Towards 5G-Enabled Self Adaptive Green and Reliable Communication in Intelligent Transportation System

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***Abstract*— Fifth generation (5G) technologies have become the center of attention in managing and monitoring high-speed transportation system effectively with the intelligent and self-adaptive sensing capabilities. Besides, the boom in portable devices has witnessed a huge breakthrough in the data driven vehicular platform. However, sensor-based Internet of Things (IoT) devices are playing the major role as edge nodes in the intelligent transportation system (ITS). Thus, due to high mobility/speed of vehicles and resource-constrained nature of edge nodes more data packets will be lost with high power drain and shorter battery life. Thus, this research significantly contributes in three ways. First, 5G-based self-adaptive green (i.e., energy efficient) algorithm is proposed. Second, a novel 5G-driven reliable algorithm is proposed. Proposed joint energy efficient and reliable approach contains four layers, i.e., application, physical, networks, and medium access control. Third, a novel joint energy efficient and reliable framework is proposed for ITS. Moreover, the energy and reliability in terms of received signal strength (RSSI) and hence packet loss ratio (PLR) optimization is performed under the constraint that all transmitted packets must utilize minimum transmission power with high reliability under particular active time slot. Experimental results reveal that the proposed approach (with Cross Layer) significantly obtains the green (55%) and reliable (41%) ITS platform unlike the Baseline (without Cross Layer) for aging society.**

***Index Terms*— 5G, self-adaptive, mobility, green and reliable communication, ITS, cross layer.**

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I. Introduction

RECENTLY, 5G-enabled energy efficient and reliable ITS has received remarkable attention by researchers, developers and users to revolutionize the vehicular network market with high proliferation in sensor-based technologies. Also, high speed networks are facilitated by modern dynamic wireless channel models for efficient and effective communication through Internet of Things (IoT) driven edge nodes. According to 3GPP Release 155G-NR, Ultra-Reliable Low Latency Communication (URLL) is the suitable candidate for several mission-critical applications an intelligent transportation system is one of them. Portable devices are dynamically tackling the vehicles with major focus on the reliable and power efficient communication platform. In addition, vehicular-to-vehicle (V2V) data delivery mechanism is the remarkable role player to keep the better connectivity for proper monitoring and management of resources.

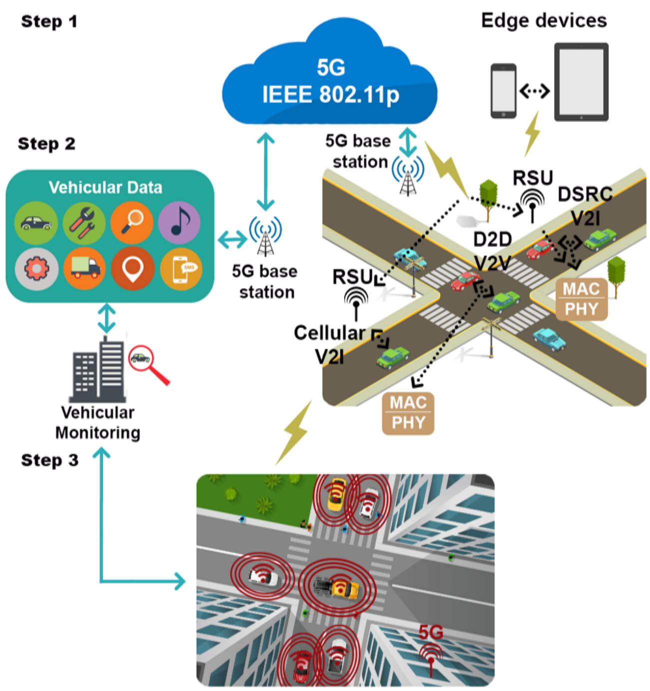

Fig. 1. 5G-enabled green and reliable communication framework of vehicular networks.

While sharing and monitoring the sensitive voluminous information between desired entities it is very important to develop the green, reliable and sustainable communication approach for pervasive and cost-effective vehicular platform as shown in Fig.1. Where three key steps are followed such as step 1, interconnection between vehicles, 5G-based edge devices, base station (BSs) and other various external entities is held over IEEE 802.11p while transcieving data. The step 2, manages and monitors the vehicular data with the help of machines i.e., device to device (D2D), vehicle to vehicle (V2V), road side units (RSUs), vehicles to infrastructure (V2I), and BSs over MAC and PHY layers through dedicated short range communication (DSRC) standard. Step 3, monitors and manages the the data transmitted by previous steps.

Due to emerging role of the IoT driven edge devices smart and pervasive transportation platform can be built. The challenging issue in smart and pervasive ITS is that edge nodes are resource-constrained and less reliable due to their power hungry nature, high mobility of vehicles and dynamic wireless channel. Besides, sensitive and resource-constrained nature of IoT based edge nodes and high mobility/speed (i.e., 60-120km/h) of vehicles will deteriorate overall the communication performance in ITS. In the mean-time traditional research works just focused on the bandwidth and delay-aware strategies.

In [1]–[3] authors address the characteristics of the generic wireless channel, which is not the potential candidate for ITS platform. Data clustering, and route selection on the basis of big data analytics in vehicular networks is presented in [4], [5]. Thus, 5G is the key enabler to intelligently allocate the resources among all the involved entities by properly managing the mobility, reliability and interconnectivity in overall transportation system.Besides, interconnectivity among vehicles is one of the fundamental traits for effective monitoring of the transportation system (see stable and longer interconnectivity among vehicles in between step 2 and 3 in Fig.1).

For heterogeneous ITS systems it is necessary to assure reliability, and latency performance as the main ingredients in heterogeneous networks. To properly manage and monitor the critical events it is necessary to analyze the activities of vehicles in an effective and corrective manner [6], [7]. Most of the heterogeneous and short range networks in relevant research [8]–[12] are not the suitable candidates due to resource-constrained nature while dealing with fair power and reliability allocation policy in ITS.Many solutions have been suggested and designed since last couple of years to remedy aforementioned problem.

The objective of this research is to develop 5G-based green, sustainable, reliable and smart ITS by proposing joint cross layer approach with the combination of physical (energy efficiency), medium access control (MAC) i.e., battery-aware, network (i.e., reliability), and application (signaling and transmission) layers. The interface among joint layers is the key to exchange the relevant information between all the involved entities by setting-up entirely different mechanism.

There are several deployment fashions for instance, horizontal, vertical, circular, and linear for sharing and obtaining the important information about each layer and applications from the practical aspect. From all joint/cross layer strategy is the suitable to integrate several key performance indicators in ITS. Besides, practical deployment of the cross layer algorithms is validated by many researchers in an efficient information/data monitoring fashion through central databases, cloud centers, etc. Furthermore, information retrieval and storage are the main entities in the cross layer process, which gives the clear direction about the addition and removal of the new layers and applications.

Moreover, emerging joint techniques are the preferred alternatives unlike conventional methods [13], because the former manages and monitors the entire network intelligently by appropriately tuning the required components.

This article contributes in three different ways, such as:

- 5G-based self-adaptive green (i.e., energy efficient) algorithm is proposed which contains four layers, i.e., application, physical (PHY), networks, and Medium Access Control(MAC) with application selection, routing/processing, duty-cycle management and data rate adjustment, respectively.
- 5G-based reliability optimization algorithm is proposed by adopting the real-time data-sets from ITS [6].
- A novel 5G-driven joint energy efficient and reliable framework for ITS is proposed. In addition, the energy and reliability optimization are performed under the constraint that all transmitted packets must utilize minimum transmission power with high reliability under particular active time slot in entire ITS.

The remaining of the paper is organized as follows. Section II presents the existing works. Section III depicts proposed joint green and reliable approach for 5G-based ITS.

Experimental results are analyzed in section IV. Section V concludes the paper.

II. Related Work

Many researchers have contributed in the research domain of industrial application with the help of innovative technologies such as, sensor networks, edge/cloud computing, 5G, massive IoT, narrow-band IoT, machine learning and big data analytics. However, there is still huge gap to be filled by highlighting the critical challenges in the current ITS. Some of the relevant works are presented. Researchers in [1], develop transmission power control based adaptive algorithm for energy saving in WBSNs, but do not discuss the cross layer approach. Energy optimization methods for WSNs are discussed in [2].

The Internet of things based healthcare frameworks and algorithms are proposed in [3]. Power transfer methods in sensor networks are presented for generic applications such as, wireless and cellular [4]. Data management methods are proposed and examined to allocate resources for instance, power and bandwidth to short-range networks [5]. A detailed survey about energy saving algorithms for wireless and industrial applications is presented in [6]. The joint power and battery lifetime management in the cloud-based industrial applications are highlighted in [7], but they do not mention the role and characteristics of the self-adaptive methods in the ITS.

Authors in [13] develop an efficient re-transmission based resource optimization scheme for general industrial networks, but do not consider the 5G-based methods and frameworks for ITS. Authors in [14], design the multi-functional self-driven schemes for the proper examination of delay and bandwidth management in cellular networks. The work in [15] examines the energy depletion level of WSN by proposing a cross layer model, which includes a Physical layer, MAC layer and routing layer, but do not include 5G-based features for ITS. Researchers in [16]–[18], discuss the energy depletion challenges merely at the medium access layer while do not focus the cross layer method for the IoT driven transportation system.

Besides, they consider the mobility of sensor-based industrial devices for critical incident monitoring, but do not focus at the joint energy efficient and reliable ITS. Authors in [13], [19], [20], present fog-computing based load-balancing and scheduling techniques for smart factories by properly following the energy-aware procedure, but their research does not particularly focus at efficient and reliable ITS. Authors in [21]–[24] present the joint delay-tolerant and robust strategies to obtain lower packet drop and high reception rate at the destination node for smart industrial applications, but the efficient and reliable transportation is not their interest.

The Duty-cycle based algorithm to minimize the idle-listening and re-transmission time at the MAC layer for saving the power and extending the lifetime of sensor nodes, while mobility management, reliability and energy saving in IoT based transportation system [22]–[26]. Authors [8] design the energy saving strategy for vehicular network driven smart green city, they discussed that cooperation among IoT based devices plays the remarkable role in heterogeneous networks. Their work do not focus at the role of IoT devices at the edge of networks in association to 5G for better and longer interconnectivity in transportation system.

Researchers [9] propose the sensing technology driven transport layer algorithm for spectrum management with the help of cooperative event sensing mechanism, but do not consider the specific energy efficient and reliable techniques for ITS. Authors in [10] address the effective communication among/between vehicles/road side units and infrastructure merely considering V2I platform, but do not consider reliability, mobility and energy in IoT driven edge nodes. Energy storage devices such as, capacitors are the emerging entities for storing and saving energy in trains/rails these days, so they focus on the deployment of storage devices at stations for monitoring the energy level of vehicles.

Delay-tolerant communication among vehicles is the need of an hour, so they propose the data layer driven latency management in vehicles, but they do not consider the reliability and energy saving strategies for ITS [11]. In [12], joint energy and speed optimization platform is designed. Because time and speed monitoring are the basic parameters for high speed trains and metro systems. Besides, energy conversion is one the promising factors to save the energy and optimize the speed. Besides, they develop the 5G-driven ITS platform for the future planning, predictions, challenges and solutions at both global and regional level in dealing with the emergency medical care. Reliable and efficient link/path establishment is necessary for vehicles while responding emergency events such as, risky or faulty travel route, and unwanted weather.

III. Proposed Joint Green and Reliable Communication Approach in Its

The 5G-driven proposed cross layer approach helps to achieve a green (i.e.,energy efficient) and reliable data delivery in vehicular networks due to its strong internetworking, interoperability and mobility management features for transportation system. Besides, proposed 5G-enabled joint green and reliable communication approach adopts the standard parameters of application, network, physical and MAC layers due to their flexible and easily integral nature at economical, less power drain, simple and fast process in the smart transportation applications. The main problem with the conventional techniques is that there is no flexibility and dynamicity while dealing with the heterogeneous networks in vehicular environment.

Besides, internetworking, interoperability, and mobility management are critical issues to be fixed in traditional transportation/vehicular networks. The proposed 5G-driven green and reliable approach comprises key interconnecting parameters i.e., IoT, IoV, cross layer, etc. IoT based Internet of Vehicles (IoVs): As classical vehicular networks do not have flexible nature with high scalability, thus cannot get the maximum information about other vehicles and infrastructure in the network. The IoVs are the promising and revolutionary paradigm for providing longer and sustainable connectivity with better traffic monitoring, safe and secure driving through

IoT driven sensor devices. The traditional vehicular networks lack the capacity to handle the vast information available for other vehicles in the network.

Initialization:
Define: $T_P, D_C, d, b, R_s, W, \sigma, TP_{max}, RSSI_{th}$
Set: $E_{i,j}(t) \quad minf(D_c, TP), \forall_i \in b, \{D_C, TP, RSSI\}$
Event $on\ E(t)$ **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
$if\ (TP \le TP_{max} \le \sigma)\ \&\&\ (10m \le d \le 300m)\ based$ on Table 1, then
Compute $D_C \leftarrow \left(\frac{T_{mov}}{T_{total}} = \frac{\frac{W}{R_s.b}}{T_{total}} = \frac{W}{R_s.b.T_{total}}\right)$
$elseif\ (LT \le RSSI_{th}(d)\ \le HT)\ \ based\ on\ Table\ 1\ then$
update TP $\leftarrow TP \pm \sigma$
$else$ update $RSSI_{th} \leftarrow RSSI \pm b$
end
end

The 5G technology is very supportive to build highly intelligent, connected, scalable, smart, secure and autonomous transportation system. The 5G-based device-to-device (D2D) communication is one of the emerging and rapidly growing platforms which has been attracted by vehicular networks in transportation system. One of the limitations of D2D communication scenario in 3GPP Release 12 is that it does not provide guaranteed coverage to the less accessed areas. Hence, entire network area is classified with three predefined scenarios for instance, in coverage, out of coverage and partial coverage. All of the aforementioned operation mechanisms are suitable for generic mobile devices, but we can extend it for vehicular networks to build intelligent transportation system by considering mobile device as the moving vehicle with on-board equipment.

Initialization: $TP, b, RSSI, HT, LT$
Define: $Mobility(\sigma), Reliability(\zeta)$
Set: $Mobility(\sigma) \leftarrow f' + f\left(\frac{v}{SOL} Cos\phi\right)$
Event on: $\zeta(d) \leftarrow Mobility(\sigma) \times (RSSI_{th}(d), mod^i)$ **do**
for i $\leftarrow 1\ to\ b\ based\ on\ Table\ 1, \forall i \in b, j \in TP$
for j $\leftarrow TP\ based\ on\ Table\ 1$
Compute $\zeta(d) = Mobility(\sigma) \times (RSSI_{th}(d), mod^i)$
end
end
$if\ (LT \le RSSI_{th} \le HT)$
update TP $\leftarrow TP + 1$
$elseif$
update TP $\leftarrow TP - 1$
$else$
update TP $\leftarrow 0$
end
end

The 5G-based cross layer design for transportation system: These days cross layer design has become the cornerstone and attractive research topic for vehicular communication in ITS. Because of strong internetworking and interoperable features of 5G, many parameters are shared among all the layers to achieve the intended outcome. So, our proposed approach adopts the desired parameters such as, signaling, transmission power data rate/modulation level, routing/processing, node's duty-cycle monitoring/scheduling, at application, PHY, networks, and MAC layers, respectively by keeping the legacy and modularity of open systems interconnection (OSI) framework.

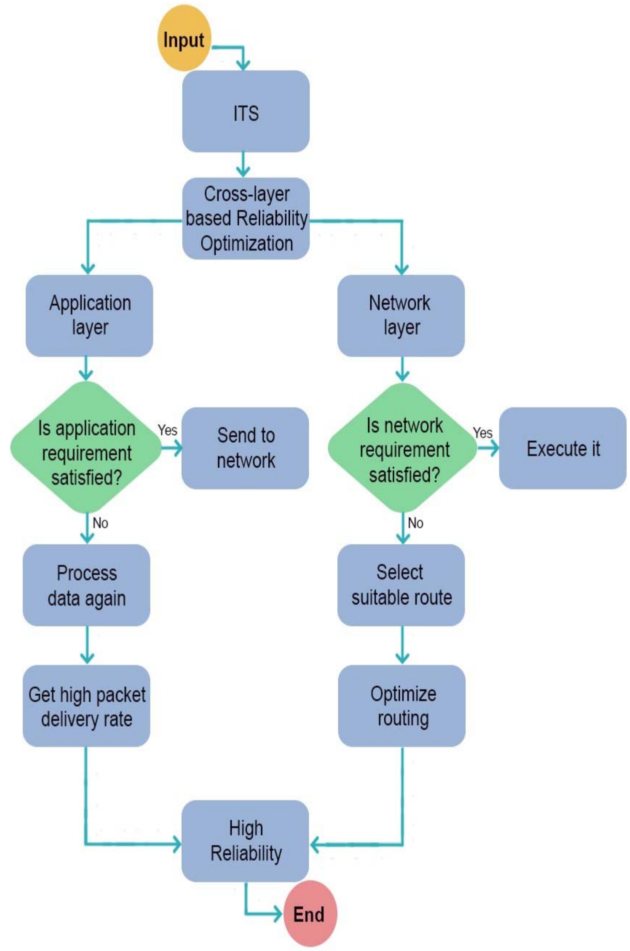

Fig. 2. Flowchart of the proposed 5G-based green algorithm for ITS.

Also, due to sporadic nature of IoT based IoVs, 5G-based MAC layer schedules the time by providing low access latency at high bitrate in both radio access and core networks, similarly at PHY layer signal to noise ratio (SNR) and packet size help to optimize the waveform of the overlay transmission at minimum power in edge nodes. It is analyzed that the sleep time gets longer and wake-up time shortens at the MAC layer with higher data rate. While this mechanism is performed differently at PHY layer, with longer wake-up period and increased data rates for vehicular networks. Thus, these two contradictory results emphasize the development of the novel optimal hybrid (i.e., cross layer) method for the energy efficiency, high reliability and sustainability in the 5G-driven ITS as shown in Figs.1,2 and 3.

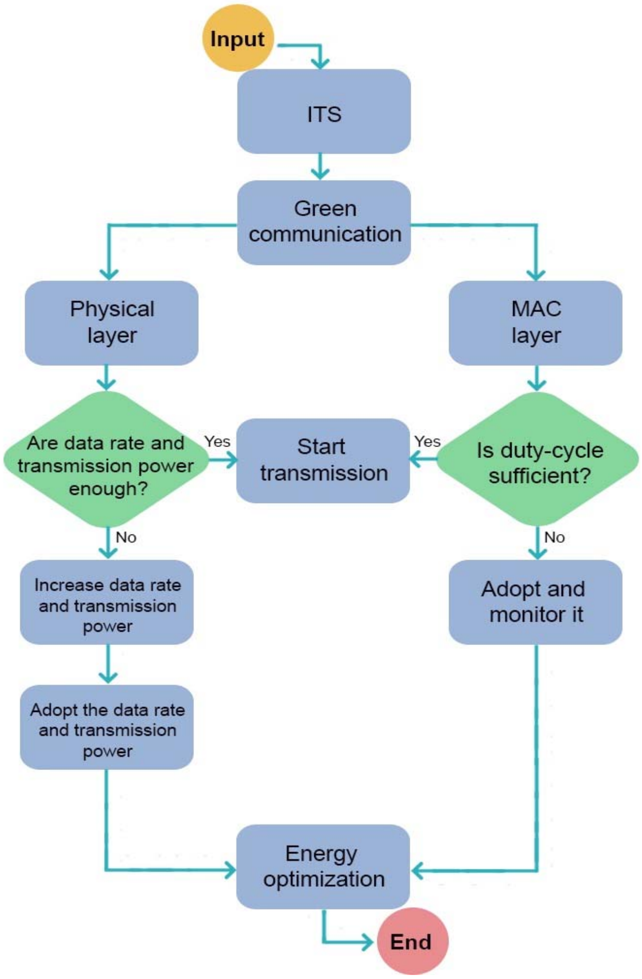

Fig. 3. Flowchart of the proposed 5G-driven reliability optimization algorithm for ITS.

In addition, proposed approach utilizes channel characteristics with particular application selection, routing/processing, node's duty cycle, and data rate/modulation level monitoring accordingly. Reliability portrays the entire image of the wireless channel by categorizing the bad and good conditions, while energy drain optimization is the proper way to get knowledge about the battery lifetime of IoT edge nodes in transportation system. The green and reliable platform is the one of the foremost need of the smart efficient and sustainable environment to portray the bright and big picture of the entire landscape. The transmission process drains more energy and shortens the battery lifetime of end IoT devices in transportation industry.

Thus, there is a need of reliable channel with adaptive nature to fairly and efficiently handle the entire process. Similarly, PHY layer deals with data transmission over wireless channels and consists of radio frequency (RF) circuits, modulation level, and transmission power control, among others. While other innovative technological trends promote the state-of-the art networks with adaptive, high speed, flexible, high data rate and small latency features. The smart, sustainable, efficient and reliable transportation is among one, which consists of power-constrained sensor driven IoT edge nodes, and shorter range.

Hence, a joint efficient, sustainable and reliable system model is proposed by considering the features of vehicular networks and OSI layers as shown in eqs (1) to (10). An Efficient, sustainable and reliable transportation system is very promising for vehicular applications. Besides, stable and efficient wireless link is useful for ITS where we assume that IoT-driven edge nodes have deadline time T while transmitting W bits. For instance at MAC layer transmitter node has duty-cycle monitoring time as $T_{act} \leq T$, and receiver node computes the entire duty-cycle duration as, $D_C = T_{act} / T_{total}$, then finally stops the data exchanging by obtaining sleep status to optimize the energy. In the same way, RSSI, data rate, transmission power, modulation level are adjusted at application, network and physical layers accordingly for ITS applications. The entire energy depletion E_{total} and reliability for the optimal ITS system are represented in eqs.(2) and (3).

$$E_{total} = E_{act} + E_{slp} = P_{act}.T_{act} + P_{slp}.P_{slp} + P_{tran}.T_{tran} \quad (1)$$

Energy dissipation and reliability problems are represented in (2) and (3), respectively.

Optimize E Subject to

$$\begin{aligned} 0 \leq D_C \leq 1 \\ 0.1m \leq d \leq 1m \end{aligned} \quad (2)$$

Optimize R_i Subject to

$$\begin{aligned} -55dBm \leq RSSI \leq -85dBm \\ 1m \leq d \leq 5m \end{aligned} \quad (3)$$

The 5G-driven proposed green and reliable algorithm adaptively adjust the time slots in MAC layer, data rate at PHY layer and dynamic routing at network layer accordingly. Numerous tasks for instance, sensing, routing, and transmission are done by IoT driven IoVs. Moreover, the energy efficient, and reliable communication system is optimized by internetworking, self-adaptive and intelligent features of 5G technology. The 5G-based proposed approach optimizes D_{C_opt} at MAC layer, and transmission power considerably at PHY layer, while network layer manages the routing, RSSI level and hence the reliability in vehicular networks for ITS as in eq.(3).

In this process the wake-up and sleep periods are shown as $T_{slp} = T_{total} - T_{act} - T_{tran}$. Power dissipation in sleep mode of the transceiver's radio is assumed to be 0.5 mw constant value. Total T_{total} time and transition time T_{tran} can further be divided as in (5), respectively.

$$T_{total} = T_{tran\_ON} + T_{tran\_OFF} + T_{act} + T_{slp} \quad (4)$$
$$T_{tran} = T_{tran\_ON} + T_{tran\_OFF} \quad (5)$$

whereas, $T_{tran\_ON}, T_{tran\_OFF}, T_{act}$ and T_{slp} are the time requirements for sleep to idle transition, idle to sleep change, active/wake up time and sleep time. The total energy drain is represented in (6). The duty cycle can be expressed in (7).

$$\begin{aligned} E_{total} &= P_{act}.T_{act} + P_{slp}.(T_{total} - T_{act} - T_{tran}) \\ &\quad + P_{tran}.T_{tran} \\ &= (P_e + P_{PA}).D_C.T_{total} + P_{slp}.T_{total} \\ &\quad \cdot \left(1 - D_C - \frac{T_{tran}}{T_{total}}\right) + P_{tran}.T_{tran} \end{aligned} \quad (6)$$

$$D_C = \frac{T_{act}}{T_{total}} = \frac{\frac{W}{R_s.b}}{T_{total}} = \frac{W}{R_s.b.T_{total}} \quad (7)$$

From (7), modulation level b is written in (8).

$$b = \frac{W}{D_C.T_{total}.R_s} \quad (8)$$

Thus E_{total} is associated with distance d, and D_C:

$$E_{total} = f(d, D_C) \quad (9)$$

For a short active time slot communication, the transmission of data stream finishes quickly. This can be possible with two methods: first, symbol rate should be larger, and the second selection of specific modulation level at PHY layer. The optimal duty-cycle and reliability are the major factors to examine the performance of the entire ITS with the proposed hybrid approach. Thus, D_{C_opt} reduces the energy drain and enhances the reliability as shown in (10) and (11).

$$D_{C\_opt} = \min_{D_C \in Q} E_{total} = \min_{D_C \in Q} f(d, D_C) \quad (10)$$

The entities in Q_i are practically finite, $Q = \{0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1\}$

$$\begin{aligned} Opt\_R_i &= max \sum_{j=1}^{n} R_{i,j} \\ &\quad S.t \;\; i \in n \end{aligned} \quad (11)$$

Whereby, Opt_R_i, i, j and n are the optimized reliability, transmitter node, receiver node, and total number of nodes, respectively in vehicular networks, as given in eq.(10).

IV. Experimental Results and Discussion

High internetworking, intelligent, interoperable traits of 5G-driven cross layer approach enhances energy efficiency and reliability in the IoT-enabled edge nodes for vehicular networks. Besides, high speed/mobility of vehicles is efficiently managed by adjusting the dynamicity of wireless channel and hence, the reliability in ITS. The proposed cross layer approach is important for heterogeneous vehicular networks to enhance energy efficiency, reliability, connectivity and sustainability. So, on the basis of these notions 5G-driven test-bed in MATLAB with real-time ITS data-sets is developed. Besides, the performance of proposed cross layer approach is analysed and compared with the Baseline (without cross layer). The proposed approach comprises four layers (i.e., application, physical, network and MAC) which plays the remarkable role in achieving network performance in terms of energy consumption, reliability in terms of the received signal strength indicator (RSSI) or packet loss ratio (PLR) and data content delivery in terms of modulation level and lifetime of IoT driven ITS in terms of sustainability. For further details see Table 1.

TABLE I
Experimental Parameters

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

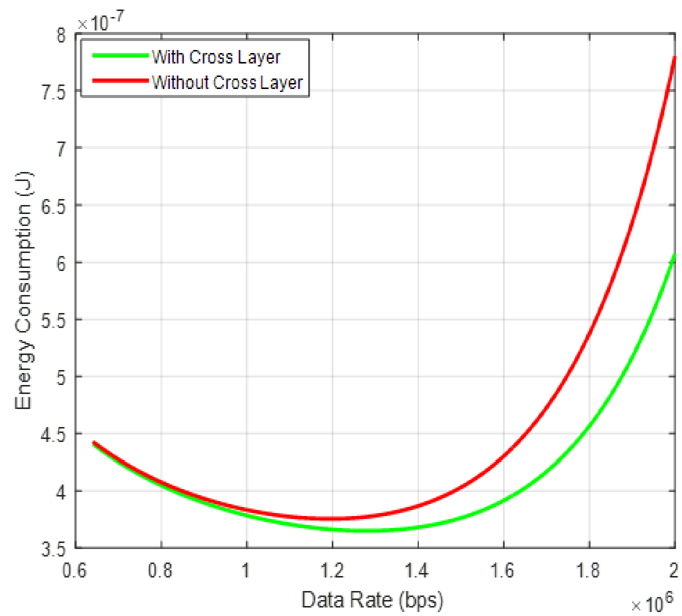

Fig. 4. Relationship between data rate and energy drain in 5G-driven ITS.

Several parameters are tuned at each layer for example, particular application selection, routing/processing, node's duty cycle, and modulation level monitoring at application, network, MAC and PHY layers accordingly. Traditional OSI layers and 5G-based protocol stack have efficient features to exchange information among each other and neighboring entities. The Fig.4 reveals the relationship between data rate (Kbps) and energy dissipation (J) for proposed cross layer and Baseline methods. It is examined that former dissipates less energy than later, hence, former is potential candidate for the green ITS platform.

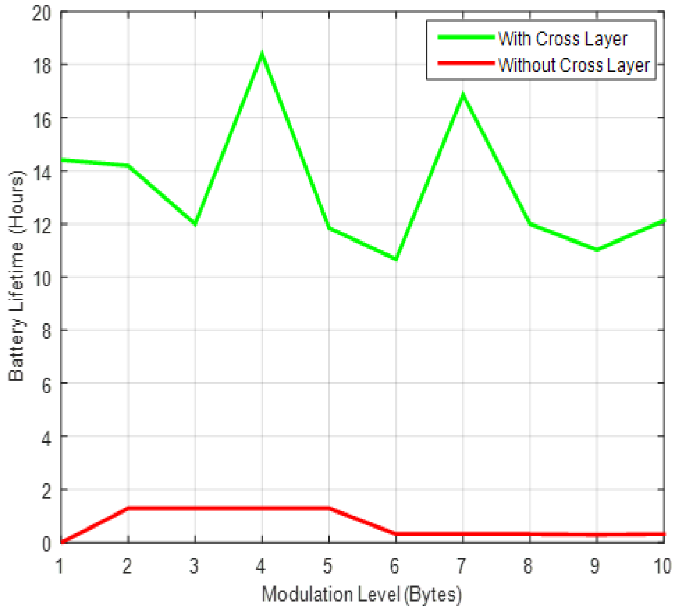

Fig. 5. Relationship between modulation level and lifetime in 5G-enabled ITS.

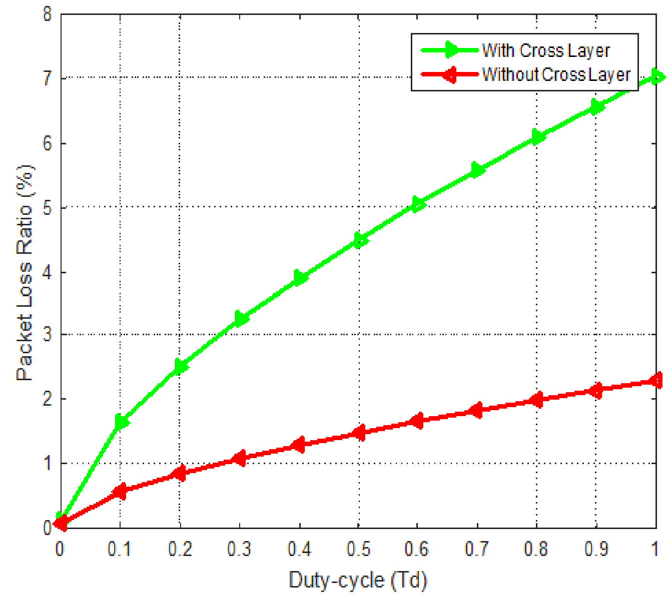

Fig. 7. Duty-cycle vs. Packet Loss Ratio for 5G-driven ITS.

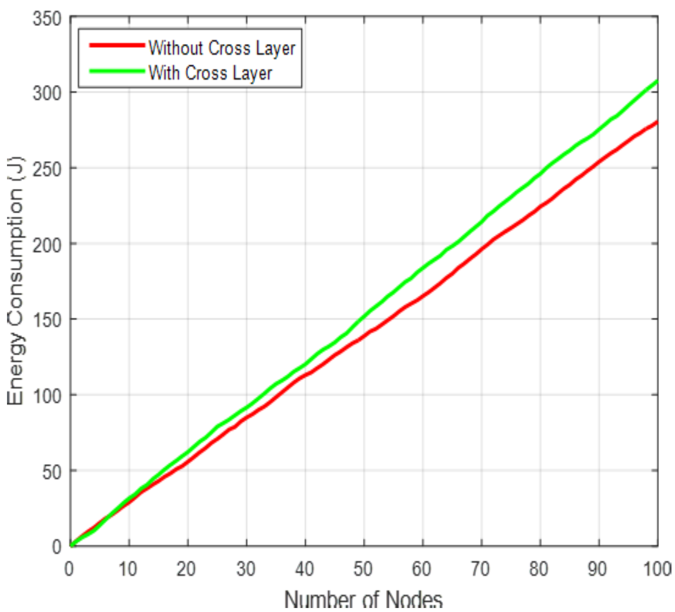

Fig. 6. Trade-off between IoT edge nodes and energy dissipation in 5G-based ITS.

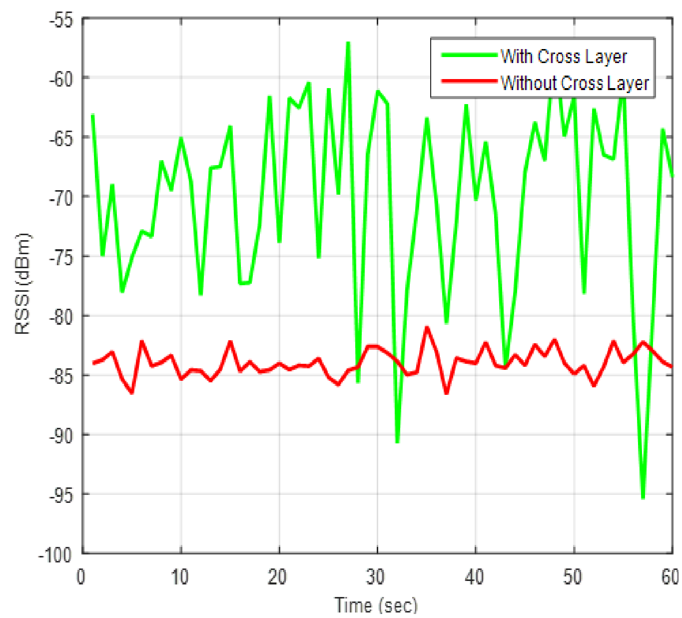

Fig. 8. Relationship between the time and RSSI for 5G-driven ITS.

Fig.5 presents the linear trade-off between modulation level and lifetime of 5G-based IoT nodes. It is observed that with the increase of modulation level more battery charge is consumed and hence shorter battery lifetime for Baseline while longer for proposed hybrid methods. Fig.6 draws connection between the number of nodes and energy drain between proposed cross layer and Baseline methods. It is interpreted that energy drain increases with the number of IoT driven edge nodes at high and acceptable rate for later and former techniques respectively. Moreover, with the increase of edge nodes computational complexity and power drain increases while content delivery from source to destination and among neighboring nodes.

Fig.7 shows the trade-off between duty-cycle and packet loss ratio (PLR) for measuring the performance of proposed cross layer and Baseline methods for ITS. It is examined that reliability increases with duty-cycle at small and large extent for Baseline and proposed methods respectively. Furthermore, proposed hybrid scheme enhances reliability due to internetworking and self–adaptive data rate allocation mechanism unlike Baseline method. Thus, it can be said that proposed mechanism is the promising and potential candidate for the vehicular applications as compared to the conventional method.

Fig.8 presents the relationship between the time and the RSSI to measure and validate the reliability during data delivery in vehicles for proposed hybrid and Baseline methods. It is examined that former has high average RSSI value (i.e., −80dBm) than the later with average RSSI (i.e., −85dBm) due to high transmission rate and less packet loss ratio in 5G-enabled intelligent IoT nodes respectively. While, proposed cross layer method shows two RSSI spikes below −85 dBm which does not affect the entire content delivery unlike Baseline method. Thus, we can say that proposed approach is more reliable and potential candidate unlike the Baseline method for ITS.

V. Conclusion and Future Work

5G-based green and reliable communication system for self-adaptive vehicular network in ITS is proposed to facilitate the end-users at cost-effective rates. IoT driven IoV progressively plays the significant role in establishing the longer connectivity with wider road infrastructure but high mobility. For heterogeneous transportation networks internetworking is one of the promising and basic traits of 5G technology with better compatibility to other heterogeneous technologies. Besides, interconnectivity and mobility management are critical challenges for self-organizing and intelligent 5G networks.

Also, due to high mobility/speed of the vehicles it is bit hard to establish reliable and sustainable connectivity for long time, and it will affect the fair resource allocation and content delivery among/between vehicles/vehicles to road side units and infrastructure. The proposed joint green (i.e., energy efficient) and reliable approach (which adopts particular application selection, routing/processing, node's duty cycle, and modulation level monitoring at application, network, MAC and PHY layers accordingly) is important. In addition, a 5G-driven ITS architecture is proposed, because internetworking and interoperable features of 5G are the key enabler to intelligently allocate the resources among all the involved entities by properly managing the mobility, reliability in terms of received signal strength indicator (RSSI) or packet loss ratio (PLR) and interconnectivity in ITS.

Extensive experimental results reveal that our proposed hybrid method is the potential candidate to enhance the energy and reliability to end-user devices in ITS with slightly more computational complexity as compared to Baseline. In near future, internet of healthcare vehicles, i.e., smart ambulance prototype and stable self-adaptive wireless channel model will be proposed for emergency patients monitoring and their record maintaining to empower the notion of medical industry 4.0. The key difficulties and limitation we faced are mobility between IoT driven edge nodes, dynamic wireless link and interoperability due to heterogeneous transportation/vehicular networks.

Besides, bandwidth management, congestion control, and synchronization between vehicles are the key challenging factors at MAC layer. While high shadowing/fading in propagation model, channel selection and estimation are critical issues at PHY layer due to high speed/mobility of vehicles. Cost-effective and shortest route selection with high prediction and reliability are major limitations observed at network layer.

Disclosures

There is no conflict of interest between all authors.

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