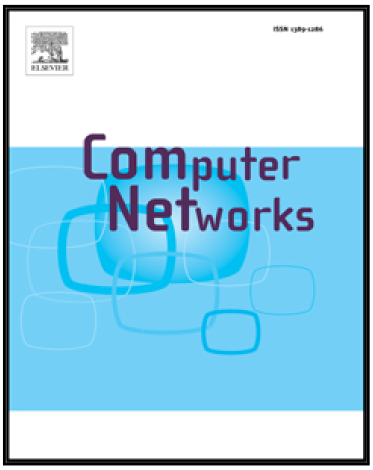

5G-enabled Hierarchical Architecture for Software-Defined Intelligent Transportation System

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5G-enabled Hierarchical Architecture for Software-Defined Intelligent Transportation System

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Abstract: With the rapid advancement of technology, an increasing number of devices are being connected to the Internet and getting smart. Such advancement brings new challenges in the field of intelligent transportation system (ITS), including transferring of high data rates, providing rapid response system to users, addition of new devices, and their remote configuration. Thus, mobile information systems, along with intelligent multimodal mobility services, cope with such constraints and take significant benefit of the associated technology from emerging information and communication frameworks. Therefore, recent advancement in the field of telecommunication has witnessed increased interest in ITS, especially vehicular ad-hoc networks (VANETS). Software-defined networks (SDNs) can also bring advantages to ITS due their flexibility and programmability to the network via their logical and centralized control entity. However, the bandwidth and continuous connection between ITS and SDN is still a challenge owing to the highly mobile nature of VANETS. Therefore, to address this issue, this paper presents a novel concept for enhancing the capabilities of ITS via the newly proposed 5G-based SDN architecture for ITS. The proposed system architecture is based on the following three function layers: sensing layer, relay layer, and core network layer. Continuous accessibility, via flexible and programmable features, is achieved through SDN features. In addition, high data rates and bandwidth are provided by the proposed 5G architecture. The simulation results show that the proposed system architecture achieves better results than the ad-hoc on-demand distance vector routing protocol.

Keywords— SDN, 5G, ITS, sensing layer, relay layer, core network layer

I. INTRODUCTION

The future potential of the Internet as a global phenomenon has led to an increasing number of devices becoming internet friendly [1]. Furthermore, traffic management in transportation working with the Internet has become easier as the number of IoT technologies are used for traffic management, i.e., intelligent transportation system (ITS) are envisioned to significantly improve the traffic and safety conditions on road. It is very important to monitor the traffic by using different means, i.e., check speed limit, pollution checks, and emergency response in case of road accidents. Traditionally, to solve such issues, CCTV cameras are used. However, such applications are not satisfactory in cases where several vehicles are moving on the road [1].

To cope with such constraints, IoT technology came up with different methodologies in traffic management; for example, ITS is envisioned to significantly improve the transportation and safety of roads. The concept of ITS is that all vehicles moving on the road are in constant communication with each other, through vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I) communication [2].

The deployment of various technologies needed to accomplish this task has been slow and very expensive [2]. It involves the installation of multiple pieces of large equipment both on the roadway, i.e., Roadside units (RSUs) and inside the vehicle, termed on-board units (OBUs). This suggests that a complete saturation of these units must exist to enable a fully functional ITS [1]. Recently, several research communities have focused on finding quick deployment and lower cost alternative methods for ITS. There already exist many protocols and standards that ensure the deployment of ITS since it is consistent across all states and vehicles. Recently, various aspects of ITS have been researched.

ITS can provide several services, but from the quality-of-service (QoS) viewpoint, the requirements of user satisfaction are not satisfactory [2]. Additionally, the capability of handling a large request is indispensable. Hence, recently, an emerging term, called software-defined network (SDN), has considered the networking paradigm between wired and wireless devices from software perspective. SDN is an emerging network paradigm that separates the control logic from the network device (switch or sensor node), leaving the device with only data forwarding functionality [3]. SDN can not only improve network flexibility and efficiency but also provide a platform for network management. It also enables flexible network management, which is a critical element of IoT. To cope with these limitations and challenges, software-defined networking is the forerunner, forming the backbone of network applications. Thus, SDN appears as a game changer technology that has revolutionized the entire networking mechanism. It decouples the network control plane from the forwarding plane to control and manage the network devices and services by using the abstraction of low-level functionality [4, 5]. It provides support for dynamic, scalable computing and storage needs of current complex digital networks and allows adaptive control and operations of networks cost-effectively. SDN overcomes the limitation of traditional networks and provides an intelligent platform to resolve network security issues. As already discussed, two planes of conventional networking, control and data plane, have been effectively separated [6]. Due to this separation, the data plane is left with forwarding mechanism, while the control plane is shifted to the controller, as shown in Figure 1. This results in a centralized application running to deploy networking policies, management tools, security measures, etc., and engrave the way of network virtualization. It also provides data flow optimization and more flexibility, accuracy, and consistency in the configuration as compared to the manual configuration of networking devices for a traditional network [7].

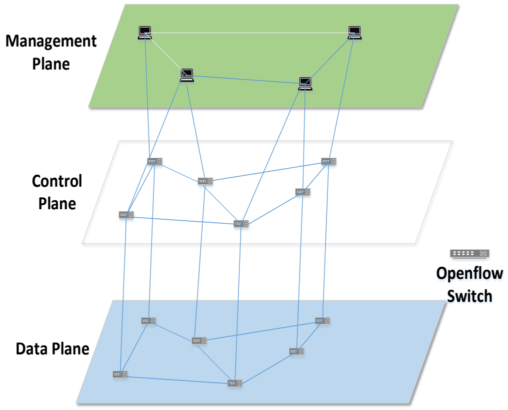

Figure 1. Layered architecture of SDN

Furthermore, software-defined network challenges are still under consideration, i.e., to cope with high mobility of vehicles exhibits more challenges while using the SDN concept. One of the major challenges is the connectivity between SDN controller and vehicles [R]. Sometimes, it is also possible that the SDN controller is not reachable. Most of the research conducted in the past did not include such issues as they followed the old fashion of vehicular networks, such as the ad-hoc on-demand distance vector routing protocol (AODV) and greedy parameter stateless routing (GPSR). Through a meaningful connection between SDN and IoV, the concept of software-defined internet of vehicles (SD-IoV) is emerging nowadays. SD-IoV provides a flexible and efficient connection, service QoS guarantee, and the support of multiple concurrent users [2]. SD-I usually controls and manages vehicular communication in a centralized manner by aggregating the network state information and deciding according to the environment. Moreover, the connection between SDN controller and vehicles needs a proper connection that maintains its connectivity throughout the communication. In this regard, some of the previous studies have exploited long-term evolution (LTE)-Advanced networks [8]. However, these technologies do not support a high and efficient bandwidth.

Therefore, while aiming at the connectivity between the vehicle and SDN controller, this paper presents a novel system architecture that addresses both these constraints. The system architecture for SDN-based ITS comprises the following three functional layers: sensing layer, relay layer, and core network communication layer. In addition, we first present a communication medium that establishes the connection between RSU and the vehicles. After that, we present a 5G system architecture that assists the vehicular network and SDN controller to establish a connectionless link and provide high bandwidth with a novel protocol stack for the communication medium.

A. *Research Contribution and Advantages*

The main contribution of this paper is as follows.

- First, the design and implementation of the hierarchical framework for integrating SDN with ITS. This integration helps the network by providing a long-term connection between various commodities.
- The development of a novel system architecture for 5G-assisted SDN for ITS help in the network by exchanging massive data. For instance, the increase in vehicles on the road faces a huge problem of connectivity and obtaining information about the route is a difficult task these days. Thus, the 5G architecture with a novel protocol stack helps the network support high mobility of vehicles and provides a bridge between RSUs and the SDN controller.
- The development of the SDN architecture allows self-organizing and self-healing phenomena, which dynamically perform self-configuration.

B. *Organization*

The rest of this paper is organized as follows. Section II presents the background and related work, which is composed of SDN, ITS, and their drawbacks. Section III presents the system architecture for 5G-assisted SDN for ITS. Furthermore, a novel communication protocol stack is proposed, which provides an underlying mechanism to help the 5G communication medium. Section IV comprises extensive simulations results and discussion; Section V is composed of comparative analysis. Finally, Section VI presents a conclusion and future direction.

II. BACKGROUND AND RELATED WORK

Recent years have witnessed several propositions on the newly derived area vehicular communication networks, where most of the studies have focused on software-defined networking [9]. In the beginning of this section, we summarize the vehicular communication networks and basic concepts of IoV with some existing techniques. In the next subsection, we review the main techniques that have been proposed so far for SDN in this scenario.

In the past decade, a newly derived concept of area vehicular ad-hoc network (VANET) has attracted much research attention. The driving motivation among the researchers includes a study on communication among vehicles, seamless internet connectivity for the improvement of road safety, indispensable alerts, and access to comfort and entertainment [10]. One of most significant VANNET applications is ITS, which has been proposed to reduce the accident rate and save lives [11]. According to the concept of ITS, all vehicles on the road are in constant communication with each another, i.e., V2V communication, and their surrounding infrastructure, i.e., V2I communication [12]. Julio et al. [13], proposed a telematics-based system for the intelligent transport and distribution of medicines. Their proposed intelligent system tracking and tracing provides some key features for vehicles, i.e., be located remotely, trace the records, and provide the incidence reports. Their system can automatically read the tags, and the use of handheld readers in their system can lead to reading delays compared to an automatic solution. For the validation, an intelligent system is set up and tested in a testbed.

Wanag et al. [14] proposed a decision-based tree technique using the vertical handoff method for selecting IoV. In this effort, they proposed a novel VHO method among WAVE, WiMAX, and 3G cellular based on a self-selection decision tree for IoVs. The decision tree decides according to user preferences, and the feedback decision method in line with the feedback of services and movements on vehicles can avoid the negative impact of service and movement changes.

According to Macedo [15], software-based implementation is a better solution than hardware-based implementation. The reason is maintenance, as it is very easy for any company to fix the older versions before releasing new products in the market. Kushan [16] proposed an SDN-based architecture for vehicular networks. DVN provides the programmability feature without requiring the exceeding latency as compared to the existing VANET architecture. The surprising feature of this study is the proposed architecture, in which the load is distributed among the controllers and the necessary local view is exploited over the network to take better decisions. According to their theoretical and simulation results, their architecture performs better than the existing Internet-based SDVN in terms of delay.

A similar study conducted by Xian Ji et al. [10] proposed an SDN-based geographic routing protocol for VANET. The authors identified that, traditionally, routing local information is used to make the routing decisions, which may further lead to the local maximum and sparse connectivity problems. To solve this problem, they presented a novel SDN-based geographic routing protocol, which is based on the node location, vehicle density, and digital map. They implemented their scheme in NS2. Finally, their achieved results proved that their approach can dramatically outperform as compared to the other routing protocols for VANNET, i.e., AODV and GPSR, regarding the packet delivery and delay time.

During the literature review, we identified an interesting and unique article on the social internet of vehicles for VANNET. Nitti [17] identified that every vehicle is capable of establishing a social relation with other vehicles autonomously. The major contribution of this paper is that it defines some relation between the vehicles and RSU. He/she proposed a solution to solve middleware, which extends the functionalities of the ITS station architecture according to ISO and ETSI standards. Finally, he/she analyzed the structure of the resulting SoV network to evaluate its navigability. The resulting analysis described that the social object relationship graph has a giant component in case of visibility between two vehicles within a range of 150 m.

Ge et al. [18] described the requirements of ITSs integrated with 5G mobile communication technologies and software-defined networking. With the development of pilotless vehicles, there is a need to use 5G mobile communications, cloud computing, and SDN technologies for vehicular networks. They proposed a new architecture of 5G software-defined vehicular networks integrating the abovementioned technologies. The simulation result indicated that there is a minimum transmission delay of 5G software-defined vehicular networks by considering the different vehicles' densities. Moreover, the throughput of fog cells in 5G-software defined vehicular networks is better than that of traditional transportation management systems.

Chen et al. [19] provided a service- and connection-oriented management system for SD-IoV. According to them, many challenges are still faced during IoV implementation: flexible and efficient connections, QoS guarantee, and multiple concurrent support. They tackled such issues by using SD-IoV. They developed a graph-based genetic algorithm and a heuristic algorithm to solve the stated issues.

Venkatraman et al. [20] provided an SDN-enabled connectivity-aware geographic-aware routing protocol (SCGRP), which is a performance-enhanced protocol for an optimized transmission of data packets. Their study aimed to extend the SDN architecture to an urban environment, which consists of vehicular networks for data transmission with a global view of the network topology.

III. 5G-ENABLED SOFTWARE-DEFINED ITS

This paper presents an SDN-based system architecture for vehicular networks, which aims to provide flexibility brought by SDN to the vehicular network to improve the overall performance of the network in a case where connectivity between cars is more important. The proposed architecture provides a central coordinator supported by SDN.

A. *System overview*

This section presents a system overview of the proposed 5G-enabled SDN for ITS. We assume that a directed graph G with vertices V and edges E can be represented by G (V, E), which shows the road network and intersections at various points in the graph. However, in the set of edges E, the various elements show the road segments. Furthermore, considering weighted values, W shows the weight of each edge in E [21]. Let us consider an example scenario where vertices V have a set of vertices, set of route vehicles represented by R at each edge (E), and a set of congested roads, indicated by C, where C □ E. In a given scenario, each vehicle sends a beacon message to its neighboring RSU after an equal interval of time. The format of the beacon message includes {*location* (l_i), *speed* (v_i), *route* (r_i), *destination* (d), *source* (s_i), *and emergency status* (em_i)}. RSU is then processed using this information after an equal interval of time along with the total number of vehicles at each edge E. Once these values are calculated, they are assigned to each edge weight, i.e., W_i. Based on these values, RSU classifies the road information, i.e., congested road.

However, there might be cases where the road is congested and RSU is unable to communicate with a vehicle on the road. To cope with such constraints, we propose a novel architecture to support ITS by incorporating 5G with SDN. The rationale behind 5G and SDN in ITS is to expand its services through its flexible nature to provides connectivity to the control entity. Furthermore, the limitation of bandwidth in a 4G network drastically decreases the network functionality in a case where the roads are congested and we need to exploit more RSU. Thus, the notion of high-speed network (data and multimedia services) is evolving as a major bottleneck in telecommunication with outstanding benefits to ITS. Such technology allows vehicles with self-motivated and enhanced routing facilities while sustaining the critical connections and services among various vehicles and RSUs.

Figure 2 delineates a core network where a scenario for the vehicular network is connected to a core network via gateway nodes. The figure shows that all vehicles are connected to a core using 5G network, where vehicular devices generate data in a massive volume. For this scenario, we exploit ID/location-based wireless communication mobility management, where a group of vehicles is communicating with each other and RSUs. RSU works as a coordinator node, which is responsible for accepting beacon messages from neighboring vehicles, and shares these beacon messages with the neighboring RSUs. The 125-bit global supports each vehicle identifies (GDID), which assists the network by providing end-to-end connectivity. GDID assists the vehicles by their *location* (l_i), *speed* (v_i), *route* (r_i), *destination* (d_i), *source* (s_i), *and emergency status* (em_i)}, and the location of the RSUs is identified by local locators (LLOC) and global locators, whereas access gateway (AGW) is denoted by RSUs. Both AGW and RSU work at each edge of the graph, which is used for inter-communication with vehicles.

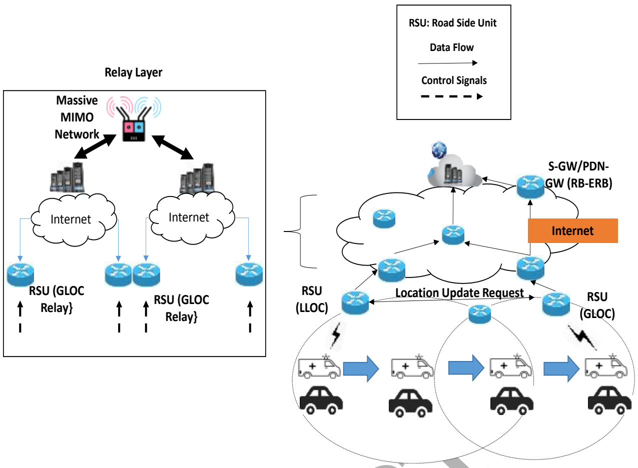

Figure 2. Designed system overview

The connectivity between RSU and vehicles on the road is achieved by the weighted equation [21]. The weight as the edge is inversely proportional to the traffic on the road, where distribution is made with the interval of [0, 1], where $W_i \in [0, 1]$. This means that a lower weighted value indicates better traffic condition, as shown in the below equation.

$$W_i = 1 - \frac{l_i \,.\, v_i \,.\, r_i \,.\, d_i \,.\, s_i \,.\, em_i}{speed\ limit\ at\ each\ road \,.\, v_i} > 1$$

W_i is the weight and v_i is the speed of each vehicle at each edge in the network.

B. *Communication Infrastructure using 5G*

After establishing the connection with RSUs, the vehicles now send their data to respective RSUs as well as neighboring vehicles, as shown in Figure 3. We assume that the roads are congested and we need high bandwidth to disseminate vehicular data toward other devices. For this reason, we propose a 5G network architecture based on the hierarchical layers, i.e., sensing layer, relay layer, and convergence layer. In our scenario, we have considered different commodities, i.e., V2V, V2I, and vehicle to pedestrian. However, the focus of this work is to maintain the connection and transfer massive data using the proposed 5G network. Figure 3 delineates the scenario where vehicles want to establish a connection with other commodities in a network. In this figure, the sensing layer is responsible for deploying vehicles, RSU, and other commodities. In the given scenario, the evolved devices do not support direct communication with each another since the relay layer is incorporated to assist the communication for a long period along with hop-by-hop communication. Multiple RSUs form a relay layer that is interconnected with the help of a network. Due to the high mobility factor, the vehicles broadcast $l_i \,.\, v_i \,.\, r_i \,.\, d_i \,.\, s_i \,.\, em_i$ at each interval of time. In addition, the relay layer helps the network architecture to send the information mentioned to the upper layer. Furthermore, the exploitation of the convergence layer is supported by a massive MIMO network that comprises a large antenna. These MIMO antennas help the network to disseminate the data toward the base station. In addition, the core network is supported by two layers, i.e., radio and network cloud.

Different functionalities are performed in radio and network cloud, i.e., user plane entity and control plane entity, which assist the network by providing a bridge between the user and control levels. We introduce a notion of D2D communication that assists the network in real-time scenarios.

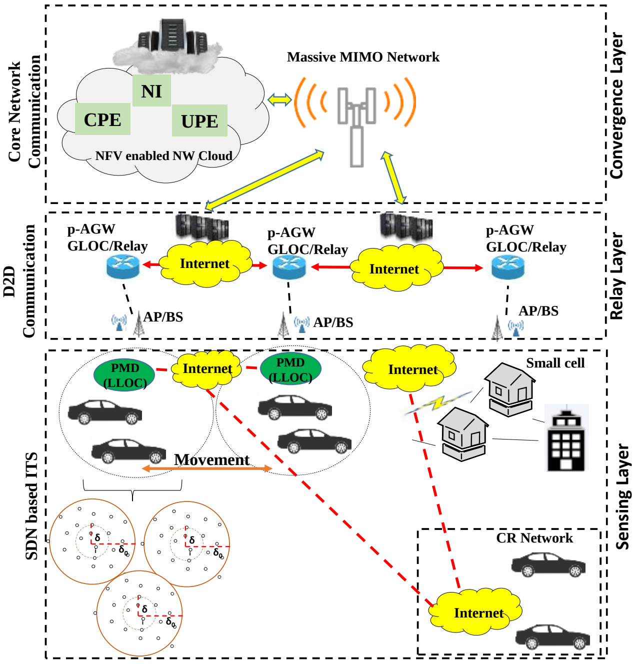

Figure 3. Proposed 5G network architecture

C. Protocol Stack

After proposing a network architecture for 5G, in this section, we present a protocol stack for green IoT in the 5G network, as shown in Figure 4(a).

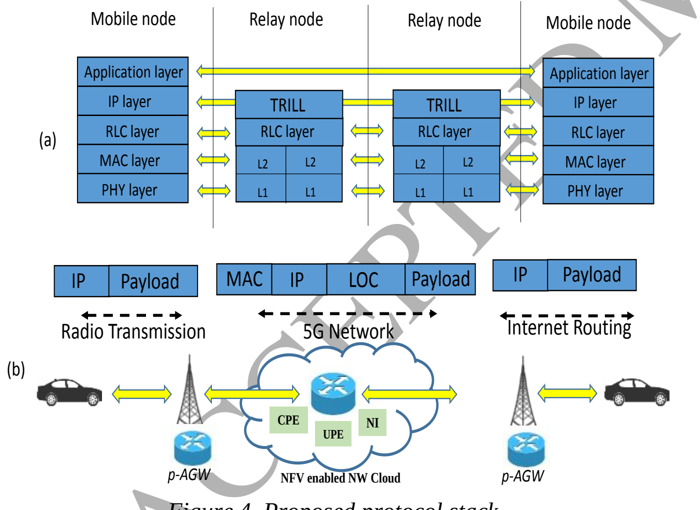

Figure 4. Proposed protocol stack

In Figure 4 (a), a protocol stack based on RSU is proposed, which can efficiently deliver the desired data. The designed protocol stack works between the vehicle and SDN controller, as well as with the neighboring RSU and other vehicles. To access the radio part of the vehicle and RSU, we use the radio link control layers, which is responsible for encapsulation of the IP packet by incorporating the MAC-in-MAC encapsulation mechanism.

After that, RSU forwards the data packet from ingress RSU to igress RSU. For this reason, the MAC header takes charge of data delivery in mobile core network layers, as shown in Figure 4 (b).

D. SDN-based ITS

The proposed mechanism is executed in five levels, of which three are main levels and two are intermediate levels. The data are gathered from different IoT-based embedded devices and sent to the processing level through SDN-based networking. Then, the processing level data are passed to the corresponding users. The flowchart of the proposed framework is shown in Figure 5.

a. Data Collection Unit

For data aggregation, various smart services of the smart city are considered, i.e., smart transportation and smart healthcare services. Sensors are placed with the smart services to collect data more efficiently, and then, sent to the above level through intermediate level 1 (IL1). There are different aggregator points (APs) in IL1, which are used to transfer the sensor's data over the SDN-based network. Aggregator points are further classified into three levels: global, local, and zone levels, which helps to lessen the congestion on the SDN-core network. To aggregate the detailed information from each sensor placed in a smart city unit is the duty of the zone level aggregator point, while the local level aggregator points (LLAPs) must gather sensor data from alike units such as transportation data from roads and hospital data from e-health services. Finally, the global level aggregator points (GLAPs) collect data from LLAPs and pass them to the SDN-core network.

The SDN-core network entails an SDN controller, which plans the data traffic from GLAPs to the SDN network. The SDN controller is set to accomplish many responsibilities, for example, it differentiates sensor data based on their IDs, optimizes the duty cycle of the sensors placed with each aggregator points, controls the topology, and based on the application requirements, performs routing decision. To enable application-precise routing of data, the SDN controller uses a precedence table according to the application priority in every SDN-enabled router. Moreover, considerable data are being generated by thousands of interconnected IoT-based devices, which decelerates the network operations. Various existing mechanisms can spot the congestion on the link. For Example, Kandula [9] proposed a pre-defined threshold of the link utilization mechanism, where a link is considered as congested if the traffic exceeds 70% of the total capacity of the link. Likewise, we used a pre-defined threshold with 75% link usage; the design limitations of this study are to evolve a framework to efficiently transfer big data over SDN. Thus, we used the existing traffic-engineering technique to improve SDN efficiency. However, we can share some productive ideas for choosing a traffic engineering technique for controlling and routing traffic over SDN. For instance, the data produced by a large number of sensors need swift processing speed routers and switches. An SDN controller trails two mechanisms to regain information of the link statistics from switches, i.e., pull and push methods. The push method is faster than the pull based, so our recommendation is to use push method for swift data routing and switching. We also used a two-tier congestion handling technique proposed by Chen [10]. In his study, the SDN controller sustained a global-level sight of the whole network by regaining information of the links from all switches in the SDN. The gathered information helps to control the traffic load on the individual link in the entire network.

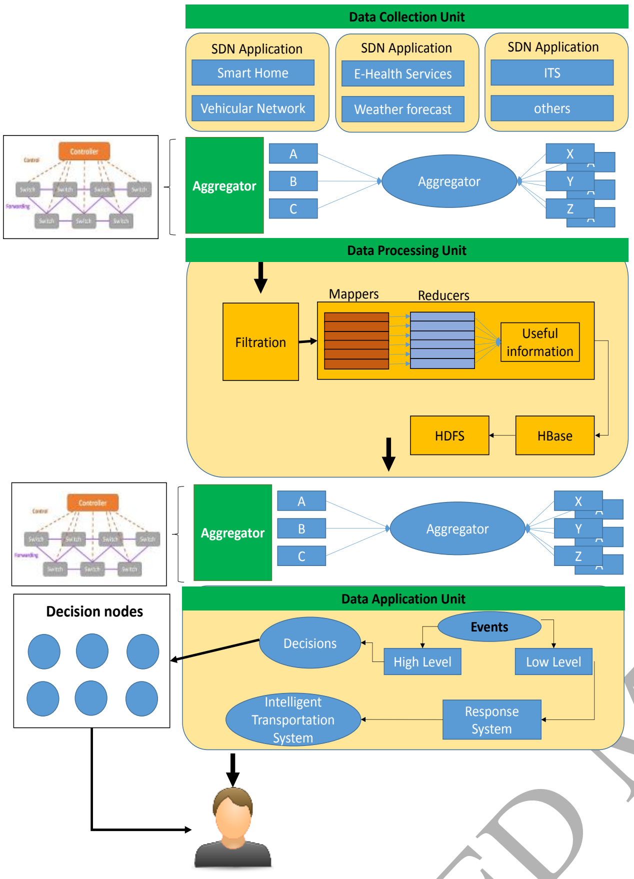

Figure 5. Proposed SDN-based ITS system architecture

b. Data Processing Unit

The data acquired from IL 1 is moved to the processing level to normalize the data expressively and extract essential information. For instance, the information of traffic congestion on the roads can help the inhabitants to reach the destination in minimum time. Big data always need more time and processing power. Thus, the real-time data processing is a challenging job using the existing mechanisms. The proposed data processing level used an effective map-reduce model for analysis of data using Hadoop ecosystem, GrapheX, and Spark for real-time data processing. Additionally, to store and manipulate the data, the Hadoop Distributed Filesystem (HDFS) is used. To process an enormous amount of data Hadoop ecosystem uses a heterogeneous cluster in the Hadoop system. In the literature, there are different mechanisms to allocate duties to the Hadoop cluster system. In the map-reduce technique, scheduling is required to split jobs into sub-jobs to process real-time data. However, once the duties are assigned to the map-reduced system, then alteration in duties are not possible. Therefore, we used an adaptive technique that can schedule the duties dynamically to balance the load on the map-reduce system. Each job tracker uses two different constraints to switch the part of the duties from the current node to another node, i.e., CPU utilization and memory requirements. The switching of the jobs is performed in real time based on the amount of a load of a cluster. It is not possible to change the task in Hadoop ecosystem, while Hadoop is processing data. We can use the heterogeneous Hadoop cluster, but it cannot produce an optimized result for a fixed job. Our proposed scheduling mechanism efficiently overcomes the problems of 1) low-performance due to node's busy state and 2) high-performance node in an idle state. For a heterogeneous cluster, this compromise between low- and high-performance nodes can make the system unstable. The proposed mechanism can check the load on every node at runtime. The node always requests for new tasks if the load is less than the threshold value, which is 75%. The proposed algorithm checks every node and its workload and decides to job assignment accordingly. The algorithm can make a node to work with its full potential in a single turn by optimizing it with the load parameter. To store, the HDFS module receives the data from a map-reduce system that can be used for further processing.

c. Data Application Unit

IL2 provides a link between HDFS and application level. Through this link, data are received by application level. IL1 and IL2 work on the same principle, but the difference can be seen on the traffic level on SDN. Furthermore, the application level can be sub-divided into two modules: 1) decision and event management and 2) named data network (NDN). In the first module, the result is generated by the execution of the data and processing level, which provides base to generate an event. Afterward, this event is broadcasted to the concerning departments, who are responsible for communicate with the respective users. This event can be categorized into two levels: high- and low-level events. For low-level events, decision modules hold the event and wait for the notification to be sent back to the data processing level. An acknowledgment is sent to the decision module once the data processing level receives the notification. After acknowledgment of notification, the decision module discards the low-level events. High-level events have high priority and are the most important. These high-priority events are processed by the decision management module on priority. Working on the event and decision module is easily understandable through the following example. Let us assume that sensors are placed in a city to collect data about the congestion level on the road. Data are transferred from the data processing level to the event and decision module. Some thresholds are defined to find whether the road is congested. If the congestion level is more than the thresh hold, then this event is categorized as the high-level event and forwarded to the concerned department, which in this case is a transportation department. If the congestion level is less than the threshold value, then its actions are taken accordingly to discard the event. Now notification has to be shared with the respective user from the concerned department. Such communication is performed after the query of the user or by broadcasting the message to the group of users. This automatic broadcast of the message is performed using the hierarchal model mentioned in section 1. We consider ICN-based networks to share information with the user while keeping user interest in mind. This is why we choose the NDN, which can proficiently achieve the user requirement by using sub/pub or pull-based communication. Every decision module performs its functionality as a name-defined network node. These nodes are further divided into three parts 1) pending interest table (PIT), 2) content store (CS), and 3) forward information base (FIB). To avoid the interest looping problem, pending interest and its unique values are stored in the PIT table. CS and FIB store the routing and incoming contents, respectively [12]. An interest packet is generated when the user wants some particular data and forwards them to NDN. The interest request is processed and the decision module sends the content over NDN. A clear picture of NDN and its operation is shown in Figure 6.

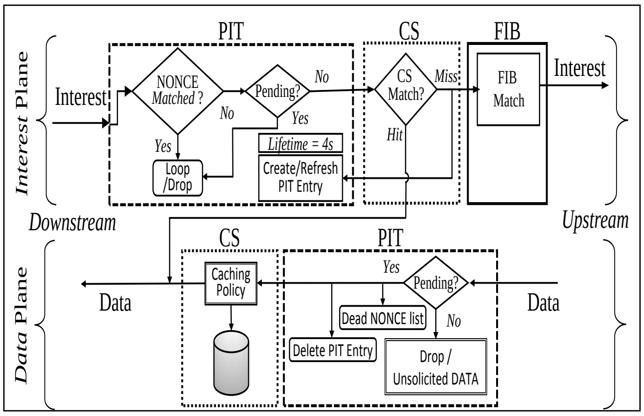

Figure 6. Working of NDN in the proposed architecture

IV. Simulation results and Discussion

In this section, we show the simulation conducted using C programming language to test the performance and feasibility of the proposed 5G-enabled SDN for ITS. In the simulation, the time given to the entire communication between the vehicles and SDN controller is 180 s, which is enough to predict the behaviour of the proposed scheme. Then, the proposed scheme is compared with the existing scheme of AODV. The velocity of the vehicles is considered to be 1 to 180 m/s. For simulation, we considered data rate of (0-1200 and 0-1500), energy (4.0 and 3.0), cost (0-30 and 10-50), and RSS (1-20, and 1-20). For the given simulations, the energy values are considered different for different applications and purposes. In our simulation, the data rate is inversely proportional to RSS since an increase in data rate decreases RSS, and vice versa.

The performance of our proposed algorithm is evaluated by considering an even distribution of traffic by generating different results. The traditional AODV protocol only finds the distance toward the base station while finding the shortest path to the destination. At an early stage, it does not bother about the route capacity and density condition and continues to suggest the shortest route unless the route gets congested. The proposed algorithm is capable of finding the shortest path; it considers the route capacity, congestion level, and travel time. The proposed technique considers two significant factors that play a vital role in avoiding congestion, which is the relation between speed and density and that between density and flow, as shown in Figures 7 and 8, respectively.

In the speed and density relation, the maximum speed can be clearly achieved if we have minimum density. If we have critical density, we can achieve the best speed that helps to avoid high density or traffic jams. As we are focusing on the urban environment, we must find the optimum density that can contribute to achieving optimum speed and max flow that control congestions on all roads. The experimental results are calculated using the queuing concepts; to get rid of congestion and to distribute traffic evenly, we put a threshold on density. As the density of a particular road approaches the maximum value, our algorithm starts diverting vehicles toward the 2nd best route and then the 3rd best route, unless the shortest route does not approach critical density.

To attain the max flow and best speed, our algorithm always remains in between the critical and optimum density. Our algorithm works best in both situations, irrespective of the traffic volume being high or low. The proposed algorithm distributes traffic on all roads such that the density on all roads according to their capacities remains optimum.

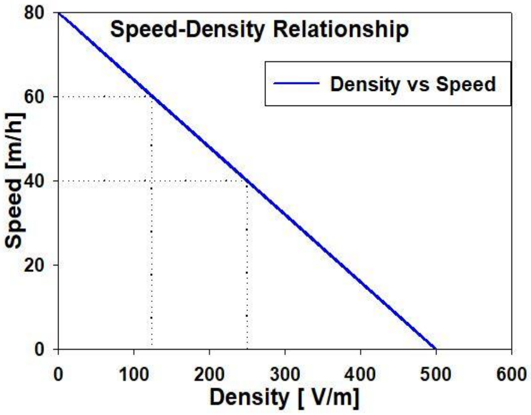

Figure 7. Optimum speed, flow, and density for congestion-free roads' speed-density relation

The experimental results are shown in Figures 9 and 10. We observed that the density on the shortest route approaches the maximum density, which causes congestion on the road, while other routes seem traffic free, which is shown in Figure 9. On the other hand, our proposed scheme distributes the total traffic on all possible routes evenly and keeps the density under control, as shown in Figure 10. As the analysis is conducted on daily traffic flow on hourly bases, the density varies in terms of regular hours and rush hours. While using the AODV protocol, because vehicles follow the shortest route instead of taking care of density, the arrival rate mostly exceeds the service rate, which causes a severe traffic jam. As a result, the queue keeps increasing (i.e., endless queue in queuing concept); this is why many vehicles always remain unserved in a time frame, as shown in Figure 11.

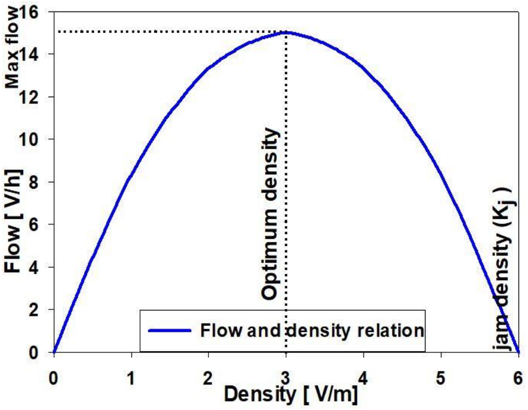

Figure 8. Optimum speed, flow, and density for congestion-free roads' flow-density relation

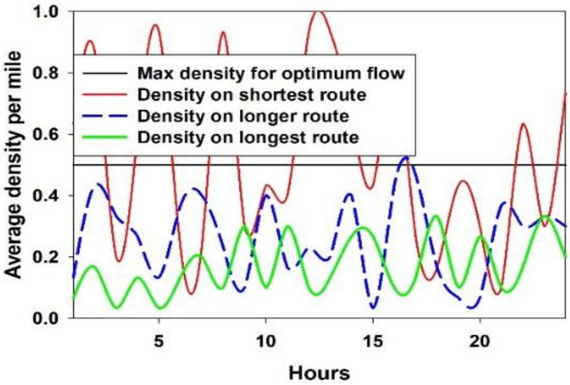

Figure 9. Average traffic density on a different route from the same source to the same destination using traditional

To check the system performance, we evaluated the proposed scheme on a different number of nodes in terms of time and processing. Figure 12 shows that if we increase the number of nodes, it takes less time to process the data. This means that due to the parallel processing nature of the Hadoop server, it processes more data in less time. Moreover, we compared our proposed scheme efficiently with the contestant's proposed scheme [22]. Figure 13 shows that the average processing time of the proposed scheme is less than that of the contestant's scheme due to the energy harvesting technique, which helps in prolonging the device lifetime. Hence, it generates more data as compared to the contestant's scheme.

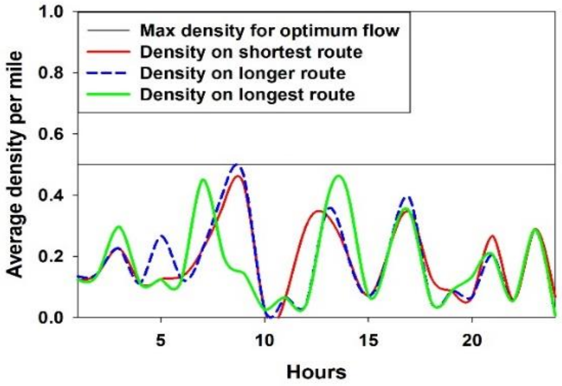

Figure 10. Average traffic density

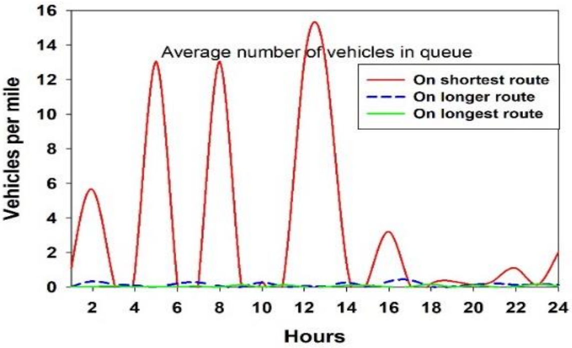

Figure 11. Average number of vehicles in the queue with AODV

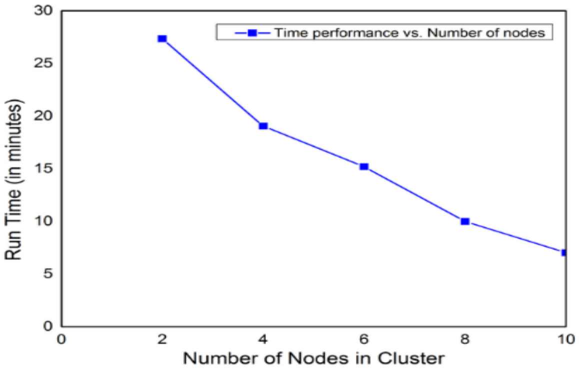

Figure 12. Error rate vs. number of iterations regarding nodes

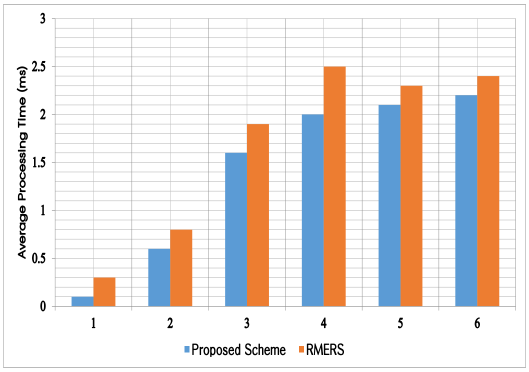

Figure 13. Processing time comparison with the existing scheme

Table 1. Classification of Existing Work Based On SDN and SD-IoV

Work	**Architecture**	**Communication**	**Controller connectivity loss strategy**	**Multiple controllers**	**Dynamic controller creation**	**Resource management**	**Contribution**
[24]	Centralized	V2V	●	●	●	●	SDN-based VANET architecture
[25]	Centralized	V2V, V2I	●	●	●	●	Broadcasting: Geo SDN-based VANETs
[26]	Centralized	V2V	●	●		●	SDN-based VANETs Routing
[27]	Hierarchical	V2V, V2I	●	●	●	●	SDN-based VANET: Decentralized
[28]	Centralized	V2V	●	●		●	Sensor VANET based SDN
[19]	Simulation Not specified	Centralized	✓	●	●	●	SD-IoV Efficiency and flexibility QOS constraints
[20]	Simulation MININET-WIFI and SUMO	Centralized	✓	●	●	●	Centralized Routing protocol Longer link life Packet delivery ratio and end-to-end delay
[10]	Simulation NS2	Centralized	✓	●	●		AODV and GPSR Packet ratio and delivery delay time
[16]	Simulation Java	Distributed	✓	●	●	●	AODV and SDVN Packet delivery ratio
Proposed Scheme	Simulation using C language and Hadoop ecosystem	Hierarchical	✓	✓	✓	✓	5G enabled SDN for ITS

V. COMPARATIVE ANALYSIS

The comparison in Table 1 highlights a compact comparison of the different architectural frameworks stated above. The implementation attribute (column) checks whether the proposed architecture was implemented (simulation or testbed) or not. The controller attribute checks whether the controller is distributed or centralized. The in-network processing checks whether there is any form of processing on the nodes. Finally, the main purpose of the architecture is listed in the focus attribute.

From a recent research, we realize that most of the work is based on a centralized structure that may experience problems of flexibility and scalability in large-scale VANETs. On the other hand, Kazmi et al. [23] considered several controllers, all of which were stable, and thus, was unable to handle all aspects and situations that can occur in the vehicular network. Moreover, most of these efforts do not include some controllers for maintaining communications and infrastructure without centralized management. Communication with the controller is crucial and cannot be the only fault-tolerant network in SDN. For any reason in the event, if the controller turns into inaccessible form, it should be able to be improved as soon as possible so that undesirable effects on the entire network are minimized. Our solution reduces this problem by grouping vehicles to create smaller SDN domains. In such a cluster, CH acts as an SDN controller for the domain that is configured as a member and communicates with the primary controller on behalf of its members. The proposed scheme also creates a structure where an application or service meets the QoS parameters required with the network status to attempt user request. The next section explains the details of the proposed solution.

VI. CONCLUSION AND FUTURE DIRECTION

The popularity of ITS creates a bridge between the real world and smart world, where it takes us to a new horizon of the intelligent transportation era. Therefore, we aim to design a system that intelligently finds a route and other services without facing any challenges. Based on such requirements of today's era, this paper proposed an architecture based on 5G and SDN. The main purpose of the proposed scheme is to provide continuous connectivity between the vehicles and SDN controller. Moreover, the role of 5G enhances the capabilities of data rates. Such enhancement helps in cases where it is more important to deliver the data in time. The results showed that the proposed system architecture outperforms the existing AIDV routing protocol in terms of average processing time, processing of vehicle's data per minute, and flow density in various scenarios.

Future developments will be concerned with different elements, such as calibration and validation of the system architecture toward urban planning. Others include an enhancement of the existing scheme toward handling vehicular network, emergency system, healthcare, human behavior [29,30] in social networks, and smart city planning.

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