White Paper
PMSE and 5G

Version 1.01
27.03.2017

CONTENT

THE PMSE-xG PROJECT

PMSE-xG is a pre-competitive research project studying 4G+/5G technologies and their applicability to wireless equipment deployed in Programme Making and Special Events (PMSE) applications. PMSE systems are mainly used by the Culture and Creative Industry, and cover all kind of production tools for audio or video processing.

PMSE-xG is a first step to bring stakeholders together and to assess the feasibility of current and future cellular mobile radio technologies (4G+ and 5G) for selected PMSE use cases. The assessment is based on implementation concepts and the validation of key performance indicators in proof-of-concept demonstrators. Research activities of PMSE-xG cover in particular ultra-reliable low latency streaming technologies for mobile and nomadic applications. Standardization activities contribute and highlight PMSE requirements to the running standardization of 5G.

PMSE-xG is co-funded by the German Federal Ministry of Transport and Digital Infrastructure. The PMSE-xG consortium consists of three leading PMSE manufactures (ARRI, Robert Bosch, and Sennheiser), an innovative mobile radio SME (Smart Mobile Labs), a leading chipset manufacture (Intel), two universities (Hannover, Erlangen-Nürnberg) and one research center of the Fraunhofer-Gesellschaft (HHI, Berlin). Several associated partners enrich the expertise of the PMSE-xG consortium by participating in an advisory board.

1 EXECUTIVE SUMMARY

The *Programme Making and Special Events* (PMSE) industry, the main driver behind professional equipment for the Culture and Creative Industry (CCI), is looking for solutions to the diminishing availability of dedicated spectrum for advanced wireless applications.
With the 5th generation mobile networks (5G) on the horizon, future cellular networks are considered as one viable option for wireless communication systems to fulfil the strict requirements of the PMSE scenarios including professional live audio and video production. The requirements from the PMSE industry extend further than the ones commonly considered for the 5G use case Ultra-Reliable Low Latency Communication (URLLC), i.e. latency below 1 ms and high reliability for a single packet transmission. In fact, even though the support of continuous streaming of packets is essential for any media application, the ability to have all devices tightly synchronized and the support of a reliable multicast are additional key requirements that PMSE applications necessitate for seamless operation.
Finally, to enable the successful integration of PMSE applications into the 5G ecosystem, a viable business model for the PMSE industry, as a vertical sector within the scope of 5G, is essential.

2 INTRODUCTION

The PMSE industry comprises all kind of production, event and conference technologies. It can be categorized into audio (e.g. microphones, in-ear monitor, and public address sound systems), video (e.g. cameras, displays and projectors) and stage control systems.

The usage of PMSE equipment plays a major role for the CCI sector. Today, for reliable operation of all the wireless equipment, such as cameras and microphones, professional PMSE requires controlled interference environments, e. g. through appropriate spectrum access and interference mitigation techniques. Up until now, the TV UHF band form the core spectrum for professional wireless audio productions even though PMSE devices share this spectrum with the actual primary user (Broadcasting Service). However, the trend within the CCI towards larger setups and the increase of quality requirements demand a much broader spectrum availability. Furthermore, dedicated spectral resources for PMSE applications become scarcer due to reassignment of important UHF frequency bands to the cellular industry[1].

Failures of wireless links during a live event or a live production are unacceptable for the CCI and their customers. Therefore, additional efforts towards an improved transmission robustness and a more effective interference management have to be considered. Not only reliability but also audio/video quality and latency are key parameters of wireless production equipment. In order to cope with all these requirements the spectrum demands increase further. However, due to the increasing reduced spectrum availability, business opportunities to expand the PMSE and CCI sectors are substantially limited. It is worth pointing out that there is a growing demand from the end users for new, and more differentiated services, like Augmented Reality (AR), Virtual Reality (VR) and other new

[1] BNetzA (online): Strategic Aspects of the Availability of Spectrum for Broadband Rollout in Germany (2017) https://www.bundesnetzagentur.de/SharedDocs/Downloads/EN/BNetzA/Areas/Telecommunications/TelecomRegulation/FrequencyManagement/ElectronicCommunicationsServices/DemandIdentificationProceedings/StrategicAspects.pdf?__blob=publicationFile

immersive experiences. These services will require and consume even more additional resources of the available spectrum. Here, the forthcoming 5G standard and its correspondent technologies could offer solutions and open new possibilities by integrating PMSE use cases into the 5G eco-system, thus fulfilling the technical requirements of PMSE applications.

The dynamic transformation of the Media & Entertainment (M&E) vertical user experience is part of the ongoing discussions both in research communities, like the 5G-PPP association[2], and in standards bodies, like 3GPP[3]. Referring to these discussions, "*5G shall enable at least six main families of M&E use cases in the 2020s with an overall user experience that well exceeds that of 4G and other legacy networks: Ultra High Fidelity Media, On-site Live Event Experience, User/Machine Generated Content, Immersive and Integrated Media, Cooperative Media Production and Collaborative Gaming*"[4]. However, comparing the Key Performance Indicators (KPIs) of the mentioned six main families with the KPIs required for PMSE, it is clear, that use cases of typical PMSE applications, as described in the following section, are not yet covered by the technical requirements of M&E, as the focus of the works has been so far only on media distribution and reception.

The goal of this white paper is to increase the awareness of what is actually needed for the media production part of CCI with regard to the ongoing definition of 5G system. The rest of the document is organized as follows: section 3 illustrates PMSE use cases. Section 4 summarizes the technical parameters of professional PMSE applications within 5G. Section 5 discusses the substantial need for a business model and section 6 finally points out issues that are to be resolved before 5G becomes a viable option for the PMSE industry.

3 USE CASES

In today's typical professional live production setups, there is a lot of wireless PMSE equipment in use, e. g., artists on stage use wireless microphones in combination with wireless in-ear monitoring systems, or wireless cameras deliver live content for big video panels placed around the stage. Every wireless audio/video link is composed of one transmitter and its destined receiver, which provides the input data for the further processing chain, or in case of an in-ear monitor system the audio stream for the artist on stage.

Transferring PMSE applications into the 5G eco-system, the complete on-site wireless equipment could be seen as one local high quality PMSE network (see Figure 1), processing audio and video data streams with a guaranteed quality of service regarding latency and reliability as well as control data for remote control of wireless devices.

The professional live audio performance use case is depicted by multiple wireless audio data flows, each of them being composed of the microphone's signal, streamed to the base station, and the in-ear audio mix, which is sent back to the artist. Due to the latency requirements of professional musicians using monitor functionality on stage or during live

[2] The 5G Infrastructure Public Private Partnership: https://5g-ppp.eu/
[3] The 3rd Generation Partnership Project: http://www.3gpp.org/
[4] 5G-PPP: 5G empowering vertical industries (2016), online https://5g-ppp.eu/wp-content/uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf

production, the local high quality network must be capable of streaming audio signals with ultra-low latency. The whole network would have to receive numerous audio signals from the artists on stage and to stream different audio mixes back to the artists or to a Public Address (PA) system over wireless and wired connections. Therefore, audio mixing capability can be implemented in a mobile edge cloud attached to the base station of the local high quality network to reduce latency or other possibilities of connecting external mixing consoles should be given.

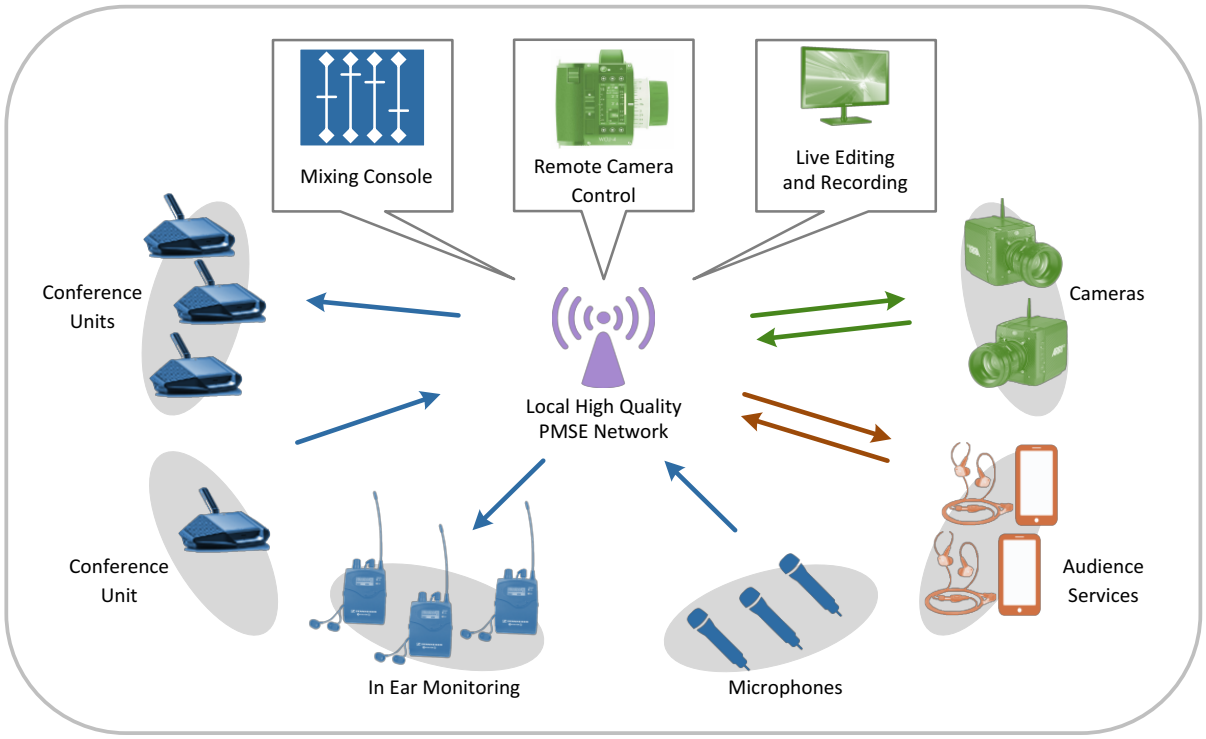

Figure 1: Topology of PMSE applications within 5G

A second use case is conferencing, which would require a similar setup. In a conference system the voice of several speakers is captured by a conference unit, transmitted to the base station of the Local High Quality Network, where the mixing of the different audio streams is done, and distributed to all other conference units connected to the network, which replay the received audio stream. Low latency is an issue because the speakers always hear themselves speaking.

In addition to the audio streams the cell processes video data, which represents the third use case. High quality video data is streamed wirelessly from several cameras to the base station and the attached mobile edge cloud, where it can be recorded or be edited. Moreover, the system should allow remote operation of the camera (e.g. focus control) by sending and receiving control data to and from the camera.

Such local high quality wireless networks for audio and video would be relevant for concerts, TV shows, sports events, theatres and musicals, press conferences and electronic news gathering. Furthermore, the scenario of a live event, where a local high quality wireless network is used to collect audio, video and other content for further distribution, offers the possibility to distribute new kind of content to the audience, e. g., individualized audio mixes, or different camera angles, which provides new ways of user experience. The respective content can be received with future standard consumer hardware (e.g.

smartphones). These services also might help people with impaired vision or hearing to follow live events.

4 TECHNICAL REQUIREMENTS

Achieving required audio/video latency together with the high reliability throughout the whole operation time is the challenge for professional PMSE applications in wireless networks. Thereby, *reliability* describes the required robustness of the service, looking at the percentage of audio/video packets that arrive in-time and without errors at the application level.

System delay refers to the latency introduced per link by the wireless communication system. In contrast to common user plane latency definitions[5], the overall system delay shall not exceed a certain upper bound independently of the system load during pre-determined time durations for reliable operation. Looking at the minimum requirements[6] defined for IMT 2020, they indicate that a maximum latency of 1 ms shall be specified. However, the stated condition under which the communication system has to fulfil these requirements namely using a single small packet in a system with no other users, is not applicable to the PMSE use case. In fact, PMSE implies that the multi-user case is explicitly considered and moreover, the specified value has to be met by every packet of a potential audio/video stream with the specified data rates.

In particular, professional live audio shows and productions require reducing the end-to-end latencies to a few milliseconds. As A/D and D/A conversion and general processing steps like audio mixing must be subtracted from the latency budget, the delay of the wireless communication system per hop has to be deterministic and shall be 1 ms or even less. Consequently, additional latencies introduced by the interface between the wireless modem and the audio/video applications must be embraced in the overall specification and calculation.

Additionally, professional live audio productions and upcoming immersive 3D recording setups require capturing samples at the exact same times. In this context, we refer to the term *synchronicity* as the maximum allowed time offset at application level between user equipment of one wireless network (see Figure 2). Each professional audio/video terminal has to independently refer to an accurate reference signal that reaches all terminal devices simultaneously, i.e. within a phase jitter much smaller than the audio/video sampling period. Without general limitations for upcoming setups, higher sampling rates for audio, e.g. 192 kHz, are also considered. Consequently, phase jitters must be controlled in the order of sub-microseconds. Both, the professional audio and video system rely on ultra-precise time synchronization at application level and would benefit from IEEE 1588 PTP and Time Sensitive Networking (TSN) features already developed or under development by IEEE 802.1[7].

[5] For instance in 3GPP: TR 38.913

[6] ITU-R WP5D: “Minimum requirements related to technical performance for IMT-2020 radio interface(s)”, Attachment 5.8 (2016)

7 http://www.ieee802.org/1/pages/tsn.html

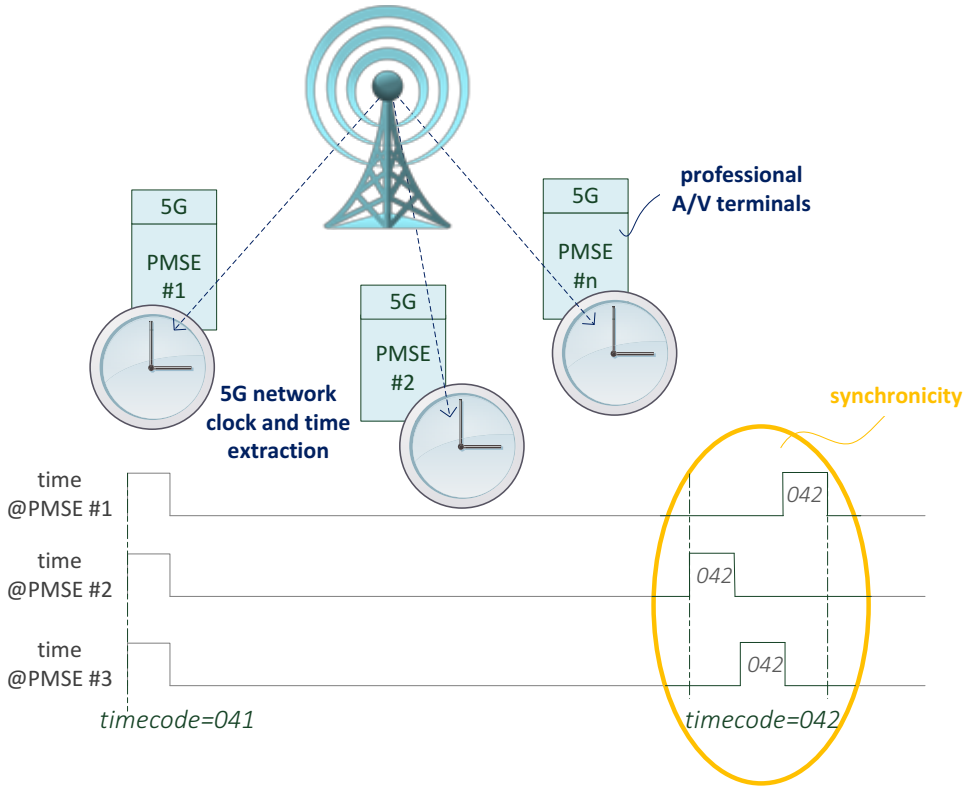

Figure 2: Time reference and synchronicity at application level

The previous described use cases make different demands on latency and reliability, and bring in the requirement of synchronicity at application level. For the three audio use cases the range of values of each requirement is summed up in one maximum value, the video requirements are defined by one use case. All discussed technical requirements driven by PMSE applications are summarized in Table 1 in comparison to the maximum value defined for IMT 2020. In contrast to IMT profiles, where a subset of the maximum requirements has to be met, PMSE use cases need all listed maximum requirements to be kept simultaneously.

Table 1 Maximum requirements driven by audio and video use cases in comparison to discussions within the 5G-PPP

	System delay [ms]	Link data rate [Mbit/s]	Reliability [%]	Number of data links	Synchronicity	Area of operation [m x m]	Mobility [km/h]
audio	1	4.61	99.99	150	1µs	100 x 100	50
video production	10	2000	99.999	20	1µs	100 x 100	100
IMT 2020[+]	1	20000	99.999	10^6	n.a.	1000 x 1000	500

[+] The requirements for IMT 2020 in current discussion are specified for the transmission of a single packet in a single-user scenario. The requirements for the PMSE equipment, however, assume a continuous stream of packets in a multi-user setup. Even though the numbers look the same, e.g. delay equal to 1 ms, the scenarios in which the PMSE equipment has to fulfil these requirements are more demanding. The number of data links for this scenario comes from a massive machine type communication use case, where participants are not active for large amount of time due to power limitations (e.g. sensors).

The audio case stresses strict timing requirements including low latency for medium rate audio streams covering the range from 150 kbit/s up to a maximum value of 4.61 Mbit/s per link while meeting high reliability at the same time. The reliability figure is valid for a packet length of 1 ms (corresponding to a packet size between 150 bit and 4610 bit) while holding the following two error distribution criteria:

- first, the maximum continuous error duration is equal to 30 ms
- second, a consecutive minimum continuous error-free duration need to be 100 ms.

The video case similarly emphasizes high data rates of up to 2 Gbit/s per camera link (Ultra High Definition, 120 frames per second, video production codec) and high reliability (not more than one corrupted video frame per hour). Considerable mobility arises from high-speed cable cameras. Both use cases consider indoor as well as outdoor scenarios and coverage of a football pitch area.

Figure 3 visualizes the stated technical requirements. The boundaries of the spider chart refer to the maximum values currently discussed in the 5G-PPP. Note that the requirement synchronicity is a new KPI and replaces 5G-PPP's KPI positioning accuracy in this overview.

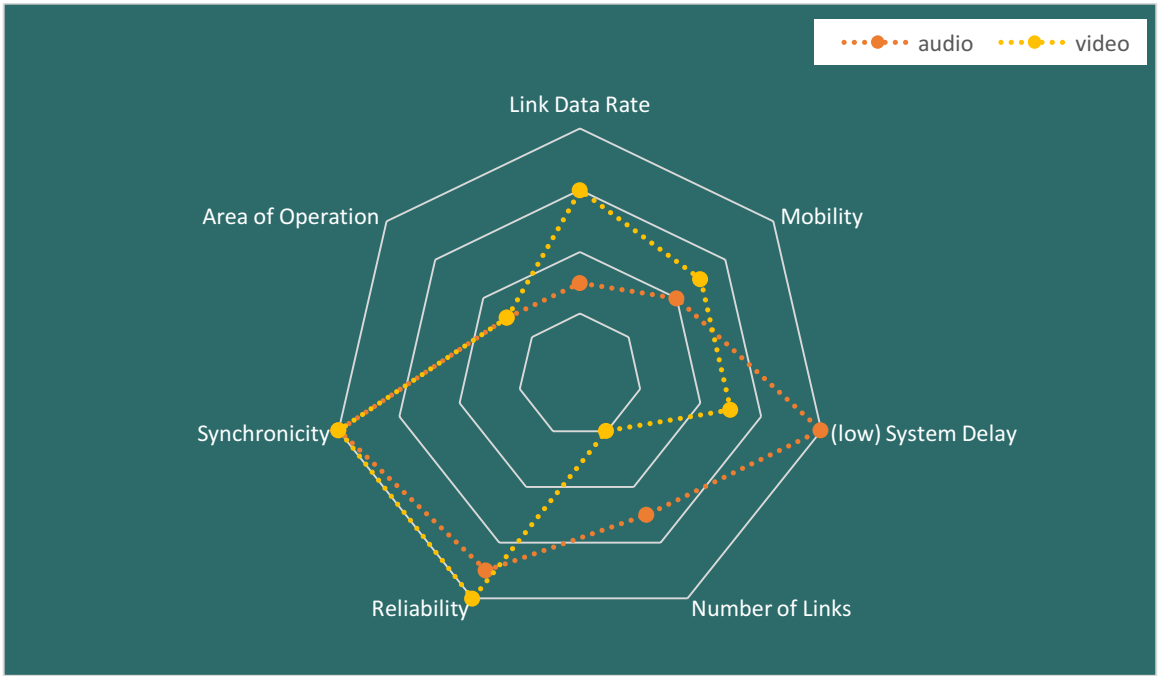

Figure 3 Capability spider chart of audio and video production use cases

5 NEW BUSINESS MODELS

There will have to be viable and sustainable new business models in cooperation with network operators or license holders that allows the global deployment of the PMSE equipment in a simple and cost-efficient way. At the moment it can be thought of two deployment scenarios that have a direct influence on the involvement of a network operator and, hence, lead to different business models. One option is a dedicated Local High Quality PMSE wireless Network with spectrum access through standardized licensed-shared access (LSA) schemes. It would imply that the network infrastructure - the base station and the core

network - has to be installed and operated by the PMSE user. The license for the spectrum has to be leased from the license holder, which could be any incumbent including IMT. A second option is the deployment of a PMSE service within a public network. It would demand a contractually guaranteed service level by the network operator that allows the undisturbed operation of the PMSE service. Hence, the PMSE user utilizes the public network and only manages the PMSE equipment and the corresponding software applications.

6 PMSE AND 5G: THE WAY FORWARD

To become a suitable alternative technology for wireless PMSE applications the 5G ecosystem would have to meet three basic prerequisites:
First, the 5G standard needs to meet the technical requirements derived from the above discussed PMSE use cases, which are currently not covered by the 5G / IMT 2020 use cases.
Second, not only would the forthcoming 5G standard have to fulfill the described requirements, but the necessary adaptations of the 5G standard would have to be implemented in commercially available 5G chipsets. In contrast to mobile phone producers the PMSE industry ships only a small number of units per year, which makes support of the PMSE industry less attractive for the IC manufacturers. However, the commercial availability of 5G chipsets is crucial for the PMSE industry to offer 5G-enabled PMSE equipment.
Third, an integration of PMSE application into 5G networks would only be feasible, if new business models are developed in close cooperation between network operators and the PMSE industry.

In conclusion, the prospective deployment of PMSE services within a 5G ecosystem in the future is not only a technical challenge but also depends on the early collaboration of the cellular industry with the PMSE industry and all other vertical sectors.