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Foreword

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

Introduction

The present document provides a feasibility study on defining and developing the concept of Cognitive Pilot Channel (CPC) for reconfigurable radio systems to support and facilitate end-to-end connectivity in a heterogeneous radio access environment where the available technologies are used in a flexible and dynamic manner in their spectrum allocation context.

As a feasibility study the presented document provides basis for decision making at ETSI Board level on standardization of some or all topics of the CPC.

1 Scope

The current trend for radiocommunications systems indicates a composite radio environment, where multiple Radio Access Technologies (RATs) links may be available at the same time. In this context, the cognitive capability of the terminals becomes increasingly a crucial point to enable optimization of the radio usage. In order to obtain knowledge of its radio environment, a cognitive radio device may sense parts of the spectrum, which is necessary for its intention. This task may result in a very time and power consuming operation, if the parts of the spectrum to be sensed are large. In this context, the Cognitive Pilot Channel (CPC) solution could lead to a more efficient approach by conveying elements of the necessary information to let the terminal obtain knowledge of e.g. the available frequency bands, RATs, services, network policies, etc., through a kind of common pilot channel

Therefore, the present document aims at providing a study of the main concepts and possible implementations for the CPC in order to improve the spectrum and radio resources utilization in Reconfigurable Radio Systems.

2 References

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Not applicable.

2.2 Informative references

The following referenced documents are not essential to the use of the present document but they assist the user with regard to a particular subject area. For non-specific references, the latest version of the referenced document (including any amendments) applies.

[i.1] Inoue, M., Mahmud, K., Murakami, H., Hasegawa, M. and Morikawa: "Seamless Handover Using Out-Of-Band Signaling in Wireless Overlay Networks," WPMC 2003, vol. 1, pp. 186-190, October 2003.

[i.2] Inoue, M., Mahmud, K., Murakami, H., Hasegawa, M. and Morikawa: "Novel Out-Of-Band Signaling for Seamless Interworking between Heterogeneous Networks," IEEE Wireless Communication Magazine, vol. 11, no. 2, pp. 56-63, April 2004.

[i.3] Inoue, M., Mahmud, K., Murakami, H., Hasegawa, M. and Morikawa, H.: "Design and Implementation of Out-Of-Band Signaling for Seamless Handover in Wireless Overlay Networks," IEEE ICC 2004, pp. 3932-3936, June 2004.

[i.4] E2RII 2 Whitepaper: "The E2RII Flexible Spectrum Management (FSM) Framework and Cognitive Pilot Channel (CPC) Concept - Technical and Business Analysis and Recommendations".

[i.5] J. Pérez-Romero, O. Sallent, R. Agustí, L. Giupponi: "A Novel On-Demand Cognitive Pilot Channel enabling Dynamic Spectrum Allocation", DySPAN '07, 17-20 April.

[i.6] ETSI TS 123 402: "Universal Mobile Telecommunications System (UMTS); LTE; Architecture enhancements for non-3GPP accesses (3GPP TS 23.402 Release 8)".

[i.7] ETSI TS 124 312: "Universal Mobile Telecommunications System (UMTS); Access Network Discovery and Selection Function (ANDSF) Management Object (MO); (3GPP TS 24.312 version 8.2.0 Release 8)".

[i.8] ETSI TS 144 018: "Digital cellular telecommunications system (Phase 2+); Mobile radio interface layer 3 specification; Radio Resource Control (RRC) protocol (3GPP TS 44.018 Release 7)".

[i.9] OMA-ERELD-DM-V1-2: "Enabler Release Definition for OMA Device Management".

[i.10] IEEE 802.21: "Working Group for developing standards to enable handover and interoperability between heterogeneous network types including both 802 and non 802 networks".

[i.11] IEEE 1900.4-2009: "IEEE Standard for Architectural Building Blocks Enabling Network-Device Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Access Networks", February 27, 2009.

[i.12] ETSI TS 122 278: "Universal Mobile Telecommunications System (UMTS); LTE; Service requirements for the Evolved Packet System (EPS) (3GPP TS 22.278 Release 8)".

[i.13] ETSI TS 125 331: "Universal Mobile Telecommunications System (UMTS); Radio Resource Control (RRC); Protocol specification (3GPP TS 25.331 Release 8)".

[i.14] ETSI TR 102 682: "Reconfigurable Radio Systems (RRS); Functional Architecture (FA) for the Management and Control of Reconfigurable Radio Systems".

[i.15] O. Sallent, J. Pérez-Romero, P. Goria, E. Buracchini, A. Trogolo, K. Tsagkaris, P. Demestichas: "Cognitive Pilot Channel: A Radio Enabler for Spectrum Awareness and optimized Radio Resource Management", ICT Summit 2009.

[i.16] IEEE 802.11b: "Supplement to IEEE Standard for Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Higher-Speed Physical Layer Extension in the 2.4 GHz Band".

[i.17] IEEE 1900.6: "IEEE1900.6 Working Group on Spectrum Sensing Interfaces and Data Structure for Dynamic Spectrum Access and other Advanced Radiocommunication Systems".

NOTE: Available at: http://grouper.ieee.org/groups/scc41/6/.

3 Definitions and abbreviations

3.1 Definitions

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

Cognitive Pilot Channel (CPC): channel which conveys the elements of necessary information facilitating the operations of Cognitive Radio Systems

Cognitive Radio System (CR): radio system, which has the following capabilities:

- to obtain the knowledge of radio operational environment and established policies and to monitor usage patterns and users' needs;
- to dynamically and autonomously adjust its operational parameters and protocols according to this knowledge in order to achieve predefined objectives, e.g. more efficient utilization of spectrum; and
- to learn from the results of its actions in order to further improve its performance.

NOTE 1: Radio operational environment encompasses radio and geographical environments, and internal states of the Cognitive Radio System.

NOTE 2: To obtain knowledge encompasses, for instance, by sensing the spectrum, by using knowledge data base, by user collaboration, or by broadcasting and receiving of control information.

NOTE 3: Cognitive Radio System comprises a set of entities able to communicate with each other (e.g. network and terminal entities and management entities).

NOTE 4: Radio system is typically designed to use certain radio frequency band(s) and it includes agreed schemes for multiple access, modulation, channel and data coding as well as control protocols for all radio layers needed to maintain user data links between adjacent radio devices.

Software Defined Radio (SDR): radio in which the RF operating parameters including, but not limited to, frequency range, modulation type, or output power can be set or altered by software, and/or the technique by which this is achieved

NOTE 1: Excludes changes to operating parameters which occur during the normal pre-installed and predetermined operation of a radio according to a system specification or standard.

NOTE 2: SDR is an implementation technique applicable to many radio technologies and standards.

NOTE 3: SDR techniques are applicable to both transmitters and receivers.

3.2 Abbreviations

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

AICPC	Acquisition Indicator CPC
ANDSF	Access Network Discovery and Selection Functions
ASM	Advanced Spectrum Management
BCH	Broadcast Channel
BSSID	Basic Service Set Identifier
Cell-Id	Cell Identity
CN	Cognitive Network
CPC	Cognitive Pilot Channel
CPICH	Common Pilot Channel
CWN	Composite Wireless Network
DBCPC	Downlink Broadcast CPC
DDF	Device Description Framework
DM	Device Management
DNP	Dynamic Network Planning
DODCPC	Downlink OPn-Demand CPC
DSA	Dynamic Spectrum Allocation
DVB-H	Digital Video Broadcast - Handheld
ECA policy	Event-Condition-Action policy
FDMA	Frequency Division Multiple Access
FSM	Flexible Spectrum Management
GPRS	General Packet Radio System
GSM	Global System for Mobile communications
JRRM	Joint Radio Resource Management
L1	Layer 1 (physical layer)
L2	Layer 2 (data link layer)

LTE	Long Term Evolution
MIH	Multimedia Independent Handover
MIH-IS	MIH Information Service
MO	Management Objects
MT	Mobile Terminal
O&M	Operation and Maintenance
OMA	Open Mobile Alliance
PLMN	Public Land Mobile Network
RACPC	Random Access CPC
RAN	Radio Access Network
RAT	Radio Access Technology
RF	Radio Frequency
RR	Radio Resource
RRM	Radio Resource Management
RRS	Reconfigurable Radio System
SDR	Software Defined Radio
SSID	Service Set IDentification
TDMA	Time Division Multiple Access
TRx	Transceiver
UE	User Equipment
UMTS	Universal Mobile Telecommunication System
WiFi	Wireless Fidelity

NOTE: IEEE 802.11b [i.16] wireless networking.

WIMAX	Worldwide Interoperability for Microwave Access

4 Cognitive Pilot Channel (CPC): Concept and Motivation

In today's composite radio environment, where radio-communications are developing in such a way that more and more services are proposed, with more and more various technologies and radio interfaces, a crucial point to enable optimization of radio resource usage is appearing to be the cognitive capability of the network and terminal, in order to switch to the most appropriate technology and frequency for the required service.

For instance, what is reported above becomes more relevant in a flexible spectrum management framework (where the spectrum allocated to the different RATs is foreseen to change dynamically within a range of different frequencies). The spectrum awareness arises as a basic challenge in a generic scenario, where a number of transceivers even with flexible time-varying assignment of operating frequency and/or RAT are deployed. Spectrum awareness from the mobile's perspective refers to the mechanisms allowing the terminal to obtain knowledge of the communication means available at a given time and place, both at switch-on stage as well as during on-going operation.

In this context, collaboration between network and terminals is very important.

In order to provide such collaboration, the concept of a Cognitive Pilot Channel (CPC) has been developed [i.1] to [i.4]. CPC can be advantageous in different scenarios.

A mobile terminal may use the CPC during one or both of the following phases:

- **"start-up"** phase: turning on, the terminal detects (e.g. on one or more well-known frequencies) the CPC and optionally could determine its geographical information by making use of some positioning system. The CPC detection will depend on the specific CPC implementation in terms of the physical resources being used. After detecting and synchronizing with the CPC, the terminal retrieves the CPC information corresponding to the area where it is located, which completes the procedure. Information retrieved by the mobile terminal is sufficient to initiate a communication session optimized to time, situation and location. In this phase, the CPC delivers relevant information with regard to operators, frequency bands, and RATs in the terminal location. During the start-up phase beginning at "switch on" of the mobile terminal, the mobile terminal is searching for a candidate network to camp on.

- **"ongoing"** phase: as soon as the terminal is registered to (or "camped on") a network, it leaves the "start-up" phase and is in the "on-going" phase situation. When the terminal is camped on to a network, a periodic check of the information forwarded by the CPC may be useful to rapidly detect changes in the environment due to either variations of the mobile position or network reconfigurations. In this phase, the same information of the "start-up" phase could be delivered by the CPC with additional data, such as services, load situation, etc. The ongoing phase ends when the mobile is no longer registered ("camped on") on any network.

The CPC can be advantageous in different various scenarios:

- In a first exemplary scenario, in order to obtain knowledge of the terminal radio environment, the sensing of the parts of the spectrum within the considered reachable frequency range (e.g. from 400 MHz up to 6 GHz) may be applied, but this could be a very time- and power-consuming operation. As an illustrative example, assuming GSM channels in a total scanned bandwidth of 550 MHz, in [i.4] scanning times of around 450 seconds (only including layer 1 detection) are mentioned. In this context, CPC can convey the necessary information to let the terminal know the status of radio channel occupancy through a kind of common pilot channel. This could considerably decrease time and power consumption.

- In another exemplary scenario, a secondary system may be searching for secondary spectrum usage opportunities to start communication. The CPC can be used to exchange sensing information between terminals, as well as between terminals and base stations in order to perform collaborative/cooperative sensing. This could greatly improve spectrum sensing characteristics, such as increase detection probability, reduce detection time, etc.

- In the third exemplary scenario, network and terminals are in a state other than start-up. In this case CPC could be used to provide necessary level of collaboration between network and terminals for a better support of different RRM optimization procedures and for optional dynamic spectrum access and flexible spectrum management.

For the purpose of these exemplary scenarios, two CPC deployment options can be considered. The first one, out-band CPC, considers that a channel outside the bands assigned to component Radio Access Technologies provides CPC service. The second one, in-band CPC, uses a transmission mechanism (e.g. logical channel) within the technologies of the heterogeneous radio environment to provide CPC services. For further details and explanations please refer to clauses 6 and 7.

Considering the definitions reported, the Table 1 below indicates in which situations, out-band and in-band CPC can be applied, (where "OK" means possible situation and "NO" means impossible situation), considering "downlink only" CPC and bidirectional CPC.

Table 1: CPC typology

	Start-up		Ongoing	
	out-band	in-band	out-band	in-band
⇩ Downlink only	OK	NO	OK	OK
⇳ Bidirectional	OK	NO	OK	OK

NOTE: During the ongoing phase, the terminal may use the in-band CPC for bidirectional communication, while, in parallel, may receive information delivered by the out-band CPC.

4.1 Baseline scenarios

4.1.1 Support for terminal at start-up phase

Figure 1 represents an example of the typical scenario of application of the out-band CPC: a heterogeneous or multi-RAT context is shown. Switching on, the mobile communication terminal has not any knowledge of the most appropriate RAT in that geographic area where it is located, or which frequency ranges the RATs existing in that specific geographic area exploit.

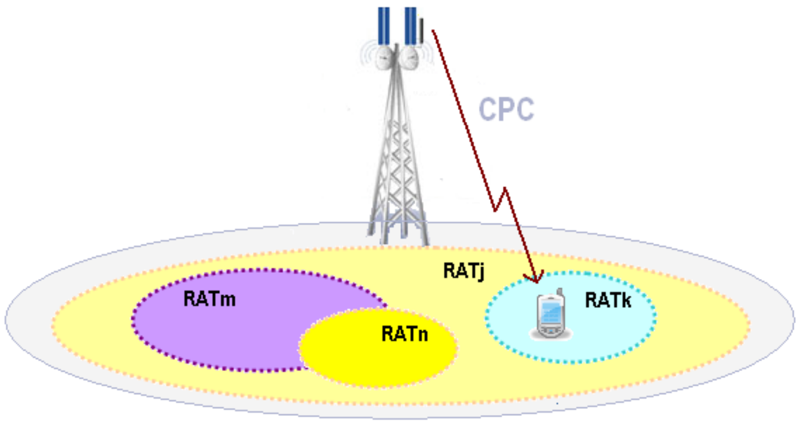

Figure 1: Example of the out-band CPC application at terminal start-up in the heterogeneous environment context

The mobile terminal will need to initiate a communication in a spectrum context which could be unknown due to dynamic reallocation mechanisms (also encompassing Dynamic Spectrum Allocation (DSA) and Flexible Spectrum Management (FSM) schemes), without requiring an excessive complexity .

In case the information about the service areas of deployed RATs within the considered frequency range reachable from a cognitive radio mobile terminal is unavailable, it would be necessary for the terminal to scan the whole frequency range in order to know the spectrum constellation. However, this is a huge power- and time-consuming effort, and sometimes it might not even be effective, as in the "hidden-node" or in the "receive-only device" cases.

In this scenario, the mobile terminal could be provided with the sufficient information via a Cognitive Pilot Channel (CPC), in order to initiate a communication session appropriately. The CPC delivers relevant information e.g. available operators, RATs, etc. in the terminal location.

In principle, the CPC covers the geographical areas using a cellular approach. In each CPC-cell, information related to the spectrum status in the cell's area is delivers, such as:

- indication on bands currently assigned to cellular-like and wireless systems (e.g. GSM, UMTS, LTE/LTE-Advanced, WiMAX, DVB-H, WiFi); additionally, also pilot/broadcast channel details for different cellular-like and wireless systems could be provided (e.g. BCH carrier for GSM system, CPICH carrier for UMTS system, beacon channel for WiFi).
- indication on current status of specific bands of spectrum (e.g. used or not used).

4.1.2 Support for secondary spectrum usage

Figure 2 shows an example of using an out-band CPC for initiating secondary spectrum usage communication. Again, heterogeneous and multi-RAT environment exists. Secondary system, including base stations and terminals, try to find secondary spectrum usage opportunities and establish communication.