TDOC 201 Structure of phase 3 outcome document

TR102801 ETSI technical Report of the different RF compliance tests for the selected

TDoc 202 (later)
Management summary

- Addressing less technical people…
- Consolidating information of phase 1+2 with findings of phase 3
- Proof that concept works!
- What happens next, next steps… appropriate standards…more research?
- IPR
- *Objective of standards*
- Prevent interference to other services
- To be spectrum efficient!
- terms spectrum efficiency, efficient use of spectrum

TDoc 203 (Georg and Brian)
Objectives of document

- Relation to Phase 1 and Phase 2 document; what is contained in earlier docs
- Identify where information can be found
- "Having identified test cases from the work carried out it is suggested that these are in cooperated in EN 300 422 as soon as practicable in order for cognitive systems to be available on the market."
- Although testing focused on PMSE-Audio and UHF-TV band…

TDoc 204
Specialities of PMSE (Georg)

- Unique, Once again
- QoS definition
- SLA
- justify it with market numbers / value; CCI cultural and creative industry

TDoc 212
Spectrum Efficiency (Georg)

Define the terms spectrum efficiency, spectral efficiency, efficient use of spectrum

TDoc 205
Cognitive properties (Maria + Axel + Andreas)

What is cognitive?

a) ITU definition of CR

- Very universal

b) What the concept allows

- What our concept allows, but is far more than
- do not to go into details – high level view only what do expect from C-PMSE?
- Mention Database

c) What is implemented in the demonstrator

- shipping to Berlin…
- Features Set cognitive

--

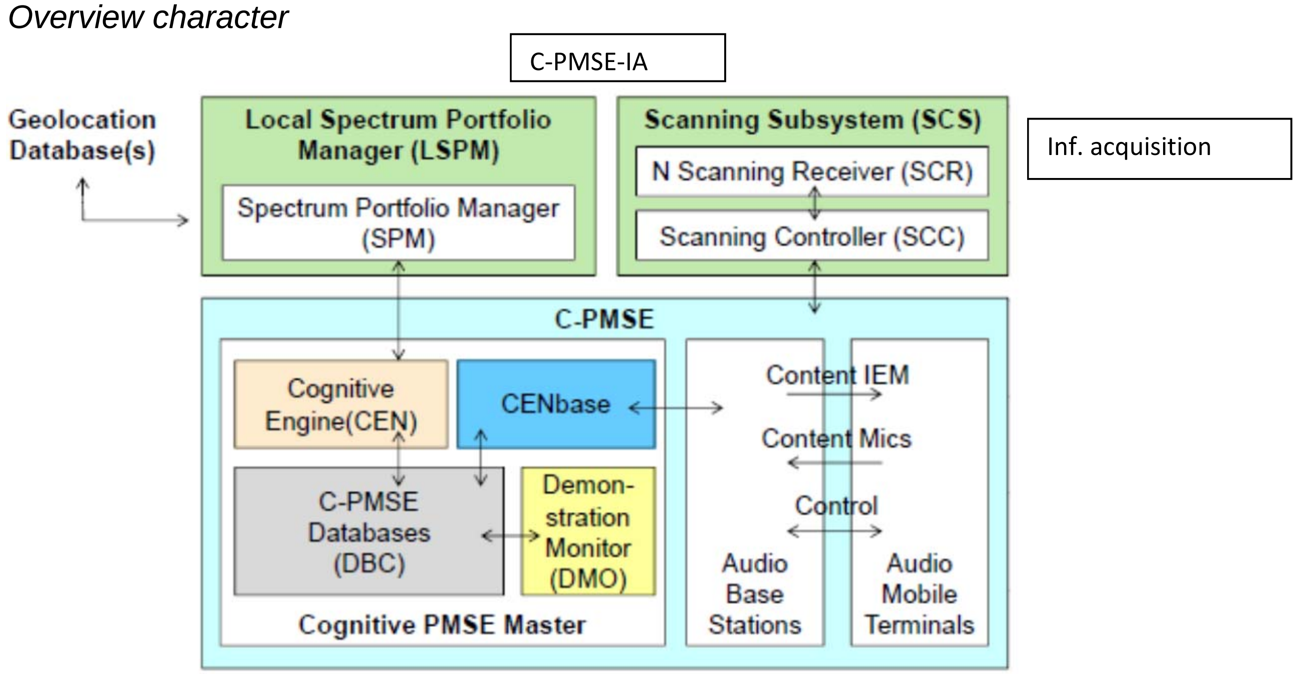
TDoc 206
Functionality of Demonstrator in BMWI C-PMSE project

BMWI C-PMSE project overview

- Brief overview on C-PMSE project… details in Annex

Architecture

Overview character



Include single internal scanner inside “C-PMSE”

Hierarchy of Databases

- Linkage to databases are outside of PMSE spectrum!
- Brian will upload on OFCOM UK concept; Brian will upload OFCOM UK interface setup

Elements of C-PMSE demonstrator

- LSPM
- SCS

  SCR, SCS
- C-PMSE
  - Inside Cognitive PMSE Master, Audio BS, Audio MT

Interface of demonstrator

Limits of realized Demonstrator

e.g. 6 PMSE links in 12

Standard is open for more links and frequency resources

Tdoc213 Interfaces on General architecture

Describe Interfaces = main part = standardisation

- Generalized Architecture, Abstracted from Berlin cause, align with Phase 1 and Phase 2 documents
-
- Brian will upload OFCOM UK interface setup, a good example, serves as geolocation database, different in each country?
- Interface LSPM<->CPMSE and SCC<->CPMSE

TDoc 211
requirements on SCS, LSPM, C-PMSE;
individual elements test procedures

Notes

Standard reflects “Minimum set of requirements to put equipment on the market”

Minimum operational performance standard

But there may be more!

Test procedure, of those test cases that are necessary

(enabler to put equipment on the market)

Testing reactions and interface

What does functionality mean in terms of technical parameters?

TDoc 207
Demo of cognitive behaviour

a) One Example of C-PMSE: BMWI C-PMSE system (Sven, Johannes)

demo cases at Messe Berlin? Results…

By Simulator?

b) = TDoc 208

TDoc 208
Further desirable demo cases and beyond

That go beyond C-PMSE project… is Berlin final and complete?

Tdoc214 Signalling

TDoc 209
Suggestions (… later)

Suggestions for standardisation

What is manufacturer specific, what is interoperable?... mixing of different hardware

Manufacturer inputs!

Suggestions for spectrum access = regulatory

e.g. Facts and figures how often to scan!

QoS insurance

CAPTURE the whole Learning curve!

Not limited to BMWI C-PMSE demonstrator

Prevent access to master database inside PMSE spectrum– should be outside spectrum

Annex

TDoc 210
Safety of Software … Brian will provide input from other groups

- RFR parameters can be altered
- Scepticism with SDR/CR
- No end user should be enabled to tweak the system in his only interest
- Manipulation risk

Objectives of document (Tdoc203)

Overview

This document TR 102 801 is the deliverable of phase 3 work by ETSI STF386. It is a refinement of the concepts and methods depicted in earlier documents by phase 1 and phase 2. Phase 1 has generated document TR 102 799 “Electromagnetic compatibility and Radio spectrum Matters (ERM); Operation methods and principles for spectrum access systems for PMSE technologies and the guarantee of a high sound production quality on selected frequencies utilising cognitive interference mitigation techniques” and phase 2 document TS 102 800 “Electromagnetic compatibility and Radio spectrum Matters (ERM); Cognitive Programme Making and Special Events (C-PMSE); Protocols for spectrum access and sound quality control systems using cognitive interference mitigation techniques”.

The refinement is based on the experience and lessons learnt during the course of a German national research project called “C-PMSE” funded by the German Federal Ministry of Economics and Technology (BMWI). This project had the aim of ensuring the high quality of productions with PMSE under a dynamically changing interference situation.

This document therefore reflects several modifications to the originally proposed architecture of a cognitive interference mitigation system and spectrum access for PMSE and to the methods of operating it.

As the majority of partners and experts participating in STF386 are also partners on the German Research project a smooth transfer of public information gained in the research project to the STF work was ensured.

Aim of this document

This document will highlight the changes made to the architectural concepts and operation methods for cognitive interference mitigation with PMSE over the phase 1 and phase 2 deliverables as a consequence of the findings by the German research project. It provides the explanation for these changes.

This document provides recommendations on the interfaces that need to be standardised to ensure proper functionality of interference mitigiation.

As the german research project is running a large demonstration at Messe Berlin, several tests of cognitive behaviour have been conducted there and a deep understanding of necessary tests has been developed which serves as the basis for defining recommended test cases in this document. The aim is to recommend test cases that should be incorporated in the relevant standards.

C-PMSE technology should be incorporated in EN 300 422 and EMC 301 489-1 as soon as practicable in order to encourage the development and widespread use of cognitive PMSE systems in the market.

Applicability

Although the testings and demonstrations with the German reseacrh project have focussed on UHF, the findings on refinement of architecture and operation method are applicable to other bands.

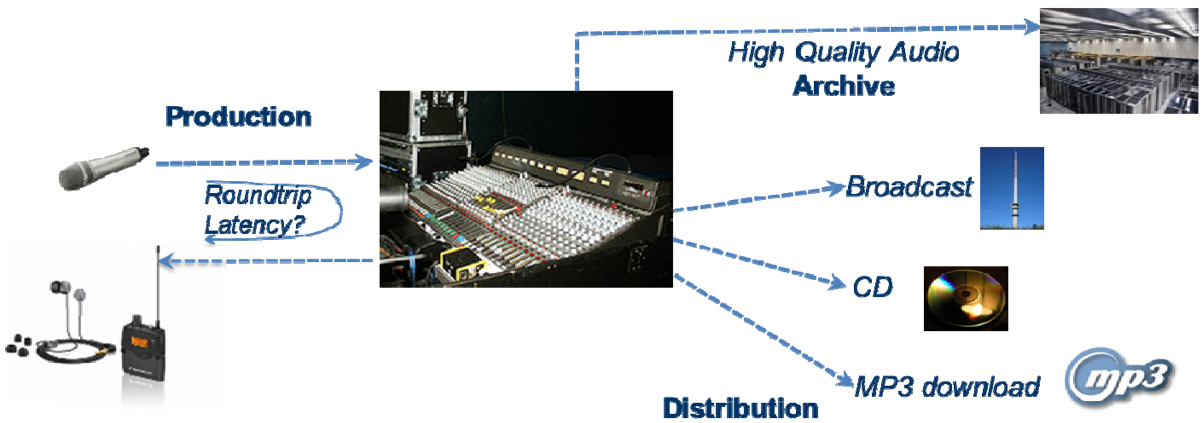
Specialities of PMSE (Tdoc204)

Overview

PMSE especially PWMS have specific requirements that differ from other wireless systems. In the following some aspects are discussed.

Latency of service

PMSE has to serve very stringent latency requirements. The difference to most other wireless systems is that with PMSE the information source is co-located with the information sink, e.g. an artist is using a wireless microphone and simultaneously an In Ear Monitor.



Roundtrip Problem scenario

The loopback from the artist back to the artist is enriched by the mixing console, where the information from other artists are added.

Experience from drummer artists tells that a roundtrip of smaller than 5 ms is needed for a high quality artistic performance. Assuming 1 ms for the mixing console, one PMSE link would be allowed to have maximum 2 ms latency, which is not in place today.

If with an event multiple microphones are used there is also a further requirement on the latency differences between the links as this may lead to acoustic holes (comb filtering) in spatial sound production or loss of synchronisation between audio and video production.

Availability of service

PMSE applications have high requirements in terms of availability of service. Availability should be 100%. In a high quality production loss of a wireless link, leading to interruptions of the audio link, called drop-outs, are not acceptable. In general no perceived interruption whatever root cause can be tolerated. As variations of received signal strength due to fading may easily reach 30 dB, typically a high margin and diversity gains are implemented on the link budget.

An event or performance cannot be repeated. Mostly these are unique events, so information would be lost totally. In other systems data can be repeated, which of course adds latency.

Robustness of transmission cannot be gained by wide temporal interleaving as this would introduce unacceptably large latency.

Mobility

Some artistic performances and ENG applications involve high speed by mobile terminals, like wireless microphones with singers on skates e.g. with Musicals Cats and Holiday on Ice or reports from cars. Therefore typically speeds up to 80 km/h have to be supported. It is not the case that PMSE doesn't involve mobility.

SNR operational conditions

RF SINR Operational conditions for analogue FM links are higher than for other systems. As the 20 kHz audio bandwidth is typically expanded to 200 kHz wide RF channels, there is only a 10 dB bandwidth expansion gain by FM. This means that audio SNR is only 10 dB better than the RF SNR. So if an non-companded audio SNR of 60 dB is demanded, the SINR at RF has to be 50 dB. For reference GSM could work successfully with 7…9 dB SINR and CDMA systems may also work with negative SINR.

Intermodulation

In PMSE deployments one may face not only strong receiver, but also strong transmitter intermodulation. If for example an artist carries a wireless microphone and an instrument transmitter or if two singers stand close with their wireless microphones, reverse intermodulation can happen, meaning that part of the transmitter power from one wireless microphone enters the output stages of the other wireless microphone. Intermodulations products will be generated due to non-lienar behaviour of the output stage. As the operational RF SINR values are typically much higher than in other systems, PMSE is more vulnerable to transmitter and receiver intermodulation. This is the reason why intermodulation products are carefully planned up to IM5 products.

Cognitive Properties

Scope

The following sections provide general definitions of terms, general concepts, and high-level functionalities to be implemented by a cognitive PMSE. Furthermore, the high-level implementation of a C-PMSE demonstrator is described.

Definition of Cognitive PMSE

A cognitive PMSE is a Cognitive Radio System (CRS) designed for the purpose and the specific requirements of PMSE applications. [Editorial note: Reference ECC Report 002 FM51]

The ITU definition of Cognitive Radio Systems (CRS) [refer to Report ITU-R SM.2152, (09/2009)] is as follows:

Definition	**Actions**
"A radio system employing technology that allows • the system to obtain knowledge of its operational and geographical environment, established policies and its internal state; • to dynamically and autonomously adjust its operational parameters and protocols according to its obtained knowledge in order to achieve predefined objectives ; • and to learn from the results obtained."	Orient, Observe Plan, Decide, Act Learn

Note: The implementations to obtain knowledge of its operational and geographical environment, and established policies (Orient, Observe) can include technology approaches such as geolocation database, sensing of the radio environment or cognitive pilot channels (CPC).

General description of cognitive functionality

Cognitive functionality includes at least following sequence of stages:

- Acquisition of context-awareness (Orient, Observe)
  - Gathering information about geo-location, radio spectrum environment, operational goals and parameters
  - Understanding and translating acquired information into suitable assessment criteria (e.g. rating of radio spectrum resources, definition of a suitable cost function for resource usage)
- Autonomous dynamic system reconfiguration (Plan, Decide, Act)
  - Planning and decision-making in order to achieve goals of operation, usually involving reasoned judgment of acquired knowledge and some optimization procedures
  - Implementation of decisions through reconfiguration and adaptation of operational parameters

Additional cognitive functionality may include learning from past actions and reoccurring situations. Learning functionality implies in general following system capabilities:

- Recognizing patterns of behaviour
- Evaluation of risks and prediction of future events

Concept of C-PMSE

In the light of the definition a cognitive PMSE, C-PMSE are able to acquire and use appropriate radio spectrum and autonomously avoid or minimise harmful interference while ensuring high audio quality by:

- obtaining knowledge about appropriate operating frequency ranges at the system's geographic location and a certain time
- measuring the radio link quality and/or sensing the radio environment
- switching the wireless audio links to (alternative) operating frequencies and adapting their link parameters
- learning from past system behaviour and events

For that, a minimum C-PMSE consists of:

- a wireless audio link with control link, accessible by a base station
- a base station, possibly with access to a sensing system and/or a geo-location database
- a mechanism to obtain knowledge about appropriate operating frequency ranges (e.g. by contacting the administration, by access to a suitable database)
- a mechanism to assess the wireless audio link quality or possible interferences (e.g. by a sensing system or internal measuring capabilities)

Implementation of BMWi C-PMSE demonstrator

BMWi C-PMSE demonstrator considers only professional wireless microphone systems with state of the art analogue transmission scheme (FM). Digital audio transmission schemes are not in the focus of the BMWi C-PMSE demonstrator.

BMWi C-PMSE demonstrator consists of three main blocks:

- C-PMSE containing the C-PMSE master including cognitive engine, and the wireless audio links
- Scanning subsystem (SCS) with scanning receivers (SCR) and scanning controller (SCC).
- Local Spectrum Portfolio Manager (LSPM) maintains the local available spectrum portfolio for operation.

Not the complete concept but a subset of its functionality is implemented in the BMWi C-PMSE platform. The implemented features are:

- Ask before talk
- Spectrum sensing (Listen before talk)
- Reaction on changes in spectrum environment and in transmission quality respectively.

Ask before talk

At start-up C-PMSE negotiates with a local spectrum portfolio manager (LSPM) and/or GLDB a spectrum range for operating at a certain time. Without negotiation C-PMSE shall not start wireless audio transmission.

With help of the LSPM it is possible to account for requirements to separate the useable spectrum range into different service classes, which offer different levels of transmission quality and spectrum allocation respectively.

Periodically C-PMSE has to renegotiate its operational spectrum ranges.

Spectrum sensing (Listen before talk)

The SCS is used for spectrum observation matters. It allows continuous sensing of the used spectrum range not only at system start-up but also during operation. To overcome hidden node and fading problems a grid of small, low cost scanning receivers (SCR) is employed.

Spectrum Rating

The spectrum rating process continuously translates measurement data of SCS into two assessment criteria:

risk: expressing the potential for getting interfered
quality: expressing the expected noise / interference level of free spectrum
expressing the measured signal-to-noise-ratio of used spectrum.

Reaction

During initialisation:

- C-PMSE rates the spectrum range provided by LSPM by means of measurement data coming from SCS to perform an initial frequency planning. The resulting frequency list is executed at C-PMSE operation start.

During operation:

- C-PMSE rates continuously the possible useable radio spectrum using measurement data from SCS. This includes by wireless audio links occupied and non-occupied radio spectrum.
- By wireless audio links occupied radio spectrum is rated by means of link quality indicator (LQI) data of each wireless audio link.
- The outcomes of rating processes can trigger related actions.

The Demonstrator in the BMWi C-PMSE Project

Scope

The following sections provide a detailed overview on the BMWi C-PMSE project and its demonstrator including architecture overview, elements, functionalities, and limits of the realized demonstrator. Furthermore, the interfaces to its LSPM and its distributed Scanning Subsystem (SCS) are provided as initial input for standardisation.

BMWi C-PMSE Project Overview

The C-PMSE project was started on April 1st, 2011 and will run in three phases for 32 month until November 30th, 2013.

The consortium of the BMWi C-PMSE project consists of five partners from industry, one research institute, and three universities.
Within the consortium Robert Bosch GmbH and Sennheiser electronic GmbH & Co. KG are representing the PMSE industry. The Institut für Rundfunktechnik GmbH (IRT), a research institute serving German, Austrian, and Swiss public broadcasters, represents the broadcasters as users of PMSE technology and the broadcasting services (like DVB-T) as primary user of radio spectrum in the UHF-TV bands. eesy-id GmbH is involved to develop sensor nodes, wiseSense GmbH for wireless coexistence and related standardization & regulation activities, and RFmondial GmbH develops monitoring software and data base infrastructures. The universities Friedrich-Alexander-Universität Erlangen-Nürnberg, Gottfried Wilhelm Leibniz Universität Hannover, and Ruhr Universität Bochum provide the practical and scientific expertise in electronics, signal processing, software defined radio, cognitive radio, radio resource management, signal classification, measurements, channel modelling, and link and system level simulation.

The C-PMSE project has two main objectives:

1. Setting up a research platform for lab and field trials, and
2. Driving standardization and regulation for cognitive PMSE systems.

Beside of the realization and setup of the lab and field trial platforms, the main goals include the development of all-necessary hardware and software components, the development and installation of a distributed scanning system with signal processing, network and data base infrastructure, and the verification of feasibility. Finally functional demonstrations and test operations on the lab and field trial platforms, which may include activities of the working group ETSI STF 386, will be performed. Coexistence investigations with other wireless services and devices, like white space devices, mobile communications, digital video broadcasting terrestrial (DVB-T), will be executed.
Standardisation and regulation activities of the project consider cognitive radio (CR)-enabled approaches for PMSE applications in worldwide regulatory frameworks. The BMWi C-PMSE project aims therefore, to provide appropriate and validated inputs for standardisations and frequency regulations.

Parts of the field trial platform will remain at Messe Berlin (fairground MBE) after the end of the project and is intended to be used for further field trials and follow up projects.

Architecture of BMWi C-PMSE Demonstrator

Figure **1** shows the block diagram of the C-PMSE demonstrator.

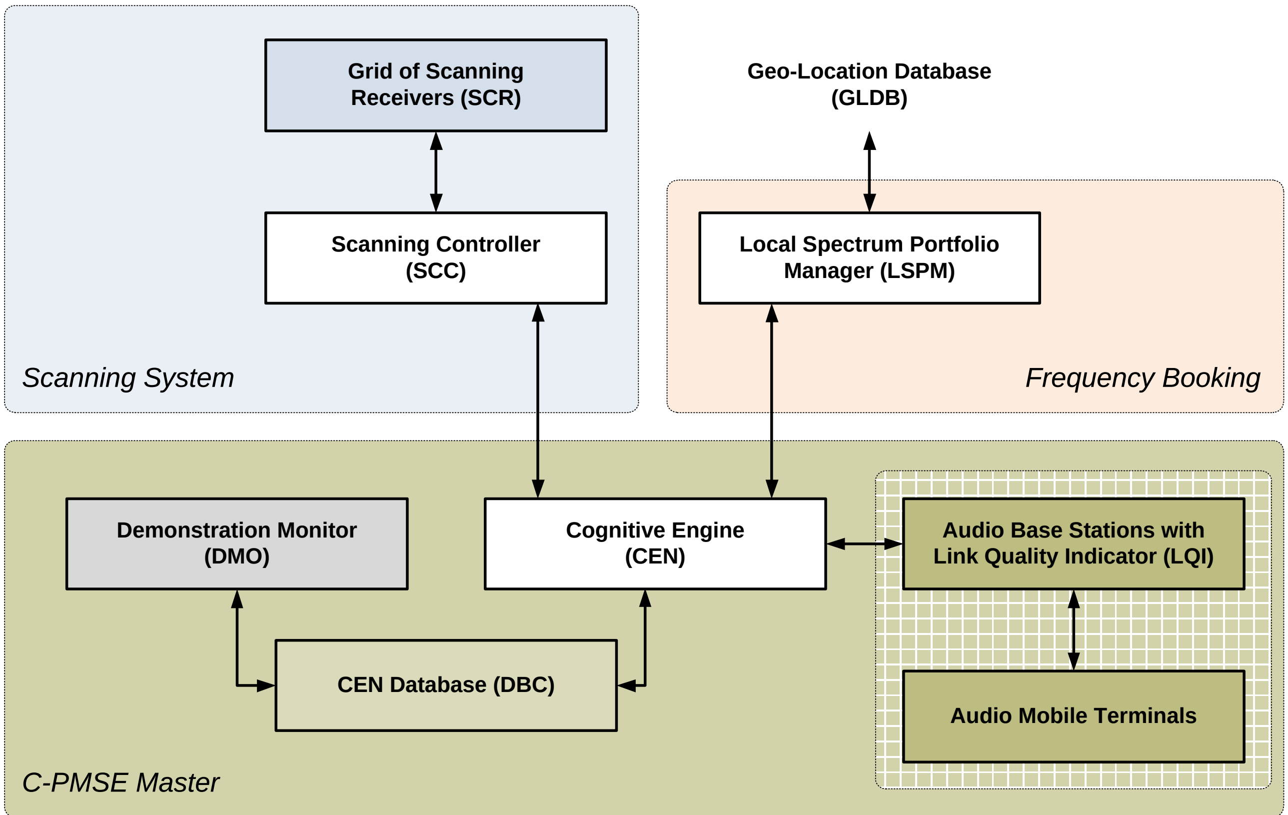


Figure 1: Block diagram of BMWi C-PMSE demonstrator

The three main blocks are:

- Local spectrum portfolio manager (LSPM) with interface to C-PMSE master and to the geo-location database (GLDB):
  - Lowest level of hierarchical GLDB
  - Task: Radio spectrum assignment to C-PMSE
- Scanning system (SCS):
  - Scanning grid with low cost scanning receivers (SCR)
  - Scanning controller (SCC)
  - Task: Continuous, and dedicated grid sensing of radio spectrum
- Cognitive PMSE (C-PMSE):
  - C-PMSE master with cognitive engine (CEN), internal database (DBC) and demonstration monitor (DMO)
  - Wireless audio links with one audio base station, one audio mobile terminal and one control channel per link.
  - Task: Maintaining high quality and availability of the wireless audio links

Elements of BMWi C-PMSE demonstrator

- Local Spectrum Portfolio Manager (LSPM)
    - LSPM is the project's realization of the lowest level of a geo-location based database (GLDB) hierarchy. It tells C-PMSE, which radio frequency ranges are available for operation. LSPM can also connect to GLDB maintained by IRT.
    - In TS 102800 LSPM is called frequency coordinator (FCO).

- Scanning System (SCS)
    - SCS comprises one Scanning Controller (SCC) and several Scanning Receivers (SCR). SCC is in charge of managing all SCR connected to it.
    - The Internal Database (DBS) within SCC is used for data exchange and act as a common interface within SCS to CEN of C-PMSE master.
    - Following a request from CEN, SCC schedules scanning jobs among its SCR, performs pre-processing (e.g. signal detection, parameter extraction) of data acquired and provides essential information to CEN. Allowing data pre-processing in SCC serves to distribute the computational load of the required signal processing and to significantly reduce the load on the interface between SCS and CEN.

- C-PMSE
    - Reconfigurable wireless audio links (audio base station + audio mobile terminal)
    - C-PMSE master

- C-PMSE master
    - C-PMSE master consists of a Cognitive Engine (CEN), an Internal Database (DBC), a Demonstration Monitor (DMO)
    - CEN constitutes the central control unit of the C-PMSE master and embodies the cognitive functionalities described in TDOC 205. CEN has the aim to guarantee interference-free high audio quality transmission of the reconfigurable wireless audio link.
    - Therefore,
        - it connects to LSPM in order to negotiate suitable radio frequency ranges for operation,
        - it continuously merges and analyses all information acquired via SCS with link quality indicators of the individual wireless audio links, and
        - it performs adequate dynamic resource allocation and transmit power control.
    - CEN is built up by different layers (see Figure 2), of which the higher layers are named CEN and the lower layers CENbase, which contains all time critical processes. CENbase is the equivalent to the Radio Resource Manager (RRM) depicted in TS 102800 without ASQ and AMCT. ASQ is not necessary in the current implementation anymore, because every system's reaction is based on the current rating of the given solutions independent on the kind of interference scenario. AMCT is not implemented, because supported wireless audio links are frequency modulated, which means, that frequency and power are adjustable only (FAT/PAT).

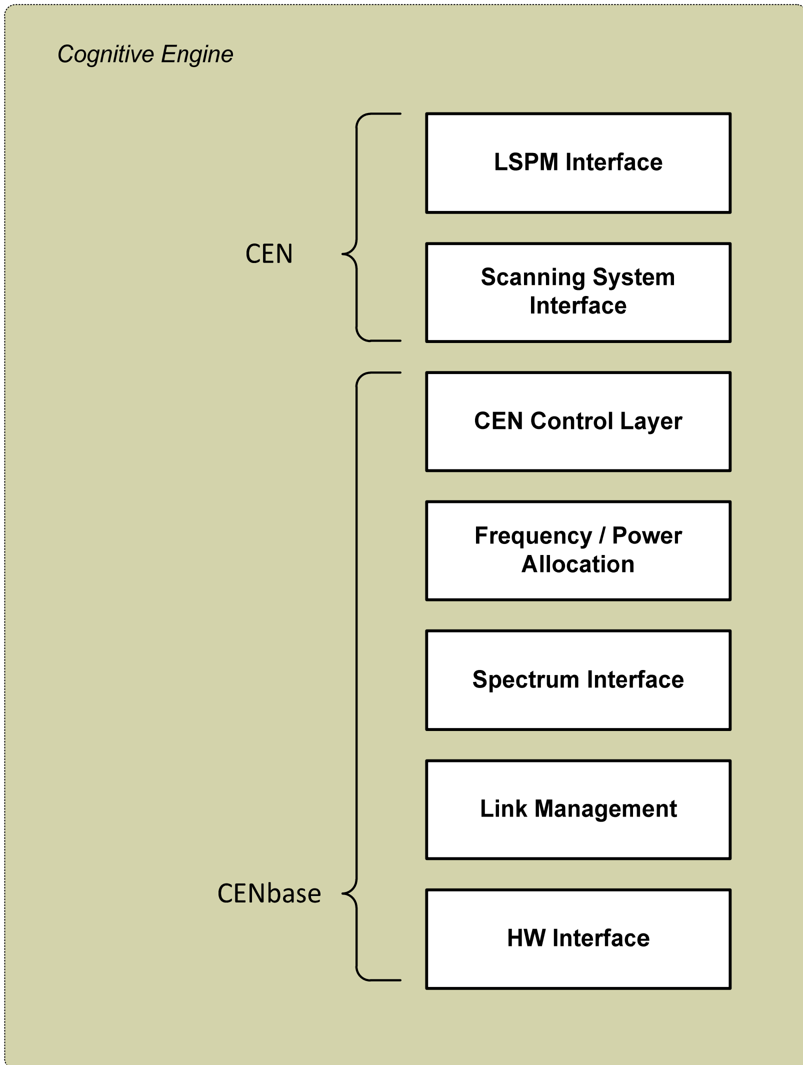


Figure 2: Layer model of cognitive engine

- The Internal Database (DBC) is used for data exchange and as a common interface for all available components within C-PMSE Master.
- DBC contains FAT/PAT, DAT, LAT, REM (see TS 102800) and the solution pool of the genetic algorithm

- DMO allows visualization, tracing, and control of the behaviour and status of C-PMSE master operation. It also provides advanced storage capabilities to store measurement traces and log files. It combines the functionality of the performance monitor (PMO) and the service level entry (SLE) described in TS 102800 and TR 102799 respectively. SLE is realized as a lookup-table read in at system start-up. SLE cannot be adjusted during operation.

- Reconfigurable wireless audio links (audio base station + audio mobile terminal)
    - Frequency agile, or
    - Transmit output power agile
    - Audio base station is equipped with link quality indicator functionality

Interfaces of realized Demonstrator

Two interfaces are realized:

- sci: interface between CEN and SCC
- fci: interface between CEN and LSPM.

Original fci descript in TS 102800 is between RRM and FCO. Now it is rearranged and placed between CEN and LSPM. It is shifted from RRM (now CENbase) to higher layer CEN due to its less time critical character.

Original cpi (interface between RRMs of collocated C-PMSE) is omitted in the realization. Every inter C-PMSE communication shall be done via LSPM.

A more detailed view on the interfaces can be found in TDOC 213.

Limits of realized Demonstrator

There are several limits in the implementation of the BMWi C-PMSE demonstrator:

- Control plane is limited to a maximum of seven links
- LQI measurement hardware supports a maximum of eight links
- Six frequency agile wireless microphones are available
- Four RF output power agile microphones are available
- CEN handles either reconfigurable frequency or reconfigurable output power mode but not both simultaneously
- HW Management layer of CENbase supports Sennheiser or Electro-Voice products only
- DBC causes time delay when acquiring measurement data from a high number of SCR
- CEN expects technology and feature homogenous wireless audio links
- FM wireless audio links need long time for settling after frequency switching caused by the very low phase noise PLL
- Frequency range of frequency agile wireless audio links is limited from 718 to 790 MHz
- Output power range of transmit power controlled links is limited to approx. 20dB
- SLE is fixed during operation

General concept of BMWi C-PMSE is open for more links and frequency resources

Example: Demonstration Cases of the BMWi C-PMSE Platform

Scope

The following sections provide detailed descriptions of demonstration cases employed by the BMWi C-PMSE project to showcase some features of its demonstrator.

Description of demonstration cases

The demonstrations cases include

a) Automatic setup mode of BMWi C-PMSE, and
b) Operational modes for automatic and user interactive operation of BMWi C-PMSE.

The demonstration cases of BMWi C-PMSE highlight frequency agile or RF output power agile actions of BMWi C-PMSE under different coexistence conditions, and/or especially highlight features.

Automatic Setup Mode

The goal of this demonstration case is to show the automatic process of BMWi C-PMSE setup.
BMWi C-PMSE is the first PMSE system offering a totally automated setup procedure.

The automatic setup process is composed of the following steps:

- Registration of wireless audio links in the DBC
  - This process is currently manual and represents a limitation of the demonstrator
- Negotiation of available frequencies with LSPM [Editorial Note: Reference to Tdoc 211/213]
  - The result of this negotiation process is a set of frequency ranges (Note: this set could be empty) available for C-PMSE operation at the event location.
- Scanning of the assigned frequency ranges making use of SCS
- CEN rates the spectrum data coming from the SCS in terms of two assessment criteria: Quality and Risk
- CEN starts initial frequency planning taking into account
  - Number of managed wireless audio links
  - Current spectrum conditions in terms of quality and risk metrics [Note: Can be visualised in the DMO]
- CEN transfers the wireless audio link parameters (i.e. frequencies) to the HW (wireless microphones) for execution.
- CEN registers the wireless audio link frequencies by LSPM. Registration will be done at event location for a certain time.

Operational Mode (Automatic / Interactive)

In general two different parameters of the wireless audio links are reconfigurable during operation which leads to two demonstration sets:

- demonstration of frequency agile behaviour
- demonstration of RF output power agile behaviour.

Both are shown in two different operational modes:

- automatic mode: system's reaction is done without user interaction
- interactive mode: every system's reaction must be confirmed by the user and / or can be initiated by him, additionally the user has the choice to accept recommendations / solutions from the CEN or to modify / renew it.

SCS monitors the useable radio spectrum (granted by LSPM) continuously while CEN computes convenient solutions (radio frequency or transmit power allocations) to fit on that spectrum. The spectrum rating process continuously translates scanning data into two assessment Criteria – Quality, Risk [Ref Tdoc 205])- which are then used to evaluate the suitability of the present solution and to trigger action if environmental changes occur.

Frequency agile behaviour

The idea of radio frequency agile behaviour is to mitigate interference by switching from an interfered frequency to a less interfered frequency during operation.
An interferer is switched on inside the operational frequency range of C-PMSE. This causes a decrease of Quality or an increase of Risk of one or several wireless audio links of C-PMSE.

- ### Automatic mode

In automatic mode CEN takes the best possible solution – that with the highest fitness value [Ref. Tdoc205]- and executes it immediately, i.e., all interfered wireless audio links are shifted in frequency.

- ### Interactive mode

In interactive mode CEN proposes the user a list of alternative solutions to improve the interference situation. CEN waits for user input. The user has now the opportunity to accept one of the proposed solutions or even to combine and modify them.. After getting user input CEN transfers the selected solution to the wireless audio links for execution and restarts computation of solutions..

Transmit power agile behaviour

Transmit power agile behaviour is used to mitigate interference by adating transmit power.. Two demonstration cases are covered:

- Interference generated by a white space device
- Interference caused by self generated intermodulation products

Automatic mode

The transmit power control algorithm is deterministic, based on the Quality assessment metric. The transmit power of each C-PMSE audio mobile terminal will be adjusted during operation as to keep the optimal signal-to-interference ratio. Minimizing the output power of each audio mobile terminal is desired in order to keep the interference levels as low as possible.

If a white space device causes interference, increasing the transmit power will help to mitigate interference.

If interference is caused by self generated intermodulation products, decreasing the transmit power of the audio mobile terminals generating the intermodulation will help to mitigate interference.

TDoc 208 - Demo Cases Beyond C-PMSE Project

The TS (ETSI Technical Specification) is the preferred deliverable when the document contains normative provisions and short time to "market", validation and maintenance are essential.

A TS may later be converted to an ES or an EN, or be used to publish the contents of a draft ES being sent for vote or a draft EN being sent for Public Enquiry or vote.

The scope shall always be clause 1 of each ETSI deliverable and shall start on a new page (more details can be found in clause 11 of the EDRs).

No text block identified. Forms of expression such as the following should be used:

Summary goes here

TOC

Heterogeneous C-PMSE operation

Using the same frequency resources / databases

In a large event, it is possible that multiple C-PMSE systems might be in operation. The transmission range of the associated PMSE links may be partially or completely overlapping. The most critical case occurs when these co-located systems share the same frequency resources, but they might also operate in completely different bands; e.g. UHF and 1.8 GHz. However, even if C-PMSE systems are using separate frequency resources, the possibility of interactions should still be considered.

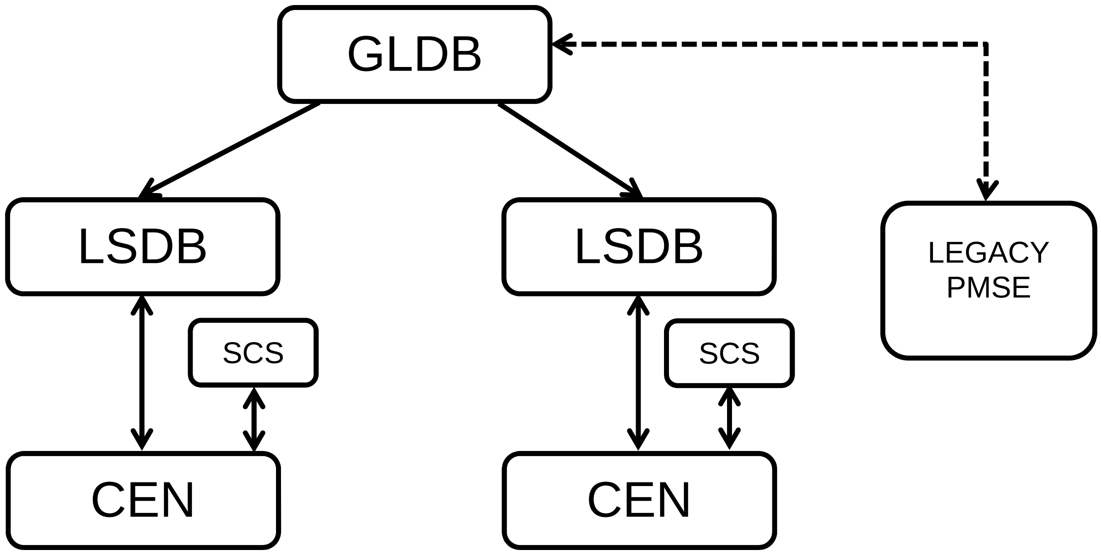


Figure (a)

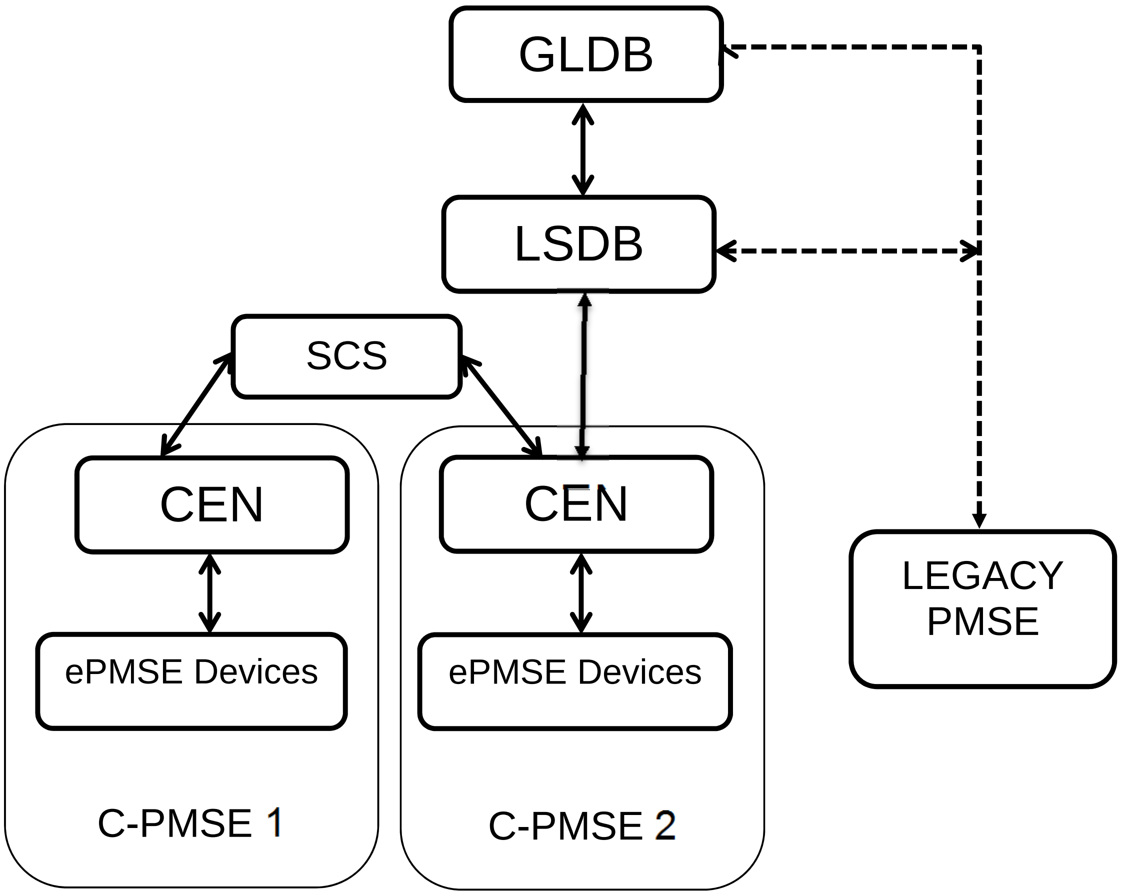

GLDB
LSDB
SCS
CEN
ePMSE Devices
C-PMSE 1
CEN
ePMSE Devices
C-PMSE 2
LEGACY
PMSE

Figure (b)

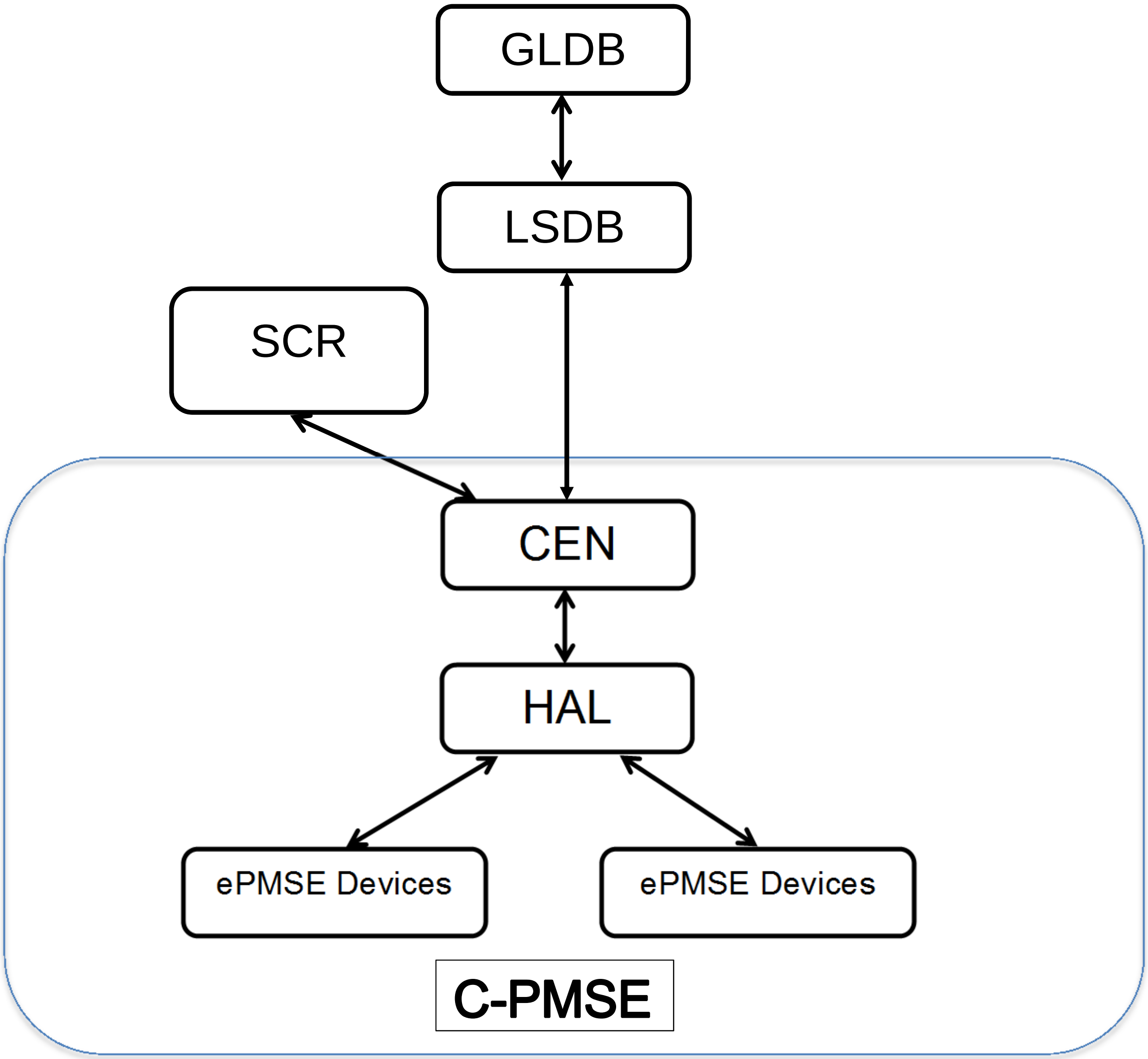


Figure (c)

Co-located C-PMSE systems are interconnected at various levels. It is important to consider what type(s) of interfaces and data formats will need to be supported. It is assumed that interconnected systems would use the same Information Acquistion C-PMSE-IA.

But if these systems are not interconnected, they might or might not use the same database. However, if a local database is available, it is desirable that all nearby systems access that database, because it would have more specific intormation than a national database. Information from the local database should be used to inform the configuration of these C-PMSE systems.

Interconnected with legacy PMSE systems

For the foreseeable future, it is likely that C-PMSE systems will sometimes be operated together with conventional (i.e., non-cognitive) PMSE systems. These legacy systems will in most cases only support a limited subset of C-PMSE [No-CEN, but cognitive features] features. It is important to consider what benefits can be obtained, if they are interconnected with such systems and how such interconnections can be accomplished; i.e., what type(s) of interfaces and data formats need to be supported. In the limiting case, information about co-located legacy systmems might have to be entered manually into the LSDB.

There are several interfaces at legacy PMSE systems like an Ethernet connection with information about the used frequencies, transmitter power level and the keep-free-bandwidth. But this knowledge is in general only possible within one manufacturer. It could be advantageous, if a C-PMSE system allows manually to input any kind of information from a legacy device.

Capability of location awareness (e.g. GPS)

In order for a C-PMSE system to operate in fully-automatic mode, it will need to have location awareness capability. Otherwise, the operator must enter this information manually. Many consumer devices now have satellite-based geolocation capability built-in. However, PMSE systems are often installed indoors where satellite signals cannot be received reliably, if at all. Therefore, a different kind of geolocation technology is needed. Work is presently ongoing in this area. Cellular and other currently available geolocation technologies do not yield sufficient accuracy (e.g., within +/-50 meters) for PMSE applications.

Coexistence of various types PMSE systems e.g. Video Cameras, IEM (In Ear Monitor)

It is often the case that audio PMSE devices must share spectrum with other kinds of PMSE systems, such as In Ear Monitors (IEM), Wireless Intercoms, and Video Cameras. These systems have very different spectrum requirements, transmission duty cycles, Signal-to-Noise requirements, interference potential, etc. It is desirable that a C-PMSE system has the capability to manage coexistence between these systems when they are sharing the same or nearby frequency resources. To do this, the C-PMSE system must have knowledge of the parameters of these systems. It might be helpful, if wideband devices like video cameras use different frequency ranges to avoid interference with C-PMSE systems.

Extension to frequency control, power control, adaptive modulation and coding (AMC)

It is possible to include the capability within a C-PMSE system to dynamically control the operating frequency and output power of its component C-PMSE transmitters for the purpose of avoiding interference with its own or other PMSE systems in use locally or to improve spectrum use efficiency. Such capability requires the C-PMSE system to incorporate a control link. Further, the modulation and coding scheme could also be changed adaptively to match the requirements of the particular audio program being carried over the link.

Possibility of interference and overlapping

Coexistence of PMSE and other kinds of systems such as White Space Devices or adjacent band LTE

In next gereration C-PMSE devices from one or more manufacturers will occur at the same location and at the same time. This will lead to sharing of the valuable frequency resources between devices in use. Therefore the C-PMSE devices preferably should be synchronized, i.e. they should exchange or at least show their internal frequency lists. This can be achieved via a common database (LSDB, local data base or even a GLDB). If a synchronization between several C-PMSE systems is not wanted or possible, each C-PMSE device will be regarded as a potential interferer to the other systems.

To avoid the interference from one C-PMSE system to another, the allocation of frequencies or audio links should be done manually beforehand. Also some frequencies could be manually blocked to allow the operation of C-PMSE systems with higher priority. This method is known as Safe Harbour Channel concept.

If one or more C-PMSE systems are used together with White Space Devices mechanisms like spectrum sensing, beacon transmitting or even the connection to geolocation databases are imaginable. A WSD is probably limited by the maximum transmitting power of one Watt and the allowed bandwidth. If a certain WDS is detected by a C-PMSE system it is tracked and regarded as an interferer to the C-PMSE System. This is the case, if a specific power and bandwith threshold is exceeded. Transient WDS in time and / or in space should also be detected by a C-PMSE system. It is not recommended to notify a database, if a WSD occurs beside a C-PMSE system.

During the migration process towards a fully automatic and autonomous C-PMSE system a mixture of analogue and digital modules within one single equipment and also between different vendors will appear. In addition the performance and parameter setting like the intermodulation sensitivity or frequency spacing might be diverging. Therefore the interfaces and formats have to be defined to interconnect the C-PMSE devices from various vendors.

The coming transmission systems (i.e. LTE) will be more frequency agile and variable in their modulation and coding schemes. Also the symbol duration as well as the duty cycle will increase. Therefore the requirements concerning the behaviour of a future C-PMSE device will rise. A higher flexibility, a faster and a more complex processing within the C-PMSE device will be necessary.

Alignment of different databases (nationally controlled)

Suggestions for a standardised interface between C-PMSE systems and nationally designated databases

To standardize an international format to exchange information between national authorities and local or temporary databases the IETF PAWS group proposes a specification called “Protocol to Access White-Space Databases”. It seems appropriate to use this specification rather than to invent a new protocol. Preferably all interactions between the LSDB and the CEN should also employ this protocol. For this purpose only a small subset of the PAWS is required. For the commutation of data on international level between regulatory authorities the full range of the PAWS should be utilized.

Fully automatic operation without manual intervention or setup

A C-PMSE system may support semi-automatic or fully automatic operation. In this case, the following services must be provided:

- Location awareness, supported by geolocation or another service, to an accuracy of +/- 50m
- Interconnection with a geolocation data base (GLDB)
- Interconnection with other local C-PMSE systems, (mandatory if the operational areas overlap)

Even in the case of fully-automatic operation, some options must still be chosen by the user, as follows:

- The number and type of PMSE transmitters (e.g., body-pack transmitters and microphones, hand held transmitters and microphones, in ear monitors, etc.)
- The operational area(s) for the C-PMSE system
- The time period(s) during which operation will be required

Document history		
<Version>	<Date>	<Milestone>
V0.1	21-02-2013	Initial Draft by Clemens and Edgar
V0.5	21-02-2013	Draft after discussion in the plenary
V0.9	18-09-2013	Draft after meting in Eppingen
V1.0	10-12-2013	Draft during meeting in Erlangen
V1.6	11-12-2013	End of Meeting in Erlangen

TDoc 210 – Safety of Software

1. Software, Firmware and User Access Restrictions

1.1 Definition

Software, Firmware and User Access Restrictions are those measures which are intended to prevent changes which could adversely impact the compliance of the C-PMSE with the requirements in the present document.

PMSE and C-PMSE systems working on ‘tuning ranges’, i.e. RF output power, frequency and RF bandwidth are parameters, which could be changed by the user as allowed by regional regulations.

Access to software and firmware is an essential tool for PMSE and C-PMSE.

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4.2.9.2 Requirement

The equipment shall not allow the user to have access to hardware or software settings that relate to the exchange of the parameters communicated between a LSDB and a Geolocation DB.

The equipment shall not allow the user to have access to any hardware or software settings that adversely impact the compliance of the C-PMSE with the requirements in the present document.

The equipment shall not accept the installation of software which can change the compliance of that equipment with the requirements in the present document.

Manufacturers who provide their software or firmware as open source code shall prevent modified software from having any impact on the compliance of the equipment with the requirements in the present document.

The configuration of equipment, and as such also the compliance with the requirements in the present document, shall not be made dependent of the correct selection by the user of the appropriate country of operation, or any other setting to be input by the end user.

4.2.9.3 Conformance

The manufacturer shall declare the measures it has taken to comply with the above requirements (see list of declared parameters in clause 5.3.1).

1 TDoc 211 – Recommended Test Procedures for Individual Elements of SCS, LSDB and C-PMSE

The TS (ETSI Technical Specification) is the preferred deliverable when the document contains normative provisions and short time to "market", validation and maintenance are essential.

A TS may later be converted to an ES or an EN, or be used to publish the contents of a draft ES being sent for vote or a draft EN being sent for Public Enquiry or vote.

The scope shall always be clause 1 of each ETSI deliverable and shall start on a new page (more details can be found in clause 11 of the EDRs).

No text block identified. Forms of expression such as the following should be used:

The present document …

EXAMPLE: The present document provides the necessary adaptions to the endorsed document.

*The Scope **shall not** contain requirements.*

Document history		
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A few examples:

Document history		
V1.1.1	April 2001	Publication
V1.3.1	June 2011	Pre-processed by the ETSI Secretariat ***editHelp!*** e-mail: mailto:edithelp@etsi.org

Comment:

This TR can not place essential requirements to put product on the market (like EN300422). We provide fundamental requirements and testing recommendations.

4 Technical Requirement Specification

4.1 Scanning System (SCS)

Definition:

A Scanning System (SCS) is an component of the C-PMSE-IA.

Note: The C-PMSE-IA can be part of a C-PMSE (single device including all).

The Scanning System (SCS) is composed of one or more Scanning Receivers (SCR) with Scanning Antennas (SCA) and one Scanning Controller (SCC).

Multiple SCR can be distributed within areas of interest.

4.1.1 Scanning Antenna (SCA)

4.1.1.1 Definition

A Scanning Antenna (SCA) is an integral or non-integral antenna connected to the Scanning Receiver (SCR). SCA may include antenna systems, e.g. multi-antenna systems, beamforming systems, or Multi-Beam.

4.1.1.2 Requirement

The SCA should be built for a radio frequency range including the radio frequencies of interest.

Further information on the antenna should be available for testing and calibration purposes.

4.1.1.3 Conformance

Requirements shall be fulfilled by the manufacturer via product specification and user manual.

4.1.2 Scanning Receiver (SCR)

4.1.2.1 Definition

A SCR is a device able to acquire measurements or information on the radio spectrum and its usage.

A SCR may have integral or non-integral SCA.

4.1.2.2 Requirement

The Scanning Receiver (SCR) shall be built for a radio frequency range including the radio frequencies of interest.

Calibration information on the SCR shall be available by the manufacturer.

The SCR shall provide an interface and protocol supported by SCC.

4.1.2.3 Conformance

Requirements shall be fulfilled by the manufacturer via product specification and user manual.

4.1.3 Scanning Controller (SCC)

4.1.3.1 Definition

A SCC is built to cope with one or multiple SCR using a protocol for control and data exchange.

Note: A multitude of standardized or vendor-specific protocols could be supported by SCC.

A SCC is built to cope with one or multiple C-PMSE using a protocol for control and data exchange.

4.1.3.2 Requirement

The interface and protocol as specified in Tdoc 213 (sci) shall be used for communications among SCC and C-PMSE, if the sci is available to attach shared infrastructure (Define: Shared infrastructure, means C-PMSE IA can be shared among multiple C-PMSE, regardless of mobile, nomadic or fixed use).

4.1.3.3 Conformance

Adequate protocol tests shall be used to verify the communications between SCC and C-PMSE, if sci is available.

(Editorial Note: Requirement for EN300422)

4.2 Local Spectrum Database (LSDB)

4.2.1 Definition

The LSDB is part of the C-PMSE-IA.

The LSDB holds information on the frequencies locally allowed for usage by C-PMSE.

Note: There are several ways to provide this information:

a) Manual license entering in case of written frequency grants by NRA.
b) Automatic license entering via some kind of GLDB operated by or on behalf of an NRA.
c) Manual or automatic entering of frequency bands allowing license exempt operation by C-PMSE.

In addition, the LSDB can be used to share information on spectrum usage among co-located C-PMSE.

4.2.2 Requirement

The LSDB shall provide an interface and protocol corresponding to TDOC 213 to interact with C-PMSE, if the LSDB is part of shared infrastructure (lsi).

Note: The LSDB should also support corresponding interfaces and protocols to frequency information databases/GLDB. This note gets an requirement, if access to GLDB is required by NRA.

4.2.3 Conformance

a) It is recommend to use an adequate protocol tester to verify the communications between LSDB and frequency information databases/GLDB.
b) It is mandatory to test the communication between LSDB and C-PMSE, if lsi is available.

Note: STF386 suggests to make lsi mandatory.

4.3 C-PMSE

4.3.1 Definition

A C-PMSE consists of a Cognitive Engine (CEN) and ePMSE devices.

A Performance Monitor (PMO) could be included.

The ePMSE devices are dynamically adjustable concerning their radio link parameters and shall report Link Quality Indicator (LQI).

Note: Radio link parameters can include: RF carrier frequency, RF output power, Occupied RF bandwidth, Adaptive Modulation and Coding

4.3.2 Requirements

A C-PMSE shall provide lsi and/or sci, if the C-PMSE can be attached to shared infrastructure.

4.3.3 Conformance

a) It is mandatory to test the communication between C-PMSE-IA and C-PMSE, if lsi and/or sci is available.

4.4 Cognitive Engine (CEN)

4.4.1 Definition

A Cognitive Engine (CEN) is a entity that is part of C-PMSE.

A CEN performs tasks required for information rating, decision making, and optional learning based on C-PMSE-IA input and PMSE device information.

A CEN is capable of configuring radio link parameters parameters to be used by attached ePMSE devices according to its decisions. A CEN can communicate with ePMSE devices via a Hardware Abstraction Layer (HAL) as specified in TDOC217 for their dynamic management.

4.4.2 Requirements

The radio link parameters defined by CEN shall not generate harmful interference to other systems.

Note: The operation of CEN should lead to a time stable and efficient utilization of the radio spectrum.

A CEN shall employ the Hardware Abstraction Layer (HAL) as specified in TDOC217 for dynamic management of ePMSE devices, if the CEN is shared for the purpose of different (e.g. multi-vendor) PMSE device support.

4.4.3 Conformance

a) Radio link parameter sets definable by CEN shall excludes sets locally disallowed for usage by C-PMSE systems based on LSDB information.
b) Radio link parameters sets definable by CEN shall excludes sets, which include frequencies already in-use by other based on LSDB information.
c) It is recommend to use adequate protocol tests to verify the communications between CEN and C-PMSE-IA, ePMSE devices via HAL.

5 Testing for compliance with technical requirements

Conditions for testing

Essential test suites

Test SCS <> Vendor (C-PMSE<> Test Radios)

Test LSDB <> Vendor (C-PMSE <> Test Radios)

5.1 Test suites SCS

On sci interfaces

5.2 Test suites LSDB

On lsi interface

5.3 Test suites C-PMSE

Tests showing that the C-PMSE follow LSDB restrictions on operational frequency range.

5.3.0 Test-LSDB is not available or deactivated => No transmission by DUT

5.3.1 Test-LSDB disallow all frequencies => No transmission by DUT

5.3.2 Test-LSDB allow a specific frequency range supported by DUT

Frequency range randomly drawn between the minimum and maximum frequencies supported by DUT. Repeated N times => No transmission of DUT outside allowed frequency range

5.3.3 Test-LSDB disallow an before allowed frequency range => DUT has to stop transmission in the disallowed part within N seconds as required by NRA.

Tests showing that the C-PMSE shows dynamic reaction

Test-LSDB allowed frequency range is N x 8 MHz wide, where N is an integer equal or greater than 1.

N is chosen in minimum so that all ePMSE links can be placed successfully.

C-PMSE has dynamic frequency selection capability active.

5.3.4 Placing narrowband interferer (e.g. PMSE like signal) on 1 and step-wise up to 3 of the carrier frequencies in use by the ePMSE links. Random placement of interferer to carrier frequencies. Power of interferer as maximum allowed RF output power for ePMSE links. LQI TEST, PMSE like

DUT adjusts frequency utilization and there are no transmissions outside Test-LSDB allowed frequency range.

5.3.5 Placing noise signal occupying 8 MHz bandwidth covering at least one carrier frequency in use by the ePMSE links. Random placement of interferer to carrier frequencies. Spectral Power Density of the interferer is equal to the maximum RF output power of ePMSE links. LQI TEST, WSD like

DUT adjusts frequency utilization and there are no transmissions outside Test-LSDB allowed frequency range.

C-PMSE has dynamic RF output power control capability active.

No test required, because no effect on frequency selection.

Terminology on spectrum use (TDOC212)

Overview

For performing an optimization in terms of spectrum use, it is important to have a clear understanding of the metrics to be improved. In the following various metrics are presented. As there is also a lot of confusion in the definition of the term “spectral efficiency” the terminology is revisited here.

Definitions

Spectral efficiency of a point to point connection

The term “spectral efficiency of a P2P connection” describes the properties of a transmission scheme for a point-to-point link. It reflects the number of bits transported per second within a given bandwidth. It is measured as bit/s/Hz. It can be increased by several options:

a) Increasing the order of modulation, e.g. from QPSK to 256 QAM.

b) Appliying Source coding. With digital transmission e.g. MP3 could be used to reduce the amount of data to be transmitted. With analogue transmission an analogue compander reduces the dynamic range and by that also is a way of increasing spectral efficiency. Source coding is not only applicable to digital transmission, it is also applicable to analogue transmission.

c) MIMO. This means multiple antennas at the transmitter and multiple antennas at the receiver. If the propagation channel offers a lot of reflections, the spectral efficiency more or less scales linearly with the number of antennas.

Spectral efficiency of a wireless communication system

The term “Spectral efficiency of a wireless communication system” describes the number of bits transported within a second and within a given bandwidth summed over all users normalized to served area. It is measured as bit/s/Hz/km^2 . It therefore reflects an aggregation over all users, thus multiple links, versus above definition which reflects only one link.

This spectral efficiency of a wireless communication system can be increased by smaller cells, i.e. smaller cell radius equivalent to more dense placing of communication nodes. Femto basestations with cellular networks are a good example for this approach.

Efficiency of spectrum use, sometimes also called short “spectral efficiency”

The term “Efficiency of spectrum use” describes the number of bits transported within a second and within a given bandwidth summed over all users normalized to area regardless what communication system the link belongs to. It is measured as: bit/s/Hz/km^2. It therefore reflects an aggregation over all users and all communication systems that share a spectrum.

It can be increased by implementation of co-primary and secondary systems, that make use of resources actually not in use by primary systems. So it is an opportunistic access by the secondary users.

As sometimes the “efficiency of spectrum use” is also named spectral efficiency, a conflict with the first definition arises. Therefore it should be avoided.

Objective in the context of a C-PMSE system

The objective with running a C-PMSE plus infrastructure is to increase the metric “efficiency of spectrum use”. This optimization is different from the activities on digitizing PMSE which mainly is related to the first definition “spectral efficiency" of the individual PMSE link. A C-PMSE system makes use of unused spectrum pieces for transmission, while still ensuring a high quality audio link at high availability level (no drop-outs).

Spectral efficiency of a PMSE link

There is large expectation that digitizing PMSE would increase "spectral efficiency" per se. This is not the case. Instead digital transmission implies additional overhead by e.g. signalling and channel training.

Spectral efficiency increase is not the primary scope of a C-PMSE system, but ensuring high quality, robustness and availability of PMSE links.

1 TDoc 213 – Generalized architecture & Interfaces

The TS (ETSI Technical Specification) is the preferred deliverable when the document contains normative provisions and short time to "market", validation and maintenance are essential.

A TS may later be converted to an ES or an EN, or be used to publish the contents of a draft ES being sent for vote or a draft EN being sent for Public Enquiry or vote.

The scope shall always be clause 1 of each ETSI deliverable and shall start on a new page (more details can be found in clause 11 of the EDRs).

No text block identified. Forms of expression such as the following should be used:

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EXAMPLE: The present document provides the necessary adaptions to the endorsed document.

*The Scope **shall not** contain requirements.*

Document history		
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A few examples:

Document history		
V1.1.1	April 2001	Publication
V1.3.1	June 2011	Pre-processed by the ETSI Secretariat ***editHelp!*** e-mail: mailto:edithelp@etsi.org

This section proposes a generalized architecture of the C-PMSE system. It describes the interfaces between C-PMSE and Local Spectrum Portfolio Management (LSDB), and between C-PMSE and Scanning System (SCS), which might be deployed as shared local infrastructure by multiple C-PMSE systems.

Generalized C-PMSE system architecture

Figure tbd depicts the a generalized C-PMSE system architecture.

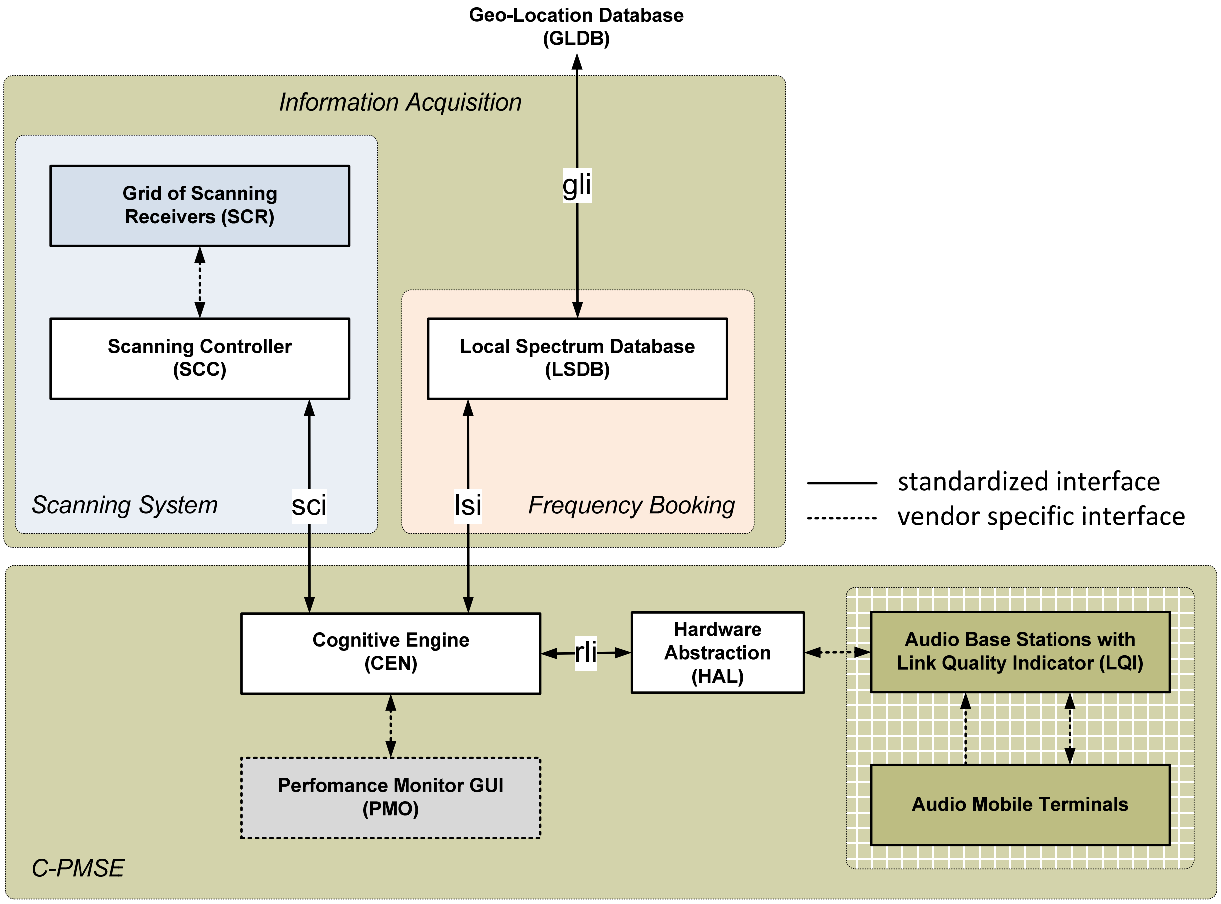

Figure 1: Generalized C-PMSE system architecture.

Functionality of SCS

The SCS consist of one SCC and one or more SCRs connected to the SCC. With the help of the connected SCRs the SCC generates a radio environment map which is power over frequency and time of the SCS installation location. This location might be divided into multiple zones. For each zone a separate radio environment map is generated. The SCC is connected to the CEN over the sci interface. The SCC provides the radio environment map of one or more zones upon request of the CEN. Optional features of the SCS include classification or localization capabilities.

Furthermore, the SCC delivers information about capabilities, location and zone configuration of the SCS to the CEN.

Functionality of LSDB

The LSDB is a database which contains a list of regional usable frequencies/frequency ranges for PMSE devices. The list is entered manually or could be granted from the GLDB automatically. The LSDB delivers the list of available frequencies to a connected C-PMSE upon request.

As an optional feature the LSDB contains a list of the currently used frequencies. Therefore, each connected C-PMSE can deliver its current link allocation to the LSDB. The LSDB distributes the list of the used frequencies to all connected C-PMSEs. There is no guarantee that the list of used frequencies is complete or consistent.

Functionality of C-PMSE

Tbd.

Interfaces

Scanning Interface (sci)

The interconnection of the Scanning System (SCS) and one or more C-PMSE is realized with the Scanning Interface (sci) based on Ethernet and TCP/IP. Via sci *scanning commands* from C-PMSE towards SCS as well as *scanning reports* from SCS towards C-PMSE are transported.

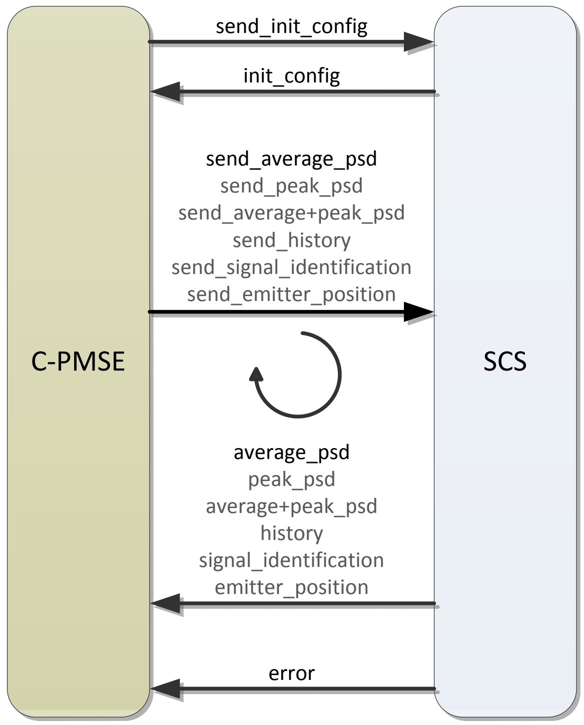

Figure 2: sci communication.

Scanning Commands & Reports

Scanning commands basically contain requests on the power spectral density and signal identification information for a certain frequency range. **Error! Reference source not found.** summarises all *scanning commands* that are necessary for a basic operation of SCS. **Error! Reference source not found.** summarises all *scanning reports* corresponding to **Error! Reference source not found.**.

Scanning Command	Parameters
‘send_init_config’ (M)	-
‘send_average_psd’ (M)	*f_start* [MHz] *f_stop* [MHz] *f_res* [kHz] *avg_nmb* [-] *zone* [-,-,...,-]

'send_peak_psd' (O)	*f_start* [MHz] *f_stop* [MHz] *f_res* [kHz] *zone* [-,-,...,-]
'send_average+peak_psd' (O)	*f_start* [MHz] *f_stop* [MHz] *f_res* [kHz] *avg_nmb* [-] *zone* [-,-,...,-]
'send_history' (O)	*f_start* [MHz] *f_stop* [MHz] *f_res* [kHz] *zone* [-,-,...,-]
'send_signal_identification' (O)	*f_center* [MHz] *bw* [kHz] *zone* [-,-,...,-]
'send_emitter_position' (O)	*f_center* [MHz] *bw* [kHz] *zone* [-,-,...,-]

Table 1: List of sci commands and its parameters

Command – 'send_init_config'

A 'send_init_config' *command* includes no parameters. This mandatory *command* requests the initial configuration of the SCS as part of the 'init_config' *report*.

Scanning Command – 'send_average_psd'

A 'send_average_psd' *scanning command* includes the start frequency *f_start*, the stop frequency *f_stop* - both in MHz, the frequency resolution *f_res* in kHz with a typical value of 25 kHz, the number of average cycles *avg_nmb* and a *zone* vector as parameters. This mandatory *scanning command* requests the average power spectral density for a certain frequency range and resolution as part of the 'average_psd' *scanning report*.

Scanning Command – 'send_peak_psd'

A 'send_peak_psd' *scanning command* includes the start frequency *f_start*, the stop frequency *f_stop* - both in MHz, the frequency resolution *f_res* in kHz with a typical value of 25 kHz and a *zone* vector as parameter. This optional *scanning command* requests the peak power spectral density for a certain frequency range and resolution as part of the 'peak_psd' *scanning report*.

Scanning Command – ‘send_average+peak_psd’

A ‘send_average+peak_psd’ *scanning command* includes the start frequency *f_start*, the stop frequency *f_stop* - both in MHz, the frequency resolution *f_res* in kHz with a typical value of 25 kHz, the number of average cycles *avg_nmb* and a *zone* vector as parameters. This optional *scanning command* requests the average as well as peak power spectral density for a certain frequency range and resolution as part of the ‘average+peak_psd’ *scanning report*.

Command – ‘send_history’

A ‘send_history’ *command* includes the start frequency *f_start*, the stop frequency *f_stop* - both in MHz, the frequency resolution *f_res* in kHz with a typical value of 25 kHz and a *zone* vector as parameters. This optional *command* requests the SCS history for a certain frequency range and resolution as part of the ‘history’ *report*.

Scanning Command – ‘send_signal_identification’

A ‘send_signal_identification’ *scanning command* includes the center frequency *f_center* in MHz, the bandwidth *bw* in kHz and a *zone* vector as parameters. This optional *scanning command* requests the signal identification inside of a certain frequency range as part of the ‘signal_identification’ *scanning report*.init

Scanning Command – ‘send_emitter_position’

A ‘send_emitter_position’ *scanning command* includes the center frequency *f_center* in MHz, the bandwidth *bw* in kHz and a *zone* vector as parameters. This optional *scanning command* requests an estimation on the emitter position inside of a confidence radius as part of the ‘emitter_position’ *scanning report*.

Scanning Report	Dataset
‘init_config’ (M)	*time* [yyyy-mm-dd_hh:mm:ss] *request_info* [...] *scs_name* [verbose] *scs_type* [verbose] *zone* [-,-,...,-] *zone_name* [verbose, verbose, ..., verbose] *zone_loc* [GNSS, GNSS, ..., GNSS] *f_range* [MHz, MHz] *f_res* [kHz, kHz, ..., kHz] *reports* [verbose; verbose; ...; verbose]
‘error’ (M)	*time* [yyyy-mm-dd_hh:mm:ss] *request_info* [...] *message* [verbose]
‘average_psd’ (M)	*time* [yyyy-mm-dd_hh:mm:ss] *request_info* [...]

	f_bins [kHz, kHz, ..., kHz] *psd_rms* [dBm, dBm, ..., dBm]
‘peak_psd’ (O)	*time* [yyyy-mm-dd_hh:mm:ss] *request_info* [...] *f_bins* [kHz, kHz, ..., kHz] *psd_peak* [dBm, dBm, ..., dBm]
‘average+peak_psd’ (O)	*time* [yyyy-mm-dd_hh:mm:ss] *request_info* [...] *f_bins* [kHz, kHz, ..., kHz] *psd_rms* [dBm, dBm, ..., dBm] *psd_peak* [dBm, dBm, ..., dBm]
‘history’ (O)	*time* [yyyy-mm-dd_hh:mm:ss] *request_info* [...] *f_bins* [kHz, kHz, ..., kHz] *hx_rms* [dBm, dBm, ..., dBm] *hx_dev* [dBm, dBm, ..., dBm] *hx_peak* [dBm, dBm, ..., dBm]
‘signal_identification’ (O)	*time* [yyyy-mm-dd_hh:mm:ss] *request_info* [...] *f_bins* [kHz, kHz, ..., kHz] *signal_type* [*verbose*]
‘emitter_position’ (O)	*time* [yyyy-mm-dd_hh:mm:ss] *request_info* [...] *f_bins* [kHz, kHz, ..., kHz] *em_loc* [GNSS] *conf_r* [m]

Table 2: List of scanning reports and its datasets

Report – ‘init_config’

An ‘init_config’ *report* includes a *time* stamp taken when the report is processed in the SCS, the *request_info*rmation containing all parameters of the preceding *command*, verbose *name* and *type* information of the SCS, vectors of available *zone*s, their verbose *name* information as well as *location* information in global navigation satellite system (GNSS) format, the frequency range *f_range* covered by the SCS in MHz, a vector of available frequency resolutions *f_res* in kHz as well as a list of available scanning commands and *reports* as a response to the mandatory ‘send_init config’ *command*.

Report – ‘error’

An ‘error’ *report* is responded by the SCS to a *command* that could not be processed by any reason and includes a *time* stamp taken when the report is processed in the SCS, the *request_info*rmation containing all parameters of the preceding *command*, and a descriptive malfunction *message*. This feature is mandadory.

Scanning Report – ‘average_psd’

An ‘average_psd’ *scanning report* includes a *time* stamp taken when the report is processed in the SCS, the *request_info*rmation containing all parameters of the preceding *command* and vectors with the frequency bins *f_bins* in kHz and the average values of the power spectral density *psd_rms* in dBm as a response to the mandatory ‘send_average_psd’ *scanning command*.

Scanning Report – ‘peak_psd’

A ‘peak_psd’ *scanning report* includes a *time* stamp taken when the report is processed in the SCS, the *request_info*rmation containing all parameters of the preceding *command* and vectors with the frequency bins *f_bins* in kHz and the peak values of the power spectral density *psd_peak* in dBm as a response to the optional ‘send_peak_psd’ *scanning command*.

Scanning Report – ‘average+peak_psd’

An ‘average+peak_psd’ *scanning report* includes a *time* stamp taken when the report is processed in the SCS, the *request_info*rmation containing all parameters of the preceding *command* and vectors with the frequency bins *f_bins* in kHz and the average and peak values of the power spectral density, *psd_rms* and *psd_peak,* both in dBm, as a response to the optional ‘send_average+peak_psd’ *scanning command*.

Report – ‘history

A ‘history’ *report* includes a *time* stamp taken when the report is processed in the SCS, the *request_info*rmation containing all parameters of the preceding *command* and vectors with the frequency bins *f_bins* in kHz, the average and peak values of the SCS scanning history, *hx_rms* and *hx_peak,* both in dBm, and the deviation of the SCS scanning history over time *hx_dev* also in dBm as a response to the optional ‘send_history’ *command*.

Scanning Report – ‘signal_identification’

A ‘signal_identification’ *scanning report* includes a *time* stamp taken when the report is processed in the SCS, the *request_info*rmation containing all parameters of the preceding *command* and a verbose *signal type* identification information as a response to the optional ‘send_signal_identification’ *scanning command*.

Scanning Report – ‘emitter_position’

An ‘emitter_position’ *scanning report* includes a *time* stamp taken when the report is processed in the SCS, the *request_info*rmation containing all parameters of the preceding *command* and an estimation of the emitter location in GNSS format as well as the confidence radius *conf_r* in meter as a response to the optional ‘send_emitter_position’ *scanning command*.

Local Spectrum Portfolio Manager Interface (lsi)

The interconnection of the Local Spectrum Portfolio Manager (LSDB) and one or more C-PMSE is realized with the bidirectional Local Spectrum Portfolio Interface (lsi) based on Ethernet and TCP/IP. After an initial login an authentication procedure (which is not part of this interface description) the C-PMSE requests available spectrum from the LSDB which offers available local spectrum resources over the lsi interface. During operation the C-PMSE can update its current frequency allocation to the LSDB. On the other hand, the LSDB notifies the C-PMSE about changes in spectrum usage which is optional.

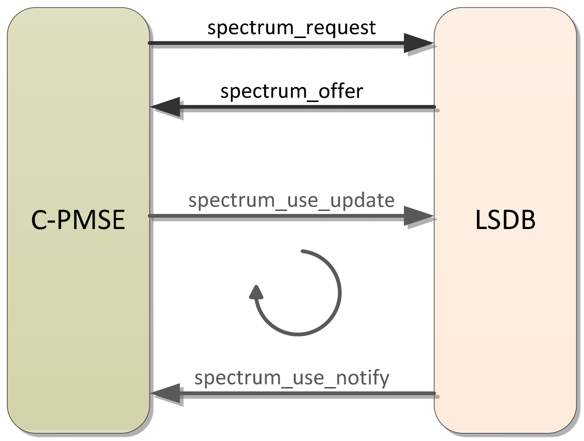

Figure 3: lsi communication.

Table … summarized the commands send from C-PMSE to LSDB.

Command name	Dataset
‘spectrum_request’ (M)	*location* [GNSS coordinates] (M) *operation_radius* [m] (M) *duration* [timestamp(start_time, stop_time)] (M) *freq_range* (start_freq, stop_freq)[Hz, Hz] (O)
‘spectrum_use_update’ (O)	*spectrum_usage* (array{center_freq, keep_free_bandwidth, output_power}) [array{Hz, Hz, dBm}] (M) *potential_generated_imd*(array{center_freq, bandwidth}) [array{Hz, Hz}](O)

Table 3: List of commands from C-PMSE to LSDB.

‘spectrum_request’

The ‘spectrum_request’ command requests available spectrum from the LSDB. Beside the information where (*location*) and when (*duration*) the spectrum should be used, the parameter *radius* gives the spatial extend of the intended spectrum usage. With the parameter *freq_range* the requested frequency range could be limited.

‘spectrum_use_update’

The current spectrum usage of the C-PMSE can be signalled to the LSDB via the ‘spectrum_use_update’ command. The *spectrum_usage* dataset contains the current link allocation of the C-PMSE which is an array containing all center frequencies (center_freq), the corresponding bandwidth which should be kept free by other devices (keep_free_bandwidth) and the used output power (output_power). The optional dataset *potential_generated_imd* contains a list of potential disturbed frequencies by intermodulation products.

Table … summarized the commands send from LSDB to C-PMSE.

Command name	Dataset
‘spectrum_offer’ (M)	*available_frequency_ranges* (array{start_freq, stop_freq, max_allowed_output_power, validity_period}) [array{Hz, Hz, dBm, timestamp}] (M) *spectrum_usage*(array{center_freq, keep_free_bandwidth, output_power}) [array{Hz, Hz, dBm}] (O) *potential_generated_imd* (array{center_freq, bandwidth}) [array{Hz, Hz}](O)
‘spectrum_use_notify’ (O)	*spectrum_usage* (array{center_freq, keep_free_bandwidth, output_power}) [array{Hz, Hz, dBm}] (M) *potential_generated_imd* (array{center_freq, bandwidth}) [array{Hz, Hz}](O)

Table 4: List of commands from LSDB to C-PMSE.

‘spectrum_offer’

After a ‘spectrum_requested’ command from the C-PMSE the LSDB answers with a ‘spectrum_offer’. The *available_frequency_ranges* dataset contains an array of the potential usable frequency ranges (start_freq, stop_freq) with the maximum allowed output power in this range (max_allowed_output_power) and the validity of this spectrum grant (validity_period). Optionally, the already used and registered frequencies at the requested location are returned with the *spectrum_usage* dataset. The list of potential disturbed frequencies by intermodulation products are returned with the *potential_generated_imd* dataset.

‘spectrum_use_notify’

Each time the link allocation list in the LSDB changes (e.g. another C-PMSE reallocates its links and signals this to the LSDB via the ‘spectrum_use_update’ command) it notifies all connected C-PMSE about this frequency change with the ‘spectrum_use_notify’ command. This is done via the *spectrum_usage* and *potential_generated_imd* dataset as described above.

Signalling for C-PMSE (TDOC214)

Overview

The CEN decides on necessary changes to PMSE links. The implementation of those changes with the radio links requires that audio basestation and audio terminals are parametrized identically e.g. both have to be tuned to the same carrier frequency or the same codec with digital transmission.

The C-PMSE has to signal to the basestation and the terminal, which parameters to use. The question now is how such a signalling can be implemented and incorporated in standards.

Considerations for Implementation of signalling

There is the question about robustness of transmission with signalling versus content plane. If a signalling command like a frequency change is not recognized by an audio terminal, and only the audio basestation performs a frequency change, than a loss of connection would result. This can happen if the signalling plane is only implemented unidirectional from the C-PMSE to the terminal. If the signalling plane is bidirectional commands on frequency change can be acknowledged.

If the content plane is interfered and a frequency change is necessary, the signalling plane should still work to ensure that the situation can be overcome.

The other question is which radio resource could be used for signalling? An inband birectional signalling imposes strong requirements on e.g. a wireless microphone. While transmitting with 100% duty cycle, the microphone would have to be enabled to receive signalling, which would be a strong blocking case.

Another frequency band and even another type of physical layer could be used. Pairing by infrared that is used today can be considered already as an initial step of bidirectional signalling.

Incorporating of Signalling in existing Standards

ITU-R BT.2069-5 (as of May 2011) and ECC Report 002 (as of February 2002) describe the "Telecommand/remote control" as "Radio links for the remote control of cameras and other programme-making equipment and for signalling". Therefore signalling with PMSE is already reflected in ITU and ECC reports. However both do not specifically address the SAP/SAB service links.

The current EN 300 422 does not consider signalling. German DKE has started the evaluation on required changes of EN 300 422 in June 2013. It is suggested to address the expected standard modification.

In addition ECC FM51 is working on a new revised ECC Report 002. It is suggested that ETSI sends a LS to FM51 to consider the expected implementation.

Definitions, symbols and abbreviations (TDOC215)

3.1 Definitions

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

Adaptive Modulation and Coding (AMC): a protocol that sets modulation and coding parameters depending on channel state

Content plane: Contains audio and / or video information, analogue or digital

NOTE: The term data plane / data channel is not used in the present document due to potential irritations. Instead control and content plane are used.

Control Plane: a plane which contains only control information (signalling), e.g. Radio Resource commands, battery status, etc.

NOTE: The term data plane / data channel is not used in the present document due to potential irritations. Instead control and content plane are used.

PMSE link: Describes the content-plane only.

3.2 Symbols

Present document does not use special symbols

3.3 Abbreviations

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

ABT	Ask Before Talk
AMC	Adaptive Modulationn and Coding
CEN	Cognitive Engine
C-PMSE	Cognitive PMSE
C-PMSE-IA	C-PMSE Information Acquisition
DMO	Demonstration Monitor
GLDB	Geolocation Database
HAL	Hardware Abstraction Layer
IA	Information Acquisition, combines Scanning System and Frequency booking
IEM	In Ear Monitor
LQI	Link Quality Indicator

LSDB	Local Spectrum database
lsi	Interface to Local Spectrum Database
PMO	Performance Monitor
PMSE	Program Making and Special Events
rli	Radio Link Interface
SCA	Scanning Antenna
SCC	Scanning Controller
sci	Interface to Scanning System
SCR	Scanning Receiver
SCS	Scanning Subsystem
SPM	Spectrum Portfolio Manager

##############Check what of below terms is needed again

AMC	Adaptive Modulation and Coding
AMCT	Adaptive Allocation Table
AMR	Adaptive Multi-Rate
AMSR	Aeronautical Mobile Satellite Service
BER	Bit Error Rate
COFDM	Coded Orthogonal Frequency Division Multiplex
CPC	Cognitive Pilot Channel
cpi	inter cognitive PMSE interface

CRS	Cognitive Radio System
CSI	Channel State Information
DAA	Detect and Avoid
DAT	Device Allocation Table
DEM	Device Manager
DET	Device Table
DFA	Dynamic Frequency Allocation
DIC	Diversity Interference Cancellation
DIP	Dual In-line Package
DPC	Dynamic Power Control
DSO	Digital Switchover
DTV	
DVB-T	Digital Video Broadcasting – Terrestrial
DVB-T2	Digital Video Broadcasting – Terrestrial; second version
DEM	Device Manager
ECN	Electronic Communication Network
EFR	Enhance Full Rate
EIRP	Equivalent Isotropic Radiated Power
ENG	Electronic News Gathering
FAT	Frequency Allocation Table
FCC	Federal Communications Commission (U.S.)
FCO	Frequency Coordinator
FDD	Frequency Duplex Division
fci	frequency coordinator interface
FM	Frequency Modulation
GMDSS	Global Maritime Distress Safety System
GSM	Global System for Mobile Communications
HMI	Human Machine Interface
HSPA	High Speed Packet Access
ID	Identifier
IEM	In Ear Monitoring
IMT	International Mobile Communications
ISM	Industrial Scientific and Medical frequency band

LTE	Long Term Evolution
MAC	Medium Access Layer
MIMO	Multiple Input Multiple Output
MRC	Maximum Ratio Diversity Combining

MSS	Mobile Satellite Service
PAT	Power Allocation Table
PHY	Physical layer
PMO	Performance Monitor
PMSE	Programme Making Special Events
PWMS	Professional Wireless Microphone System
QoS	Quality of Service
REM	Radio Environmental Map
RF	Radio Frequency
RFID	Radio Frequency Identifier
RMS	Root Mean Square
RRM	Radio Resource manager
RRS	Reconfigurable Radio System
ROI	Return on Investment
RSSI	Received Signal Strength Indication
sci	scanning receiver interface
SCR	Scanning Receiver
SESAR	Single European Sky ATM Research
SINR	Signal to Interference and Noise Ratio
SL	Service Level
SLA	Service level Agreement
SLE	Service Level Entry
SLM	Service Level Monitor
SNR	Signal to Noise Ratio
SRD	Short Range Device
T-DAB	Terrestrial Digital Audio Broadcast
TIMSI	Temporary International Mobile Subscriber Identity
ToA	Time of Arrival
TTI	Transmission Time Interval
TTV	Time To Violation
TVBD	Television Band Device
UHF	Ultra High Frequency
UMTS	Universal Mobile Telecommunication System
UWB	Ultra-Wideband
W-CDMA	Wideband - Code Division Multiple Access
WLAN	Wireless Local Area Network
WRAN	Wireless Regional Area Network
WSD	White Space Device

BMWi	Federal Ministry of Economy and Technology
CDMA	Code Division Multiple Access
CR	Cognitive Radio
(ePMSE	Enhanced PMSE)
HW	Hardware
IM3(5,7)	Third(Fifth, Seventh)-Order Intermodulation
IRT	Institut für Rundfunktechnik GmbH
ITU	International Telecommunication Union
ITU-R	ITU-Radiocommunication
LNA	Low Noise Amplifier
MBE	Messe Berlin
NRA	National Regulatory Authorities
PLL	Phase-Locked Loop

Tdoc 217 Radio Link Management Interface (rli)

Scope

The following sections provide a detailed overview on the interface between cognitive engine and connected wireless PMSE links. Two processes for rli communication are described.

Overview

Radio link management interface connects the hardware abstraction layer (HAL) with the cognitive engine (CEN) as depicted in **Figure 1**.

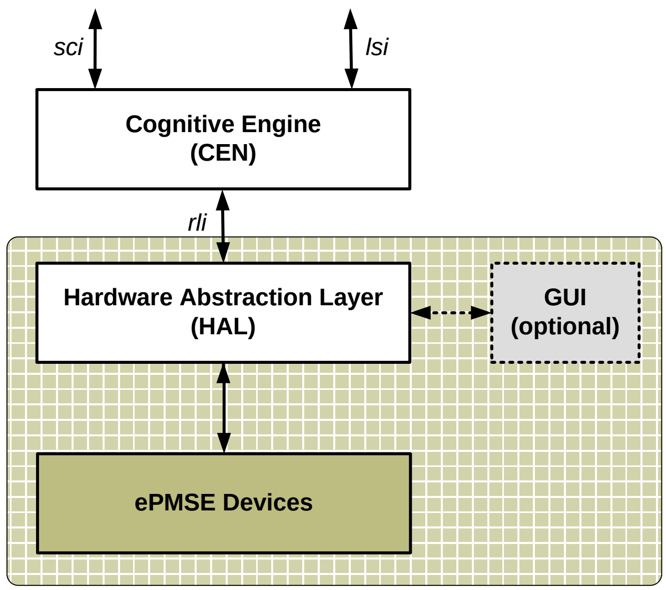

Figure 1: Architecture overview

rli is a bi-directional interface carrying commands, status and hardware information. It provides device capability information from ePMSE devices to CEN (e. g. RF bandwidth, minimum channel spacing, output power settings, …) and management commands from CEN to ePMSE devices. Status information like link quality indicator and battery state are communicated from ePMSE devices to CEN.

The hardware abstraction layer serves as vendor specific bridge to translate vendor specific hardware language to standardized commands for rli communication. For that reason HAL shall be provided by the corresponding vendor of ePMSE devices.

To get access to HAL without a cognitive engine or any other higher layer software an optional GUI is provided.

If more than one kind of PMSE devices is co-located, all devices can be managed by one CEN when connected to it via a specific HAL (see

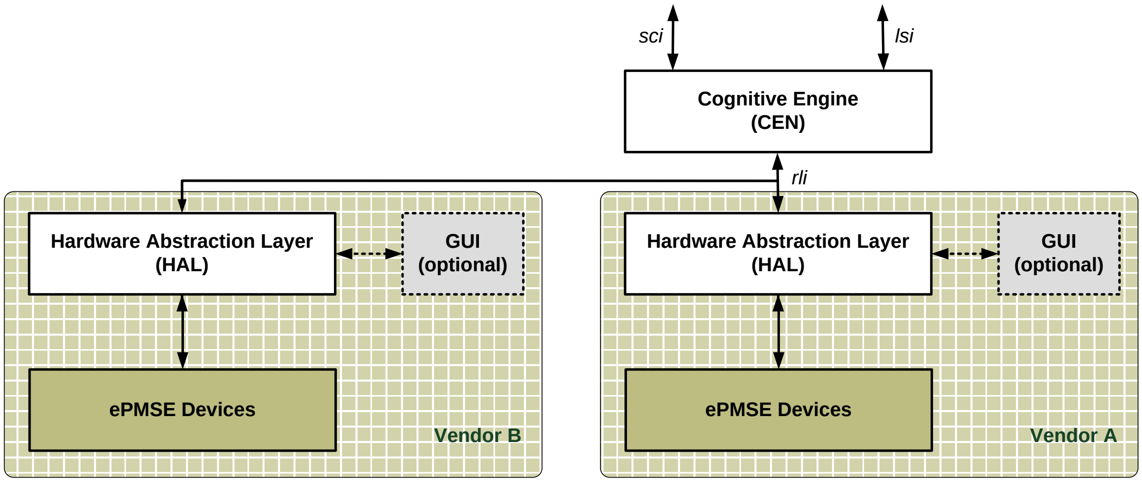

Figure 2). So it is possible to share one CEN with C-PMSE of different vendors or with different command syntaxes.

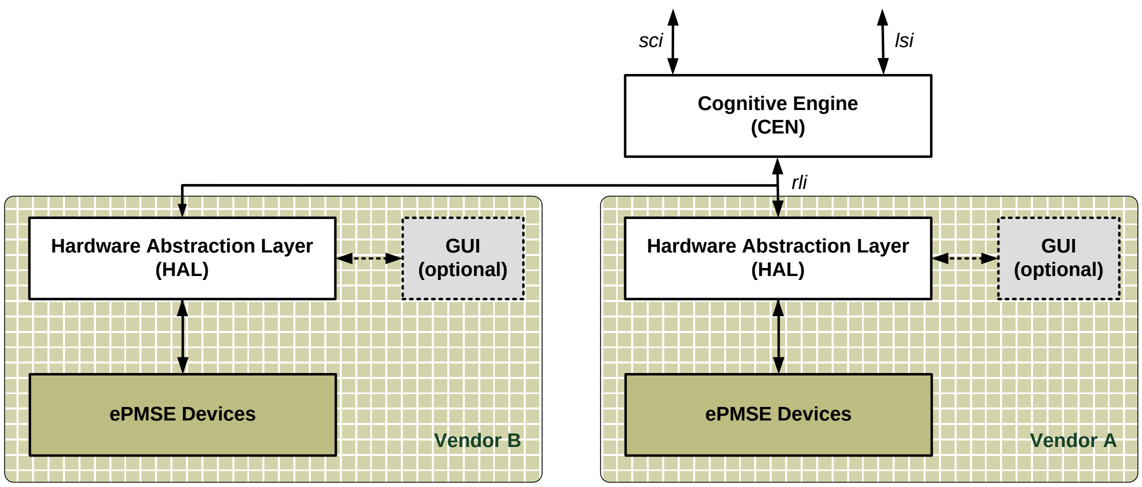

Figure 2: Two co-located C-PMSE connected to one CEN

Two processes are running. The Device Management Process is in charge of detecting what devices are connected and what capabilities they are having.

The Dynamic Link Management Process ensures that decisions by the CEN are immediately implemented in the PMSE devices.

The Device Management process is less time critical than the Dynamic Link Management Process.

X.2 Device Management Process

The Device Management Process run by CEN includes detection of PMSE devices like audio basestations that are connected to the Hardware Abstraction Layer (HAL) and passes their capabilities to the CEN. An example could be supported frequency range by a ePMSE device.

The detection could be a one time process during initialisation of a C-PMSE or a continuous process supporting adding and removing ePMSE links during operation. Such a Plug and Play scheme would support automatic configuration of the system.

As a minimum set a detection scheme during initialisation must be supported.

Commands that interrogate and pass capabilities of connected ePMSE links can be found in below section.

X.3 Dynamic Link Management Process

Dynamic Link Management Process reflects the alteration of radio link parameters based on decisions by the cognitive engine. The HAL translates commands on the rli into vendor specific commands to PMSE devices. As drop-out time has to be minimized the Dynamic Link Management Process running in the CEN has to be conducted in real time. Decisions by the CEN signalled on rli have to be implemented at the ePMSE links with low latency.

Dynamic Link Management Process includes alteration of parameters like carrier frequency, transmit power, modulation and coding. As a minimum set the commands for alteration of frequency must be supported.

The commands generated by the two processes have identical syntax.

X4. Commands on rli interface

Below the necessary commands on rli interface are given. First the commands from CEN to HAL are given and then vice versa.

From CEN to HAL:

rli Command	Parameters	Notes
set_frequency_link (M)	*Link_number #, f_carrier* [Hz], Acknowlede mode (yes/no)	To allow also a mix of very narrowband and wideband transmission schemes, e.g. PMSE effect control. Acknowledged mode is optional.
set_power_link (M)	*link_number #, power* [dBm]	
set_AMC_link (O)	*link Number #, AMC#*	AMC modes are vendor specific
ask_capabilities_link (M)	*link Number #*	Returns link capabilities
set_RFpower_onoff_link (M)	*link_number #, on/off*	Switches transmit device on / off
ask_identity_link (M)	*link_number #*	
ask_quality_link (M)	*link_number #*	
ask_rssi_link (M)	*link_number #*	
ask_status_link (O)	*link_number #*	

From HAL to CEN:

rli Command	Parameters	Notes
confirm_set_frequency_link	*link_number #*	This acknowledge reflects that a

(O)		frequency change was successfully implemented on ePMSE link and the link is up and running again.
capabilities_link (M)	*link number #,* *f_start [Hz], f_stop [Hz],* *stepsize [Hz],* *channel_bandwidth [Hz]* *min_channel_spacing [Hz],* *min_IMD_spacing [Hz],* *output_power [dBm],* *TX_IMD_performance [dBc]* *RX_IMD_performance [dBc]*	Channel_bandwidth and output_power are lists of possible discrete settings; RX_IMD_performance may be set to infinity if not relevant; dBc-values are always positive
identification_link (M)	*link_number #, PMSE type (Audio/Video/Effect/Safety/Others), text string*	Text string may contain equipment code
quality_link (M)	*link_number #, LQI [SNR dB]*	EVM and BER figures can be converted to SNR
rssi_link (M)	*link_number #, RSSI [dBm]*	
status_link (O)	*link_number #, yes/no*	"yes" implies that content plane and bidirectional control plane works.

Note

In a P2MP environment like conference systems a link is comprised out of all links to all paired devices. In such scenarios the weakest RSSI and the lowest SNR are returned from HAL to CEN.

Necessary Additions to EN 300 422 regarding C-PMSE (TDOC220)

Introduction

This chapter deals with the necessary additions to EN 300 422-1 V1.4.2 (2011-08) recommended by ETSI STF 386 to cover the necessary changes implied by the introduction of cognitive properties for PMSE.

STF386 proposes to add a Part III on cognitive radio resource management. Part III should cover the following aspects:

- Definition of new terms (e.g. definition of ePMSE)
- Discuss the role of content and control planes
- Definition of new elements of a C-PMSE system
- Interface definitions and their protocols
- New protocols
- Requirements
- Testing setups
- Testing for compliance
- References (e.g. TR102 801)

Proposals for modifications to existing parts

Proposal addition to Section 2.1, Normative Reference

- Include TR 102 801 (Outcome document of phase C STF386)

Proposal additions to Section 3.3

- Include new definitions, symbols, and abbreviations

Proposals for addition of a new Part III

Proposal Section 17

- Definition of C-PMSE (include sketch). General overview on the behaviour of a C-PMSE system. Explain the breakdown of each of the elements and how they interact. Discuss the purpose of each interface.

Proposal Section 18

- Define the elements of the C-PMSE (18.1, 18.2…)

Proposal Section 19

- Define the interfaces (sci, lsi, rli)

Proposal Section 20

- Conformance Testing of a C-PMSE System (e.g. apply stimulus to the system as a whole)
- Maybe defined as a sole “OTA” (over the air) test stimulus

- Interface tests (if interfaces are provided) – One Sentence only adequate protocol tester