6G and Autonomous Vehicles: The Future of Intelligent Transportation

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***Abstract*—Connected autonomous vehicles are expected to become increasingly widespread in the coming decade, fundamentally transforming the utilization of communication networks across urban environments. These vehicles are highly data-intensive and continuously exchange information with surrounding vehicles, infrastructure, and cloud services to enable perception, decision making, and control. This constant connectivity imposes unprecedented loads on existing communication technologies such as mobile 5G broadband networks, which must handle massive volumes of real-time data transmission with low latency and high reliability requirements. This study examines how large scale deployment of connected autonomous vehicles could affect the performance and scalability of 5G networks, with a focus on bandwidth utilization under dense vehicular connectivity. In addition, it explores the potential role of 5G and beyond communication technologies, which are expected to become the dominant network infrastructure during the era of widespread connected autonomous vehicle adoption, in addressing these challenges. The findings emphasize the need for adaptive network architectures to ensure seamless and reliable communication for future autonomous transportation systems.**

***Index Terms*—5G, 6G, Connected Autonomous Vehicles, IoT, Transportation, Digital Twin**

I. Introduction

Connected autonomous vehicles (CAV) are expected to be equipped with a wide range of sensors that enable vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication. It is estimated that CAVs will have more than 30 sensors including Camera, Light Detection and Ranging (LiDAR) and radar sensors [1], [2]. Traditional approaches to autonomous decision-making and traffic control rely heavily on edge computation, leveraging the processing power embedded within CAVs. However, such devices can only access data that is locally visible and available to individual CAVs, resulting in a limited understanding of the broader urban mobility network.

In this paper, we aim to investigate a centralized (or semi-centralized) computational environment capable of processing data collected from the CAV network to enable effective management and monitoring of urban mobility. In such an environment, and with the widespread adoption of CAVs, the data gathered from onboard sensors can be uploaded to cloud servers to support various mobility management tasks, including traffic monitoring and control, infrastructure maintenance, incident detection, and cooperative perception among vehicles. Furthermore, continuous data sharing would allow traffic authorities to construct real-time digital twins of the transportation network, enabling traffic flow optimization and coordinated decision-making between vehicles and infrastructure systems.

Although some sensors, such as radar, generate relatively small volumes of data, LiDAR and camera sensors can produce significantly higher data rates. For instance, a 1080p camera generates substantial amounts of data depending on whether the video is stored in raw or compressed form. Raw 1080p video, which contains unprocessed pixel data, can produce approximately 1 gigabyte (GB) per second, depending on the color format and frame rate. While this high data rate preserves maximum visual quality, it demands considerable bandwidth and storage capacity. In contrast, compressed video can significantly reduce the data volume to around 5 megabits per second for 1080p at 30 frames per second, or roughly 2 GB per hour. However, each CAV is expected to have at least 6 or more cameras onboard [3], and it is important to note that data compression introduces latency and computational overhead, which may not be suitable for real-time decision-making applications, particularly in the context of autonomous vehicles.

Kazhamiaka et al. [4] argue that each CAV can generate between 3 to 6 terabytes (TB) of data per hour, depending on the sensors installed. Such large volumes of data traffic can significantly overload the capacity of existing communication networks, such as fifth-generation (5G). In Australia, current 5G wireless technology networks provide an average download speed of approximately 200 Mbps and an average upload speed of about 17 Mbps [5], although actual performance may vary depending on the service provider and network conditions.

In mobile broadband, uplink capacity refers to the bandwidth and capacity of the network for uploading data, while downlink capacity refers to the bandwidth and capacity for downloading data from the network. At present, approximately 85% of total internet traffic consists of downloads, with the remainder being uploads. Consequently, network planners have primarily focused on providing higher-capacity and more reliable downlink connections, and existing network infrastructures are largely optimized to meet user download demands. However, with the emergence of CAVs, the proportion of upload traffic is expected to increase significantly, as CAVs continuously transmit large volumes of sensor and video data to cloud servers. This shift could place substantial strain on 5G networks, potentially leading to reduced reliability, increased latency, and congestion in densely connected vehicular environments.

As mentioned earlier, edge and fog computing architectures can help reduce the bandwidth demand associated with continuous cloud uploads by enabling preliminary data processing and feature extraction closer to CAVs. This distributed model reduces latency and network congestion while supporting time-sensitive decision making at the edge. However, uploading sensor data to cloud platforms remains essential for broader objectives such as large-scale traffic management and analytics, infrastructure planning, digital twin development, and collective learning across vehicle fleets.

In this paper, we adopt an agent-based modeling (ABM) approach to conduct an experimental evaluation within a study area located in the City of Melbourne in Australia. The study analyzes the number of vehicles passing across various Traffic Analysis Zones (TAZs) and examines the existing 5G (or 4G, the fourth generation of mobile communication technology, where 5G is not yet available or accessible) communication network's uplink performance across the same area. Subsequently, we investigate how the gradual conversion of conventional vehicles to CAVs would impact the current 5G communication network in terms of data load and bandwidth utilization. The findings of this research help estimate the additional network load imposed by CAV communication requirements and assess how this shift in demand could affect existing network users. These insights enable urban planners to prepare for the large-scale adoption of CAVs and to upgrade current communication infrastructures to effectively accommodate the data-intensive demands of autonomous mobility.

II. 5G AND BEYOND MOBILE NETWORK

Mobile communication has undergone remarkable technological advancements across successive generations. First-generation (1G) mobile communication systems were introduced in the 1970s and officially launched in 1979. These systems were based on analog technology, specifically using AMPS (Advanced Mobile Phone System). Major limitations of 1G included poor voice quality, low reliability, limited network capacity, and a lack of security features. With the launch of second-generation (2G) networks in 1991, wireless communication transitioned to fully digital systems for the first time. These networks were designed to support voice communication, (Short Message Service) SMS, fax, and MMS services. By using digital signals for voice, 2G networks; particularly those based on the Global System for Mobile Communications (GSM), also allowed data transmission alongside voice at speeds of 30–35 kbps.

The advent of third-generation (3G) networks, introduced in 1998 and launched in 2002, represented a major technological leap, providing mobile Internet access, higher data transmission speeds, and advanced services such as audio and video streaming. Additionally, 3G networks were enhanced to 3.5G through High-Speed Packet Access (HSPA), boosting data transmission rates up to 14 Mb/s. However, 3G required compatible devices, and the cost of upgrading as well as the higher power consumption posed significant challenges. The transition from 3G to 4G brought another major breakthrough, increasing data rates from approximately 100 Mb/s to 1 Gb/s [6]. The 4G network, launched in 2009, introduced LTE (Long Term Evolution) and offered significantly improved download speeds of up to 100 Mbps. It enhanced the user experience by supporting advanced services such as online gaming, video conferencing, and HD mobile television. The 4G LTE system design also reduced latency in high-speed data transmission, thereby improving overall network efficiency and speed. However, 4G LTE networks faced challenges, including complex hardware requirements, a large number of radio transmitters, and higher battery consumption.

5G, was launched in 2019 and offers significantly higher data rates, lower latency, and greater connectivity compared to previous generations. It supports simultaneous connections for a large number of devices, providing users with real-time experiences. 5G technology also facilitates the development of smaller Internet of Things (IoT) devices and has the potential to reduce manufacturing costs. Moreover, it enables new services that rely on ultra-reliable, low-latency connections, transforming various industries. The existing 5G infrastructure provides a robust solution to address the increasing demand for higher data rates and the rapid growth in the number of connected devices. It offers data speeds up to ten times faster than previous generations, operating primarily within the 1–10 gigahertz (GHz) range, compared to less than 100 megahertz (MHz) for 3G and 4G networks. Moreover, 5G technology spans a broad spectrum, from 700 MHz at the lower end to millimeter-wave frequencies reaching up to 90 GHz [7], [8].

The sixth-generation (6G) network, currently under development, will support advanced cellular data services and is expected to be significantly faster than 5G. Like previous generations, it will operate as a broadband cellular system, dividing geographical areas into smaller units called cells. 6G is anticipated to be more heterogeneous than earlier networks and will enable applications such as Virtual and Augmented Reality, the Internet of Skills, ubiquitous computing, and pervasive intelligence [9]. The evolution toward 6G networks promises to overcome the limitations of current communication infrastructures in supporting large-scale connectivity for CAVs. While 5G networks provide peak data rates of up to 20 Gbps and latency in the range of a few milliseconds, 6G is expected to deliver transmission speeds reaching 1 Tbps, approximately 50 times faster than 5G, while reducing latency to below 1 millisecond [10]. Operating across the 95 GHz to 3 terahertz (THz) frequency spectrum, 6G will offer massive bandwidth and enable data-intensive, delay-sensitive applications such as autonomous mobility. Furthermore, 6G will integrate self-optimizing, AI-driven network architectures designed to enhance energy efficiency, spectrum utilization, and communication reliability.

III. Literature Review

Autonomous vehicles' connectivity with their surroundings, known as V2X communication, coupled with their ability to operate without human intervention, can significantly transform urban mobility. CAVs can interact with their environment and consequently enable intelligent transportation systems (ITS). One of the key enablers for future CAV transportation ecosystems is the 5G communication network. Titus [11] discussed the impact of 5G on CAVs performance and operation. He argued that 5G's ultra low latency and massive connectivity will enable continuous data exchange between vehicles and infrastructure, supporting functions such as traffic flow optimization, platooning, and cooperative maneuvering. The paper highlighted that 5G can significantly reduce decision delays in perception and control modules, thereby enhancing traffic efficiency and safety in ITS. Hakak et al. [12] conducted a comprehensive survey highlighting how 5G's key features, including enhanced mobile broadband (eMBB), ultra reliable low latency communication (URLLC), and massive machine type communication (mMTC), can fulfill the communication requirements of CAVs. The study emphasized that 5G enables high speed, low latency V2X communication, which is essential for tasks such as collision avoidance, path planning, and coordinated decision making. However, they also noted that CAVs generate enormous volumes of high dimensional sensor data such as video, LiDAR, and radar, and processing and transmitting this data in real time through 5G networks can overload available bandwidth and computational resources. Kakkavas et al. [13] also highlighted the importance of transitioning 6G communication technologies to meet the scalability and latency requirements of large scale CAVs deployments. They investigated the role of 5G in CAVs through two key use cases, namely remote driving and quality of service (QoS) based automation level selection. Their findings demonstrated that while 5G can support high uplink throughput and millisecond level latency, current non standalone (NSA) architectures remain constrained by their reliance on 4G cores and therefore are potentially incapable of handling the massive data volume generated by CAVs.

Biswas and Wang [14] discussed the integration of 5G with other emerging technologies such as IoT and edge intelligence to support secure, decentralized, and intelligent CAV ecosystems. The study found that 5G enhances V2X communication reliability, while edge intelligence enables distributed decision making close to vehicles, thereby reducing latency. In addition, they emphasized that IoT connectivity serves as the foundation for real time data exchange among vehicles, infrastructure, and cloud platforms, enabling seamless interoperability across heterogeneous devices and facilitating large scale cooperative driving. Saleh et al. [15] considered another use case for 5G in the era of CAVs that can add additional load on the network. They focused on positioning and localization and evaluated 5G small cell densification for urban autonomous navigation. Using time of arrival trilateration, the authors found that an inter cell spacing of 160 m can achieve sub meter positioning accuracy in dense urban environments such as Manhattan. This finding demonstrates that 5G infrastructure can complement or even replace traditional GPS based localization, which often fails in multipath or obstructed urban settings. Zhou et al. [16] reviewed 5G-enabled cooperative localization approaches and argue that 5G can enhance localization accuracy to the centimeter level and enable real-time cooperative positioning through sensor fusion and machine learning-based filtering techniques. Tang et al. [17] explored how 5G communication can improve cooperative perception in autonomous driving. The study proposed a matching algorithm that leverages 5G's ultra reliable and low latency communication to synchronize sensing data and positional information among vehicles in real time. The results demonstrated that 5G connectivity enables consistent environmental awareness across vehicles, reducing perception uncertainty and enhancing the safety and coordination of cooperative autonomous driving.

Miao et al. [18] examined how the 5G network environment introduces both new opportunities and security challenges for CAVs. They argue that 5G's characteristics such as ultra low latency, massive connectivity, and high bandwidth are essential for real time V2X communication and decision making in CAVs. However, these same features also expand the system's attack surface, making secure authentication and data exchange critical. 6G networks are expected to address such security challenges through AI driven threat detection, quantum resistant encryption, and blockchain-based authentication, therefore paving the way toward a reliable and efficient CAV ecosystem.

The communication network architecture also plays a major role in addressing the connectivity needs of CAVs. Elbery et al. [19] analyzed the architectural differences between Dedicated Short-Range Communications (DSRC) and 5G for connected and autonomous vehicle communication. Their study evaluated how each technology supports safety critical V2X applications and cooperative driving scenarios. The findings revealed that while DSRC offers reliable short range communication, 5G provides greater scalability, lower latency, and broader coverage, making it more suitable for large scale vehicular networks. The authors concluded that future vehicular communication architectures should adopt hybrid designs that combine the stability of DSRC with the flexibility and capacity of 5G to ensure reliable and resilient CAV connectivity. This work has been done by [20] where they proposed a multi radio 5G framework that integrates DSRC, Long-Term Evolution Advanced (LTE-A), and millimeter-wave (mmWave) technologies under a unified control structure. This architecture enhances network flexibility and reliability by enabling seamless data exchange across different communication layers, thereby improving the responsiveness and stability of CAVs ecosystems.

Existing literature shows that 5G (and beyond) can play a significant role in the realization of an efficient and reliable CAV ecosystem. Current 5G communication networks can enable CAV connectivity, particularly when data processing is localized through edge or fog computing. However, when the high volume of environmental data collected by CAV sensors, including cameras, LiDAR, and radar, needs to be transferred to centralized cloud servers, the 5G communication network can become overloaded. Such network overload can not only undermine the efficiency of CAVs connectivity but also affect other network users who previously did not have to share network capacity with data intensive CAV operations. In this research, we aim to experimentally evaluate how large scale data transmission can overload existing 5G uplink channels and how emerging 6G technologies could potentially address these challenges.

IV. Methodology

The IoT interconnects billions of sensors and other devices (i.e., things) via the Internet, enabling novel services and products that are becoming increasingly important for industry, government, education and society in general [21]. In this paper we consider each of the CAVs as an IoT device connected to the Internet using the cloud environment to process the data. IoT has been widely adopted in various applications that require data-intensive analytics in a centralized architecture, such as smart agriculture, healthcare, manufacturing, and smart city applications [22]–[28].

To analyze the impact of CAVs on communication network utilization, we first investigated the traffic flow in a study area covering the Parkville, Carlton, West Melbourne, North Melbourne, and Central Business District (CBD) neighborhoods of the City of Melbourne. The dataset used in this research spans an area of approximately 6.5 km^2 and includes around 120,000 trips across a 24-hour simulation period. This dataset represents real-world spatiotemporal traffic flow patterns across the study area, based on data derived from the Australian Bureau of Statistics, the City of Melbourne, and the Victorian Integrated Survey of Travel and Activity (VISTA) [29].

To identify the existing traffic flow, an agent-based modeling (ABM) approach was employed. ABM enables the microscopic simulation of individual vehicle behavior and thus allows estimation of vehicle density across the network at any given time. Such an approach helps to estimate the expected load imposed by CAVs on the 5G infrastructure across different zones within the network. One of the leading ABM platforms is the Simulation of Urban Mobility (SUMO), an open-source application that efficiently simulates traffic flow and determines road density [30], [31]. In this research we used SUMO to identify the traffic flow across zones of 200 by 200 meters in the study area at various times of the day. The road network and the corresponding divided zones are illustrated in Figure 1.

In the next step, to identify the existing 5G uplink coverage, a field experiment was conducted. Using a mobile measurement application, a vehicle was driven across different zones within the study area, where the 5G uplink signal strength was recorded in real time. After identifying the traffic flow and 5G uplink coverage level across the study area, we developed

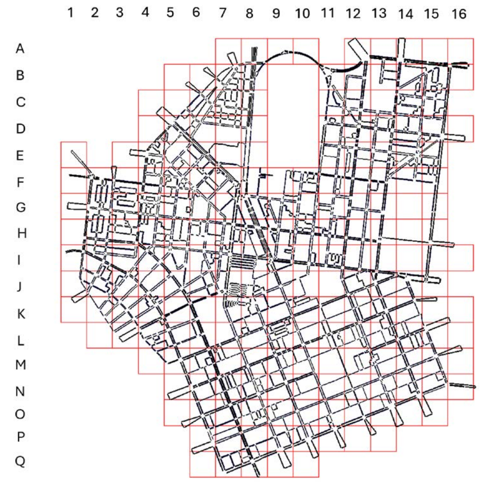

Fig. 1. The road network of the study area along with the corresponding 200 m × 200 m zones.

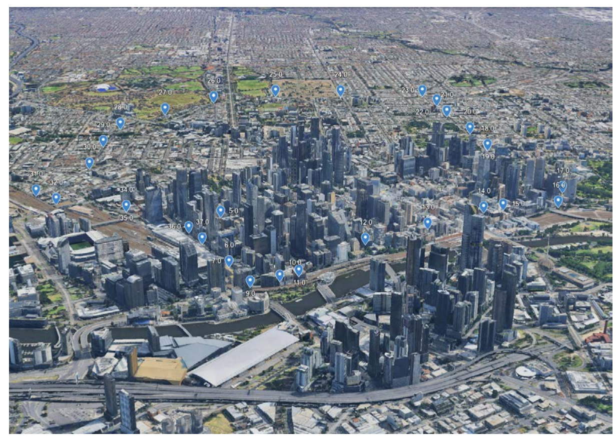

Fig. 2. Mobile broadband network uplink testing locations across Melbourne (used Google Earth (http://earth.google.com) for visualisation.

TABLE I
OBSERVED DOWNLOAD AND UPLOAD SPEEDS ACROSS MELBOURNE

Location	Network	Download Speed (Mbps)	Download Size (Bytes)	Upload Speed (Mbps)	Upload Size (Bytes)	Latency (ms)	Server
1	5G	320.116448	342734464	56.541856	75281536	10	Melbourne
2	5G	372.747184	605485824	93.081512	121803623	9	East Burwood
3	5G	342.146448	433114240	147.254168	121640654	10	East Burwood
4	5G	780.644520	1171835335	146.061688	121981390	8	East Burwood
5	5G	558.944920	558846336	84.865048	102508750	8	East Burwood
6	LTE	58.776128	96363520	42.244816	31485696	13	Melbourne
7	5G	203.183816	302033280	23.737712	25490432	9	Melbourne
8	5G	657.816264	851692670	51.743856	57612544	9	East Burwood
9	LTE	135.250800	224516608	30.677080	27900928	18	Melbourne
10	LTE	65.373272	94683154	19.438848	21566336	16	Melbourne
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
36	5G	272.186544	270481267	78.216656	112267239	15	Melbourne
37	5G	427.441320	624133247	53.921000	66988416	20	Melbourne
Max	–	1657.03 (Loc 18)	–	175.96 (Loc 19)	–	22 (Loc 17)	–
Min	–	27.25 (Loc 16)	–	3.36 (Loc 31)	–	8 (Loc 4, 27, 30)	–
Avg	–	531.6	–	70.8	–	12.1	–

a scenario to analyze how converting 20% of the existing vehicles to CAVs would impact the uplink conditions. In this scenario, we assumed that each CAV continuously uploads its camera data to the cloud in real time.

$$\text{Throughput (bps)} = \frac{8 \times \Delta\text{Bytes}}{\Delta t} \tag{1}$$

where ΔBytes is the transferred bytes between two devices, and Δt is the time interval taken to transfer the data (in seconds).

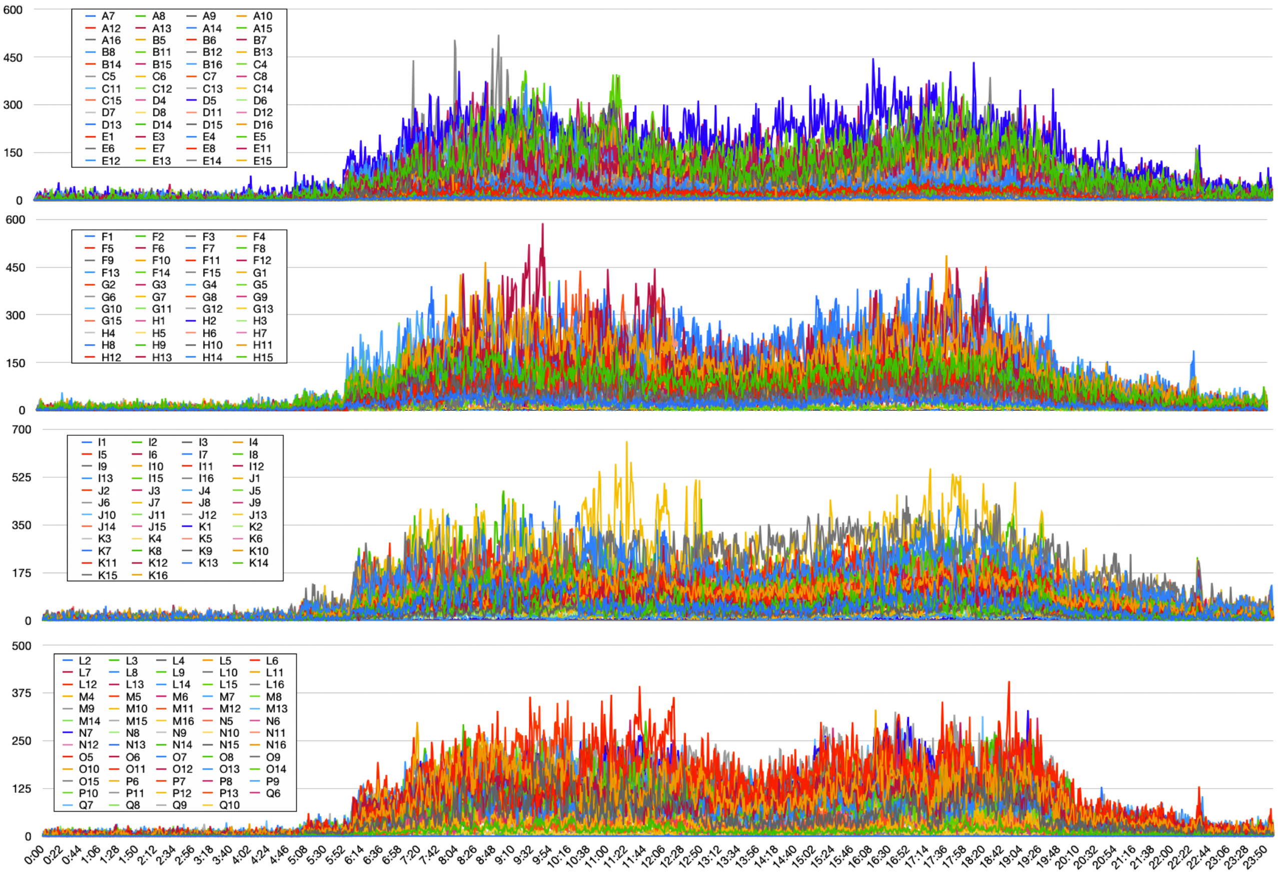

Fig. 3. Number of vehicles travelling in each segment, every minute over a 24-hour period.

For direction-specific measurements:

$$\text{Uplink (bps)} = \frac{8 \times \Delta\text{Bytes from CAVs}}{\Delta t}, \quad (2)$$

$$\text{Downlink (bps)} = \frac{8 \times \Delta\text{Bytes to CAVs}}{\Delta t}. \quad (3)$$

V. Results

Table I presents the measured downlink and uplink performance from various observation points across Melbourne, obtained using Speedtest by Ookla[1]. The table summarizes the observed download and upload speeds as well as the corresponding server locations for each point of interest illustrated in Figure 2. All measurements were conducted using Melbourne-based servers to ensure standardized and comparable network performance results across different sites.

In order for a mobile broadband network (i.e., 6G) to accommodate the described scenario, it must provide a minimum uplink capacity of approximately 30 Mb/s per vehicle transmitting compressed video streams, as summarized in Table II. Consequently, a network segment serving around 700 connected vehicles would require a total uplink capacity of roughly 21 Gb/s to ensure seamless data transmission. This estimation assumes that the video streams are compressed before transmission, which imposes additional computational demands on the CAVs for real-time video encoding. Furthermore, the calculation only accounts for video data, excluding other high-bandwidth sensory inputs such as LiDAR, radar, and ultrasonic sensors. Vehicles equipped with multiple cameras, such as trucks or heavy vehicles with more than six cameras, would require substantially higher uplink capacity, further increasing the overall network load. It is important to note that this estimate represents a baseline for normal urban driving conditions and does not account for potential increases in vehicle density, traffic congestion, or special events, all of which could further elevate bandwidth demand.

[1]Speedtest (https://www.speedtest.net/) by Ookla is a widely used network diagnostic tool that measures internet connection parameters such as download speed, upload speed, latency, and jitter.

TABLE II
Bandwidth needed per CAV (6 Cameras, no overhead included)

Video Type	Per Camera Rate	Per Car Total Bandwidth
Compressed 1080p @30 fps	5 Mb/s	30 Mb/s
Raw 1080p (1 GB/s $\approx$ 8 Gb/s)	8 Gb/s	48 Gb/s
Raw 1080p ($\approx$500 GB/hour $\approx$ 1.11 Gb/s)	1.11 Gb/s	6.67 Gb/s

It is worth mentioning that the growing demand for higher bandwidth has driven the need for improved connectivity, as evidenced by the exponential increase in global mobile network traffic in recent years. According to [32], global monthly mobile data traffic in 2015 was approximately 3.7 Exabytes, around 1.4 TB per second. By 2025, estimated this figure to have risen to around 180 Exabytes (EB) per month, or approximately 69 TB per second [33]. This is nearly 50-fold increase over a decade indicating the massive surge in data demand and the corresponding necessity for mobile networks to expand capacity. As data-intensive applications like CAVs proliferate, the transition from 5G to 6G will be crucial to sustaining network performance, reliability, and scalability.

VI. Conclusion

This paper discussed how the large-scale deployment of connected autonomous vehicles will place significant demands on existing mobile broadband networks, particularly regarding uplink capacity, latency, and reliability. The continuous exchange of high-volume sensor and video data can quickly exceed the capabilities of current mobile infrastructures. To meet these requirements, future communication technologies such as 6G will be essential, offering higher data rates, sub-millisecond latency, and intelligent, adaptive network management.

References

[1] F. Götz. (2021, Jan.) The data deluge: What do we do with the data generated by avs? [Online]. Available: https://blogs.sw.siemens.com/polarion/the-data-deluge-what-do-we-do-with-the-data-generated-by-avs/. Accessed: 4 Nov. 2025.

[2] M. N. Ahangar, Q. Z. Ahmed, F. A. Khan, and M. Hafeez, "A survey of autonomous vehicles: Enabling communication technologies and challenges," *Sensors*, vol. 21, no. 3, p. 706, 2021.

[3] Samsung Semiconductor. (2023, Mar.) Autonomous driving and the modern data center. [Online]. Available: https://semiconductor.samsung.com/news-events/tech-blog/autonomous-driving-and-the-modern-data-center/. Accessed: 4 Nov. 2025.

[4] F. Kazhamiaka, M. Zaharia, and P. Bailis, "Challenges and opportunities for autonomous vehicle query systems," in *Proc. Conf. on Innovative Data Systems Research (CIDR)*, 2021.

[5] OpenSignal, "Australia – mobile network experience report (october 2024)," Oct. 2024, [Online]. Available: https://www.opensignal.com/reports/2024/10/australia/mobile-network-experience. Accessed: 2 Nov. 2025.

[6] M. Kiruthiga Devi and M. Padma Priya, "Evolution of next generation networks and its contribution towards industry 5.0," *Resource management in advanced wireless networks*, pp. 45–80, 2025.

[7] Y. Wang, J. Li, L. Huang, Y. Jing, A. Georgakopoulos, and P. Demestichas, "5g mobile: Spectrum broadening to higher-frequency bands to support high data rates," *IEEE Vehicular technology magazine*, vol. 9, no. 3, pp. 39–46, 2014.

[8] N. Foroughimehr, "Millimetre wave absorption by the cornea," Ph.D. dissertation, Swinburne, 2024.

[9] Ericsson. (2024) 6g – follow the journey to the next-generation networks. [Online]. Available: https://www.ericsson.com/en/6g. Accessed: 2 Nov. 2025.

[10] J. Crawford. (2025, Oct.) 6g vs 5g: Understanding the next leap in mobile connectivity. [Online]. Available: https://techresearchonline.com/blog/6g-vs-5g-understanding-the-next-leap-in-mobile-connectivity/. Accessed: 2 Nov. 2025.

[11] N. E. Titus, "The impact of 5g technology on autonomous vehicles," *Research Invention Journal of Biological and Applied Sciences*, vol. 3, no. 2, pp. 36–39, 2024.

[12] S. Hakak, T. R. Gadekallu, P. K. R. Maddikunta, S. P. Ramu, C. D. Alwis, and M. Liyanage, "Autonomous vehicles in 5g and beyond: A survey," *Vehicular Communications*, vol. 39, p. 100551, 2023.

[13] G. Kakkavas, M. Diamanti, V. Karyotis, K. N. Nyarko, M. Gabriel, A. Zafeiropoulos, S. Papavassiliou, and K. Moessner, "5g perspective of connected autonomous vehicles: Current landscape and challenges toward 6g," *IEEE Wireless Communications*, vol. 31, no. 4, pp. 299–306, 2024.

[14] A. Biswas and H.-C. Wang, "Autonomous vehicles enabled by the integration of iot, edge intelligence, 5g, and blockchain," *Sensors*, vol. 23, no. 4, p. 1963, 2023.

[15] S. Saleh, A. S. El-Wakeel, S. Sorour, and A. Noureldin, "Evaluation of 5g cell densification for autonomous vehicles positioning in urban settings," in *Proc. Int. Conf. on Communications, Signal Processing, and their Applications (ICCSPA)*, 2021, pp. 1–6.

[16] B. Zhou, Z. Liu, and H. Su, "5g networks enabling cooperative autonomous vehicle localization: A survey," *IEEE Transactions on Intelligent Transportation Systems*, vol. 25, no. 11, pp. 15 291–15 313, 2024.

[17] Z. Tang, J. He, K. Yang, and H.-H. Chen, "Matching 5g connected vehicles to sensed vehicles for safe cooperative autonomous driving," *IEEE Network*, vol. 38, no. 3, pp. 227–235, 2023.

[18] J. Miao, Z. Wang, X. Ning, N. Xiao, W. Cai, and R. Liu, "Practical and secure multifactor authentication protocol for autonomous vehicles in 5g," *Software: Practice and Experience*, vol. 54, no. 10, pp. 1852–1869, 2024.

[19] A. Elbery, S. Sorour, H. Hassanein, A. B. Sediq, and H. Abou-Zeid, "To dsrc or 5g? a safety analysis for connected and autonomous vehicles," in *Proc. IEEE Global Communications Conf. (GLOBECOM)*, 2021, pp. 1–6.

[20] I. Mavromatis, A. Tassi, G. Rigazzi, R. J. Piechocki, and A. Nix, "Multi-radio 5g architecture for connected and autonomous vehicles: Application and design insights," *arXiv preprint arXiv:1801.09510*, 2018.

[21] A. Yavari, "Internet of things data contextualisation for scalable information processing, security, and privacy," Ph.D. dissertation, RMIT University, 2019.

[22] A. Yavari, H. Bagha, H. Korala, I. Mirza, H. Dia, P. Scifleet, J. Sargent, and M. Shafiei, "Parcemon: Iot platform for real-time parcel level last-mile delivery greenhouse gas emissions reporting and management," *Sensors*, vol. 22, no. 19, p. 7380, 2022.

[23] A. Yavari, I. B. Mirza, H. Bagha, H. Korala, H. Dia, P. Scifleet, J. Sargent, C. Tjung, and M. Shafiei, "Artemon: Artificial intelligence and internet of things powered greenhouse gas sensing for real-time emissions monitoring," *Sensors*, vol. 23, no. 18, p. 7971, 2023.

[24] A. Yavari, H. Korala, D. Georgakopoulos, J. Kua, and H. Bagha, "Sazgar iot: A device-centric iot framework and approximation technique for efficient and scalable iot data processing," *Sensors*, vol. 23, no. 11, p. 5211, 2023.

[25] A. Yavari, D. Georgakopoulos, H. Agrawal, H. Korala, P. P. Jayaraman, and J. K. Milovac, "Internet of things milk spectrum profiling for industry 4.0 dairy and milk manufacturing," in *2020 International Conference on Information Networking (ICOIN)*. IEEE, 2020, pp. 342–347.

[26] H. Bagha, A. Yavari, and D. Georgakopoulos, "Iot-based plant health analysis using optical sensors in precision agriculture," in *2021 Digital Image Computing: Techniques and Applications (DICTA)*. IEEE, 2021, pp. 01–08.

[27] ——, "Hybrid sensing platform for iot-based precision agriculture," *Future Internet*, vol. 14, no. 8, p. 233, 2022.

[28] A. Yavari, P. P. Jayaraman, D. Georgakopoulos, and S. Nepal, "Contaas: An approach to internet-scale contextualisation for developing efficient internet of things applications," 2017.

[29] H. Bagha, F. M. Choudhury, and S. Winter, "Melbourne's parking dynamics and traffic flow: A dataset for microscopic agent-based simulation," Preprint, 2025, [Online]. Available: https://doi.org/10.21203/rs.3.rs-7285789/v1.

[30] P. A. Lopez, M. Behrisch, L. Bieker-Walz, J. Erdmann, Y.-P. Flötteröd, R. Hilbrich, L. Lücken, J. Rummel, P. Wagner, and E. Wiessner, "Microscopic traffic simulation using sumo," in *Proc. 21st IEEE Int. Conf. on Intelligent Transportation Systems*, 2018, [Online]. Available: https://elib.dlr.de/124092/.

[31] H. Bagha, F. M. Choudhury, and S. Winter, "Autonomous vehicles empty cruising impact on parking dynamics," in *Proc. 16th ACM SIGSPATIAL Int. Workshop on Computational Transportation Science*, 2023, pp. 52–61.

[32] C. Systems, "Visual networking index: Global mobile data traffic forecast 2015–2020," 2015, [Online]. Available: https://usermanual.wiki/m/58df72a70db22a2f0b0f2ca942fcbc9158378e1902254e891b831b36863fee96.pdf.

[33] Ericsson, "Mobility report, june 2025," Jun. 2025, [Online]. Available: https://www.ericsson.com/en/reports-and-papers/mobility-report/dataforecasts/mobile-traffic-update. Accessed: 2 Nov. 2025.