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Wireless Industrial Applications (WIA);
Radio equipment to be used in the 5,725 GHz to 5,875 GHz frequency range with power level up to 400 mW;
Methods and concepts for a WIA system approach to sharing in the 5,725 GHz to 5,875 GHz band

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

Modal verbs terminology

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Introduction

The present document describes radio aspects related to the central coordination point (CCP) concept. The intended application domain is wireless industrial applications (WIA) within the 5,8 GHz WIA band.

The concept of a central coordination point (CCP) is a mechanism which allows the coordination of multiple devices and/or multiple networks using single or multiple spectrum access technologies with the intension of optimizing spectrum efficiency and ensuring coexistence. The objective of the CCP as described in the present document, is to establish an automated adaptive coexistence management for the 5,8 GHz WIA band, which means that the CCP identifies and manages the available spectrum for WIA under its control. The CCP employs mitigation techniques like Dynamic Frequency Selection (DFS) and Detect and Avoid (DAA) in order to protect incumbent services or applications.

NOTE: The term device is used in the present document as a synonym for equipment.

The technical specifications of higher layer protocol mechanisms that are needed to allow a multi-vendor-capable-CCP are not part of the present document.

1 Scope

The present document describes methods and concepts for a Central Coordination Point (CCP) in order to support spectrum sharing between WIA devices with power level up to 400 mW and other systems operating in the 5,725 GHz to 5,875 GHz band, i.e. the 5,8 GHz WIA band. The present document covers two aspects:

- CCP for sharing with incumbent services/applications (e.g. those identified in ECC Report 206 [i.1]).
- CCP for Intra-system coexistence.

2 References

2.1 Normative 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.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

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The following referenced documents are necessary for the application of the present document.

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2.2 Informative references

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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] ECC Report 206: "Compatibility studies in the band 5725-5875 MHz between SRD equipment for wireless industrial applications and other systems".

[i.2] Gnad, A.; Krätzig, M.; Schade, J.; Schönrock, R.; Trikaliotis, S.; Rauchhaupt, L.: "Software Defined Radio und Cognitive Radio in der industriellen Automation. Deutsche Forschungsgesellschaft für Automation und Mikroelektronik (DFAM), ISBN: 978-3-8163-0614-6, VDMA Verlag, Frankfurt(Main), 2011".

[i.3] CENELEC EN 62591 (2010): "Industrial communication networks - Wireless communication network and communication profiles - WirelessHART™".

[i.4] CENELEC EN 62734 (2015): "Industrial networks - Wireless communication network and communication profiles - ISA 100.11a".

[i.5] CENELEC EN 62657-2 (2015): "Industrial communication networks - Wireless Communication networks - Part 2: Coexistence management".

[i.6] CENELEC EN 61158-1:2014: "Industrial communication networks - Fieldbus specifications - Part 1: Overview and guidance for the IEC 61158 and IEC 61784 series".

[i.7] CENELEC EN 61918:2013: "Industrial communication networks - Installation of communication networks in industrial premises".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in CENELEC EN 62657-2 [i.5] and the following apply:

5,8 GHz WIA band: Wireless Industrial Automation (WIA) assigned total frequency range of 5 725 MHz to 5 875 MHz

Central Coordination Point (CCP): device coordinating resources in the different wireless systems/networks

coexistence (wireless communication coexistence): state in which all wireless communication solutions of a plant using shared medium fulfil all their application communication requirements

frequency range: range of operating frequencies over which the equipment can be adjusted

harmful interference: interference which endangers the functioning of a radionavigation service or of other safety services or which otherwise seriously degrades, obstructs or repeatedly interrupts a radiocommunications service operating in accordance with the applicable Community or national regulations

network: all of the media, connectors, repeaters, routers, gateways and associated node communication elements by which a given set of communicating devices are interconnected

NOTE: The definition is the same as in CENELEC EN 61158-1:2014, 3.1.30 [i.6].

node: end-point of a branch in a network

NOTE: The definition is the same as in CENELEC EN 61918:2013, 3.1.50 [i.7].

radio equipment: an electrical or electronic product, which intentionally emits and/or receives radio waves for the purpose of radio communication and/or radiodetermination, or an electrical or electronic product which is always completed with an accessory, such as antenna, so as to intentionally emit and/or receive radio waves for the purpose of radio communication and/or radiodetermination

radio communication: communication by means of radio waves

radiodetermination: determination of the position, velocity and/or other characteristics of an object, or the obtaining of information relating to those parameters, by means of the propagation properties of radio waves

radio waves: electromagnetic waves of frequencies lower than 3 000 GHz, propagated in space without artificial guide

3.2 Symbols

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

dBm	dB relative to 1 milliwatt
GHz	Gigahertz
Hz	Hertz
kHz	kilohertz
MHz	Megahertz
W	Watt

3.3 Abbreviations

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

AARM	Automation Application Resource Management
AFA	Adaptive Frequency Agility
BFWA	Broadband Fixed Wireless Access
CCP	Central Coordination Point
CCW	CCP Controlled WIA
DAA	Detect And Avoid
DFS	Dynamic Frequency Selection
EIRP	Effective Isotropic Radiated Power
FSS	Fixed Satellite Services
ISDB	Incumbent Service/Application Database
ITS	Intelligent Transport System
LRDB	Local Industrial Environment Resource Database
RF	Radio Frequency
RLAN	Radio Local Access Network
RRM	Radio system and device Registration and Management
SM	Spectrum Manager
SRE	Spectrum Resource Engine
SSU	Spectrum Sensing Unit
TTT	Transport and Traffic Telematics
WIA	Wireless Industrial Application

4 Concept of Central Coordination Point

4.1 Overview

The idea of a central coordination point (CCP) is to coordinate between multiple devices and/or multiple wireless networks using single wireless communication solution or multiple wireless communication solutions. The aim is to further improve the use of spectrum. The main idea is that a central device should coordinate the use of spectrum by these devices and/or networks with respect to bandwidth, time and space for multiple devices and/or networks, instead of using mitigation techniques individually per radio device.

In general, the functional architecture for radio systems with CCP shall fulfil the following basic requirements:

- Support of spectrum coordination mechanisms to provide coexistence between different systems and services in the same frequency range, with the aim of:
  - Protection of incumbent radio systems (e.g. Radiolocation, BFWA, ITS).
  - Avoidance of harmful interferences.
- Support of mechanisms for automatically spectrum allocation and spectrum access, with the aim of:
  - Recognition of free and occupied spectrum.
  - Detection and classification of incumbent radio systems and services.
- Support mechanisms for continuous surveillance of the frequency spectrum condition.

The resources can be selected in time, in frequency and in space domain. The CCP can organize the available spectrum resources and assign resource blocks to the different wireless networks or devices within the 5,8 GHz WIA band.

The CCP shall communicate with network access points or with individual wireless devices by means of one or more communication channels and protocols. Therefore, the CCP shall fulfil the following requirements:

- Support of different radio technologies.
- Support of interface for interoperability.
- Support of interface for coordination.

Two scenarios can be considered:

1) CCP for sharing with other incumbent services/applications. This scenario is described in clause 4.2.
2) CCP for intra-system coexistence. This scenario is described in clause 4.3.

The CCP for intra-system coexistence can substitute manual coexistence management as defined by CENELEC EN 62657-2 [i.5].

The CCP is scheduling resources to the different wireless systems. This can include CCP to single device communications or CCP to network access point communication. In the latter case, the network access point will then use the CCP information to configure and control its own wireless network.

If WIA systems are not controlled by a CCP and operate independently using their own spectrum access mechanisms, then there is no coordination between the WIA systems, and they rely on their own techniques for network formation, network discovery, service discovery and interference management, including the protection of incumbent services.

4.2 CCP concept for sharing with other incumbent services and applications operating within the 5,8 GHz band

4.2.1 General

A CCP concept for sharing with other incumbent services and applications is intended to take away the burden of implementing the needed mitigation techniques for the used spectrum in each device. Another benefit of this concept is that the CCP can sense the incumbent services at the edges of the installed area with a better receiver sensitivity as the WIA devices can perform it; this behaviour is also required in the ECC Report 206 [i.1].

If the available spectrum not used by incumbent services is identified by the CCP, then the CCP shall calculate the most efficient spectrum assignments that can be assigned to the CCP controlled systems and CCP controlled devices based on their WIA requirements on communication needs.

WIA systems in a factory environment may operate exclusively over one or more network access technologies and many of these WIA systems may be capable of operating simultaneously in a factory environment. For example CCP controlled WIA systems and incumbent services/applications within the 5,8 GHz WIA band, such as radiolocation, transportation system and BFWA are depicted in Figure 1.

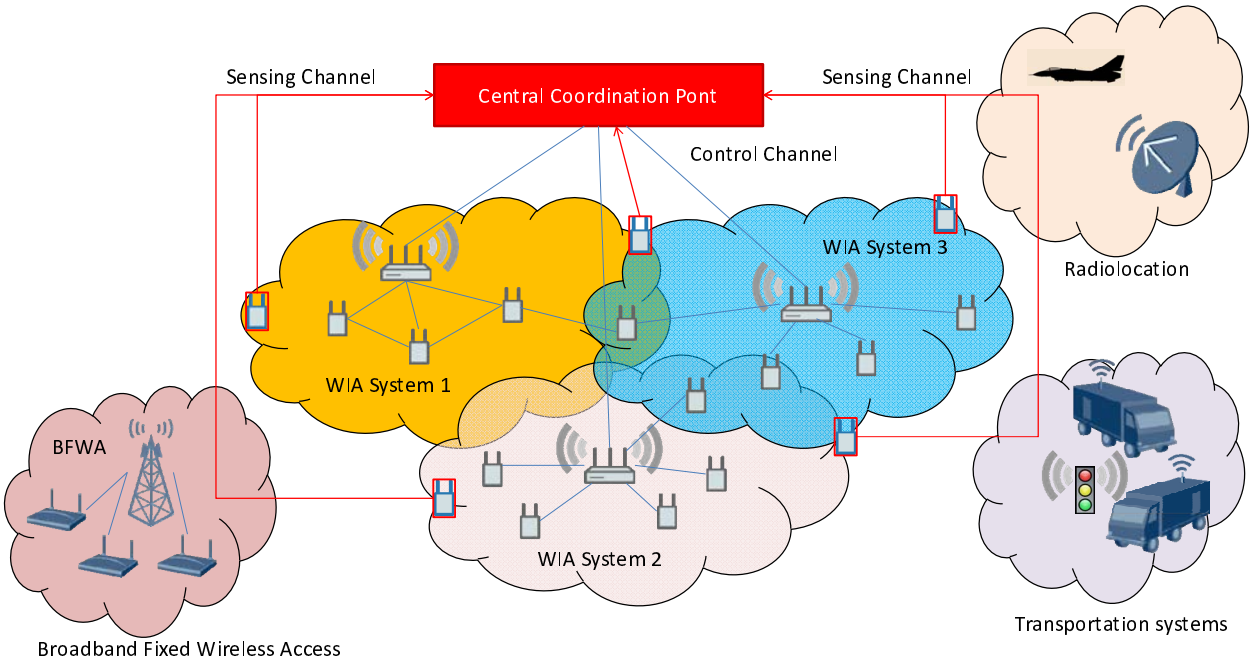

Figure 1: CCP controlled WIA systems and incumbent services and applications

Figure 2 shows the incumbent services and applications using the 5,8 GHz WIA band. The incumbent services and applications with a high regulatory involvement are the following: radiolocation, fixed satellite services (FSS), transportation systems like Transport and Traffic Telematics (TTT), ITS non-safety and broadband fixed wireless access (BFWA).

Table 1 shows typical parameters for some incumbent services and applications in the 5,8 GHz WIA band as defined in ECC Report 206 [i.1].

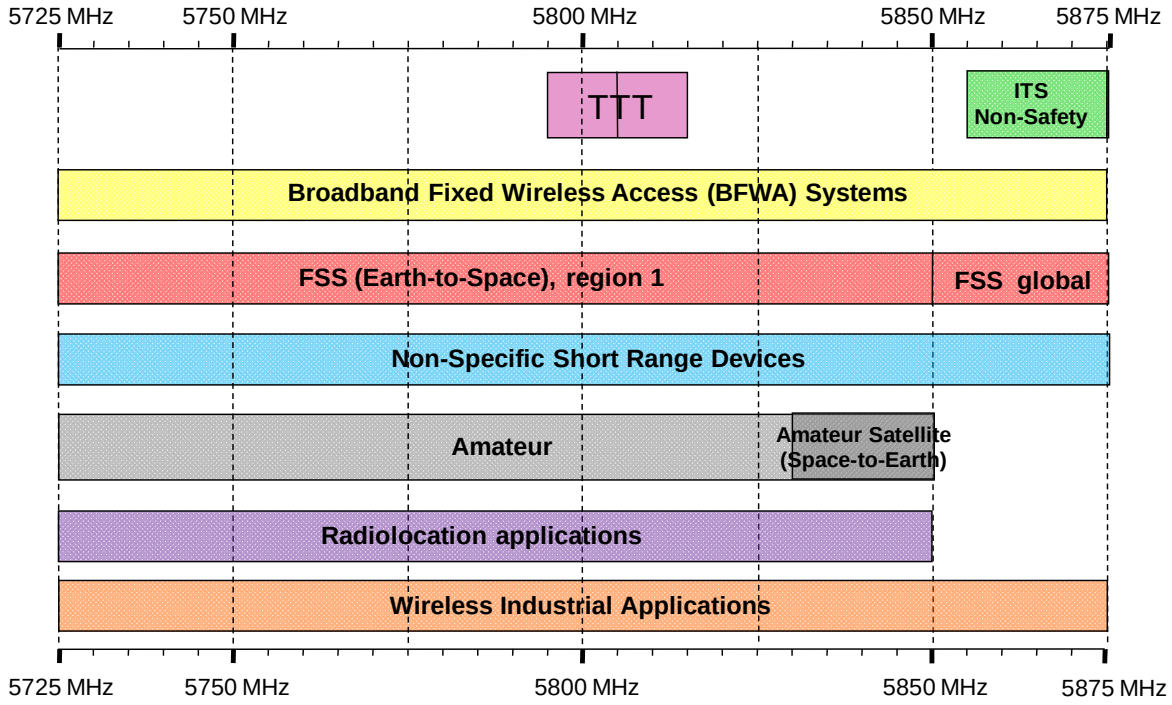

Figure 2: Overview of incumbent service/applications

Table 1: Incumbent services and applications

Incumbent service application	Frequency band [MHz]	Type	Application characteristic	Transmit power [eirp]
Radiolocation	5 725 to 5 850	Defence	Dynamic in time and location	25 kW to 2 800 kW
BFWA	5 725 to 5 875	Fixed Service	Static	4 W
TTT	5 795 to 5 815	Transport and Traffic Telematics	Static	2 W to 8 W
ITS non-safety	5 855 to 5 875	Transportation	Dynamic in time	1 mW to 200 mW

4.2.2 Incumbent Protection

CCP controlled WIA systems employ a centralized coordination with an centralized or an distributed spectrum sensing to identify free and occupied frequency ranges in the 5,8 GHz WIA band. The spectrum sensing unit (SSU) may have multiple radio interfaces or an universal radio interface for monitoring a number of channels or frequency ranges simultaneously. It determines the operation of incumbent services on certain channels or frequencies within the 5,8 GHz WIA band.

To protect incumbent services and applications an automated non-collaborative metrics-based coexistence management shall be used, as WIA systems and incumbent services/applications are not capable to exchange information. Since they are fully independent, WIA systems will have to rely only on incumbent service/application detection and estimation. In other words, each potentially interfered WIA system classifies the behaviour of the interfering incumbent services or applications and adapts its own behaviour to the new conditions.

4.3 CCP concept for intra-system coexistence operating within the 5,8 GHz band

4.3.1 General

The intra-system coexistence, as achieved by the CCP concept, fulfils the viewpoint of an automatic adaptive coexistence management mechanism.

The CCP shall organize the spectrum access for multiple WIA systems within the 5,8 GHz WIA band. Currently many coexistence issues and mitigation techniques exist, because there is no coordination between these WIA systems. Therefore WIA systems operating in 5,8 GHz WIA band will require new intra-system coexistence schemes in order to optimize radio resource usage. These coexistence schemes can be enabled by a Central Coordination Point (CCP). This CCP can provide assistance for radio network coexistence, via the transmission of context information and measurement results, and also enable multi WIA system control.

The CCP organizes the simultaneous operation of multi WIA systems and WIA devices in industrial environments. Therefore the CCP, CCP controlled WIA systems and CCP controlled WIA devices shall provide a control channel for information collection from WIA systems and WIA devices to the CCP as well as to carry control or assistance information from the CCP to the WIA systems and WIA devices. In order to provide some of the control or assistance services the CCP performs decision making via control channel. In order to provide some of the information collection service the CCP shall provide information on available WIA systems and/or WIA devices via control channel. The control channel can use the wired connection between CCP and CCP controlled WIA systems or the wireless connection between CCP and CCP controlled WIA systems and CCP controlled WIA devices, between CCP controlled WIA systems and CCP controlled WIA devices, between CCP controlled WIA systems and between CCP controlled WIA devices.

The CCP shall provide multi radio technology capability and a wired network access.

WIA systems in an industrial environment may operate exclusively over a single radio technology, but WIA devices within these networks may be capable of operating on multiple different radio technologies simultaneously. Therefore multi WIA system control shall use the ability of specific WIA devices to communicate on more than one WIA system in order to provide advanced services to WIA systems on which that device is not active. A device with multi radio access capability can be used to provide assistance to WIA systems in an effort to coordinate transmissions across WIA systems and to improve the performance within a WIA system. Intra network WIA devices can exist that are capable to communication with WIA system 1 and also capable to communicate with WIA system 2. This WIA device can be seen as green marked in Figure 3. WIA systems with single radio access capability need assistance from CCP. The CCP manages the medium utilization of WIA systems by coordinating their transmissions.

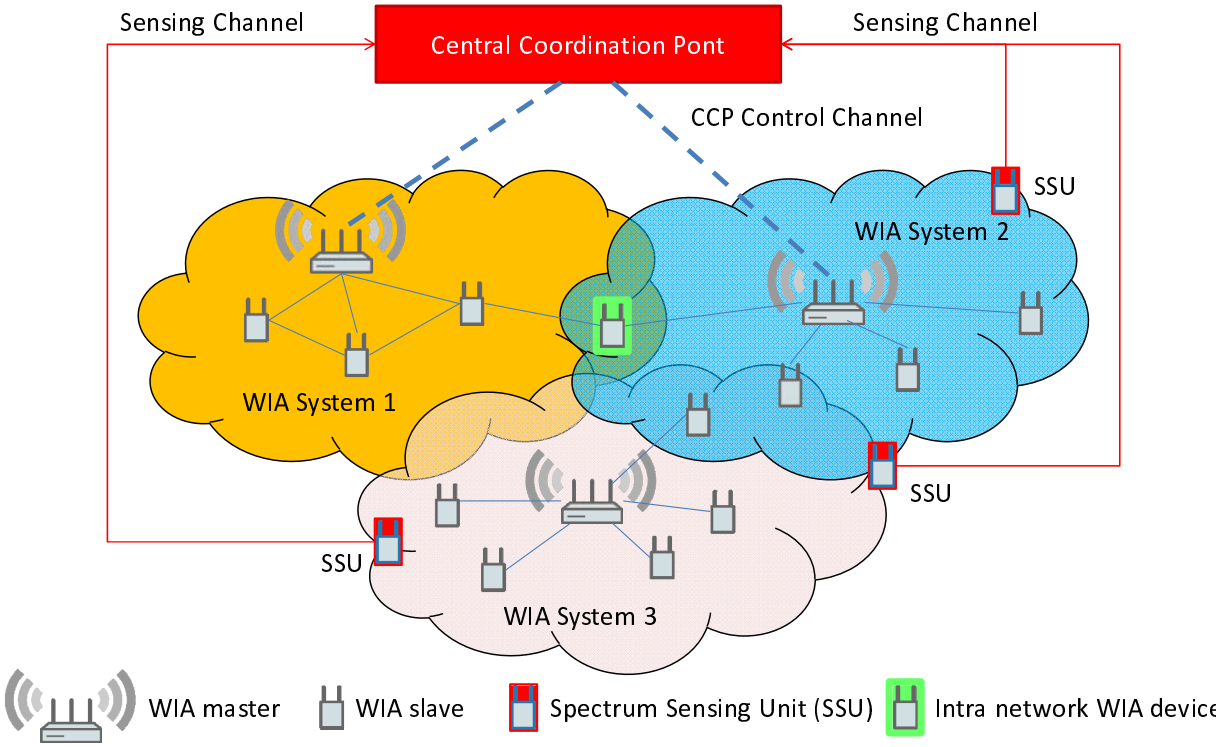

Figure 3: CCP for intra-system coexistence

Conceptually, multi radio access technology assistance or wired technology assistance help to cooperate with coexistence issues not only by minimizing harmful interference, but also by expanding the services available to WIA devices and to include services from devices outside the local network. The services offered by every device are added to the CCP, but in order to access this CCP a common control channel capable of WIA-agnostic communication is necessary.

4.3.2 Inter-Network Sensing Assistance

WIA system 1 (see Figure 3) or WIA device(s) belonging to WIA system 1 can be requested to sense the operating channel of WIA system 2 and report the results to a CCP. This could be useful for networks consisting of low-powered devices with limited sensing capability.

The CCP collects location information and operating characteristics of different WIA systems which includes the operating channel of the low complexity WIA system. The CCP then instructs SSU or WIA devices to perform periodic sensing on the operating channel of the low complexity WIA system with specific sensing algorithms applicable to detect low complexity WIA systems with a low medium utilization. If harmful interference is detected, the CCP informs the low complexity WIA system and instructs it to move to another operation channel provided no incumbent service is operating on that channel (see clause 4.2).

Optionally, the CCP can also instruct the spectrum sensing unit (SSU) to monitor one or more alternative channels for WIA system. Once high interference is detected, the CCP can instruct the WIA system to change the operation channel to a validated alternative channel. Hence, the service discontinuity, which occurs as a result of the harmful interference, is reduced at the WIA system.

5 Architecture of CCP

5.1 General

The CCP shall be responsible for the following activities:

- protection of incumbent services and applications
- establishment of communication channels
- register wireless communication systems in the location(s) of interest in the company
- inventory of wireless industrial applications
- release or rejection of newly registered wireless industrial applications
- generation of requirements for the use of wireless industrial applications based on the agreed decisions of the internal procedure

Figure 4 depicts the functional architecture of a CCP system for WIA.

The CCP system has three entities, as shown in Figure 4:

- local industrial environment resource data base (LRDB);
- spectrum manager (SM) with incumbent service/application database, spectrum resource engine, radio system and device registration and management and automation application resource management;
- spectrum sensing unit (SSU).

Each entity is defined by its functional roles and interaction with other entities.

The CCP controlled WIA system (CCW) represents a WIA system that is under control of a CCP. The CCW consists of a device, which supports an interface to the CCP and operates at the same time as CCP client and WIA master. The CCP manages the available resources spectrum, time and space and assigns the resources to the CCP Client. The CCP client receives the resource information and acts as WIA master and manages the registered and connected WIA slaves. Therefore, the CCW uses available spectrum resources obtained with help of local industrial environment resource database, with additional knowledge about spectrum usage by its neighbour CCW and about incumbent service/applications provided by the spectrum manager (SM) and by a permanent spectrum sensing with the SSU. The LRDB provides the CCW location range information on the available frequencies and associated maximum EIRP values that the WIA master and WIA slave are permitted to use.

CCP allows protection of incumbent services by using the information provided by the spectrum sensing unit, WIA master and WIA slave.

The SSU observes the spectrum in and around the local industrial environment and delivers spectrum usage data from different CCW and incumbent services/applications to LRDB and SM.

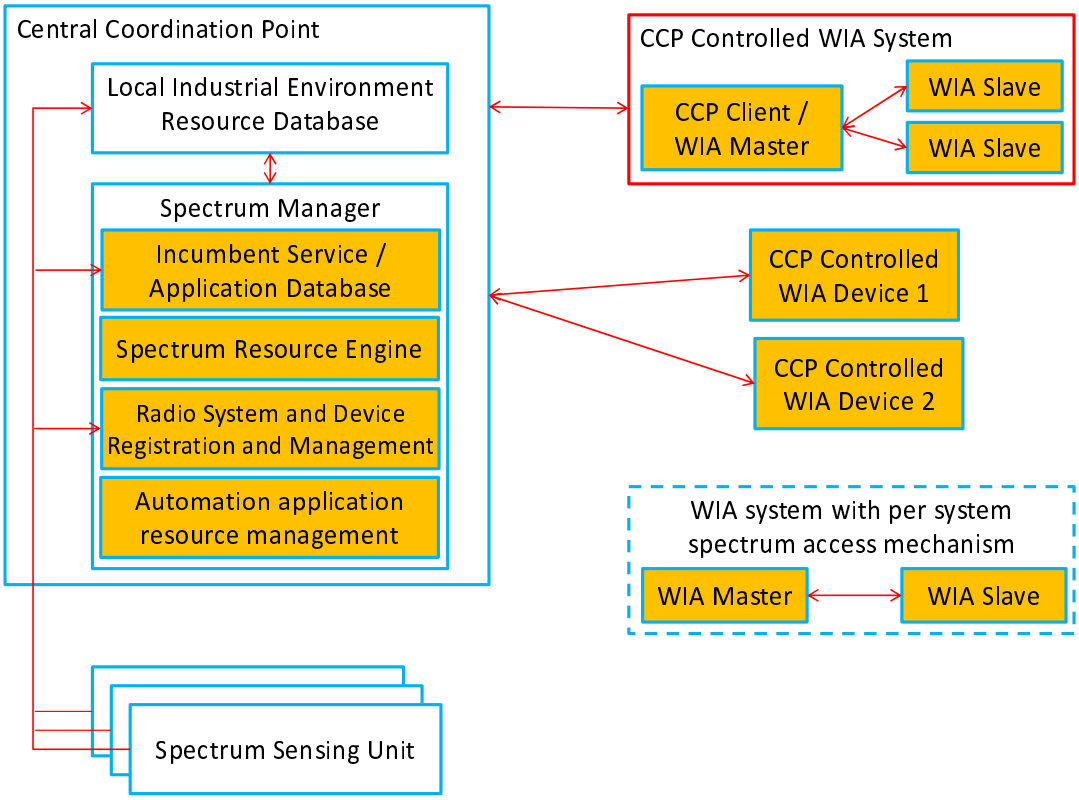

Figure 4: Overview of CCP for WIA

5.2 Equipment Types

5.2.1 WIA device

5.2.1.1 WIA device with per device mitigation and spectrum access mechanism

WIA devices are devices with function of WIA master or WIA slaves. WIA devices with "per device mitigation and spectrum access mechanism" shall provide the needed mitigation and spectrum access mechanism for the assigned spectrum, such as dynamic frequency selection and frequency agility mechanisms. Manual coexistence management according to CENELEC EN 62657-2 [i.5] can be used for intra-system coexistence but cannot replace mandatory mechanisms to protect incumbent services within this band. CENELEC EN 62657-2 [i.5] should be established to increase the effectiveness of using the spectrum in an industrial premises environment if the device cannot participate in the CCP concept.

5.2.1.2 CCP controlled WIA device

CCP controlled devices are devices with function of WIA master and CCP client or WIA devices with function of CCP client only. The CCP controlled WIA devices is under control of CCP. The CCP controlled WIA device shall not transmit by itself. If the communication between CCP and CCP controlled device is established and the CCP enables the transmission, then the CCP controlled device can transmit without dynamic frequency selection and without adaptive channel access mechanism. In case the communication between CCP and the CCP controlled device fails, the transmission shall stop. A heart-beat signal or similar mechanisms shall enable a monitoring of the communication between CCP and CCP controlled device. Battery powered WIA devices such as used in WirelessHART® [i.3] (see note below) and ISA 100.11a [i.4] wireless networks, spend most of their time in sleep mode to save power and have limited sensing capability. These types of WIA systems do not perform active spectrum sensing. Therefore, they are subject to dynamic interference. In that context, a co-located network such as an RLAN (WIA system 2 or 3) could take specific sensing measurement to assist a wireless network consisting of such low-powered devices with limited sensing capability.

NOTE: WirelessHART is the trade name of a product supplied by the HART Communication Foundation. This information is given for the convenience of users of the present document and does not constitute an endorsement by ETSI of the product named. Equivalent products may be used if they can be shown to lead to the same results.

5.2.1.3 CCP-controlled WIA device with per device mitigation and spectrum access mechanism

WIA devices with per device mitigation and spectrum access mechanism which are also CCP controlled shall fulfil the requirements of clauses 5.2.1.1 and 5.2.1.2.

If the communication between CCP and CCP controlled device is established and the CCP enables the transmission, the controlled device can transmit without dynamic frequency selection and frequency agility mechanisms. In case the communication between CCP and the CCP controlled device fails, the transmission shall be in line with dynamic frequency selection and frequency agility mechanisms.

5.2.2 Central Coordination Point

The CCP is a centralized coordination device or system.

The tasks for CCP are incumbent services and applications sensing, provide mechanism to incumbent service and application protection and establish an automatic coexistence management between multiple WIA systems and WIA devices.

The CCP shall establish a wired or wireless communication to a common data base containing geolocation and spectrum usage information by incumbent services/applications (LRDB and ISDB); sense incumbent services and applications and obtain the requirements of the CCP controlled WIA devices (see CENELEC 62657-2 [i.5]) and assign resources accordingly to the CCP controlled WIA devices.

If more than one CCP is in use in a certain configuration then they shall establish a wired or wireless communication direct or indirect between the CCPs. All requirements of a single CCP, see clause 4.1, shall apply.

5.3 Local Industrial Environment Resource Database

The LRDB contains information about a WIA device within a CCP controlled WIA system, CCP controlled WIA devices and WIA system with per device spectrum access mechanism with location specific information and radio specific information. The LRDB shall provide this information to the SM. The radio specific information is information about the available frequencies and associated maximum EIRP values that the WIA device or WIA system is permitted to use. This will allow protection of incumbent services and is derived from information provided by WIA device.

5.4 Spectrum Manager

5.4.1 Overview

The spectrum manager (SM) within a CCP shall be responsible for maintaining the requirements of automation application, maintaining spectrum availability information, channel selection, channel management, scheduling spectrum sensing operation, access to the database, regulatory domain policies and enabling intra-system coexistence.

The SM within a CCP shall be responsible for ensuring protection of incumbent services and applications (e.g. Radiolocation, BFWA, Transportation systems) and efficient spectrum utilization while complying with regulatory policies. For that, the SM centralizes all the decisions within the WIA network with respect to spectrum availability and utilization. In summary, the key functions of the SM are the following:

- Maintain requirements of automation application
- Maintain spectrum availability information
- Channel classification and selection
- Association control
- Channel set management
- Accessing the database service
- Scheduling quiet periods for spectrum sensing
- Making channel move decisions for one or more CCP devices
- Self-coexistence with other WIA network

5.4.2 Incumbent Service Database

The incumbent service/application is allowed to dynamically use its spectrum band or parts of it during the WIA operation. The incumbent service/application database (ISDB) contains regulatory information about incumbent service/application and information how the WIA network or system will react in case of an incumbent service/application has been detected. The SM transmits the information necessary to WIA devices that all regulatory requirements can be fulfilled by the WIA network with CCP.

The incumbent services/applications are defined by:

- Frequency band
- Incumbent type:
  - Defence (Radiolocation)
  - Fixed Service
  - Transportation
- Incumbent operation characteristic:
  - Static
  - Dynamic by time
  - Dynamic by geography
  - Dynamic by time and geography

For that reason a number of potential WIA detriments are possible:

- Reduce frequency band
- Reduce coverage
- Decrease capacity
- Decelerate access to spectrum

5.4.3 Spectrum Resource Engine

The Spectrum Resource Engine (SRE) makes use of the radio regulation specifications, since radio regulations specify important coexistence parameters such as frequency band, output power and mitigation techniques. These specifications shall be taken into account within the spectrum management process.

Furthermore, WIA systems and incumbent services/applications use the same resource (the frequency spectrum). If WIA systems and incumbent services/applications overlap in frequency and time domain and the ratio of wanted and disturbing signals is less than the required signal to interference ratio, these overlaps lead to harmful interference.

Therefore, the spectrum resource engine shall automatically schedule the operation of WIA systems to protect incumbent services/applications. The radio resource that is partially reserved by the incumbent services/applications shall be identified and resource occupancy information shall be submitted to the WIA systems and devices. The rest of available radio resource shall be allocated to local WIA system according to the application needs.

Additionally the SRE can schedule the operation among WIA systems to minimize coexistence issues.

5.4.4 Radio System and Device Registration and Management

The RRM manages all WIA systems and devices. Therefore, all these WIA systems and devices shall be registered at RRM before operation starts.

5.4.5 Automation Application Resource Management

The Automatic Application Resource Management (AARM) contains information about the application traffic, and time and error requirements of automation applications. Resources can be provided to the AARM by the controlled devices or by a tool. Resources can be static or dynamic.

5.5 Spectrum Sensing Unit

The Spectrum Sensing Unit (SSU) is necessary for the implementation of a CCP controlled WIA system. The SSU observes the available RF spectrum to determine its occurrence of incumbent services/applications and occupancy of other WIA systems. This process is called sensing and takes into account parameters of the radio channel, of the network, of the user, of the environment. Additionally the parameters described in CENELEC EN 62657-2 [i.5] should be taken into account. An overview of selected parameters is given in Figure 5.

Spectrum sensing is generally a passive process, and does not interfere with other users of the spectrum. The sensed signals shall be characterized, catalogued and classified from SSU. The related signal classification is typically based on signal analysis and signal parameter estimations.

The SSU shall implement spectrum sensing receivers. The results of classified signals shall be reported to the SM.

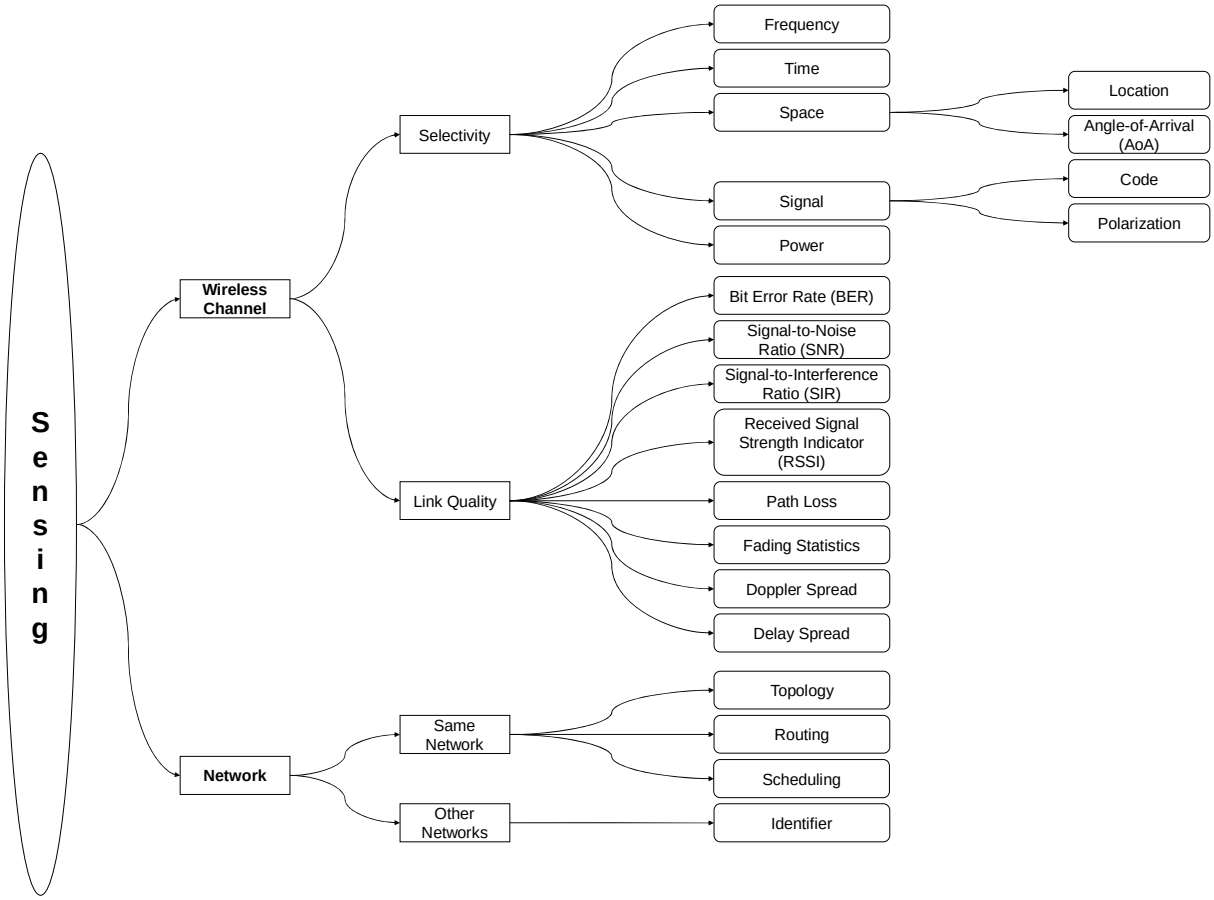

Figure 5: Sensing parameters in a cognitive radio [i.2]

5.6 Functions

5.6.1 Mitigation techniques

5.6.1.1 General

The CCP shall implement the needed mitigation techniques for example Dynamic Frequency Selection (DFS), Detect and avoid (DAA) and Adaptive Frequency Agility (AFA).

History

Document history		
V1.1.1	June 2016	Publication