Top Level Newsletter: Connected Vehicle

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Vol 38: This issue includes two 6G related articles of general interest:
1. Positioning and sensing in 6G: challenges
2. 6G Wireless Systems: Vision, Requirements, Challenges, Insights, and Opportunities

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.

1. Positioning and Sensing in 6G: Gaps, Challenges, and Opportunities (Ali Behravan et al)

Published in IEEE Vehicular Technology Magazine (Volume: 18, Issue: 1, March 2023)

Abstract: Among the key differentiators of 6G compared to 5G will be the increased emphasis on radio-based positioning and sensing. These will be utilized not only for conventional location-aware services and for enhancing communication performance but also to support new use case families with extreme performance requirements. This article presents a unified vision from stakeholders across the value chain in terms of both opportunities and challenges for 6G positioning and sensing as well as use cases, performance requirements, and gap analysis. Combined, this motivates the technical advances in 6G and guides system design.

Introduction and Motivation: Large bandwidth and massive arrays employed in the emerging wireless communication networks along with network densification enable additional services, such as radio-based positioning and sensing, which are beyond data transmission, with minimal cost by using the same infrastructure and spectrum. The positioning of active communication devices has become an integral part of the recent and ongoing standards, such as in the 3rd Generation Partnership Project (3GPP) and IEEE. Position accuracy requirements have also been increasing from tens of meters, as mandated by regulatory agencies, to the decimeter level for future use cases, such as indoor factories, unmanned aerial vehicles (UAVs), vehicle-to-everything applications, and so on .
On the other hand, the positioning of passive targets, i.e., the sensing of objects that do not transmit (only reflect/scatter) radio signals, has not yet been included in 3GPP standards. Radio-based sensing covers a broad class of applications, such as radar-like range and Doppler estimation, radio imaging, environmental monitoring, and material identification. Hence, there is no single performance indicator and requirement that can be defined for a sensing service. As discussed in this article, different use case families have different and new key performance indicators (KPIs) and require varying levels of sensing accuracy.

In addition to supporting new use cases, another important motivation of integrated positioning and sensing in a mobile communication network is that information about the environment can also be used to improve the communication performance. As an example, a digital twin of the environment that is created by sensing can be used to aid communication functions, such as radio resource management, beamforming, mobility management, minimization of driving tests, and so on.

In a recent 6G localization and sensing study conducted by the authors for the European Union Hexa-X project, the potential of sensing with radio waves to enable new use cases and applications as well as improve communication aspects of 6G systems was investigated. In this article, we highlight the key findings from that study, providing a detailed gap analysis for positioning and sensing use cases in 6G as well as envisioned 6G radio enablers and challenges, which serve to motivate continued research in this area. (451 words).

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2. 6G Wireless Systems: Vision, Requirements, Challenges, Insights, and Opportunities (H.Tatari et al)

Proceedings of the IEEE Year: July 2021, Volume: 109, Issue: 7 *(repeated from newsletter v20)*

Abstract: Mobile communications have been undergoing a generational change every ten years or so. However, the time difference between the so-called “G’s” is also decreasing. While fifth-generation (5G)

systems are becoming a commercial reality, there is already significant interest in systems beyond 5G, which we refer to as the sixth generation (6G) of wireless systems. In contrast to the already published papers on the topic, we take a top-down approach to 6G. More precisely, we present a holistic discussion of 6G systems beginning with lifestyle and societal changes driving the need for next-generation networks. This is followed by a discussion into the technical requirements needed to enable 6G applications, based on which we dissect key challenges and possibilities for practically realizable system solutions across all layers of the Open Systems Interconnection stack (i.e., from applications to the physical layer). Since many of the 6G applications will need access to an order-of-magnitude more spectrum, utilization of frequencies between 100 GHz and 1 THz becomes of paramount importance.

As such, the 6G ecosystem will feature a diverse range of frequency bands, ranging from below 6 GHz up to 1 THz. We comprehensively characterize the limitations that must be overcome to realize working systems in these bands and provide a unique perspective on the physical and higher layer challenges relating to the design of next-generation core networks, new modulation and coding methods, novel multiple-access techniques, antenna arrays, wave propagation, radio frequency transceiver design, and real-time signal processing. We rigorously discuss the fundamental changes required in the core networks of the future, such as the redesign or significant reduction of the transport architecture that serves as a major source of latency for time-sensitive applications. This is in sharp contrast to the present hierarchical network architectures that are not suitable to realize many of the anticipated 6G services. While evaluating the strengths and weaknesses of key candidate 6G technologies, we differentiate what may be practically achievable over the next decade, relative to what is possible in theory. Keeping this in mind, we present concrete research challenges for each of the discussed system aspects, providing inspiration for what follows.

Excerpt: ...Starting from the technical capabilities needed to support the 6G applications, we discuss the new spectrum bands that present an opportunity for 6G systems. While a lot of bandwidth is available in these new bands, how to utilize it effectively remains a key challenge. For instance, frequency bands at 100 GHz and above present formidable challenges in the development of hardware and surrounding system components, limiting the application areas where all of the spectra can be utilized. We discuss the deployment scenarios where 6G systems will most likely be used, as well as the technical challenges that must be overcome to realize the development of such systems. *This includes new modulation methods, waveforms and coding techniques, multiple-access techniques, antenna arrays, RF transceivers, real- time signal processing, and wave propagation aspects.* We note that these are all substantial challenges in the way of systems that can be realized and deployed. Nevertheless, addressing these challenges at the PHY layer is only a part of resolving the potential issues. Improvements in the network architecture are equally important. The present *core network* design is influenced—and encumbered—by historical legacies. For example, the submillisecond latency required by many of the new services cannot be handled by the present transport network architecture. To this end, flattening or significant reduction of the architecture is necessary to comply with 6G use case requirements. The basic fabric of mobile Internet—the Transmission Control Protocol/Internet Protocol *(TCP/IP)—is not able to guarantee quality- of-service (QoS) needed for many 6G applications, as it is in effect based on best effort services*. These and many other aspects require a complete rethink of the network design, where the present transport networks will begin to disappear and be virtualized over existing fiber, as well as be isolated using modern software-defined networking (SDN), and virtualization methodologies. At the same time, the core network functions will be packaged into a microservice architecture and enabled on the fly. (673 words)

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