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Improvement of 5G Transportation Services with SDN-Based Security Solutions and beyond 5G

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Abstract: The transportation industries forecast that by 2050 more than 50% of vehicles on the road will be autonomous vehicles, and automotive services will dynamically support all vehicles. All of them will be serviced using the latest technology, which includes the Software Defined Network (SDN) and available new generations (5G+ or 6G) at the time. Although many transportation services and rapid facilities are achievable dynamically, transportation services with automation and intelligent actions are still not mature because the legacy of transport services cannot be corporate with the 5G+. These expected problems can be improved through the following possible and manageable approaches: flexible framework of 5G automotive services from the legacy systems, designing energy-efficient and intelligent infrastructures with SDN, and managing security solutions that evolve with the emerging technology. An efficient model (flexible framework) is proposed to secure smart transportation services with a secure and intelligent connected system and security solutions based on the 5G concept. Although 5G is considered in this framework, the method and steps of design and solution phases will be adaptable to the 5G+ framework. Furthermore, the basic properties of SDN allowed us to design a novel approach for measuring data traffic related to transport services and transport management, such as the priority of the transportation services. With the emergence of 5G+ capabilities, transportation services expect more challenges through future user requirements, including dynamic security solutions, minimum latency, maximum energy efficiency (EE), etc. Future automotive services depend on many sensors and their messages received through secure communication systems with 5G+ capabilities. As a result, this theoretical model will prove that 5G capabilities provide security facilities, better latency, and EE within the transportation system. Moreover, this model can be extendable to improve the 5G+ transportation services.

Keywords: transportation; SDN; autonomous vehicles; 5G network; and traffic services

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1. Introduction

Fifth-generation (5G) capabilities are expected to handle users according to their requests, which could be services or applications. Handling different groups of users with their preferred transportation services requires efficient technology, providing low-cost and minimum energy consumption. Transport service developers have already started to use emerging technologies, allowing users to maximize the transportation facilities. Although electric cars and autonomous vehicles use efficient technologies, 5G and its emerging technologies will improve the users' features and the standard of services. The emerging technologies include 5G based on the Software-Defined Networking (SDN) and 5G based on the Internet of Things (IoT). Here, the SDN concept dominates in the improvement of traffic performance. Users' expectations of 5G and 5G+ are manifold, but the availability of the network is still delayed by heavy data traffic. This expectation depends on the channel capacity and transmission rate, which are some of the 5G requirements. Despite many expectations, users' devices should be able to use online services and applications without any delay. Using an efficient approach for Energy Efficiency (EE), the channel capacity and transmission rate need to be focused on managing the data traffic. In this research, heavy traffic and the search for solutions to enhance the uptime of the online services and applications motivated us to analyze the measurement and management of the traffic. Furthermore, the basic properties of SDN prompted us to design a novel approach for a transportation system because it configures and programs according to the priority of the services. In addition, its switching facilities provide many monitoring opportunities to manage and improve network traffic. Configuring network issues and parameters through the SDN is a programmable approach that simplifies traffic management.

Comparing the existing and our proposed frameworks, we have added adequate features which allow us to enhance transportation services with emerging technologies such as 5G+ based VCS (Vehicular Communication Services). Additionally, we considered integrating the connected and intelligent approach to security solutions as a new feature. In this integration, we kept the legacy features of the transportation system. For instance, we may add the instance viral monitoring system configured through the connected and intelligent system, including Cooperative Intelligent Transport Systems (C-ITS). This will guarantee the users' safety and security dynamically while users are traveling. High bandwidth and ultra-low-latency capabilities of 5G improve the accessibility and connectivity of VCS [1]. Regarding the C-ITS, 5G and 5G+ capabilities in VCS will be increasing the transportation services with proactive approaches such as security and Vehicle-to-Everything technology [2]. Although 5G capabilities partially support the VCS of the autonomous vehicles, 5G+ capabilities will allow us to improve the features of the VCS and users' requirements [3].

The rest of the current paper presents a scheme for managing traffic through the following sections: We present a literature review and related works in Section 2. After that, Section 3 provides a generic approach to new and emerging technology, which led us to innovate the novel transportation model/framework. Section 4 introduces the traffic measurements that are relevant to the 5G environment. We discuss the network and traffic management issues in Section 5. Traffic management in 5G and beyond is considered in Section 6. Additionally, it includes the latest challenges to traffic management. In Section 7, we summarize the points as conclusions and consider future work to develop a measurement tool for managing real-time data traffic.

2. Literature Review and Related Work

Traffic between the source and destination of the entire network is not necessarily the same because many devices such as switches and routers may change the pattern and characteristics of the traffic. Using SDN controllers in the 5G network communication systems simplifies the data traffic challenges such as minimizing delays and latency. This simplification allows us to manage the data traffic through the appropriate measurements and optimizations. With an efficient optimization algorithm, a selected data traffic path between the controllers and switches minimizes delays [4]. Although SDN is employed to control the data path in 5G systems, emerging technologies such as 5G based on SDN enhance the controllability and the reliability of the data path when the delay exceeds the limit.

According to [5], a Named Data Networking (NDN) innovation can be applied to efficiently handle content-based services in future 5G networks. All services depend on traffic management, which simplifies the services according to the users' preferences. Although NDN improves 5G networks, changing legacy networks will be a significant step for more flexibly and feasibly disseminating content. Regarding the implementation of NDN, the existing network infrastructure of the legacy systems needs to be modified according to the 5G requirements, such as energy efficiency. Although authors focused on efficient caching through stateful SDN in NDN [5], SDN will improve the management of the network traffic of vehicular communication and 5G-based transportation systems. These improvements minimize energy consumption.

2.1. Transportation with Future Technologies

Emerging technologies of transportation facilities have grown in many directions because users and service providers expect to adapt to new systems quickly. Legacy systems and adopting a new system without significant changes in infrastructures are a big challenge in transportation systems. All future infrastructures rely on 5G and beyond, but their network will be emerging with other technologies such as SDN, IoT, and photonics. Using these emerging technologies, transportation service provisions can minimize costs and energy consumption. When the appropriate technique identifies or removes the unwanted energy for the interferences from the 5G systems, energy-saving is possible. As shown in Figure 1, we illustrate the possible services of transportation that influence 5G cellular connectivity (5G-CC). According to [6], connectivity is one of the essential technical concepts for improving transportation services and infrastructure. The study of 5G-CC provides the best solutions with emerging technologies. It creates many challenges for analyzing Autonomous Driving Vehicles (ADV) and the future transportation system with an efficient framework.

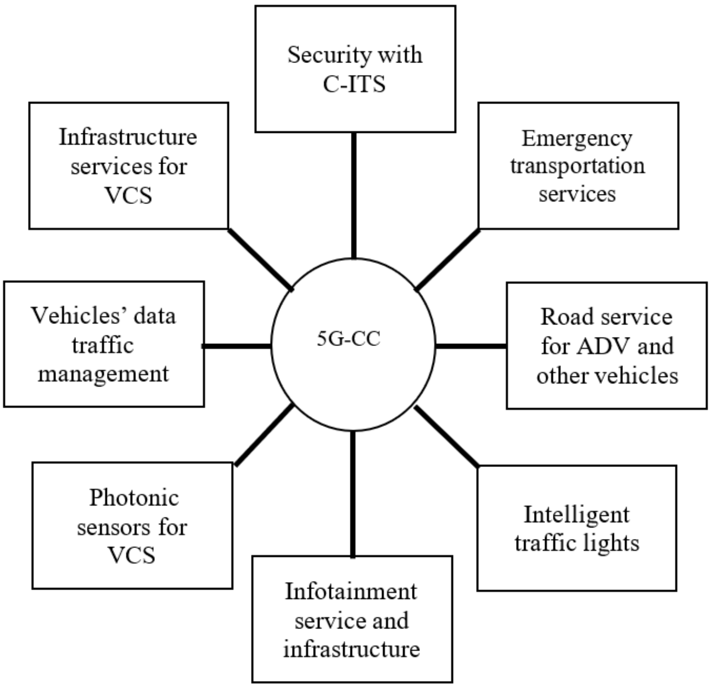

Figure 1. Transportation services with 5G cellular connectivity.

Infotainment (reports safety news such as an accident) services depend on efficient and secure data or text transmission from road service units to vehicle users. Here, all reliable transmission systems enhance the facilities of handling transportation services such as sending and delivering quick messages. Reliable transmission means that connectivity should provide the connections between the user and the service provider quickly and efficiently.

Future transportation systems need to absorb the energy dynamically with the necessary absorbing 5G-based sensors, including photonic sensors that have emerged with 5G technology [7]. This research delivers the EE and harvests the dynamic energy from the electrojet, which influences the ionosphere and photons. Further, EE with photonic technology will increase the reliability and lifetime of future communications systems.

Table 1 shows the different multiple accessing methods for enhancing EE, which depends on the latency. Thus, transportation service providers can improve the network traffic of the transportation service with minimum latency and delay.

Table 1. Benefits of 5G-based multiple accessing schemes.

Schemes	Requirements for Analyzing Data Traffic of the Transportation System	Overall Benefits for Improving Data Traffic
NOMA	Power allocations	High spectral efficiency
SCMA	Sparse coding schemes with non-orthogonal codes	More diversity
PDMA	Specific pattern division schemes with non-orthogonal codes	Efficient receiver with low complexity
MUMA	Legacy coding schemes with non-orthogonal codes	Better EE
BOMA	Building block sparse constellation	Simple and low complex receiver
LPMA	Multilevel lattice code	Power and code domain

In the 5G transportation service and infrastructure, multiple access provides some benefits for managing the data traffic of the transportation system.

2.2. Existing Transportation Services with SDN

According to [8], traffic management involves lightweight data, which may be around 40 bytes. Lightweight admission control and traffic management with SDN allow the service providers to improve the traffic of lightweight data, such as monitoring at the data plane. The measurement and classification of smart systems during the data traffic over 5G mobile networks should be considered carefully with the efficient algorithms [9]. Existing transportation services use a legacy system with the basic concept of SDN. When SDN technology grew with a new programmable control layer, transportation service providers enhanced the services through efficient network configurations.

According to [10], traffic engineering (TE) solutions with SDN provide efficient traffic management according to the situations. Instead of using a fixed weight setting of routing algorithms, a dynamic weight setting allows the service providers to improve the traffic performance and network management. Traffic measurements considered in the network applications are a prerequisite for traffic management. Despite many traffic models, traffic measurements are dynamically monitored using the SDN concept, which enhances the monitoring facilities and manages and controls the traffic systematically. Anteater's status detection tool [10] provides traffic measurement facilities through the traffic prediction of SDN static analysis.

2.3. Network Traffic Issues with SDN Based IoT

Billions of IoT devices depend on IoT services influenced by traffic management within the wireless and 5G mobile network environments. Although many SDN architectures are available for service handling, future SDN-based IoT systems will provide better services.

The IoT devices exchange the data for transmitting necessary information when different networks merge with the IoT environment. Although 5G IoT provides new challenges and IoT solutions as given in [11], IoT-based 5G networks are being developed to improve services with efficient data traffic management. Thus, modification to IoT applications within future IoT-based 5G networks is possible. Therefore, promising IoT applications must consider the available traffic managing schema to follow enhanced network resources by keeping the delay of services at the minimum rate. The massive amount of data gathered by IoT devices and sensors, etc., need an efficient management technique to improve the communication performance in future smart cities [12]. Despite the self-organizing technique for handover processing, the authors suggested intelligent traffic management. According to [13], relay selection procedures increase the data rate of communication in the IoT. As far as the traffic between the IoT terminals is concerned, traffic management depends on many problems, such as IoT terminals facing inter-cell interference. SDN provides programmability, controllability, flexibility, and management despite billions of objects in the IoT network. Here, the authors analyzed IoT applications and generalized IoT-SDN solutions, which simplify the application of wireless capabilities and improve performance.

2.4. Ways of Network Traffic Measurement

Although measuring network traffic flow within the specific application is the same, different types of data and channel conditions, etc., vary the data rate and other aspects of performance such as delay.

According to [14], managing communication resources with minimum latency requires a new technique. Although 5G requirements support system resource management, achieving better latency is difficult because of growing communication capacity. The authors proposed a novel architecture with the cognitive engine and data engine, which influences resource cognitive intelligence. In this architecture, latency can be improved through computing, caching, and communication strategies.

Mobile data traffic is increasing with mobile users, but managing dynamic data traffic and network planning requires an intelligent solution [15]. Designing a cell association and traffic-offloading algorithm in real-time traffic measurement may be the ultimate solution for improving traffic problems.

Cognitive radio network architecture enhances the network traffic facilities and the quality of service (QoS) when service providers deliver the variable data traffic and channel conditions [16]. Artificial Fish Swarm Algorithm (AFSA) is a new intelligent optimization algorithm suitable for solving large-scale complex optimization problems when we consider the data traffic among the billions of IoT devices in 5G environments. Using AFSA, the traffic and link capacity of crowdsourcing tasks such as the services of IoT devices can be optimized intelligently [17].

2.5. Intelligent Approach to Secure Solutions

There are many transportation services in 5G applications, such as driver safety. Although methods of measuring network traffic flow based on the transportation services within the specific application are the same, different types of data and channel conditions, etc., vary the data rate and other aspects of performance such as delay. Connected and intelligent transport systems based on 5G will continue to rely on ubiquitous broadband connectivity. Future public safety of transport services depends on the emerging technology based on 5G and beyond. Our proposed framework enhances the required services through the connected and intelligent system. The novelty of the framework is that maximizing the secure services with minimum cost depends on the energy and complexity of the overall technology. When the end-users in the transport sector define future requirements and solutions, this novelty will be maintaining intelligently and proactively with the emerging technologies. The transport system may enhance their existing feature or add entirely new features in future services. Using a lower band of spectrum (THz) for limiting the frequencies through 5G+ allows us to utilize the intelligent reconfigurable system in future transport services.

The collaborative 5G-based spectrum management and sharing and artificial intelligence (AI) enable the transport sector to improve its services. Using connected and intelligent systems, future Intelligent Transportation Systems (ITS) services become more cost-efficient, secure, and sustainable. Due to new requirements arising in ITS, traffic efficiency is one of the challenges during the safety management of the transportation system. Safety-related data often require Ultra-Reliable and Low-Latency Communications (URLLC). For instance, the infotainment category with sensors (vehicle-as-a-sensor) requires high data-rate connections between vehicles or between vehicles and the cellular network at high vehicle speeds and dynamic interference conditions [18]. To improve the 5G+ transportation system, the URLLC enhances the rate of the VCS of the ITS and C-ITS. Despite the recent and ongoing enhancements to 5G+ transportation services, this paper [18] supports us to create the mathematical formulation for the intelligent value obtained from the user data traffic and other network parameters such as rate considered in the transportation services.

3. A Framework of 5G Transportation

This section presents the appropriate framework of 5G transportation, which provides transport systems with high-quality services, maximum security, and low cost. Users expect more services and applications with the best and low-cost (energy-efficient) frameworks despite the many frameworks. Additionally, 5G enable more services and applications with the better complexity limitation. However, the limitations of the potential frameworks used in the 5G environments are still slowing down the flow of transportation services. Further, a large volume of unexpectedly heavy traffic prevents regular online services and applications from the providers. Accessing online requests and internet services according to users' preferences and priorities is possible through the frameworks, which manage the network traffic and improve traffic performance.

As shown in Figure 2, the proposed framework provides the necessary facilities for improving the different types of services considered in the transportation system. Here, solutions to the future challenges and potential problems of the transportation system are the main features considered as facilities. Although many existing traffic models, such as the data traffic aggregation and the data traffic slicing models, are available, this section focuses on traffic approaches using SDN. When the application layer of SDN holds the transportation services, the management issues of the data traffic used in the transportation system improves. Controllers are the brain of the control layer of the SDN, which organizes the data traffic according to the technical properties.

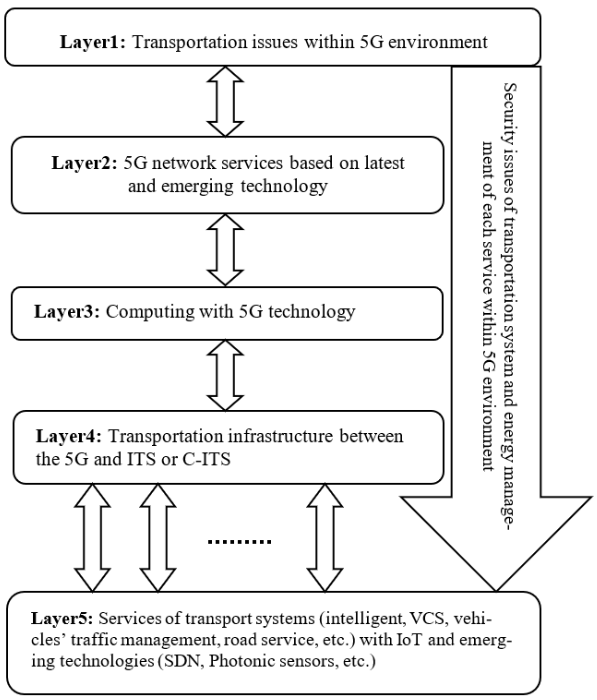

Figure 2. A framework of 5G transportation service.

The basic properties of SDN support us to improve 5G-based transportation services in which the traffic measurement related to transportation services and transport management are considered. The proposed framework's novelty of the 5G-based designs with emerging technology such as SDN improves transportation services. Considering its novelty, the proposed framework is adaptable with many factors which evolve with technology requirements and users' priorities. They are intelligence within the transportation services, ITS of autonomous system and self-driving in connected vehicles, proactive approach of security solutions, etc. Adapting these factors' influence to the novel approach is possible through the layers shown in the flexible framework of the transportation service (Figure 2).

3.1. A Proposed Framework

A framework for 5G transportation services should be able to take new limitations such as EE. According to this research, the proposed framework provides the necessary features to handle the present and future limitations with 5G+ requirements. Multiple Access (MA) allows the data to be distributed according to the users' preferences/priorities and transmitted concurrently between the users and service providers. In some situations, users also can be called potential service providers. For instance, broadcasting services such as audio and video provide multiple programs to different users according to their preferences.

Data traffic is increasing with some users, and devices need an intelligent traffic management system that provides data traffic according to priority through the control system of the SDN technology. According to [19], softwarization handles the data traffic in a programmable approach, allowing users to manage their data whenever they want. In addition to this, the flexibility and reliability of the system's operation simplify users' potential challenges, such as the speed of browsing during peak times. Network data management and softwarization increase end-to-end reliability, which improves traffic performance such as speed. Emerging 5G systems and applications can handle maximum data traffic when the transportation system employs multiple radio access technologies.

The novelty of the proposed framework depended on the intelligent approach of the security solutions to improve the intelligent features of ITS in the connected vehicles. An enhanced version of the future transportation services should monitor the safety and deliver the appropriate security solutions dynamically. Although sensors dominate the controllability of the features in transportation services, connected and intelligent systems based on AI configure the features dynamically. As an extra feature, AI-based security solutions, ITS of autonomous driving in connected vehicles, and intelligent navigation dynamically provide proactive services. Additionally, the ITS allows transportation users to reduce the waste of time and energy by optimizing routes, reducing congestion, improving vehicle and driver performance, and promoting better management of the transportation system.

3.2. Modeling Framework for Self-Driving

Although modeling network traffic is expected to have the above properties, basic MA based on SDN enhances access to the management of network traffic. In this research, a modeling framework for a 5G transportation service (F5TS) allows the users to handle self-driving vehicles with minimum operational functionalities. Further, the measurement of the F5TS allows service providers to handle and manage the dynamic network traffic. In the proposed framework, the following modules offer the necessary functionalities of SDN-based MA and enhance the transportation services. These are SDN-based MA functionalities and network configurations. Figure 3 shows the management issues of transportation services and infrastructures. A transportation system depends on excellent management, which deals with the priority of emergency services, handling data traffic (small, medium, and large data packets) during vehicular communication, and minimizing energy consumption. This model can handle real-time data traffic, such as the data traffic from vehicular communication. Furthermore, priority users ($\mathbf{P_u}$), load users ($\mathbf{L_u}$), energy users ($\mathbf{E_u}$) and security users ($\mathbf{S_u}$) are examples of the management issues considered in the transportation system. These issues rely on the excellent services and infrastructure of the 5G transportation system. Here, the process of network traffic management depends on the traffic management protocols and the functions of SDN, and the preference of users' conditions and demands.

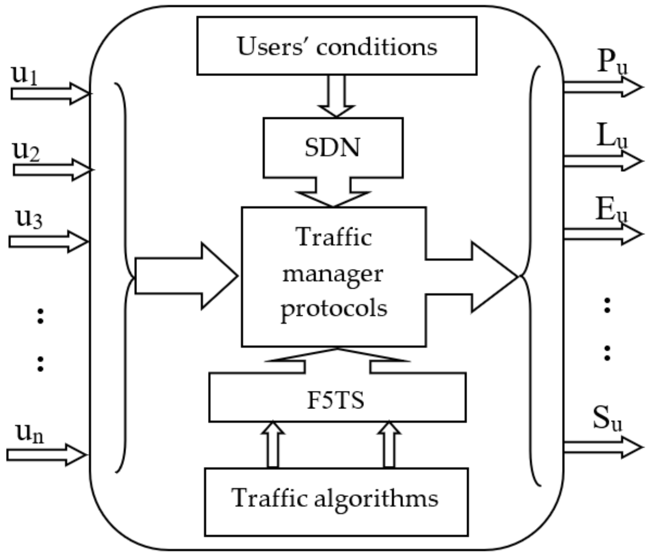

Figure 3. Managing issues of transportation services and infrastructure with F5TS.

In this F5TS, accessing functionalities provide some additional management facilities such as prioritization and intelligent systems. The focus of F5TS is to improve the flexibility and availability of services facilities with maximum security. The complexity of infrastructure defined within the 5G-based transportation system can also be simplified in F5TS. Simultaneously accessing many transportation services is not easy when the number of users within the square kilometers increases. However, F5TS improves the performance of a transportation service using the low-complex infrastructure of 5G networks and protocols. A data transmission protocol between users or service providers or users and service providers depends on the flow and modeling of network traffic. Hence, modeling network traffic with SDN-based MA needs to be considered in 5G environments. In this model, the following properties enhanced the network traffic flow according to the users' wishes:

1. Accessing multiple flows of traffic.

Provided by the MA protocols and algorithms regarding the data traffic management.

2. Priority of traffic.

By increasing the configuration features, different versions of orthogonal multiple access (OMA) and non-orthogonal multiple access (NOMA) schemes allow us to configure the priority of the traffic.

3. Dynamic traffic.

All real-time transmissions depend on the dynamic traffic, which needs to be programmed dynamically using SDN concepts to analyze the quality and quantity of the traffic.

4. Intelligent traffic.

Using the SDN controller and its programmable approach, intelligent traffic minimizes energy consumption and increases energy efficiency. Intelligent transport system using a software-defined network (SDN).

An intelligent transport system using SDN enhances the control of the automation programmability functions when users need more services. Transport service providers also update the services securely with multiple SDN controllers. Further, SDN-based 5G+ technology allows the service providers to handle multiple services with minimum energy cost.

3.3. Functionalities of the Framework

The transportation system has multiple services with many functions and features. Multiple functions dominate the 5G-based MA because many different communications provide the services to users. For instance, vehicular communications such as UAVs (Unmanned Aerial Vehicles) and drones handle many services and applications.

Table 2 shows the expected functionalities of generic MA, the measurement details of transportation services for managing the data traffic influenced by vehicular communication used in Autonomous Driving Vehicles (ADV). In these selected scenarios, enhanced Mobile Broadband (eMBB), massive Machine-Type Communications (mMTC), millimeter-wave (mmWave), Ultra-Reliable Low-Latency Communications (URLLC), IoT, relay, Long-Term Evolution (LTE), WiFi, and Vehicle-To-Vehicle (V2V) were considered. Semiari et al. [20] explain the integrated mmWave–microWave communications and introduce the Ultra-Reliable Low-Latency Communications (URLLC)-aware frame structure. Although mmWave communications alone may not provide enough support, the integrated version improves wireless communications' future challenges. Due to the spectrum scarcity, existing wireless networks do not allow researchers to enhance the requirements of future services. However, this integrated version not only enhances the basic requirements but also provides high-speed communication.

Table 2. Expected functionalities of 5G MA in selected traffic scenarios.

Selected Scenarios	Expected Functionalities of 5G MA	Measurement Details of Services Used for Managing the Traffic of Transportation
eMBB	Large network capacity High user density Uniform user experience Easy multi-user multi-inputs multi outputs (MU-MIMO) Mixed traffic types of transmission Highly efficient small packets transmission	Power Bandwidth, spectrum Uptime, availability EE, spectral efficiency, etc. Rates, packet details, etc. Packet size and rate details
mmWave	Degree of multi-connectivity	End-to-end round-trip latency, inter-site distance
mMTC	Massive connectivity Highly efficient small packets transmission	Complexity, scalability Packet size and rate details
URLLC	Ultra-low latency transmission Ultra-high reliability transmission Highly efficient small packets transmission	Accuracy of latency Lifetime, EE Packet size and rate details
IoT	Massive connectivity	Complexity, scalability
Relay	Higher fidelity by jointly processing Extended coverage	Signal to noise ratio Power and some users
LTE	Connectivity	Adequate power control
WiFi	Connectivity	Fixed-power transmissions
V2V	Lower collision probability Higher resource utilization	Power and secrecy Complexity, EE, etc.

According to [21], a smart BH solution depends on millimeter-wave (mmW) technologies because this emerging approach allows researchers to enhance the communication requirements of the outdoor urban small cells and 5G cellular spectrum.

4. Traffic Measurement with SDN

Although many different types of network traffic occur in a transportation system, traffic measurement for monitoring all transport data should be improved when the service provider employs SDN. To manage the specific traffic measurement, considering each link of the system individually will be improving the accuracy of measurement when using SDN. For instance, the data traffic of the transport system has many links, such as the data between the user and service provider, the data of the speed check, the data of signals, etc. For measurements, each system can use some network parameters. Within the transportation system, data management depends on reliable network communication channels. With the SDN, F5TS allows the users and service providers to handle the measurement of the traffic load used during the transportation service.

Traffic measurements depend on the latency, jitter, and packet loss, which need to be considered during the data transmission. Packet loss may happen in many ways when users exchange voice or text messages.

4.1. Measurements with Network Parameters

The network parameters allow us to see the status of the network in various conditions, applications, etc. Despite many network parameters such as topology, traffic, and performance, we focused on network traffic parameters. Designing such parameters with an SDN-based MA improves the network measurement and network traffic monitoring, which encourages service providers to measure the status of traffic flow continuously. Network traffic parameters depend on the number of packets per second when packets pass through the network components such as network ports. The parameters used in the network traffic allow us to investigate the behavior of network users who use different types of services and applications. Regarding the SDN, data and control traffic are essential for the configuration of the measurements. Although the data traffic of the SDN is between the switches, the traffic flow's characteristics depend on the statistical information collected from the switch port. Control traffic of SDN occurs between a specific SDN controller and switches or many SDN controllers and switches. To measure traffic flow between any two nodes, statistical information such as packet size and packet rate is used with the delay of the end-to-end traffic matrix considered between the two nodes assumed as the entire network.

As shown in Figure 4, the solutions for transportation services provide the limitations of the energy consumptions, which depend on the users. Although these measurements give predictions of the services and reliability of the infrastructure, data traffic can be simplified through the F5TS, which depends on the version of the emerging technologies. All applications and services rely on traffic flows, which may be categorized to manage the traffic. For instance, priority is one of the traffic management procedures, so the priority of the traffic can be categorized according to the time and situation. Here, transportation deals with efficient data traffic management, which handles the network data traffic intelligently and dynamically.

Transportation services and infrastructure involved with 5G provide better measurements depending on the latency, bandwidth, connectivity, EE, and throughput. Solutions for the transportation system depend on these measurements. These 5G requirements are considered to be measurements for improving the solutions of the transportation system.

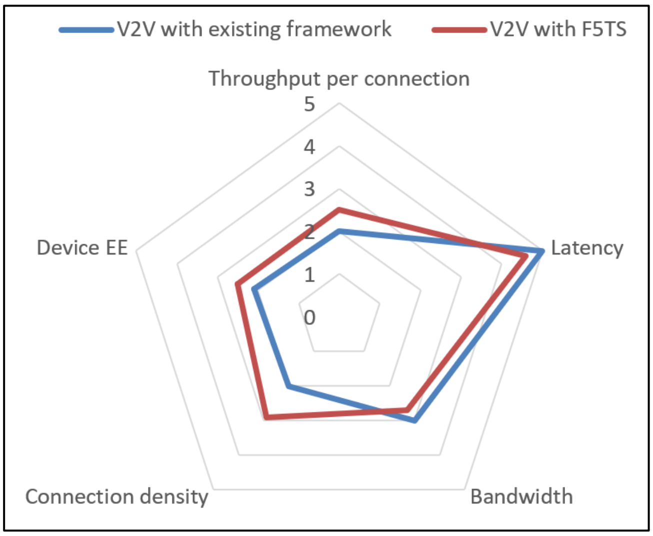

Figure 4. Solutions for transportation services.

4.2. Generic Measurements of the Framework

Although F5TS consists of SDN and other modules, finding traffic that passes through the switches was considered. Here, SDN plays a major role in improving the transportation system's data traffic monitoring and measurement. Generally, network traffic depends on User Datagram Protocol (UDP) traffic and Transmission Control Protocol (TCP) traffic. Within the SDN layers, the number of traffic measurements needs to be considered for the configuration of network traffic management. In the control layer, the processing time of the End-to-End (E2E) delay is the duration of the total delay between the starting and endpoints. Measuring E2E delays influence the traffic flows of TCP and UDP, which are two different types of traffic measured carefully for managing traffic. In this measurement, the functions of the SDN-based MA support the optimization of the processing time of E2E delay.

In the data layer of SDN, the transmission time and waiting time dominate in the E2E delay calculation that measures the characteristics of the traffic. To improve the measurement, optimizing the transmission and waiting time depended on the design of the algorithm and protocol should be considered in the F5TS. The measurements used in an intelligent approach and security solutions allow transport operators to enhance QoS. In the future, novel QoS prediction techniques will be useful in driverless and drone transport use. Applying this technique to F5TS, users will have efficient and secure services through highly reliable communication links with appropriate QoS characteristics as demanded by ITS services. In this measurement, AI can also play a meaningful role in determining when to perform a certain autonomous task in the vehicle in an efficient manner. The QoS prediction can also be used to predict the most economical time for a software update as a proactive service. Interestingly, in many cases, including certain C-ITS and telematics applications, these performance fluctuations are not a problem if they can be predicted in advance. The real-time QoS predictions enhance the proactive security solution for protecting the services intelligently. This would allow service providers, mobile network users, and automotive applications to dynamically adapt their behaviors to the prevailing or imminent QoS level in the automotive industry.

This paragraph presents the mathematical formulation of finding intelligent value to clarify the conditions in which it works well. Since data traffic has many characteristics, we present the mathematical formulation for selected or stationary traffic. This formulation is also applicable to real-time or nonstationary users ($\mathbf{P_u}$ or $\mathbf{L_u}$ or $\mathbf{E_u}$ or $\mathbf{S_u}$) traffic. In the framework, all delivered data of the user packets in the network are compared with predicted data of the packets. Thus, we consider an error approximation of user traffic; that is, user packets are approximated as an error. Suppose that a traffic path in the network is shared by $\boldsymbol{K}\ (>1)$ users. Let $\boldsymbol{D_k(t)},\ \boldsymbol{t} = 1,\ 2,\ \ldots\ \boldsymbol{K}$, denote the cumulative amount of data transmitted by user k observed during the selected time. In this mathematical formulation, $\boldsymbol{D_k(t)}$, can be considered as delivered or predicted data.

In the mathematical formulation, the calculation of QoS allows us to improve the service, including ITS and other intelligent features of transportation services depended on the accuracy means minimum or no error ($\boldsymbol{e}$ = 0) calculated from (1) [18]. Intelligent value is inversely proportional to error as in (1) because when errors increase during the calculations of QoS in any of the data of ITS, intelligence decreases over the period ($\Delta \boldsymbol{t}$). Here, all delivered and predicted data are time-dependent.

$$\boldsymbol{Error}(\boldsymbol{e}) = \frac{\left|\boldsymbol{D_{del}}(\boldsymbol{t}) - \boldsymbol{D_{pre}}(\boldsymbol{t})\right|}{\Delta \boldsymbol{t}} \tag{1}$$

To maintain the QoS level dependent on the delivered ($\boldsymbol{D_{del}}$) and predicted ($\boldsymbol{D_{pre}}$) data, the ITS will continue to rely on ubiquitous broadband connectivity, an efficient 5G network, and reliable infrastructure. Additionally, QoS depends on bandwidth, packet loss, and the rate of request data (frequent, confidential, etc.). For instance, intelligent content delivery over wireless via SDN depends on variable or dynamic bandwidth. It investigates the network and packets by sending and receiving a point. Measuring error with a dynamic bandwidth is a challenge that enhances the intelligence in transportation systems.

$$D_{pre}(t) = \mathbf{F} \times D_{pre}(t) + \mathbf{n} \tag{2}$$

Here, $\mathbf{F}$ is the transition matrix from $(t-1)$ to t, $\mathbf{n}$ is the added noise that varies with the communication channel. In the prediction stage, the state of the ITS with uncertainty at the time, t, is estimated from its previous state at the time $(t-1)$.

4.3. Traffic Prediction

Although measuring traffic prediction is responsible for predicting the future situation of the traffic from the previous characteristics of traffic flow, measuring real-time traffic is better than traffic prediction. Previous traffic characteristics of specific applications or services allow us to organize future traffic plans such as contingencies and scheduling. Using SDN technology, many researchers have investigated the influences of prediction and optimization. In this research, SDN-based MA supports improving traffic prediction through the appropriate protocols, which enhance the MA capacities. Anteater provides the traffic measurement, which depends on the traffic prediction measured through the SDN static analysis. The network validation tool was also considered for predicting traffic depending on monitoring the errors in the OpenFlow applications. However, the authors of [22] studied traffic using another model. Therefore, they considered traffic prediction in resource allocation. Additionally, they studied end-to-end delay and bandwidth with decreasing packet loss. Although many valuable comments are related to traffic, digital techniques that monitor the priority of the transportation services and vehicular traffic management within smart cities enhance the intelligence and QoS of the ITS. Techniques based on ITS minimize the overall cost through energy-efficient architecture emerging with 5G technology, prioritized security management of transportation, and vehicular communication services.

Automation facilities are continuous services in plans such as the timing of transportation services and the priorities of electric vehicles. To minimize the overall cost and energy consumption, the timing of each transportation service should be automated with programming, which provides the automation time intelligently. The priorities of electric vehicles depend on the user's program, such as emergency cases and long-distance traveling. For these priorities, electric vehicles need continuous charging facilities. Here, the legacy system allows us to improve the possible modifications and facilities. Some electric vehicles already have systems for charging facilities. In this case, introducing new or upgrading the software design will provide automation facilities. In some cases, auto manufacturers may have to extend the hardware from an existing system.

Risk predictions depend on the reliability of vehicular communication and transportation services. Reliability shows the efficiency of the services and proves that the lifetime of the transportation system maintains a guarantee period without any system faults. Regarding ADVs, the following risk predictions can be considered:

- Driverless vehicles face many different objects, which are not in the programmed list.
- With natural weather conditions, smart environments should be secured for 24 h and seven days. These environments will be the best when service providers maintain risk prediction systems.
- Emergencies depend on many unexpected problems created by many risks, such as human errors.
- Energy management provides energy according to the needs of the electronic devices used in driverless vehicles. Here, the risks are the reliability of the devices because the failure of devices causes many problems such as accidents.
- Cybersecurity is one of the potential issues created by risks, such as the failure of electronic components used in driverless vehicles.

These risks need to be predicted for minimizing human errors and mistakes, which form security problems such as threats. Further, combinations of all these risks allow cyberattacks indirectly within the transportation system.

5. Transport Management with SDN

As shown in Figure 5, data traffic management depends on traffic measurements, which influence the characteristics and functionalities of the traffic flows.

Despite the many measurements in network traffic problems, all of these need to be managed according to the specific situation and conditions. In these problems, F5TS provides many facilities to manage network traffic with SDN technology and concepts. Traffic management depends on the traffic flow measurements considered between the nodes, which could be anywhere within the entire network. This ensures that all network components are in working condition and that the network is available to all accessing users. Further, this maintains the network performance through the SDN-based MA, which reduces the overall implementation complexity and improves the performance. The management of traffic varies according to many factors, such as applications, services, and environments. Further, measurements of 5G-based traffic depend on emerging technologies.

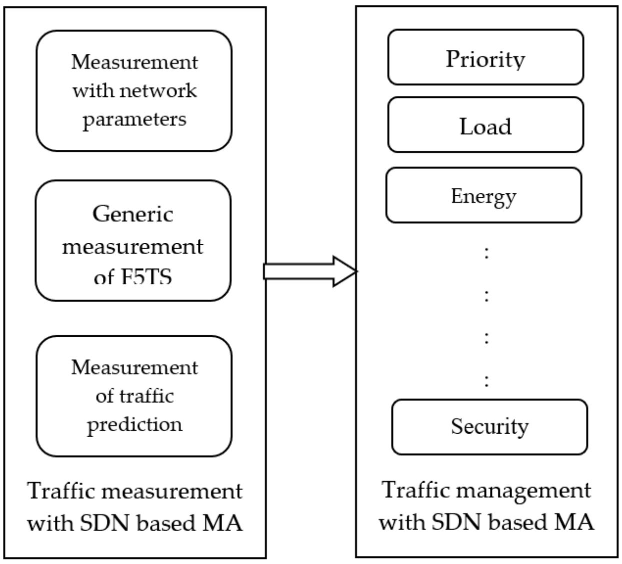

Figure 5. Managing vehicular data traffic within 5G environments.

5.1. Traffic Priority

Increasing heavy traffic needs to be organized using efficient traffic management. Some services, such as medical services, depend on traffic prioritization, which is the organization of the traffic according to priorities. Although many traffic management algorithms are available, the SDN-based MA and its functional requirements allow 5G users and service providers to improve traffic priorities.

5.2. Traffic Load

The use of traffic in the control and data layers in SDN is significant for the distribution of traffic according to the load. In SDN, the forwarding of decision-making is centralized with the appropriate load balancing. Splitting traffic loads at the package level rather than at the flow level is better for traffic management.

Another work has been proposed as a Quality of Experience (QoE) using the SDN-controlled framework, as shown in [23]. However, the authors studied SDN traffic control using another approach. They studied TE in terms of TE management, which is implemented through traffic load balancing, Quality of service (QoS), EE scheduling, and traffic management in an IP/SDN network. Secondly, they used TE measurements and have focused on the application and network layers. Nevertheless, the authors of [24] proposed a new architecture for supporting spectrum management in heterogeneous wireless networks in 5G environments.

5.3. Energy-Saving Based on Traffic

One of the main challenges in traffic management is energy saving. Managing traffic reduces energy consumption and increases the lifetime of the devices used in the 5G and existing network. The use of an SDN-based MA for managing traffic should consider specific services or applications and energy-saving, which reduces the cost of the public services and applications.

According to [25], recent research on EE using NOMA within the 5G environment seems to corroborate existing theories. This research used the density function of channel gains, outage performance, and ergodic sum rate with basic theories to improve the EE. In the future, 5G users can justify the claim that a given 5G system is set with an ergodic sum rate; thus, this proposed approach based on these theories will explain why EE is increasing.

Despite many modulation schemes, employing a novel quadrature space-frequency index modulation in 5G wireless communication will increase the EE and the data rate without any extra cost of energy [26]. Further, this approach can be employed to improve the satellite channels and communication when future 5G wireless systems are deployed in satellite modems.

According to [27], satellite links and communication require a reliable system with optimal latency and minimal energy consumption. Here, the authors presented a simulated annealing and clustering hybrid algorithm (SACA) to enhance reliability and achieve minimum latency.

Future 5G+ networks are expected to have a simple and manageable traffic model that should measure the various properties of real-time traffic with maximum accuracy and minimum initial conditions [28].

5.4. Security Based on Traffic

Security issues are growing with the increasing number of services, applications, and users. Anomalous traffic is also threatening most of the potential and future networks. Managing traffic will detect anomalous traffic and provide appropriate solutions to secure the network.

An example can be seen in [29], where they focused on a mechanical approach to SDN in 5G networks. Additionally, they studied the currently proposed systems and then explored the high demand for the future. However, they focused on the results of SDN in network security. According to [30], service providers try to reduce the cost of the data traffic while preventing unwanted traffic such as DDoS attacks. The authors proposed a new approach to improve the network services, which depends on the mobile backhaul SDN.

Anomalous traffic damages services and applications randomly. Hence, this anomalous traffic should be detected from previous traffic patterns that provide the details of traffic prediction. Thus, SDN-based MA supports the detection of anomalous traffic and protects future traffic systems.

5.5. Intelligent Security Solutions

Security solutions need to be proactive because ITS set up the necessary protection services and facilities according to on-coming security alerts. In order to create an intelligent security solution, SDN involvement allows the transport service creators to simplify the ITS configurations without losing legacy systems and software.

Table 3 provides the tentative security solutions for securing the ITS when the error (e) changes with different data ($\mathbf{P_u}$ or $\mathbf{L_u}$ or $\mathbf{E_u}$ or $\mathbf{S_u}$) considered in the traditional and SDN environment. Using (1) and (2), security, which is proportional to intelligence value, can be maintained for different ITS levels. When we considered the different ADVs, the security increased with decreasing error. Some automated functions with drivers, both automated and manually operated, condition automation within a limited time, and fully self-driving cases are considered in four ITS levels, respectively.

Table 3. Security with traditional and SDN environments for ITS-based ADVs.

ITS Levels	Traditional e > 0.05	SDN E = 0.05	SDN e = 0.005	SDN e = 0.001
Driver-assisted ADVs	20%	35%	40%	50%
Partial ADVs	30%	40%	45%	55%
Limited condition ADVs	35%	45%	50%	60%
Full ADVs	25%	40%	55%	70%

Table 3 is completed for managing the data traffic related to the transport services. Intelligent security solutions of ADV rely on predictions and proactive notes which depend on future security attacks. To maintain transport management, intelligent security solutions should be designed with the evolving VCS and emerging technology. When an error is decreased, the best intelligence can be maintained proactively. Still, it is a trade-off with the EE because it will be very expensive to prevent or detect attacks intelligently and proactively. The design complexity of intelligent security solutions and the cost of energy consumptions will be very high.

6. Transportations in 5G and Beyond

According to the future autonomous vehicles, solutions and challenges are increasing simultaneously with the future emerging technologies that focus on 5G and beyond.

6.1. Solutions

Users and service providers expect to have many solutions for improving transportation services. Although transport solutions depend on technical, business, and political aspects, this section explores the limitations of emerging technologies and technical capabilities of transport solutions. In this section, the following issues will enhance transport solutions.

The EE of all technical devices requires risk monitoring and confirmation of whether these devices are in working order. When these devices lose reliability and have a decreased lifetime, many connecting components linked with these devices create security issues. Therefore, the calculation of EE is very important for monitoring energy levels and power failures. When energy continues with the same energy level, the reliability and EE secure the components and necessary devices.

Although EE is one of the 5G+ requirements, energy cost increases with the designs and other factors. As shown in Figure 6, by using intelligent techniques with the emerging SDN technologies, service providers can improve the EE with efficient framework designs.

Latency not only reduces the delay but also improves the speed of the processing. This means that the timeframe for risks to occur is much smaller for those who deliberately want to attack. Regarding the emerging technologies, future transportation solutions will be dependent on these 5G+ technologies. These include SDN-based 5G networks, IoT-based 5G communication networks, and IoT sensors based on photonic technology.

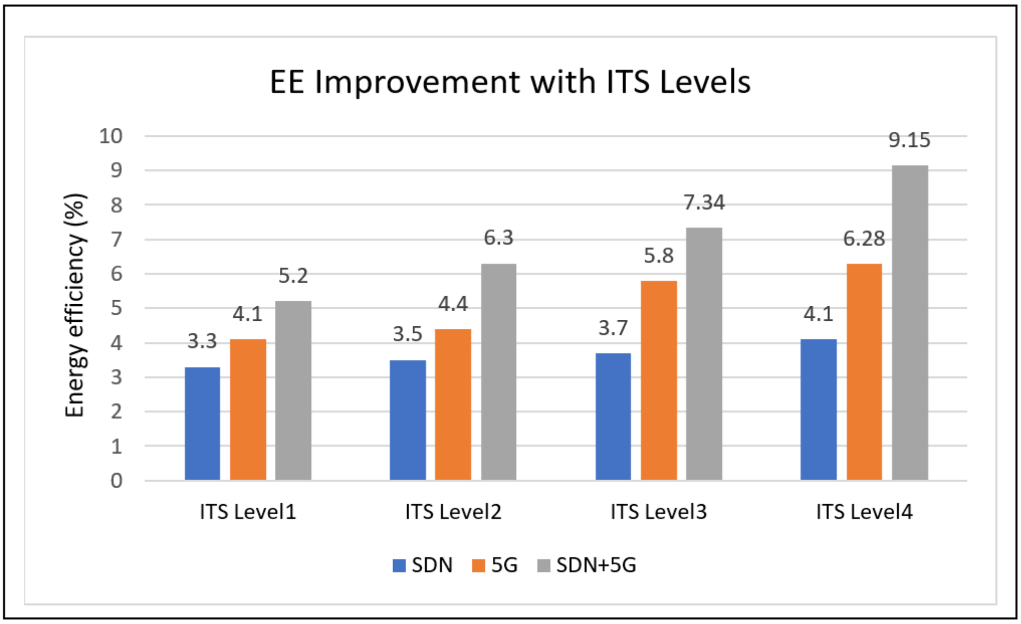

Figure 6. Comparison of EE with the levels of ITS.

When the levels of ITS are set with the emerging technologies, latency (Figure 7) is improved with the complexity of algorithms focused on ITS levels. Despite the complexity, ITS Levels depend on many factors, including traffic management with SDN-based MA, as in Figure 5. The secrecy rate of 5G+ and 6G communication will be future challenges in emerging technologies. This can be improved through the efficient design of a framework which focuses on an improved plan of EE and latency.

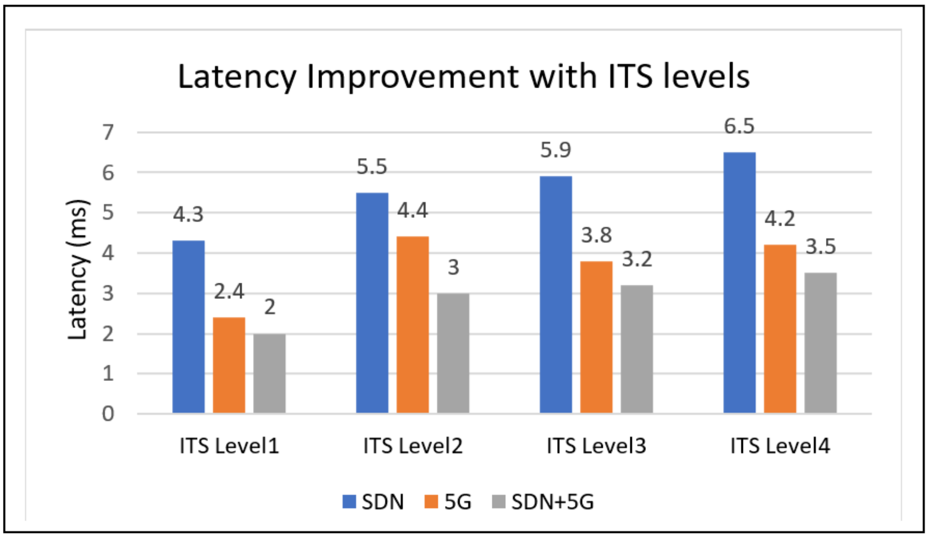

Figure 7. Comparison of latency with different levels of ITS.

6.2. Challenges

With 5G and beyond, energy-efficient management will be a significant challenge. Traffic monitoring, analysis, and measurement are some concepts considered when femtocells are employed in 5G networks [31]. Different traffic models, such as dynamic and static models described in [32], allow us to develop a new approach that provides efficient traffic management. Although many challenges encouraged us to explore the traffic modeling used in IoT-femtocell-based applications, some of them involved accessing technologies such as dynamic spectrum access.

Managing data traffic within 5G environments is increasing with many internal and external factors. Furthermore, it enables an easier mechanism of quality of service for large applications through 5G networks.

Photonic technology in the transportation system will open many challenges and benefit users and service providers. In autonomous vehicles, energy-saving and the involvement of sensors for safety and security are potential problems. When many vehicles are on the road, eye safety, rays' interferences, and security issues are problems created by the existing sensors. Here, photonic technology includes Optical Phased arrays (OPAs) and photonic integrated circuit (PIC) technology allows transportation service providers to face the challenges mentioned above. In particular, OPA improves EE and energy saving with an appropriate design using silicon. Using photonic technology, PIC enhances eye safety because the shorter wavelength of this approach reduces rays' interaction.

The upcoming formations about the 5G domain can anticipate the innovation and extensive integration of small cells. These cells are mobile telephone nodes that require minimal power consumption, ensuring optimum utilization of the frequency inside the finite region while enhancing bandwidth efficiency, which is one of the measurements considered in network traffic performance. The reinforcement of bandwidth efficiency bars any further increment to the range results in the rapid expansion of condensed networks amongst numerous interconnected IoT devices [33]. Figure 8 shows the security issues and future challenges related to the 5G+-based VCS and ITS.

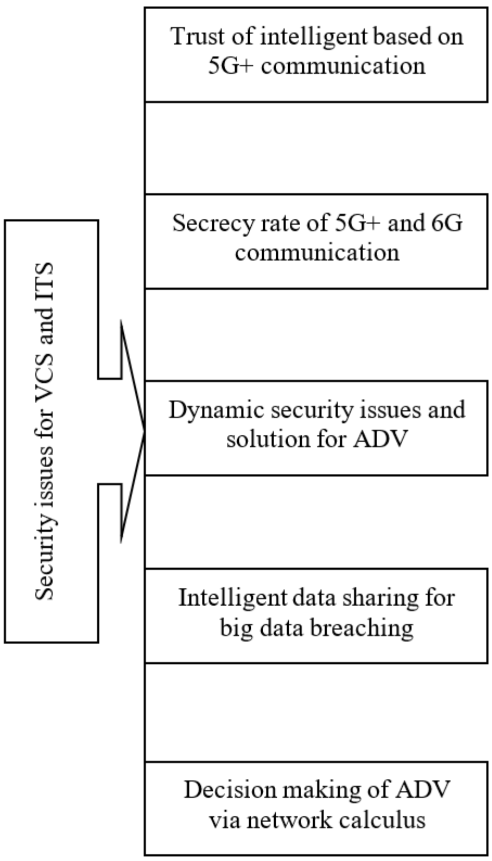

Figure 8. Open research challenges.

5G networks promise to offer enormous services to various users. However, this promise results in more network requirements. Although 5G requirements allow us to handle more traffic, all types of network traffic are increasing with the number of users [34]. Thus, it is necessary to maintain the network's resources to satisfy the unlimited growth of 5G networks. However, there is no complete standardized definition of the

5G requirements, but valuable efforts have considered 5G issues such as those in [35]. However, this has led many researchers to discuss the significance of traffic management schemas. Thus, some have studied the use of SDNs, such as [36], for traffic issues, where they used different controllers for managing traffic, especially for WiFi networks. However, as shown in [37], 5G standardization is expected to be ready by 2020. Thus, more issues, including delay, reliability, and traffic issues, will be discussed after the initial applications.

On the other hand, virtual traffic management systems that incorporate all the key technologies must be designed and implemented for managing heavy loads of future networks such as video delivery. Thus, the requirements of 5G services have thoroughly increased to satisfy a higher data rate (10 to 100$\times$ higher data rate), reduced latency (1 ms end-to-end round-trip latency), and massive connectivity (10 to 100$\times$ number of connected devices), as shown in [38]. During traffic flow, the efficient connection of traffic management should satisfy the vast growth in different aspects of future networks. Traffic management and optimization based on big data and artificial intelligence [39] improve latency and increase the performance of traffic flow.

According to [40–45], many new challenges will be possible to enhance the QoS and EE through efficient, intelligent techniques integrated within the proposed framework. These enhancements will certainly improve future ITS and C-ITS. For instance, medical testing of passengers and their responses before starting a journey will be a potential challenge. All ADVs face many complicated issues such as response time of results, the accuracy of early detection techniques, and energy management, which are potential problems. The proposed model will be flexible and enhance the VCS with the emerging 5G+ technologies to improve the solutions to these issues. The importance of UAV-assisted ITS is vital in densely populated areas, where on-road delivery is not a perfect solution for delivering services in emergencies. Regarding the VCS, our proposed framework supports UAV-assisted ITS.

Although we have studied the various framework for improving transportation facilities, emerging technologies based on SDN allowed us to propose a flexible framework. The challenge of this framework is to adapt the features of new user requirements considered in the 5G+ systems. Decision-making of ADV via network calculus can be possible in this framework, and it supports analyzing performance with quick decision-making. In future transportation systems such as ADV, multiple services can be improved with the results obtained from this research. Hence, ADV needs massive wireless connectivity considered in 5G and 5G+ wireless networks.

7. Conclusions and Future Work

In this improvement, emerging technology such as SDN plays an important role in the transportation system's 5G-based infrastructure, which relies on evolving user requirements such as latency and EE. In this research paper, energy-efficient framework, data traffic measurements influenced to transportation services, and management of transportation services are considered. According to [46], SDN was tested with different networks to improve the data traffic measurements, such as delay and data rate. Using these SDN tests with the 5G network, we finalized the latency and EE results as in Figures 6 and 7. These results confirm that the framework's design supports improving the transportation services with emerging technology such as SDN. Despite the ADV, VCS, and ITS, the improvements of the 5G+ transportation system can be extended from the 5G based framework.

This theoretical research proposed a flexible framework with the SDN based on the 5G network for analyzing future transportation services. This framework allows the service provider to add emerging technologies whenever the ADV or electrical vehicles need some upgrading with new services and features. SDN based on 5G+ can be considered for future ADV, VCS, and ITS in future transportation systems. This framework can be used as the legacy framework of future developments.

The network traffic performance is measured for analyzing the data of transportation services, such as the traffic status of the vehicle users. Using [46], all results are obtained as in Figure 4, which proves that improvements in traffic performance will enhance the transportation services, including VCS.

We studied and introduced the novel QoS prediction techniques that enhance the proposed framework's strength and other measurement facilities. Optimizing measurements and managing potential and future data traffic can enhance the QoS. In this research, the improvement of EE will prove that we can improve the QoS of the future ITS and transportations services.

In future work, minimum energy consumption and maximum security is the biggest challenge because ADV and electric vehicles need more security, which consumes more energy. This flexible framework will be developed using an efficient tool for analyzing real-time data traffic problems related to transportation services. Although we completed the preliminary testing with the 5G, we will extend the test for 5G+ and emerging networks such as 5G+ based on SDN. Further, dynamic energy will allow us to develop a system, which can transfer energy wirelessly. In addition, future electric cars should be rechargeable wirelessly while we drive. As M. Agiwal et al. [7] suggested in their survey paper, harvesting energy through Ionosphere science and photonics technology will be possible for charging and recharging the future electric vehicles and their communication devices or systems of the public services, including future transportation services.

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References

1. Gohar, A.; Gianfranco, N. The Role of 5G Technologies in a Smart City: The Case for Intelligent Transportation System. *Sustainability* **2021**, *13*, 5188. [CrossRef]
2. Noh, G.; Kim, J.; Choi, S.; Lee, N.; Chung, H.; Kim, I. Feasibility Validation of a 5G-Enabled mm Wave Vehicular Communication System on a Highway. *IEEE Access* **2021**, *9*, 36535–36546. [CrossRef]
3. Chowdhury, M.Z.; Shahjalal, S.A.; Yeong, M.J. 6G Wireless Communication Systems: Applications, Requirements, Technologies, Challenges, and Research Directions. *IEEE Open J. Commun. Soc.* **2020**, *1*, 957–975. [CrossRef]
4. Luo, M.; Lin, S.C.; Akyildiz, I.F. Multi-Controller Control Traffic Balancing in Software-Defined Networks. US Patent 15/199,387, 4 January 2018.
5. Mahmood, A.; Casetti, C.; Chiasserini, C.F.; Giaccone, P.; Härri, J. Efficient Caching Through Stateful SDN in Named Data Networking. *Trans. Emerg. Telecommun. Technol.* **2018**, *29*, e3271. [CrossRef]
6. Pan, M.S.; Lin, T.M.; Chiu, C.Y.; Wang, C.Y. Downlink Traffic Scheduling for LTE-A Small Cell Networks with Dual Connec-tivity Enhancement. *IEEE Commun. Lett.* **2016**, *20*, 796–799. [CrossRef]
7. Agiwal, M.; Roy, A.; Saxena, N. Next Generation 5G Wireless Networks: A Comprehensive Survey. *IEEE Commun. Surv. Tutorials* **2016**, *18*, 1617–1655. [CrossRef]
8. Pinto, P.R.; Cardoso, R.; Amaral, P.; Bernardo, L. Lightweight Admission Control and Traffic Management with SDN. In Proceedings of the 2016 IEEE International Conference on Communications (ICC), Kuala Lumpur, Malaysia, 22–27 May 2016; pp. 1–7. [CrossRef]
9. Dighriri, M.; Lee, G.M.; Baker, T. Measurement and Classification of Smart Systems Data Traffic Over 5G Mobile Networks. In *Technology for Smart Futures*; Springer: Cham, Switzerland, 2018; pp. 195–217. [CrossRef]
10. Shu, Z.; Jiafu, W.; Jiaxiang, L.; Shiyong, W.; Di, L.; Seungmin, R.; Changcai, Y. Traffic Engineering in Soft-Ware-Defined Networking: Measurement and Management. *IEEE Access* **2016**, *4*, 3246–3256. [CrossRef]
11. Li, S.; Xu, L.D.; Shanshan, Z. 5G Internet of Things: A Survey. *J. Ind. Inf. Integr.* **2018**, *10*, 1–9. [CrossRef]
12. Cia, M.D.; Mason, F.; Peron, D.; Chiariotti, F.; Polese, M.; Mahmoodi, T.; Zorzi, M.; Zanella, A. Using Smart City Data in 5G Self-Organizing Networks. *IEEE Internet Things J.* **2018**, *5*, 645–654. [CrossRef]
13. Dao, N.-N.; Park, M.; Kim, J.; Paek, J.; Cho, S. Resource-Aware Relay Selection for Inter-Cell Interference Avoidance in 5G Heterogeneous Network for Internet of Things Systems. *Futur. Gener. Comput. Syst.* **2018**, *93*, 877–887. [CrossRef]

14. Chen, M.; Yongfeng, Q.; Yixue, H.; Yong, L.; Jeungeun, S. Data-Driven Computing and Caching in 5G Networks: Architecture and Delay Analysis. *IEEE Wirel. Commun.* **2018**, *25*, 70–75. [CrossRef]
15. Sun, D.; Zhao, K.; Fang, Y.; Cui, J. Dynamic Traffic Scheduling and Congestion Control across Data Centers Based on SDN. *Future Internet* **2018**, *10*, 64. [CrossRef]
16. Gamage, S.; Khan, J.Y.; Ngo, D.T. Adaptive Resource Allocation with Traffic Peak Duration Prediction and Admission Control for Cognitive Wi-Fi Networks. *Comput. Netw.* **2018**, *142*, 240–252. [CrossRef]
17. Shen, D.; Yan, W.; Peng, Y.; Fu, Y.; Deng, Q. Congestion Control and Traffic Scheduling for Collaborative Crowdsourcing in SDN Enabled Mobile Wireless Networks. *Wirel. Commun. Mob. Comput.* **2018**, *2018*, 9821946. [CrossRef]
18. Fodor, G.; Vinogradova, J.; Hammarberg, P.; Kumar, K.N.; Hieu Do, R.B.; Baig, M.U. 5G New Radio for Automotive, Rail, and Air Transport. *arXiv* **2021**, arXiv:2101.08874.
19. Petrov, V.; Lema, M.A.; Gapeyenko, M.; Antonakoglou, K.; Moltchanov, D.; Sardis, F.; Samuylov, A.; Andreev, S.; Koucheryavy, Y.; Dohler, M. Achieving End-to-End Reliability of Mission-Critical Traffic in Softwarized 5G Networks. *IEEE J. Sel. Areas Commun.* **2018**, *36*, 485–501. [CrossRef]
20. Semiari, O.; Saad, W.; Bennis, M.; Debbah, M. Integrated Millimeter Wave and Sub-6 GHz Wireless Networks: A Roadmap for Ultra-Reliable Low-Latency Communications. *arXiv* **2018**, arXiv:1802.03837.
21. Malila, B.; Falowo, O.; Ventura, N. Intelligent NLOS Backhaul for 5G Small Cells. *IEEE Commun. Lett.* **2018**, *22*, 189–192. [CrossRef]
22. Tajiki, M.M.; Akbari, B.; Mokari, N. QRTP: QoS-Aware Resource Reallocation Based on Traffic Prediction in Software Defined Cloud Networks. In Proceedings of the 2016 8th International Symposium on Telecommunications (IST), Iran, Tehran, 27–28 September 2016; pp. 527–532.
23. Awobuluyi, O.; Nightingale, J.; Wang, Q.; Alcaraz-Calero, J.M. Video Quality in 5G Networks: Context-Aware QoE Manage-ment in the SDN Control Plane. In Proceedings of the 2015 IEEE International Conference on Computer and Information Technology, Liverpool, UK, 26–28 October 2015; pp. 1657–1662.
24. Lin, K.; Wang, W.; Wang, X.; Ji, W.; Wan, J. Qoe-Driven Spectrum Assignment for 5G Wireless Networks Using SDR. *IEEE Wirel. Commun.* **2015**, *22*, 48–55. [CrossRef]
25. Zhang, Y.; Jianhua, G.; Erchin, S. Performance Analysis of a 5G Energy-Constrained Downlink Relaying Net-Work with Non-Orthogonal Multiple Access. *IEEE Trans. Wirel. Commun.* **2017**, *16*, 8333–8346. [CrossRef]
26. Patcharamaneepakorn, P.; Wang, C.-X.; Fu, Y.; Aggoune, E.-H.M.; Alwakeel, M.M.; Tao, X.; Ge, X. Quadrature Space-Frequency Index Modulation for Energy-Efficient 5G Wireless Communication Systems. *IEEE Trans. Commun.* **2018**, *66*, 3050–3064. [CrossRef]
27. Liu, J.; Shi, Y.; Zhao, L.; Cao, Y.; Sun, W.; Kato, N. Joint Placement of Controllers and Gateways in SDN-Enabled 5G-Satellite Integrated Network. *IEEE J. Sel. Areas Commun.* **2018**, *36*, 221–232. [CrossRef]
28. Mirahsan, M.; Wang, Z.; Schoenen, R.; Yanikomeroglu, H.; St-Hilaire, M. Unified and non-parameterized statistical modeling of temporal and spatial traffic heterogeneity in wireless cellular networks. In Proceedings of the 2014 IEEE International Conference on Communications Workshops (ICC), Sydney, Australia, 10–14 June 2014; pp. 55–60. [CrossRef]
29. Akram, H.; Pascal, B. Leveraging SDN for the 5G Networks: Trends, Prospects, and Challenges. *arXiv* **2015**, arXiv:1506.02876.
30. Wang, J.-F.; Hai, Z.; Shuai-Zong, S.; Yu, H.; Shuai, C.; Xuan, H. Using Complex Network Theory for Temporal Locality in Network Traffic Flows. *arXiv* **2018**, arXiv:1807.03454. [CrossRef]
31. Alzahrani, A.; Vijey, T.; Muhammad, S.Q. Relevance of Energy Efficiency Gain in Massive MIMO Wireless Network. *Int. J. Adv. Comput. Sci. Appl.* **2017**, *8*, 351–356. [CrossRef]
32. Al-Turjman, F.; Ever, E.; Zahmatkesh, H. Small Cells in the Forthcoming 5G/IoT: Traffic Modelling and Deployment Overview. *IEEE Commun. Surv. Tutor.* **2018**, *21*, 28–65. [CrossRef]
33. Jundhare, M.D.; Kulkarni, A.V. An Overview and Current Development of Femtocells in 5G Technology. In Proceedings of the Advances of 2016 IEEE International Conference on Advances in Electronics, Communication and Computer Technology (ICAECCT), Pune, India, 2–3 December 2016; pp. 204–209. [CrossRef]
34. Alshaflut, A.; Thayananthan, V. Estimating Data Traffic through Software-Defined Multiple Access for Iot Applications Over 5G. *Networks* **2018**, 59–66. [CrossRef]
35. Jaber, M.; Imran, M.A.; Tafazolli, R.; Tukmanov, A. 5G Backhaul Challenges and Emerging Research Directions: A Survey. *IEEE Access* **2016**, *4*, 1743–1766. [CrossRef]
36. Katoh, M.; Sato, I.; Watanabe, N. Traffic Engineering for Iot. In Proceedings of the International Conference on Information NetWorking, Kota Kinabalu, Malaysia, 10 March 2016; pp. 195–200.
37. Zhao, Y.; Zhang, X. New Media Identity Authentication and Traffic Optimization in a 5G Network. In Proceedings of the 2017 IEEE 2nd Advanced Information Technology, Electronic and Automation Control Conference (IAEAC), Chongqing, China, 25–26 March 2017; pp. 1331–1334. [CrossRef]
38. Liu, C. Trend, Technology, and Architecture of Small Cell in the 5G Era. In Proceedings of the 2016 International Symposium on VLSI Design, Automation and Test (VLSI-DAT), Hsinchu, Taiwan, 25–27 April 2016; pp. 1–2.
39. Guo, A.; Yuan, C.; He, G.; Xu, L. Research on SDN/NFV Network Traffic Management and Optimization based on Big Data and Artificial Intelligence. In Proceedings of the 2018 18th International Symposium on Communications and Information Technologies (ISCIT), Bangkok, Thailand, 26–28 September 2018; pp. 377–382. [CrossRef]

40. Both, C.B.; Borges, J.; Gonçalves, L.; Nahum, C.; Macedo, C.; Klautau, A.; Cardoso, K. System Intelligence for UAV-Based Mission Critical with Challenging 5G/B5G Connectivity. *arXiv* **2021**, arXiv:2102.02318.
41. Bojadjievski, S.; Kalendar, M.; Shuminoski, T. 5G Emerging and Mission Critical Framework with Ultra-Reliable Low Delay. *Wirel. Pers. Commun.* **2021**, *119*, 2561–2575. [CrossRef]
42. Ahangar, M.N.; Qasim, Z.A.; Fahd, A.K.; Maryam, H. A Survey of Autonomous Vehicles: Enabling Communication Technologies and Challenges. *Sensors* **2021**, *21*, 706. [CrossRef] [PubMed]
43. Qadir, Z.; Ullah, F.; Munawar, H.S.; Al-Turjman, F. Addressing Disasters in Smart Cities Through Uavs Path Planning and 5G Communications: A Systematic Review. *Comput. Commun.* **2021**, *168*, 114–135. [CrossRef]
44. Autili, M.; Chen, L.; Englund, C.; Pompilio, C.; Tivoli, M. Cooperative Intelligent Transport Systems: Choreography-Based Urban Traffic Coordination. *IEEE Trans. Intell. Transp. Syst.* **2021**, *22*, 2088–2099. [CrossRef]
45. Wang, Y.; Sarkis, J. Emerging Digitalisation Technologies in Freight Transport and Logistics: Current Trends and Future Directions. *Transp. Res. Part E Logist. Transp. Rev.* **2021**, *148*, 102291. [CrossRef]
46. Emran, M.; Thayananthan, V.; Umair, M.; Kotuliak, I. Analysis and Verification of Wi-Fi Handover Delay Model in SDN Based Network. In Proceedings of the 2021 IEEE International Conference on Communications (ICC), Montreal, MT, Canada, 14–18 June 2021.