A Comprehensive Survey: Benefits, Services, Recent Works, Challenges, Security, and Use Cases for SDN-VANET

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ABSTRACT Vehicular communication networks is a powerful tool that enables numerous vehicular data services and applications. The rapid growth in vehicles has also resulted in the vehicular network becoming heterogeneous, dynamic, and large-scale, making it hard to meet the strict requirements, such as extremely latency, high mobility, top security, and enormous connections of the fifth-generation network. Previous studies have shown that with the increase in the application of Software-Defined Networking (SDN) on Vehicular Ad-hoc Network (VANET) in industries, researchers have exerted considerable efforts to improve vehicular communications. This study presents an exhaustive review of previous works by classifying them based on based on wireless communication, particularly VANET. First, a concise summary of the VANET structure and SDN controller with layers and details of their infrastructure is provided. Second, a description of SDN-VANET applications in different wireless communications, such as the Internet of Things (IoT) and VANET is provided with concentration on the examination and comparison of SDN-VANET works on several parameters. This paper also provides a detailed analysis of the open issues and research directions accomplished while integrating the VANET with SDN. It also highlights the current and emerging technologies with use cases in vehicular networks to address the several challenges in the VANET infrastructure. This survey acts as a catalyst in raising the emergent robustness routing protocol, latency, connectivity and security issues of future SDN-VANET architectures.

INDEX TERMS Vehicular ad hoc network (VANET), SDN, 5G, Internet of Vehicles (IoV), routing protocol, connectivity, mobility management, security.

I. INTRODUCTION

Connected vehicles promote the development of existing plans of action in the automotive industry. The capacity to test data and perform good decision making will studies that seek to improve the livability and versatility of urban areas. Connected vehicles enhance the safety and ease of travel and supply data manufacturing in a multibillion-dollar industry. The number of linked vehicles is anticipated to reach 250 million by 2020 [1]. Internet of Vehicle (IoV) is one of the changes that has occurred in the IoT. IoV evolved from VANET, which is a modern technology used to control vehicle-to-vehicle contact (V2V). VANET has been utilized in vehicle-to-infrastructure (V2I) communi-

cations in external applications involving road safety and entertainment-related information, such as those in [2] and [3] However, V2I can be described as a type of technology that enables vehicles to interact with one other with or without the use of a roadside unit (RSU) while traveling in and out of the network. Moreover, despite the signal-attenuation-limiting external issues, such as buildings and other obstacles, RSUs can be classified as another challenge in the network.

Furthermore, it is of significant challenge to meet the various demand of QoS (Quality of service) in IoV. Future connected vehicles are anticipated to play a significant role as mobile centers of data collecting and processing in day-to-day human life. Therefore, IoV should be able to accommodate distinguished services requests with various QoS requirements.

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For example, safety-related services need low latency and high reliability, streaming services spent tough constraints on connection speed and stability, and delay-tolerant services are generally bandwidth-consuming. However, heterogeneous network substrates can barely support the difference of these services and the network, but it cannot obtain the global view of all the service required in order to make normalizes among them for the aim of serving as many requests as possible. There is one more challenge that is to how to manage and control in a scalable and flexible manner. With the ever-increasing vehicular network size and density as well as the highly-evolved physical layer technology, the management and control of IoV will become an underlying bottleneck impeding vehicular network performance. That is, due to the high mobility of services, hand off events among different infrastructures are more frequent, comparison with conventional wireless networks. Passive Handoff without former knowledge on vehicles' traces in ineffectual and is likely to cause service interruption. Also, access and admission control should be tightly coupled with the QoS-driven resource allocation process. However, there is still a lack of unified and universal ways to deal with the management and control issues that emerge in IoV.

In order to cope with the aforementioned challenges, a consensus has been gradually reached on the necessity of fundamental reconsideration on IoV design.

SDN over VANET has successfully demonstrated its superiorities against others. As the name suggests, it is the integration of SDN and VANET. SDN is the other technology that concentrate on the both sides (industry and academy) as there is huge chance for it to be used most all over the world in the future. SDN is a new technology that provides a network architecture to splits the control from the data. The control in this sort of technology is centralized in which it allows the network to be dynamic as well as the network resources can be easily arranged efficiently with cost-effective manner. Regardless of having the big potential to address VANET system can be increasingly beneficial from utilizing the SDN controller because of the separation that is found between the control plane and data plane in VANET, network intelligence can be intelligently central, and the primary infrastructure of the network is separated from the applications. There is a need to develop such systems which can speed up the traffic movement at intersections as per traffic demand the congestion problems by getting the benefit of the advancement in the area of V2I communication. The management and control of SDN over VANET is still an open issue.

In this context, this review paper tries to critically evaluate some recent proposals, i.e., to use SDN as architecture applicable to realize an efficient and flexible management and control of IoV. This paper contains of the following points:

- Initially a complete survey of SDN and VANET with emphasis on their possibilities and its requirements.
- This survey includes four types of applications in terms of routing protocol and mobility with connectivity

management, low latency and security applications in SDN-VANET approaches has their advantages and difficulties, mainly with respect to security-related services and data communication mechanism efficiency. However, we are totally agreed that, the proposed survey is able to offer the requisite perspectives to improve the development to be more robust infrastructure network in terms of routing protocols and improve connectivity management and mobility between V2V and V2I in SDN-VANET architecture. Apparently, this can be considered as the first overall survey that illustrate such a study and investigation on SDN-VANETs.

- The classification of this survey is based on the communication models supported, packet delivery ratio, throughput, average delay time, technique, simulation tool that using in their technique, types of controllers and protocols of SDN used and remarks to provide the required insights to achieve higher output speeds and reduced delays and overhead, the fastest route with low latency and high throughput can be used for higher network efficiency. A table that compares the finding results of the recent researches found in literature and discusses their problems along with the used network parameters that have been used in their algorithms.
- A view of some the advantages of SDN-VANET discussed and open issues with the research directions. Also, the emerging technologies discussed as they are integrated with SDN-VANETs to enhance the functionality with use cases.

In addition, this review paper can be organized into following sections. Section II the background and overview contain five attributes including the main VANET characteristics, SDN features, SDN over VANET, SDN over VANET services and VANET routing protocol. Section III discusses the applications of SDN-VANET. IV. Comparison of some algorithms based on their parameter used. V. Advantages of SDN-VANET. VI. Use cases with emerging technologies. VII. Open issues with research direction.

II. BACKGROUND AND OVERVIEW

In this section, VANET introduced. Here, the need to explore how SDN can enhance VANET networks. In addition, the details of Software-Defined VANET are explored as well. As shown in Fig. 1 A simplified view of the background and review.

A. VANET

Communication in VANET is carried out through mobile broadband (e.g., 4G/LTE) using V2V correspondence with ad hoc design and V2I correspondence within the RSU. The conventional VANET services incorporate car and road security administration and traffic safety, and the effectiveness of traffic services are intended to enhance the traffic flow and benefit the neighborhood. Infotainment services provide data and entertainment. These devices use specific short-range
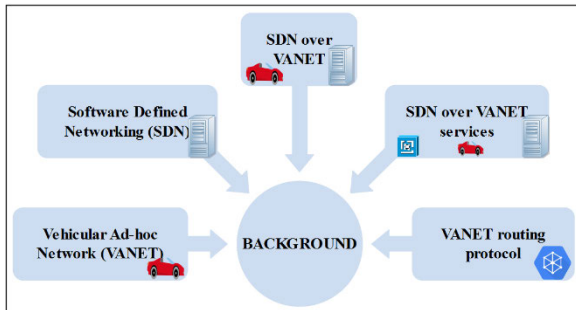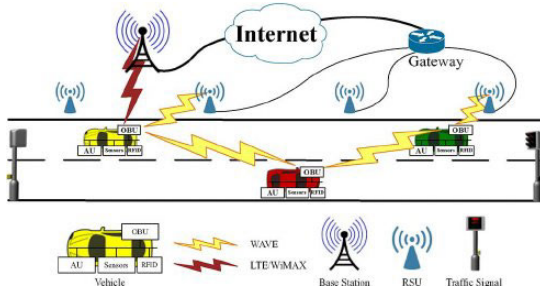
FIGURE 1. A view of the background.

FIGURE 2. Network structure in IoV [8].

FIGURE 3. Basic SDN architecture [7].

FIGURE 4. OpenFlow switch in IoV.

communication (DSRC) and run on a band of 5.9 GHz with 75 of the bandwidth range in approximately 1000 m and are used in ad hoc communication, wherein wires are unnecessary and each connected node can move freely. RSUs are also called routers because they operate similarly to a router in V2V communication on the road and interact with other network devices. Public communications have higher priority than private data communications even if the network must support both. Vehicular communication evolves as a part of ITS. Fig. 2 shows the structure of an IoV network. There are mainly three components of VANET namely On Board Unit (OBU), Application Unit (AU) and Roadside Unit (RSU) [4]–[7]:

B. SDN

SDN can be defined as the partition between the system (control plane) and the sending capacities (data plane). The task of the rules is created in the controller before sending the data to a network device while the controllers command the logic dictating the network behavior [4]. According to [5] SDN is defined as a recent network that can be the solution to the limitations of old traditional networks that have been in use in previous decades. Fig. 3 Logical representation of SDN [7]. The abstraction of the existing VANET to integrate with SDN concepts is described as follows:

1) CONTROL PLANE

This plane is used to control all vehicles and RSUs in the data plane. It stores and runs the status of all SDN switches gathers the data of each vehicle, such as vehicle location, speed, and network connectivity the topological network data obtained
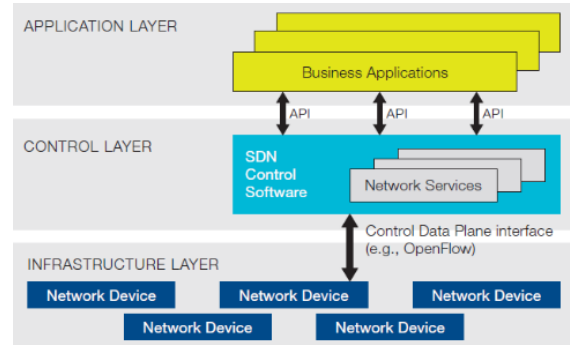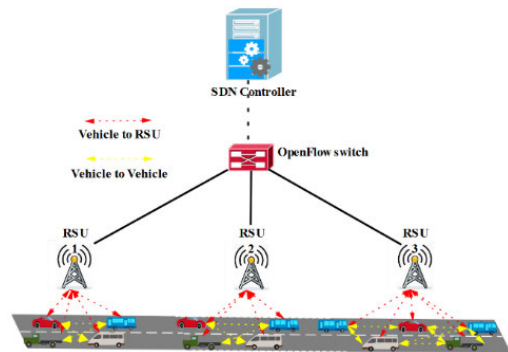
is dependent on the global positioning system (GPS). A controller can utilize such data to locate the forwarding decisions and then determine the most suitable route in forwarding the packets of information and reaching the destination [9].

2) DATA PLANE

This plane is built using network components, which provide connectivity. The network components comprise of vehicles and RSUs that contain SDN/OpenFlow (OF) switches. The vehicles are considered the main data plane components, whereas RSUs are the stationary data plane components. SDN switches apply diverse deployment policies. The configuration of every vehicle is given through the control interface. The notice of every vehicle is sent to the SDN controller to enhance network configuration. The IEEE 802.11p has utilized for V2V and V2R/R2V communication in vehicular networks. The entire vehicle data contain the direction, position, and speed. These data will be placed in the established RSU in OF's flow table.

3) OF PROTOCOL

OF can be conveyed and organized effectively in the grounds network and is utilized generally in the communication interface between the data and control planes of the SDN infrastructure [3]. As shown in Fig. 4 this protocol comprises three primary parts, namely, OF switch, protocol, and controller. The OF switch is located in the data plane or infrastructure

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layer of the SDN pattern. The three sections in an OF switch include the flow table, secure channel, and OF protocol. Each flow table contains one flow entry utilized for handling the flow in the switch. The security channel is utilized to allow the availability between the switch and controller through the OF protocol. The OF controller is crucial in the handling of the packets flowing in the network. A flow entry comprises of match field, timeout, and activity. The data in the match field includes the source and the destination. The break time can be determined by using the vehicle's speed and its distance to the RSU. [10], [11], [12] and [13] provide additional details on the SDN controller.

4) OPENRADIO

OpenRadio, designed for a programmable wireless network dataplane. Built around a commodity multi-core hardware platform, the core component of OpenRadio is a software abstraction layer that exposes a modular and declarative interface to program the PHY (baseband) and MAC layers. An operator describes a protocol by defining rules to match subsets of traffic streams and specifying actions to process them. Rules are logical predicates on parameters of packets such as header fields, received signal strength, channel frequency and other fields that may be programmed. Actions describe behavior such as encoding/decoding of data and scheduling of traffic on the channel.

OpenRadio's declarative interface is built on a *principled refactoring of decision and processing paths in wireless protocols*. Specifically, we observe that protocols can be finely partitioned into two separate parts: processing blocks which specify how a protocol transforms analog waveforms into bits, and decision logic which specifies when different processing transformations are used.

OpenRadio's design provides two benefits, essentially, it decouples wireless protocol definition from the hardware, even while ensuring that commodity multi-core platforms can be used for implementing the protocols. While the second benefits is the design of this software abstraction layer that exposes a modular and declarative interface to program wireless protocols. The key idea is a principled decomposition of wireless protocols into separate *processing* and *decision* plane components with a simple, well understood API between them. This decomposition is the main enabler of an efficient implementation of a flexible and modular wireless programming interface.

5) OPENROADS

OpenRoads provides researchers control of the network through two means, namely, control of the datapath using OF and control of the device configuration using SNMP. Via control given by OF and SNMP, we further provide abstract events and functions for network management in OpenRoads. The abstraction in turns allows us to manage with ease heterogeneous network devices, namely different wireless technologies such as WiFi and WiMAX.

Being a widely deployed interface, SNMP allows researchers to configure the switches and wireless access points in a network. Configuration is especially critical in wireless devices, where parameters like transmit power can directly impact on the datapath performance. Further, controllers can also be promptly informed of network events such as a host joining a WiFi AP. Moreover, there are some specifications of OpenRoads architecture:

a: OPEN ROADS' iNTERFACE
- Abstraction for network control (in terms of events) installed on top of NOX.
- Provide a some of recent features for communication such as API, (wireless) device control and flow management.
- Offer a uniform interface for sellers and heterogeneous technologies, while allowing a carry out of specific control for the technology if demanded.
- Varying the direction of flows for host can be achieved within a dozen lines of C/C++.

b: PHYSICAL INFRASTRUCTURE
- Enable OF by firmware improvement.
- SNMP easily available.
- Software reference switch/Net-SNMP for AP.

c: DATA-PATH CONTROL
- **OpenFlow**
  - Controlling the export forwarding by means of flow table manipulation (separate control from datapath).
  - Communicating by using OF messages.
- **FlowVisor**
  - Slice flow space in a flexible way based on "flow-space".
  - The slicing is achieved through selective proxying / rewriting / blocking of OF messages.

6) SDN CONTROLLER LISTS
There are a classification between five SDN controllers based on some categories are presented in Table 1.

a: POX/NOX
POX is a one of open source controllers that responsible for evolution of SDN applications. Where this controller offers an effective method to employment the OF protocol that known as the de facto communication protocol which is placed between the switches and controllers. By employment the POX controller, a further flexibility is achieved in order to running a different application such as load balancer, switch, firewall and hub. This controller is a python based SDN controller which is evolved from the NOX controller.

While, NOX controller which is centralized controller was implemented in C++ language. Noteworthy, the NOX is the first controller possess an open-source feature which was

TABLE 1. Summary of the SDN controller classification.

Controllers / Classification	POX/NOX	Trema	Ryu	OpenDayLight	Floodlight
Open Source	Yes	Yes	Yes	Yes	Yes
Platform Support	Linux-Mac-Windows	Linux	Linux	Linux-Mac-Windows	Linux
Architecture	Centralized	Centralized multithreaded	Centralized multithreaded	Distributed	Distributed
OF support	V1.0	V1.0	V1.0-V1.2-V1.3	V1.0	V1.0
GUI support	Yes	No	Yes	Yes	Web GUI (Using REST)
Language support	Python	Ruby-C	Python	Java	Java
Virtualization	Mininet-Open vSwitch	Built- in Emulation Virtual tool	Mininet-Open vSwitch	Mininet-Open vSwitch	Mininet-Open vSwitch
Documentation	Poor	Medium	Medium	Medium	High
Routing	Yes	No	Yes	Yes	Yes
Dynamic network taps	No	No	Yes	Yes	Yes
Multi-Layer Network Optimization	No	No	No	Partial	No
Load balancing	No	No	No	Yes	No
Network Monitoring	Partial	Partial	Yes	Yes	Yes
Traffic rerouting, transport networks	Yes	Yes	Yes	Yes	Partial

*NOTE: OF = OpenFlow, GUI = Graphical User Interface.

presented in 2008. However, this controller is implemented on the top of server. Meantime, the selective server plays an important role in storing the most important data for the network global view. the essential components of a NOX-based network: a some of switches and one or more server network-attaching. The NOX controller software (the management applications which operate on NOX) run on these selective servers. In general, The software of NOX controller can be considered as comprising several processes that carried out by different controller (typically, single NOX software on each server within the network) as well as a single network view (this is remained in a database running on any server in the same network).

The network view has the entire results of NOX's network observations; the whole applications utilize this state to perform management decisions. the deterioration of network switches behavior attributed to use the NOX in order to control network traffic, to overcome this limitation, a suitable switch must be chosen that offering the OF abstraction.

b: TREMA

it is a framework for C and Ruby that builds software platform for developers of OF protocol. The easiest way to utilize the Open Source software with free charge.

c: RYU

it is a component-based SDN controller. Ryu involves a collection of a different built-in components. where these components can be extended, composed, and replaced for producing new customized applications for recent controller. thus, to create a new developed component, any programming language can be employed.

C. SDN IN THE VANET ENVIRONMENT

This section presents the SDN networking. We explore how SDN can enhance VANET networks [14]. by conducting a comprehensive survey on the implementation of SDN in VANET [15]. An architecture of operations is proposed to present how the network can benefit from and support the software defined vehicular network services and the new functionalities. The network intelligence and state can be in the center due to the separation between the control and data planes in VANET. The infrastructure of the main network can be exported from the applications. Therefore, the VANET environment has potential for use in obtaining high adaptability, versatility, and scalability. The two main elements of SDN are the control and data planes. The router protocol is deployed to communicate between these two planes. SDN controls the suppleness and programmability of the network, causing the system to become aware and adapt to

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the conditions and requirements. The awareness also allows the software-defined VANET to achieve the best decisions based on the obtained data from sources.

The SDN controller tracks the status of the data plane elements and injects the forwarding rules through a well-defined application programming interface called the southbound interface (SBI). The most prominent SBI is OF. In addition to the controller, a common programming abstraction is applied in the upper layers, that is, the network applications are provided by the northbound interface. Extending the SDN principles (flexibility, programmability, and centralized control) is beneficial in managing the networking and communication resources in vehicular networks, such as the optimization of channel allocation and network selection and the reduction of interference in multi-channel and multi-radio environments, enhancement of packet routing decisions in multi-hop environments, and effective handling of mobility in high-speed scenarios.

D. SDN IN VANET SERVICES

1) SDN ASSISTED VANET SAFETY SERVICE

An example of the use of VANET technologies is the enhancement of street safety with the use of V2V technology communication. However, the implementation in street safety is similar to the use of software-defined VANET in the enhancement of administration compared with the application of conventional strategies. Hence, SDN is used to maintain the farthest point of frequencies with the goal point.

2) SDN BASED ON THE DEMAND OF VANET SURVEILLANCE SERVICE

Surveillance service is used in both emergency and authority vehicles. This type of service can be used in additional spaces where software-defined VANETs are located. This service can be implemented differently from the traditional way. In an SDN-based system, the request is created by the SDN controller, wherein the controller pulls out the flow rules of the surveillance information to extend the requesting nodes. In the case of multiple requests going into the same surveillance data, the controller can insert all the rules to ensure that many copies are sent to numerous destinations.

3) WIRELESS NETWORK VIRTUALIZATION SERVICE

Wireless networks aim to offer abstract logical networks in the shared resources of the physical network. SDNs can be used in the server to virtualize the arrangement administrations and enable diverse streams to choose distinctive radios/interfaces utilizing diverse frequencies. Assuming that the radio frequencies utilized by every individual system is unique, then the singular system's activity is disconnected from the others and is accordingly viably cut from the systems to create virtual remote systems. The remote nodes and RSUs are gathered to ensure that each one will only forward traffic from the selected group of wireless nodes. However, the controller will be in charge of which radio interface will

help the programmability of the traffic located in the SDN controller.

SDN is a powerful innovation eligible of promoting the dynamic nature of VANET and ITS applications by encouraging flexibility in network management and large-scale optimization with unified abstraction [16]. Future candidate innovations in 5G VANETs must be dependent on cloud computing, SDN, and fog computing (FC) to meet the requesting requirements of future ITS. Some initial studies have been completed to incorporate both innovations into vehicular communication networks [16]–[19].

E. VANET ROUTING PROTOCOL TOPOLOGY-BASED ON ROUTING PROTOCOLS

Many researchers have proposed routing protocols for the new technology VANET. The protocols are used to present a path between the network nodes by decreasing the overhead [20]. thereby enabling the used protocols to be assembled in the categories of proactive and reactive routing.

1) PROACTIVE (TABLE-DRIVEN) ROUTING PROTOCOLS

In this class of routing protocols, the nodes are maintained with data on the routing information. These data and information are saved anytime another node receives them [20]. Therefore, the paths are created rapidly without delay. This protocol does not require route discovery and low latency in real-time applications, but its unlisted tracks are used widely in the bandwidth [18]. Broadcast nodes in the network can be classified into two cases (periodically or in the way of response) according to [20] and on the basis of how they deal with the changes in the network topology. Each network node will continue routing to update the routing table with a collection of data in the destination information as follows:

destination addresses,

- Number of nodes to obtain the addresses.
- Highest sequence number established for that destination.

The previous information can be used on all nodes to identify the difference between the old path or the road and the new ones. Furthermore, to update the table with the new information continuously, the topology must change rapidly in each change wherein a new set of information is introduced into the routing table. In a new spread, the node–increment order number is transferred with the routing table. Also, the routing table is exploited through the other nodes to approve the update of their routing table and eliminate the routing loops. Two types of updates can be utilized to limit the traffic produced by all these updates.

- Incremental updates: in this case, the data that is changed from the last updated can be sent.
- Complete updates: in this case, the entire data that is in the routing table is transferred to all nodes in the network.

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TABLE 2. Categories of single and multi paths in SDN-VANET.

Categories	Features	Limitations
Single path	Good for lower traffic or spare network and implementing is easy	Higher delay, low throughput
Multi-path	Ensured data delivery, load balancing, short latency	Only work for dense network

TABLE 3. Categories hybrid and centralized network in SDN-VANET.

Categories	Features	Limitations
Hybrid	Low uplink overhead in central controller, load balancing.	Low data delivery, high local overhead
Centralized	Active route, high PDR	Load on the central controller

TABLE 4. Categories of prediction and beacon mode in SDN-VANET.

Categories	Features	Limitations
Prediction mode	Low overhead, scalable, good for dense network	High delay due to complex prediction algorithm
Beacon mode	Active route, high PDR	High uplink overhead

TABLE 5. Summary of the most recent approaches to cope with the directionality implications in SDN-VANET based on routing protocol.

Ref	Comm.MS	PDR	Through put	Delay time	RP	Tool	Controller	South Bound API	Techn	Remarks
[11]	V2V, V2I	88%	-	-	GPSR, OLSR, AODV, DSDV	NS-3 & SUMO	-	Open Flow	Routing protocol	*Design SDN, which mainly for wired infrastructures, particularly in information center place.
[29]	V2V, V2I	35%	-	20%	SDGR, AODV, GPSR	NS-2, SUMO	POX	Open Flow	Routing protocol	*Novel SDN-based SDGR, *Provides global view, and compute optimal path.
[31]	V2V, V2I	90%	-	-	OLSR, GPSR	NS-3, SUMO	POX	Open Flow	Routing protocol	*A trajectory-prediction-based vehicle status update policy by moderating SDN management load.
[36]	V2V, V2I	85%	-	10ms	OLSR, DSDV, DSR, DB	NS-3, SUMO	-	Open Flow	Routing protocol	*Enhance data transmission efficiency.
[37]	V2V, V2I	60%	-	8s	DSDV, GRA	NS-2, Mobi-Sim	-	-	Routing protocol	*Improve QoS to prevents access to cloud services in OBU reduce delay, minimizes broken link rate and build safer path.
[38]	V2V, V2I	70%	-	-	AODV, OLSR, DSDV	NS-3	-	-	Unicast traffic	*Broadcast Safety Messages in two scenarios compare between SDN-routing and traditional routing VANETs.
[39]	V2V, V2I	80%	750 kbps	60ms	HRLB, GPSR, GLRV, VDLA, VLBR	NS-3	POX	Open Flow	Hierarchical geography routing protocol	*A protocol partitions a large region into multiple little grids. *Build a route cost function together with load balancing and retain two routes with lower costs of the selected grids.

*NOTE: REF = reference, Comm.MS = communication models supported, PDR = packet delivery ratio, Delay time = average delay time, RP = routing protocols used, Techn = technique used.

2) REACTIVE (ON-DEMAND) ROUTING PROTOCOLS

These protocols are the opposite of their proactive counterpart. Such protocols can only create the route as needed. The following process is performed when routing is necessary for the network. A global process can discover the route and launch the path. Then, the data or flow is sent from the destination to the source. However, the routes are created using some types of algorithms to obtain the best route. Source routing implies that every hub incorporates its location in the header of the bundle, which conveys the entire succession rundown of nodes via which the packet should transmit. This steering convention includes two foundation activities called route discovery and route maintenance. According to [21] the source node goes through an RREQ to propose the method of data or packet transmission to the specific definition node. Accordingly, the mechanism is used to detect the route between the source and distention for future use. Therefore, when the link is broken between them, the discovery can find it again to protect from the data loss and discover a new route in case of broken links.

The features of this protocol do not require periodic flooding to update the routing table and are only needed upon request. Moreover, decreased beacon is required to maintain bandwidth. However, the drawbacks of this protocol are that it has a high route discovering latency and excessive
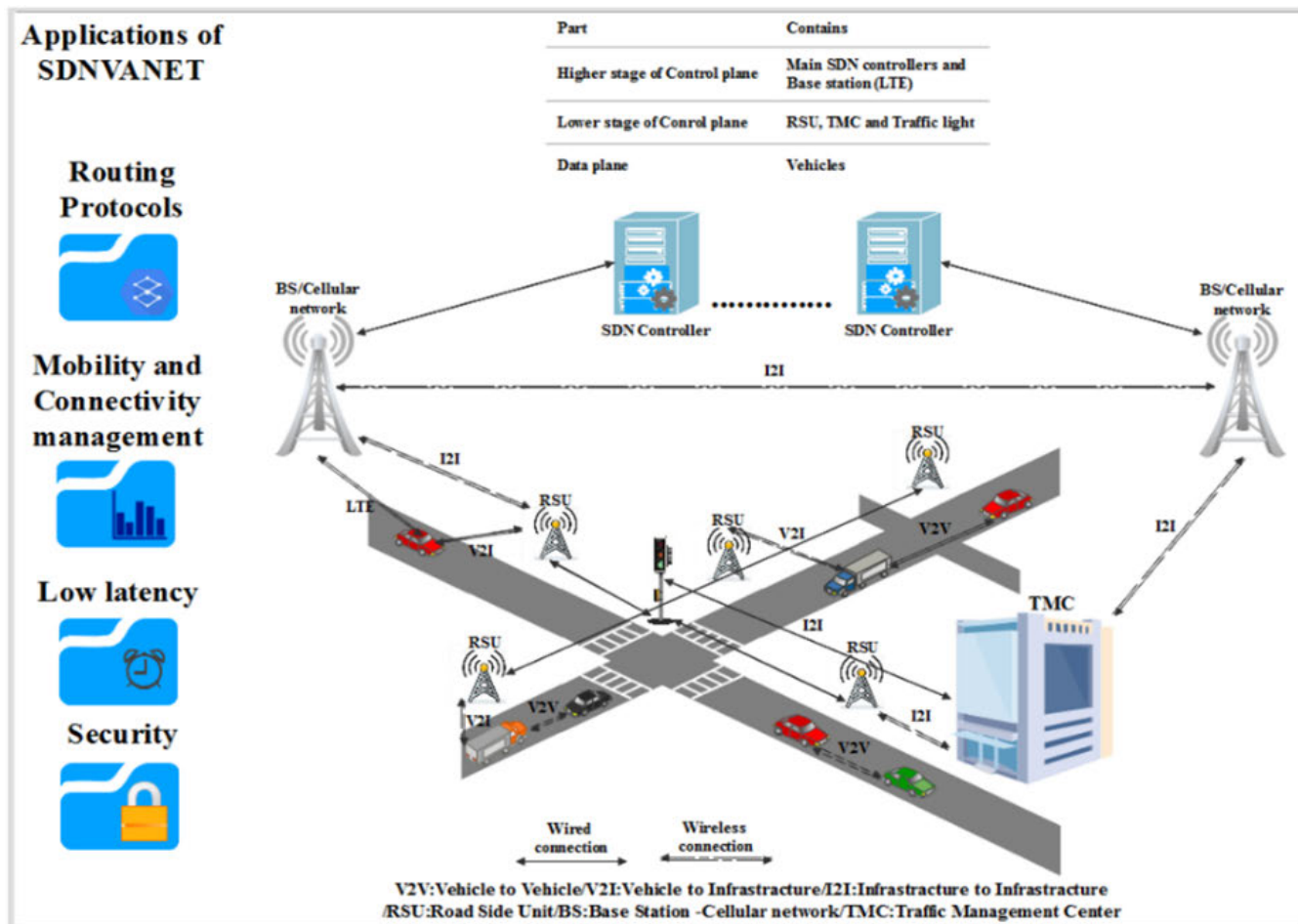
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FIGURE 5. Applications of SDN-VANET.

flooding of the network causing interruptions in node communication [22].

III. APPLICATIONS OF SDN-VANET

In this section, we investigate recent studies related to the SDN–VANET paradigm. The applications of SDN–VANET are summarized in Fig. 5.

A. SURVEY ON ROUTING PROTOCOL

Networks without an infrastructure can incorporate a wide range of without help operated devices. A portion of these devices will likely be unable to communicate with an SDN controller for different reasons, including support, capacity, or basically client decision. Hence, to accomplish regressive compatibility (when the connection with the SDN controller is lost), every wireless SDN device must assist a fallback mechanism in reverting to the conventional routing protocols in classic ad hoc networks, see Table 5.

In [23] and [24], nodes only create one copy of the data packets to reduce network load. In [25] nodes selectively send copies of packets to their neighbor nodes. In these replication-based techniques, the nodes settle on the routing

decisions, as indicated by a few principles, such as utility [25] or likelihood-based routing [26]. These strategies assume that the movement patterns of nodes are not simply irregular and that future contacts are dependent on past data. A large portion of these VANET applications is enabled through the design of different routing protocols. Routing protocols differ from broadcasting [27], route-discovery [27], position-based protocols [28], to clustering-based protocols [29], [30].

1) COMPARISON OF THE SUBCATEGORIES OF ROUTING SCHEMES IN SDN-VANET

This section classifies the different proposed routing schemes. Given that the majority of existing routing schemes in SDN–VANET are designed for unicasting, we classify the unicast routing schemes in this study.

2) SINGLE-PATH AND MULTIPATH

In most studies [31] and [32], the controller computes only one path (for the unicast). However, because of the highly dynamic nature of SDN–VANET, the links may be valid for a very short time, which may be insufficient to

accomplish the transmission of the required amount of data. Therefore, some schemes [33] and [23] have established multiple routes to guarantee the delivery of data messages. The number of paths used in data transmission are presented in Table 2.

3) CENTRALIZED AND HYBRID SCHEMES

In centralized routing schemes [24]–[26], [34] the controller provides per-flow routes to vehicles, which are efficient in data message transmission based on the computation of the global-view controller, as shown in Table 3.

4) BEACON AND PREDICTION-BASED SCHEMES

The network topology can be updated using the two modes of beacon- or prediction-based modes. All vehicle status information is collected by receiving the beacons sent by vehicles in the beacon-based mode [31], [32]. By contrast, the controller only collects a limited number of beacons from vehicles and predicts the link status based on historical data [34], [27]. The approach of network topology maintenance is presented in Table 4.

According to [11] and [30], the user of architectural design and a collection of offers was proposed in SDN–VANETs. In the suggested architecture targeted at enhancing the network adaptability and programmability and offering other services, techniques, and modifications for VANETs in the network to fulfill the rapid and new needs of specialized VANET applications. The study also shows the feasibility and communication performance of SDN–VANETs. Reference [30] aimed mainly to link the creative network services to an expert in vehicular communications. This architecture contains different elements, including vehicles and RSUs, which are engaged in the application layer. Some use cases were helpful in illustrating how the architecture authorizes rapid network innovation. The advantages of this study are the permitted implementation of the term programmability by choosing the routing protocols and the obtained adaptability by the usage of network to disengage multiple residents.

According to [28] the SDGR protocol built for the VANET was proposed to cover the specific and basic requirements of VANETs. In [29] the authors used SDN to offer on-demand routing protocols in VANETs. In their study, the authors used global and local types of levels. First, the global level is used to determine the location of the vehicle and calculate the global route based on the vehicle's information. Second, the local level is utilized to consider the route in each vehicle. As a result, viewing the packet reception can be delayed and SVAO performs better than the ad hoc routing protocols DSR, DSDV, OLSR, and DB.

In [35] the proposed SDN distributed architecture to improve the communications via V2V and V2I while enhancing resource consumption and reducing latency. We allocate a defined network of base stations to the control plane while the data are stored in the vehicles. Increasing the reliability of contact and operation requires improved routing protocols

and fast computing capabilities for automobiles that cannot be addressed by the SDN design alone. While [36], addressed the loss connection between the nodes and controller when the traditional unicast routing protocol for safety applications was used.

Taking a step further, the authors in [37] used a hierarchical routing scheme with a load balancing (HRLB) protocol for SDVN, exploited the advantages of the SDN central controller and designed a hierarchical routing from both global and local perspectives. Given that VANET is a type of low latency-sensitive network, high priority should be given to the latency generated by the architecture and its operation. In [43] a comprehensive survey on the implementation of SDN in VANET networks was conducted. The proposed architecture operations benefited the SDN–VANET services and new functionalities supporting them. The use of separation between the control and data planes in VANET allows the network intelligence and state to be in the center.

B. SURVEY ON MOBILITY AND CONNECTIVITY MANAGEMENT

Effective mobility management in SDN–VANET is essential in maintaining a stable and precise global topology perspective at the SDN controller, which is required for the authorization of different networking tasks. SDN can provide network control with flexibility and programmability. This survey describes the previous studies on VANET in SDN, especially those that improve connectivity management and mobility between V2V and V2I as shown in Table 6.

In [23] proposed a performance-enhanced protocol in an SDN-enabled connectivity-aware geographical routing protocol (SCGRP) to optimize the transmission of data packets. The proposed protocol aims to extend the use of an SDN controller to the urban environment of VANETs for data transmission with a global view of the network topology. The routing procedure is transferred to the remote controller to calculate the in-time routing measurements and obtain effective routing decisions, which are served by the vehicles utilizing cellular technology. SCGRP predicts the node connectivity and connection lifetime between the forwarding vehicles in a path. Therefore, the packet was sent in the most connected path with the least connection breakages from the decreasing transmission delay and expanding packet delivery ratio (PDR). While,an SDN-based hierarchical architecture in [26]. addressed the problems of mobility management and poor network connectivity in an efficient manner. Two applications were also implemented to demonstrate the coefficient mobility management and QoS supported by integrating the layered design and harnessing capabilities. Several studies on route decisions were dependent on latency control.

In [31] the flexibility and programmability of SDN in vehicular networks contribute to the improvement of the overall framework performance in situations where connection loss exists between the vehicles and the essential SDN controller. The proposed arrangement utilizes the clustering technique to create independent and local SDN areas. The
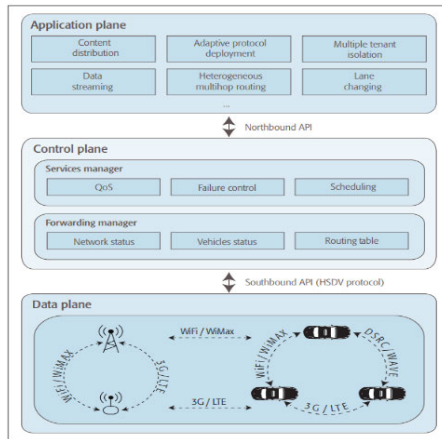
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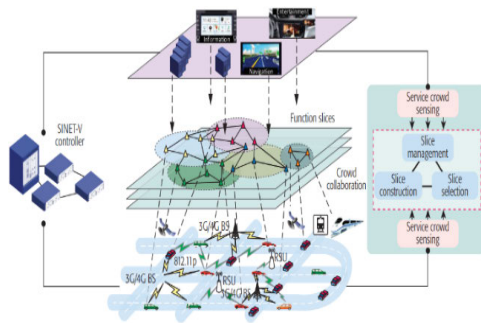**FIGURE 6.** Three layers of HSDV architecture [31].

FIGURE 7. Illustration of a software defined vehicular network [38].

simulation results demonstrated that the proposed solution was better than the conventional routing protocols (GPSR, DSDV, and AODV). However, HSDV obtained more delivery rates and lower latency and overhead. Fig. 6 depicts the three layers of the HSDV architecture.

In [38], a novel customized smart identifier networking (SINET-V) is proposed to improve the crowd collaboration in software-defined vehicular networks. In (SINET-V), the function can be flexibly and properly organized by a group of network components with crowdsensing. Hence, multiple functions can motivate different applications through the use of intra and interslice collaborations. Moreover, the authors of this study analyzed the potential in different vehicular instances and obtained results that present the successful development of higher mobility and high QoS in SINET-V in a realistic urban vehicular scenario Fig. 7. The combination of FC and VANET with IoV enhanced the reliability of communication and QoS because of the fog architecture located between the physical servers and vehicles.

Moreover, authors in [39] proposed another routing protocol for SDN–VANET that considers the measurements obtaining the coefficient mobility management and fix routes with minimal communication delay. In this case, the routing protocol enhanced packet distribution and reduced latency. The suggested method used network-wide knowledge trans-

parency in the SDN controller to differentiate between the interacting nodes the steadiest routes with the shortest path.

C. SURVEY ON LOW LATENCY

VANET is a low latency-sensitive network and high priority should be given to the latency generated by the architecture and its operation. Hence, we provided the various delay parameters used. A comparative study of the low-latency requirement in this survey was conducted against VANET and the existing SDN controller as shown in Table 7. The use of SDN allows the efficient delivery and control of FC networks. Thus, its use reduces the latency of service. In addition, the functionality of programming versatility of SDN offers serious support in deploying the FC services allowed by SDN on edge devices. The use of SDN topology data permits diverse reconfiguration in the router flow tables to aid the application of adaptive networking services and help reduce latency, thereby obtaining improved end-user experience. For instance, X vehicle travels outside the RSU coverage area. However, C may obtain the service alerts from neighbor vehicle Y because Y is within the RSU coverage area. In this kind of situation, RSU C may dedicate other resources to vehicle Y to address its additional demands i.e., support for vehicle X.

In [40], services are given to missed cars by taking advantage of the characteristics of information-centric networking. In [41] the automatic navigation system (ANS) was proposed with the use of autonomic computing architecture in VANETs to perform self-management in navigation and to increase the scalability of VANET. However, this system used each car as a mobile sensor to obtain information on traffic locations. This information can also be used to predict the best route in the system using the routing algorithm. The key advantages of this system are as follows. This system is used to improve the travel time of all vehicles. By comparing the results with other algorithms, ANS showed it was 16.7% faster than any other routing algorithm. In [42] introduced an approach of software-defined edge computing in transferring the requests done by vehicles at the edge of the network. The proposed framework successfully integrated the capabilities of mobile edge computing (MEC) inside the network base stations that allow vehicles to communicate numerous services. This method enabled high service accessibility and was also beneficial to QoS. In addition, this approach worked as an extension of Mininet–Wi-fi and was tested on several experiments to compare the delivery service latency in the core cloud and the edge of the network.

Additionally, the authors in [43] proposed the SDNi–MEC architecture, such that the calculation of the V2V path for data offloading can be determined to utilize the centralized path in the network edge rather than using a dispersed route among vehicles. The algorithm of LifeTime-based network state routing (LT-NSR) was proposed and executed in the SDNi-MEC server to discover the V2V routing path with the longest lifetime dependent in the present network topology. By utilizing the centralized model and 5G network in the

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TABLE 6. Summary of the most recent approaches to cope with the directionality implications in SDN-VANET based on connectivity management and mobility.

Ref	Comm. MS	PDR	Through put	Delay time	RP	Tool	Contr oller	South Bound API	Techn	Remarks
[23]	V2I	60%	-	10%	CRP routing protocol	Mininet, SUMO	Open daylight	Open Flow	Geographic routing protocol	*SCGRP explores the varied traffic situations among the road segments before choosing the routing path.
[26]	V2V, V2I	90%	-	0.01s	GPSR, CLWPR	ONOS, Mininet	Flow Visor	Open vSwitc h	Cloud computing	*SDN- based hierarchical system supports a centralized database store for a consistent vision of the topology.
[31]	V2I, V2I	50%	32%	28%	AODV, GPSR, DSDV	NS-3	-	-	Clustering	*Connection loss between vehicles uses cluster. *Improve overall performance of VANET by SDN.
[38]	V2V, V2I	47%	-	-	-	iPhone 6	-	Open Flow	Crowd collabor- ation	*Virtualize slices are flexibly organizing by a group of network elements. *Enhance crowd collaboration for SDNs.
[39]	V2V	92%	-	60ms	AODV, ROMSGP	NS-3, SUMO	-	Open Flow	Flow instantiation	*Optimized a novel packet routing planned with a source routing-based (FI). *Considers link stability and shortest delay time.

*NOTE: REF = reference, Comm.MS = communication models supported, PDR = packet delivery ratio, Delay time = average delay time, RP = routing protocols used, Techn = technique used.

SDNi–MEC design, the network topology, and V2V paths can be obtained and built from the periodically reported context, which was sent from the vehicles and placed in the setting database of the SDNi–MEC server. The use of LT-NSR is executed in the SDN controller of the SDNi–MEC server. The algorithm of LifeTime-based path recovery (LT-PR) was also proposed to recover/repair a broken V2V path while maintaining the compared V2V path. For circumstances with low- and high-vehicle density, LT-NSR, LT-PR, and GD-NSR have comparative performance.

In [44], the author proposed a strategy in a mixed network between VANETs and cellular networks to reduce the elevated cellular network costs and unstable VANET latency. The technique suggested the increase in bandwidth capacity to allow the access of automobiles in cellular networks and file requests for SDVN power. In [45], an SDN architecture for GeoBroadcast in VANETs was used to solve the mentioned problems, and the solution in this method is dependent on the geographical distribution, which manages the routing of Geo Broadcast. Hence, the proposed solution can be used to reduce the latency and distribute it in the loading time. The latency can be reduced by using the combination of SDN with VANET with 5G in the use of the central controller.

Reference [46] proposed a new SDN design actualized in a savvy city. The IoT organizes inside the keen city and communicates with one another through the SDN. An application of the SDN controller in the brilliant city is the adjustment of traffic lights and other traffic controllers, which the IoT arranges during a crisis. The authors also proposed a calculation process to adjust the routes in a crisis by utilizing the traffic lights and introduced a testing system that estimated the distinction as far as both typical and traffic delays between
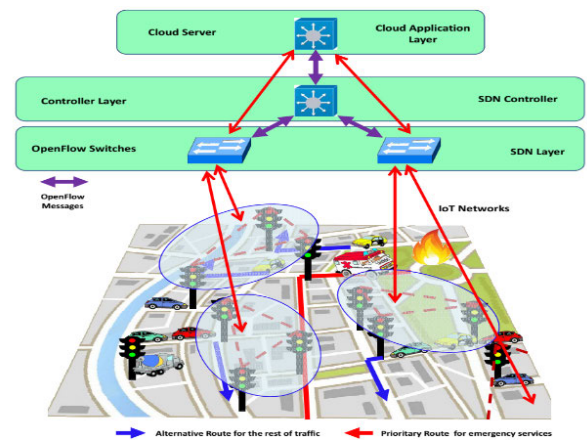
FIGURE 8. Scenario and proposed architecture in [46].

the two unique situations. In the main situation, crisis activity or calculation is absent and the assets share the streets with ordinary traffic. The proposed calculation is connected in the subsequent circumstance to obtain an elective route in conventional traffic. Second, the method obtains not only an elective path in ordinary traffic but also guarantees that the crisis assets are providing the city with its needs. The outcomes demonstrated abatement in the postponement of both typical and crisis deals. Fig. 8 shows an example of utilization. Fig. 9 shows the machine learning system used in the scheme in [47]. The author proposed a novel data delivery scheme for vehicular networks in urban environments and focused on the analysis of the source and destination nodes in the blind zone. A fuzzy method of rule-based wireless transmission was designed to associate delivery paths to vehicles in the blind region. The information transmission quality
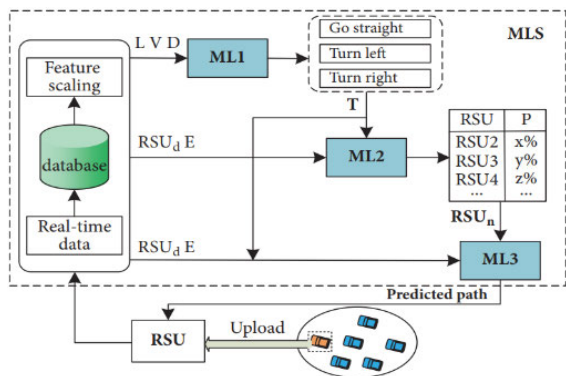
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FIGURE 9. Machine learning system [47].

FIGURE 10. SDN over VANET security architecture [55].

was enhanced by upgrading the V2V communication. A key innovation in this fuzzy rule-based methodology was the approach of vehicle speed forecast. Unique in its relation with the regular fragment-based expectation technique, the authors outlined a vehicle-based short-term strategy of vehicle speed forecast. The key point of this data delivery method was the specially planned scheme of machine learning fixed in each RSU that provided the routing decisions by processing and delivering lively traffic information. The combined operation of the machine learning scheme and RSU allows this scheme to abandon the GPS without decaying the network performance. The wired communication between RSUs reduced the delay from the unreliable carry and forward manner in the pure V2V communication network. In [48] proposed the SDN-based solutions for improving the data offloading technique in VANETs. This technique involves priority managing services and load balancing that remain at the SDN controller. Moreover, the authors utilized to decrease the traffic congestion of the network is data offloading strategy by promoting high network scalability with minimized cost.

Moreover, obtaining low latency in SDN–VANET is very important in maintaining a steady and precise global topology view at the SDN controller, which is required for the authorization of different network functions, such as routing, traffic, and security, used in the network.

D. SURVEY ON SECURITY
Scientists have focused on analyzing and developing the data transmission mechanism by developing various designs for SDN–VANET architectures. In exponential advances in next-generation innovations, such as 5G and vehicle networks, the convergence of vehicular networks and 5G systems are predicted via network engineers and service operators.

In [12], a structure spreads the ordinary V2V message confirmation. The concept in this study was to organize every message with short identifiers of recently approved messages. Message verification is a basic mechanism in VANET security that does not require any input in the protected domain of all passengers. The size of the network, topographical value, mobility, and connection can be unregulated geographically and truly adaptable.
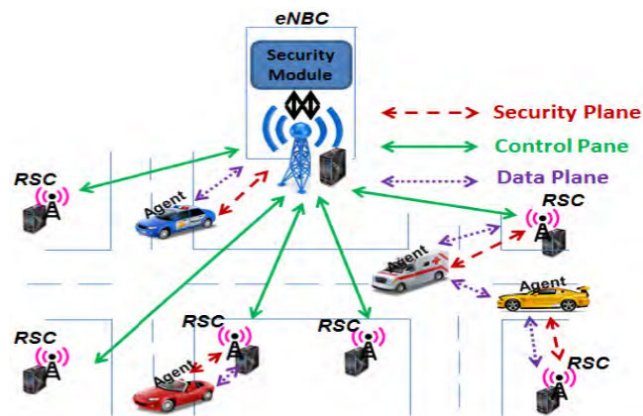
This method can be developed rapidly without global positioning to determine its standards.

The authors of [50]–[53] investigated the VANET security challenges. Solutions, such as ARAN, have been used according to the server certificate and digital signature. Two other solutions (SEAD and SMT) were also investigated, and NDM is found to be dependent on the algorithm called asymmetric cryptography, which determines the location of a mobile IP address accurately. In addition, the majority of solutions use traditional methods to preserve messages. Several methods have been proposed for the structure of a safe design system in data flow while protecting the security and the network necessities of VANETs.

In [54] suggested an SDN-enabled combination of the two terms in VANET and 5G networks. This method can be used in a buffer-aware flowing manner for real-time multimedia streaming of applications. Moreover, the proposed method in this study intended to maintain the most updated communication latency and use it to guarantee good QoS during the communication between continuous eNodeBs.

SDN gathers data with respect to user mobility and level of the player buffer to accomplish satisfactory QoS. The quality of the network signal is utilized to obtain a proficient transferring technique for media streaming. Notably, a combined architecture of these three technologies was used in a security approach for VANETs in [55]. The authors attempted to use long-range wireless communication, such as LTE/WiMAX, in the control plane and obtain higher bandwidth with lower-cost wireless communication, such as Wi-Fi, in the data plane. By combining these technologies, the authors attempted to achieve simple management and high security based on a recent SDN security plane. Fig 10 shows SDN over VANET security architecture.

As shown in Fig. 11 in [56] the authors needed to solve the application problems and infrastructure of VANET in a data cycle of traffic management systems, for example, scalability, dynamic programming and packet flow management. The authors proposed an architecture that operates in end-to-end directions (from the SDN agent vehicle to the

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TABLE 7. Summary of the most recent approaches to cope with the directionality implications in VANET over SDN based on low latency.

Ref	Comm. MS	PDR	Through put	Delay time	RP	Tool	Contr oller	South Bound API	Techn	Remarks
[41]	V2I	40%	30%	21s	-	EstiNet	-	OpenFlow	Mobile sensor for recognition	*Virtualize slices organize by a group of network elements. *Enhance crowd collaboration for SDNs.
[42]	V2V,V2I	-	-	50%	-	Mininet, SUMO	POX	OpenFlow	MEC strategy	*Centralized controller inside network base stations for V2I and level caching for V2V.
[43]	V2I	85%	1Mbps	120s	-	NS-3	-	OpenFlow	Data offloading	*A prediction control scheme called OHD-SDN in MEC.
[44]	V2I	-	-	160 ms	-	SUMO, OMNeT, Veins	-	OpenFlow	Optimal rebating strategy	*Optimization strategy in control plane to balance delay time with cost on cellular networks.
[45]	V2V,V2I	85%	-	81%	-	OpenNet	Floodl ight	OpenFlow	GeoBroadcas t routing	*Automatic manage the geographical location of RSUs. *GeoBroadcast mechanism using traditional IP.
[46]	V2V,V2I	-	-	29%	-	Mininet	-	OpenFlow	Traffic lights with IoT	*SDN possibilities reduce delay in Smart Cities and IoT. *Modify routes in an emergency situation using traffic light.
[48]	V2V	-	15kbps	1ms	-	-	-	OpenFlow	Data offloading	*The load balancer, priority manager and traffic routing in SDN are controlled effectively with extending the size of network.
[49]	V2V,V2I	-	-	1.5s	AODV, GPSR	Matlab, Java	-	-	Routing protocol	* Distributes load among categorized controllers with the exploits local view over network to provide the best decisions.

*NOTE: REF = reference, Comm.MS = communication models supported, PDR = packet delivery ratio, Delay time = average delay time, RP = routing protocols used, Techn = technique used.
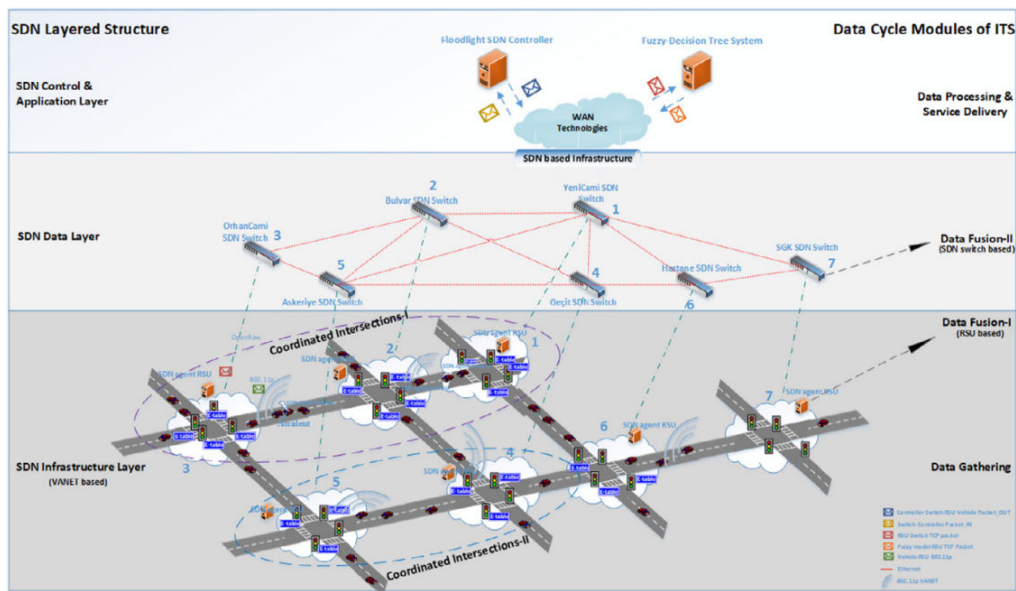
FIGURE 11. Data cycle modules of ITS with the intersection topology and its combination of proposed SDN via VANET [56].

controller and from the controller to the SDN agent vehicle). The architecture was tested and used under various intersections/phases and network frameworks in the urban city with

several signaling methods found in previous studies, such fixed-time signaling, Webster equation, ant colony algorithm, and particle swarm optimization [57]–[62], [64]–[66], [66].

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The authors also discussed other procedures to differentiate the source of attacks. In [67] and [68], a new 5G SDVN architecture was used to further reduce the latency of communication and enhance the QoS. A propped architecture was also used to merge the two cloud and FC services to improve and increase network performance. This proposal can use SDN to maintain the scalability and flexibility of vehicular networks. The architecture also combined other elements, including cloud–FC services. However, the controllers are responsible for collecting and sharing data. RSU controls the fog cell, and the vehicles that utilizing a multi-hop broadcasting to communicate which are within a fog cell.

Although several architectures were suggested in this survey for increased connectivity efficiency and protection in VANETs, the feasibility and accuracy of these architectures remain controversial. In particular, the emerging protection and privacy problems from the relation of modern technologies (such as NFV (network function virtualization), SDN and MEC) with the established VANET must be examined closely. The previous studies recorded the solutions and advantages of utilizing SDN controller to enhance the vehicular system. However, still there are some issues such as, QoS, security and latency in SDN controller which are the root of SDN that can impede the efficiency of SDN–VANET. The dynamic real-time change, swift as needed development (availability), and combination of service context are crucial in allowing the successful cases and averting performance visibility gaps in SDVNs.

IV. COMPARISION OF SOME ALGORITHMS BASED ON THE PARAMETER USED

The VANET handles mainly systems to improve the divergence between the complexity induced by vehicle-prepared communication interfaces or infrastructure-based connectivity. A review of studies modeling and implementing this issue is summarized in Table 8 , which illustrates the challenges in SDVN. The analysis of this review shows the problem of each study based on the network and result parameters used in their research. The research reflecting the device entities related to the issue shows the trace of overhead communication between vehicles (data plane entities) and the SDN controller. However, the researchers must improve the decoding method for the messages between vehicles (data plane) and the SDN controller. Machine learning or FC routing protocol can be considered in implementing the solution for this problem because of their ability to obtain a fast link on the SDN control. The authors in [5] designed the framework of a safety message dissemination of cloud-assisted downlink to disseminate the traffic data by using the benefits of both wireless and cloud computing technologies. Using this proposed method, a large number of data was gathered from the flow. The gateway collects the response from the cellular network and uses it for the nearby vehicles with V2V communication. Hence, to reduce the packet loss caused by transmission, a simultaneous message propagation strategy of multipoint protection is the remedy. Moreover, the outcome was analyzed mathematically through the planned scheme's delay in dissemination. A number of modeling studies have been introduced to the new process system. The findings showed the suggested scheme could not only disseminate messages effectively and rapidly but also lower the cost of cellular communication significantly.

A novel algorithm was developed in [69] for traffic management. This algorithm was built according to the game theory to identify the shortest time taken by the vehicle from the source to the destination. In addition, the proposed algorithm was tested in a cooperative way and reduced vehicle density in each road segment. As a result, the experiments showed this algorithm obtained the lowest average waiting time and lowest time for travel from the source to the destination.

In [70] provided an appropriate solution for the growth of traffic flow, especially in large cities, which grows on a daily basis. The traditional systems have some drawbacks because they cannot handle the current traffic situation successfully. However, a system of smart traffic management was introduced to manage road traffic situations effectively. This system intelligently modified the signal timing according to the traffic density on the specific roadside and the controlled traffic flow by connecting more efficiently than local servers. The decentralized method was efficient because the system runs even when a local server or centralized program crashes. In an emergency situation, the centralized server communicates with the nearest rescue department in a timely manner. In addition, a consumer can inquire about the potential level of traffic on a particular road while saving time in traffic jams.

In [71], the traffic information collection and diffusion problems of IoV infrastructures were investigated. First, the features of GPS data in Beijing city cabs were analyzed in a time-invariant and small-world nature. Second, the authors established the relation between the features and assessed the efficiency of data collection and distribution. Ultimately, the use of IoV was suggested to aid in the infrastructure of local traffic collection. This IoV was a portal filtering scheme for data collection and urban traffic control. The result stated that a few cars have a high prospect of serving as gateways and only reliable routes must be chosen as the direction of knowledge transfer in our heterogeneous IoV vehicle network to achieve better transmitting efficiency and lower connectivity costs.

In [72], offered a routing method for dynamic IoT vehicles to find the shortest path with real data gathered from a traffic detector analyzer. The data provided by these detectors were transferred to the control unit and then changed according to traffic speeds. The solution approach was the use of vibrant programming, which found the shortest path within several paths. Fig. 12 shows the system of dynamic traffic management in IoT vehicle routing. In [73], a new structure SDIV was presented to cover the proprietary and closed way issues in the old network architecture of IoV. However, the installation of the new method was inefficient due to some of the other IoV features. The improvement in the rule installation reduced the flow table size while ignoring the data
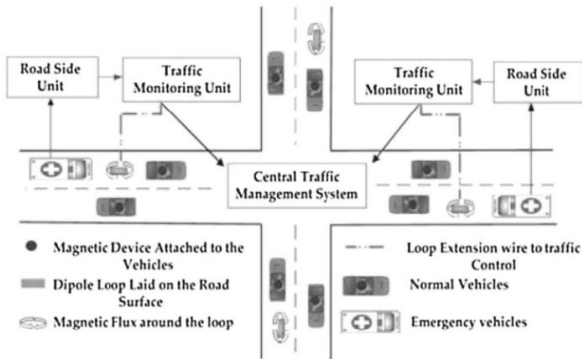
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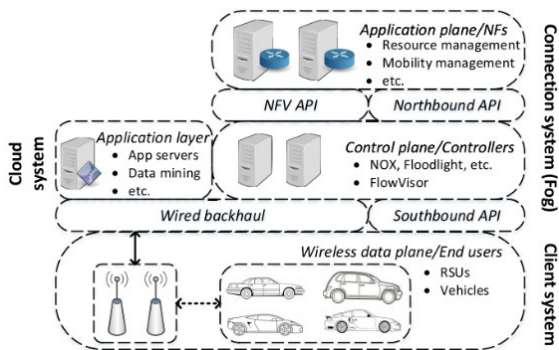**FIGURE 12.** Smart traffic management system [72].

FIGURE 13. Architecture of SD-IoV [74].

transmission in real-time services. The separation of a wired data plane from its wireless counterpart is suitable for the IoV features. The assessment was conducted according to the test and based on the implementation with real traces present, and the improvement rule significantly reduced the number of rules without affecting the efficiency of data transmission.

In [74], the authors developed a new management scheme of service-oriented and dynamic vehicular connection in SD–IoV. The new service was created to enhance the effectiveness and flexibility of resource use and improve the QoS guarantee. This service could also be used to help many concurrent requests. The new structure of SD–IoV was tested in the process of cutting-edge technologies, including SDN, NFV, and IoV, which were combined to realize the next generation ITS. As a result, overlay vehicular networks assist as a new resource use pattern in the SD–IoV scenario to take advantage of the new SD–IoV characteristics. Fig. 13 shows the architecture of SD–IoV in the paradigm of SDN and IoV.

In [75], implemented an SDN-enabled hybrid used for transferring the message in the IoV architecture. Therefore, some of the features of this new system, such as improved network compatibility and scalability, make it superior. Such features can also be used to simplify network management. Hence, this type of system can support reliable and fast network data transmission. The SDN controller is used to select the best RSU paths for efficiently transferring data. Although SDN realizes flexible and programmable network control, which is still in the early stages of mobile networks (for example, VANETs and 5G).

In [32], an SDVN strategy was proposed to improve network management. The proposed strategy shared the network resources linking the elements, and the network distrusted resources to RSUs to be ineffectual in situations when the traffic density under an RSU's coverage range changes because it forces the RSU to obtain extra data and flows, can cause corruption in the QoE of end-users. To address such conditions, the authors proposed a technique for the management of data flows and transmission power and actualized it on the controller.

In the wake of recognizing inadmissible vehicles (i.e., their QoE reduces), the model modifies their signal levels via decreasing the interference with RSUs. While, in [76] to bring real-time visibility of road traffic situations.

The key idea is dependent on a data-flow management structure that appropriates undesirable vehicles to each RSU. SDN has also been used to control the cooperative message dissemination in vehicular communications [17]. Specifically, RSU controls the data dissemination in the V2V and I2V channels. The centralized RSU coordinates the planning choices of vehicles with many guidelines that determine which channel it should tune to transmit or receive the data packets. This technique qualifies the cooperative dissemination by utilizing the SDN pattern.

In future VANET situations, ITS can be incorporated to obtain high PDR, which promotes high network adaptability with low cost [29], [30], [47], [26], [39] and [11].

The arrangement of the controller and OF switches is application-explicit. For example, the SDN controller can be introduced at the RSUs, base stations, traffic management, data centers, or vehicles, whereas the OF turns the functions are typically integrated into vehicles. All the proposed SDVN structures failed to incorporate the security modules or analyze any of the security problems of their proposed models. Such failure can be a problem because of the utilization of VANETs in life-critical applications.

V. ADVANTAGES OF SDN-VANET

The implementation of SDN into VANET has many advantages in mobility management. However, in this section, the four advantages can be classified into the connectivity situation, routing selection, frequency/channel selection, and power selection.

A. CONNECTIVITY SITUATION

The SDN controller has the potential in improving the management and control of networks by disengaging the control and data planes to obtain versatility in VANET. Moreover, the assistance of SDN need not swap the beacon data with another type.

B. ROUTING SELECTION

In the first section of this work, we explained that the routing decision in SDN networks are informed due to the current network status that the controller able to obtain instantaneously. The network data traffic of VANET can turn into unbalanced

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TABLE 8. Comparision on some SDN-VANET architectures of different network parameters used and result parameters with thier problem research.

Ref	Problem	Network parameters					Result parameters		
		No. of nodes	Vehicle density	Comm. range	Scenario	Tool	PDR	Through put	Delay time
[5]	High transmission delay and data redundancy	√	-	√	Urban	OMNeT	√	-	√
[69]	disaster results blocked roads and increases vehicle density	√	√	-	Urban	Java	-	-	√
[70]	anticipating the traffic density results reducing the traffic congestion	√	√	√	Urban	MATLAB	-	-	√
[71]	Reduce cost, resource wastage and improving transmission performance	√	√	√	Urban	MATLAB	-	√	-
[72]	Advertise minimal cost, long scalability, compatibility	-	√	√	Urban	-	√	-	√
[75]	How to achieve effective and prompt message delivery in emergency services	√	√	√	Urban	OMNeT,SUMO	-	√	-
[75]	High number of rule installation due to fixed size of flow tables at OF	√	-	-	Urban	Mininet	-	√	√
[76]	Dynamic vehicular connection as (OVNC) problem	√	√	√	Vehicular network	TrasoNET	√	√	-

*****NOTE:** REF = reference, No. of nodes= Number of nudes, Comm. range = Communication range, PDR = packet delivery ratio, Delay time = average delay time.

due to two reasons. First, the shortest path routing that can cause traffic is concentrated on the selected nodes. Second, the application is video-dominant, which results in the occupation of a large bandwidth on the path. The routing overhead can be decreased periodically, and the SDN controller can obtain global information and then settle on the ideal routing decision. Furthermore, the knowledge of connections among the switches in the center of the SDN controller makes the routing flexible and adaptable because the routing decisions might replace due to the lack of success in certain switches.

C. FREQUENCY/CHANNEL SELECTION
Frequency/Channel selection can occur once the DNS wireless node contains many wireless interfaces or radios, such as cognitive radios, which can be configurable. The DNS-based VANET allows the enhancement of the coordination of the channel and frequency used in this channel. For example, the SDN controller can choose the best time and which type of channel can be used in VANET.

D. POWER SELECTION
On the basis of the obtained awareness, the SDN-based VANET can realize the information that can be used in choosing which power of the wireless interface and transmission range can be used. For example, SDN control can gather information from the neighboring SDN nodes and then

control the highly scattered node density. The nodes are then instructed to increase the power to obtain additional sensible packet deliveries and decrease interference.

In any case, the vehicles are moving rapidly and the topology of the network changes progressively. Accordingly, the choices made by the SDN controller should be convenient. Moreover, the SDN controller able to settle on the best routing decision dependent on the global data, which is difficult to accomplish.

VI. USE CASES WITH THE EMERGING TECHNOLOGIES
In this part, different use cases illustrate how the simple management and arrangement of SDN into VANETs can solve the different challenges. The combination of SDN with vehicular networks can fulfill the needs of security and safety applications.

A. HETEROGENEOUS SUPPORT
The current vehicle network is dependent on IEEE 802.11p and wireless connectivity through V2V and V2I communications. Increasing VANET applications request several wireless interfaces to reduce the communication cost. DSRC is cost-perfect, but the coverage area can incur a higher cost because the cellular network is applied with 4G/5G and many different network interfaces, such as WiMAX, Wi-Fi, LTE, UMTS, and 4G/5G, are used. Various wireless technologies

are used in the logical and forwarding plane to enhance the use of channel and bandwidth.

B. THE ROLE OF SDN CONTROLLER IN 5G

At present, 5G networks are required toward aid in the different reliable and dependable applications. A technique has been proposed by using SDN in the structure of 5G networks and an abstracted platform is also given by SDN to upgrade the adaptability and programmability of the framework in the design and deployment networks. The routing decisions in SDN have increased adaptability in the dynamic routing protocols used in VANETs. Adaptability and scalability can be obtained by reordering the data flow routes intelligently as needed. Hence, 5G networks are used to activate the traffic routes on a flow-by-flow premise. Accordingly, the improved speed and latency in SDN ensures scalability, reliability, and dynamic provisioning.

C. DYNAMIC QoS

QoS is used to ensure a specific degree of action in an application within its capability and manage applications, such as those involving safety and the traffic in data flows. QoS is utilized to obtain low average delay time and reduced packet loss. Voice through IP traffic able to be managed in terms of guaranteeing the error, bandwidth and jitter. SDN provides the adaptable and programmable of the network to ensure the dynamic surrounding environment and adjust its connections, which are dependent on such situations. SDN assists in giving proficient channel allocation because DSRC distributes 75 MHz of bandwidth with one control channel and six service channels. The SDN controller concentrates on the RSUs and decides on the channel allocation and information transmission prioritization [77]. SDN able to adjust to the dynamic topology of vehicles with resource reallocation. Therefore, we can propose a productive routing protocol for VANETs through the position and topology prediction of the vehicle via the SDN controller [78].

D. TRAFFIC CONTROL SYSTEM

In view of this usage case also demonstrates how immense vehicle traffic able to be monitored with handled via the SDN model alongside the FC concept. Currently, FC is used in travelling vehicles, cloud networking, and sensor networks to provide examples of where RSUs can fill the fog systems. The control plane in SDN can gather and keep singular vehicle data successfully and sensibly in a centralized manner while optimizing the V2V/V2I multi-hop routing. This process is similar to that of a vehicle sending a question to a network operating node, wherein SDN specialists track the vehicle details in memory and the system begins to transfer the information through the switches in the chosen RSUs.

E. ROAD CONDITION MONITORING

In this case, SDN is responsible for gathering information from the sensors that will be used to keep track of the road conditions. These information exchanges among vehicles and infrastructure on the road occur in real-time. Communication through SDN uses heterogeneous wireless network interfaces to increase the overall network execution. SDN is also used to update the SDN controller with execution constraints from time to time and ensure its stability.

F. VIDEO STREAMING

The primary issue related to movement in traffic information streaming in the VANET is higher mobility. SDN able to be utilized to enhance the quality of the video. The SDN controller has a global aspect for all cars in the path. Hence, the controller can use an algorithm that chooses the shortest path. The controller also encourages the tracking of bandwidth availability, accessibility, link failure, and jitter to update the forwarding path. Therefore, SDN ensures that all updates and changes are implemented by using QoE.

VII. EMERGING TECHNOLOGIES

The interest in applications that improve the profitability and recreation will continuously develop as the reliance on augmented reality applications and numerous others become the recent standard.

As a result, SDN multiplies everything through the development of technologies (e.g., IoT, IoV, 5G, FC, and others). Inside each area, SDN provides the ability to obtain fine-grained and QoS-aware resource allocation for particular flows while additionally addressing the changes in traffic designs through powerful network reconfigurations. Subsequently, a short review of a portion of the many technologies is presented alongside further research opportunities on SDN to improve at least one part of their usefulness.

A. SDN AND IoT

By integrating SDN with other convenient technologies (for example, combining technologies such as VCC and IoT with SDN in the architecture of the vehicular networks), the type of combination can provide synergistic capabilities because IoT is considered a beneficial technology in vehicular networks that can obtain new solutions. In [69], SDN could offer automation, whereas IoT has been used in connection with the resources in a network. In [70], the SDN prototype was integrated with IoT and the scenario used a set of pilot users. SDN was utilized to manage the shared and heterogeneous environment and realize the different quality levels of tasks in a dynamic scenario. The combination of these technologies has many benefits, but other issues based on sporadic connectivity also prevent the solution of problems involving vehicular networks. Thus, exploring these technologies from a suitable perspective is necessary to solve the constant issues in vehicular networks and ultimately realize the effective management of road traffic.

B. BLOCKCHAIN

Blockchain is the key technique used in Bitcoins [79]. Blockchain is the key technique used in Bitcoins [79]. A blockchain is a collectively observable database stringing

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a sequence of blocks in the block headers through cryptographic hashing. Such blocks include multiple-user transactions, and each new block is bundled with a chosen miner. The miner can be selected based on the unanimity technique. In [80], an ideal blockchain is conserved by a few specified parties. This method can be used to keep track of transactions performed by users. Various applications are implemented using such a technology, such as SDVNs [81], 5G [82], IoT [83]. The elaborate working methodology and applications of blockchain technology are explained in [84]–[88].

C. THE SIXTH GENERATION 6G
Moreover, ML has some potential applications linked to vehicular networks, such as fast channel equalization and adaptive resource allocation [89]. The main goal of developing such a network is to improve the intelligent functions of the system and enhance the suitability of the environment in different application requirements, such as enhanced mobile broadband and ultra-reliable and low-latency communications. This type of network is built with a heterogeneous space-air-ground structure and can interact with humans more intelligently than any other network. Moreover, 5G and 6G are new technologies that contain SDN to allow flexible adjustments in different scenarios.

The accomplish of the objectives of 6G, there are a new method, for example NFV, reactive vehicular system control and cognitive radio, these are proposed in 5 generations. Nonetheless the key performance indicators (KPIs) of the 6G network demand additional development to intelligent radio, network intelligentization and self-learning with proactive investigation.

VIII. OPEN ISSUES WITH RESEARCH DIRECTION
In this part, firstly we epitomize our discoveries alongside the architectures learned assembled through our survey of latest Attempts of SDN-VANET and its combination with latest technologies, for example, FC, IoV, IoT and 5G to help to develop the applications of vehicular network possibilities. At that point, we provide the latest works within SDN-VANET infrastructure with the potential research directions just as future work issues and challenges. A portion of these challenges that we discovered in section III, on the other hand, this part quickly includes the remaining open research directions and their challenges.

In addition, there are many architectures and research works have been explained in this survey to enhance the QoS [35], [37], connectivity with the mobility management [31], [39], low latency [46], [44] and security [55], [56] in the vehicular network, but there are many issues still need to solve it, for example, cost, security, emergency services, heterogeneity and the performance of SDN controller in miss situation. The researchers need to address the following open issues:

-Some architectures of VANET are centralized network and able to be a singular point of unsuccessful and the luck of the controller from overload and cannot give a proper outcome. While the decentralized network is able to be a single controller which is can handle this issue.

-Network security slicing in 5G presents a set of the network functions and special limitations in 5G that are integrated to present with a special use case or business Because of the advantage of V2V and V2I, SDN controller can configure the several NFV and physical networks functions in one slice. Furthermore, an attack maybe gets capacities to attack to slices for example, when adjusting the configuration of another customer's slice. Hence, the serious efforts are yet necessary to planning a perfect pattern to become a secure slicing in 5G.

-SDN able to provide high security to the infrastructure but it is unstable to new attacks. Furthermore, the critical issue to the attacks in the two part of communication south bound and north bound are as well.

-Emergency utilities in developed distances involve the pattern.

management of emergency circumstances that demand activation of emergency utilities such as, police vehicles, firetruck and ambulance). Management turns into a heavy challenge when joined high vehicle density within traffic management systems. Fast response in these conditions increases the effectiveness of emergency management and decreases its effect on the ordinary function of VANET infrastructure and transport system. The efficient coordination of information networks, traffic signal systems, and emergency utilities requiring to modify the network data flows to promote the need for activities influencing the prompt handling of emergency cases, including traffic signal activation, deflection of traffic flows, and reservation of car park spaces.

IX. CONCLUSION
This paper reviews a considerable number of studies related to the performance of SDN-VANET. In particular, it focused on vehicular network architectures combined with SDN. The pros and cons of these architectures in terms of routing protocol, QoS, mobility management, security, and privacy are also considered. The potential and expected solution using SDN to obtain high management of services in the network and to deploy them efficiently are also explored. The generalized architecture of SDN, VANET and their features after being merged are presented. Then, comparisons in terms of the types of control paths, types of network used, and the update modes of the network topology are provided. A comprehensive survey of open SDN-VANET routing protocols, connectivity and mobility management research is also conducted. The SDN-VANET architectures of different network parameters used in most algorithms and the resulting parameters with their problem studies are presented. This survey is the first to address the strengths and weaknesses of VANET infrastructures. The open issues and the research directions encountered by the latest works are highlighted, including the integration of VANET with SDN, the current and emerging technologies as well as the use cases are also elaborated.

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