5G in industrial application (status: Sept. 28th 2023)

5G, the fifth generation of mobile networks is dealt as an enabler for enhanced Mobile Broadband (eMBB), Ultra Reliable Low Latency Communication (URLLC) and massive Machine Type Communication (mMTC) [5] although it is not expected to be used solely in factories of the future, thus a thorough integration is required [6]. In terms of factory automation, URLLC and mMTC are predominant challenges. With 5G also nontechnical improvements became available, with the opportunity of is the frequency band licensing for local 5G campus networks. Thereby, the owner of the property and user of the network services becomes the role of the network operator, which might ease questions of liability and data security. In Germany the frequency ranges of 3,7 - 3,8 GHz and 24,25 - 27,5 GHz are offered for 5G campus networks. Moreover, open, software based solutions for 5G systems arouse interest, as for example the projects of O-RAN Alliance (https://www.o-ran.org) and OPEN AIR Interface (openairinterface.org) show.

While the label 5G shows the progression from the Long Term Evolution (LTE) networks, the technological advancements of the network system are realized by releases. In June 2019, 3rd Generation Partnership Project (3GPP) finalized Release 15 [3]. Some key features are the support of Milimeter Wave (mmWave) technologies and massive Multiple Input Multiple Output (MIMO). As the first release of 5G it introduced the New Radio (NR) features of 5G which specify the physical layer and some higher layer procedures. The physical layer offers new flexibility, such as selectable transmission intervals in a Time Division Duplex (TDD) scheme and different subcarrier spacings from 15 kHz to 120 kHz. Besides NR, Release 15 focused on network slicing, a native cloud integration to bring computational power directly to the edge of 5G, and a major rework of the core architecture. Through a higher flexibility, Release 15 can be tweaked in order to achieve lower latencies or higher data rates but, in fact, it does not deliver any guaranteed Quality of Service (QoS).

The specification of Release 16 [4] was finished in July 2020. It focuses on core components, for instance, Release 16 strengthens the URLLC aspect and introduces a new QoS flow concept and an integration approach for 5G with Time Sensitive Networking (TSN). Here, two TSN-Translator functions, i.e. the Device Side TSN Translator (DS-TT) and the Network Side TSN Translator (NW-TT), are added to the system to enable the 5G integration as virtual TSN bridge in a way that the superior TSN system is configurable without in detail knowledge of the 5G communication.

Release 15 and Release 16 are in the interest of potential users today. Release 15 products are commercially available and public land mobile networks operators rolled out networks starting in 2020. Release 16 is approaching the threshold to do so. Also, the Release 17 is finally specified by 3GPP and Release 18 will be finished in early 2024. Although, the implementation of these releases in semiconductors and software for network components and user equipment will still take time. Enhanced time synchronization, positioning and sidelink services as well as 5G system support for AI based services and personal IoT networks belong to the goals of these releases. The further future of mobile communication towards Release 19 or even 6G is not determined yet and a matter of fundamental research.

The activities of research, specification and implementation of 5G are accompanied by various organization representing the vertical stakeholders, for example the 5GAA (5gaa.org) for the automotive domain, the 5G-ACIA (5g-acia.org) for connected industries and automation or the 6G Infrastructure Association (6g-ia.eu). They define requirements for future specification and at the same time support the application of 5G in their domains. For example, 5G-ACIA has been endorsing several testbeds to showcase industrial use cases of 5G for example in the field of mobile robotics, gantry cranes and AI enabled production. These testbeds prove the feasibility, provide basic performance metrics and show the

economic benefit that can be realized today. Nevertheless, the upcoming releases are required fully fulfill the promise 5G.

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