Top Level Newsletter: Connected Vehicle

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Vol 48.0: Introduces the concept of the “Metaverse” as applicable to connected and automated vehicles. The metaverse aims to blur the boundary between the physical world and digital content. To achieve this goal, the metaverse relies heavily on extended reality (XR), the Internet of Things, and communication technologies.

General Notes

This series of newsletters is intended to provide the IEEE member with a top level briefing of the many different subjects relevant to the research, development and innovation of the connected vehicle.

The objective is to provide a platform for fast learning and quick overview so that the reader may be guided to the next levels of detail and gain insight into correlations between the entries to enable growth of the technology. Intended audiences are those that desire a quick introduction to the subject and who may wish to take it further and deepen their knowledge. This includes those in industry, academia or government and the public at large. Descriptions will include a range of flavors from technical detail to broad industry and administrative issues. A (soft) limit of 300 to 600 words is usually set for each entry, but not rigorously exercised.

As descriptions are not exhaustive, hyperlinks are occasionally provided to give the reader a first means of delving into the next level of detail. The reader is encouraged to develop a first level understanding of the topic in view. The emphasis is on brief, clear and contained text. There will be no diagrams in order to keep the publication concise and podcast - friendly. Related topics in the case of Connected Vehicle technology, such as 5G cellular and the Internet of Things will be included. The terms Connected Vehicle and Automated Driving will be used inter-changeably. Articles from other published sources than IEEE that add to the information value will occasionally be included.

This newsletter forms part of the regional Advanced Technology Initiative (ATI) of which connected vehicles form a constituent part. Technical articles solely from IEEE journals/magazines are referred to by their Digital Object Identifier (DOI) or corresponding https link. The link for each article is provided. Those readers who wish to delve further to the complete paper and have access to IEEE Explore (www.ieeexplore.ieee.org) may download complete articles of interest. Those who subscribe to the relevant IEEE society and receive the journal may already have physical or electronic copies. In case of difficulty please contact the editor at kaydas@mac.com. The objective is to provide top level guidance on the subject of interest. As this is a collection of summaries of already published articles and serves to further widen audiences for the benefit of each publication, no copyright issues are foreseen.

Readers are encouraged to develop their own onward sources of information, discover and draw inferences, join the dots, and further develop the technology. Entries in the newsletter are normally

either editorials or summaries or abstracts of articles. Where a deepening of knowledge is desired, reading the full article is recommended.

Articles A1 to A5 discuss the concept of the "Metaverse" as applicable to connected and automated vehicles.
(Published in: IEEE Vehicular Technology Magazine, December 2023, Volume 18, no 4, Section: Guest Editorial, page(s): 19 to 21) by Pengyuan Zhou et al)

The metaverse aims to blur the boundary between the physical world and digital content. To achieve this goal, **the metaverse relies heavily on extended reality (XR), the Internet of Things, and communication technologies**. Concurrently, connected vehicles and intelligent transportation systems (ITSs) are envisioned as the future paradigm of driving and becoming reality thanks to increasingly powerful onboard vehicular processing capacity and advanced vehicle-to-everything networking technologies.

Observing a large number of overlapping enabling technologies, we expect a convergence between the metaverse and connected vehicles that would eventually benefit both fields. Connected and automated vehicles are mobile platforms equipped with significant sensing and computing capabilities that can broaden metaverse use cases. On the other hand, immersive metaverse applications can improve the driver's experience as well as passengers' in-vehicle entertainment and passenger. Richer information collected and created from the metaverse has created new challenges, such as information filtering, object positioning, vision transformation, and so on. These challenges are often computation intensive and bring considerable additional delay to connected and automated vehicles, which demand near-real-time reactions. Researchers have thus proposed edge and cloud computing, machine learning, and computer vision solutions to tackle such challenges.

This special issue of *IEEE Vehicular Technology Magazine* aims to present works that apply different techniques to improve the driving experience of automatic/connected vehicle services in terms of facing the coming metaverse era.

Article [A1] highlights the potential of connected automated vehicle (CAV)-assisted mobile crowdsensing in shaping the metaverse. By leveraging edge intelligence, the proposed framework offers enhanced data quality and transmission efficiency. The authors point out that the transition to 6G demands content-aware communication that aligning with the metaverse's nuances. However, the acceleration of mobile crowdsensing in the metaverse raises concerns about data privacy and security, emphasizing the importance of robust anomaly detection and security measures.

Article [A2] delves into the integration of pretrained foundation models with edge intelligence for the metaverse. The authors present a model caching and inference framework optimized for mobile edge networks. A novel least context algorithm is introduced, leveraging a proposed metric, namely, age of

context, to enhance mobile artificial intelligence (AI) service accuracy. This research offers a glimpse into the future interplay between edge AI and the metaverse.

Article [A3] highlights a multifaceted approach to enhance vehicular automation by harnessing the power of digital twin networks (DTNs), with a keen focus on perception, planning, and control. By integrating diverse learning methodologies, the authors set a new benchmark for traffic management and vehicular safety. This research not only underscores the future of sustainable transportation but also underscores the synergy between CAVs and DTNs for optimized driving experiences.

Article [A4] introduces a DT- and AI-empowered panoramic video streaming scheme for XR-assisted connected AVs that reduces transmission latency and intelligently responds to user requirements. Specifically, the authors proposed a DT-enabled distributed XR service management framework that provides low latency and smooth XR services across different domains in the vehicular metaverse. In addition, they presented a case study on XR streaming-based virtualized resource allocation and a novel deep reinforcement learning-based method that minimizes transmission latency. Quantitative experimental results demonstrated that the positive role of AI in connected AV networks can be enhanced by DTs. Finally, open issues and potential research directions for the XR-assisted vehicular metaverse were discussed.

Article [A5] discusses the challenges and requirements of edge caching for metaverse CAVs (meta-CAVs) and ITSs (meta-ITSs). The specific requirements of vehicular applications translate to specific needs for dynamic, secure, and intelligent caching. To address these challenges, the authors propose using AI-assisted content caching for meta-CAVs and meta-ITSs. They survey the techniques commonly found in the literature that can improve caching performance. These techniques, such as long short-term memory, reinforcement learning, and federated learning, allow for predicting the popular content, deciding caching location based on spatial and temporal data, and devising dynamic and secure caching policies. A case study is presented, showcasing the advantages of using multiagent federated reinforcement learning in edge caching for meta-CAVs and meta-ITSs.
In conclusion, the articles featured in this special issue shed light on the intricate interplay and potential synergies among the metvaverse, connected vehicles, and intelligent transportation systems, presenting both the inherent challenges and exciting opportunities at this crossroad.

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