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Evolution of 5G Network: A Precursor towards the Realtime Implementation of VANET for Safety Applications in Nigeria

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Abstract— A crucial requirement for the successful real-time design and deployment of Vehicular Adhoc Networks (VANET) is to ensure high speed data rates, low latency, information security, and a wide coverage area without sacrificing the required Quality of Service (QoS) in VANET. These requirements must be met for flawless communication on the VANET. This study examines the generational patterns in mobile wireless communication and looks into the possibilities of adopting fifth generation (5G) network technology for real-time communication of road abnormalities in VANET. The current paper addresses the second phase of a project that is now underway to develop real-time road anomaly detection, characterization, and communication systems for VANET. The major goal is to reduce the amount of traffic accidents on Nigerian roadways. It will also serve as a platform for the real-time deployment and testing of various road anomaly detection algorithms, as well as schemes for communicating such detected anomalies in the VANET.

Keywords/Index Terms— Algorithm, 5G-Network, Potholes, Road, Speed-Bumps and VANET

1. Introduction

Intelligent Transportation Systems are increasingly being developed as a result of developments in computing, sensing devices, and wireless communication (Costanzo, Fajjari, Aitsaadi, & Langar, 2018).

These systems are being developed with the intention of enhancing driving experiences and assuring the safety of people and property while they are on the road. The most important piece of technology in this regard is called a Vehicular Adhoc Network (VANET), which refers to the utilization of vehicles as nodes in the construction of a network for the purpose of communication between other vehicles or roadside infrastructure. (V2V) or between vehicles and roadside infrastructure (V2I) (H Bello-Salau et al., 2018; H. Bello-Salau, Aibinu, et al., 2019). Moving automobiles acted as nodes in VANET, transmitting information among other vehicles within a communication radius of 100 to 300 meters (H Bello-Salau et al., 2018; H. Bello-Salau, Aibinu, et al., 2019). Applications of VANET include increasing road safety through real-time cooperative collision warning systems (Xu et al., 2018), intelligent transportation systems for optimized traffic management and congestion reduction (Khatri et al., 2021), efficient emergency services and roadside assistance enabled by quick communication (Kadhim, Mohammed, Majid, Mohamd, & Tao, 2016), infotainment and passenger services for personalised in-vehicle experiences (Shafi, Ratnam, & Applications, 2022), improved fleet management and logistics operations for improved efficiency(Khaliq, Qayyum, & Pannek, 2017), which all require low latency and delay. Especially, when use to communicate safety information such as road surface status conditions, traffic status among others.

Despite the promising potential of VANETs, real-time network implementation for safety applications such as road anomaly detection and communication in developing nations like Nigeria remains a big difficulty. The high mobility of vehicles, as well as other dynamic factors such as mechanism for sensing road surface anomalies (potholes, speedbumps, and rutting), routing scheme, and routing algorithm in either V2V/V2I VANETs with minimal end-to-end delay, latency, and security of the communicated information, remain important research issues (H. Bello-Salau, Onumanyi, et al., 2019) that must be addressed in order to realize real-time implementation and deployment of VANETs, as well as the most suitable handover techniques to be utilized for seamless communication (Karanja, Misra, & Atayero, 2023)

This serves as the impetus for the recommended system that is presented here, which is oriented towards the second phase of an ongoing project for real-time road anomaly detection, characterization, and communication via VANET. In the first part of the project, a new approach for real-time road anomaly detection and characterization was developed and tested, as detailed in (H Bello-Salau et al., 2018). Additionally, the various strategies for conveying the sensed road abnormality in VANET have been examined, and the specifics of these investigations are given in (H. Bello-Salau, Aibinu, et al., 2019). The most important challenge, on the other hand, is to create a physical real-time implementation of the VANET that has all-encompassing capabilities of detecting road anomalies and delivering the information in either V2V or V2I with the least amount of delay and latency possible while maintaining the information's security. We acknowledge the inspiration gotten from (Misra, 2021), to conceptualize and develop this research.

Hence, in this paper we examine the different evolution of mobile wireless communication, while proposing a framework for the possible implementation and deployment of VANET for road surface anomaly detection and communication in Nigeria. While addressing the challenge of delay, latency and security issues by a paradigm change from the conventional communication scheme in VANET via Wireless Access in Vehicular Environment / Dedicated Short Range Communication (DSRC) as specified by the IEEE 802.11p standard to an integrated cellular VANET approach. Thus, harnessing the strength of the evolving developed fifth generation (5G) networks with high data rates of up to a maximum 20Gbps and the low latency of about 1ms when used for real-time applications. With the goal of reducing anomaly induced accidents in the country. The rest of the paper is structure as follows: Section 2 presents an overview of the evolution of mobile wireless technology generation; section 3 examines the 5G network technology as a precursor for the real-time implementation of VANET. While, Conclusions are drawn in section 4.

2. An Analysis of the Evolution of Mobile Wireless Technologies

This section examines the growth of mobile wireless technology, which has seen extraordinary evolution over the last few decades, revolutionizing the way we communicate and access information. It also investigates the key milestones in mobile technology and provides insights into the expected trends leading up to the anticipated 6G technology, while evaluating the suitability of current trends such as 5G for integration into VANET for communicating time critical information that requires low latency. The mobile technology's generational technology was divided into four group namely: The foundation technology (1G to 2G), internet everywhere technology (3G to 4G), changing connectivity (5G), and anticipated future technology (6G), with specifics discussed as follows:

2.1 1G to 2G: The Foundation

The move from first generation (1G) to second generation (2G) mobile technology was a watershed moment in the evolution of mobile technology. Key achievements throughout this time period are studied, as well as their importance on creating the groundwork for today's mobile communication networks. The first generation of mobile technology, known as 1G, appeared in the 1980s and offered analogue cellular systems that allowed for wireless voice communication (P. Sharma, 2013; Shukla, Khare, Garg, & Sharma, 2013). 1G systems had poor voice quality, limited network capacity, and were susceptible to interference (Sterling & Kittross, 2001). Despite these limitations, 1G laid the groundwork for future breakthroughs in mobile wireless technology. In addition, the advent of the second generation, 2G, mobile communication technology in the 1990s resulted in a paradigm change in mobile communication. 2G networks made use of digital cellular technologies, which improved call quality and introduced new features (P. Sharma, 2013; Shukla et al., 2013). 2G networks replaced analogue signals with digital signals, resulting in more efficient use of the frequency spectrum and higher capacity for speech and data transmission (Rappaport, 2002; Sahoo, Hota, Barik, & Software, 2014).

With the introduction of 2G technology, mobile communication was transformed, expanding its possibilities beyond voice conversations. 2G networks facilitated the growth of data services, including the breakthrough launch of short messaging services (SMS) (P. Sharma, 2013). With 2G, users could not only make calls but also send text messages, ushering in a new era of mobile connection. Thus, the transition from 1G to 2G was critical in laying the groundwork for modern mobile wireless technologies. The innovations made in 2G paved the way for succeeding generations, allowing for the rapid spread of mobile services. Better speech quality, the introduction of digital signals, and the debut of basic data services transformed mobile devices into flexible instruments (Shukla et al., 2013), paving the way for mobile internet and the myriad of services we now enjoy.

2.2 3G to 4G: Internet Everywhere

The transition from third generation (3G) to fourth generation (4G) mobile wireless technology resulted in a revolutionary shift in connectivity and information availability. The significance of key breakthroughs during this time period on realising the ideal of "Internet Everywhere" through widespread mobile broadband is reviewed. The introduction of third generation (3G) mobile wireless technology in the early 2000s was critical in enabling greater data transfer rates and the advent of mobile internet access. 3G networks provided considerable gains over previous generations, allowing customers to access the internet on their mobile devices and enable a variety of multimedia services such as video calling and mobile TV (Shukla et al., 2013). The introduction of fourth generation (4G) mobile wireless technology in the late 2000s signified a significant advancement in mobile wireless technology. 4G networks enabled significantly better data transmission speeds, making mobile broadband a reality (P. Sharma, 2013). This technology transformed smartphones into sophisticated devices capable of streaming high-quality films, participating in video conferences, and utilising a wide range of mobile applications for communications purposes, such as VANET.

The goal of "Internet Everywhere" began to take shape with 4G, allowing users to stay connected and access online services regardless of their location. The introduction of 4G networks has a profound impact on a wide range of companies and sectors, including e-commerce, media streaming, and mobile app development. The widespread availability of 4G networks facilitated seamless connectivity, allowing people to access information, communicate, and do business while on the road (Afzal et al., 2018; Bhandari, Devra, Singh, & techniques, 2017). The switch from 3G to 4G was a watershed moment in the history of mobile wireless technology. Faster data transmission speeds, low latency, and increased capacity delivered in 4G networks established the groundwork for a digitally connected world. 4G networks were critical in supporting the expansion of the mobile app market and stimulating innovation in numerous industries (Sauter, 2011), defining the digital landscape as we know it today.

2.3 5G: Transforming Connectivity

Mobile wireless technology's fifth generation (5G) is revolutionising connection and ushering in a new era of transformational possibilities. The key breakthroughs and revolutionary impact of 5G on numerous businesses and sectors were investigated, emphasising its ability to alter communication, enable new technologies, and promote innovation. The introduction of 5G signifies a substantial advancement in mobile wireless technology. 5G networks provide significantly enhanced data transmission speeds, lower latency, and enormous device connectivity (Chettri & Bera, 2019). These developments allow for the seamless transmission of massive amounts of data, promoting a highly linked ecosystem capable of supporting a wide range of applications and services. 5G's disruptive impact can be seen in a variety of industries, including healthcare, transportation, and manufacturing. 5G technology provides remote healthcare services (Damaševičius, Bacanin, Misra, & Networks, 2023; Siriwardhana, Gür, Ylianttila, & Liyanage, 2021), allowing healthcare professionals to deliver telemedicine, perform remote procedures, and monitor patients in real time. 5G enables the development of autonomous vehicles, sophisticated traffic control systems, and increased safety measures in the transportation industry (Gohar & Nencioni, 2021).

5G's capabilities are not confined to traditional sectors. Its potential inspire innovation in areas such as augmented reality (AR) and virtual reality (VR) (Baratè, Haus, Ludovico, Pagani, & Scarabottolo, 2019). 5G networks deliver the high bandwidth and low latency needed for immersive experiences, paving the way for breakthroughs in entertainment, gaming, and remote collaboration, as well as VANET adoption. The impact of 5G technology goes beyond technical improvements. Also, 5G is pushing changes in business models and opening up new opportunities for stakeholders. It supports IoT and machine-to-machine (M2M) communication (Ratasuk, Prasad, Li, Ghosh, & Uusitalo, 2015), enabling for the integration of smart devices and the creation of innovative services and applications such as Vehicle to Vehicle Communication (V2V) and Vehicle to Infrastructure Communication (V2I).

2.4 Expected 6G Technology: Envisioning the Future

As the globe embraces 5G technology's disruptive potential, researchers and industry professionals are already imagining the next phase of mobile wireless communication: 6G. This section digs into the promising gains that 6G technology is expected to bring, as well as its potential to revolutionise connectivity, data transfer, and user experiences. The much-anticipated 6G technology is set to revolutionise mobile wireless communication. 6G is envisioned to produce unparalleled data speeds, promising to outperform 5G networks by several orders of magnitude (Chi, Zhou, Wei, & Hu, 2020). 6G is projected to offer transformative experiences such as ultra-high-definition video streaming, virtual and augmented reality applications, and real-time artificial intelligence processing.

6G is projected to address some of the fundamental difficulties experienced by its predecessors, such as network dependability and coverage, in addition to speed. Furthermore, 6G intends to provide seamless connectivity in both urban and rural areas through enhanced satellite and terrestrial integration (Rajatheva et al., 2020). Furthermore, the new network architecture is expected to be more energy-efficient, lowering environmental impact while enabling a wide range of linked devices and sensors. 6G's potential applications go beyond regular connectivity. According to Wang et al.'s (2023) study report, 6G's support for low-latency, high-reliability connectivity would expedite the deployment of driverless vehicles, smart city infrastructure, and industrial automation. Furthermore, combining 6G with emerging technologies such as blockchain and edge computing might open the way for new business models and digital services. While 6G is still in its early stages of development, the collaborative efforts of academia, industry, and standardization organizations are moving it forward. The study by Lu et al. (2022) emphasizes the importance of interdisciplinary research and international collaboration in addressing the complexity of 6G design and implementation. The basis for a breakthrough 6G technology may be established by actively involving stakeholders and predicting future use cases, ushering in a new era of connectivity and disruptive innovations. Nevertheless, this study focuses on the prospect of harnessing 5G technology for communication in VANET. Table1 summarizes the various generations of the wireless mobile technology while highlighting the technology used, standards, data rate, core networks, the multiplexing switching approach among others.

3. 5-G NETWORK: A PRECURSOR FOR REAL-TIME VANET IMPLEMETATION

This section provides an overview of the developed 5G network as a forerunner to the real-time deployment of VANET safety applications. It focuses on the key features and benefits of 5G technology and its applicability for VANETs, as well as the 5G Architecture for vehicular communication and the integration of 5G and VANETs.

The 5G technology offers several key features and advantages that make it highly suitable for the application in Vehicular Ad-hoc Networks (VANETs). One of the fundamental features of 5G is its significantly higher data rates compared to previous generations of wireless communication. With 5G, peak data rates of up to 20 Gbps can be achieved, enabling ultra-fast and reliable communication between vehicles and infrastructure (Rost et al., 2017). This high data rate capability is crucial for supporting real-time applications in VANETs, such as cooperative collision avoidance systems and autonomous vehicle coordination.

In addition to high data rates, 5G technology provides ultra-low latency, which is essential for enabling real-time and mission-critical

Table 1: Evolution of various Generations of Mobile Wireless Commutations (Bhandari et al., 2017; Sahoo et al., 2014)

Parameters/Generation	1G	2G	3G	4G	5G
Deployment	1970 – 1980	1990 – 2001	2001 – 2010	2011	2015 - 2020
Data Rates	2kbps	14.4 – 64kbps	2Mbps	200Mbps – 1Gbps	1Gbps and higher
Technology	Analog Cellular Technology	Digital Cellular Technology	CDMA, WCDMA, UMTS, EDGE	WiMax, LTE, Wi-Fi	WWW
Multiplexing Switching	FDMA	TDMA, CDMA	CDMA	CDMA	CDMA
Switching Type	Circuit	Circuit	Circuit, Packet	Packet	Packet
Core Network	PSTN	PSTN	Packet N/W	Internet	Internet
Standards	MTS AMTS IMTS	2G: GSM 2.5: GPRS 2.75: EDGE	IMT-2000 3.5G: HSDPA 3.75G: HSUPA	Single unified standard, LTE, WiMax	Single unified standard
Handoff	Horizontal only	Horizontal only	Horizontal & Vertical	Horizontal & Vertical	Horizontal & Vertical
Service	Analog voice	Digital voice with higher clarity SMS, MMS	Enhanced audio video streaming Video conferencing support Web browsing at higher speeds IPTV support	Enhanced audio, video streaming IP telephony HD mobile TV	Dynamic information access, Wearable devices with AI capabilities

Bandwidth	Analog	25MHz	25MHz	100MHz	30GHz to 300GHz
Internet Service	Narrowband	Narrowband	Broadband	Ultra-broadband	Wireless World Wide Web (WWWW)
Shortfalls	Low capacity, Unreliable handoff, Poor voice links, Less secure	Digital signals were reliant on location & proximity, required strong digital signals to help mobile phones	Need to accommodate higher network capacity	Hard to implement complicate hardware required.	

communications in VANETs. Latency refers to the time delay between sending a data packet and receiving a response. With 5G, latency can be reduced to as low as 1ms (Camacho, Cárdenas, Muñoz, & Manufacturing, 2018).Low latency is crucial for enabling fast response times in safety-critical scenarios, such as collision avoidance or emergency vehicle communication. by minimizing communication delays, 5G technology ensures that information can be exchanged quickly and efficiently among vehicles and infrastructure, enhancing overall road safety.

Moreover, 5G offers massive device connectivity, allowing a large number of vehicles and infrastructure components to connect simultaneously. This feature is particularly important in VANETs, where a dense deployment of vehicles and roadside units is expected. 5G can support up to 1 million connected devices per square kilometer, ensuring seamless communication and coordination among vehicles, infrastructure, and other networked devices (Singh, Saluja, & Kumar, 2021). This capability enables efficient traffic management, congestion control, and cooperative maneuvers among vehicles, leading to improved traffic flow and reduced travel times.

We note that, the architecture of 5G networks plays a crucial role in enabling efficient and reliable communication in Vehicular Ad-hoc Networks (VANETs). 5G architecture follows a decentralized and distributed approach, with the concept of network slicing being a key element. Network slicing allows the virtual partitioning of the network infrastructure into multiple logical networks, each tailored to specific requirements. In the context of VANETs, network slicing enables the creation of dedicated slices for vehicular communication, ensuring the prioritization of critical safety messages and efficient resource allocation (Khan, Luoto, Samarakoon, Bennis, & Latva-Aho, 2021). This architecture allows for seamless integration of vehicular networks into the broader 5G ecosystem while providing the necessary flexibility and scalability to support diverse VANET applications.

To enable effective communication in VANETs, the 5G architecture incorporates several essential components. The Radio Access Network (RAN) serves as the interface between vehicles and the core network. It includes small cell base stations and roadside units that provide the necessary coverage and connectivity for vehicles (Lin & Lee, 2021). The core network consists of multiple functional entities, such as the Mobility Management Entity (MME), Serving Gateway (SGW), and Packet Data Network Gateway (PGW), which are responsible for managing network mobility, traffic routing, and packet forwarding. Additionally, the architecture includes the Multi-access Edge Computing (MEC) framework, which brings computation and storage capabilities closer to the network edge, allowing for low-latency and high-bandwidth services in VANETs (Ksentini & Frangoudis, 2020; Liyanage, Porambage, Ding, & Kalla, 2021). The integration of these components in the 5G architecture forms a robust foundation for efficient and reliable vehicular communication.

Furthermore, the 5G architecture leverages software-defined networking (SDN) and network function virtualization (NFV) principles to enhance network flexibility and agility in VANETs. SDN enables centralized control and programmability of network resources, allowing for dynamic management and allocation of bandwidth based on real-time traffic demands (Costanzo et al., 2018; Hakiri & Berthou, 2015). NFV virtualizes network functions, enabling the deployment and management of network services as software instances on general-purpose servers, thereby reducing infrastructure costs and enhancing scalability. These architectural concepts empower VANETs with the ability to adapt to varying network conditions, efficiently utilize resources, and provide a flexible and scalable platform for innovative vehicular applications.

Furthermore, the integration of 5G technology with Vehicular Ad-hoc Networks (VANETs) holds significant promise for enhancing the capabilities and performance of vehicular communication systems. 5G provides a robust and scalable infrastructure that can seamlessly integrate with VANETs, enabling efficient communication between vehicles, infrastructure, and the broader Internet. One key aspect of integrating 5G and VANETs is the convergence of cellular networks and vehicular networks. This convergence allows vehicles to directly connect to the cellular network infrastructure, providing a wider coverage area and leveraging the existing cellular infrastructure for seamless connectivity (Aljeri & Boukerche, 2020). By integrating 5G with VANETs, vehicles can benefit from a more extensive communication range, improved reliability, and enhanced service availability.

Moreover, the integration of 5G and

VANETs facilitates the realization of advanced cooperative and connected vehicular applications. The high data rates and low latency of 5G technology enable real-time and reliable exchange of information among vehicles and between vehicles and infrastructure. This enables the development of cooperative collision avoidance systems, where vehicles can exchange information about their positions, speeds, and intentions to proactively avoid potential collisions (Gharba et al., 2017). Furthermore, the integration of 5G and VANETs enables intelligent traffic management and optimization, as vehicles can share real-time traffic information and receive optimized routing and navigation instructions based on the current traffic conditions (Ni, Lin, Zhang, & Shen, 2016). Such integration enhances road safety, improves traffic flow, and reduces congestion.

To realize the integration of 5G and VANETs, various standardization efforts have been undertaken. For instance, the 3rd Generation Partnership Project (3GPP) has developed specific standards, such as the Cellular-Vehicle-to-Everything (C-V2X) communication standard, which defines the protocols and procedures for enabling direct communication between vehicles and cellular networks (Chen et al., 2023). These standards ensure interoperability and compatibility between 5G networks and VANETs, allowing for seamless integration and efficient communication. Standardization efforts play a vital role in driving the widespread adoption of 5G technology in VANETs and promoting the development of innovative vehicular applications.

Summarily, 5G is an evolved network characterised with high-speed data rates, low delay, latency and security. it is an access technology that is project to be capable of catering for various user applications requirements by leveraging on the existing long-term evolution (Hakiri & Berthou) network architecture in providing various services to users (Hussain, Hussain, & Zeadally, 2019; Shah, Ahmed, Imran, & Zeadally, 2018). In this regard, this technology will be harnessed towards addressing the limitation of the existing IEEE 802.11p standard, which guide the wireless communications of VANET safety and non-safety applications.

This discussion is built on the premise that the intended ITS safety application that will be communicated in the projected VANET implementation and deployment has been detected and process for routing. In this paper, the intended safety application is sensed road anomalies (potholes and bumps) (Bello-Salau et al., 2018), processed for routing via the optimal communication route (Bello-Salau et al., 2019). With emphasis, being on how to reduce end-end delay, latency, ensuring security of transmitted information in the network, providing mechanism for mitigating congestion as well as reducing communication load fairness towards the real-time implementation.

The evolved 5G network has the capability of harnessing some LTE resources, thereby enabling the possibility of interoperability of an unlicensed band, Wi-Fi and other systems such as Bluetooth and ZigBee. Hence, providing possibilities of seamless communication for VANET safety (communicating sensed road anomalies) and non-safety applications (infotainment). Furthermore, the possibility of Device to Device Communication (D2D) strategy incorporated in the 5G network will aid in the extension of coverage capacity as well as leveraging on cloud radio access networks for improving coordination among base stations as well as vehicles (Shah et al., 2018). In addition, there is the possibility of improved spectrum utilization via sharing of resources among primary, secondary and tertiary users (Noma-Osaghae, Misra, & Koyuncu, 2022).

Therefore, the 5G network coupled with the high-speed data rates of up to a maximum 20Gbps and low latency of about 1ms when used for real-time applications makes it a viable tool for the real-time implementation and deployment for VANET Table 2 present recent exploration and overview of application of 5G technology in VANET

4. Conclusion

This paper provided an overview of various generations of mobile wireless communication as well as emphasizing the developed 5G network as a feasible tool for real-time VANET implementation and deployment. Despite the aforementioned benefits of 5G, its features and architecture make it suited for establishing real-time exchange of safety information in either V2V or V2I scenarios. This study seeks to present our preliminary findings regarding the viability of using the 5G network for real-time VANET safety application implementation in Nigeria. Other difficulties are being investigated towards the realization of development and implementation, such as developing a radio propagation model for interference mitigation during deployment and dynamic spectrum allocation for transmitting the safety application in VANET

Table 2 present recent exploration and overview of application of 5G technology in VANET

Paper	Goal	Method	Achievement	Limitation	Technology used	Application Area in VANET	Prospect for real-time deployment
(Singh, Saluja, & Kumar, 2021)	Described vehicular communication network issues and how 5G radios can improve connected vehicle communications.	LIDAR sensors on automobiles generated data. V2I and V2V communications used a clustering VANET with mmWave.	Researchers showed that 3GPP Release 17 will improve connection and handoffs.	Release 16 V2I connectivity has low cellular capacity and frequent handoffs.	3GPP Release 16/17 & mmWave	Vehicular Communications, focusing on clustering, V2I, V2V, and dynamic beam alignment.	Yes, on real-time mmWave transmission.
(Zhang, Lagutkina, Akpinar, & Akpinar, 2021)	Machine learning-assisted big data processing in VANETs.	Berlin's highways, suburbs, and urban roads were employed in three traffic congestion scenarios. These characteristics may affect vehicle speed and distance.	The Urban scenario has 0.99 accuracy and the Highway scenario 0.945. The richer the dataset, the higher the precision and accuracy in NLoS circumstances, similar to machine learning-based systems.	VANETS' big data application was unsuitable for suburban and highway scenarios due to performance.	LTE	Security protocol-based application	Yes, real-time SVM for NLoS circumstances.
(S. Sharma, Agarwal, & Mohan, 2020)	The report highlights 5G-VANET security vulnerabilities for connected	A thorough literature review revealed 5G-VANET security	5G-VANET improves network search, interference, and noise.	5G-VANET's drawbacks include low processing power for data	5G	security	Probable

	automobiles.	issues in machine learning, IoT, AI, and cloud computing.		authentication, secrecy, and cryptography..			
(Tahir, Katz, & Rashid, 2021)	The article compared realistic VANET Wireless technologies. The Finnish meteorological Institute used it for road weather and vehicular network piloting.	Finnish test sites (Petäjämaa and Sod5g). Petäjämaa monitored weather, took research measures, and supported VANET protocols. Sod5g uses 2.3GHZ 5G-test network.	In settings with limited mobility and support, IEEE802.11p performs well, whereas 5G performs well in latency, cyclic prefix, and coverage.	5G V2X applications take longer to roll out than IEEE802.11-P	IEEE802.11P and cellular based-5G network	Vehicular location and road weather monitoring system.	Yes, Applied outdoor

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