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SDR'10

Wireless Innovation Conference and Product Exposition

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ETSI Reconfigurable Radio Systems (RRS) Tutorial

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Overview

- Introduction to ETSI Reconfigurable Radio Systems (RRS)
  - Vision and Scope of ETSI RRS on Cognitive Radio (CR), Software Defined Radio (SDR),
  - Regulatory Activities.
- WG1: Cognitive Radio Systems Aspects
  - Overall Cognitive Radio Vision.
- WG2: Radio Equipment Architecture
  - SDR related Standardization,
  - SDR Handset Architecture and Interfaces.
- WG3: Cognitive Management and Control
  - Functional Architecture for the Management and Control of RRS,
  - Cognitive Pilot Channel,
  - TV White Spaces.
- WG4: Public Safety
  - Public Safety and Security Aspects.
- Conclusions

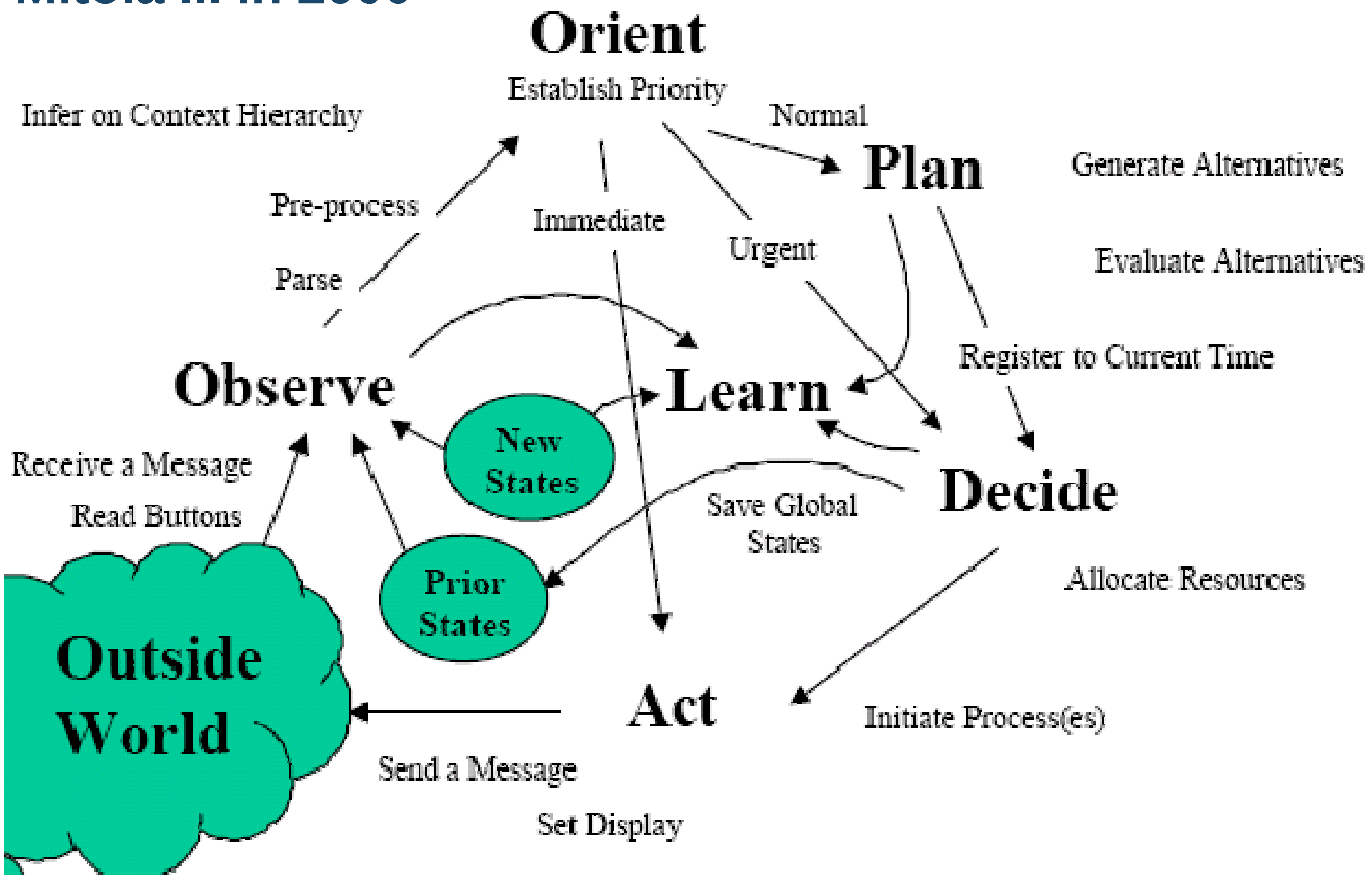
Part 1:
Introduction to ETSI Reconfigurable Radio Systems

- **Introduction to ETSI Reconfigurable Radio Systems (RRS)**
  - ETSI RRS Structure;
  - Vision and Scope of ETSI RRS on Cognitive Radio (CR), Software Defined Radio (SDR);
  - Working axes of current relevance in the field;
  - Trends 3GPP & IEEE;
  - Selection of recently started, Cognitive Radio related Research projects (EU funded);
  - Revision of R&TTE Directive;
  - ETSI RRS: Process towards Standards;
  - ETSI RRS: How to contribute;
  - Regulatory Activities.

Introduction to ETSI Reconfigurable Radio Systems

- **ETSI RRS was created in 2008 and focuses on four domains**
  - **WG1 - “System Aspects”: Provide coherence among TC RRS WGs and to avoid gaps between related activities;**
  - **WG2 - “Radio Equipment Architecture”: Common reference architectures for SDR/CR radio equipments (handsets, BS, etc.), related interfaces, etc.;**
  - **WG3 - "Cognitive Management and Control“: System functionalities for Spectrum Management, Joint Radio Resource Management and Functional Architecture for the Management and Control for Reconfigurable Radio Systems as well as Cognitive Pilot Channel;**
  - **WG4 - “Public Safety”: Applications in the Public Safety and Defense domain, focusing on applications of RRS in Public Safety and Defense.**
- **ETSI RRS is center of competence for CR and SDR in ETSI**
- **Selected available documents (http://pda.etsi.org/pda/queryform.asp):**
  - ETSI TR 102 802 details the Cognitive Radio Vision of ETSI RRS,
  - ETSI TR 102 680 details the SDR Handset Architecture and Interfaces approach,
  - ETSI TR 102 683 and ETSI TR 102 682 detail the CPC and FA work.

- The general Cognitive Radio idea was originally introduced by Joseph Mitola III in 2000



Joseph Mitola III, Cognitive Radio - An Integrated Agent Architecture for Software Defined Radio, 2000, http://web.it.kth.se/~maguire/jmitola/Mitola_Dissertation8_Integrated.pdf

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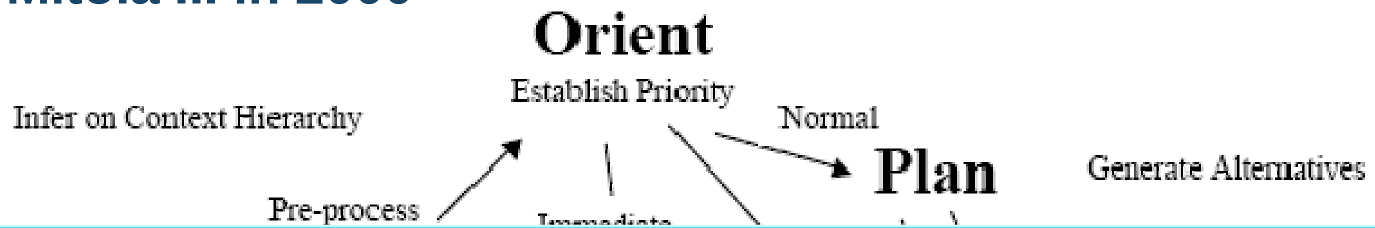


The key message is that Cognitive Radio (CR) relates to

- **Observing the environment („acquisition of context information")**
- **Learning, Orienting, Planning, Deciding & Acting**

CR is **<u>not</u>** equivalent to concepts like Opportunistic Spectrum Usage, Dynamic Spectrum Management, etc.

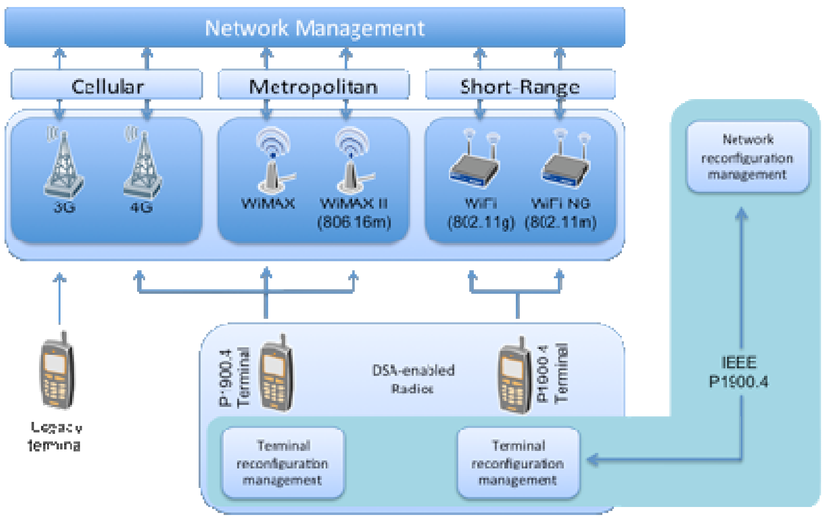
Joseph Mitola III, Cognitive Radio - An Integrated Agent Architecture for Software Defined Radio, 2000, http://web.it.kth.se/~maguire/jmitola/Mitola_Dissertation8_Integrated.pdf

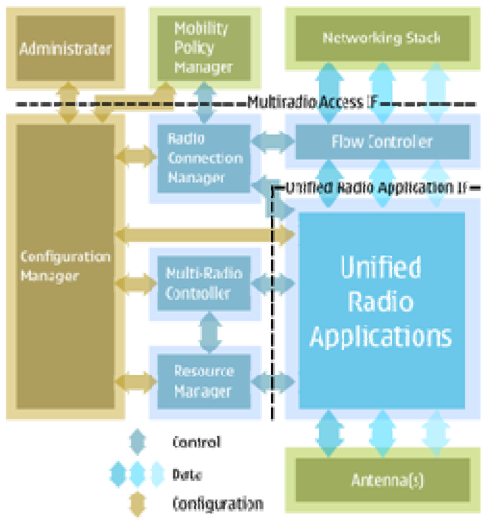
- **The general CR framework introduced by J. Mitola III lead to the following three working axes of current relevance in the field:**

1. Heterogeneous Framework

   - A UE is operating in a **heterogeneous radio framework**, including for example 3GPP, WiFi NG (IEEE 802.11ac), WiMAX NG (IEEE 802.16m), etc.; **SDR is typically a „enabling technology" for this;**
   - A UE is typically able to select radio links subject to constraints imposed by network (if any);
   - A UE is typically able to **maintain multiple radio links simultaneously.**

IEEE 1900.4 Standard

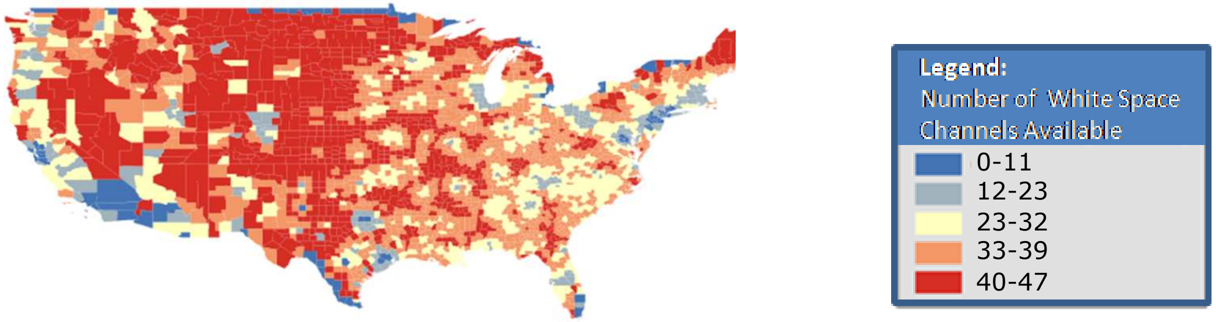




ETSI RRS SDR Architecture for Mobile Devices

2. Opportunistic Spectrum Access - (TV) White Spaces

- **Idea:** A „Secondary User (SU)“ accesses to spectrum while the „Primary User (PU)“ is absent, leading to dramatically higher spectrum utilization and near-zero deployment time;
- **Requirements:** Mobile Devices/Network identify unused portions of licensed spectrum, and utilize that spectrum without adverse impact on the primary licensees or other users (e.g. PMSE being an incumbent user of the UHF band);
- **Key Challenges:** How to manage interference avoidance
  - FCC approach: A combination of a Data-Base and Terminal based Sensing;
  - CEPT (Group SE43) studies techniques similar to those proposed by FCC: A central dabase contains data about the usage plans of primary users (and those spectrum availabilities for secondary users), secondary users need to access the data-base and apply sensing on top of it for identifying whether spectrum is available.

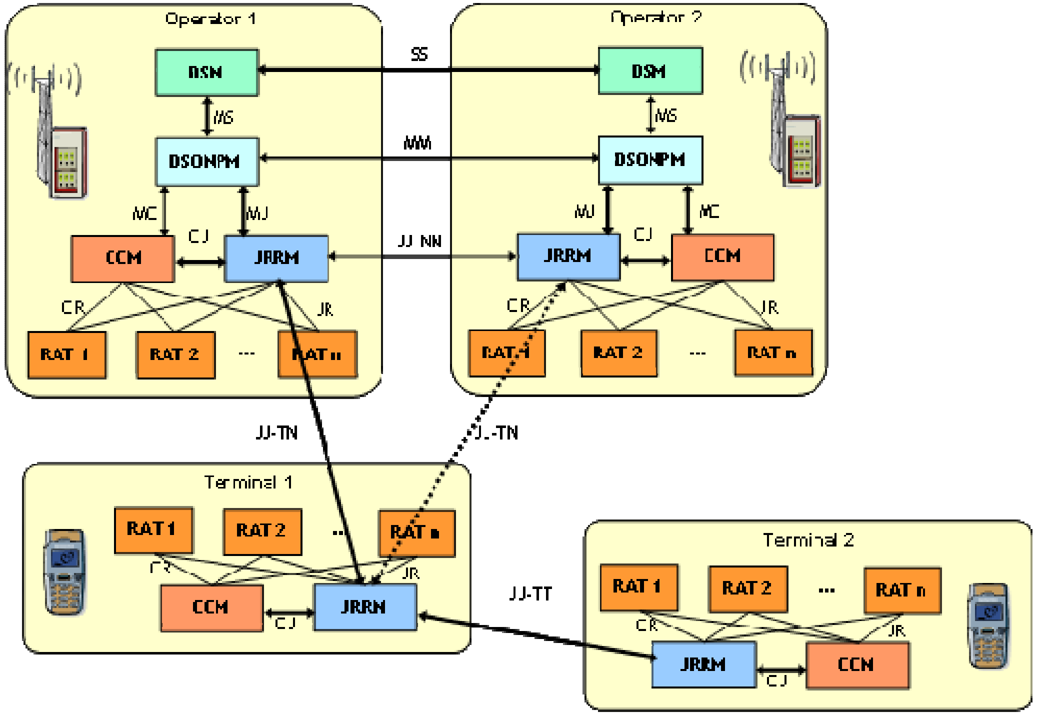


www.showmywhitespace.com, Spectrum Bridge, Dec 2009

3. Fully flexible dynamic spectrum management (long term)

- NW operators can deploy RATs dynamically (over frequency/time/location),
- NW operators can aquire/exchange Spectrum / Spectrum Usage Rights (for example this approach is under investigation in the UK by OFCOM),
- Mobile Devices autonomously adapt to diverse heterogeneous radio framework.

ETSI RRS Functional Architecture for Flexible Spectrum Management



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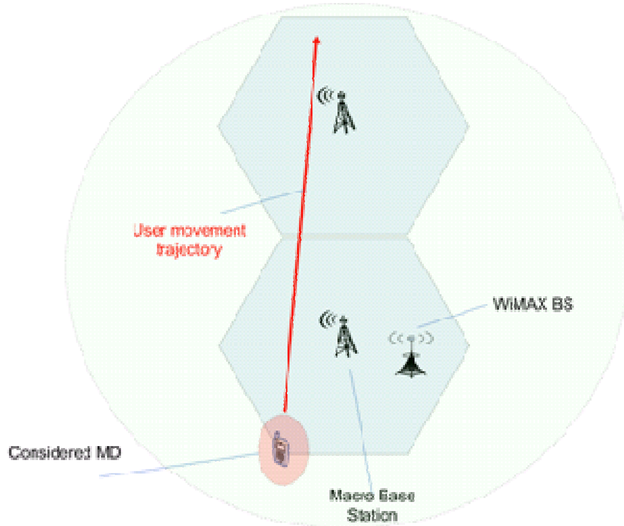
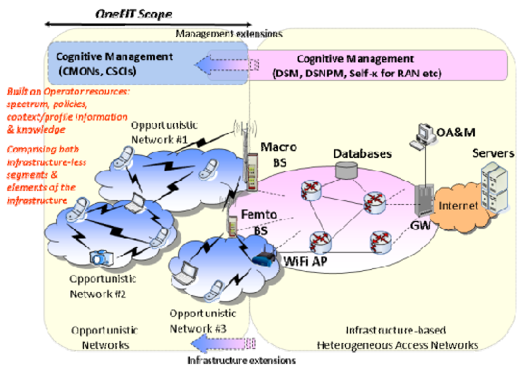
Trends 3GPP & IEEE

- **3GPP defines ANDSF (Access Network Discovery and Selection)**
  - **3GPP TS 23.402: "The ANDSF contains** data management and control functionality **necessary to provide** network discovery and selection assistance **data as per operators' policy. The ANDSF shall respond to UE requests for access network discovery information and may be able to initiate data transfer to the UE, based on network triggers";**
  - **A generic approach has been defined to enable efficient discovery of non-3GPP access networks and steer terminals towards preferred access networks;**
- **IEEE 802.22: A standard for Wireless Regional Area Networks (WRAN) using White Spaces in the TV frequency spectrum;**
- **IEEE 802.19.1: A standard targeting mechanisms for coexistence among dissimilar or independently operated TV Band Device (TVBD) networks and dissimilar TV Band Devices;**
- **IEEE 802.11af: A standard for allowing 802.11 wireless networks to be used in the TV white space („WiFi for White Spaces");**
- **IEEE SCC41: A new AdHoc group currently discusses the set-up of a new standard, likely to define MAC/PHY mechanisms for White Space access,** <u>not</u> **limited to TV White Spaces.**

- **A selection of recently started, Cognitive Radio related Research projects (EU funded) are given below**
  - **FP7 FARAMIR studies, among others, Radio Environment Maps (REM); concepts like user-context-dependent information provision are an up-to-date research topic;**

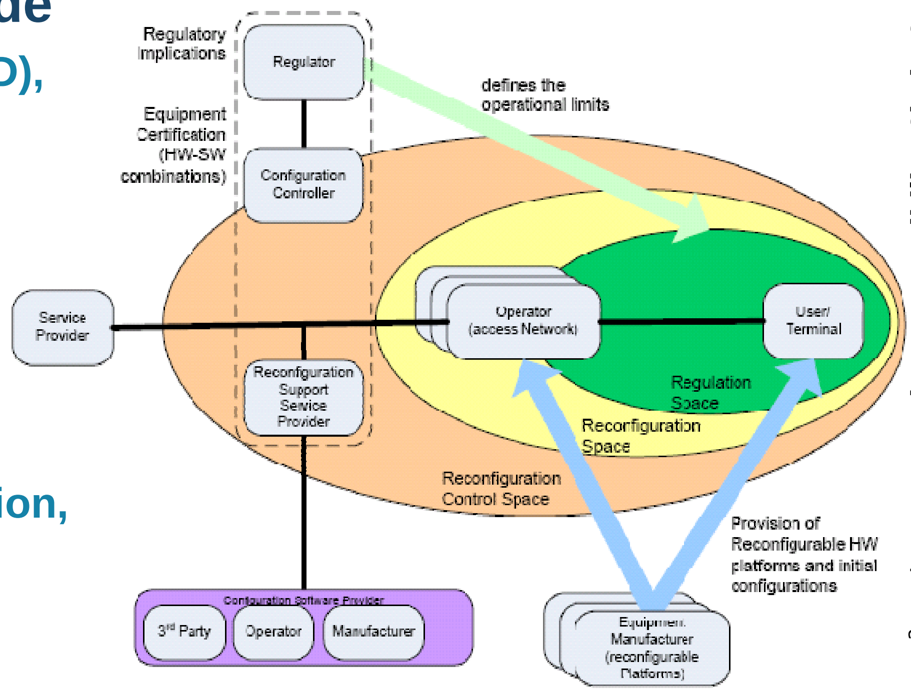


  - **FP7 OneFIT studies Opportunistic Networks and Context delivery based on Cooperation between cognitive management systems (C4MS);**



  - **FP7 CONSERN studies Self-Growing Networks based on Cognitive Radio principles.**

- The level of regulation required for Cognitive Radio is currently unclear
  - Corresponding discussions are ongoing for WRC'12 preparation and beyond;
  - Example: Do we need an out-band CPC with a globally harmonized frequency band allocated to it ?
- Potential regulatory issues include
  - Conditions for conformity (R&TTE D),
  - Interoperability,
  - Standardizaton,
  - Market surveillance,
  - Liability, Responsibility,
  - Spectrum Access/Trading,
  - Privacy and Data Protection,
  - Lawful interception and data retention,
  - Etc.



ICT-E2R White Paper: **The Responsibility Chain Concept**

- The European Commission is currently in the process of revising the R&TTE Directive
  - One objective is to allow for SDR User Devices in the future
- ETSI RRS sees the following challenges
  - Vertical Market model
    - Provision of novel features, like novel RAT, may impact DoC / physical CE marking etc.
  - Horizontal Market model
    - Provision of features, e.g. update of a RAT, by 3rd party SW providers may impact DoC / physical CE marking etc.
    - Identification of responsibilities e.g. in case that device does not operate following the rules, or in post market surveillance.
- ETSI RRS has identified the following approaches
  - Digital / Dynamic DoC,
  - Digital / Dynamic CE marking,
  - Device / HW / SW registration process,
  - Device / HW list of authorized 3rd party SW,
  - Security checks (against inapprioriate downloads, etc.),
  - SDR reconfiguration log history.

ETSI RRS: Process towards Standards

Normative Process

- Use case Definition (TR)
- System requirements Specification (TS)
- System Architecture Specification (TS)
- Protocol and Interfaces Specification (TS)

Feasibility Study Process

- **Study Item (TR)**

An initial study, resulting in a Technical Report, which performs a feasibility study for additional or new feature

ETSI RRS: How to contribute

- ETSI targets global standards and is open for participation to all ETSI members
- ETSI RRS is open to liaise with different bodies
- Future ETSI RRS meetings:
  - 8-10-Feb-2011, Paris, France
  - Register at http://portal.etsi.org, Email reflector: http://list.etsi.org/
- ETSI facilitates Market Introduction through Harmonized Standards (avoiding type approval)
- Contact Information:
  - ETSI portal: http://www.etsi.org
  - ETSI RRS Chairman: Markus Mueck, Infineon Technologies, Germany
  - Email: MarkusDominik.Mueck@Infineon.com

Conclusion Part 1: Roadmaps, Trends, etc.

❑ Business Relevance:

- Heterogeneous Radio Framework
  - **Roadmap relevance: Immediate,**
  - **Evolution building on existing NW/Terminal Architecture,**
  - **Possible evolution towards Software Defined Radio as Enabler.**
- Opportunistic Spectrum Access - (TV) White Spaces
  - **Roadmap relevance: Within a few years,**
  - **New Standards are under Development (IEEE 802.11af, etc.).**
- Fully flexible dynamic spectrum management
  - **Long term vision (i.e. 5-10 years),**
  - **Research- and Standardization requires still considerable effort.**

❑ What is next ?

- **SDR is under investigation in ETSI RRS for Network (BS) & Terminal side,**
- **Further flexibility of spectrum usage.**

Part 2:
WG1 - Cognitive Radio Systems Aspects

- Cognitive Radio Systems Aspects
  - WG1 Mandate;
  - Definitions;
  - Objectives for RRS;
  - Spectrum Use Scenarios for RRS;
  - Architectural approaches for CRS;
  - Use Case Families
    - Use Cases related to SDR Reference Architecture for Mobile Device;
    - Use Cases related to Reconfigurable Radio Systems operating in IMT bands and GSM bands;
    - Use Cases related to Operation in White Space Frequency bands.

WG1 Mandate

- To develop and maintain a common technical framework for SDR and CR systems standardization in TC RRS regarding system level aspects;
- To define Use Cases related to Reconfigruable Radio Systems;
- To collect and define requirements on Reconfigurable Radio Systems from relevant stakeholders;
- To collect and define technical specifications for Reconfigurable Radio Systems management and usage;
- To identify gaps, where existing standards, e.g. from ETSI and 3GPP, do not fulfil the requirements, and suggest further standardization activities to fill those gaps;
- To deliver its findings in the form of ETSI deliverables as appropriate.

Definitions

Software Defined Radio

- Radio transmitter and/or receiver employing a technology that allows the RF operating parameters including, but not limited to, frequency range, modulation type, or output power to be set or altered by software, excluding 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: This is the current definition of ITU-R Recommendation WP 1B.

Cognitive Radio

- Radio which has the capability
  - To obtain the knowledge of radio operational environment and established policies and to monitor usage patterns and user's 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.

Definitions

Radio System

- System capable to communicate some user information by using electromagnetic waves
  - NOTE: Radio system is typically designed to use certain radio frequency bands 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.

Cognitive Radio System

- Radio system employing technology that allows the system
  - to obtain knowledge of its operational and geographical environment, established policies and its internal state;
  - to dynamically and autonomously adjust its operational parameters and protocols according to its obtained knowledge in order to achieve predefined objectives; and
  - to learn from the results obtained.
    - NOTE: This is the current definition of ITU-R Recommendation WP 1B.

Definitions

- **Reconfigurable Radio Systems**
  - **Generic term for radio systems encompassing Software Defined and/or Cognitive Radio Systems.**

Objectives for RRS

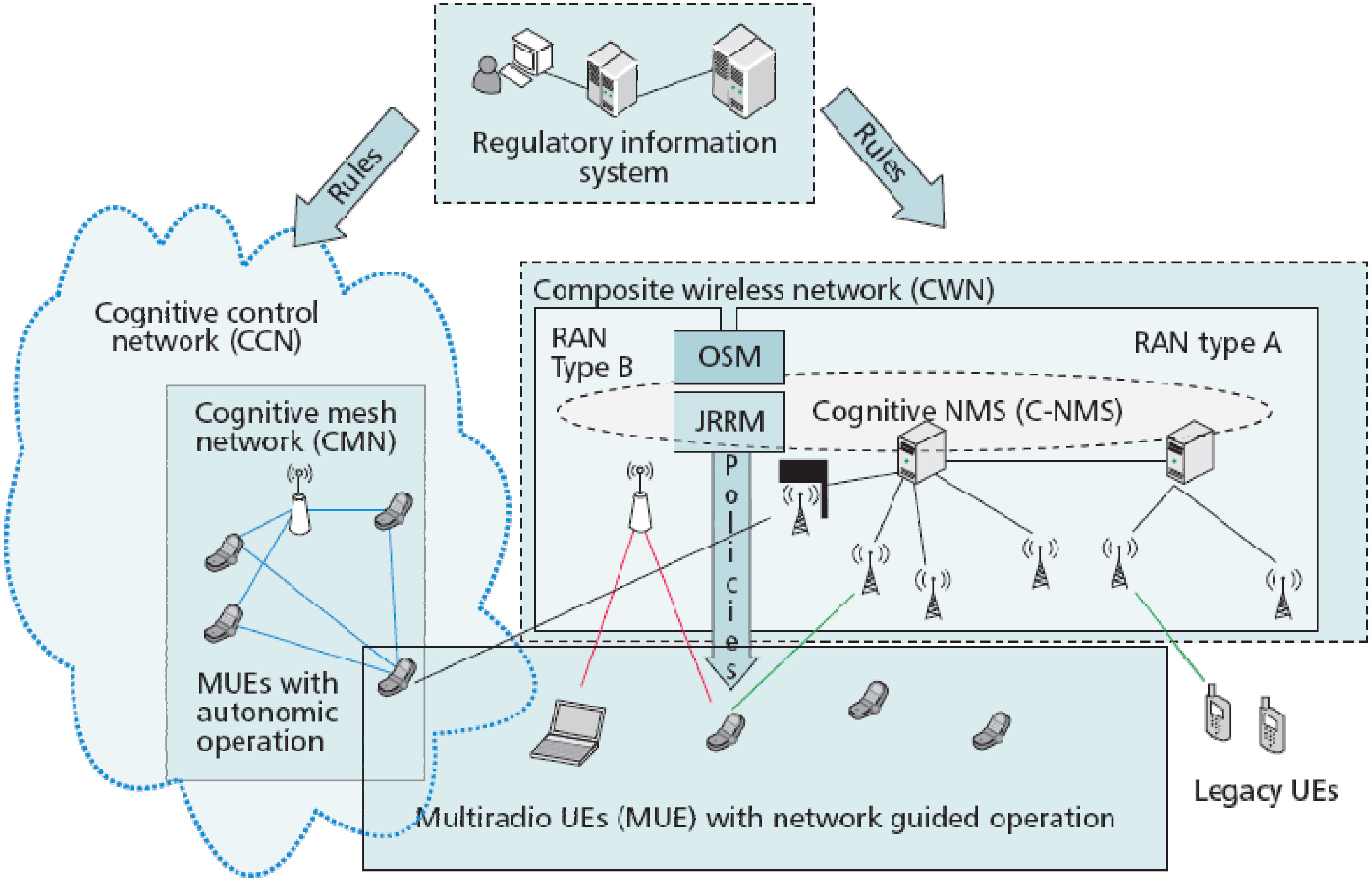
- **More efficient and flexible use of spectrum**
  - Obtain knowledge of the radio operational environment and location, and act based on this knowledge
- **Enhancing user experience**
  - Could facilitate cross-operator access;
  - Efficient personal area networks;
  - Flexible access to the Future Internet;
  - Connecting to the smart spaces.
- **Optimization of the mobile operator network**
  - Spectrum refarming;
  - Upgrading a pre-existing RAT and deploy of a new RAT to a pre-existing network;
  - Addition of multiple standards modes;
  - Radio resource optimization;
  - Cognition enabler.

Spectrum Use Scenarios for RRS

- **Dedicated spectrum (licensed bands)**
  - Software defined multiradio in end-user mobile devices;
  - Radio access technology selection in composite wireless networks;
  - Radio resource usage optimization in composite wireless networks.

- **Shared spectrum in bands without primary/incumbent users**
  - Cognitive radio networks in bands that do not require licensing (license exempt bands), and which thus do not have multiple spectrum user classes.
- **Secondary usage in bands with primary/incumbent users**
  - Cognitive radio networks sharing a band, on a secondary basis, with other systems to whom the band is licensed to.
- **Spectrum dedicated for CRS**
  - Cognitive radio networks in a band which is licensed for cognitive use.

Architectural approaches for CRS



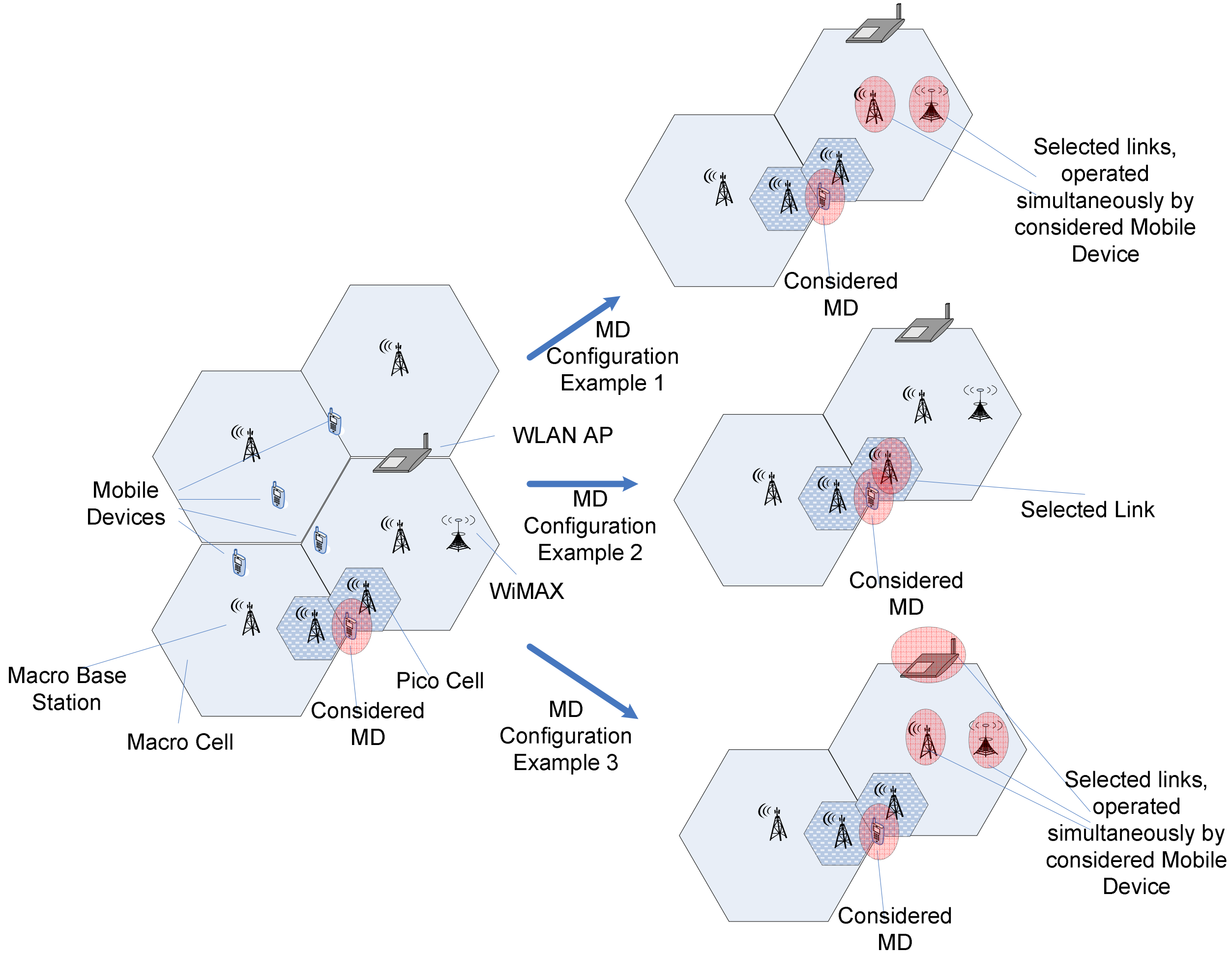
Use Case Families

- Use Cases related to SDR Reference Architecture for Mobile Device;
- Use Cases related to Reconfigurable Radio Systems operating in IMT bands and GSM bands;
- Use Cases related to Operation in White Space Frequency bands.

Use Case for a selected family

- ❑ Use Cases related to SDR Reference Architecture for Mobile Device
  - Terminal-Centric Configuration in a Heterogeneous Radio Context
  - Network driven Terminal Configuration in a Heterogeneous Radio Context
  - Addition of new features, such as support for novel radio systems, to Mobile Devices
  - Provision of a new cognitive feature (e.g. cross-technology spectrum measurement)
- ❑ Use Cases related to Reconfigurable Radio Systems operating in IMT bands and GSM bands
- ❑ Use Cases related to Operation in White Space Frequency bands

Terminal-Centric Configuration in a Heterogeneous Radio Context



- ❑ **MDs exploit context knowledge / NW policies for link selection**

Use Case for a selected family

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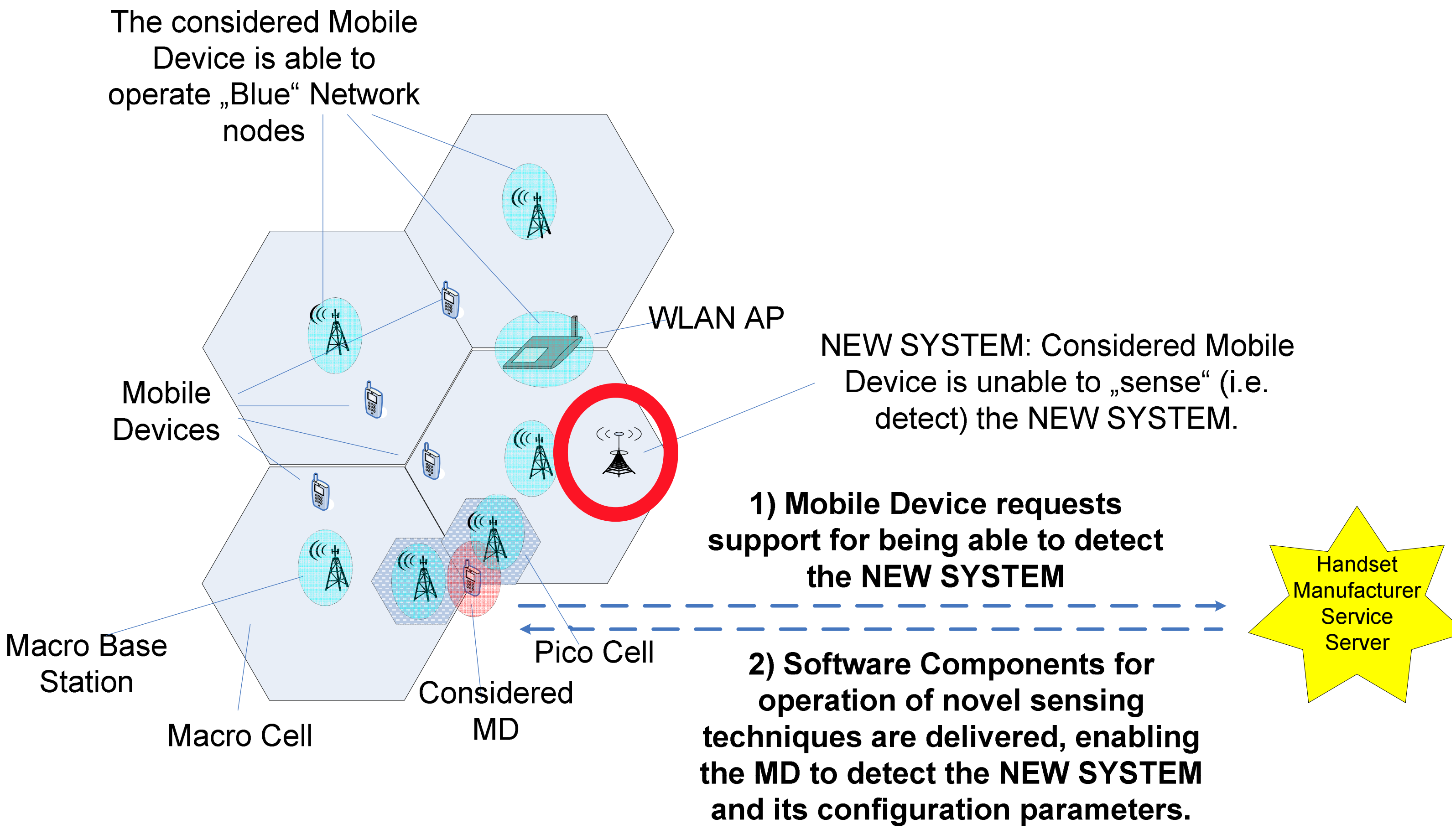


- ❑ **MDs exploit context knowledge / NW policies for link selection**

Use Case for a selected family

- ❑ Use Cases related to SDR Reference Architecture for Mobile Device

- ❑ Use Cases related to Reconfigurable Radio Systems operating in IMT bands and GSM bands
  - Spectrum refarming
  - Upgrading a pre-existing RAT and deploy of a new RAT to a pre-existing network
  - Addition of multiple standards modes
  - Radio Resource optimization
  - Cognition enabler.

- ❑ Use Cases related to Operation in White Space Frequency bands

Use Cases definition for RRS operating in IMT bands and GSM bands

- Use Cases focus on intra-operator scenarios for which the spectrum resources are assigned to and managed by a single operator;

- Currently 5 different Use Cases are investigated
  - Spectrum refarming;
  - Upgrading a pre-existing RAT and deploy of a new RAT to a pre-existing network;
  - Addition of multiple standards modes;
  - Radio Resource optimization;
  - Cognition enabler.

Use Case for a selected family

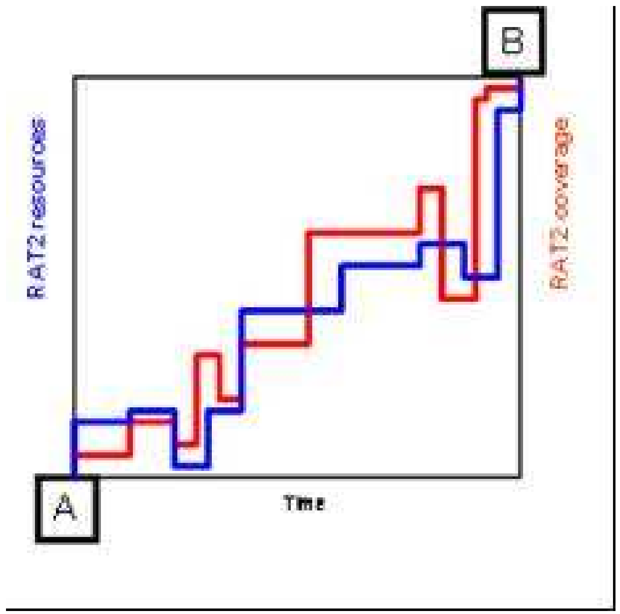
- ❑ **Use Cases related to SDR Reference Architecture for Mobile Device**

- ❑ **Use Cases related to Reconfigurable Radio Systems operating in IMT bands and GSM bands**
  - **Spectrum refarming**
  - **Upgrading a pre-existing RAT and deploy of a new RAT to a pre-existing network**
  - **Addition of multiple standards modes**
  - **Radio Resource optimization**
  - **Cognition enabler.**

- ❑ **Use Cases related to Operation in White Space Frequency bands**

Scenario: Spectrum refarming

- **The operator is updating its network with a new RAT2 which is progressively introduced in the frequency band of the previous technology RAT1, transparently and with no constraint for the customers.**



Use Case for a selected family

- ❑ **Use Cases related to SDR Reference Architecture for Mobile Device**

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  - **Upgrading a pre-existing RAT and deploy of a new RAT to a pre-existing network**
  - **Addition of multiple standards modes**
  - **Radio Resource optimization**
  - **Cognition enabler.**

- ❑ **Use Cases related to Operation in White Space Frequency bands**

Scenario: Upgrade and new deployment of a RAT

- Upgrade of an existing RAT
  - The MNO upgrades a RAT managed by a RBS by downloading the necessary software packages from a network node, instead of changing the RBS hardware (e.g. addition of HSPA+ functionalities to the UMTS).
- Deploy a new RAT in frequency bands already supported by the RBS
  - The hardware related to the RF part of the RBS (e.g. Radio Unit) supports the new RAT deployment from the frequency bands point of view (e.g. deployment of the UMTS in the GSM bands).
- Deploy a new RAT in frequency bands currently not supported by the RBS
  - The hardware related to the RF part of the RBS (e.g. Radio Unit) doesn’t currently supports the new RAT deployment from the frequency bands point of view (deployment of the LTE in the 2.6 GHz into a RBS currently managing GSM in the 800 MHz band).

Use Case for a selected family

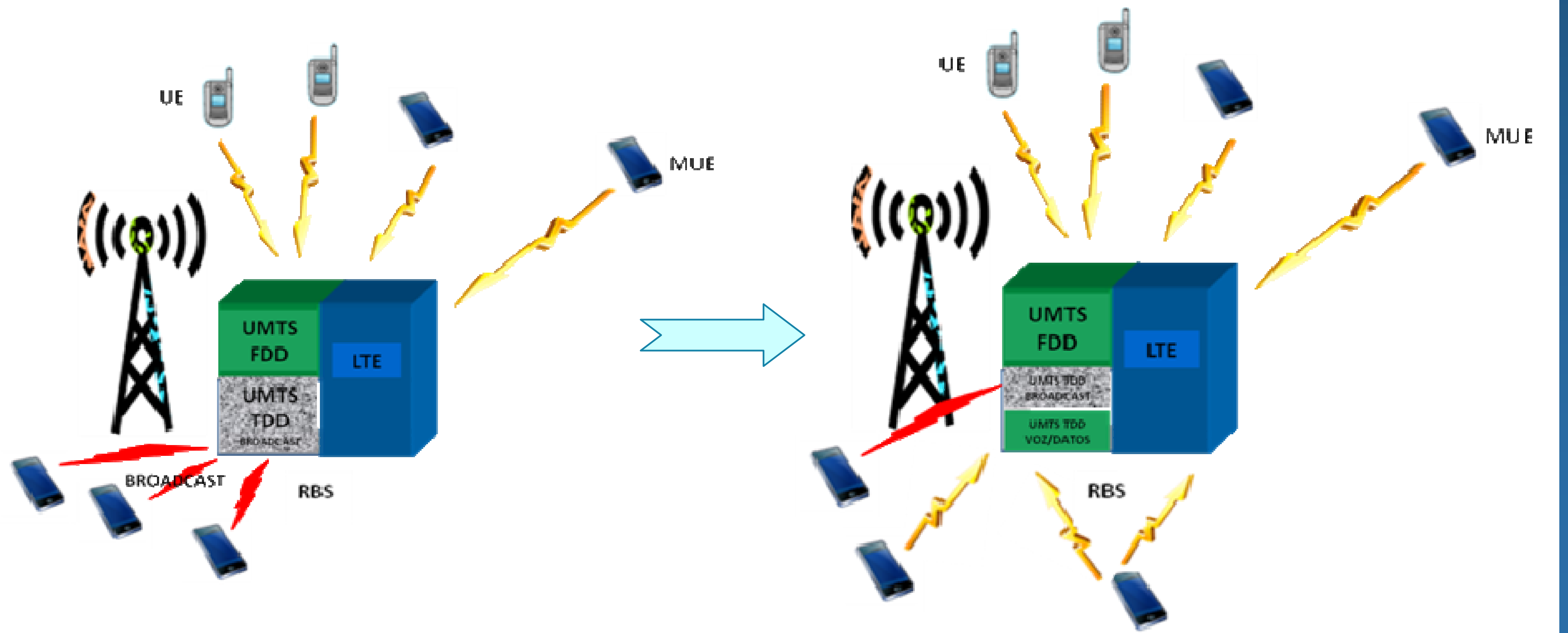
- ❑ Use Cases related to SDR Reference Architecture for Mobile Device

- ❑ Use Cases related to Reconfigurable Radio Systems operating in IMT bands and GSM bands
  - Spectrum refarming
  - Upgrading a pre-existing RAT and deploy of a new RAT to a pre-existing network
  - Addition of multiple standards modes
  - Radio Resource optimization
  - Cognition enabler.

- ❑ Use Cases related to Operation in White Space Frequency bands

Scenario: Addition of multiple standards modes

- The context in which the MNO needs to add capacity provided by FDD and TDD modes and to share dynamically services between such modes is considered



Use Case for a selected family

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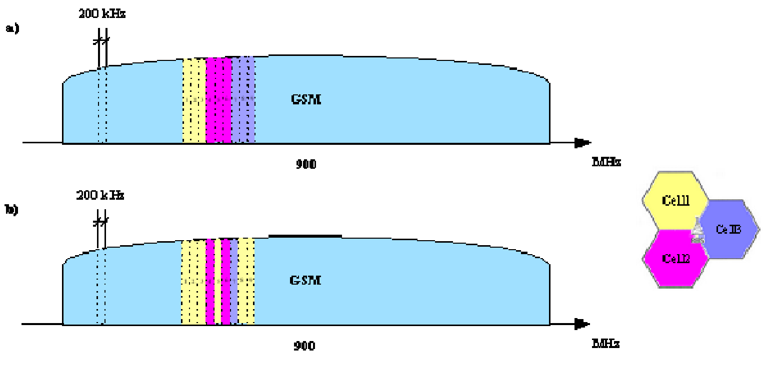
  - Radio Resource optimization
  - Cognition enabler.

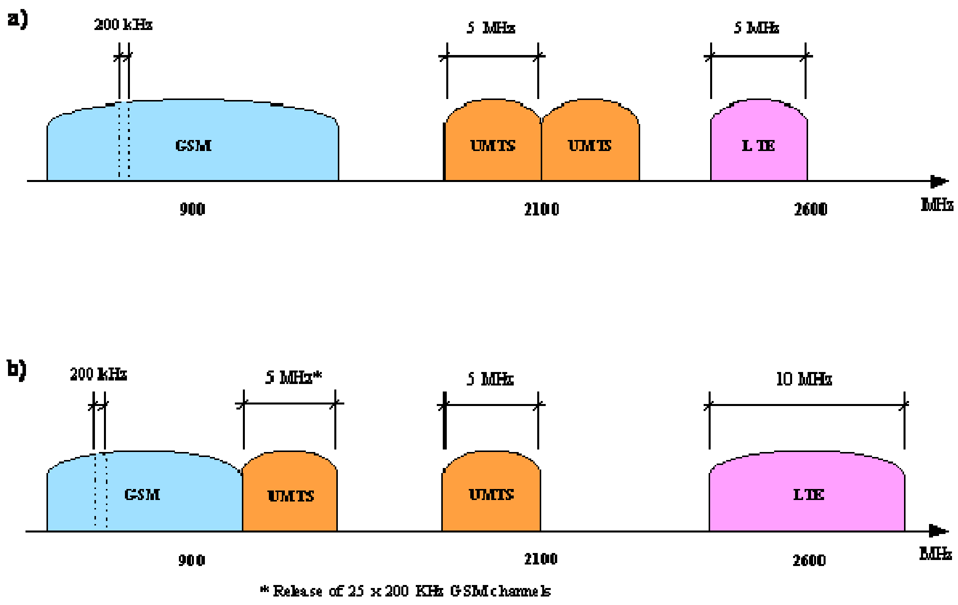
- Use Cases related to Operation in White Space Frequency bands

Scenario: Radio Resource optimization

- The MNO manages in an efficient way the radio resources (e.g. reducing blocking percentages, redistributing resources among different RATs and/or minimizing interference problems on mobiles side) within its own licensed frequency bands.



Intra-RAT reconfiguration



Inter-RAT reconfiguration

Use Case for a selected family

- ❑ Use Cases related to SDR Reference Architecture for Mobile Device

- ❑ Use Cases related to Reconfigurable Radio Systems operating in IMT bands and GSM bands
  - Spectrum refarming
  - Upgrading a pre-existing RAT and deploy of a new RAT to a pre-existing network
  - Addition of multiple standards modes
  - Radio Resource optimization
  - Cognition enabler.

- ❑ Use Cases related to Operation in White Space Frequency bands

Scenario: Cognition enablers

- Considering an heterogeneous or multi-RAT context managed by a single operator in which Radio Resource optimization schemes could be performed dynamically in time, efficient mechanisms to provide the sufficient information to the terminals for initiating a communication session appropriately are needed (e.g. Cognitive Pilot Channel).

Use Case for a selected family

- ❑ Use Cases related to SDR Reference Architecture for Mobile Device
- ❑ Use Cases related to Reconfigurable Radio Systems operating in IMT bands and GSM bands
- ❑ Use Cases related to Operation in White Space Frequency bands
    - Mid-/long range wireless access over white space frequency bands
    - Short range wireless access over white space frequency bands
    - Ad-hoc networking over white space frequency bands
    - TV White Space (TVWS) usage for Cellular Communication

Use Cases for UHF White Space in 470-790 MHz frequency band (1/2)

- **White Space**
  - part of the spectrum, which is available for a radiocommunication application (service, system) at a given time in a given geographical area on a non-interfering / nonprotected basis with regard to primary/incumbent services and other services with a higher priority on a national basis.

- **As a result from the transition from analogue to digital TV transmission, certain parts of the UHF frequency band 470-790 MHZ might not be used TV transmission in the future.**
- **ETSI TC RRS work related to White Spaces is targeting these bands.**

Use Cases for UHF White Space in 470-790 MHz frequency band (2/2)

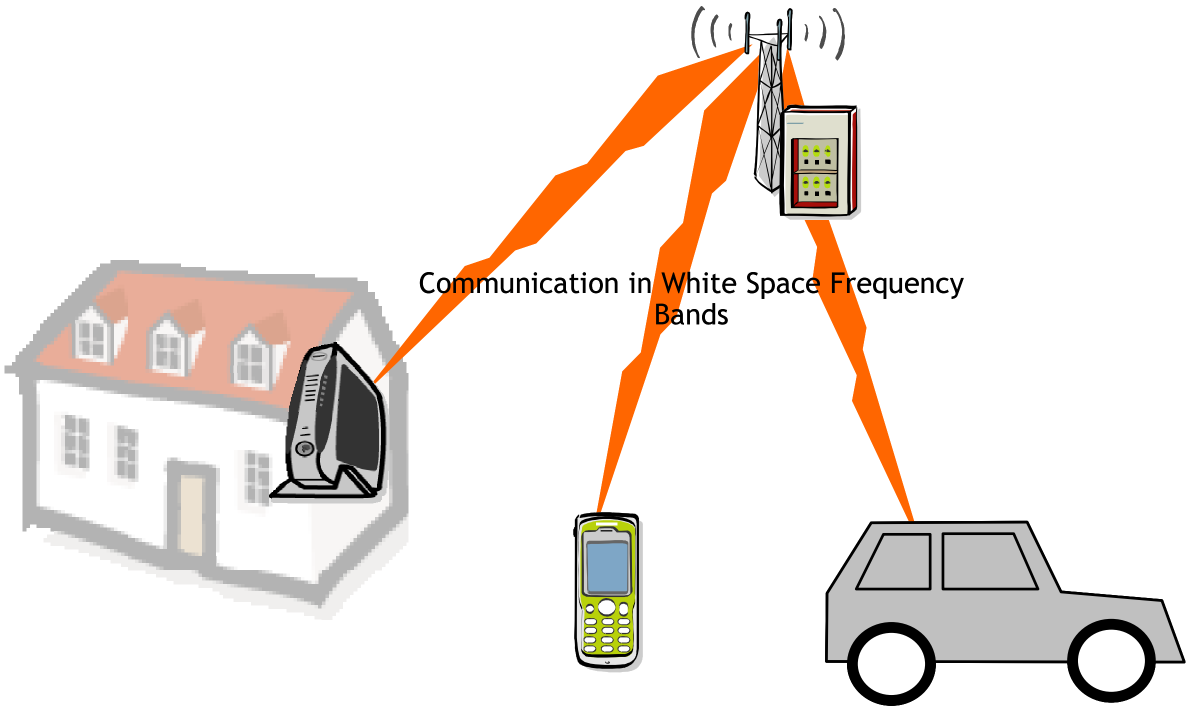
- The use cases are categorized into three basic groups
  - Mid/long range wireless access over white space frequency bands
    - Cellular networks type of solutions.
  - Short range wireless access over White Space frequency bands
    - Local area networkbbbs type of solutions.
  - Ad-hoc networking over White Space frequency bands
- Use case actors
  - Mobile terminals; fixed terminals;
  - Wireless base station; mobile operator;
  - Regulatory database;
  - TV broadcaster;
  - Master node of a wireless microphone system; wireless microphone.

Use Case for a selected family

- Use Cases related to SDR Reference Architecture for Mobile Device
- Use Cases related to Reconfigurable Radio Systems operating in IMT bands and GSM bands
- Use Cases related to Operation in White Space Frequency bands
  - Mid-/long range wireless access over white space frequency bands
    - *Mid-/long range, no mobility*
    - *Mid-/long range, low mobility*
    - *Mid-/long range, high mobility*
    - *Network centric management of TV White Spaces*
  - Short range wireless access over white space frequency bands
  - Ad-hoc networking over white space frequency bands
  - TV White Space (TVWS) usage for Cellular Communication

Use Case: Mid/long range wireless access

- **Mid/long range use cases address <u>mobility</u>**
  - **Separate use case scenarios for no/low/high mobility**



Use Case for a selected family

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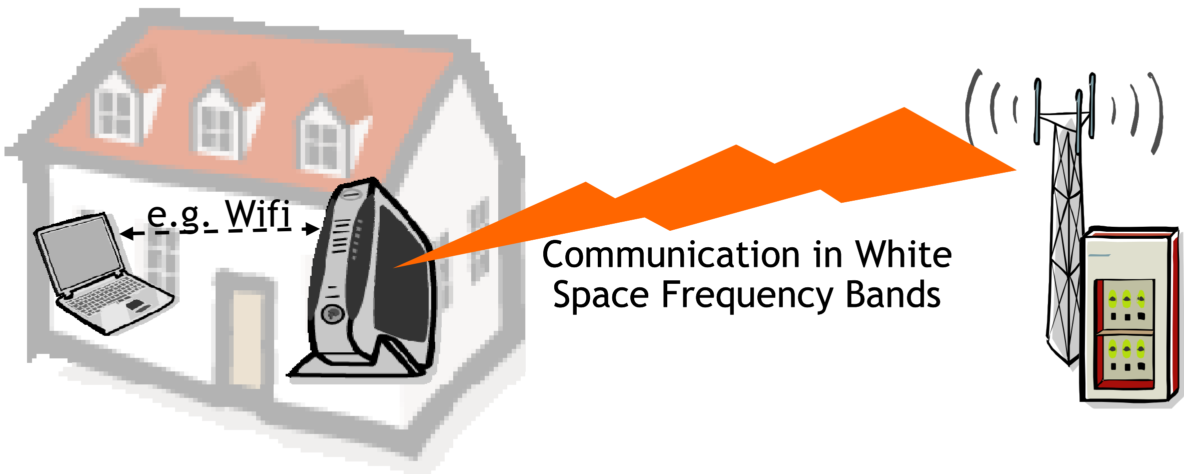
- ❑ **Use Cases related to Reconfigurable Radio Systems operating in IMT bands and GSM bands**

- ❑ **Use Cases related to Operation in White Space Frequency bands**
  - **Mid-/long range wireless access over white space frequency bands**
    - ***Mid-/long range, no mobility***
    - ***Mid-/long range, low mobility***
    - ***Mid-/long range, high mobility***
    - ***Network centric management of TV White Spaces***
  - **Short range wireless access over white space frequency bands**
  - **Ad-hoc networking over white space frequency bands**
  - **TV White Space (TVWS) usage for Cellular Communication**

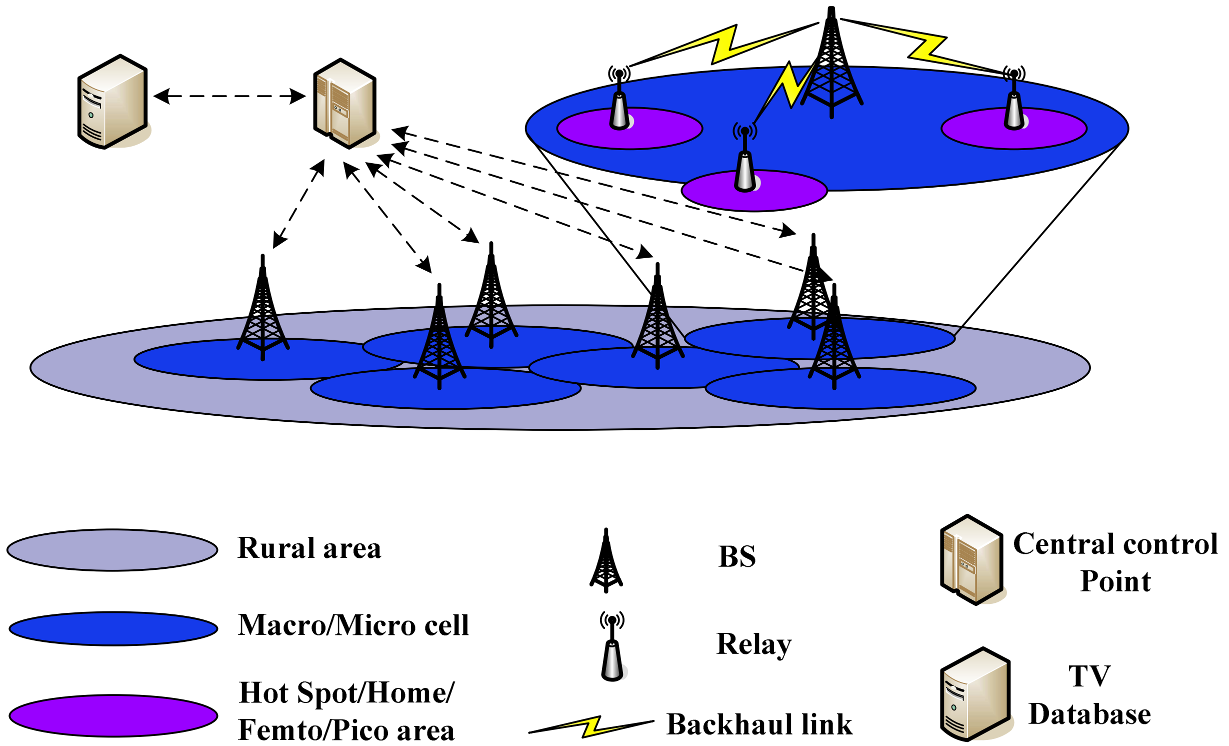
Scenario: No mobility

- E.g. a fixed mounted home base station accesses Internet by using white space frequency bands
  - In this scenario the home base station uses some other frequency band for its own connectivity



Scenario: No mobility

- The "no mobility" scenario covers also the case of utilizing the white space frequency bands as a backhaul link e.g. for relay stations



Use Case for a selected family

- Use Cases related to SDR Reference Architecture for Mobile Device

- Use Cases related to Reconfigurable Radio Systems operating in IMT bands and GSM bands

- Use Cases related to Operation in White Space Frequency bands
  - Mid-/long range wireless access over white space frequency bands
    - *Mid-/long range, no mobility*
    - *Mid-/long range, low mobility*
    - *Mid-/long range, high mobility*
    - *Network centric management of TV White Spaces*
  - Short range wireless access over white space frequency bands
  - Ad-hoc networking over white space frequency bands
  - TV White Space (TVWS) usage for Cellular Communication

Scenario: low mobility

- A mobile terminal connects to base station by using white space frequency bands
  - It is assumed that the mobile terminals are at most slowly moving, e.g. pedestrians users

Use Case for a selected family

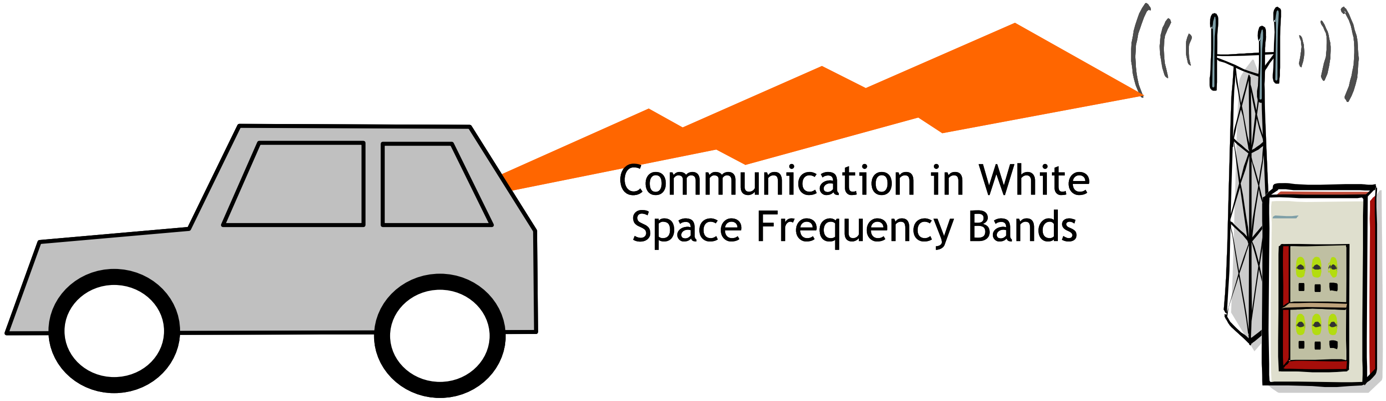
- ❑ **Use Cases related to SDR Reference Architecture for Mobile Device**

- ❑ **Use Cases related to Reconfigurable Radio Systems operating in IMT bands and GSM bands**

- ❑ **Use Cases related to Operation in White Space Frequency bands**
  - **Mid-/long range wireless access over white space frequency bands**
    - ***Mid-/long range, no mobility***
    - ***Mid-/long range, low mobility***
    - ***Mid-/long range, high mobility***
    - ***Network centric management of TV White Spaces***
  - **Short range wireless access over white space frequency bands**
  - **Ad-hoc networking over white space frequency bands**
  - **TV White Space (TVWS) usage for Cellular Communication**

Scenario: high mobility

- In this scenario the mobile device is within (or it is mounted in) a fast moving object, like a high speed train or a car in highway
  - The velocity of the terminal can be upto 250 km/h



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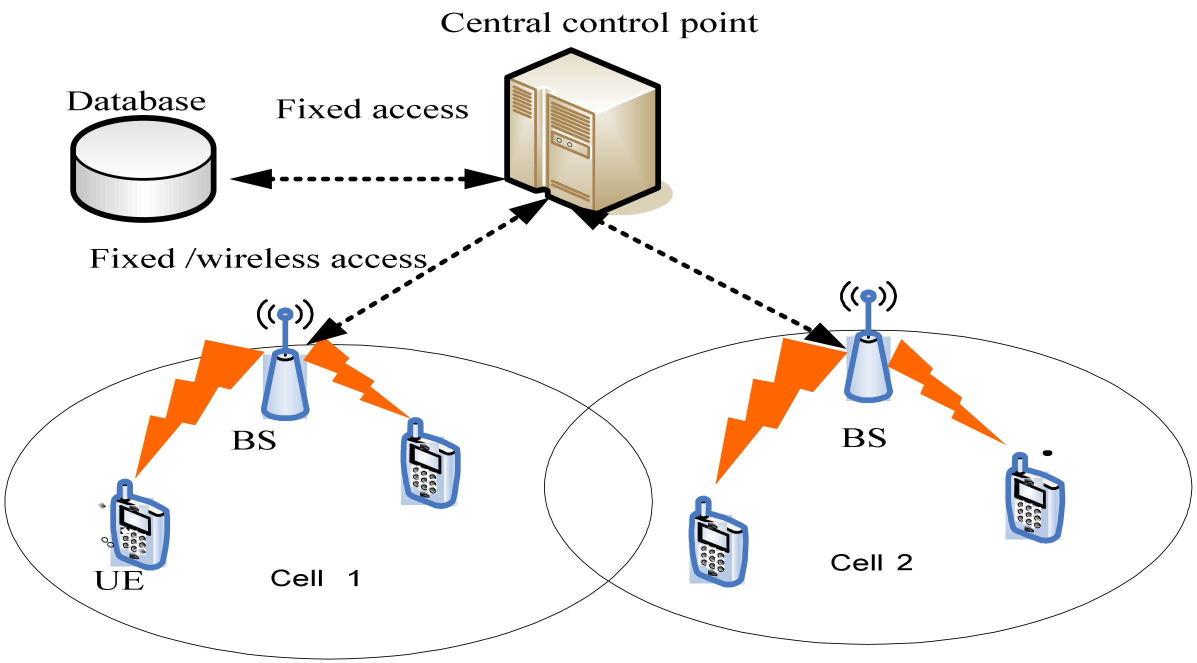
Network centric solutions

- Mid/long range wireless access scenarios are network centric



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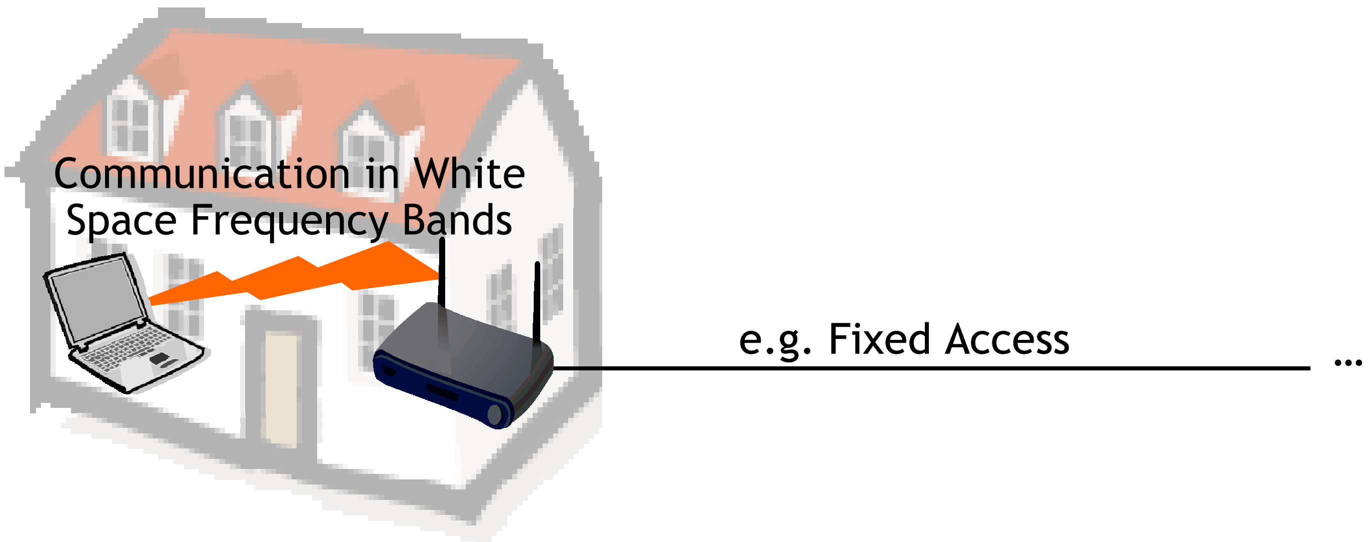
    - *Networks without coexistence management*
    - *Networks with distributed coexistence management*
    - *Networks with centralized coexistence management*
    - *Hybrid of networks with distributed and centralized coexistence management*
  - Ad-hoc networking over white space frequency bands
  - TV White Space (TVWS) usage for Cellular Communication

Use Case: Short range wireless access

- In short range use cases the focus is on different <u>coexistence</u> solutions between the secondary users of white space spectrum
  - No coexistence
  - Distributed coexistence management
  - Centralized coexistence management



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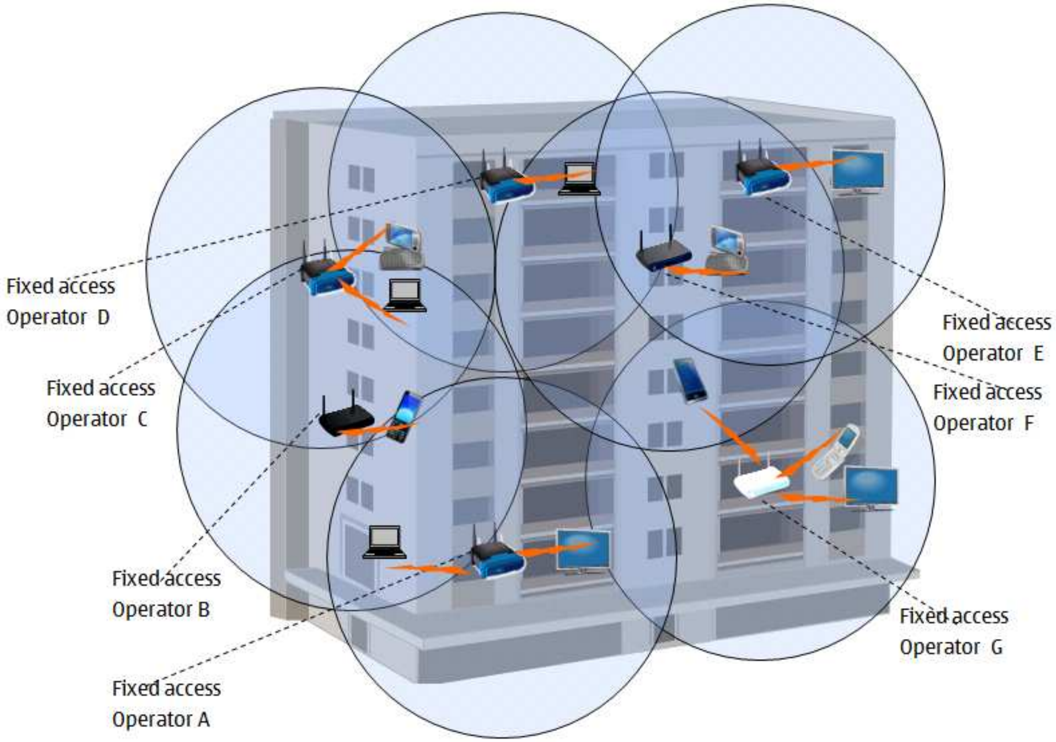
Scenario: Distributed Coexistence Management

- Different white space networks are independently deciding their spectrum use;
- The networks cooperate e.g. in their band selection in order to ensure successful coexistence.



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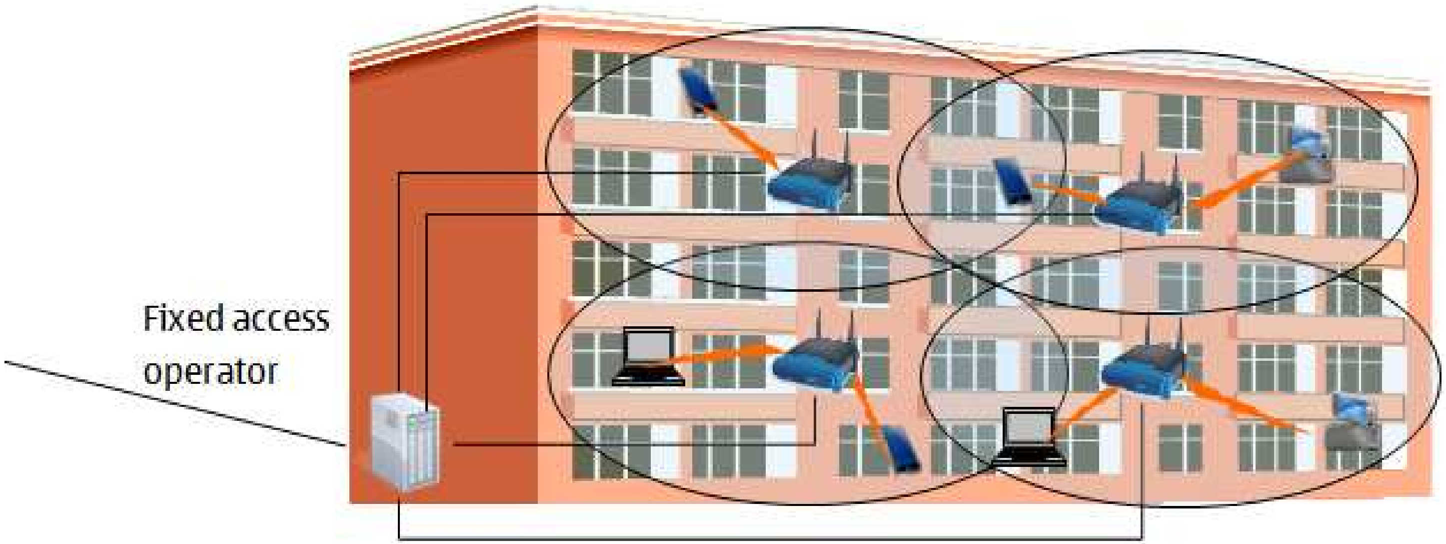
Scenario: Centralized Coexistence Management

- In centralized coexistence management there is a centralized control entity that takes care of the issues related to the coexistence of all the networks operating on the white space frequency bands in the location of interest.



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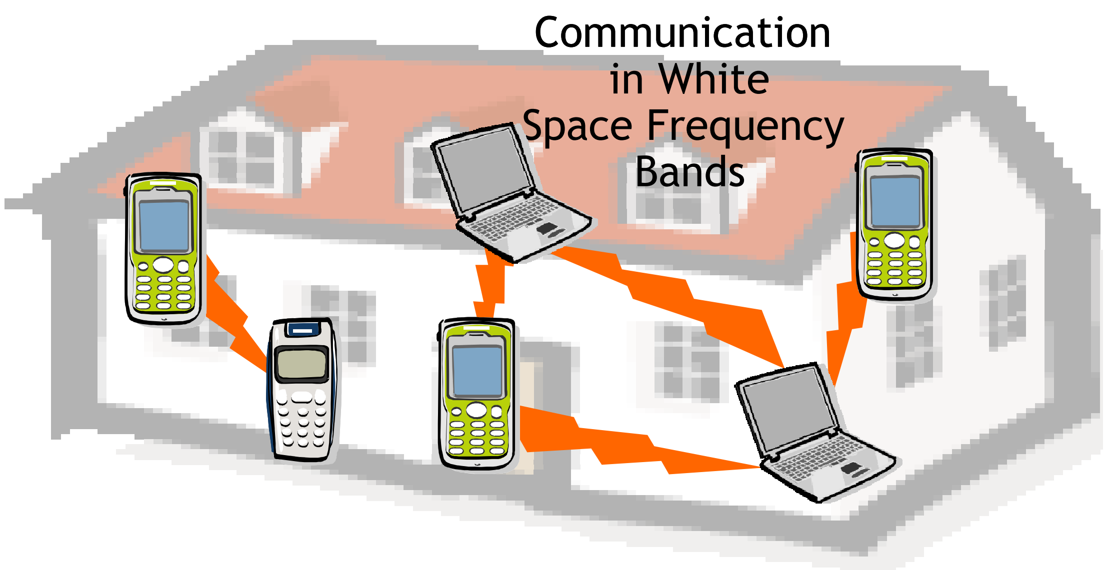
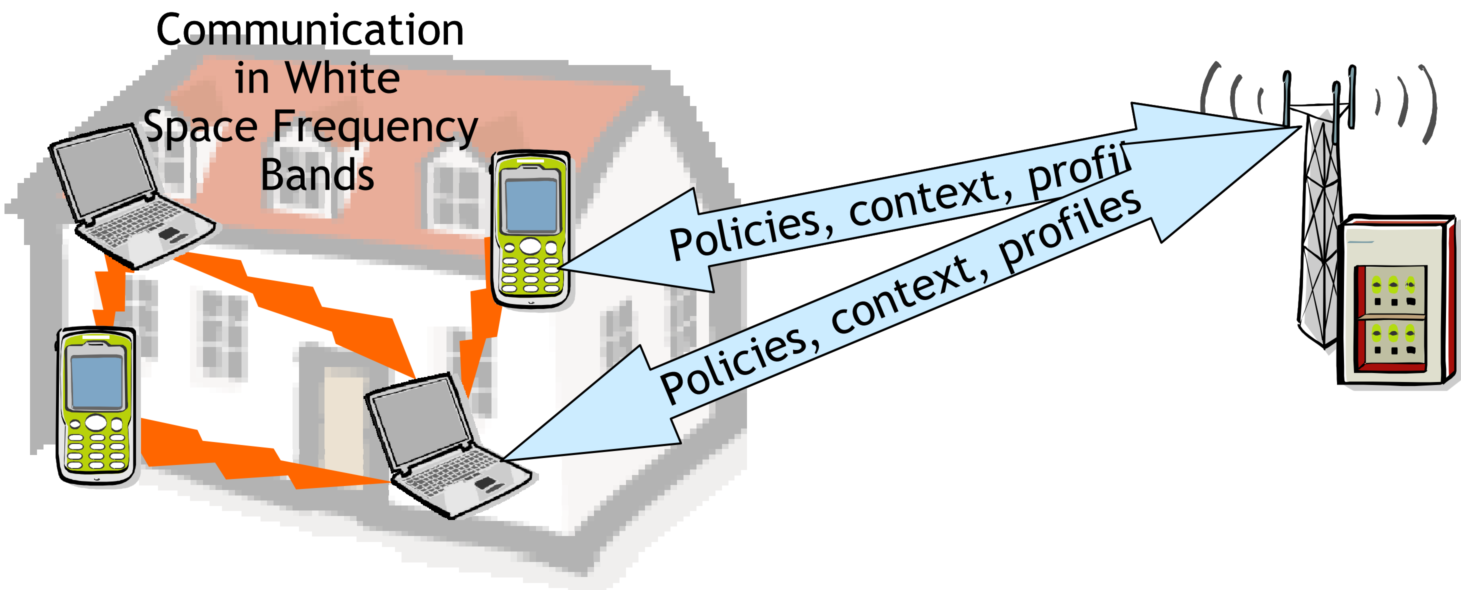
Use Case: Ad-hoc networking

- **As scenarios, this use case includes**
  - **Device-to-device connectivity;**
  - **Ad-hoc networking;**
  - **Multihop mesh networking.**



Use Case: Ad-hoc networking

- The ad-hoc networking can be supported by the infrastructure (as below), or alternatively, the information required for utilization of white space frequency bands can be obtained by individual terminals by alternative means.



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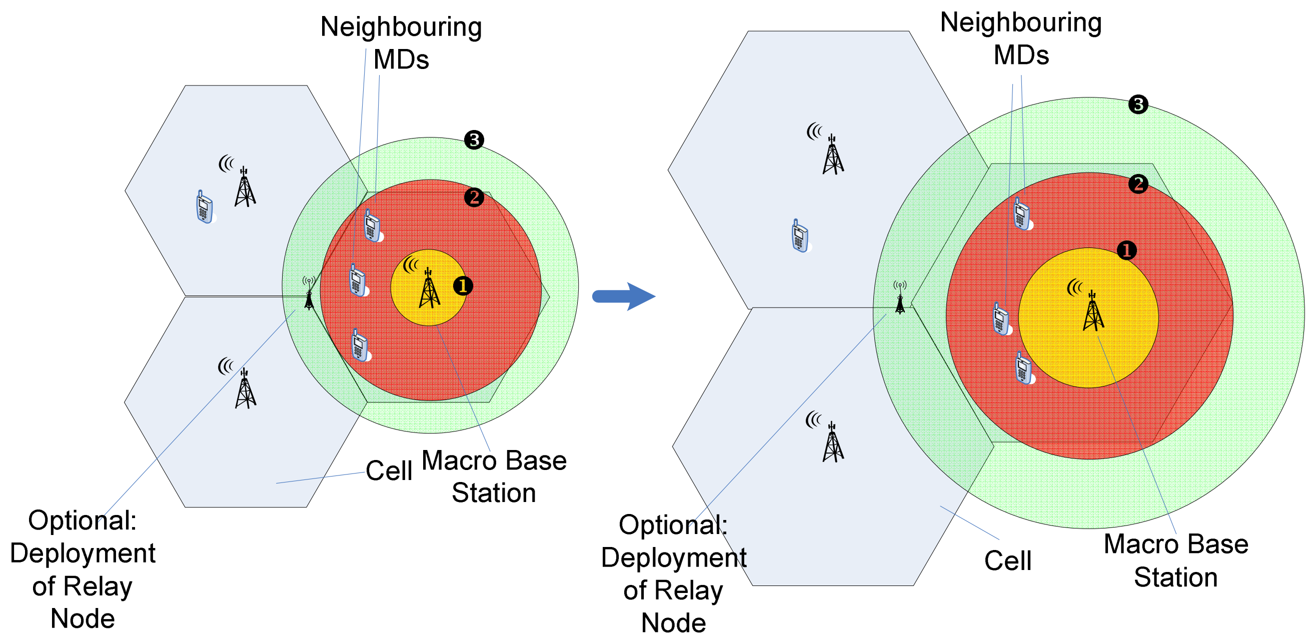
  - **Ad-hoc networking over white space frequency bands**
  - **TV White Space (TVWS) usage for Cellular Communication**
    - ***Scenario "Lighter infrastructure deployment through larger cell sizes"***
    - ***Scenario "Increased spectral efficiency through reduced propagation loss"***
    - ***Scenario "Increased spectral efficiency through extended macro diversity"***
    - ***Scenario "TVWS Band-Switch in case that primary user re-enters"***

TV White Space (TVWS) usage for Cellular Communication



„Traditional“ cellular communication

TVWS cellular communication exploiting advantageous propagation characteristics

- **The lower propagation losses experienced by the wireless signals over the TV band allow to increase the cell size of the cellular system. This results in a less dense infrastructure deployment of macro RBSs, which reduces CAPEX and OPEX of cellular operators. The system design has to take into account that the TVWS bands are eventually only available for a limited period.**

Conclusion Part 2:
WG1 - Cognitive Radio Systems Aspects.

- Key Definitions are presented;
- An overall CRS vision is given;
- 3 Use Case Families have been identified:
  - Use Cases related to SDR Reference Architecture for Mobile Device;
  - Use Cases related to Reconfigurable Radio Systems operating in IMT bands and GSM bands;
  - Use Cases related to Operation in White Space Frequency bands.
- What is next ?
  - Building on Use Cases, the next steps consist in
    - Derivation of normative System Requirements Specifications;
    - Derivation of a normative System Architecture Specifications;
    - Derivation of Protocol and Interfaces Specifications.

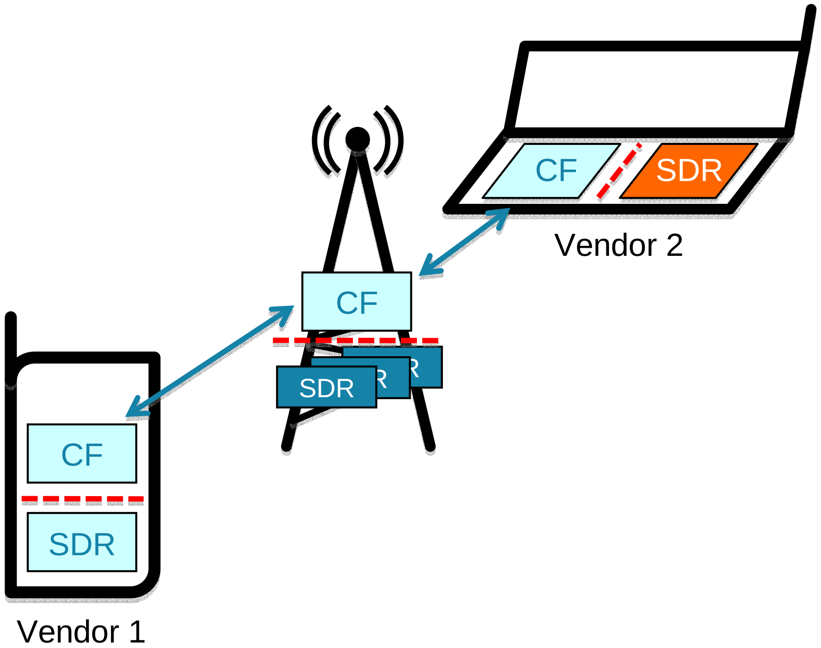
Part 3:
WG2 - Radio Equipment Architecture

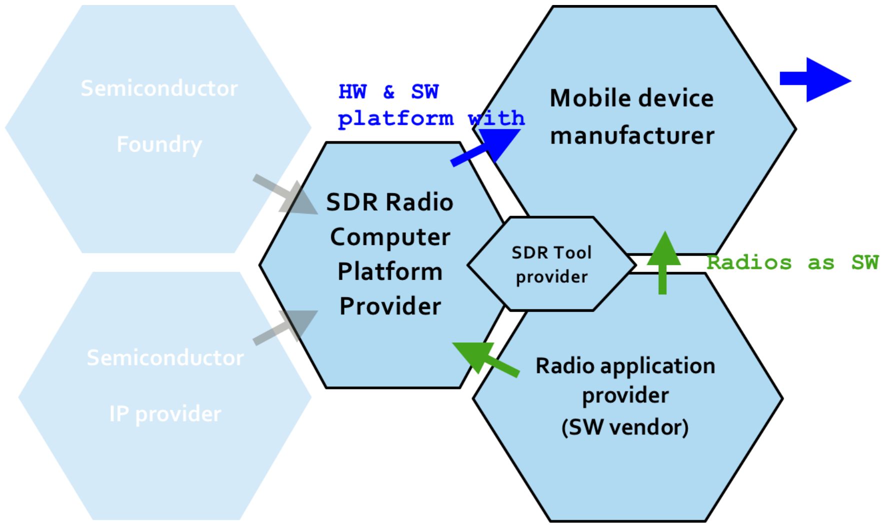
- Radio Equipment Architecture
  - Why SDR standards?
  - Radio Equipment Architecture;
  - Mobile device SDR use cases;
  - Use case description & information flow;
  - Mobile Device Reference Architecture;
  - “True SDR” Radio Computer Concept;
  - Multiradio Interface definition;
  - Base Station SDR Status.

Why SDR standards?

- SDR as the underlying implementation technology for Cognitive Radio functionality

- To enable business relations between potential stakeholders





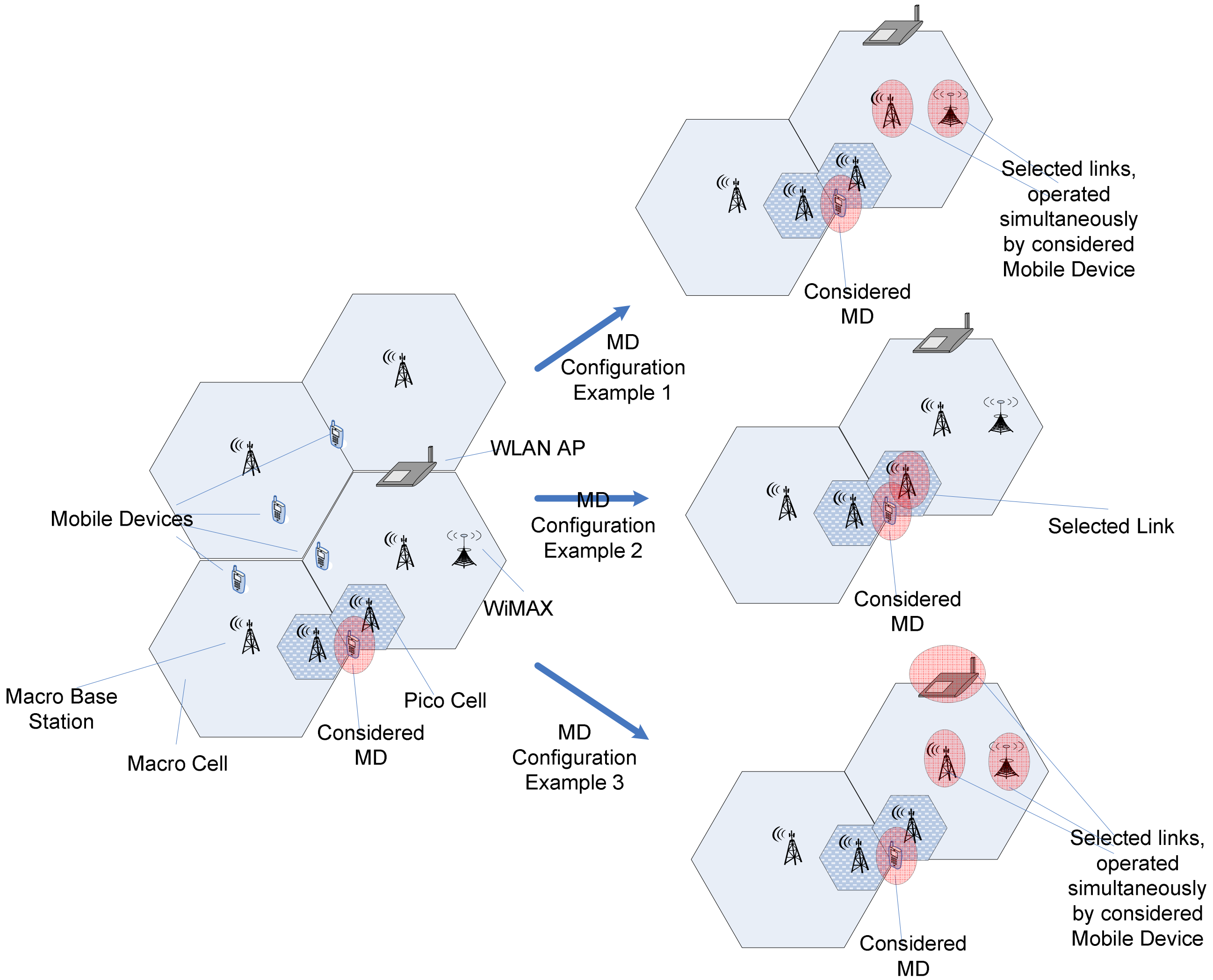
RRS WG2: Radio Equipment Architecture

- Proposes common reference architectures for SDR/CR radio equipment (e.g. mobile handset devices, radio base stations);
- Collects and defines requirements and scenarios for common reference architectures from relevant stakeholders;
- Builds on proposed common reference architectures by defining related functionalities: interfaces and protocols;
- Identifies gaps where existing ETSI and 3GPP standards do not fulfil the architecture requirements, and suggests and pursues further standardization activities to fill those gaps
  - To ensure the coverage of the most relevant standardization bodies across the globe.

Mobile device SDR use cases

- A use case based approach has been adopted to derive requirements for the SDR architecture
  - Terminal-centric configuration in a heterogeneous radio context;
  - Network-centric configuration in a heterogeneous radio context;
  - Addition of new features, such as support for novel radio systems, to Mobile Devices;
  - Provision of a new cognitive feature.

Use case description

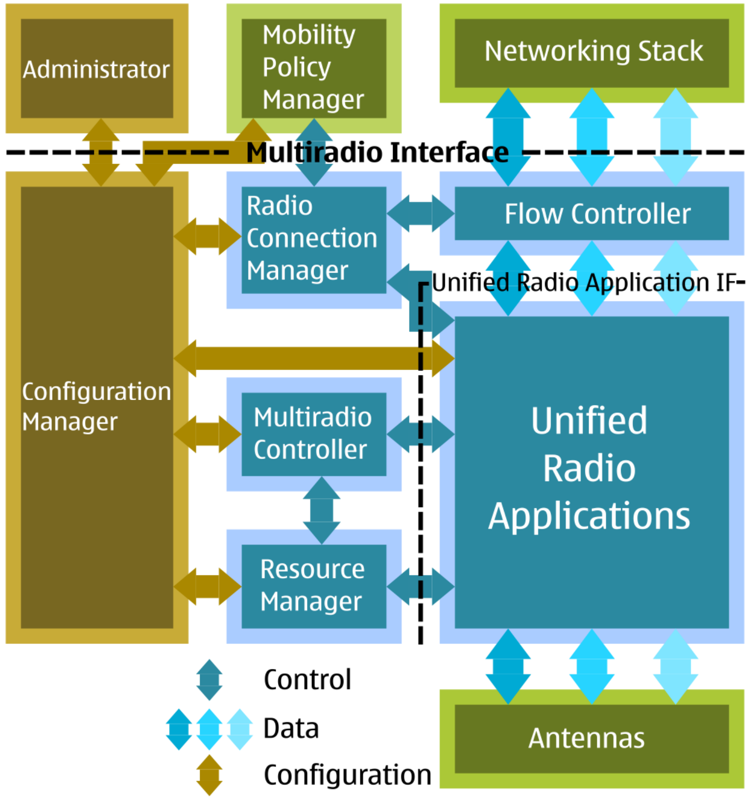


Mobile device SDR deployment scenarios

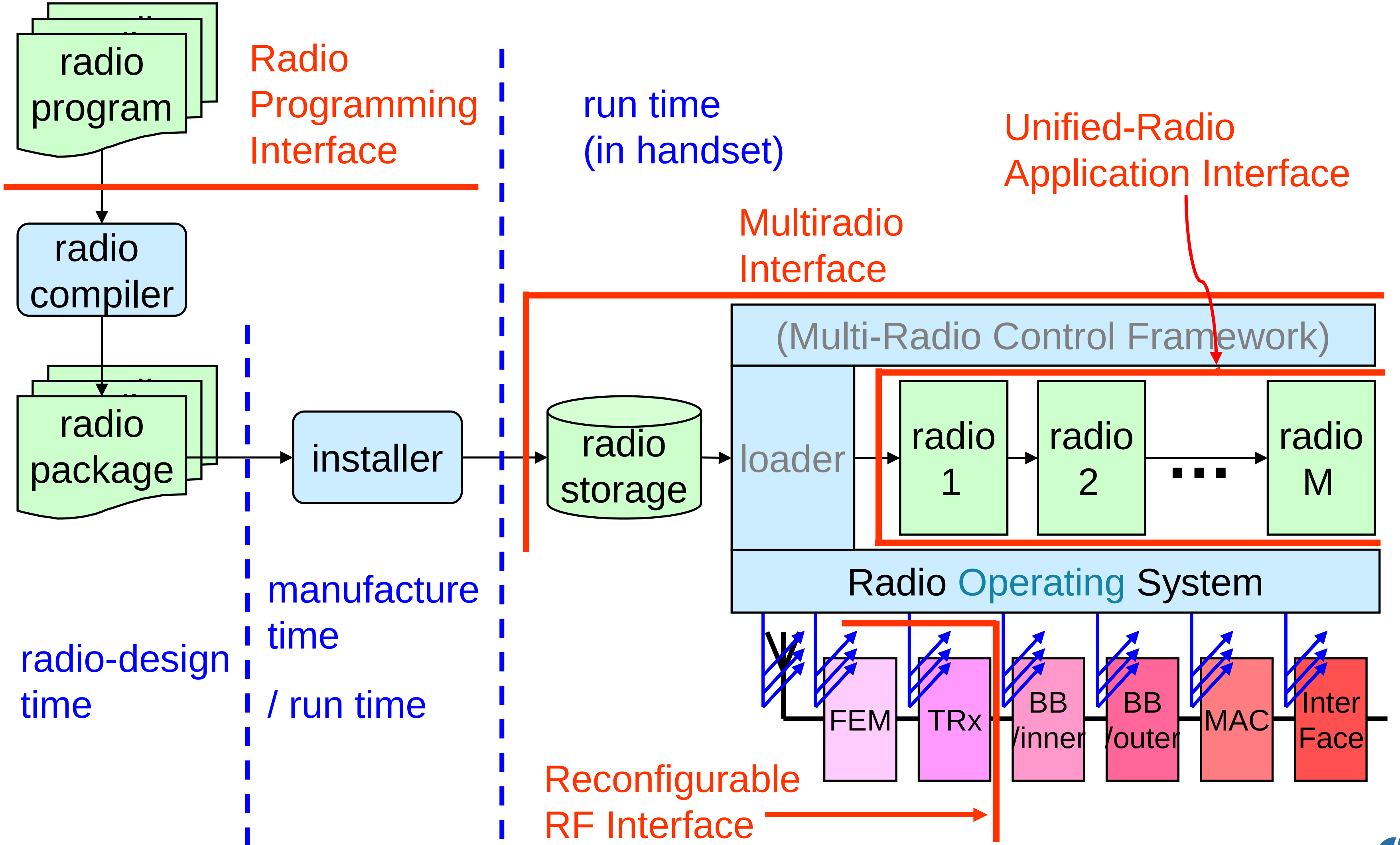
- **Software Defined Radio technology is expected to evolve gradually towards "true" SDR…**
  - ***Radios are legacy implementations:*** **CR functionality is limited to gathering readily available information from the specific RATs, and to configuring the RATs using legacy means;**
  - ***Radios use pre-defined fixed resources:*** **additional CR functionality is possible with reconfiguration parameter management;**
  - ***Radios have fixed resource requirements:*** **HW resource sharing is possible within the SDR platform;**
  - ***Radios have dynamic resource requirements:*** **fine-grained HW resource sharing is possible at the cost of less determinism;**
  - ***Radios come from third-party vendors (horizontal market scenario):*** **additional platform security issues need to be addressed.**

WG2 Mobile Device Reference Architecture

- The MD reference architecture defines functional interfaces for separating the generic SDR platform (control framework) and the specific RATs
  - Responsibilities for functional entities derived from Use Cases: allows easier development of cross-RAT cognitive functionalities;
  - The completeness of the control framework implementation depends on the SDR deployment scenario.
- Not an implementation architecture;
- Multiradio Interface (to the SDR sub-system) is seen with the most potential for standardization within ETSI.

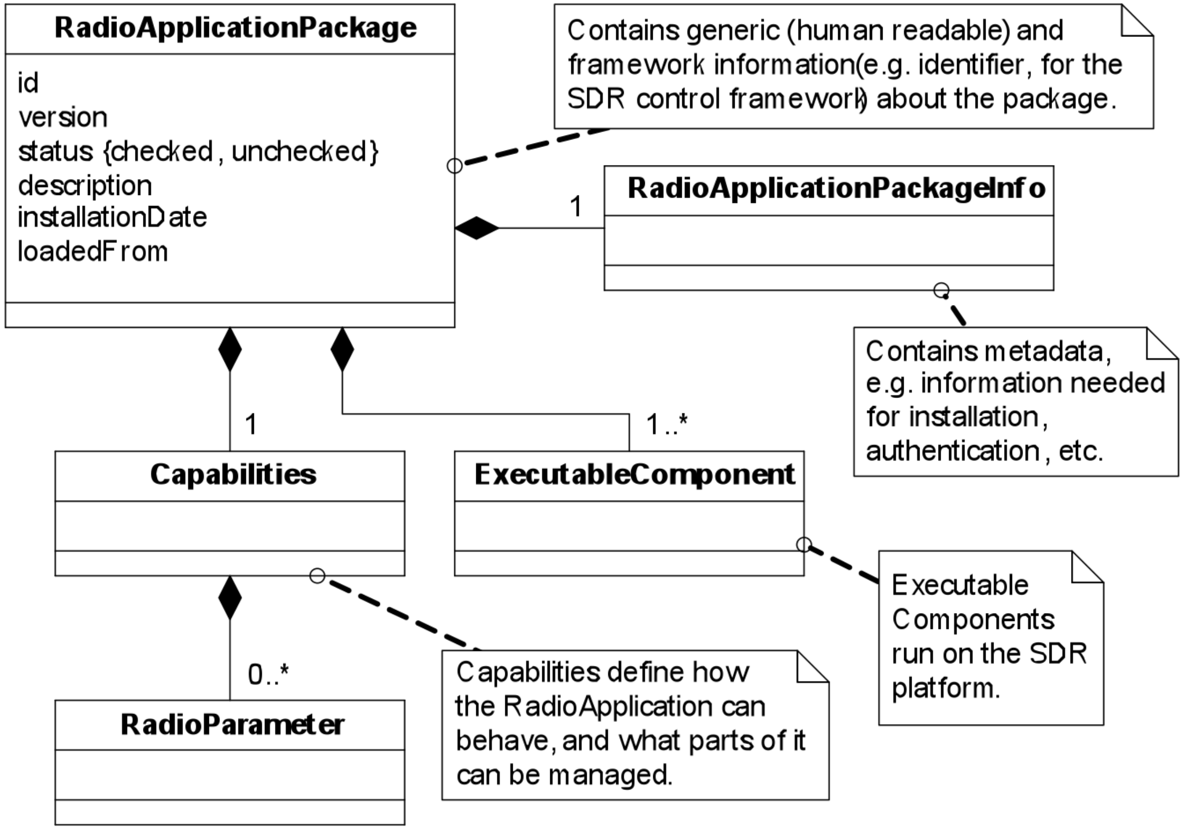


"True SDR" Radio Computer Concept



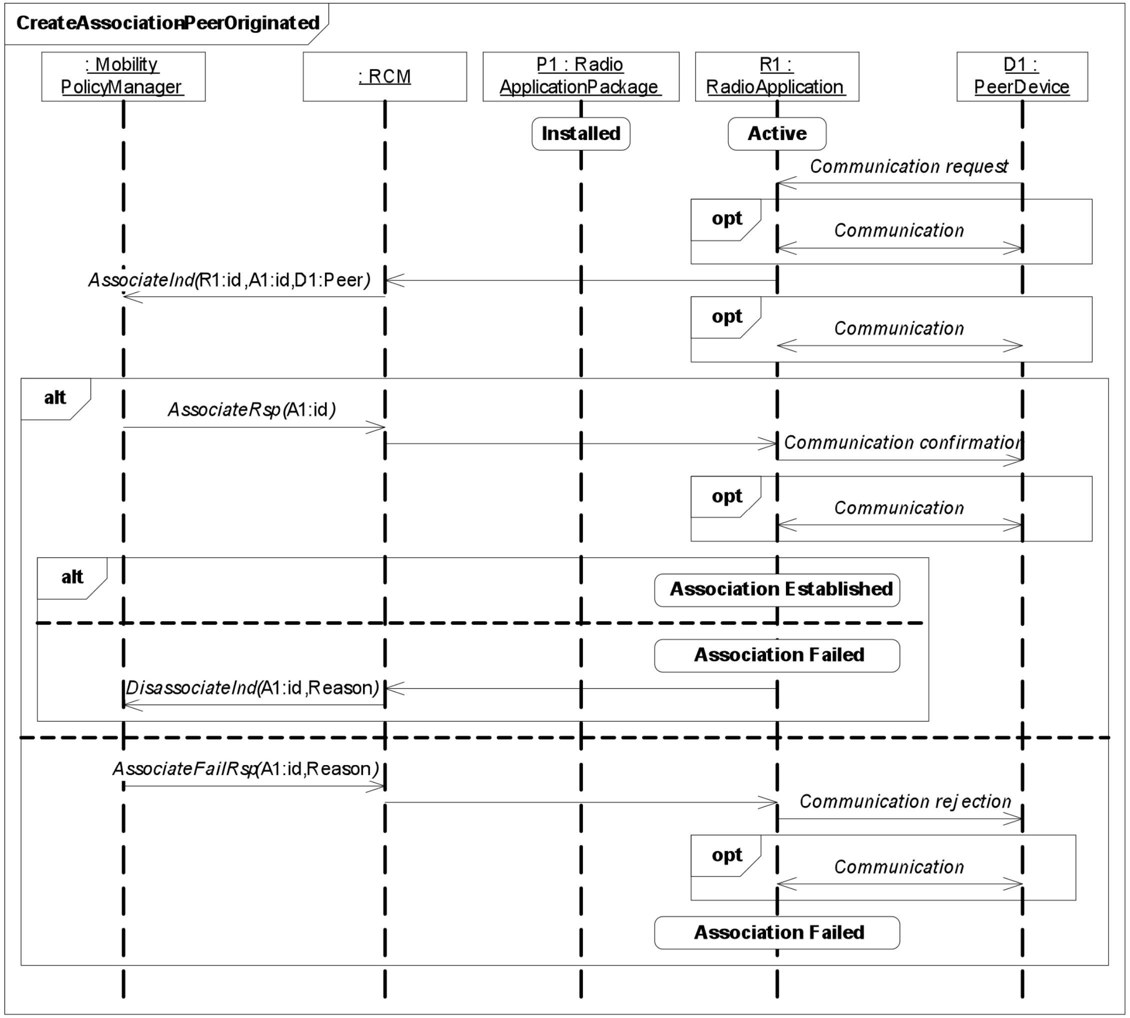
Multiradio Interface definition (1/2)

- Static information model:



Multiradio Interface definition (2/2)

- Dynamic service description:

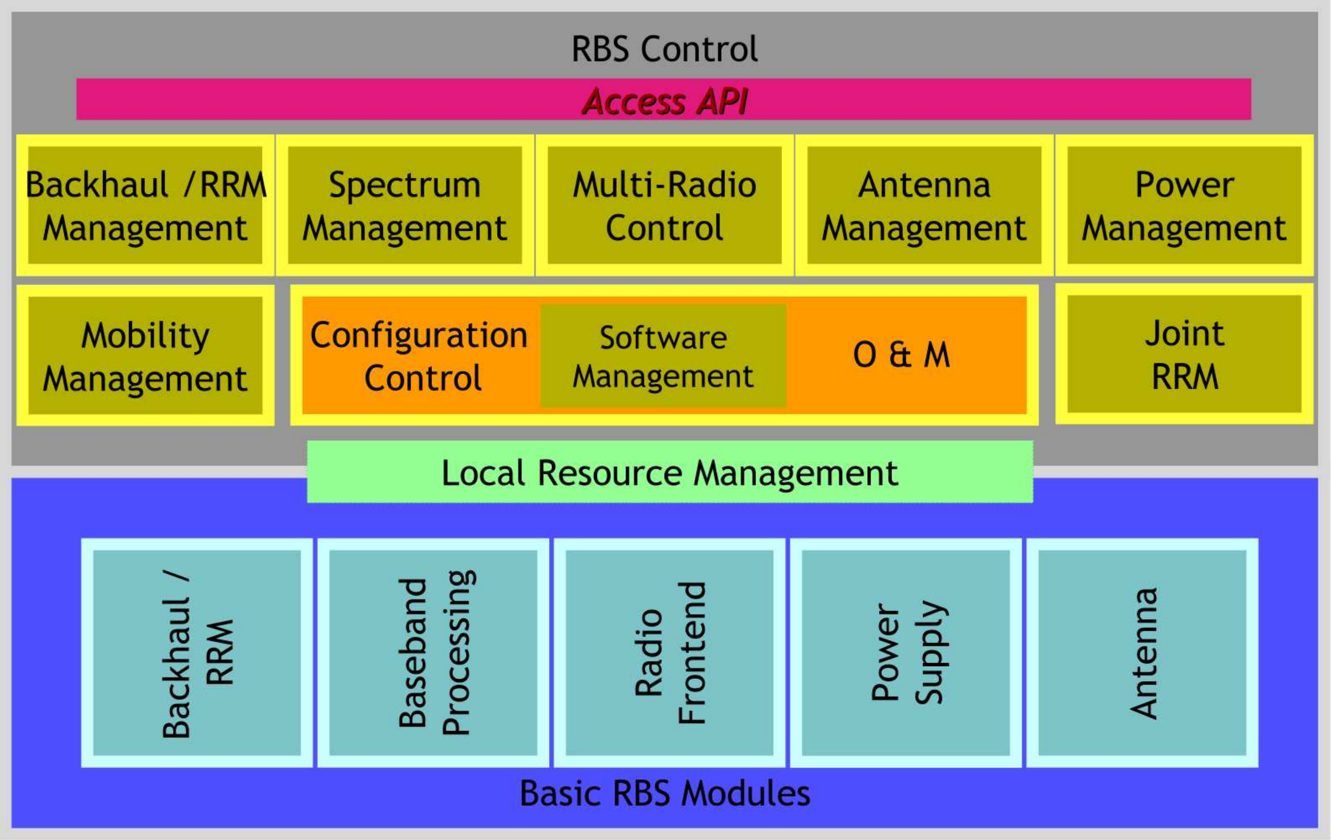


Base Station SDR Status

- Initial survey on implementation and cost aspects of reconfigurable base stations has been done;
- Telecom operator requirements for SDR base stations:
  - Fast network planning and update according to capacity and coverage needs;
  - Fast and cost efficient network deployment and commissioning;
  - Flexible network operation especially with respect to technology migration, spectrum reuse;
  - Maintenance optimization.
- Telecom OEMs have stated the need for:
  - Efficiently follow different customer requirements;
  - Reduce number of product variants and allow efficient product management.

WG2 Reconfigurable base station architecture

- A high-level architecture has been outlined to cover the flexibility aspects with most standardization potential



Conclusion Part 3:
WG2 - Radio Equipment Architecture

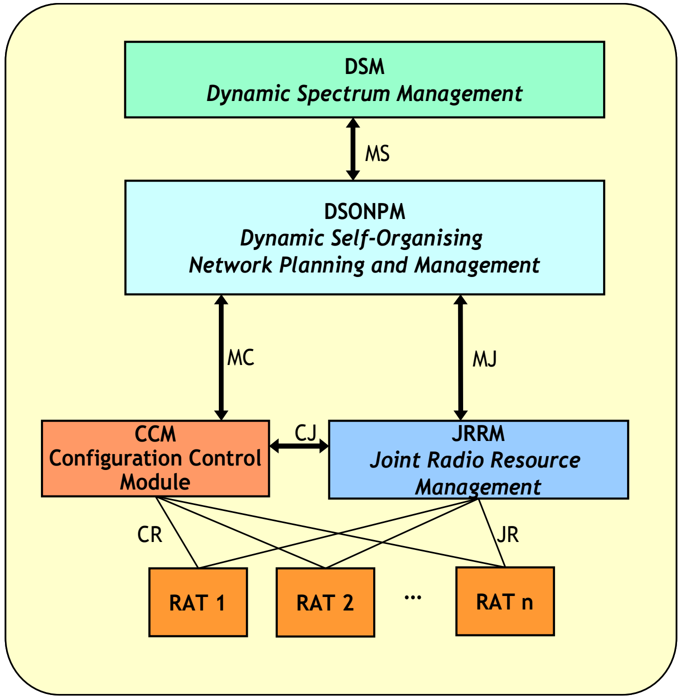
- RRS WG2 Reconfigurable Radio Architecture deals with reference architectures and interfaces to cover SDR/CR equipment;
- Mobile device (MD) use case use case work gives insight on the overall responsibilities of the systems, and is used to derive requirements on the equipment;
- SDR technology advances addressed through deployment scenarios;
- The functional MD reference architecture is under definition, work focusing on Multiradio Interface;
- Initial studies on reconfigurable base stations have been done, and the potentially relevant standardization topics identified.

Part 4:
WG3 - Cognitive Management and Control

- Cognitive Management and Control
  - Functional Architecture for the Management and Control of Reconfigurable Radio Systems;
  - Cognitive Pilot Channel (CPC);
  - CPC Two Components / Transport Options;
  - General Information Model on the information stored on network side;
  - Recent discussions in ETSI related to CPC.

ETSI RRS: Functional Architecture for the Management and Control of Reconfigurable Radio Systems

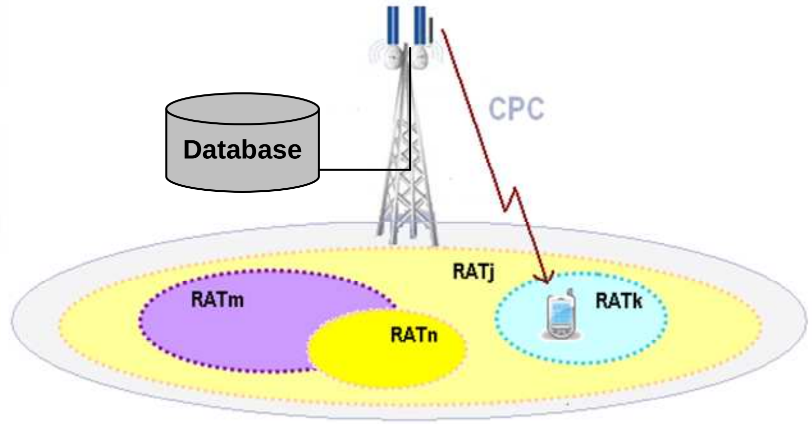
- Scope: Network with heterogeneous access technologies
  - Reconfigurable UEs / Mobile Devices and Reconfigurable Base Stations
- Functional Architecture addresses generic framework on possible network evolution concepts
  - Access Selection: Select the best radio access for a given user/session based on service requirements, radio conditions, network load, policies;
  - Base Station Configuration and Reconfiguration to maximise the networks efficiency;
  - Spectrum management for optimal, dynamic spectrum usage;
  - Self-Management of Radio Network Infrastructure;
  - Cognition Support Mechanisms (e.g. CPC).



- Details available in ETSI TR 102 682

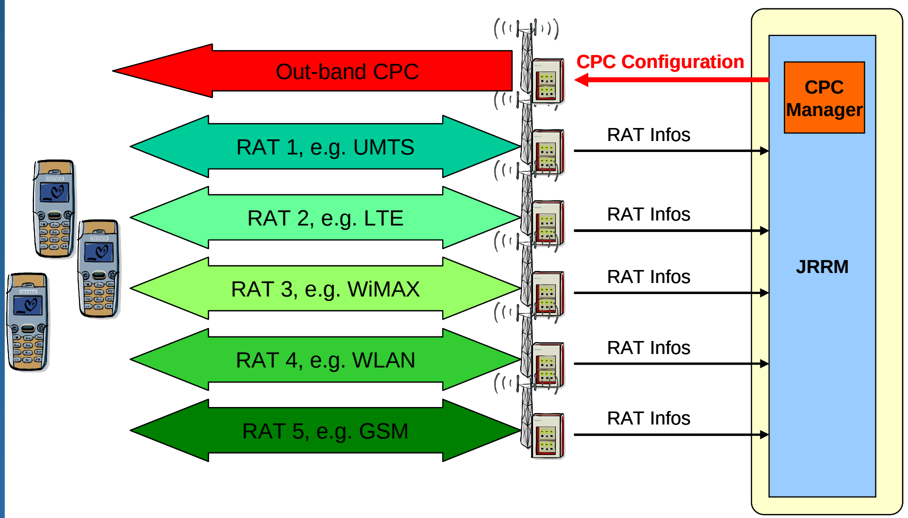
ETSI RRS: Cognitive Pilot Channel

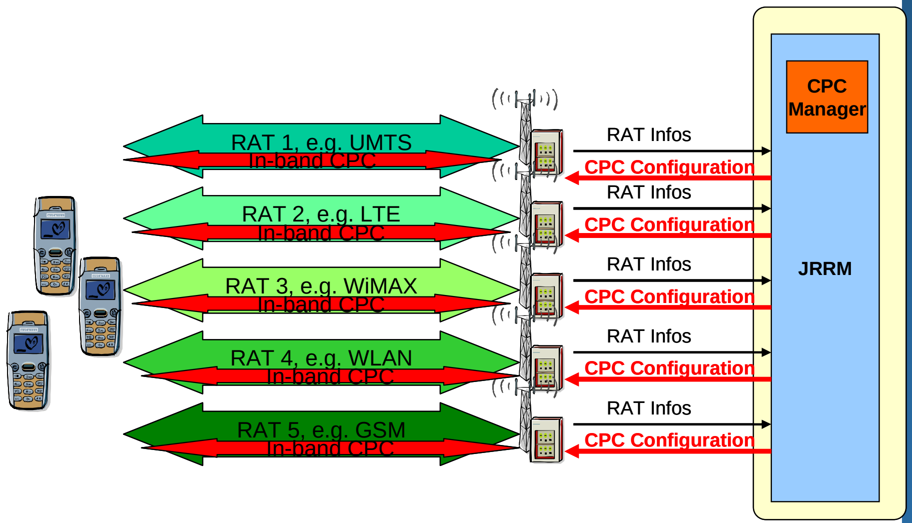
- **Scope: Cognitive Pilot Channel (CPC) serves mainly to**
  - **support the user terminal for an efficient discovery of the available radio accesses in a heterogeneous wireless environment.**
- **Moreover, CPC takes *additional scenarios* into account:**
  - **Flexible spectrum management as well as possible changes of the radio access technologies used in that spectrum;**
  - **Secondary spectrum usage (e.g. in TV White Spaces);**
  - **RRM optimization.**



Cognitive Pilot Channel (CPC)

- 2 components – CPC can use one of them or a combination:
  - Outband CPC: A physical channel outside the components radio access technologies
  - Inband CPC: A logical channel within the components radio access technologies



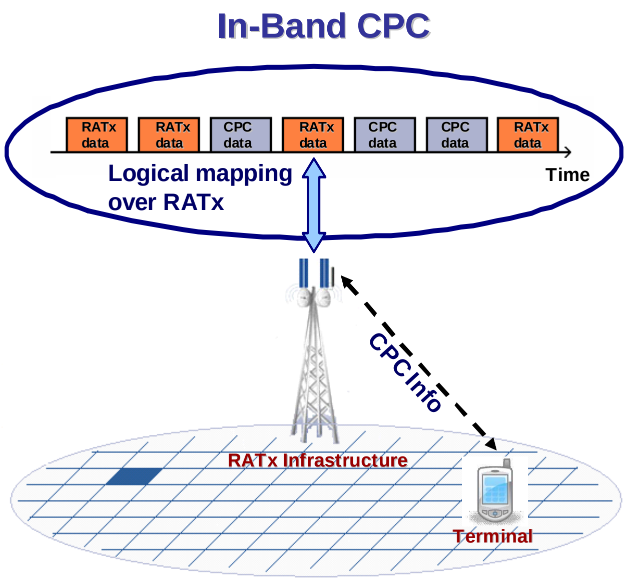


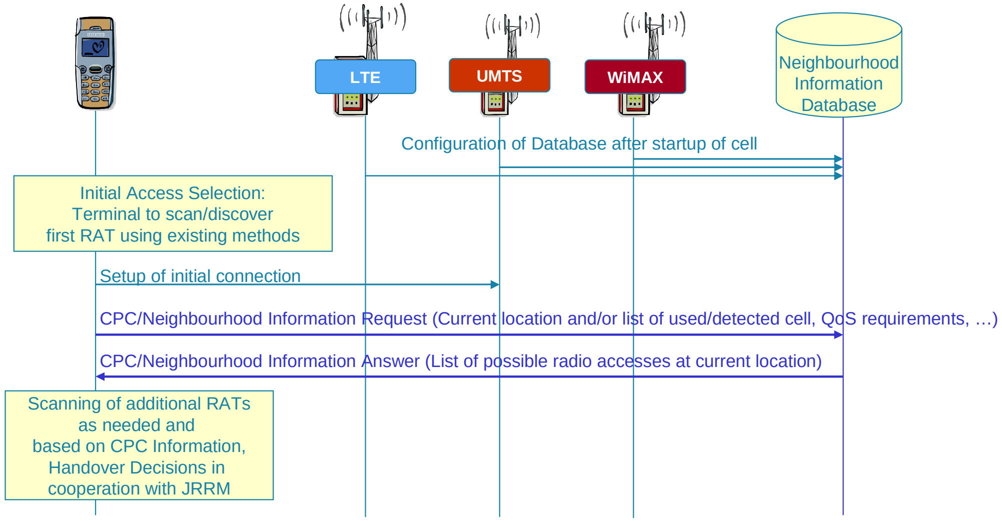
- The CPC may have both downlink and uplink components

CPC Transport Options

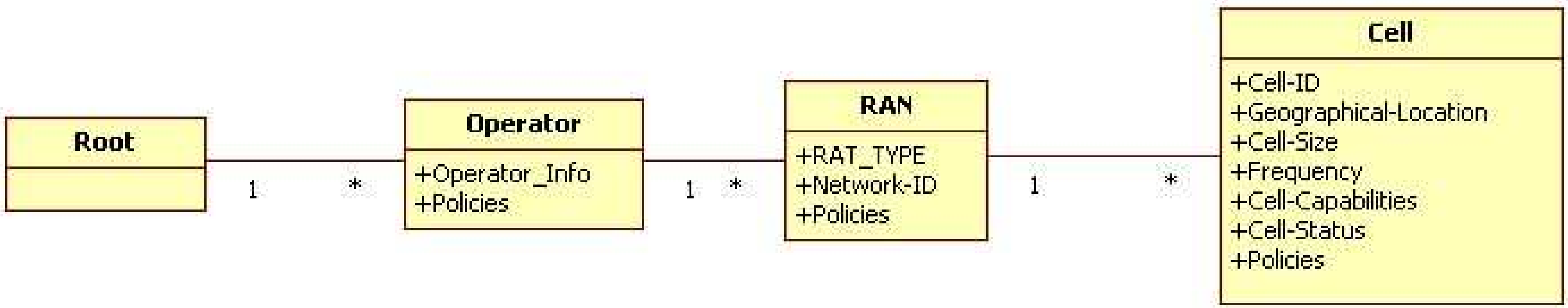
- **RAT-specific transport:**
- **As one example, CPC information can be transported using GSM by extending the Radio-Resource Management messages.**
- **Broadcast as well as on-demand communication is supported**

- **Higher layer transport:**
- **This option is RAT independent. Typically, messages are transported via IP.**





General Information Model on the information stored on network side



- **More information: ETSI TR 102 682 "Cognitive Pilot Channel";**
- **Related work in other standardization bodies:**
  - **3GPP Access Network Discovery and Selection Function (ANDSF);**
  - **IEEE SCC41 (IEEE 1900.4);**
  - **This related work is summarised in Annex B of TR 102 682.**

Recent discussions in ETSI related to CPC

- Following statements have been made during the RRS#10 meeting by the TC chairman reflecting the current opinion of the group:
  - ETSI RRS does not currently see a need to consider an out-band CPC on a world-wide harmonized frequency at WRC’12;
  - ETSI RRS intend to pursue CPC related studies where the priority is seen on the in-band CPC.
- Next steps (under discussion) can be to evolve the concept of the in-band CPC towards “Control Channels for Cognitive Radio Systems” including communication mechanisms for the coexistence and coordination of different cognitive radio networks and nodes.

Conclusion Part 4:
WG3 - Cognitive Management and Control

- A Functional Architecture for the Management and Control of Reconfigurable Radio Systems is defined;

- Various approach on the Cognitive Pilot Channel (CPC) are elaborated
  - CPC Two Components / Transport Options;
  - General Information Model on the information stored on network side.

- What is next ?
  - Recent discussions in ETSI related to CPC.
    - Concept of the in-band CPC towards "Control Channels for Cognitive Radio Systems" including communication mechanisms for the coexistence and coordination of different cognitive radio networks and nodes.

Part 5:
WG4 - Public Safety

- **Public Safety**
  - **WG4 responsibility and work areas;**
  - **Challenges, drivers and opportunities;**
  - **Architecture;**
  - **Future Developments.**

WG4 Mandate

- To collect and define the related Reconfigurable Radio Systems (RRS) requirements from relevant stakeholders in the Public Safety domain eventually including military ones;
- To define the system aspects for the applications of RRS in Public Safety;
- To deliver its findings in the form of Technical Reports, Technical Specifications and other relevant ETSI deliverables as appropriate;
- To evaluate the application of RRS technologies to the Public Safety domain;
- To evaluate the application of flexible spectrum allocation and spectrum sharing in the public safety domain and define access policies, roles and procedures for managing and sharing PPDR spectrum.

Related European FP7 projects

The European Commission has financed a number of projects in Public Safety communications.
Two projects specifically focused on the application of SDR to the Public Safety domain:

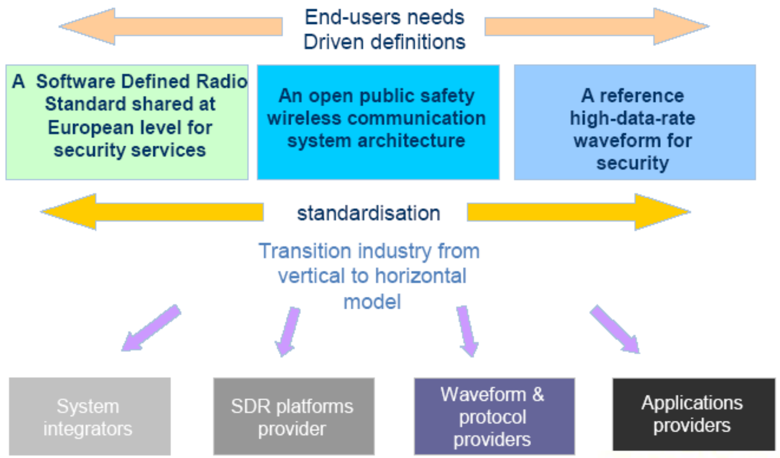
WINTSEC (Wireless INTeroperability for SECurity)

With the support of End-Users from 6 EU nations, WINTSEC explores a mix of complementary solutions to overcome the barriers for wireless interoperability across different agencies.

3.5 MEuro

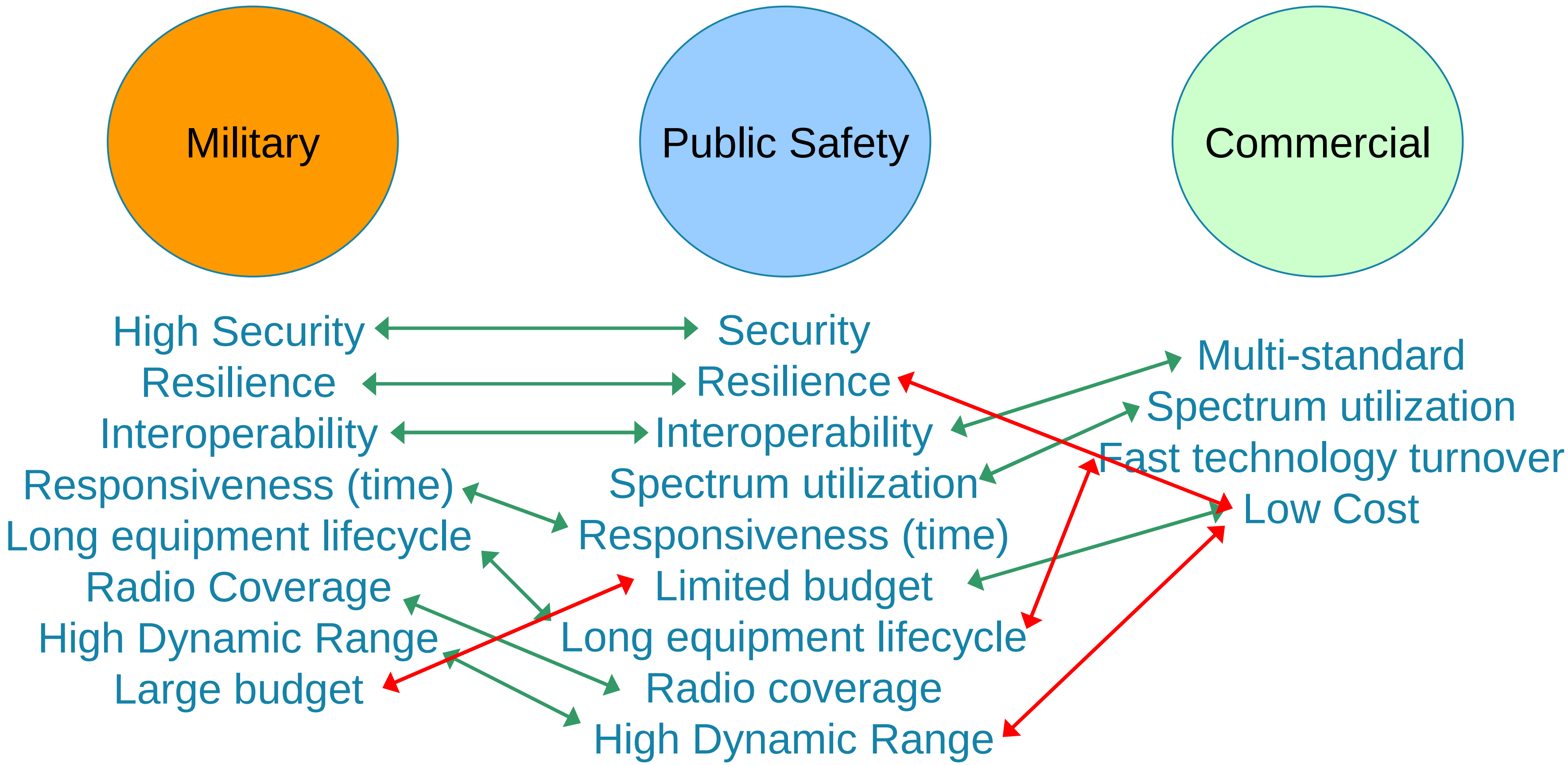
EULER (EUropean Software defined radio for wireLEss in joint security opeRations)

Use of SDR to rapidly resolve a major international crisis where public safety and military organizations of various types and nations must operate jointly.



15 MEuro

Different markets, different requirements ?



Synergies **Differences**

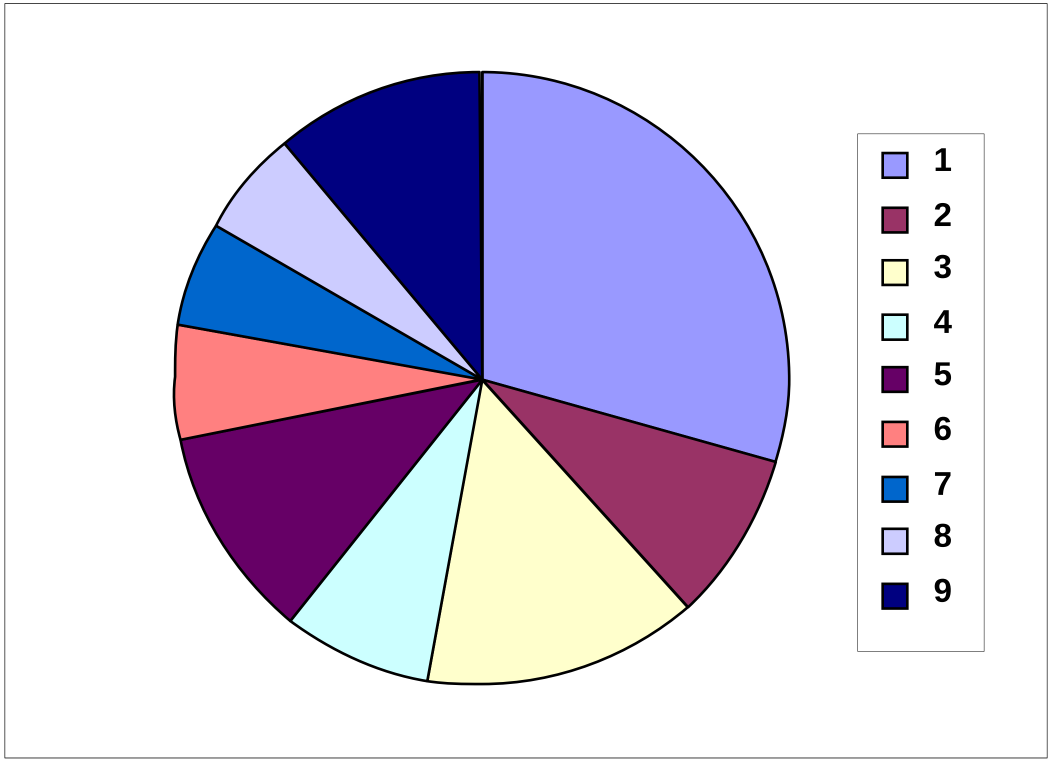
Main Challenges in Public Safety communications

- Interoperability barriers among the wireless equipment and systems of the various public safety organizations;
- Public Safety responders need high communication bandwidth to transmit images and video;
- Public safety operations are usually unplanned and communications facilities are not guaranteed;
- Public Safety users may not have the terminals related to the wireless networks existing in the emergency area;
- Evolving Technologies and standards may cause the existing wireless equipment to become obsolete. Equipment lifecycle can be a problem.

SDR and CR may have the potential to resolve these challenges

Drivers: What the public safety users want ?

Requested enhancements of PPDR communications



1	Broadband connectivity
2	Wireless interoperability with other safety agencies
3	Improved reliability of the wireless network
4	Capability of using existing commercial network systems (for example: GSM/UMTS)
5	Increased user mobility
6	Avoid to use multiple terminals
7	Improved communications underground/tunnel
8	Capability of creating local wireless networks.
9	Improve roaming across region or countries

Questionnaire results (25 users across Europe)

Challenge: Interoperability

In Europe, TETRA and TETRAPOL are the dominant PPDR networks, but other wireless communication systems are also used (or they will be used) by PPDR organizations:

- Analog PMR;
- Satellite Communications;
- DMR;
- APCO 25;
- Commercial networks (e.g. GSM, GPRS, WiMAX, UMTS, LTE).

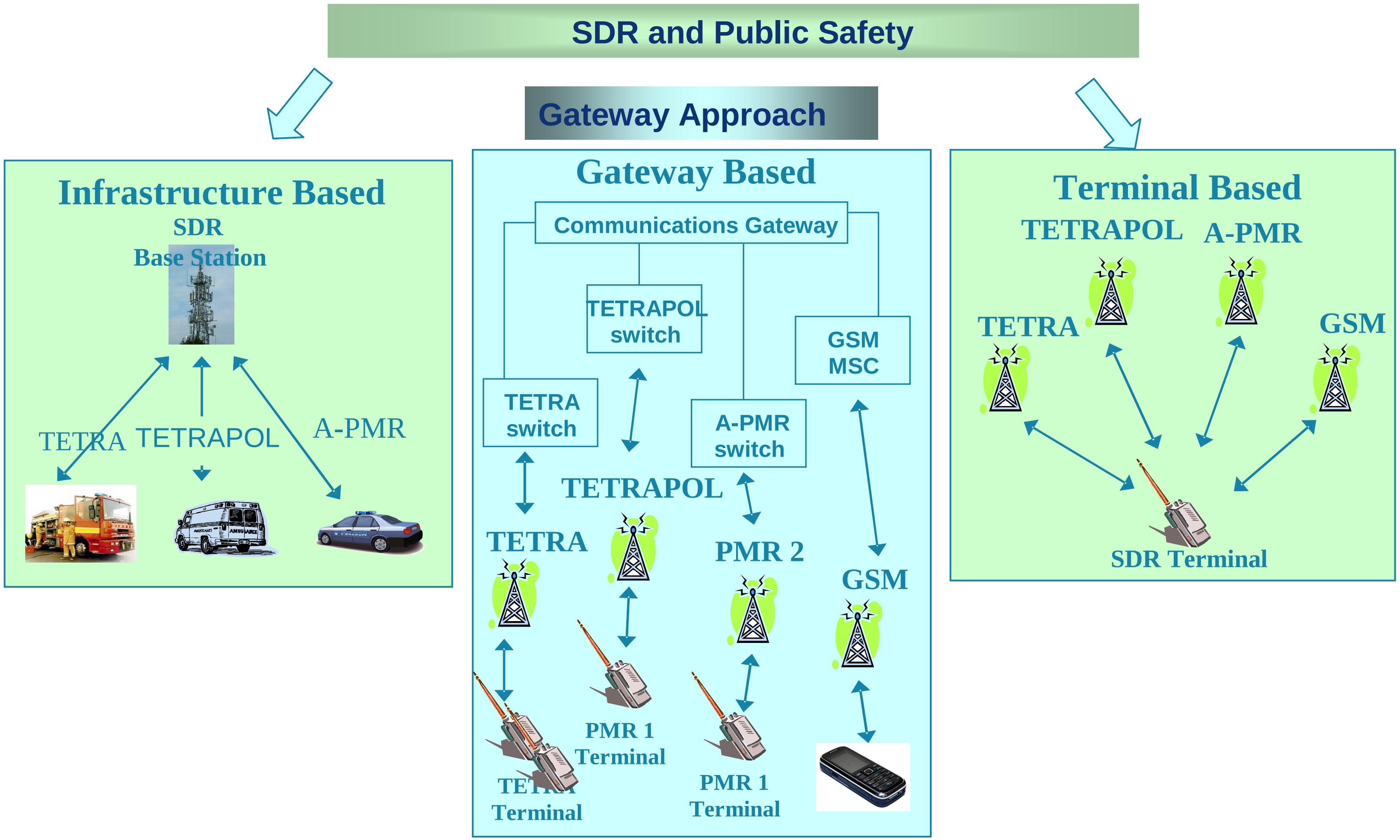
Even TETRA and TETRAPOL networks are currently not interoperable in Europe.

SDR technology may provide the capability to overcome interoperability barriers.

Commercial domain (multi-standards terminals) and Military domain (JTRS, SCA) have similar needs.

Potential for synergies ?

Challenge: Interoperability



Challenge: Radio frequency spectrum in Europe for PPDR

The existing spectrum identified for PPDR type services does not meet the actual needs, particularly for high speed data communication. It is quite difficult to identify new harmonized bands across Europe below 1 GHz. Allocation of new bands above 1 GHz have a large economical impact on existing PPDR networks (i.e. TETRA).

The following potential solutions or research areas have been identified:

- **Spectrum sharing of PPDR with military and commercial networks;**
- **Dynamic Spectrum management (local, temporary use) to increase capacity before a major event**

➔ Cognitive Radio may improve Spectrum utilization

PSS Spectrum Allocations

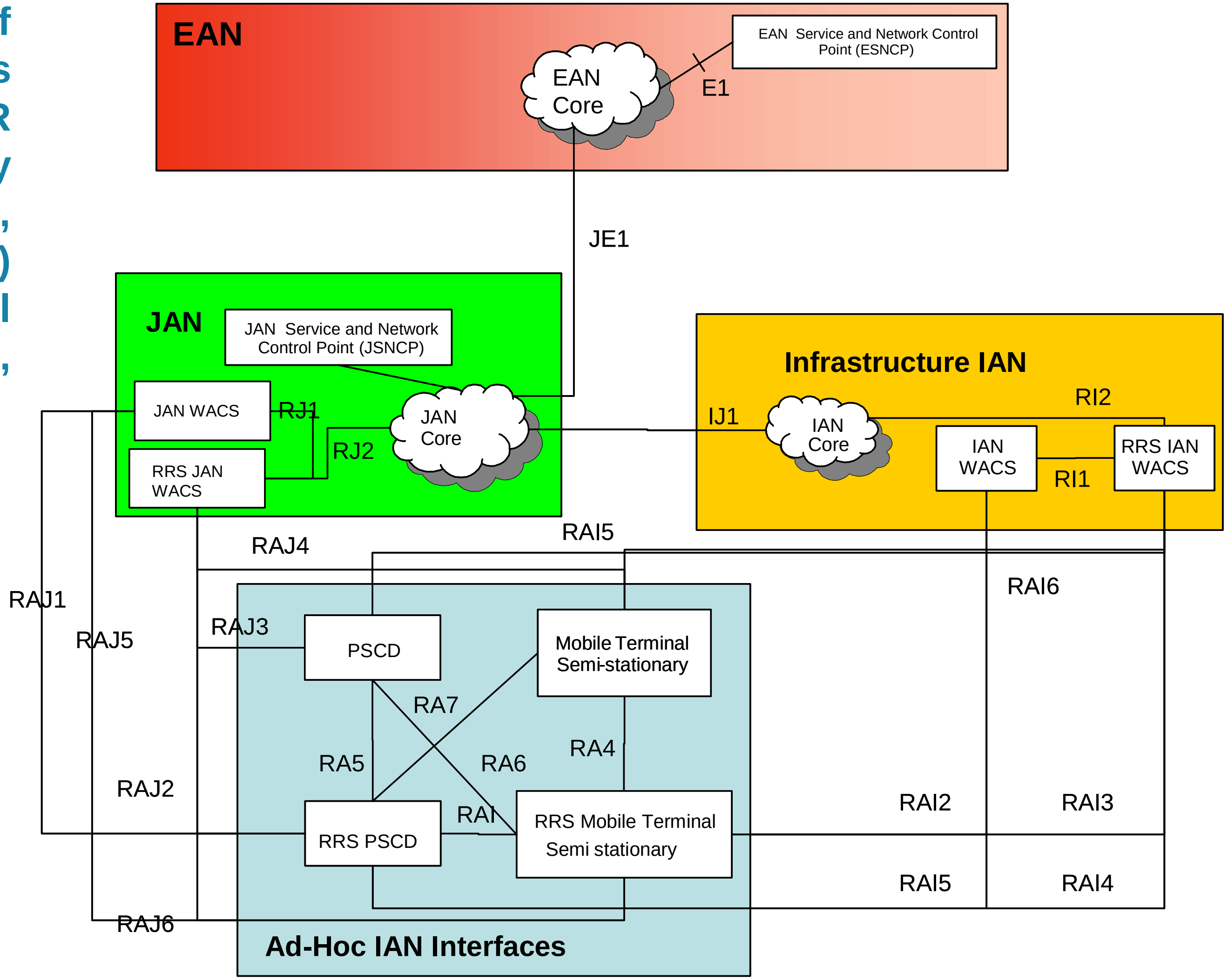
Frequency Band	United States Tuning Range (MHz)	United States Available Bandwidth MHz	Europe Tuning Range (MHz)	Europe Available Bandwidth MHz
VHF Low band*	25 - 50	6.3		
VHF High band*	150 - 174	3.6		
220 MHz band*	220 - 222	0.1		
UHF band*			380 - 385	5
	450 - 470	3.7	390 - 395	5
700 MHz band	764 - 776	12		
	794 - 806	12		
800 MHz band*	806 - 821	1.75		
	851 - 866	1.75		
NPSPAC band	821 - 824	3		
	866 - 869	3		
4.9 GHz band	4940 - 4990	50	Under Consideration	
Total		**97.2**		**10**

(* denotes approximate avaiable bandwidth)

From Working Group Frequency Management of CEPT/ECC - Public Protection and Disaster Relief (PPDR) 11-12 March 2010, Mainz (Germany)

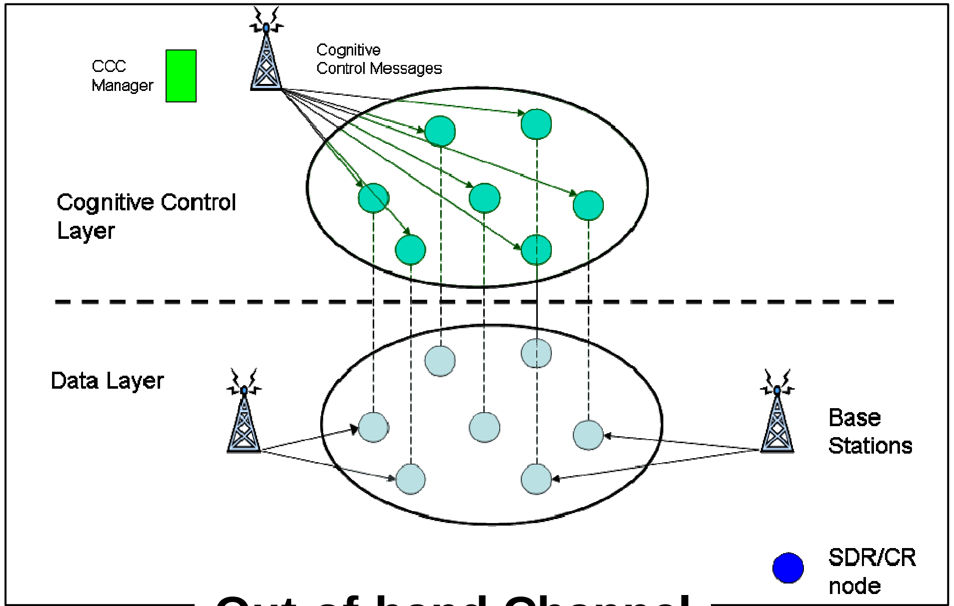
Architecture

The architecture of future PPDR networks based on SDR and CR must address legacy systems (e.g. TETRA, TETRAPOL, APCO25) and existing hierarchical structures (e.g. EAN, JAN, IAN, Ad-hoc IAN).

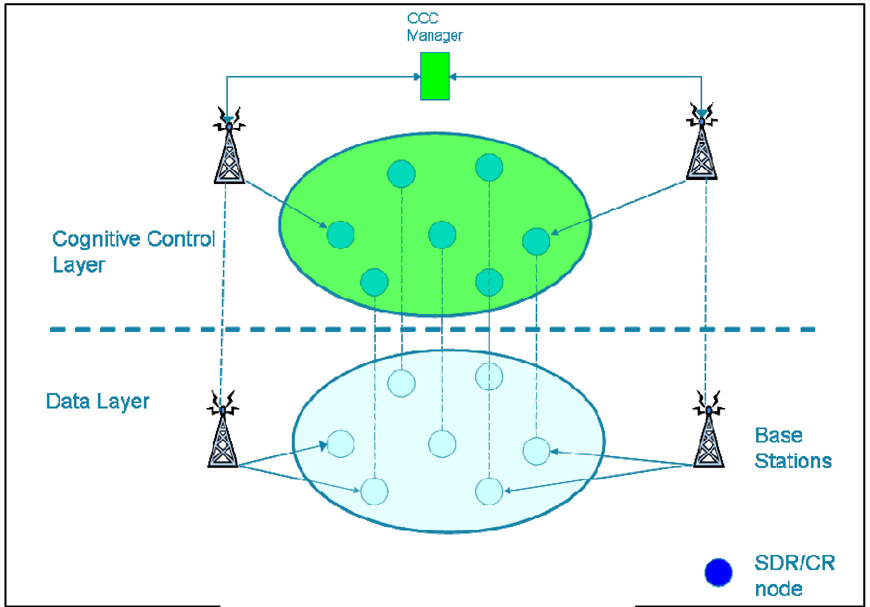


Architecture

A number of architectures have been investigated. Due to the hierarchical organizational structure of Public Safety organizations, a centralized architecture is preferred for Public Safety Cognitive Radio networks.



Out-of-band Channel

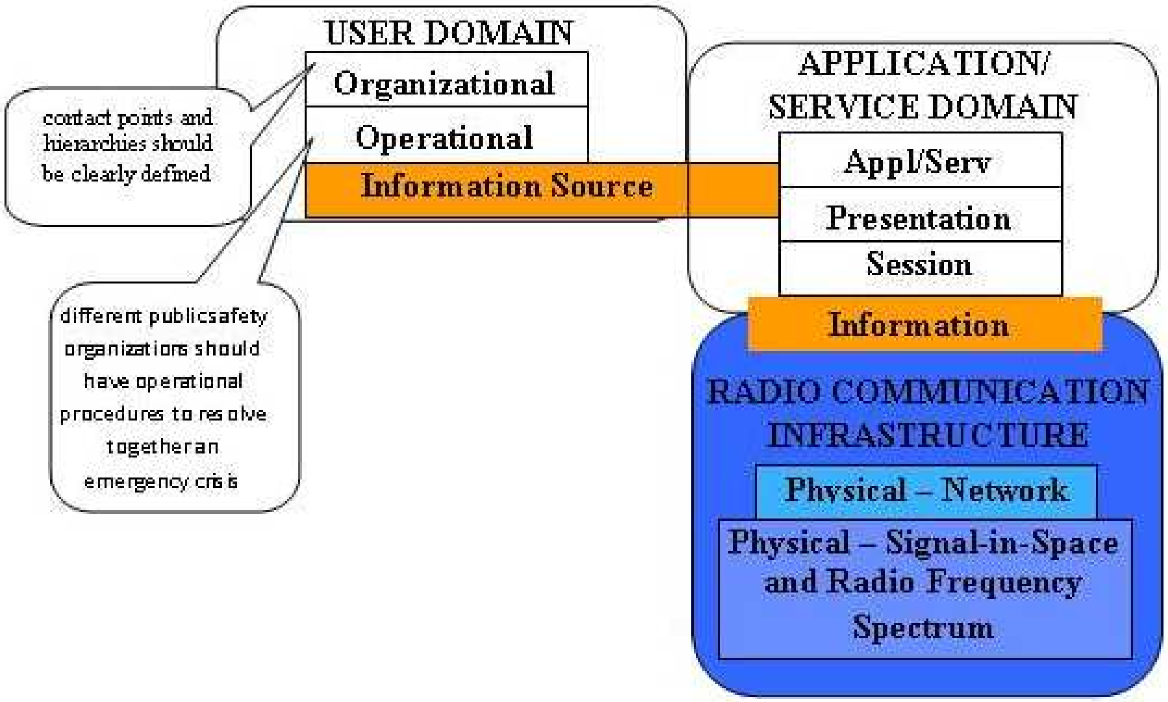


In-band Channel

The architecture will be based on a Cognitive Pilot Channel, which can be In-band (e.g. TETRA, TETRAPOL data channels) or Out-of-band.

Architecture

Interoperability: the main line to follow in order to develop this concept is the Interoperability among users involved and the consequent requirements. Here the term "Interoperability" has seen only from radio communications infrastructure point of view and the related information flow supported by:



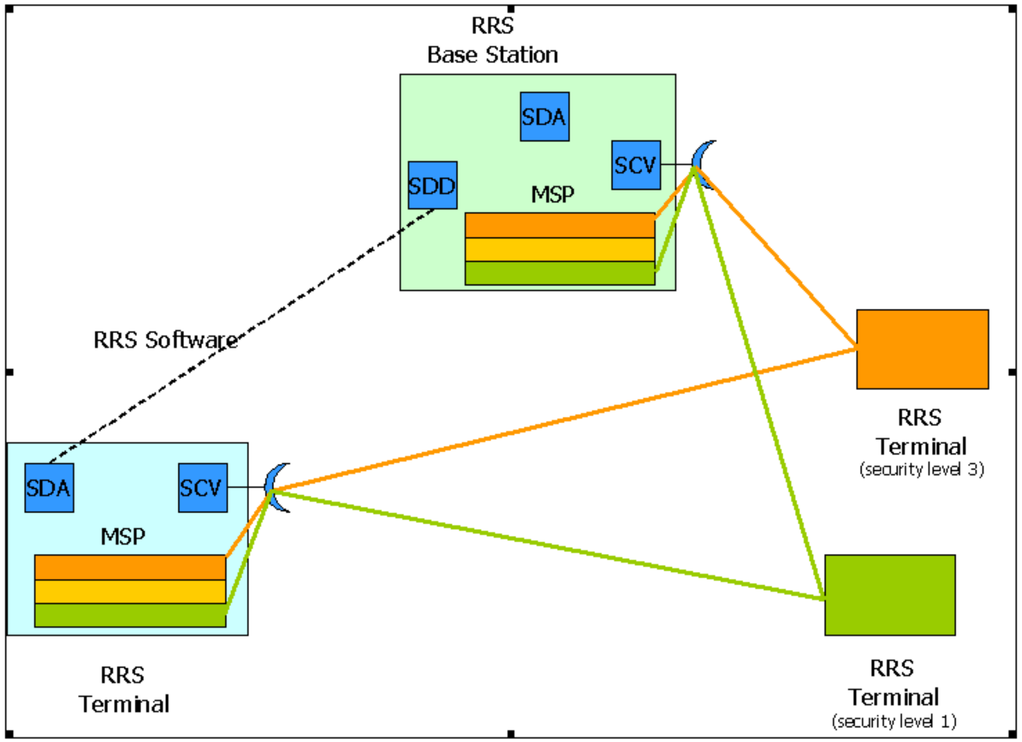
Security & Resilience

Security is essential in Public Safety networks. Future SDR/CR based PS networks must provide the same level of security and resilience of existing technologies (e.g. TETRA, APCO25).

Reconfigurability can be used to improve network resiliency and adaptability in complex operational environments.

Specific functions are needed:

- Software Download Authentication (SDA)
- Software Download Distributor (SDD)
- Spectrum Conformance Validator (SCV)
- Multilevel Security Path controller

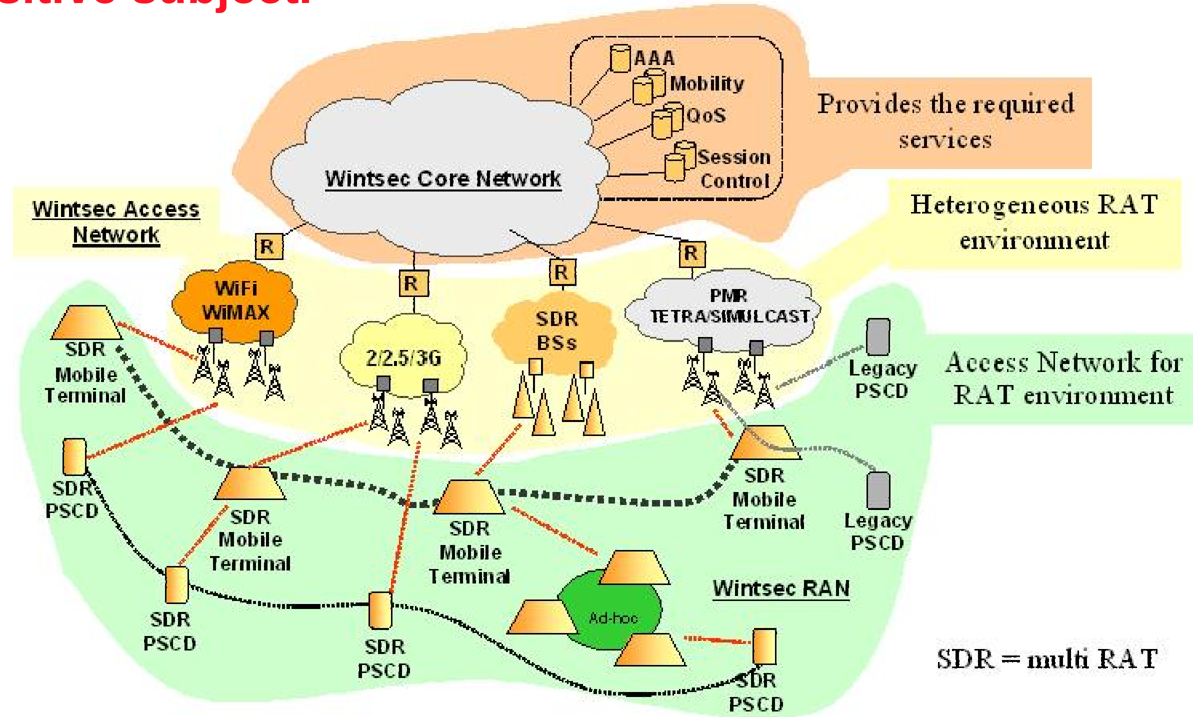


Security & Resilience

Security at data and services level: **some effort has been provided so as to investigate effective solutions including the SDR application in Core Networks able to enable transparent communication among different PS&G agencies using different RATs.**

The ways these services are integrated and performed in the specific deployed network is a sensitive subject.

from WINTSEC program



RAT = Radio Access Technology

Conclusion Part 5:
WG4 - Public Safety

❑Future Development includes

- Investigate Spectrum sharing of Public Safety networks with commercial or military networks;
- Investigate the feasibility of Multi-standards terminals for Public Safety both with the commercial domain (i.e. WG2) and the military domain (i.e. reuse of SCA);
- Define business models to support the "case" for Software Defined Radio and Cognitive Radio in the Public Safety domain;
- Investigate/reuse security concepts between WG4 and the other WGs in ETSI TC RRS (e.g. WG1, WG2 and WG3);
- Investigate Cognitive Radio extensions of TETRA in collaboration with ETSI TC TETRA.

Overall Conclusion

- ETSI RRS has developed a Vision on Cognitive Radio Systems;
- A variety of key Use Cases and Scenarios are elaborated;
- Related Enablers building on SDR are defined, including for example a SDR MD Architecture and related Interfaces;
- Related Enablers building on CR are defined, including for example a "Functional Architecture for the Management and Control of Reconfigurable Radio Systems" and a "Cognitive Pilot Channel";
- Key approaches for Public Safety applications are defined;
- Next steps consist in following the proposed ETSI RRS standardization process
  - Use case Definition (TR);
  - System requirements Specification (TS);
  - System Architecture Specification (TS);
  - Protocol and Interfaces Specification (TS).
- ETSI RRS is furthermore involved in key regulatory activities, e.g. in suggesting ways forward for the revision of the R&TTE Directive in Europe;
- There is furthermore a strong desire to further cooperate with related SDOs, in particular with the Wireless Innovation Forum !

Further Questions ?

Thanks for your interest and participation !