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**Reconfigurable Radio Systems (RRS);**
**Cognitive Pilot Channel (CPC)**

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650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
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# Contents

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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

References are either specific (identified by date of publication and/or edition number or version number) or non-specific.

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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.

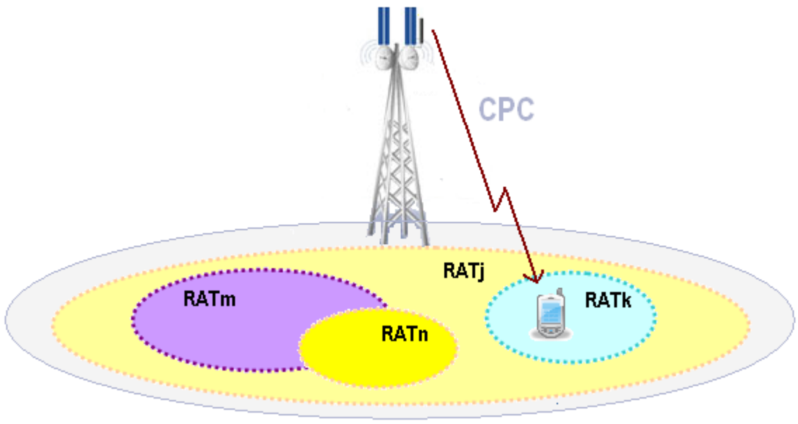



**Figure 1: Example of the out-band CPC application at terminal start-up in the heterogeneous environment context**

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.

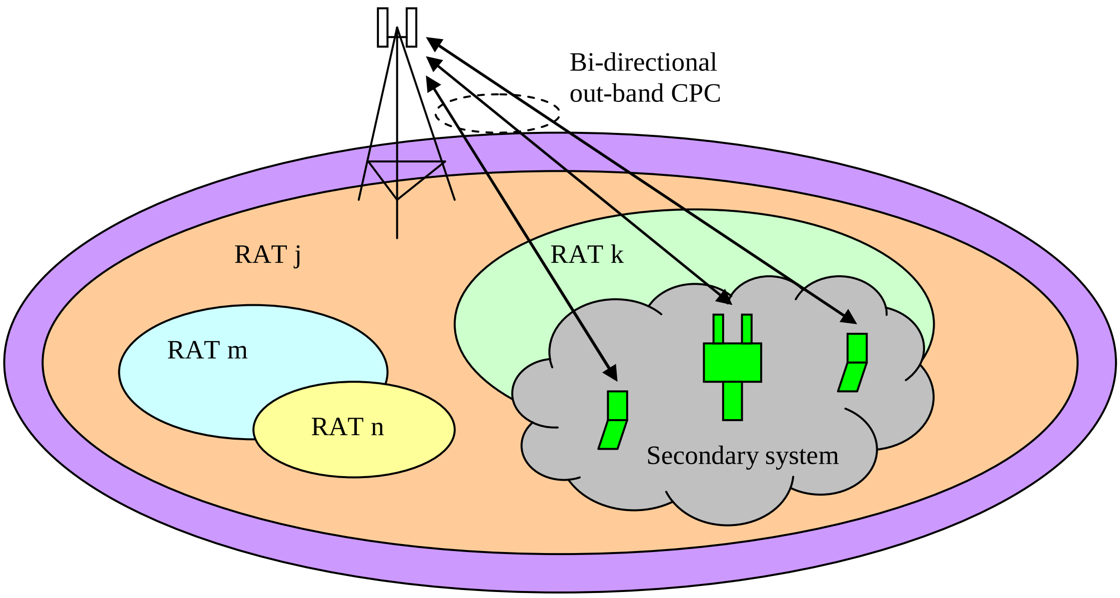



**Figure 2: Example of the bi-directional out-band CPC application for secondary spectrum usage communication**

To establish communication, secondary system needs to reliably detect secondary spectrum usage opportunities. After that, secondary base stations need to start offering wireless access service to secondary terminals, for example, to start transmitting some broadcast messages. Finally, secondary terminals need to connect to secondary base stations to start communication. Due to strong regulatory restrictions on secondary access, such procedure in general case will be much more time and power-consuming than described before procedure in the procedure of terminal start-up. A bi-directional out-band CPC can play an important role to improve this procedure.

CPC could deliver information on frequency bands allowed/available for secondary access in this geographic region. This will greatly decrease the time for spectrum sensing and also will ensure that secondary system adhere to the regulatory framework.

After such information is acquired by the secondary system, secondary terminals and/or base stations need to perform accurate spectrum sensing in the specified frequency bands. To reduce time for spectrum sensing and to increase its accuracy cooperative/collaborative sensing is very advantageous. When this sensing method is used, distributed sensors (terminals and/or base stations) need to exchange sensing information to increase sensing reliability and/or reduce time required to perform the detection of secondary spectrum usage opportunities. A bi-directional out-band CPC could be used as means for such sensing information exchange.

Finally, the bi-directional out-band CPC could be used by secondary base stations and terminals to decide which part of the spectrum should be used for communication, if, for example, multiple spectrum opportunities are detected.

### 4.1.3 Support for radio resource usage optimization

In a system operating an out-band CPC in a dedicated frequency band(s), the bandwidth of such system is expected to be not very high. The bandwidth should be enough for delivering medium- and long-term changes in the radio environment and for occasional bi-directional communication during secondary system usage and radio resource optimization mechanisms.

On the other hand, in heterogeneous wireless environment with optional dynamic spectrum access and flexible spectrum management features, collaboration between network and terminals is essential for radio resource usage optimization. Such collaboration will typically include exchange of context information, policies, etc between network and terminals, where such exchange could occur on the short-term time scale. Bandwidth requirements in this case could be too high for out-band CPC.

In this context, a possible alternative to the use of the out-band CPC could be the in-band CPC, conveying CPC information using a transmission mechanism (e.g. a logical channel) in the same radio access technologies that are used for the user data transmission, and allowing to bear information to both uplink and downlink.

In-band CPC will not fully substitute out-band CPC, rather both channels will complement each other.

## 4.2 Functionalities and features of the CPC

The CPC could offer the following functionalities and features:

1) helping the mobile terminal to select the proper network depending on the specific conditions (e.g. desired services, RAT availability, interference conditions, etc.), even providing support to Joint Radio Resource Management (JRRM), enabling a more efficient use of the radio resources;

2) helping the secondary system to establish communication by indicating frequency bands allowed/available for secondary usage, by providing means for sensing information exchange during spectrum sensing, and by assisting in secondary system start-up;

3) providing support for an efficient use of the radio resource by forwarding radio resource usage policies from the network to the terminals;

4) providing means for exchange of context information, policies, etc between network and terminal management entities for spectrum usage optimization;

5) providing support to reconfigurability by allowing the terminal to identify the most convenient RAT to operate with and to download software modules to reconfigure the terminal capabilities if necessary;

6) providing support to knowledge gathering by helping the terminal identify the specific frequencies, operators and access technologies in a given region without the need to perform long time and energy consuming spectrum scanning procedures;

7) helping the network provider to facilitate dynamic changes in the network deployment by informing the terminals about the availability of new RATs/frequencies, thus providing support to dynamic network planning (DNP) and advanced spectrum management (ASM) strategies;

8) releasing the benefits of secondary trading and flexible use, both in technical and in economic terms;

9) providing information of the current status of specific spectrum bands (e.g. used or unused).

## 4.3 Possible advantages of the CPC

By considering a CPC as described above, the following advantages are pointed out:

- simplifying the RAT selection procedure;
- improving secondary system start-up procedure;
- avoiding a large band scanning, possibly simplifying the terminal implementation (physical layer) for manufacturers;
- the CPC concept seems relevant for the implementation of DSA/FSM schemes;
- enabling collaboration between network and terminal management entities for spectrum usage optimization;
- the CPC concept as a download channel could be useful to the operator and user in a roaming scenario where it could be necessary to download a new protocol stack to connect to the network.

Finally, the CPC is shown to be a relevant part of cognitive networks as the radio enabler to help the access of the user terminals to the multi-component radio network.

# 5 CPC Contents Definition

Clause 5.1 describes a model on what kind of information is stored on network side followed by options of the organization of CPC geographical related information in clause 5.2. Then the following clauses describe for different CPC-deployment cases, which parts of that information are transmitted over the CPC via the air-interface.

## 5.1 Information Model on the information stored on network side

A general information model on the information relevant for the CPC stored on network side is shown in figure3.

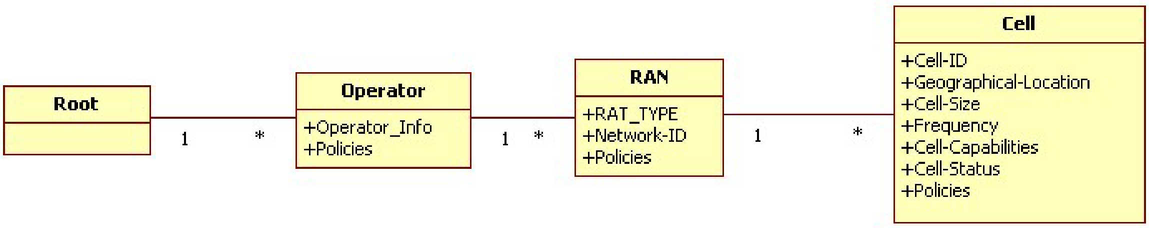



**Figure 3: CPC database information model**

The following fields are considered in the CPC database information model:

- Root: The root of the database.
- Operator: There can be several operators. For each operator, some operator information (e.g. the name of the operator) as well as policies on operator level are stored.
- RAN: Each operator can have several al radio access networks (RANs).
- Each RAN has a Radio Access Technology Type (RAT_TYPE), e.g. "GSM" "UMTS", "CDMA2000", "WiMAX", "LTE", etc.
- Additionally, a Network-ID is stored for each RAN. This Network-ID can include e.g. the PLMN-identity in case of GSM or UMTS or the SSID in the case of WiFi.
- Further on, policies on RAN level can also be included.
- Cell: Each RAN can have several cells. For each cell, the Cell-Id (e.g. Cell-identity for UMTS or BSSID in the case of WiFi), the geographical location of the center of the cell (e.g. longitude, latitude), the cell-size, frequency, cell-capabilities (e.g. cell capacity) and cell-status (including e.g. cell-load) can be stored.
- Further on, policies on cell level can also be included.

Policies are defined by the operator and are related to the operator's strategy regarding the management of traffic load and radio resource and spectrum usage optimization, with respect to user's demands.

Moreover, some sensitive information may not be available in certain use cases.

## 5.2 Organization of CPC geographical related information

There is a need to organize the information delivered over the CPC according to the geographical area where this information applies.

A difference can be made between two options differing on how they provide geographical related information:

- Mesh-based approach: The geographical area is divided in small zones, called meshes. In that case the CPC should provide network information for each one of these meshes, being possibly transmitted over a wide zone and therefore including a lot of meshes. Initial requirements evaluations seem to conclude that this solution could require a very high amount of bandwidth.
- Coverage area approach: In this approach, the concept of mesh is not needed in defining the CPC content, and the coverage area is provided for the different RATs. The following items could be provided in this approach: operator information, related RATs and for each RAT, corresponding coverage area and frequency band(s) information.

## 5.2.1 Mesh-based approach

In this approach, the CPC operates in a certain geographical area subdivided into meshes [i.4]. A mesh is defined as a region where certain radio electrical commonalities can be identified (e.g. a certain frequency that is detected with a power above a certain level in all the points of the mesh, etc.). The mesh is univocally defined by its geographic coordinates, and its adequate size would depend on the minimum spatial resolution where the above commonalities can be identified. The concept is illustrated in figure 4, where, for simplicity, square meshes of identical dimension have been considered, although other approaches could exist based on e.g. dynamic definition of meshes with an adaptive size.

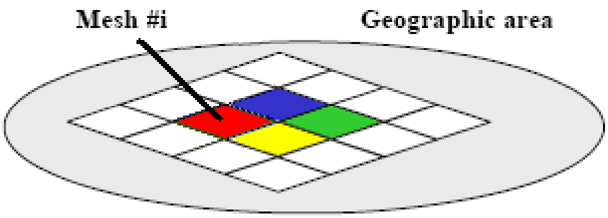



**Figure 4: CPC mesh-based approach**

It can be logically inferred that there will be very likely little variations of the CPC information when moving from a given mesh to a neighbouring one. From this observation, a possible optimized implementation of the concept to reduce the required CPC bandwidth could be considered. The base station transmits all the information of a reference mesh and for the other meshes the network would send the identifier of the reference mesh together with the delta CPC information. The delta CPC information stands for the pieces of CPC information which differ from the information corresponding to the reference mesh. This includes operators, RAT's and frequencies that appear or disappear in the present mesh with respect to the reference mesh. The network may determine the reference mesh as the one having the most commonalities in terms of CPC content. The mobile terminal infers the CPC information by decoding the information of the reference mesh and the delta CPC information corresponding to the mesh in which it is located.

## 5.2.2 Coverage area approach

In this approach the CPC content for a given geographical zone is organized taking into account the area, under-laying CPC umbrella, where such information has to be considered valid.

For instance, in case the CPC information is related to availability of operator/RAT/frequency, as in Figure 2, the CPC content will be organized e.g. per coverage area of each RAT.

It is worth to be noted that knowing the position of the mobile terminal is not a strict requirement for the CPC operation using this approach, but a capability that enables higher efficiency in obtaining knowledge:

- in case positioning is not available, as long as the mobile terminal is able to receive the CPC information, the information about the different regions in that area are available;
- in case positioning is available, a subset of the information at the actual position could be identified. The mobile terminal could then use that information.

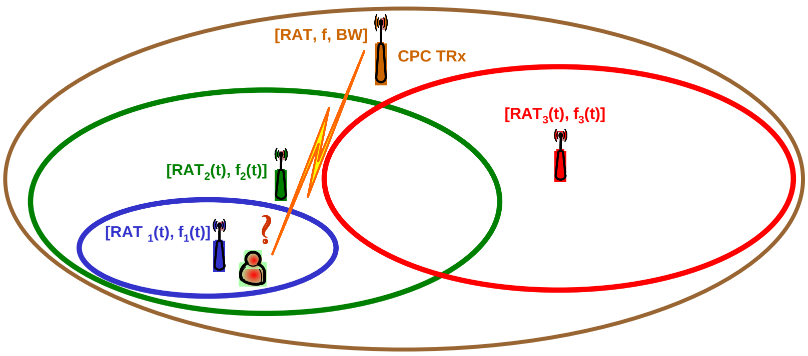



**Figure 5: Example of CPC coverage area based approach**

## 5.3 CPC contents to support terminal start-up

### 5.3.1 Content in the case of mesh-based approach

The information conveyed in the CPC for a given mesh is shown in [i.4]. In particular, for each mesh, location information indicating the geographic coordinates is transmitted.

Similarly, the CPC indicates the list of available operators in the mesh, including, for each operator, the available RATs and the corresponding frequency ranges per RAT (figure 6). In addition to this basic information, other optional terminal-dependent aspects such as maximum transmitted power levels allowed depending on e.g. whether the terminal is indoor or outdoor could also be included in the CPC.

The mesh-based approach has been evaluated and in some cases could require bit rate values in the order of hundreds of Kbit/s (see [i.5]).

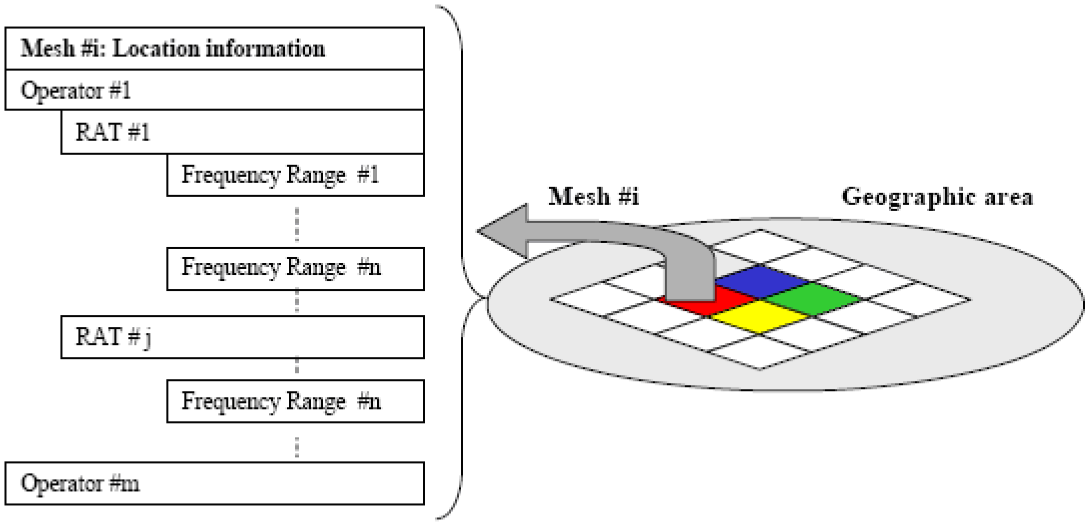



**Figure 6: CPC information to be sent for each individual mesh [i.4]**

### 5.3.2 Content in the case of coverage area approach

The structure of the basic CPC message to be conveyed is reported in figure 7.

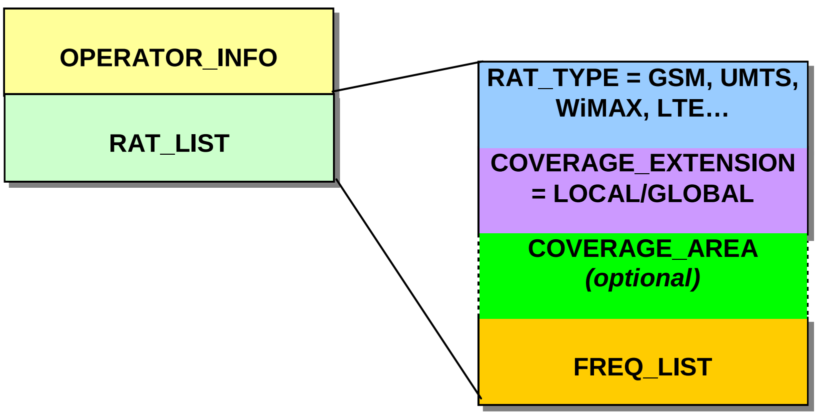



**Figure 7: CPC message structure**

The following fields are considered in the CPC message structure. In the case of CPC Out-band solution, all the fields reported below are considered. The structure includes:

- *Operator information:* operator identifier. This information is repeated for each Operator to be advertised by the CPC.

- *RAT list:* for each operator, provide information on available RATs. This information is repeated for each RAT of i-th Operator.
  - *RAT type:* could be for instance "GSM", "UMTS", "CDMA2000", "WiMAX", "LTE", etc.
  - *Coverage extension:* could be GLOBAL (i.e. wherever the CPC is received) or LOCAL (i.e. in a area smaller than CPC coverage).
  - *Coverage area:* to be provided in case of LOCAL coverage (e.g. reference geographical point).
  - *Frequency information:* provide the list of frequencies used by the RAT.

In the case of CPC In-band solution, other fields could be added to the reported ones. Such fields could include Policies, Context Information, etc.

Taking into account the same assumptions used for evaluating the mesh-based approach in [i.5], the first preliminary evaluations performed on the coverage area approach show that the required bit rates could be in the order of few tens of Kbit/s [i.15].

## 5.4 CPC contents to support secondary spectrum usage

In this case, a bi-directional out-band CPC is used to assist in establishing a secondary spectrum usage communication. In this case, CPC participates in three procedures:

- Acquiring initial information on frequency bands for secondary usage.
- Assisting in spectrum sensing.
- Assisting in secondary system start-up.

During acquiring initial information on frequency bands allowed/available for secondary usage, CPC operates as downlink broadcast channel, similar to the start-up scenario.

It conveys information of frequency bands allowed/available for secondary usage, operators operating in these frequency bands, RATs used, and possibly information on other secondary systems for communication in particular frequency bands. This information could greatly reduce frequency range that should be accurately sensed. Such information could be received by secondary base stations and/or terminals.

Compared to the start-up scenario, one additional feature is required in this scenario. Out-band CPC provides opportunity for bi-directional communication. This can be done, for example, by providing dedicated time intervals for bi-directional communication in parallel to time intervals for downlink broadcast only.

During assisting in spectrum sensing, out-band CPC operates as bi-directional channel. As such it is used by secondary base stations and terminals to exchange spectrum sensing information, including control information coordinating measurement schedule, raw/processed measurements, and detection decisions/results. This topic is currently under investigation in IEEE 1900.6 [i.17] working group, which is developing "Spectrum Sensing Interfaces and Data Structures for Dynamic Spectrum Access and other Advanced Radio Communication Systems."

As a result of spectrum sensing multiple spectrum opportunities may be detected. Secondary system needs to decide which of them it will use for communication. If such decision is made in a distributed manner, exchange of information between secondary base stations and terminals is required. In other situation, when decision is solely made on network side, it could be reported to secondary terminals to speed-up the procedure of acquisition of secondary base station signals.

## 5.5 CPC contents to support radio resource usage optimization

This clause describes how the CPC is used for collaborative radio resource usage optimization by providing means to exchange context information between network and terminals and providing policies to terminals. This will assist in decision making and reconfiguration of network and terminals.

A terminal may receive information delivered by the out-band CPC. When the terminals have some level of connection with a network, the in-band CPC can be used. Generally, an in-band CPC is bi-directional and information to be exchanged is much more detailed and dynamic than the one broadcasted over out-band CPC. Consequently, for this purpose, an in-band CPC could be a more technically efficient solution compared to an out-band CPC.

Several specifications are currently in place detailing information to be exchanged over out-band and in-band CPC channels to assist the radio resource usage optimization. One example is the information model defined in IEEE 1900.4-2009 [i.11] (see annex B for more details).

# 6 Out-Band CPC

This clause presents the out-band CPC concepts. Specifically, clause 6.1 describes the out-band CPC scope, followed by the scenario deployments and use cases in clause 6.2. Clause 6.3 provides some feasibility studies on possible CPC access technologies while clause 6.4 details the information delivery strategies. A possible CPC dimensioning methodology is presented in annex A considering the different delivery strategies as well as the different options for CPC contents organization.

## 6.1 Scope of the Out-band CPC

The "Out-band" CPC is a CPC conceived as a radio channel outside the component Radio Access Technologies.

In the Out-band solution, the CPC either uses a new radio interface, or alternatively uses an adaptation of legacy technology with appropriate characteristics.

Figure 8 depicts the concept of an out-band CPC solution.

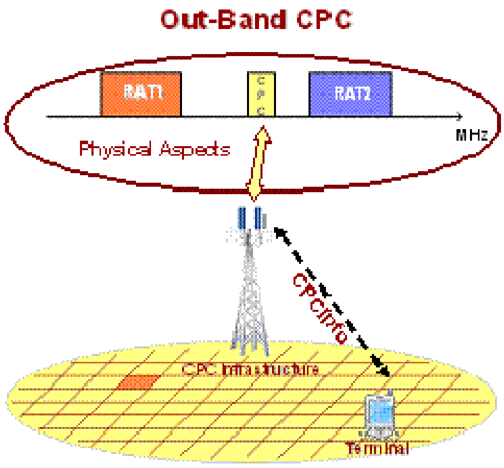



**Figure 8: Out-band representation**

At least two possible solutions are envisaged for the out-band CPC implementation:

- a new RAT, specifically standardized for CPC, could be developed, in order to fit with bandwidth and signalling requirements;
- on the other side, the re-use of already existing RATs (or the relevant parts of them) could be a valuable alternative.

In that context, one of the main issues to be discussed when dealing with Out-band CPC is the required bandwidth and the location of the operative frequency band.

NOTE: The identification of candidate frequency bands for the CPC is out of the scope of the present document.

The goal of the Out-band CPC is to provide start-up information to devices (e.g. available networks, their frequencies, their location, etc.). Possible applications of out-band CPC are:

- Providing start-up information to terminals, including information on operators, frequency bands and RATs in certain geographic area.
- Providing start-up information to secondary base stations and/or terminals, including information on frequency bands allowed/available for secondary usage in certain geographic area.
- Updating information on changes of radio environment in certain geographic area, where changes may occur due, for example, dynamic spectrum access or flexible spectrum management.
- Providing opportunity for two-way communication for the purpose of, for example, software downloading, collaborative/coordinated spectrum sensing, etc.

## 6.2 Scenarios/deployments and use cases

Figure 9 shows the downlink-only Out-band CPC with reference to other deployed RATs. The CPC Manager, i.e. the entity that controls and manages the CPC, is connected to the RAT carrying the Out-band CPC. The CPC Manager may obtain the information to be distributed over the Out-band CPC from the Joint Radio Resource Management (JRRM [i.14]) or other functions on network side, e.g. from the network management. In principle, the CPC Manager may obtain the information to be sent over the Out-band from one of the Management Entities of the Network, e.g. Joint Radio Resource Management (JRRM) or Operation & Maintenance (O&M). Additional CPC relevant information e.g. retrieved via scanning procedures may also be used to update the CPC Manager.

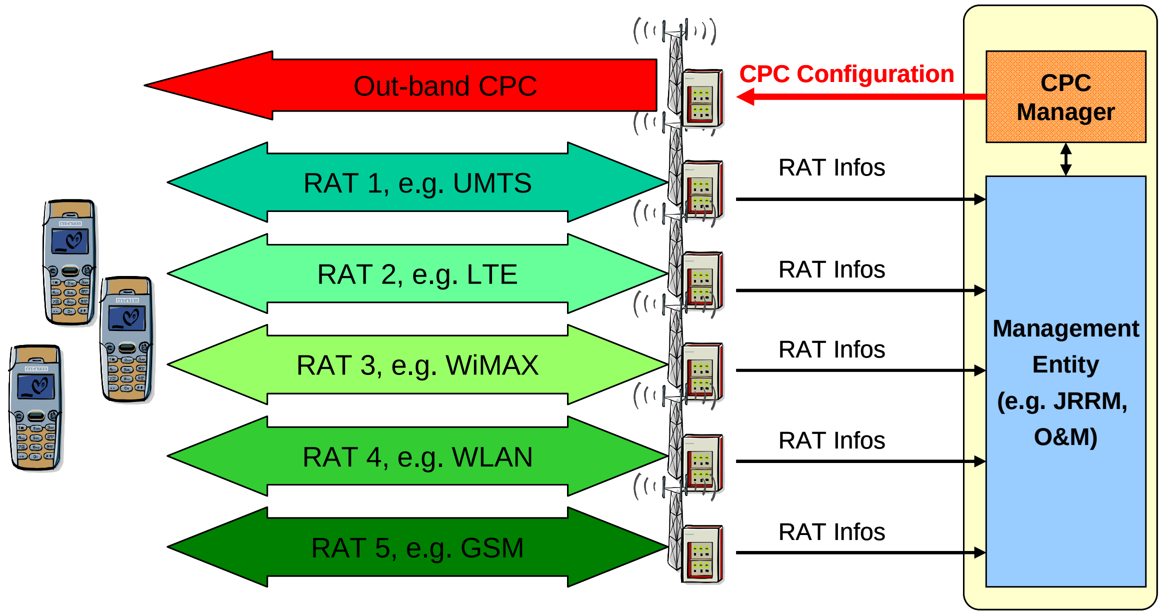



**Figure 9: Out-band CPC as a further RAT. In this example, the out-band CPC is shown as a downlink only CPC during the start-up phase**

The steps of the Out-band CPC operation procedure on terminal side are described in figure 10. After switching on the terminal, it will have first to detect and synchronize with the CPC. Then the information carried by the CPC can be extracted, evaluated and used to select and connect to a network. The steps 2 to 4 can also be performed periodically to detect changes in the environment due to either variation(s) of the mobiles position or network reconfigurations.

In the latter case, the out-band CPC is not only used in the start-up phase but also in the on-going phase. Depending on the deployments of the in-band CPC and out-band CPC, the two CPCs may not carry the same information neither the same level of accuracy. For example, once connected to a network, the terminal may need information related to a wider coverage area, to other RATs or to other operators than what is already provided by the in-band CPC. The terminal will have to listen to the out-band CPC without interrupting the on-going data connection, if any.

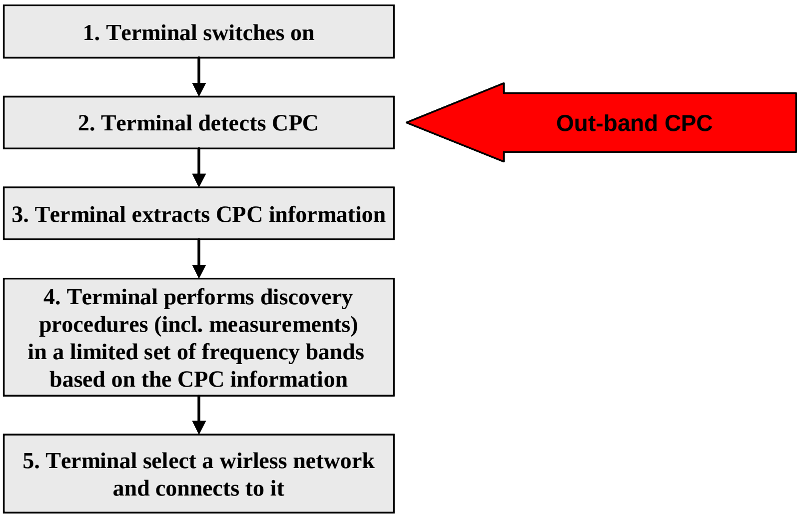



**Figure 10: Out-band CPC operation procedure on terminal side**

In the procedure described above, the out-band CPC provides only downlink information transfer. However, in other scenarios, the Out-band CPC may have both downlink as well as uplink information transfer.

Figure 11 shows a bi-directional out-band CPC scenario, where CPC assists secondary base stations and terminals to perform fast and coordinated sensing of frequency bands, potentially available for secondary communication. After secondary spectrum opportunity detection has been performed, bi-directional CPC is used for starting operation of the secondary system.

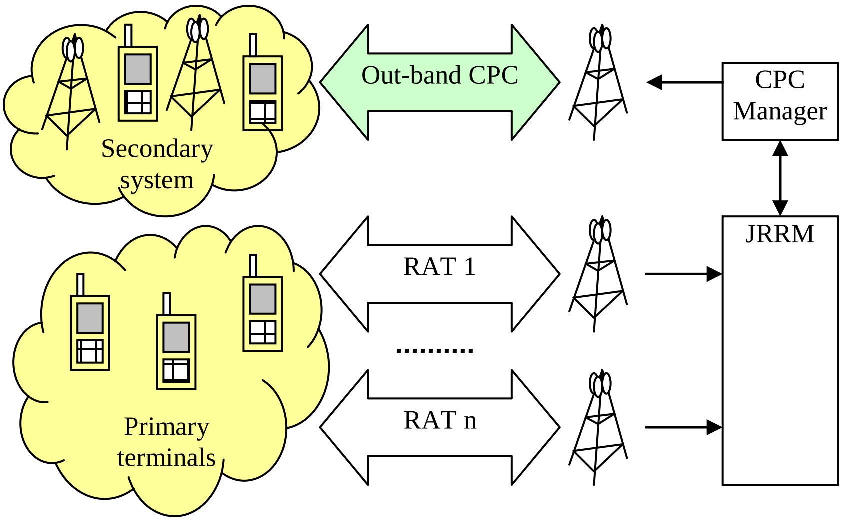



**Figure 11: Bi-directional out-band CPC**

Figure 12 shows steps of the bi-directional out-band CPC operational procedure.

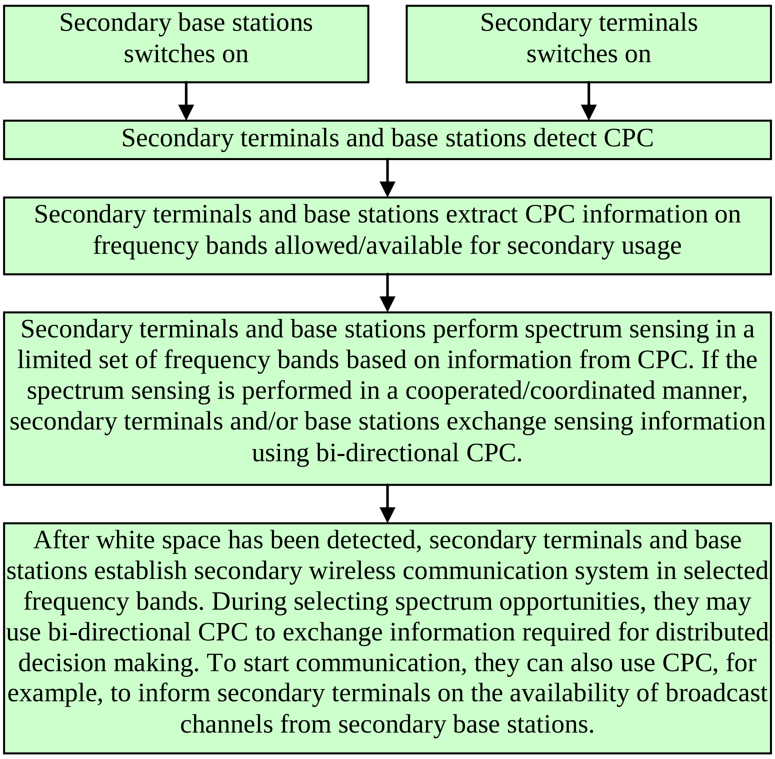



**Figure 12: Bi-directional out-band CPC operational procedure**

## 6.3 Feasibility studies on CPC access technologies

The re-use of already existing RATs (or the relevant parts of them) would seem to be a valuable alternative in order to identify the CPC access technology.

A couple of possible solutions to re-use the already existing RATs are currently under investigations:

- considering the GSM system as bearer;
- using Wi-Fi connectivity.

### 6.3.1 GSM

The approach could be based on the following points, taking into account the architecture and main feature of GSM system:

- the L1-L2 are entirely GSM-based:
- the CPC messages are transmitted as RR-layer [i.8] signalling messages, in a way similar to System Information on BCH;
- as initial case, only the broadcast of information is considered (i.e. no uplink channel is needed).

The GSM system is a TDMA/FDMA based one, with a bandwidth of 200 kHz for each carrier. In addition, on each carrier, 8 time-slots are available, each one with a minimum bit-rate of 9,6 kbps using the most reliable GSM coding (higher bit-rate per time-slot could be available using newer coding schemes, such as (E)GPRS encoding). Therefore, in theory one GSM carrier could offer a minimum bit-rate of 8 × 9,6 kbps = 76,8 kbps.

### 6.3.2 WiFi approach for Out-band CPC at switch on of a mobile

In the particular case of densely populated areas, another potential approach based on the exploitation of existing standards and already deployed radio systems consists of using the WiFi Access points to deliver out-band CPC information. The basic assumption is that the WiFi frequency bands are not affected by Dynamic Spectrum Allocation (DSA) and hence can be used as a reference at switch-on of a mobile terminal in a DSA context.

In the urban environment, WiFi hot spots are densely deployed and can be linked to CPC information databases via wired network infrastructure as shown in figure 13.

Specific location-dependant CPC data describing the radio environment (in terms of RATs and corresponding frequencies) are periodically updated and provided by the CPC manager entity to the WiFi hot spots which deliver the information within their respective coverage areas. The very last link from any hot spot to the user equipment is a short range radio link with sufficient throughput capability offered by the WiFi technology.

Hence, it could be envisaged to deliver an information service by the WiFi hot spots via a kind of push mode to a mobile terminal that switches-on within the hot spot coverage area.

This rather low level protocol would be transparent to the user in that

- it would not require any action from the user to sense the hot spot presence (we may use the action of a beacon associated with the hot spot that triggers the WiFi radio in a terminal that switches-on within the hot spot coverage area); and
- it would not require any action from the user to ask for the delivery of the information.

In this scenario the CPC coverage would be a series of "islands" instead of global coverage which can also be depicted as a "many-time/many-where" coverage situation as opposed to the "any-time/any-where" coverage situation of the classical CPC concept.

Moreover, provided that IEEE 802.11b standard [i.16] does implement the Media Independent Hand over (MIH) function defined in IEEE 802.21 standard [i.10], it could be thought of a dedicated CPC implementation through the MIH Information Service (MIH-IS) which is particularly relevant for this purpose.

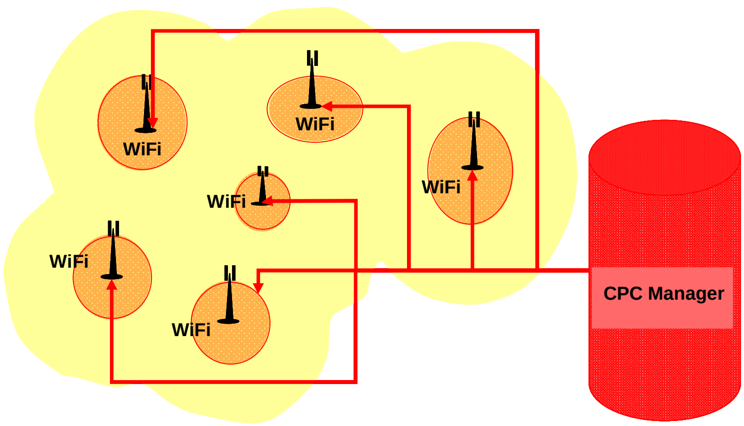



**Figure 13: Densely populated environment with WiFi hot spots fed by CPC database information**

## 6.4 Information delivery strategies

As described in [i.5], at least two possible strategies could be identified for delivering the CPC content:

- broadcast approach;
- on-demand approach.

## 6.4.1 Broadcast approach

The basic principle of broadcast transmission has been developed in [i.5]and is hereafter recalled:

- this strategy only uses a Downlink Broadcast CPC (DBCPC) channel where the information of all the available RATs/frequencies is broadcast periodically and continuously;
- the terminal receives the CPC and waits for the information corresponding to the area where it is located;
- the organization of the information content broadcast by CPC can be done in several ways as detailed in clause 5.

Figure 14 depicts the broadcast CPC operation as described above, assuming a periodicity of $T_B$ in delivering the information.

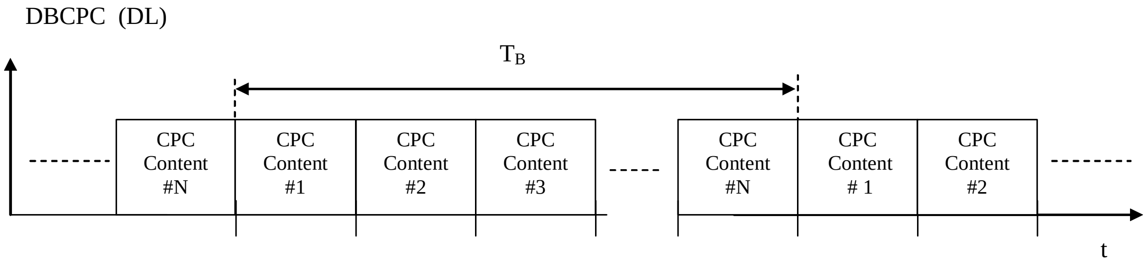



**Figure 14: Broadcast CPC operation**

## 6.4.2 On-demand approach

The basic principle of on-demand transmission has been developed in [i.5]and is hereafter recalled:

- this strategy makes use of both downlink and uplink components, and it consists in the following logical channels:
  - Random Access CPC (RACPC): an uplink slotted channel where the mobiles operating with CPC send requests to retrieve the needed CPC information. Each request basically could optionally contain an indicator of the geographical coordinates of the mobile terminal. An operation according to a simple access protocol such as S-ALOHA can be envisaged for this channel.
  - Acquisition Indicator CPC (AICPC): This downlink channel follows the same slotted structure of the uplink RACPC and is devoted to indicate that a request has been successfully received. The channel consists in Acquisition Indicators (AI) each one indicating the identifier of the terminal whose request has been received or the value Null if no request has been received.
  - Downlink On-Demand CPC (DODCPC): This downlink logical channel is used to transmit the CPC information to the requesting Mobile Terminal (MT).
- the terminal receives the CPC, perform a random access to the channel, sending a request for CPC information; in case of success, the requested information is conveyed on the DODCPC to the terminal.
- the uplink and the downlink channels are organized in slots of duration $T_S$. The AICPC and the DODCPC are multiplexed on the same time slots by making use of different fields of a certain burst structure. The transmission of the CPC information requires a time $T_{m,OD} = N_s \times T_s$ being $N_s$ an integer number of slots depending on the bit rate of the downlink channel.

Figure 15 depicts the on-demand CPC operation as described above.

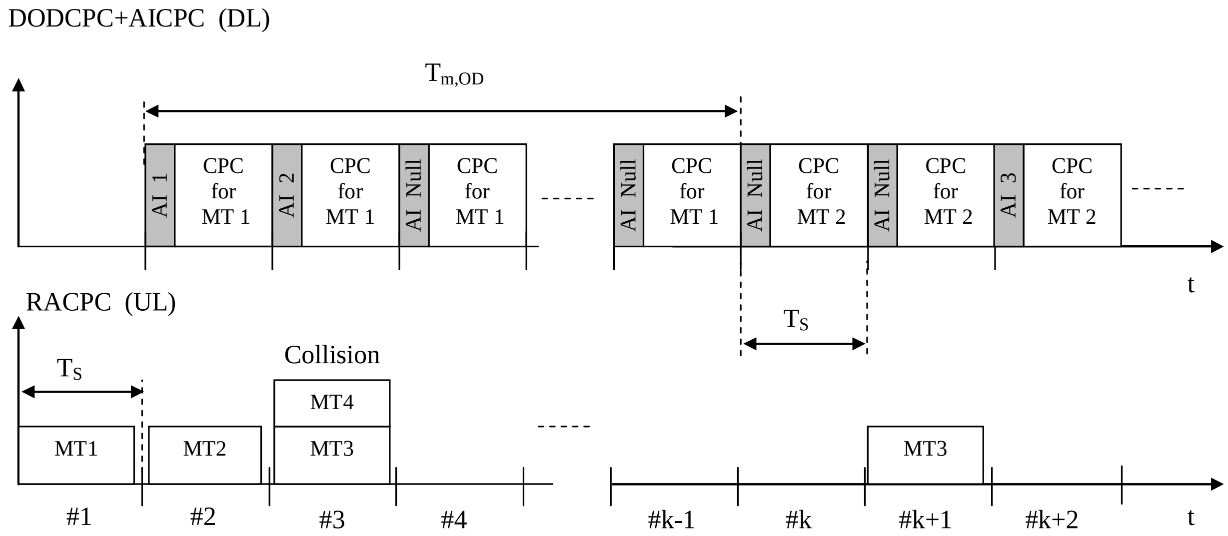



**Figure 15: On-Demand CPC operation**

# 7 In-Band CPC

This clause presents the in-band CPC concept. Specifically, clause 7.1 describes the in-band CPC scope, followed by the scenario deployments and use cases in clause 7.2. Clause 7.3 describes different implementation options and procedures for the in-band CPC. A possible CPC dimensioning methodology is presented in annex A.

## 7.1 Scope of the In-band CPC

The in-band CPC is CPC conceived as a logical channel within the technologies of the heterogeneous radio environment.

The in-band CPC can provide downlink as well as uplink information transfer.

In the in-band solution, the CPC is transmitted using specific channels of the existing access technologies. In fact the in-band CPC could be understood as a logical channel within one or some of the technologies available in a heterogeneous radio environment. Notice that in this context, the in-band CPC can provide both downlink as well as uplink information transfer.

The in-band CPC does not require a new frequency to be agreed and harmonized as far it uses existing infrastructure. In that sense, some possibilities would be to use some default worldwide de-facto standard RATs, like e.g. GSM or UMTS, to convey CPC, mapping it on a logical channel.

Figure 16 depicts the concept of in-band CPC solution.

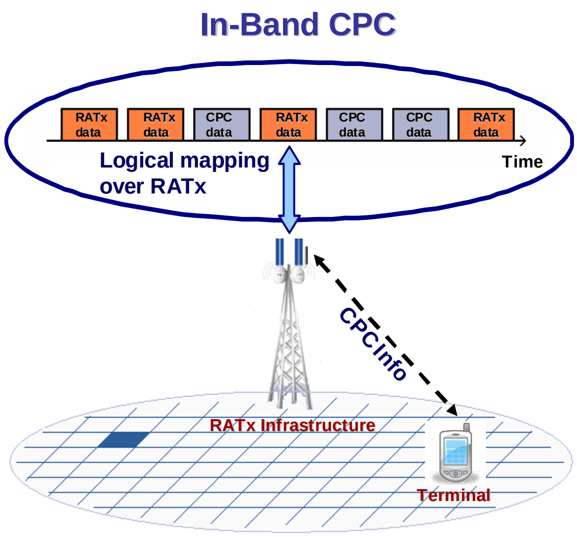
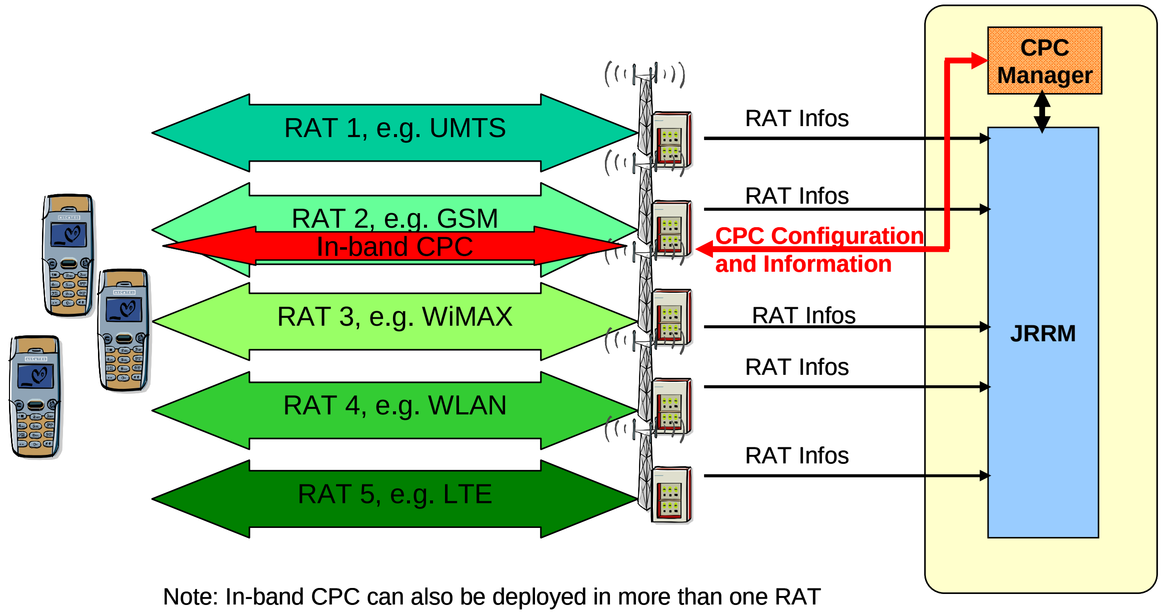



**Figure 16: In-band representation**

Notice that this kind of solution of the CPC could require slight modifications to the standards already deployed in order to carry the CPC information.

## 7.2 Scenarios/deployments and use cases

Figure 17 presents the architecture of an In-band CPC, with reference to the deployed RATs: The in-band CPC can be implemented in one or more of the available RATs. The CPC information can be conveyed via each one of the available RATs. Therefore, in this case the CPC Manager is connected to all the RATs carrying the in-band CPC. The CPC Manager may obtain the information to be distributed over the In-band CPC from the Joint Radio Resource Management (JRRM) or other functions on network side, e.g. from the network management. Additional CPC relevant information e.g. retrieved via scanning procedures may also be used to update the CPC Manager. The CPC Manager is connected to each RAT carrying an In-band CPC and configures which information to be distributed over the In-band CPC. In the case that then In-band CPC supports also Up-link communication, the Up-link information is sent to the CPC Manager.




NOTE: In the figure, the in-band CPC is shown as having both up- downlink components.

**Figure 17: In-band CPC using available RATs**

## 7.3 Implementation options and Procedures

### 7.3.1 Application Layer Implementation (IP-based CPC)

The Logical IP-based CPC on Application Layer can be seen as one possible solution for the in-band CPC.

This scenario can be seen as a migration option because no modification is needed to existing RATs.

As a draw back, the terminal has to find a first radio access e.g. with traditional procedures and attach to a first network which may typically require authentication and authorization procedures.

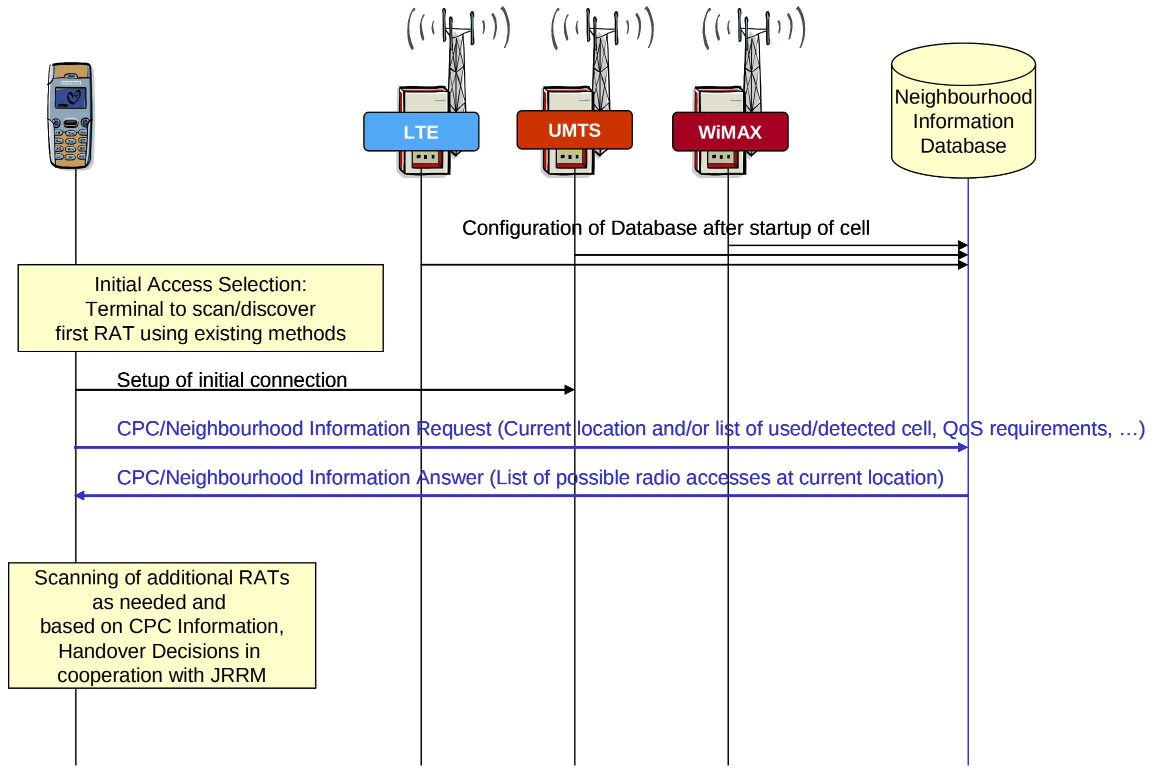



**Figure 18: shows an example scenario using the higher-layer CPC**

On network side, there is a neighbourhood information database (which can be part of JRRM and/or DSONPM [i.14]). The base stations provide information about their RATs, capabilities, capacity, location and coverage which is then put into the database.

When a terminal wants to get information on available radio accesses at its current location, it has first to detect and connect to one RAT, e.g. using legacy procedures. Then, the terminal can submit a dedicated request on CPC/Neighbourhood Information towards the database using e.g. IP transport for this request.

This request may already contain location information, e.g. in the case the terminal has a GPS receiver. However, as many terminals may not have such a GPS receiver, it is also possible to send only information on which cell the terminal is connected to and optionally - if available - information on other measured cells. Based on this information, the database can also make an estimation of the current location of the user. Then, the database checks which radio accesses are available at the current location of the user. A further refinement of the selection can be made by providing additional constraints, e.g. on requested service parameters. This information will be sent back to the terminal which can then make an optimized scanning based on the received information. Further on, the terminal may switch of the scanning on some RATs to save energy in the case the CPC information indicates that no access of that RAT is expected at the user's location. Additional procedures, e.g. access selection and initiation of vertical handovers will then be made in cooperation with the JRRM.

It has to be noted that 3GPP is using a similar concept in their work on the "Access Network Discovery and Support Function" (ANDSF). The architecture as shown in figure 19 is described in TS 123 402 [i.6].


**Figure 19: 3GPP Architecture for Access Network Discovery and Support Functions [i.1]**

TS 124 312 [i.7]defines information models (Management Objects) that can be used by the Access Network Discovery and Selection Function (ANDSF) and the mobile terminal. A description of this ANDSF MO is included in clause B.2.

## 7.3.2 Mapping on existing standards

The scope of this clause is to present a possible CPC In-band solution focusing on the legacy systems GSM and UMTS. In particular, possible "free spaces" in the exchange of the protocol messages in terms of "not used bits" of said systems could be identified, in order to send additional information (e.g. related to the CPC) using said bits and without heavy new investments in the network.

The general idea (valid for both GSM and UMTS systems, and applicable in principle to any system) is to exploit the padding bits of a protocol message in order to transport useful information (e.g. CPC information) using the System Information messages and, more in general, the RR/RRC signalling [i.13]. More in detail, the following RR/RRC signalling messages could be available:

- System Information messages: these signalling messages is always present inside a cell and is periodically repeated with a constant amount of padding bits potentially usable;
- RR/RRC protocol messages different from the System Information: these signalling messages provide only temporally (during the period of signalling) a certain quantity of padding bits leading to a variable amount of padding bits potentially usable during time.

Considering the preliminary evaluations performed, or both GSM and UMTS system, the available bit rate is very sensible with respect to the cell which the terminal is camped on since the mapping and the structure of the System Information depends on network choices.

# 8 Combination of In-Band and Out-Band CPC

Figure 20 shows a CPC procedure on terminal side, which combines the usage of out-band and in-band CPC. The consecutive steps consist in:

- Start-up phase: when the terminal is switched on, it starts listening to the out-band CPC in order to obtain basic parameters (e.g. available networks at that location), then select and connect to a network.
- Ongoing phase: once the terminal is connected to a network it stops listening to the out-band CPC and start receiving the in-band CPC within the registered network.

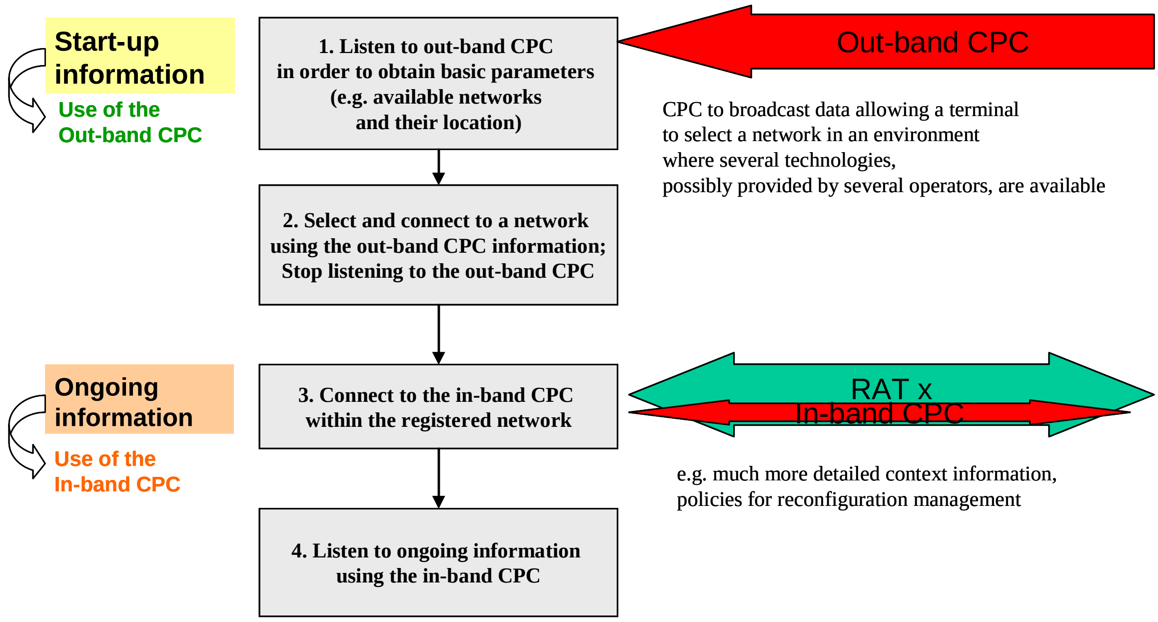



**Figure 20: Terminal-side CPC procedures combining Out-band and In-band CPC**

It can be noted that [i.4] describes an example of a hierarchical implementation scenario for the combined operation of the out-band and in-band CPC.

# 9 Summary and Recommendations for Standardization

The today's wireless communications landscape is characterized by the coexistence of a plethora of disparate Radio Access Technologies (RATs) providing different capacity and coverage capabilities, mobility support, applications and services. In this heterogeneous environment, mobile terminals should accordingly set up their operational parameters with the aim to enable a more efficient use of the radio resources. As a result, in order to implement the optimal action, a mobile terminal needs to be enabled to obtain knowledge of its environment and established policies. The Cognitive Pilot Channel (CPC) concept has been proposed as a possible solution to provide such information to the terminal, in order to acquire the necessary radio awareness at a given time and place (especially in a flexible spectrum management context) and to take decision according to the policies received.

The present document has provided a feasibility study on the CPC concept by defining its main characteristics in the context of Cognitive Networks (CN) for Reconfigurable Radio Systems (RRS). The main functionalities and features of the CPC, the operational procedures including CPC information modelling and CPC information delivery strategies, as well as some exemplary scenarios, have been described in the document.

Two CPC deployment options have been presented in the document. The first one, out-band CPC, considers that a channel, outside the bands assigned to the component Radio Access Technologies, provides CPC service. The second one, in-band CPC, is conceived as a logical channel within the technologies of the heterogeneous radio environment providing CPC services.

**The need for standardization (why standardization is needed)**

Exemplary scenarios where the CPC is seen as useful are:

- The CPC can be used to support a terminal during the start-up phase, conveying the necessary information to let the terminal know the available RATs and corresponding used frequencies in a given geographical area.
- In the context of a secondary system the CPC can be used to exchange sensing information between terminals and base stations in order to perform collaborative/cooperative sensing facilitating the searching of white spaces to start communication.
- The CPC can be used for a more efficient level of collaboration between a network and the terminals by supporting Radio Resource Management (RRM) optimization procedures and additionally for an optional dynamic spectrum access and flexible spectrum management.

In this context, the standardization of CPC would be beneficial because:

- From an operator viewpoint standardization of the CPC could facilitate the managing of both the start-up and on-going phases, helping the mobile terminal to identify the spectrum availability, to select the proper network, to provide support to Joint Radio Resource Management (JRRM), and in summary to enable a more efficient use of the radio resources.
- Providing support to reconfigurability by allowing the terminal to identify the most convenient RAT to operate with and allowing the terminal to reconfigure its capabilities if necessary, e.g. facilitating advanced radio resources management strategies.
- As a key enabler for Cognitive Networks, the CPC can facilitate the secondary spectrum usage, avoiding/minimizing interferences, trying to enhance the efficiency of this type of communications.

This feasibility study has clarified several CPC aspects: it is apparent that further technical research activities on this field are still needed and are currently underway in different research projects.

**Recommendations on what should be standardized**

Based on the above arguments, the present document has provided inputs for a possible standardization of certain topics of the CPC such as:

- Definition and specification of physical and data link layer (L1 and L2) technologies and protocols for the out-band CPC in both downlink only and bidirectional operation. This should include the definition of the message structure and delivery procedures for cases like using the CPC concept for speeding up the start-up procedure in the context of a full DSA environment, for using the CPC as a support for secondary spectrum usage and for using the CPC as a support to radio resource management optimization.
- Definition and specification of message structure and delivery procedures for the in-band CPC for example to support radio resource usage optimization in the context of heterogeneous wireless environments.

# Annex A: Downlink CPC dimensioning methodology

In the following, a methodology for dimensioning the downlink CPC is provided. Both broadcast and on-demand possibilities for the CPC information delivery identified in clause 6.5 and the mesh-based and coverage-area based strategies for the CPC contents definition in clause 5 are considered. The objective is to identify those parameters that play a relevant role in the CPC dimensioning to determine the required downlink capacity per CPC transceiver in accordance with a given CPC deployment. This methodology can be used as a reference to establish a comparison between the different approaches in different scenarios.

In order to formulate the CPC dimensioning methodology the following parameters are taken into account:

1) The physical and link layer design will end up with a certain downlink capacity to convey information through the CPC from every single CPC transceiver (TRx) in the downlink, denoted here as $R$ bits/s/TRx.

2) Whatever the deployment strategy is, it will be characterized here by a certain density of CPC transceivers over a given geographical area, $T$ TRx/km$^2$.

3) Therefore, given a certain CPC radio interface and a CPC deployment strategy, the resulting offered downlink capacity is $R \times T$ bits/s/km$^2$.

4) The computation of the CPC demanded capacity will depend on both the CPC delivery strategy (broadcast/on-demand) and on the CPC contents approach (mesh-based, coverage-area based), as detailed in the following:

   a) For a Broadcast mode, information about the operators/RATs/frequencies available within the range of a CPC transceiver is provided continuously and periodically. Let assume a periodicity of $P$ seconds. Then, depending on the CPC content definition solution, the following situations are considered:

      a1) Mesh-based approach: In this case the CPC signals the information corresponding to specific geographical areas called meshes. Then, let denote by $X_m$ meshes/km$^2$ the density of meshes to be signalled by the CPC, and by $M_m$ bits/mesh the number of bits needed to represent a single mesh. The required CPC capacity is given by:

      CPC demanded capacity for Broadcast mode and Mesh-based approach = $M_m \times X_m / P$ bits/s/km$^2$.

      a2) Coverage area-based approach: In this case, the CPC signals the coverage areas of the different RATs. Then, let denote by $X_c$ areas/km$^2$ the density of coverage areas to be signalled by the CPC, and by $M_c$ bits/area the number of bits needed to represent a single coverage area. The required CPC capacity is given by:

      CPC demanded capacity for Broadcast mode and Coverage-based approach = $M_c \times X_c / P$ bits/s/km$^2$.

   b) For an On-demand mode, information about the operators/RATs/frequencies available within the range of a CPC transceiver is provided upon request. Let denote the density of requests by $L$ requests/s/km$^2$. Let assume the most general case in which positioning information is not known. Then, depending on the CPC content definition solution, the following situations are considered:

      b1) Mesh-based approach: In this case the CPC will have to provide, for each request, the information corresponding to all the meshes in the CPC transmitter coverage area (i.e. a total of $X_m / T$ meshes/request). Then, the total amount of information to be delivered per request is $X_m \times M_m / T$ bits/request, and the corresponding demanded capacity:

      CPC demanded capacity for on-demand mode and Mesh-based approach = $M_m \times X_m \times L / T$ bits/s/km$^2$.

b2) Coverage area-based approach: In this case, the CPC will specify for each request the information corresponding to all coverage areas in the CPC transmitter range (i.e. a total of $X_c/T$ areas/request). Then, the corresponding demanded capacity is:

CPC demanded capacity for on-demand mode and Coverage area-based approach = $M_c \times X_c \times L/T$ bits/s/km$^2$.

It is worth mentioning that, when information on positioning is included in the request, the amount of information of the on-demand CPC can be reduced (e.g. only the list of RATs/frequencies available in the position where the terminal is located could be transmitted, which could be encoded with $M_m$ bits/request and, therefore, the demanded capacity would simply be $M_m \times L$ bits/s/km$^2$).

A proper dimensioning strategy will match the demanded CPC capacity with the offered CPC capacity.

The following table summarizes the parameters involved in the CPC dimensioning, according to the above discussion.

| | | |
|---|---|---|
| CPC capacity per transceiver | | $R$ bits/s/TRx |
| Density of CPC transceivers | | $T$ TRx/km$^2$ |
| CPC offered capacity | | $R \times T$ bits/s/km$^2$ |
| **Broadcast CPC** | | |
| Periodicity | | $P$ s |
| Mesh-based | Density of meshes to be signalled | $X_m$ meshes/ km$^2$ |
| | Bits needed to represent a mesh | $M_m$ bits/mesh |
| CPC demanded capacity for broadcast CPC /mesh-based | | $M_m \times X_m/P$ bits/s/km$^2$ |
| Coverage area-based | Density of areas to be signalled | $X_c$ areas/km$^2$ |
| | Bits needed to represent an area | $M_c$ bits/area |
| CPC demanded capacity for broadcast CPC /coverage area-based | | $M_c \times X_c/P$ bits/s/km$^2$ |
| **On-demand CPC (without positioning)** | | |
| Density of requests | | $L$ requests/s/km$^2$ |
| Mesh-based | Bits to be sent to each request | $M_m \times X_m/T$ bits/request |
| CPC demanded capacity for On-demand CPC/no positioning/ mesh-based | | $M_m \times X_m \times L/T$ bits/s/km$^2$ |
| Coverage area-based | Bits to be sent to each request | $M_c \times X_c/T$ bits/request |
| CPC demanded capacity for On-demand CPC / no positioning/ coverage area-based | | $M_c \times X_c \times L/T$ bits/s/km$^2$ |
| **On-demand CPC (with positioning)** | | |
| Density of requests | | $L$ requests/s/km$^2$ |
| Bits to be sent to each request | | $M_m$ bits/request |
| CPC demanded capacity for On-demand CPC/with positioning | | $M_m \times L$ bits/s/km$^2$ |

# Annex B: State of the art

# B.1 Overview on IEEE 1900.4 Information Model

IEEE 1900.4 standard [i.11]uses an information model based on an object-oriented approach.

Three key groups of classes are defined:

- Policy classes.
- Terminal classes.
- Composite Wireless network (CWN) classes.

Policy classes are shown in figure B.1.

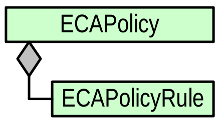



**Figure B.1: Policy classes**

Policy classes are used to abstract:

- Spectrum assignment policies.
- Radio resource selection policies.

These classes are used to describe policies of type Event-Condition-Action.

Correspondingly, the following is described in these classes:

- Event that triggers the evaluation of the policy condition.
- Condition that has to be fulfilled before applying the policy action.
- Action that has to be performed if the event has occurred and the condition is fulfilled.

Terminal classes are shown in figure B.2.

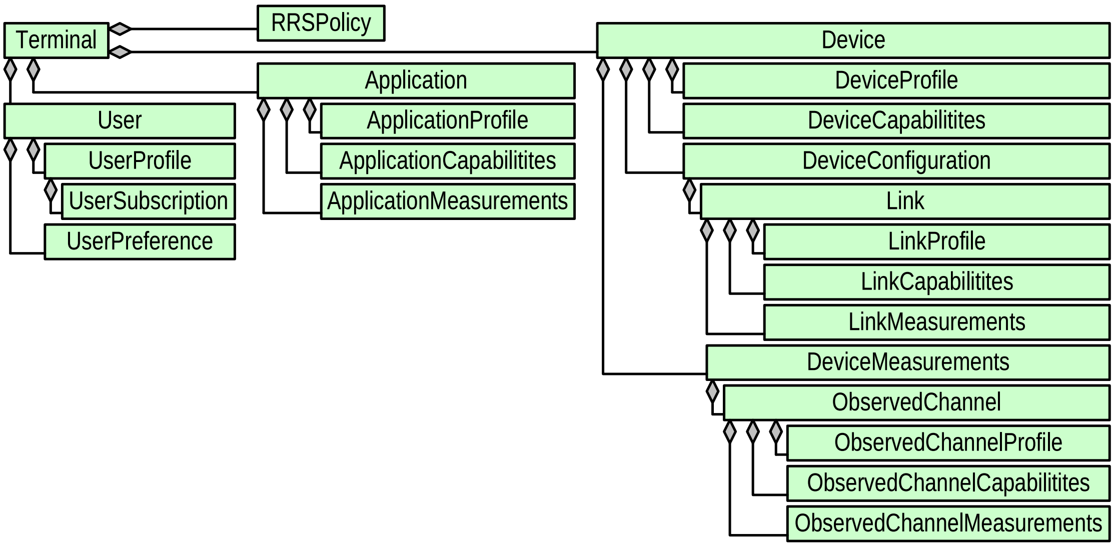



**Figure B.2: Terminal classes**

Terminal classes are used to abstract:

- User.
- Application.
- Device.
- Radio resource selection policy.

User class describes information related to a user of the terminal:

- UserProfile class contains general information about one user of terminal, for example, user ID:
  - UserSubscription class contains information about one subscription of the user.
- UserPreference class describes in a formalized form one preference of the user, for example, preferred operator and radio interface, perceived service quality, maximum cost.

Application class describes one currently active application:

- ApplicationProfile class contains general information about the application, for example, application ID, traffic class, direction (downlink or uplink), links used to deliver this application, QoS requirements.
- ApplicationCapabilities class contains information about measurements supported by this application, for example, delay, loss, and bandwidth measurements.
- ApplicationMeasurements class contains measurements performed by this application.

Device class describes all radio interface related hardware and software of a terminal, as well as, measurement information related to radio resources within the terminal:

- DeviceProfile class contains general information about the terminal, for example, terminal ID.
- DeviceCapabilities class contains information about terminal capabilities including both transmission and measurement capabilities, for example, supported radio interfaces, maximum transmission power.
- DeviceConfiguration class contains information about the current configuration of terminal:
  - Link class contains information about one active connection between terminal and RANs:
    - LinkProfile class contains general information about this active connection, for example, link ID;

    - LinkCapabilities class contains information about measurements supported on this active connection, such as block error rate, power, and signal-to-interference-plus-noise-ratio measurements;
    - LinkMeasurements class contains current measurements related to this active connection.

- DeviceMeasurements class contains current measurements related to terminal, for example, battery capacity and terminal location:
  - ObservedChannel class describes one frequency channel that does not have active connection with the terminal, but is observed by this terminal:
    - ObservedChannelProfile class contains general information about this frequency channel, for example, channel ID, frequency range;
    - ObservedChannelCapabilities class contains information about measurements supported on this frequency channel, such as interference and load measurements;
    - ObservedChannelMeasurements class contains current measurements related to this frequency channel.

RRSPolicy class describes one radio resource selection policy received by this terminal.

CWN classes are shown in figure B.3.

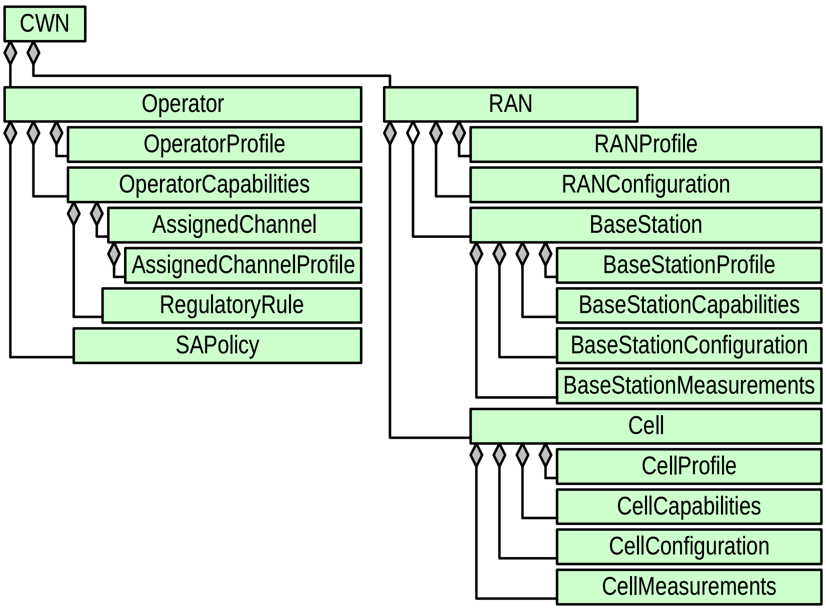



**Figure B.3: CWN classes**

CWN classes are used to abstract:

- Operator.
- RAN.

Operator class describes operator of this CWN:

- OperatorProfile class contains general information about the operator, for example, operator ID.
- OperatorCapabilities class describes operator capabilities:
  - AssignedChannel class describes one frequency channel assigned to this operator:
    - AssignedChannelProfile class contains general information about this frequency channel, for example, frequency channel ID, frequency range, and allowed radio interfaces.

- RegulatoryRule class describes in a formalized form one regulatory rule to be applied to one or several assigned channels.

- SAPolicy class describes one spectrum assignment policy specified by this operator.

RAN class describes one RAN of this CWN:

- RANProfile class contains general information about this RAN, for example, RAN ID.
- RANConfiguration class describes current configuration of this RAN, for example, RAN users.
- BaseStation class describes one base station of the RAN:
  - BaseStationProfile class contains general information about this base station, for example, base station ID, vendor, and location.
  - BaseStationCapabilities class contains information about base station capabilities including both transmission and measurement capabilities, for example, supported radio interfaces, supported channels, transport capability.
  - BaseStationConfiguration class contains information about the current configuration of the base station, for example, frequency channels and radio interfaces used.
  - BaseStationMeasurements class contains current measurements performed by this base station, for example, transmission power and load measurements.
- Cell class describes one cell of the base station:
  - CellProfile class contains general information about this cell, for example, cell ID, location, coverage area.
  - CellCapabilities class contains information about cell capabilities, for example, supported radio interfaces, supported channels, supported measurements.
  - CellConfiguration class contains information about the current configuration of the cell, for example, terminals served and transport service used.
  - CellMeasurements class contains current measurements related to this cell, for example, transmission power, cell and traffic loads, throughput, and interference measurements.

For each of the classes described above, IEEE 1900.4 [i.11] describes its members and their type, where data types are specified using ASN.1 notations.

# B.2 Overview on 3GPP ANDSF Management Object

TS 124 312 [i.7] defines information models (Management Objects) that can be used by the Access Network Discovery and Selection Function (ANDSF) and the UE. The ANDSF MO is used to manage intersystem mobility policy- as well as access network discovery information stored in a UE supporting provisioning of such information from an ANDSF.

The Management Object (MO) is compatible with the OMA Device Management (DM) protocol specifications, version 1.2 and upwards, and is defined using the OMA DM Device Description Framework (DDF) as described in the Enabler Release Definition OMA-ERELD-DM-V1_2 [i.9].

The MO consists of relevant parameters for intersystem mobility policy and access network discovery information that can be managed by the ANDSF.

The service requirements and the functional requirements for the access network discovery and selection are described in TS 122 278 [i.12] and in TS 123 402 [i.6] respectively.

The ANDSF MO is used to manage intersystem mobility policy as well as access network discovery information stored in a UE supporting provisioning of such information from an ANDSF.

The ANDSF may initiate the provision of information from the ANDSF using a server initiated session alert message.

The UE may initiate the provision of information from the ANDSF, using a client initiated session alert message of code "Generic Alert". The "Type" element of the OMA DM generic alert message has to be set to "urn:oma:at:ext-3gpp-andsf:1.0:provision".

The intersystem mobility policy information consists of a set of one or more intersystem mobility policy rules. At any point in time there should be at most one rule applied, that rule is referred to as the 'active' rule. There may hence be zero or one 'active' rule.

The rules have a number of conditions (e.g. current access technology and location) where one or more may be present and set to a value. The rules also have a number of results (e.g. preferred access technology and restricted access technology) to be used whenever a rule is "active". If there are no results for the 'active' rule, it is implementation dependent how UE performs network selection. Irrespective of whether any rule is 'active' or not, the UE periodically re-evaluates the ANDSF policies. When ANDSF policy selection rules identify an available network, the highest priority rule becomes "active" rule and network re-selection is performed.

The relation between Policy and DiscoveryInformation is that Policies prioritize the access network, while DiscoveryInformation provide further information for the UE to access the access network defined in the policy.

The MO has a node indicating the position of the UE. The trigger for updating the value of this node is that the location information it contains is no longer valid (i.e. the UE has changed its position) or some other manufacturer specific trigger. The update of the information contained in this node does not necessarily imply any interaction with the ANDSF server.

The MO defines validity areas, position of the UE and availability of access networks in terms of geographical coordinates. The way such coordinates are retrieved is implementation dependant (e.g. GPS receiver).

The Management Object Identifier is: urn:oma:mo:ext-3gpp-andsf:1.0.

The OMA DM Access Control List (ACL) property mechanism as standardized (see Enabler Release Definition OMA-ERELD-DM-V1_2 [i.9]) may be used to grant or deny access rights to OMA DM servers in order to modify nodes and leaf objects of the ANDSF MO.

The following nodes and leaf objects are possible under the ANDSF node as described in figure B.4:

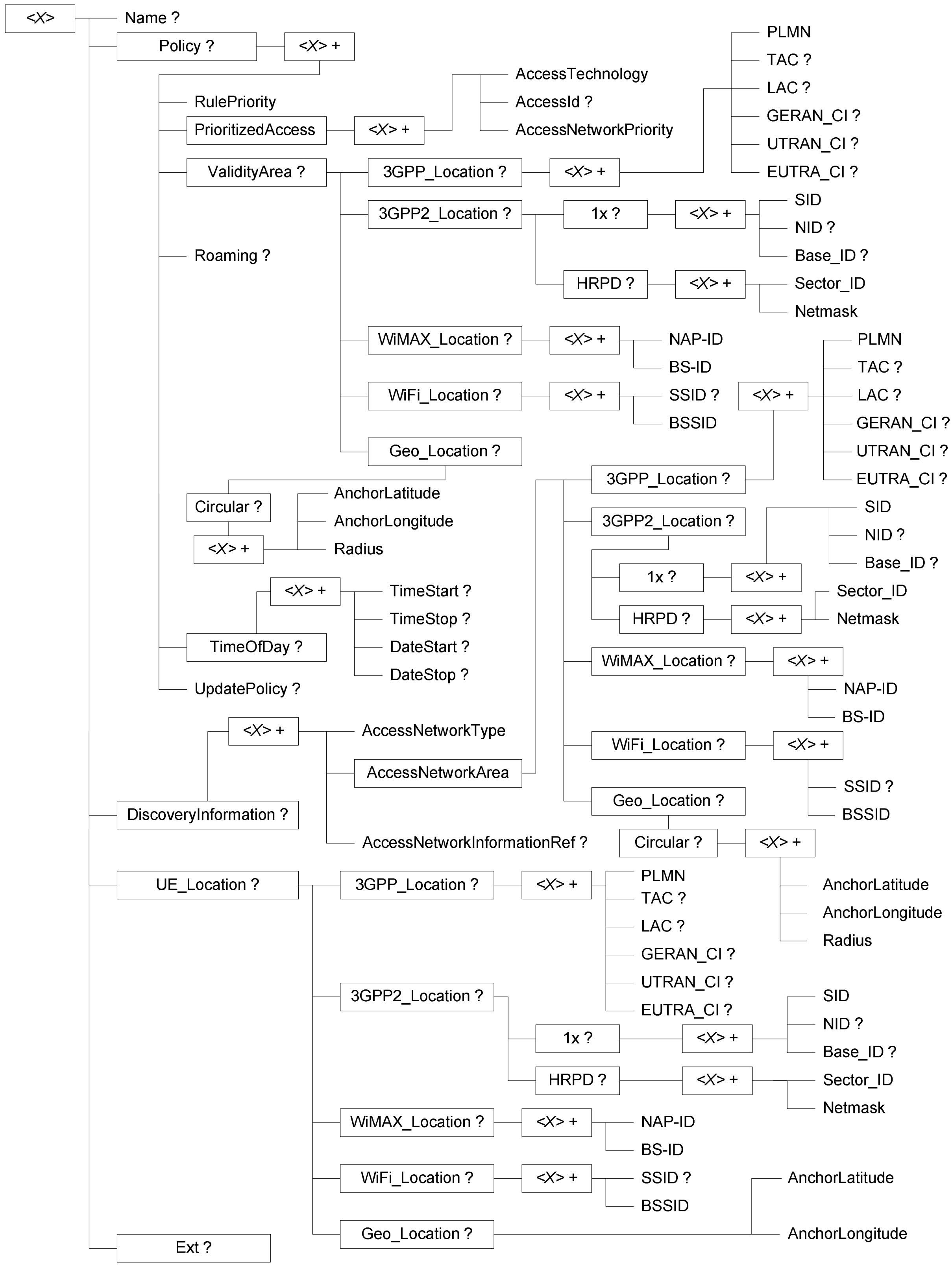



**Figure B.4: The ANDSF MO (Source: TS 124 312 [i.7])**

# History

| Document history | | |
|---|---|---|
| V1.1.1 | September 2009 | Publication |
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