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**Reconfigurable Radio Systems (RRS);**
**Feasibility study on temporary spectrum access**
**for local high-quality wireless networks**

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# Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Reconfigurable Radio Systems (RRS).

# Modal verbs terminology

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# 1 Scope

The present document addresses different technical possibilities for local high-quality wireless networks (nomadic or fixed) to access spectrum on a shared basis during a certain time period ranging from short-term (e.g. some days to some weeks) to long-term (e.g. some months to some years).

Also the present document describes high-level use cases, review the feasibility of existing spectrum sharing frameworks, and, if required, propose evolved, extended or new technical solutions for spectrum sharing and network architectures addressing different network topologies and device types.

# 2 References

## 2.1 Normative references

Normative references are not applicable in the present document.

## 2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.



[i.1] PMSE-xG White Paper.

NOTE: Available at http://www.pmse-xG.research-project.de.

[i.2] ECC Report 205: "Licensed Shared Access (LSA)", February 2014, CEPT WG FM PT53.

[i.3] ETSI TS 103 235: "Reconfigurable Radio Systems (RRS); System architecture and high level procedures for operation of Licensed Shared Access (LSA) in the 2 300 MHz - 2 400 MHz band".

[i.4] Funktechnologien für Industrie 4.0: "VDE Positionspapier, ITG AG Funktechnologie Industrie 4.0", June 2017.

[i.5] Functional Safety and IEC 61508. .

NOTE: Available at http://www.iec.ch/functionalsafety/.

[i.6] ECC Report 102: "Public Protection and Disaster Relief Spectrum Requirements", Helsinki, January 2007.

[i.7] 5GPPP White Paper: "5G and e-Health", September 2015.

[i.8] WWRF White Paper: "A New Generation of e-Health Systems Powered by 5G", November 2016.

[i.9] ECC Report 132: "Light Licensing, Licence-Exempt and Commons", June 2009.

[i.10] 3GPP TR 32.855 (V1.0.0) (02-2016): "3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Telecommunication management; Study on OAM support for Licensed Shared Access (LSA); (Release 14)".

[i.11] Ericsson, RED Technologies, and Qualcomm Inc. conduct the first Licensed Shared Access (LSA) pilot in France.

NOTE: Available at http://www.redtechnologies.fr/.

[i.12] D. Guiducci et al.: "Sharing under licensed shared access in a live LTE network in the 2.3-2.4 GHz band end-to-end architecture and compliance results", 2017 IEEE International Symposium on Dynamic Spectrum Access Networks (DySPAN), Piscataway, NJ, 2017, pp. 1-10.

[i.13] FCC 15-47: "Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550- 3650 MHz Band", April 2015.

[i.14] FCC 16-55: "Order and Reconsideration and Second Report and Order, Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550- 3650 MHz Band", May 2016.

# 3 Definitions and abbreviations

## 3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

**temporary:** spectrum allocations lasting, existing or effective for a period of time only; which can range from short-term (e.g. days or weeks) to long-term (e.g. months to years)

## 3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:



| | |
|---|---|
| AGV | Automated Guided Vehicle |
| AR | Augmented Reality |
| BEM | Blocking Edge Mask |
| CBRS | Citizen Broadcast Radio Service |
| CBSD | CBRS Device |
| CEPT | European Conference of Postal and Telecommunications Administrations |
| DP | Domain Proxy |
| ECC | Electronic Communication Committee |
| ESC | Environmental Sensing Capability |
| FCC | Federal Communications Commission |
| GAA | General Authorization Access |
| HEN | Harmonized European Norm |
| IA | Incumbent Access |
| IEC | International Electrotechnical Commission |
| IEM | In-Ear-Monitor |
| IMT | International Mobile Telecommunications |
| KPI | Key Performance Indicator |
| LC | LSA Controller |
| LR | LSA Repository |
| LSA | Licensed Shared Access |
| LSR | LSA Spectrum Resource |
| LSRAI | LSA Spectrum Resource Availability Information |
| MFCN | Mobile/Fixed Communication Networks |
| mMTC | massive Machine Type Communication |
| MNO | Mobile Network Operator |
| MVNO | Mobile Virtual Network Operator |
| NPRM | Notice of Proposed Rule Making |

| | |
|---|---|
| NRA | National Regulatory Authority |
| OAM | Operation, Administration, and Maintenance |
| PA | Public Address |
| PAL | Priority Access License |
| PER | Packet Error Rate |
| PMSE | Programme Making and Special Events |
| PPA | PAL Protection Area |
| PPDR | Public Protection Disaster Relief |
| QoS | Quality of Service |
| RAT | Radio Access Technology |
| RF | Radio Frequency |
| SAS | Spectrum Access System |
| SLA | Service Level Agreement |
| SRC | Spectrum Resource Controller |
| SRR | Spectrum Resource Repository |
| UC | Use Case |
| UCC | Use Case Class |
| WIA | Wireless Industrial Automation |

# 4 Local High-Quality Wireless Networks

## 4.0 Introduction

The next generation of broadband mobile communication networks aims to integrate applications of vertical sectors in its holistic ecosystem of enabling technologies, spectrum management frameworks and networking paradigms. To make this happen, key requirements of vertical sectors should be communicated, properly discussed, and finally reflected within the relevant design and standardization processes.



Clause 4 of the present document analyses the communication requirements of selected vertical sectors, e.g. Industrial Automation, Utilities, Culture and Creative Industry, PPDR, e-Health, etc. The analysis will identify a set of use cases typically demanding predictable Quality of Service (QoS) levels at all operation times, within short-term to long-term deployments in local environments. As well, the set of identified use cases favour private network infrastructure and own management functionality for implementing specific security standards or simply due to privacy reasons.

Based on this analysis, the concept of *local high-quality wireless networks* is proposed as a collective term to enclose that kind of use cases.

## 4.1 High Level Use Cases and Requirements

### 4.1.1 Programme Making and Special Events (PMSE)

#### 4.1.1.1 General

Programme Making and Special Events (PMSE) is a term denoting wireless applications used to support broadcasting, news gathering, audio and video production for film, theatre and music, as well as special events such as sport events, culture events, conferences, and trade fairs.

The PMSE industry delivers key enabling equipment for the culture and creative industries, both having a significant socio-economic impact in the EU.

Typical PMSE equipment includes for example wireless microphones, in-ear monitors, video cameras, conference systems, light and remote controls.

Wireless audio PMSE equipment (e.g. wireless microphone, in-ear monitors, conference systems) employ digital or analogue wireless technologies, which are specific, typically link-based developments of the PMSE manufactures to support reliable, very low latency audio streaming transmissions required by the targeted professional audio applications.

#### 4.1.1.2 Use Cases and Requirements

##### 4.1.1.2.0 General

This clause introduces three representative high-level use cases (UCs) of the PMSE industry and their requirements:

- Use case 1 (UC-1): Live Performance
- Use case 2 (UC-2): Presentation
- Use case 3 (UC-3): Tour Guide

For each UC, a short description is provided, as well, its major requirements as defined and used in the German research Project PMSE-xG [i.1] are discussed.

These three UCs highlight two key aspects of wireless audio productions: low latency and high reliability. As such, they can be grouped into a use case class (UCC) addressing *low latency and high reliability audio streaming* applications. As a general requirement for this UCC, all wireless mobile devices need to be synchronized inside one local high-quality wireless network.

##### 4.1.1.2.1 UC-1: Live Performance

The use case 'Live Performance' involves several wireless microphones (handheld or body-worn) used to capture the singers voice or the sound of instruments, several stereo in-ear monitors (IEM), at least one mixing console and a PA system.

A typical scenario is for instance a concert, where an artist on stage is using a wireless microphone while he is hearing himself via the wireless IEM system. The audio signal coming from the wireless microphone is streamed to one or more mixing consoles, where different incoming audio streams (e.g. from different music instruments, choir) are being mixed. After mixing, several audio streams can be generated, e.g. PA mix, individual IEM mixes for the artists or recording mixes. From those, IEM mixes are wirelessly transmitted to the artist and musicians while most of the other mixed signals are streamed via wired connections.



Depending on the type of event, the number of active wireless audio links or the data rates of the respective wireless audio streams may vary. However, the requirements regarding latency and reliability remain principally the same for all kind of live events/productions. Reliability is an essential feature because during live productions one cannot afford repeating audio transmissions until it is error-free. Low latency is an essential feature because in this use case source and sink of the audio transmission can be co-located, think of an artist equipped with wireless microphone and IEM. Because the artist receipts audio of the environment also via its cranial bone, very low end-to-end delay (i.e. from the wireless microphone to the mixing desk back to the IEM) is tolerated.

Table 1 summarizes the KPIs of the use case Live Performance.

**Table 1: KPI Requirements for the UC-1: Live Performance, as described in [i.1]**

| KPI | Requirement |
|---|---|
| End-to-end delay | < 4 ms |
| User data rate | The user data rate per audio link can vary depending on the application but will stay constant during operation:<br>150 kbit/s - 4,61 Mbit/s |
| Control data rate | ≤ 50 kb/s<br>Data rate per control link |
| PER | The PER of the system is required to be below $10^{-4}$ for a packet size of 1 ms. Depending on the error concealment the following exemplary error distribution may be tolerable:<br>• maximum continuous error duration = 30 ms<br>• consecutive minimum continuous error-free duration = 100 ms |
| Number of audio links | 50 - 300 simultaneous |
| Event area | ≤ 10 000 $m^2$, indoor and outdoor |
| Mobile user speed | ≤ 14 m/s |

#### 4.1.1.2.2 UC-2: Presentation

In the use case Presentation, a presenter on stage is using a wireless microphone for example to present a slide set to the audience. The wireless microphone is used for streaming the presenter's voice to the loudspeakers installed in a conference room. When using more than one wireless microphone a mixing console is added, which mixes the incoming audio streams to one or more output audio streams. One of these outgoing audio streams may be distributed to the loudspeaker inside the conference room, another via Ethernet to several clients of the audio distribution network. In this use case, no IEM is required, which relaxes the requirement on end-to-end latency.

Low latency and high reliability of the wireless link are essential for the use case, so that the assisting playback via the loudspeakers is not irritating the audience or the moderator by distortions or not matching auditive-visual impression.

Table 2 summarizes the KPIs of the use case Presentation.

**Table 2: KPI Requirements for the UC-2: Presentation, as described in [i.1]**

| KPI | Requirement |
|---|---|
| End-to-end delay | < 10 ms |
| User data rate | 150 kbit/s - 1,15 Mbit/s |
| Control data rate | ≤ 50 kb/s<br>Data rate per control link |
| PER | The PER of the system is required to be below $10^{-4}$ for a packet size of 1 ms |
| Number of audio links | 5 - 10 simultaneous |
| Event area | ≤ 10 000 $m^2$, indoor and outdoor |
| Mobile user speed | ≤ 5 m/s |
| Security | Encryption of the user data |

#### 4.1.1.2.3 UC-3: Tour Guide

In the use case Tour guide, a guide is guiding a group of visitors being in close proximity. One can think for instance of a conducted tour in a factory site, museum, sports venue or a guided city tour. The guide speaks to a wireless microphone and the audio is distributed to the receiving head-sets of the visitors, so the distribution of the spoken information from the guide to the audience while walking from spot to spot is in focus. Nevertheless, one can imagine interactions between guide and audience in the form of questions and answers turning the tour guide system in a mobile conferencing solution.

Low latency and high reliability of the wireless link are essential for the use case, so that the assisting playback via the headphones is not irritating the audience or the guide by distortions or not matching auditive-visual impression. Here, at least one multicast audio link (from the guide to the visitors) should be supported, and up to ten unicast audio links (from the visitors to the guide) are necessary.

Table 3 summarizes the KPIs of the use case Tour guide.

**Table 3: KPI Requirements for the UC-3: Tour-Guide, as described in [i.1]**

| KPI | Requirement |
|---|---|
| End-to-end delay | < 10 ms |
| User data rate | 150 kbit/s - 350 kbit/s |
| Control data rate | ≤ 50 kb/s<br>Data rate per control link |
| PER | The PER of the system is required to be below $10^{-4}$ for a packet size of 1 ms |
| Number of audio links | 5 - 10 uni cast, 1 - 2 multicast but 50 - 100 devices |
| Event area | ≤ 10 000 $m^2$, indoor and outdoor |
| Mobile user speed | ≤ 5 m/s |
| Security | Encryption of the user data |

## 4.1.2 Wireless Industrial Automation (WIA)

### 4.1.2.0 Introduction

Industrial communication has fundamentally different requirements to conventional commercial communication. Essentially, industrial communication is used to control and monitor real-world actions and conditions concerning specific physical equipment, while the primary function of commercial communication is data transfer and processing.

Industrial communication has a broad range of use cases and deployment scenarios with a unique set of requirements on the communication latency, reliability, availability, and throughput. The isolated application and heterogeneity of wireless communication systems in existing industrial deployments can be mainly attributed to the following three reasons:

i) challenging propagation and channel conditions with strong fading and multipath effects;

ii) no determinism for channel access; and

iii) extreme requirements in terms of very low latency and high degree of reliability.

### 4.1.2.1 Industrial Communication Requirements

#### 4.1.2.1.0 General

Many of the industrial application use cases have extremely high requirements on the communication system. Figure 1 shows a comparison between mobile broadband and industrial communication. As illustrated, industrial communication has particularly high requirements in terms of high reliability and low latency. Please note that requirements on high reliability and low latency in industrial applications typically come hand in hand, i.e. extreme values for both metrics are needed at the same time. Other distinguishing factors include device density, relatively small packets with very short inter arrival times, and high data rates that further increase the requirements in industrial communication. Moreover, dependent on the use case there is a need to support very high communication distances such as in process automation deployment scenarios. In use cases of logistics and warehouses, communication distances are typically small and a high degree of flexibility is expected. An example includes the scenario to rapidly deploy and run different processes or to support the mobility and connectivity of mobile devices such as augmented guided vehicles (AGVs), which are interacting with different processes and warehouses.



Figure 1 shows a consolidated view for high-level industrial use cases. Not all requirements are to be supported at the same time. In addition, for the different use cases the presented metrics vary significantly. In the following, different industry high-level use cases and their related requirements are presented.

#### 4.1.2.1.1 Discrete Manufacturing

In discrete manufacturing, a countable number of objects is produced. This involves assembling, testing or packaging products in many discrete steps (e.g. in automotive, general consumer electronic, goods production, etc.). Discrete manufacturing has the most stringent communication requirements on latency and reliability, and these can be in the range of (1 ms - 12 ms) for latency and $10^{-9}$ packet error rate (PER) for reliability [i.4]. Examples of discrete manufacturing include printing machines, pressing machines and packaging/palletizing machines. In discrete manufacturing, machine tools, robots, sensors and programmable logic controllers typically exchange small sized data packets with very short intervals. Small data sizes generated periodically at very small instants of time from a high density of devices eventually constitute significant overall data rate requirements in a production facility. Redundancy, cyber security and functional safety are also very important for factory automation.

#### 4.1.2.1.2 Monitoring and Maintenance

The monitoring of sensor data and collection of maintenance information from machines typically do not have very tight requirements on the communication latency and reliability. The reliability requirements for monitoring and maintenance application use cases is in the order of $10^{-4}$ packet error rate (PER), which means that only one out of 10 000 packet should be lost within the relatively relaxed time budget (typically more than 20 ms) [i.4].