Survey on using 5G technology in VANETs

Josip Balen*, Branimir Tomasic†, Kruno Semialjac‡, Hrvoje Varga§
*, ‡ Faculty of Electrical Engineering, Computer Science and Information Technology Osijek, Osijek, Croatia
† Mbanq, Osijek, Croatia
§ Roxoft, Osijek, Croatia
josip.balen@ferit.hr, branimir.tomasic@etfos.hr, kruno.semialjac@etfos.hr, hrvoje.varga@etfos.hr

***Abstract*—The fifth-generation of mobile networks (5G), is considered as a promising technology for empowering the current communication mainly in mobile networks. The main advantages compared to the current 4G architecture include high bandwidth, ultra-low latency, high mobility and scalability support, massive connectivity, higher reliability, and increased availability. In this paper, a brief overview of current scientific work and trends in using 5G technologies in VANETs is given. The 5G technology can be efficiently used to support vehicle-to-everything (V2X) communications in VANETS while enabling real-time video streaming. It can provide new applications and services which are expected to improve security, performance, autonomous driving, business and entertainment, along with traffic safety and efficiency. Integration of 5G in VANETs will satisfy the increasing communication demands and help in the evolution of intelligent transportation systems.**

Keywords*—*5G, mobile network, ITS, VANET

I. INTRODUCTION

As the automotive industry is becoming increasingly larger and the interior of the car becomes capable of providing more and more comforts of the modern age, the speed of transmitting and receiving various information is essential. Therefore, vehicular ad-hoc networks (VANETs) and 5G networks are taken into consideration. By using these modern network technologies, vehicles can support intelligent capabilities such as connecting to infrastructure or interconnecting, reporting about traffic accidents, route planning to avoid traffic jams, and leading to more advanced functionalities such as autonomous driving.

Main problems in existing VANET communication standards (e.g. IEEE 802.11p) include lack of spectrum, high latency, and relatively unreliable message transmission. The existing standard also shows poor scalability and a lack of guaranteed service delivery in large networks. While numerous studies already utilize the existing LTE network, 5G shows a very large potential in vehicle-to-everything (V2X) communication and therefore motivates further research with the new network [1].

By using a 5G technology in combination with VANETs, many of the aforementioned challenges can be addressed as it is expected that introducing 5G in VANET will improve performance, security, and efficiency. Unlike 4G mobile technology, the new 5G has a better threshold tolerance for high mobility and scalability, massive connectivity, and reduced latency, for example making high-quality real-time video streaming possible. 5G technology is driven by eight specification requirements: higher network throughput, availability, coverage, and bandwidth per area; low network latency, number of simultaneously connected devices, prolonged battery life for IoT devices, and 90 % reduction in energy consumption, as shown in Figure 1 [2]. In [3] a new prediction a new prediction-based 5G-V2X communication protocol for transmitting multi-hop safety messages in a city scenario is proposed. The proposed protocol offers a lower delay and performs significantly better than the hybrid LTE/IEEE 802.11p protocol.

Given the many ideas about the appearance and shape of the 5G network, major operators and device manufacturers have been actively conducting technological surveys, demonstrations, and tests with the aim of proving concepts and defining standardization [4]. Several research programs have also been established to study the feasibility and implementation of new ideas at the academic level. One example is the European Union, which coordinates 5G research programs under different teams. The EU believes that the 5G telecommunications system will be the most critical building block of our digital society in the period 2020 - 2030. Europe has taken significant steps to lead the global development towards this technology and has recognized that 5G will be the first example of a truly converged network environment in which wired and wireless communications will use the same infrastructure, navigating towards a future networked society. It is believed that 5G will provide extremely high bandwidth not only to individuals but also to connected objects. Therefore, the future 5G infrastructure is expected to serve a wide range of applications and sectors, including professional use such as autonomous driving, e-health, energy management, and safety applications, the example of which can be seen in Figure 2. Regarding the need for 5G radio capacity on current bands, the European Commission wants to coordinate the use of the 700 MHz band for mobile services to provide a faster and better quality broadband network and cover wider areas, including rural and remote regions. The specific goal of the EU is to provide mobile broadband speeds higher than 100 Mbps.

The rest of the paper is organized as follows. Section II shows basic VANET working principles together with specific challenges encountered using highly dynamic network topology. Section III is divided into four subsections, Section III-A presents related work oriented towards security, Section III-B presents performance-oriented related work. In Section III-C related work regarding business and entertainment is presented and final Section III-D presents related work regarding safety. The final section, Section IV, concludes the paper.

II. VANET WORKING PRINCIPLES

The basic principle of VANET is simple - all vehicles should be equipped with a widely used, but somewhat modified, wireless local network (WLAN), which will be used to connect onboard computers in different vehicles, as well as connect vehicles with the Internet. Although VANET is conceptually simple, the design and implementation are technically and economically very demanding. The key features in the development of the VANET network are high mobility, dynamic network topology, unbounded network size, and frequent exchange of information [5]. Furthermore, every application which is built for VANET nodes needs to take standards into consideration to ensure safety and proper functionality when used on different VANET topologies as well as on different equipment. Every original equipment manufacturer (OEM) wants to create its variation of a product using VANET with its specific characteristics which must remain in compliance with defined standards. These standards include minimizing communication load, support for diverse applications, congestion control mechanisms, fairness in resource access, and reliability [6]. Although VANET resembles other networks, it has some specific features that no other network has [7]. VANET network topology is highly dynamic since vehicles travel at high speed and have multiple paths that they can choose. The dynamic network topology poses a great challenge to optimization algorithms that aim to improve channel throughput or using a previously defined packet route. Also, roadside units (RSUs) have a limited range. Therefore, frequent connections and disconnections are inevitable as vehicles move in and out of RSUs' range. One of the critical problems in VANET is to remove delay constraints and to ensure the timely delivery of emergency messages. Since not all environments are equally suitable for efficient and fast message transfer (e.g. cities or countryside), communication environments also have to be taken into consideration. For example, reflective objects can degrade the strength and the quality of received signals. When adding the fact that surrounding objects can also move as well as sending/receiving vehicles, the effects of fading and disappearing must also be taken into consideration. Vehicles are equipped with various onboard sensors which provide information about vehicle speed, direction, potential problems, etc. All gathered information needs to be processed, results taken into consideration for vehicle operation and navigation, and if needed, distributed to other vehicles. In VANET, optimization has a very important role since vehicles are mobile and hence, their resources are limited. To ensure a longer-lasting battery and efficient usage of onboard CPU and storage, the network needs to be highly optimized. Security and privacy are also some of the main concerns in VANET [8]. The main challenge is to balance the need for security and privacy. When some information is received, the receiver wants to be sure that it can trust the source of that information, while on the other hand, the availability of such trust may be in contrast to the privacy requirements of the sender. Because VANET is a decentralized, and self-organized network, there is no centralized management and coordination system; efficient use of available wireless channel bandwidth is a difficult task. The lack of an entity capable of synchronizing and managing the transmission events of different nodes can result in less efficient channel use and a large number of packet collisions.

III. 5G TECHNOLOGY TRENDS IN VANETS

This section gives a brief overview of 5G trends in VANETs. In the first subsection, emphasis is put on security by merging VANETs with software-defined networking (SDN) and finding the best security measurements. In the second subsection, achieving the best performance in data transmission and minimizing delay is the main task. In the following subsection, the main focus is on business and entertainment and similar technologies for smart and integrated city transportation as well as the whole city as one smart and fully functional unit. In the last subsection, safety and prevention of accidents are considered.

A. Security oriented

VANETs will certainly have security issues that traditional communication networks have such as confidentiality, integrity, and availability. An overview of various authentication methods in VANETs is available in [9]. When all this is taken into account, the VANET network is much more demanding because any type of attack can result in the loss of human life. In a dynamic network such as VANET, sending information such as an event like *„The traffic accident has occurred 100 m in front of you"*, the system must be very reliable and without any message delay.

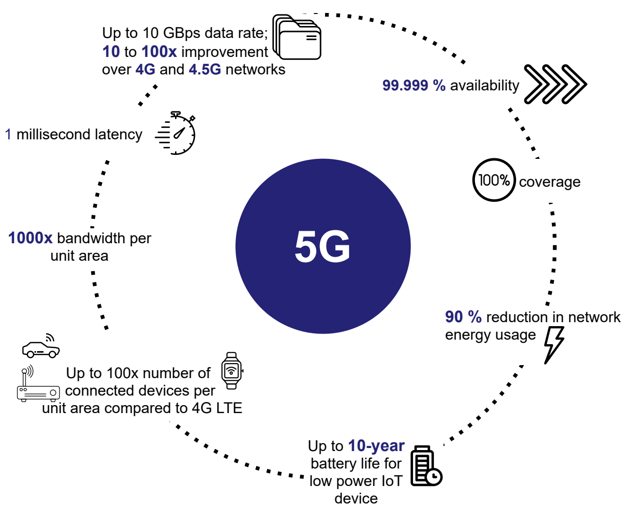

Fig. 1: Specification of 5G network

Icons downloaded from Flaticon

Hussain et al. [10] in their work mention that it is necessary to integrate 5G networks with vehicles, in order to achieve a quality intelligent transportation system (ITS) that should enable the safety of all users. In their work, they presented a thorough analysis of the VANET network: security issues, requirements, different forms of attacks, and network standards. They investigated the security features of each layer of the 5G network architecture and described the possibility of its use in vehicle communication to improve the efficiency of the VANET network. They concluded that current research on VANET network security is mostly focused on the upper layers of the communication model, which makes those on the lower layer more vulnerable. Security at the physical layer of VANET communication should be ensured along with security at the application and network layers. Furthermore, it is very important to enable the connection of the VANET network with technologies such as the Internet of Things, the cloud, and social networks to achieve important commercial services. The 5G network should reduce the occurrence of the security flaws on the physical layer of VANET, but it cannot solve all the problems due to its shortcomings. However, the future research could achieve the goal of the full integration of the both networks.

In [11], a new trust management system for VANETs is presented. By using blockchain technology it tries to implement secure message transmission and node trustability prediction. The system is a combination of Whale (WOA) and Sea Lion Optimization algorithm (SLnO), which got their name from feeding behaviors of respective species. The new proposed algorithm was tested against known ciphertext attack (KCA) and chosen ciphertext attack (CCA), known plaintext attack (KPA) and chosen plaintext attack (CPA), and performance of key sensitivity was also tested. Results showed that against the KCA and CCA the algorithm improved security by 5 %, on average, in comparison with the genetic algorithm (GA)

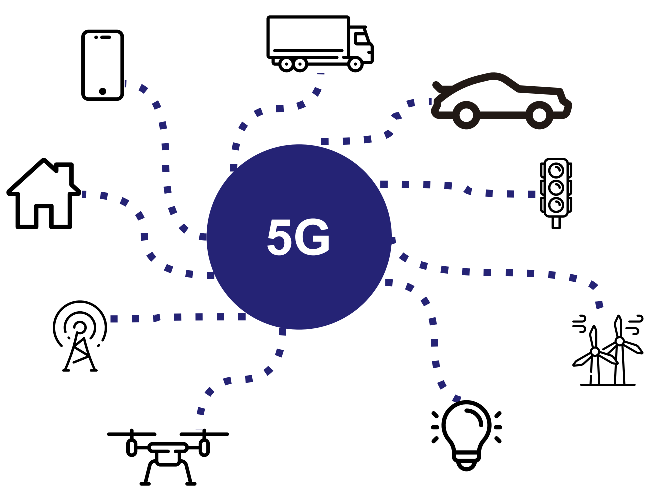

Fig. 2: Utilization of 5G in various use cases
Icons downloaded from Flaticon

and dragonfly algorithm (DA). Further results showed that against the KPA and CPA the algorithm improved security by 3 % in comparison with GA, and up to 10 % in comparison with DA. While analyzing key sensitivity only 18 % of original data could be obtained, on average.

Paper [12] presented an effective implementation of security services in VANET based on merging it with the SDN and 5G. The goal of this approach was to balance mobility, network, security, and performance. They tested different types of Distributed Denial-of-Service (DDoS) attack such as targeting controllers by themselves or vehicles in the network. While analyzing DDoS attacks the results showed that attacks were blocked in their early stages, it took, on average, 2 s from the start of the attack to its complete blockage. The time can be improved by lowering the gap between threshold and victim tolerance but it is an environment-dependent problem. The simulation was also performed to test the efficiency of packet delivery. In comparison to traditional automotive routing like Greedy Perimeter Stateless Routing (GPSR), the newly proposed approach performed 15 % better, with 90 % packet delivery. The failure fallback recovery mechanism was also included, to ensure that the performance of this approach does not fall under the performance of GPSR.

The integration of the best features of different network technologies must be fundamental for a reliable VANET network. Once, when the previous approach is harmonized, it is possible to develop hybrid algorithms that would focus on message reliability and node availability. Secure transmission of essential information from vehicle A to vehicle B should be strictly encrypted with vehicles generated keys. If the security of transmitted messages cannot be ensured, the VANET network can lose fundamental features and only be used for commercial and informational purposes.

B. *Performance oriented*

Centralized computing infrastructure and software models often cannot meet the real time application demands for low delays in the case of when large amounts of data are generated due to the long transmission time. Therefore, it is necessary to merge the classic centralized cloud infrastructure approachable through 5G with the decentralized approach in VANETs by using edge and fog computing, and SDNs.

Luo et al. in [13] present a decentralized type of architecture which is shown in Figure 3. However, it is very challenging to achieve efficient content sharing due to its extremely large data volume, rapid topology change, and unbalanced traffic. Machine learning could be useful for predicting vehicle movements and for traffic control. Most vehicles move similarly, if not along the same route every day. Vehicles could be pre-allocated to specific stations to avoid congestion, which means that the network model would reduce the burden of the congested base station. By simulating and comparing their algorithm with the existing Greedy-MWIS algorithm (Maximum Weighted Independent Set) and Random-greedy, the results showed that their algorithm is similar to Greedy-MWIS. In conclusion, more data will be delivered and more nodes will be served than with the Random-greedy algorithm, but it will have fewer transmissions in each period.

The new architecture of 5G VANET was proposed in [14], by integrating SDN and Cloud-RAN with 5G communication with the goal to increase performance throughout the network. The architecture comprises four fog computing frameworks: zone controllers, cluster-heads, vehicles and BBU controllers, SND controllers, and optical transmission network (OTN) all with their own logical structure.

By comparing the proposed architecture with traditional architecture and 5G SD VANETs the performance was tested with a number of vehicles varying from 10 to 60. Results showed that throughput was better from 5G SD VANETs for 35 % and 700 % better than traditional architecture. They also tested throughput by using average and adaptive bandwidth, here the proposed architecture was also performing better throughout the simulation. Further testing showed lower delay by 0.02 ms and lower control overhead by the average of 70 network packages in comparison with 5G SD VANET per number of vehicles. This paper presented new, yet to be optimized, architecture with admirable results.

A step towards improving performance was made in [15] where Khan and others proposed a hybrid-fuzzy logic guided genetic algorithm (H-FLGA) for resource optimization in 5G VANETs. By using the Fuzzy Inference System (FIS) they weighted and optimized different options and the Type of Service (ToS) requirements of customers. The algorithm uses two inputs ToS (throughput, delay, cost) and value, that is 0 or 1, and gives the output of FIS priority coefficients for optimized weights of multi-objective in the range between [0, 1]. The results of multi-objective costs were compared with GA and they showed a decrease from 10.32 to 2.2 with using H-FLGA. They also compared End-to-End delay with GA and their previous work [14], the results were a delay of 0.113 s using GA, 0.171 s using [14] and 0.062 s by using H-FLGA. Furthermore, they discussed the complexity of the algorithm and concluded that the algorithm is efficient. They also analyzed signaling overhead on the controller and got a logarithmic increase.

In article [16] written by Storck and Duarte, by using a 5G network based on SDN they analyzed data traffic based on video services. By creating the 5G V2X ecosystem they put networking intelligence on the SDN controller, which enabled dynamic network management. Because of the video traffic they used Dynamic Adaptive Streaming over HTTP (DASH) and tested three algorithms: PANDA, FESTIVE and TOBASCO2. The algorithms were compared on average delay with vehicle count increasing from 10 to 60 vehicles. Tests showed that PANDA and TOBASCO2 algorithms presented similar results, with a few milliseconds advantage towards TOBASCO2. The FESTIVE algorithm showed better results on low and high vehicle count, but lower results, in comparison to TOBASCO2, in 30 to 50 vehicles for a few milliseconds. Throughput was also tested and it showed an average of 1100 Mbps when using the PANDA algorithm in the ecosystem. However, the scenario taken into consideration was only based in rural areas, highways with four lanes. The city scenarios still need to be evaluated.

VANETs are still a new technology and it has to adapt to each advancement in the field of communications. Presented papers give an inside look at the current state of performances concerning VANETs, but each day the performance is moved towards even higher values. Nevertheless, these papers already have some outstanding performance and they will be a great step for next researchers.

C. Business and entertainment oriented

As the new technologies emerge, the infotainment applications get more advanced requiring more data transmission and necessitating better internet services. Because of VANETs' high mobility, these requirements became a major problem and new solutions and algorithms are needed to solve it.

Among the various network services that exist in the provision of customer services, the most demanding are those related to media streaming. That kind of application uses large amounts of data which can affect the efficiency of the network. Batalla et al. in [17] present a solution for custom protocols applied in 5G networks, which can increase the bandwidth availability for direct connections between devices. Moreover, video streams would be sent from the base station, while the connection between devices would optimize the allocation of resources. The results show that the proposed data transferring model is more efficient from the standard approach and suitable for smart cities with future 5G communication infrastructure. Such future cities will include a VANET network, where the vehicles would be one of the devices for transferring media, so it would be necessary to continue research in this direction to provide customers the best possible service.

Link aware high data transmission (LHT) [18] is proposed to ensure the quality of infotainment applications. LHT is based on bandwidth and signal strength evaluation for the next node. Running the simulation in SUMO the results showed the highest peak signal to noise ratio in comparison to MERVE and COMIP algorithms throughout the simulation. This ensures better video quality and higher video frame transmission. The simulation also tested the SSIM index (image degradation sensitivity and image perception), LHT also had the best results, because of the ability to adopt high mobility patterns and frequent changes in networks. Furthermore, data rate and delay were also tested and LHT again showed the best results. The data rate was higher for three kbits/s in comparison to MERVS and five kbits/s in comparison to COMIP, while the delay was on average lower by 0.13 ms in comparison to MERVS and 0.18 ms in comparison to COMIP.

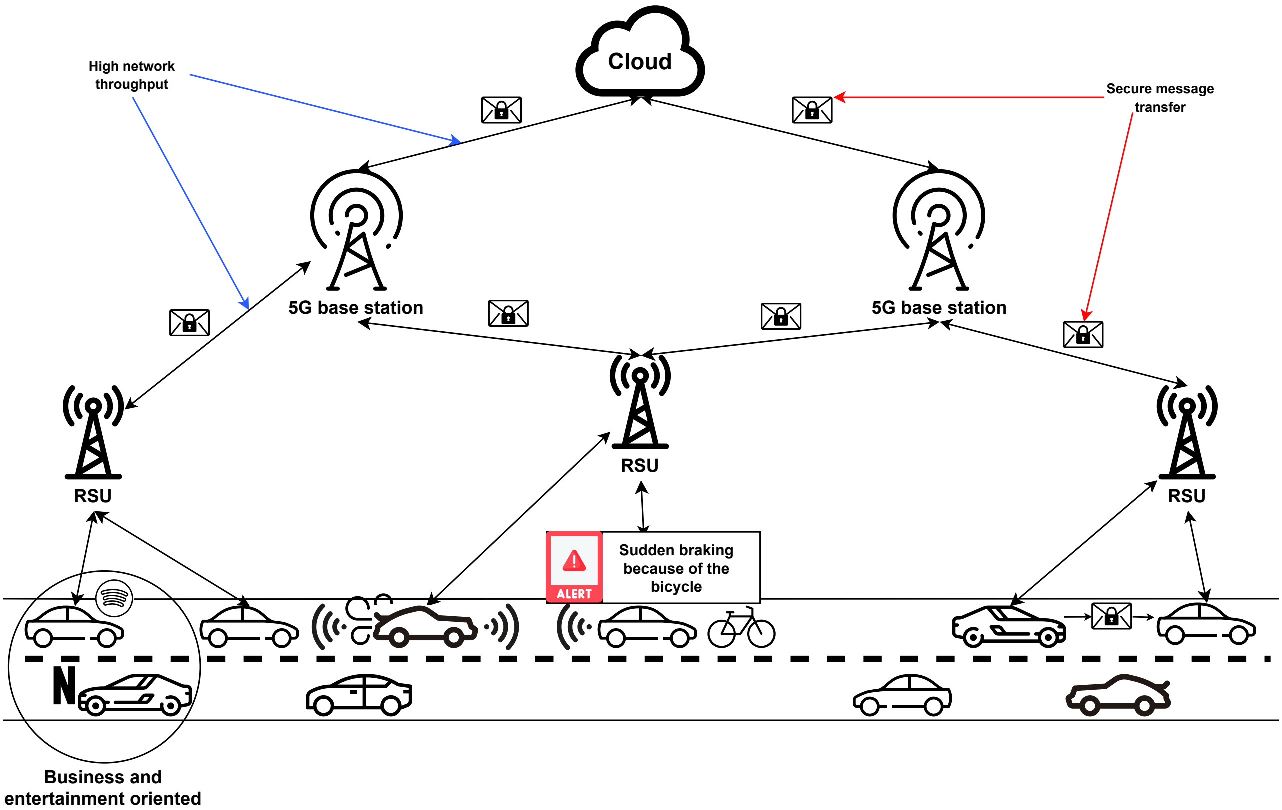

Fig. 3: Architecture of content sharing in VANET

Icons downloaded from Flaticon

In [19], the authors explained the basics of fog computing. Fog computing is expanding the facility of cloud computing from the network's center to the edge of the network. Fog computing has some advantages like location awareness, ultra-low latency in real-time for smart cities. Vehicular fog computing is the integration of vehicular networks as well as fog computing and it is promising to work in real time and location aware response. Vehicular fog computing is a relatively new technology and it is still in the initial phase of concepts and use cases. This paper is briefly explaining the three-layered vehicle fog computing model to enable traffic management. The authors also explained the interaction between fog and cloud. They explained that the VCC and VFC are promising to provide ubiquitous Internet communication, as well as the response to the huge traffic demands for integrated transport cities. A fog to cloud system is the most promising for a large number of cars at one place, like parking lots, or cars parked at the side of the road.

The fundamental part of VANETs are ways of transmitting data, either by using newly created vehicular networks, or some ways of link-aware high data transmission, or some other solution. It is important to understand the technical limitations and find suitable solutions. The other part of VANET is using less data, and to be eco-friendly, and that is manageable by processing little tasks on parked cars using fog computing.

D. Safety oriented

The development of the industry and technology is raising people's living standards which is causing, among other things, an increased number of passenger vehicles. An increased number of vehicles is causing traffic congestion that can sometimes lead to traffic accidents, and therefore traffic management optimization is necessary. Heavy traffic and traffic collisions besides having a negative impact on passenger safety, can also have a negative influence on people's daily activities, work efficiency causing negative social and economic factors. In order to improve transportation efficiency and increase the safety of passengers it is required to integrate technologies such as 5G and Internet of vehicles (IoV) in VANETs.

In [20], the authors assumed that four vehicles with vehicle-to-vehicle (V2V) connection are moving for Kmax time from 0 m to 3600 m on a straight highway, which has four lanes. The simulation had a scenario where the vehicles exited the rural area and entered the urban area, then moved through the urban area and again to the rural area. The network was divided into two cases, in rural area absolute position measurement was acquired from Global Positioning System (GPS) signal, whereas in urban area position was obtained from Uplink Time - Difference - of - Arrival (UTDoA) by using Vehicle to Infrastructure (V2I) scenario. The result can be separated into two sections. The first section states that vehicles are in a rural environment, the error of cooperative localization with the

Alternating Direction Method of Multiplier (ADMM), and conventional absolute position measurement is 35 cm and 40 cm, respectively. The second case is that vehicles are in an urban environment, each error with ADMM and absolute position measurement increases to 55 cm and 65 cm, respectively. The result showed that autonomous driving is possible in both urban and rural areas.

Authors in [21] proposed VISAGE, a multi-level SDN based on 5G vehicular architecture using vehicles as fog computing infrastructure. Its architecture is made from two sub-nodes: a permanent cloud with a central SDN controller (CSDNC) and temporary fogs with local SDN controllers (LSDNC). Such a hybrid model helps simplify management and configuration while also enhancing the scalability of the network. Apart from CSDNC and LSDNC other key elements would be fog nodes, vehicles, with equipped On-Board Unit (OBU) to increase communication and computation capabilities, base stations (BS) to ensure the communication between fog nodes and CSDNC and customers which can be vehicles, organizations and/or individuals. Some applications and potential use cases of VISAGE could be hot information catching, enhancing environmental perception, and computation offloading in the 5G VANET. However, the performance through simulations is yet to be estimated and therefore the efficiency of their solution cannot be verified.

Talib et al. [22] in their work explore the impact of new technologies that are crucial for the creation of a functional ITS. The 5G provides efficiency, scalability, and the ability to deliver higher capacity requirements while using fewer resources. It even has the ability to provide real-time services and applications with minimal latency so emergency services can have a fast and prompt response. SDN can enable VANETs to adjust the network topology changes and by doing it safety measures are upgraded. Also merging data plane and control plane, the data transfer between nodes and central controller is more reliable and faster. Merging of technologies such as VANETs, SDNs, 5G, and others should be the basis for creating a secure ITS that will follow, and allow, global developments. Furthermore, incorporating cameras and roadside sensors in these technologies can increase safety even further.

In [1], the authors presented a system that is used for safety-critical applications in VANET. The issue in V2X communication is that WAVE/DSRC technology has limitations mainly in connection due to various obstacles, and this issue will not be solved in the near future. It is shown that using a hybrid system that consists of cellular networks and Wi-Fi Direct can solve a problem. The system is providing connectivity and monitoring vehicles in the network, as well as local data transmission by Wi-Fi Direct, and reduction of long connection establishment time of Wi-Fi Direct. The possibility of using a smart mobile device-based approach for V2X communication is also elaborated. Limitations of using several types of wireless network technologies or protocols available to a smartphone, such as NFC, Wi-Fi, Cellular, and Bluetooth for safety critical applications are also elaborated. The solution presented in the paper is using a hybrid system based on using cellular network and Wi-Fi Direct on smartphones to provide support in connectivity for V2X communication.

Safety is one of the most important parts of the automotive industry and because of that, it is also important for VANETs to be aware of it. By merging VANETs with other technologies like SDNs, 5G, and IoV some safety issues are avoided. VANETs are also incorporating some sensors and cameras in their systems to cover as many inputs as possible so that, if it is needed, the system can timely intervene and prevent any accidents.

IV. CONCLUSION

In this paper, we provide a brief survey of using a new 5G mobile network with a promising technology that will enable communication between vehicles - VANET. Utilization of both types of network can result in a drastic reduction in accidents, travel time, and reduced fuel consumption. The ideal future goal would be that every type of vehicle collaborates in VANET for more secure and faster commutes. These days, where traffic is growing, internal communication between nodes is required to improve traffic safety with the aim of reducing collisions and accidents. In order to achieve effective communication, data must be protected and successively transmitted between vehicles from possible hacker attacks. Furthermore, the 5G network with its characteristics such as high transfer speeds and the possibility of multiple connected devices, can affect the performance of traffic overall. For example, reducing congestion and route optimization increases traffic flow efficiency and directly affects safety. Moreover, 5G allows the flow of big data through the network which allows vehicles to use high-quality multimedia that can be used for useful purposes such as observing road conditions, but also for commercial purposes such as watching movies or playing music. Finally, research conducted in the domain of 5G and VANET networks offer services that are acceptable for providing a satisfactory user experience and creating future ITS. Our future work includes the usage of the 5G network and conducting experiments in various scenarios and networks, such as VANET and the network of robots.

V. ACKNOWLEDGMENT

This work is supported by the project "Research and development of autonomous robotic fire extinguisher for prevention, early detection and fire extinguishing" under the grant KK.01.2.1.02 co-financed by the European Union from the European Regional Development Fund within the Operational programme Competitiveness and Cohesion 2014-2020 of the Republic of Croatia.

REFERENCES

[1] S. Jeong, Y. Baek, and S. H. Son, “A Hybrid V2X System for Safety-Critical Applications in VANET,” in *2016 IEEE 4th International Conference on Cyber-Physical Systems, Networks, and Applications (CPSNA)*, Oct. 2016, pp. 13–18.

[2] “5G technology and networks (speed, use cases, rollout),” https://www.thalesgroup.com/en/markets/digital-identity-and-security/mobile/inspired/5G.

[3] S. K. Gupta, J. Y. Khan, and D. T. Ngo, “A 5G-Based Vehicular Network Architecture to Enhance Road Safety Applications,” in *2021 IEEE 94th Vehicular Technology Conference (VTC2021-Fall)*, Sep. 2021, pp. 1–7.

[4] R. N. Mitra and D. P. Agrawal, “5G mobile technology: A survey,” *ICT Express*, vol. 1, no. 3, pp. 132–137, Dec. 2015.

[5] A. A. Ahmed and A. A. Alzahrani, “A comprehensive survey on handover management for vehicular ad hoc network based on 5G mobile networks technology,” *Transactions on Emerging Telecommunications Technologies*, vol. 30, no. 3, Mar. 2019.

[6] S. A. A. Shah, E. Ahmed, M. Imran, and S. Zeadally, “5G for Vehicular Communications,” *IEEE Communications Magazine*, vol. 56, no. 1, pp. 111–117, Jan. 2018.

[7] V. Kumar, S. Mishra, and N. Chand, “Applications of VANETs: Present & Future,” *Communications and Network*, vol. 5, no. 1, pp. 12–15, Feb. 2013.

[8] S. Sharma, P. Agarwal, and S. Mohan, “Security Challenges and Future Aspects of Fifth Generation Vehicular Adhoc Networking (5G-VANET) in Connected Vehicles,” in *2020 3rd International Conference on Intelligent Sustainable Systems (ICISS)*, Dec. 2020, pp. 1376–1380.

[9] P. Wang, C.-M. Chen, S. Kumari, M. Shojafar, R. Tafazolli, and Y.-N. Liu, “HDMA: Hybrid D2D Message Authentication Scheme for 5G-Enabled VANETs,” *IEEE Transactions on Intelligent Transportation Systems*, vol. 22, no. 8, pp. 5071–5080, Aug. 2021.

[10] R. Hussain, F. Hussain, and S. Zeadally, “Integration of VANET and 5G Security: A review of design and implementation issues,” *Future Generation Computer Systems*, vol. 101, pp. 843–864, Dec. 2019.

[11] N. Malik, P. Nanda, X. He, and R. P. Liu, “Vehicular networks with security and trust management solutions: Proposed secured message exchange via blockchain technology,” *Wireless Networks*, vol. 26, no. 6, pp. 4207–4226, Aug. 2020.

[12] A. Hussein, I. H. Elhajj, A. Chehab, and A. Kayssi, “SDN VANETs in 5G: An architecture for resilient security services,” in *2017 Fourth International Conference on Software Defined Systems (SDS)*, May 2017, pp. 67–74.

[13] G. Luo, Q. Yuan, H. Zhou, N. Cheng, Z. Liu, F. Yang, and X. S. Shen, “Cooperative vehicular content distribution in edge computing assisted 5G-VANET,” *China Communications*, vol. 15, no. 7, pp. 1–17, Jul. 2018.

[14] A. Khan, M. Abolhasan, and W. Ni, “5G next generation VANETs using SDN and fog computing framework,” *2018 15th IEEE Annual Consumer Communications & Networking Conference (CCNC)*, 2018.

[15] A. A. Khan, M. Abolhasan, W. Ni, J. Lipman, and A. Jamalipour, “A Hybrid-Fuzzy Logic Guided Genetic Algorithm (H-FLGA) Approach for Resource Optimization in 5G VANETs,” *IEEE Transactions on Vehicular Technology*, vol. 68, no. 7, pp. 6964–6974, Jul. 2019.

[16] C. R. Storck and F. Duarte-Figueiredo, “5G V2X Ecosystem Providing Entertainment on Board Using Mm Wave Communications,” in *2018 IEEE 10th Latin-American Conference on Communications (LATINCOM)*, Nov. 2018, pp. 1–6.

[17] J. M. Batalla, P. Krawiec, C. X. Mavromoustakis, G. Mastorakis, N. Chilamkurti, D. Negru, J. Bruneau-Queyreix, and E. Borcoci, “Efficient Media Streaming with Collaborative Terminals for the Smart City Environment,” *IEEE Communications Magazine*, vol. 55, no. 1, pp. 98–104, Jan. 2017.

[18] K. N. Qureshi, F. Bashir, and N. Ul Islam, “Link Aware High Data Transmission Approach for Internet of Vehicles,” in *2019 2nd International Conference on Computer Applications Information Security (ICCAIS)*, May 2019, pp. 1–5.

[19] Z. Ning, J. Huang, and X. Wang, “Vehicular Fog Computing: Enabling Real-Time Traffic Management for Smart Cities,” *IEEE Wireless Communications*, vol. 26, no. 1, pp. 87–93, Feb. 2019.

[20] H. Kim, S. H. Lee, and S. Kim, “Cooperative localization with distributed ADMM over 5G-based VANETs,” in *2018 IEEE Wireless Communications and Networking Conference (WCNC)*, Apr. 2018, pp. 1–5.

[21] A. Soua and S. Tohme, “Multi-level SDN with vehicles as fog computing infrastructures: A new integrated architecture for 5G-VANETs,” in *2018 21st Conference on Innovation in Clouds, Internet and Networks and Workshops (ICIN)*, Feb. 2018, pp. 1–8.

[22] M. S. Talib, “Converging VANET with Vehicular Cloud Networks to reduce the Traffic Congestions : A review,” *undefined*, 2017.