convex Optimization in MATLAB	Propagation model	Two Ray Ground
Simulation time	900 sec	Transmission range	300m
Vehicles nodes	10, 100	Mutimedia Encoder	MPEG-4
Velocity of vehicles	60 to 120 km/h	Video Stream	StarWar IV(400 frames)
Data Type	CBR	Multimedia rate	30 frames/s
Transmitter/Receiver	Mobile state	Background CBR traffic	10-20-40-60-80[13-14]
Packet Length	512 Bytes, and 1000 bytes	Background packet rate	20 packets/sec
Channel	Wireless mobile	Network area	100m × 100m
Antenna	Directional, Omni directional	Video format	CIF, 352 × 288
Standard	IEEE 802.11p	Node density	10-20-50-100-150

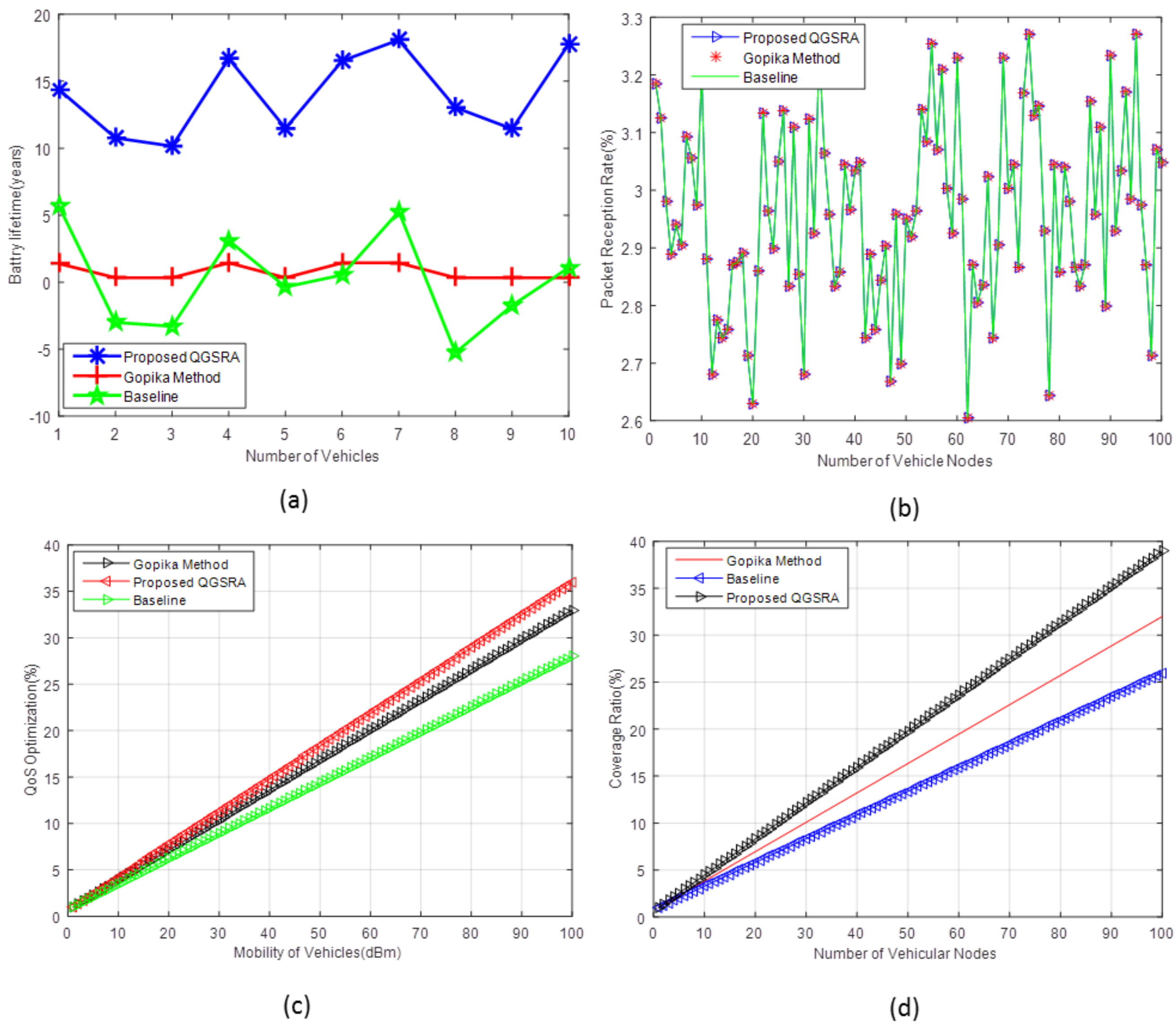


Fig. 4. QoS optimization in V2V increasing the number of vehicles: a) Battery lifetime, b) Packet reception rate, c) QoS optimization, d) Coverage

We aim at obtaining smooth and error-free communication at high data rate in vehicles with low storage space, minimum power levels and high RSSI values. Moreover, less error-prone and stable wireless channel dissipates less power and occupies small space with longer battery lifetime in IoT-based ITS at user side.

IV. Experimental Results And Discussion

We used a MATLAB-based convex-optimization tool in which the vehicles support a speed between 60 and 120 km/h. The RSSI value of the wireless link is used as key parameter to provide the clear insight about performance of the ITS for each transceiver in the V2Vcommunication scenario. Here, aggregated values of RSSI and transmission power are considered to effectively and fairly optimize the QoS in ITS. Dynamic behavior of vehicles shows more PLR and instability of RSSI level; thus, QoS optimization leads to better analysis of risk-oriented events and future road maps in ITS environment. Table 2 shows the used experimental parameters. Speed/mobility of vehicles determines the quality of wireless channel in which high RSSI value and less packet loss ratio (PLR) represent a good quality indicator. The proposed QGSRA algorithm is compared with conventional methods (i.e., Gopika's and Baseline [1]) for smart city environment over IoT-based ITS. The reference approaches used the mixed integer linear programming to optimize the heuristic problem of implementation cost of edge devices to meet the vehicular network coverage computational requirements for the urban areas. To further examine the proposed methods, real-time datasets of ITSs [13-14] are considered for computing the desired outcome in terms of performance metrics. Moreover, experimental results are validated from V2V aspect by entirely analyzing the ITS behavior for event-triggered situations. In addition, ambulance as a vehicle is adopted for the use-case in healthcare environment by observing the variations of the wireless channel, the vehicle's mobility through statistical tool, and the analysis of variance (ANOVA). Figure 4 reveals the relation between QoS optimization and vehicular nodes with high mobility. Specifically, Figure 4 (a) shows the relationship between increasing number of vehicles and the battery lifetime for the proposed QGSRA scheme and conventional methods. It is very clear how the former performs much better than the previous approaches by greatly enhancing battery lifetime. Figure 4 (b) highlights that the achieved performance in terms of energy saving can be reached without degrading the packet reception rate. Figure 4 (c) exploits linear tradeoff between mobility of vehicles and ITS performance; however, the proposed QGSRA optimizes QoS at better level than the previous competing schemes. Finally, Figure 4 (d) depicts the tradeoff between number of vehicles nodes and the coverage ratio confirming that the proposed QGRSA guarantees a bigger coverage in V2V communication scenario compared with the traditional approaches.

V. Challenges And proposed Solutions For Iot DRIVEN V2V Communication

Several challenges arises while optimizing the QoS during multimedia V2V communication over edge computing platforms; in this section we highlighted few of them proposing possible solutions.

A. High mobility of vehicles and data rate compatibility

High speed and mobility of the vehicles on one hand gives quick and timely response to the critical/emergency events while on the other hand consumes more power and battery charge with performance degradation during multimedia V2V communication over IoT driven edge computing networks. In addition, one of the major concerns is the different data/transmission rates of the multiple devices in heterogeneous networks. For example, when the data rate of the transmitting entity is higher and the backlog of the receiving entity is lower than the threshold data/transmission rate, there will more packet loss and congestion, hence the more power and battery drains.

Proposed solution: To address this challenge, a joint power and bandwidth management approach should be developed by considering the dynamic nature of the vehicular multimedia networks to develop a specific QoS architecture over the edge computing network platform.

B. Heterogeneity and interoperability

Emerging trends and practices in the innovative technologies have made the lives of customers easy and comfortable while in the mean-time heterogeneous and dynamic characteristics are very challenging to manage and monitor from uniform standard perspective. Future network technologies form the self-adaptive environments with lack of suitable solution to remedy the interoperability and dynamicity issues. Due to voluminous amount of data, high mobility and different data/transmission rates, there are more possibilities to discharge batteries and less reliability and coverage for vehicles in the rural areas during multimedia communication. This factor represents the major threat to the deployment of IoT; furthermore, the diversity in deployed edge computing networks degrades the end user's satisfaction while handling the multimedia services in the vehicular networks which is considered as one of the critical challenges. Heterogeneity is the broader concept to bring core and innovative technologies closer to talk and understand each other's language (i.e., interoperability). Once the cooperative environment between the IoT enabled devices, protocols, gateways, hardware and software is developed, it is necessary to satisfy the network and end users requirements by achieving a green, sustainable, reliable and available platform during multimedia V2V communication.

Proposed solution: To tackle this challenge there is a need of a specific standard for the ITS to support V2V multimedia communications integrated with the edge computing paradigm in order to implement QoS optimization schemes as well as hybrid green, sustainable and reliable techniques.

C. Resource constrained IoT-based ITS

The unprecedented proliferation in the sensor-based devices and their convergence with the other highly emerging technologies has revolutionized the entire landscape of the future heterogeneous platforms. For example, IoT-based edge computing networks with adaptive and decisive capabilities can efficiently optimize the QoS during multimedia communication in V2V. Due to the dynamic nature (high mobility and speed) of the vehicles, more power is drained with high battery charge consumption of the portable vehicular entities. Emerging technological trends in the heterogeneous ITSs, with particular reference to V2V communication, have caught the attention from every direction. One of the critical challenges in the IoT-based ITS platforms is to manage and monitor the large data amount coming from sensors, cameras, and global positioning system (GPS) in an effective manner. Besides, smooth and stable transportation is very vital to be achieved for emergency V2V communication. This entire process will directly impact the QoS in the ITSs.

Proposed solution: To address this challenge, a joint transmission power and energy harvesting technique for the QoS optimization in vehicular multimedia communication needs to be developed.

D. Limited spectrum and high congestion

Due to the rapid proliferation in the IoT driven edge computing devices, a massive amount of data need to be monitored and managed. Moreover, due to limited spectrum of the edge computing based IoT devices, it is challenging to extend the network in order to avoid congestion; thus, a smart spectrum management is one of the suitable solutions to alleviate this issue. In particular, two renowned spectrum allocation techniques for edge computing networks, full duplex (FD) and cognitive radio (CR) have been proposed in the last few years [13]. The key impact resource sharing in edge computing platforms supporting V2V multimedia communication allows to autonomously allocate both power and bandwidth toward the implementation of a sustainable and reliable platform.

Proposed solution: To resolve this challenge related to the spectrum monitoring and sharing with high reliability, it is vital to steady the received signal strength indicator (RSSI) and manage the mobility during high speed vehicular networks to increase network performance as shown by the proposed QGRSA algorithm.

VI. Conclusions and future research

The paper proposed a QoS optimization framework for V2V multimedia transmission supporting IoT driven edge computing systems. Due to more dynamic and resource sharing characteristics of vehicles, it is vital to manage and monitor the QoS from both the network and user perspectives. In the considered use-case of QoS optimization during multimedia transmission over edge computing networks in V2V (i.e., ambulance to ambulance) communication, there is a need for clear, bright and high resolution images of users and networks. In this regard, we proposed the QGSRA algorithm well suited for multimedia communication in V2V over edge computing platform. The proposed scheme has been validated through real-time data sets and its performance has been compared with the classical competing methods in terms of performance metrics such as greenness, sustainability, reliability, and availability. The obtained results confirmed that the QGRSA scheme is the potential candidate to optimize the QoS during multimedia communication in V2V over edge computing networks. In near future, we will develop the mobility management model for the wireless channel in V2V in order to manage the mobile healthcare applications by measuring the user/network satisfaction in terms of QoE/QoS.

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