VOL. 20, NO. 3, 2021, 26-31
www.elektrika.utm.my
ISSN 0128-4428

ELEKTRIKA
Journal of Electrical Engineering

A Survey on Internet of Vehicle (IoV): Applications & Comparison of VANETs, IoV and SDN-IoV

Muhammad Arif Hakimi Zamrai*, **Kamaludin Mohamad Yusof**, **Muhammad Afizi Azizan**, **Muhamad Azam Asri Azman** and **Shaik Mazhar Hussain**

Faculty of Engineering, School of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia.

*Corresponding author: mahakimi8@graduate.utm.my

Abstract: *The swift evolution of communication network technologies brings the smart connected objects into existence. The objects or things are connected and able to communicate with each other through Internet of Things (IoT). Internet of Vehicle (IoV) are the subset of the IoT technologies that has been implemented to the vehicle. IoV is the evolution of traditional Vehicular Adhoc Networks (VANETs) bringing new technologies to the smart connected vehicles. IoV network communication is purposedly to serve a real time data exchanged on roads between the vehicles and roads, vehicles and vehicles, vehicle and sensors, and vehicles and everything through different network technologies. There are significant differences between IoV, SDN-IoV and VANETs in term of network architecture, features, and applications that available. IoV and IoV-SDN is using different network framework giving different flexibility and scalability. In term of features and applications, IoV and IoV-SDN are having more wider and broad wireless connection technology in contrast with VANETs. In this survey paper, the survey will focus on the introduction to SDN, and differences of application and features in IoV, SDN-IoV and VANETs.*

Keywords: Internet of Vehicle (IoV), SDN, SDN-IoV, VANETs

Article History: received 7 September 2021; accepted 27 October 2021; published 27 December 2021.

1. INTRODUCTION

The emergence of Internet of Things (IoT) is empowering the wireless connection throughout daily activities in everyday life. Bringing this technology to the vehicle invents the emerging Internet of Vehicle (IoV). Connected vehicles encourage enhancement in the automotive development industry bringing out the new inevitable and foreseeable technology of the future. Connected vehicles are aimed to augment and enhance the safety, ease of travel and infotainment to the vehicle's passengers and drivers.

The development and vast utilization of wireless communication technologies have seen the appearance of a world of connected things. The Internet of Things (IoT) has lately flourished and become a new and novel connection paradigm that provides connectivity to abundance of devices communicating to each other and providing sensing abilities. The connection is utilizing the communication technologies such as Wi-Fi, ZigBee, Long-Term Evolution (LTE) and Bluetooth to initiate the connection enhancing an extensive variety of applications, which include smart homes, smart cities and smart vehicles[1], [2].

It is projected that massive 25 billion devices will be connected to the Internet by 2020 with big part of the numbers are coming from the vehicles [2]. The number of interconnected vehicles is expected to increase in demands exponentially and the global connected car market size is projected to reach USD 166.0 billion by 2025, from an estimated USD 53.9 billion in 2020. The growth of the global connected car market is influenced by factors such as increasing trend of in-vehicle connectivity solutions and government initiatives toward developments in intelligent transportation systems. Therefore, the connected car market is expected to witness significant growth in the future [3].

IoV is one the technology evolution that derived from the IoT that has been immersed to the vehicle. IoV has been evolved from Vehicular Ad-Hoc Network (VANET) that used to be a modern technology to communicate vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) prior to the IoV emergence. As IoV emerges, IoV comprises of Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Road Side Unit (V2R), Vehicle-to-Sensors (V2S), and Vehicle-to-Everything (V2X) [4], [5].

With the broad wireless communication technology that existed, data interchange from the vehicle enables a great development in communication systems improving the traffic efficiency. VANETs inherits the features of Mobile Adhoc NETworks (MANET) with moving nodes and communicate wirelessly with limited wireless communication technology [4]. As of the Intelligent Transportation System (ITS), the vehicle communicates exchanging real time data between each other intelligently [6]. Data collection and sharing between vehicles, sensors and the infrastructure offers wide variety of application to the drivers and traffic managements to ensure driver safety, efficient traffic controls and infotainment. The emergence of new wireless technology with higher data bandwidth introduces IoV, allowing data collections and information transfer from vehicles through many types of wireless communication providing vast numbers of applications [1].

Snowballing number of vehicles demand requires massive scale deployment of IoV architecture which can be an intimidating task due to the lack of flexibility in typical IoV architecture [7]. Software Defined Network (SDN) is a key technology to achieve programmable and flexible IoV by separating control plane and data plane. With SDN integrated to the IoV enables intelligence and state of the network to be logically controlled centrally. The segregation of control and data plane is logically centralized but can be physically distributed [8]. The data plane will act and follow as the instruction coming from the controller plane.

This paper will be divided into three sections, Section 1 will introduce VANETs, IoV and SDN. On Section 2 will discuss the applications of SDN-IoV and Section 3 will deliberate on the comparison between VANETs, IoV and SDN-IoV.

1.1 Software Defined Network (SDN)

Every network architecture consists of three fundamental planes for a successful connection. It consists of data plane, control plane and application plane as illustrated in Figure 1 [9]. Control plane is considered as a central or the brain to define the routes and path for the arriving and departing packets in the network layer. The data plane then refers to the instruction provided by control plane and execute the packet forwarding based on the given rule [7], [9]. The application plane is the intermediate for the users to monitor and control the device which mainly consists of business end-to-end applications [9].

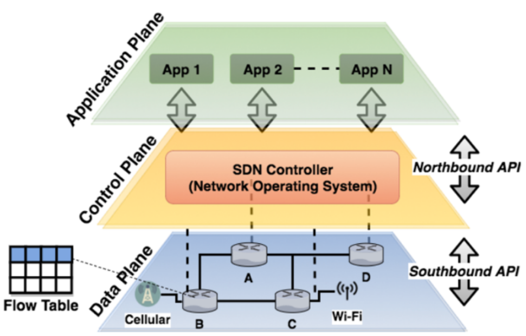

Figure 1. SDN Architecture

The traditional network architecture is that the control plane and data plane are bundled into same networking device. The networking devices like switches and routers were only configurable using a proprietary interface, be it vendor specific tools or just the Command Line Interface (CLI) on the device and there were no Application Programming Interfaces (APIs) to allow the external third-party program to configure. In SDN network architecture, the control plane and data plane are decoupled. It gives more flexibility to the control plane to control the forwarding rules directly through another program using APIs [9].

SDN is a network architecture that facilitates the network to centrally controlled and can be programmed using software applications [10]. With SDN, the network architecture turns out to be programmable and flexible through software applications and can be developed with many programming languages such as Java, Python, and C++ or any specific-purpose languages such as Nettle, Netcore, Procera and Pyretic [11]. The network policies can be implemented effectively and centrally with the centralized control plane. The benefit of this separation is that the network operations can be centralized and network forwarding decisions and overall network conditions can be monitored from a single and centralized point [10].

2. APPLICATION OF SDN-IoV

There are vast and remarkable number of applications that have been implemented in the VANET and IoV to collect crucial information to help inform and divulge the drivers and pedestrians.

The IoV applications are divided into three following categories:

2.1 Safety Applications

The most principal aim of safety applications of VANETs and IoV is to prevent, minimize road accidents and reduce the fatality during collisions. Safety applications are vital and critical with the intention to proactively provide the drivers pre-warning collisions and beforehand errors of the vehicles [6], [12].

Safety measures that are available in the IoV are intersection collision avoidance, public safety related applications, vehicle diagnostic and maintenance, and information sharing from other vehicles [13].

Apart from that, with IoV, the emergency rescues system is mainly referring that the driver has the option to press the emergency button which connected to the vehicle's intelligent transport system during the emergency. Then the distress signal is broadcasted to the rescues service platform calling for the rescue team at the very high speed and instantly without delay. Upon the collisions, the accidents information then will be broadcasted to the surrounding vehicles to avoid additional accidents and minimize the traffics jam [14].

2.2 Comfort and Infotainment

Infotainment applications are intended to improve passenger's comfort and one of the reasons IoV increase in demand [15]. File sharing and download, on-board social network, weather forecast, and stock information are few examples of infotainment features. Besides, the infotainment feature will bring so many conveniences and accessibilities to the driver using voice control and remote control using smart phone or any compatible mobile devices [14].

2.3 Traffic-efficiency and management

The traffic management can easily monitor the traffics through the IoV. It is intended to prevent and minimize road accidents and reduce traffic congestion. Vehicles will be informed about traffic conditions based on the destination and current location. If the route is congested, drivers may follow the recommended route to reduce time travel and fuels [16]. The traffic management is able to sends the traffic information to the drivers at the certain location wirelessly through the IoV network. The information that has been grasp to the driver will help the driver to makes the appropriate judgement to help the driver arrive to the destination faster and safer [14].

With the intelligent traffic management built into the traffic control, the traffic signal can be more adaptive and dynamic to the environment based on the historical and statistical traffic data in the past. This feature help to relieve the traffic congestion effectively and reduce the travel time [14].

3. COMPARISON OF VANETS, IOV AND SDN-IOV

IoV is considered as the superset of VANET. IoV is a blend of the VANET and IoT, and the combination of these are to augment and expand the VANET capability. The common objective of VANET and IoV are similar which to strengthen the overall driving experience and minimize road accidents. Some numerous parameters and variables can distinguish between IoV and VANET. While for SD-IoV, the network architecture is slightly different compared to classical IoV. SD-IoV or known as Software Defined IoV, is using Software Defined Network as the architecture of the network. The control plane is separated and decoupled from the data plane to maximize the control of the network forwarding procedure [17]. SD-IoV will give more flexibility to the control and forwarding rules in addition to more processing resources in the IoV network environment compared to the typical IoV. The only difference between SD-IoV and IoV is SD-IoV is using SDN as the network architecture separating control plane and data plane separately [9]. Table 1 shows the differences between VANETs and SDN-IoV.

In this section, the author will do the abstract and concept comparison of the aim and philosophies of the SDN-IoV and VANETs and no technical parameters will be used in this survey paper.

3.1 Aim of VANETs, IoV and SDN-IoV

The most principle and prominent aim of VANET on its first creation is to enhance traffic safety to avoid casualties and improve traffics efficiency to minimize time, cost, and pollutant emission. As it lacks entertainment features, leading to less market demand [13].

While in IoV, the main objective is to enhance traffic safety, traffic efficiency, with an additional of commercial infotainment and support of different type of network communication medium [18]. The infotainment that available in IoV increases the demands as it provides opportunities for the passengers to access online services, including online music, video streaming and remote access monitoring. This type of infotainment enhances the user experience during passengers on board.

In IoV-SDN, the network architecture has changed compared to IoV. The SDN helps the network monitoring and control to be much more flexible with the increasing number of vehicles connected through the centralize controller in the network control plane. While the data plane encompasses vehicles connecting to the SDN enabled wireless access points and application plane denote various type of services or application that run over SDN-IoV network [8].

3.2 Communication Principles

There are two types of communication that VANETs have which are Vehicle-to-Vehicle (V2V) and Vehicle-to-Roadside Unit (V2R) communications [13]. The VANET general communication architecture purpose is to enable the vehicles to communicate with each other and with the roadside unit (RSU).

I. Vehicle-to-Vehicle (V2V)

Vehicle can communicate to each other with its nearby vehicle directly without relaying the connection to the RSU. The aim of this direct communication is mainly for safety, security, and emergency purposes.

II. Vehicle-to-Roadside Unit (V2R)

V2R mainly refers for data and information exchange between vehicles and roadside units such as traffic lights or warning signs on road. Roadside units are also be used as data and log storage servers. The V2R connection is able to reach long distance communication unlike short distance as V2V and work as intermediate hops to widen and increase the communication range of vehicles.

Nevertheless, In SD-IoV, vehicles are intelligent with heterogenous network framework. IoV has five types of essential communication that are possible on its network architecture which include Vehicle-to-Vehicle (V2V), Vehicle-to-Road Side Unit (V2R), Vehicle-to-Infrastructure (V2I), Vehicle-to-Sensors (V2S), Vehicle-to-Everything (V2X) [4], [5]. Each type of communication uses different wireless technology to gather and congregate the data and information.

I. Vehicle-to-Infrastructure (V2I)

The connections to the infrastructure enable the vehicles to connect to the Internet and benefits the internet services.

II. Vehicle-to-Sensors (V2S)

The vehicles will be able to monitor the vehicle behavior and conditions during driving. These includes speeds, position, tire pressure, oil pressure, engine condition and more [4].

III. Vehicle-to-Everything (V2X)

As IoV is the superset of IoT, it enables the vehicle to connect to everything sharing information that support the connection. These includes between vehicle and personal device such as phones, tablets and more. With this kind of connections, passengers are able to share many types of services such as file sharing, music, and video streaming connections.

Table 1. VANETs and SDN-IoV differences.

No	Parameters	VANETs	SDN-IoV
1.	Aim / Objective	The most principle and prominent objective of VANET on its first creation is to enhance traffic safety to avoid catastrophe casualties and improve traffics efficiency to minimize time, cost, and pollutant emission.	enhance traffic safety, efficiency, and commercial infotainment. The infotainment that available in IoV increases the demands as it provides opportunities for the passengers to access online services, including online music, video streaming and remote access monitoring.
2.	Communication Principles	Two types of communication: • Vehicle-to-Vehicle (V2V) • Vehicle-to-Road Side Unit (V2R)	Five types of communication • Vehicle-to-Vehicle (V2V) • Vehicle-to-Road Side Unit (V2R) • Vehicle-to-Infrastructure (V2I) • Vehicle-to-Sensors (V2S) • Vehicle-to-Everything (V2X)
3.	Communication Technology	Two types of communication technology: • Wireless Access in Vehicular Environment (WAVE): i. Dedicated Short Range Communication (DSRC) • Continuous Air Interface for Long and Medium range (CALM) i. GSM2G/GPRS-2.5G ii. UMTS-3G iii. Infrared communication	Five types of communication technology • Wireless Access in Vehicular Environment (WAVE): i. Dedicated Short Range Communication (DSRC) • Continuous Air Interface for Long and Medium range (CALM) i. GSM2G/GPRS-2.5G ii. UMTS-3G iii. Infrared communication • Bluetooth • ZigBee • 4G/LTE
4.	Compatibility	Due to the underlying incompatible network architecture, personal device is unable to communicate with the vehicle causing compatibility issues.	Due to the IoT features that have been built in, thus efficiently integrating the information transfer among other nodes like personal devices and smart devices.
5.	Usability	Local and discrete, which suitable for limited scale application like alerting and informing drivers of any mishaps along the roads or avoiding collision.	Have the flexibility and sustainable application, which it has computing networks and communication capabilities.
6.	Processing Power	Has constraint in term of computation and processing capacity to handle local information gathered by the sensors around the environment.	The networks are connected to the cloud, which involves big data analytics using cloud computing. The processing is processed in the cloud, which includes data analysis and real-time data collection.

3.3 Communication Technology

VANETs main difference to the SDN-IoV is the communication technology that these network architectures used. VANETs is using Wireless Access in Vehicular Environment (WAVE) and Continuous Air Interface for Long and Medium range (CALM) as a communication standard. In WAVE, Dedicated Short-Range Communication (DSRC) is used as a communication medium to connect between vehicles. DSRC includes Dynamic Spectrum Access (DSA) that allows the vehicle to communicate troughed unused spectrum [4]. CALM communication standard enables the vehicle to connect to a low bandwidth internet communication via GSM2G/GPRS-2.5G, UMTS-3G and Infrared communication [4].

In addition to the SDN-IoV, IoV supports additional network technologies such as Bluetooth, ZigBee, and 4G/LTE. Bluetooth are common in most automobile these days to connect to the personal devices or device controls in 2.4 GHz frequency band at 3 Mbps data rate. While ZigBee enables the vehicle to connect with the internal sensors (V2S) at rate of 250 Kbps. 4G/LTE technology is mainly used for vehicular machine-to-machine communication and infotainment feature with transfer speed up to 100 Mbps for a node in motion and 1 Gbps for a node in stationary [19].

3.4 Compatibility

Now, everyone depends on personal devices like smartphone, laptops, tablets and more. In VANETs, due to the unsupported and incompatible network architecture with smart device, it is unable to communicate and connect causing compatibility issues [4].

While in IoV, it provides more compatibility and applications due to the IoT features that have been built in, thus efficiently integrating the information transfer among other nodes including personal device

3.5 Usability

VANET is local and discrete, which suitable for limited scale application like alerting and informing drivers of any mishaps along the roads or avoiding collision. The vehicles are considered as temporary nodes and random. VANETs have less scalability compared to IoV [10].

IoV does have the flexibility and sustainable application, which it has computing networks and communication capabilities due to the vehicle's networks are connected to the cloud [20].

3.6 Processing Power

Processing resource in VANETs has a constraint in term of computation and processing capacity to handle local information gathered by the sensors around the environment [4].

In IoV, the networks are connected to the cloud, which involves big data using cloud computing. The processing is processed in the cloud, which includes data analysis and real-time data collection.

5. CONCLUSION

This paper has given the main differences and application of VANETs, IoV and SDN-IoV. IoV and SDN-IoV are mainly have the same applications, the only difference is the network architecture which SDN-IoV is using SDN as the network architecture separating control plane and data plane. The significant differences are mostly between IoV and VANETs. We have identified that IoV are having more capabilities in the communication features compared to VANETs. As there are many limitations in VANETs, the limitation gaps have been covered with the IoV network technology by supporting many types of communication technologies when communicating with the other nodes as discussed in the previous section. In conclusion, SDN-IoV are more superior in term of application and practicality because of the additional SDN architecture that being added making it a more flexible and robust vehicular network environment.

REFERENCES

[1] I. Yaqoob, I. A. T. Hashem, Y. Mehmood, A. Gani, S. Mokhtar, and S. Guizani, "Enabling communication technologies for smart cities," *IEEE Commun. Mag.*, vol. 55, no. 1, pp. 112–120, 2017, doi: 10.1109/MCOM.2017.1600232CM.

[2] Y. Mehmood, F. Ahmad, I. Yaqoob, A. Adnane, M. Imran, and S. Guizani, "Internet-of-Things-Based Smart Cities: Recent Advances and Challenges," *IEEE Commun. Mag.*, vol. 55, no. 9, pp. 16–24, 2017, doi: 10.1109/MCOM.2017.1600514.

[3] A. Mehra, "Connected Car Markets worth $166.0 billion by 2025 AT 5974," *MarketsAndMarkets*, 2020. https://www.marketsandmarkets.com/PressReleases/connected-cars.asp (accessed Jul. 04, 2021).

[4] R. Gasmi and M. Aliouat, "Vehicular Ad Hoc NETworks versus Internet of Vehicles-A Comparative View," *Proc. - ICNAS 2019 4th Int. Conf. Netw. Adv. Syst.*, pp. 0–5, 2019, doi: 10.1109/ICNAS.2019.8807870.

[5] K. Mershad, "SURFER: A Secure SDN-based Routing Protocol for Internet of Vehicles," *IEEE Internet Things J.*, vol. 4662, no. c, 2020, doi: 10.1109/JIOT.2020.3038465.

[6] F. Cunha *et al.*, "Data communication in VANETs: Protocols, applications and challenges," *Ad Hoc Networks*, vol. 44. Elsevier B.V., pp. 90–103, Jul. 01, 2016, doi: 10.1016/j.adhoc.2016.02.017.

[7] K. Gaur and J. Grover, "Exploring VANET using edge computing and SDN," *2019 2nd Int. Conf. Adv. Comput. Commun. Paradig. ICACCP 2019*, pp. 1–4, 2019, doi: 10.1109/ICACCP.2019.8882917.

[8] A. J. Siddiqui and A. Boukerche, "On the Impact of DDoS Attacks on Software-Defined Internet-of-Vehicles Control Plane," *2018 14th Int. Wirel. Commun. Mob. Comput. Conf. IWCMC 2018*, pp. 1284–1289, 2018, doi: 10.1109/IWCMC.2018.8450433.

[9] Q. Yan, F. R. Yu, Q. Gong, and J. Li, "Software-defined networking (SDN) and distributed denial of service (DDOS) attacks in cloud computing environments: A survey, some research issues, and challenges," *IEEE Commun. Surv. Tutorials*, vol. 18, no. 1, pp. 602–622, 2016, doi: 10.1109/COMST.2015.2487361.

[10] H. S. Abdulkarem *et al.*, "DDoS Attack Detection and Mitigation at SDN Data Plane Layer," *IEEE Internet Things J.*, vol. 7, no. 5, pp. 2019–2022, 2020, doi: 10.1109/GPECOM49333.2020.9247850.

[11] C. D. Cajas and D. O. Budanov, "SDN Applications and Plugins in the OpenDaylight Controller," in *Proceedings of the 2020 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering, EIConRus 2020*, Jan. 2020, pp. 9–13, doi: 10.1109/EIConRus49466.2020.9039054.

[12] N. Gupta, A. Prakash, and R. Tripathi, "Medium access control protocols for safety applications in Vehicular Ad-Hoc Network: A classification and comprehensive survey," *Vehicular Communications*, vol. 2, no. 4. Elsevier Inc., pp. 223–237, Oct. 01, 2015, doi: 10.1016/j.vehcom.2015.10.001.

[13] S. Sharma and B. Kaushik, "A survey on internet of vehicles: Applications, security issues & solutions," *Veh. Commun.*, vol. 20, p. 100182, 2019, doi: 10.1016/j.vehcom.2019.100182.

[14] Z. Fantian, L. Chunxiao, Z. Anran, and H. Xuelong, "Review of the key technologies and applications in internet of vehicle," *ICEMI 2017 - Proc. IEEE 13th Int. Conf. Electron. Meas. Instruments*, vol. 2018-Janua, pp. 228–232, 2017, doi: 10.1109/ICEMI.2017.8265773.

[15] C. Campolo and A. Molinaro, "On vehicle-to-roadside communications in 802.11p/WAVE VANETs," *2011 IEEE Wirel. Commun. Netw. Conf. WCNC 2011*, no. i, pp. 1010–1015, 2011, doi: 10.1109/WCNC.2011.5779273.

[16] R. G. Engoulou, M. Bellaïche, S. Pierre, and A. Quintero, "VANET security surveys," *Comput. Commun.*, vol. 44, pp. 1–13, May 2014, doi: 10.1016/j.comcom.2014.02.020.

[17] M. Iqbal, F. Iqbal, F. Mohsin, M. Rizwan, and F. Ahmad, "Security issues in software defined networking (SDN): Risks, challenges and potential solutions," *Int. J. Adv. Comput. Sci. Appl.*, vol. 10, no. 10, pp. 298–303, 2019, doi: 10.14569/ijacsa.2019.0101042.

[18] J. Contreras-Castillo, S. Zeadally, and J. A.

Guerrero-Ibanez, “Internet of Vehicles: Architecture, Protocols, and Security,” *IEEE Internet Things J.*, vol. 5, no. 5, pp. 3701–3709, 2018, doi: 10.1109/JIOT.2017.2690902.

[19] A. A. Almazroi, “Performance analysis of 4G broadband cellular networks,” *Int. J. Adv. Appl. Sci.*, vol. 5, no. 9, pp. 12–17, 2018, doi: 10.21833/ijaas.2018.09.003.

[20] F. Yang, S. Wang, J. Li, Z. Liu, and Q. Sun, “An overview of Internet of Vehicles,” *China Commun.*, vol. 11, no. 10, pp. 1–15, 2014, doi: 10.1109/CC.2014.6969789.