

5G FOR VERTICALS: FROM THEORY TO PRACTICE AND BEYOND



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The 3rd Generation Partnership Project (3GPP) completed its Fifth Generation (5G) New Radio (NR) Release 16 and approved the OpenAPI specification in July 2020. The 5G NR technology is expected to support numerous future applications in one or a mix of three usage scenarios: enhanced Mobile Broadband (eMBB), massive Machine Type Communications (mMTC), and Ultra Reliable Low Latency Communications (URLLC). However, 5G is still lacking its killer applications. Which vertical applications will fully utilize the capabilities offered by 5G that cannot be provided by 4G? What is the unprecedented performance gain these applications can achieve with 5G in practice? To answer these and similar questions, the 3GPP started to focus on specific applications and field performance evaluations in Release 17, which includes communication service requirements for critical medical applications, enhancements for unmanned aerial vehicles, enhancements for cyber-physical control applications in vertical domains, enhanced relays for energy efficiency and extensive coverage.

This Feature Topic (FT) aims to shed some light on the novel applications that can be realized by exploiting the features provided by 5G, the performance improvement of the current applications, and the limitations of 5G on meeting the requirements of future applications. This will also help in identifying the roadmap for the development of the sixth generation (6G) mobile network.

We thank all the contributors for their interest in this FT. A large number of papers were received and underwent a rigorous review process. Five papers were accepted in this Feature Topic. They cover a wide range of topics on how technologies of 5G and beyond can support future vertical applications.

The article by Nakimuli *et al.* shows how 5G can support a novel operation approach for automated guided vehicles (AGVs) in an Industry 4.0 environment. AGVs are unmanned transport vehicles used to replace manned industrial trucks and conveyors. Typically, due to strict latency requirements, they are controlled by an onboard programmable logic controller (PLC) for guidance. However, when the AGV movements need to be coordinated, the local control is challenged. The authors propose a remote control architecture, where the PLC is divided into a local responder PLC and a remote initiator [SW1] PLC supported by the 5G network.

The article by Fodor *et al.* focuses on the novel 5G's

capability that shall be provided to support fast, reliable, and non-limiting connectivity for transport applications. The article first summarizes the technical foundations of 5G NR which can fulfil the basic requirements imposed by emerging use cases in the transport sector. Then, it reviews special connectivity requirements of transport use cases and technology enablers, such as positioning techniques, reference signal design and multi-transmission and reception point (TRP) selection, and novel QoS-prediction techniques.

The article by Shicong Liu *et al.* deals with the timely topic of integrating low Earth orbit (LEO) satellites with the terrestrial cellular networks. This article first introduces the roadmap of LEO SatCons development, after which the opportunities for employing LEO SatCons are discussed. In particular, the article discusses the key performance indicators (KPIs) of space-based wireless networks to highlight which verticals could benefit from them. Then, it discusses the potential impact of LEO SatCons on typical use cases such as Industrial IoT, agriculture, eHealth, energy, intelligent vehicular networks, remote interactions, finance, and smart cities. Finally, it introduces some key technologies that support the desired vertical applications.

The article by Bartoletti *et al.* proposes a full-stack architecture, integrated in the 5G network infrastructure, providing location-based analytics, that are conceived as location data analytics functions (LDAFs). Such functions are classified as people-centric and network-centric. People-centric analytics provide insights and empower domains such as smart cities and transportation. Network-centric analytics enable advanced network management.

The article by Alamany *et al.* proposes an approach to extend Network Function Virtualization (NFV) Management and Orchestration (MANO) to deploy network slices with the required QoS to fulfil the vertical/application domain KPIs. Moreover, it includes runtime KPI monitoring and different ways of providing QoS guarantees from the network slice and its NSs to the final deployed connectivity and computing services.

The guest editors wish to support and sympathize with the nations that are being severely impacted by the COVID-19 pandemic. We would like to thank the medical community for their sacrifice and tireless efforts, and remember the many lives lost to the pandemic.

Finally, we hope that these articles will help the readers in opening new research areas and highlight the benefits of 5G and beyond 5G technologies for various vertical applications.

BIOGRAPHIES

LUCA VALCARENCHI [M '99, SM'14] holds a Laurea degree in electronics engineering (1997) from the Politecnico di Torino, Italy, a M.S. in electrical engineering (1999), and a Ph.D. in electrical engineering-telecommunications (2001) both from The University of Texas at Dallas (UTD). He has been an associate professor at the Scuola Superiore Sant'Anna of Pisa, Italy since 2014. He has published more than 200 papers in international journals and conference proceedings. He has actively participated in the TPC of several IEEE conferences, such as Globecom and ICC. He received a Fulbright Research Scholar Fellowship in 2009 and a JSPS "Invitation Fellowship Program for Research in Japan (Long Term)" in 2013. His main research interests are optical network design, analysis, and optimization; communication network reliability; energy efficiency in communications networks; fixed and mobile network integration; and 5G transport. He is an IEEE Senior Member and *IEEE Communications Magazine* technical editor.

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