Project acronym:	SENDORA
Project title:	SEnsor Network for Dynamic and cOgnitive Radio Access
Project number:	European Commission – 216076
Call identifier:	FP7-ICT-2007-1.1
Start date of project:	01/01/2008 **Duration:** 36 months

Deliverable reference number:	D7.6
Deliverable title:	Preliminary report on demonstration activities
Version:	V1.0
Due date of deliverable:	Month M30 (06/2010)
Actual submission date:	30/06/2010
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Project co-funded by the European Commission within the 7th Framework Programme		
DISSEMINATION LEVEL		
PU	Public	**X**
PCA	Public with confidential annex	
CO	Confidential, only for members of the consortium (including Commission Services)	

EXECUTIVE SUMMARY

This preliminary report provides the progress of the implementation of architecture demonstration of the SENDORA system for both scenario#1 and scenario#2 defined in details in D7.1, D7.2 and D7.4. In a first step, a summary of the two system demonstration scenarios will be given. Then, their validation in the OpenAirInterface framework based on emulation version will be described. This document reports an intermediate status of the demonstration implementation progress. The final status will be depicted in deliverable D7.8 delivered at M36.

ACRONYMS

Acronym	Meaning
AP	Access Point (WiFi)
AWGN	Additive White Gaussian Noise
BTS	Base Station
CH	Cluster Head
CPCH	Cognitive Pilot Channel
CR	Cognitive Radio
CRRC	Cognitive Radio Resource Control
CRRM	Cognitive Radio Resource Management
CS	Communication and Sensing capabilities (terminal)
CSCH	Cognitive Sensing Channel
ED	Energy Detector
FC	Fusion Centre
PS	Primary System
PU	Primary User
S	Sensor
SCAN	Spectrum Scanning message
SN	Secondary Network
SU	Secondary User
T	Terminal
WSN	Wireless Sensor Network

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1. INTRODUCTION

1.1. D7.6 PURPOSE

The validation of SENDORA project objectives is performed through different complementary means, among which system demonstrations on hardware platforms. The corresponding demonstration scenarios and associated validation trials are defined in D7.1 "Validation Trial Definition". Then the validation of the project objectives is completed through simulations and emulations, under realistic environment conditions. Simulation and emulation frameworks are described in D7.5 deliverable. The objective of this deliverable is to describe the status on the progress of the realization of demonstration activities following the trials and scenarios described in D7.1 and D7.2 and demonstration architecture defined in D7.4. We will provide in the first part of this deliverable a summary of the two system demonstration scenarios given in details in D7.2 and D7.4. Then we will describe the demonstration and integration steps.

The implementation steps of the demonstration are:

- The implementation of the primary Wi-Fi system module. This module is currently fully implemented in the emulator.
- The implementation of architecture demonstration scenario#1 composed of the fusion centre module, the wireless sensor network (WSN) modules and the secondary network module. These modules are fully implemented and have been validated in the OpenAirInterface framework based on emulation version [ABKK08] [KGKAB10].
- The implementation of architecture demonstration scenario#2 composed of the cognitive Ad-Hoc Network module including the sensor module. This part is under implementation.

1.2. DOCUMENT VERSION SHEET

Version	Date	Description, modifications
1.0	23/06/2010	First version

2. SYSTEM DEMONSTRATION SCENARIOS

In D7.1, two real-time system demonstration scenarios and associated trials have been defined to prove the project concept of the WSN aided Cognitive Radio (CR). These scenarios reminded below are the basis for the system demonstration activities in the project.

2.1. SYSTEM DEMONSTRATION SCENARIO #1

This first system demonstration scenario shall demonstrate a secondary network providing the users with a cognitive nomadic broadband access using a sensor network aided Cognitive Radio technology based on an independent sensor network.

The secondary network shall receive transmission opportunities from the Fusion Centre and adapt its communications to take advantage of these opportunities. The objective is to take advantage of unused spectrum in an optimised way, in order to propose to the secondary users a broadband access on a best effort basis. The Fusion Centre (FC) is able to provide such information by computing sensing information provided by a dedicated sensor network. This sensor network is made of sensor nodes with detection and transmission capabilities. The system demonstration scenario #1 is represented on Figure 1.

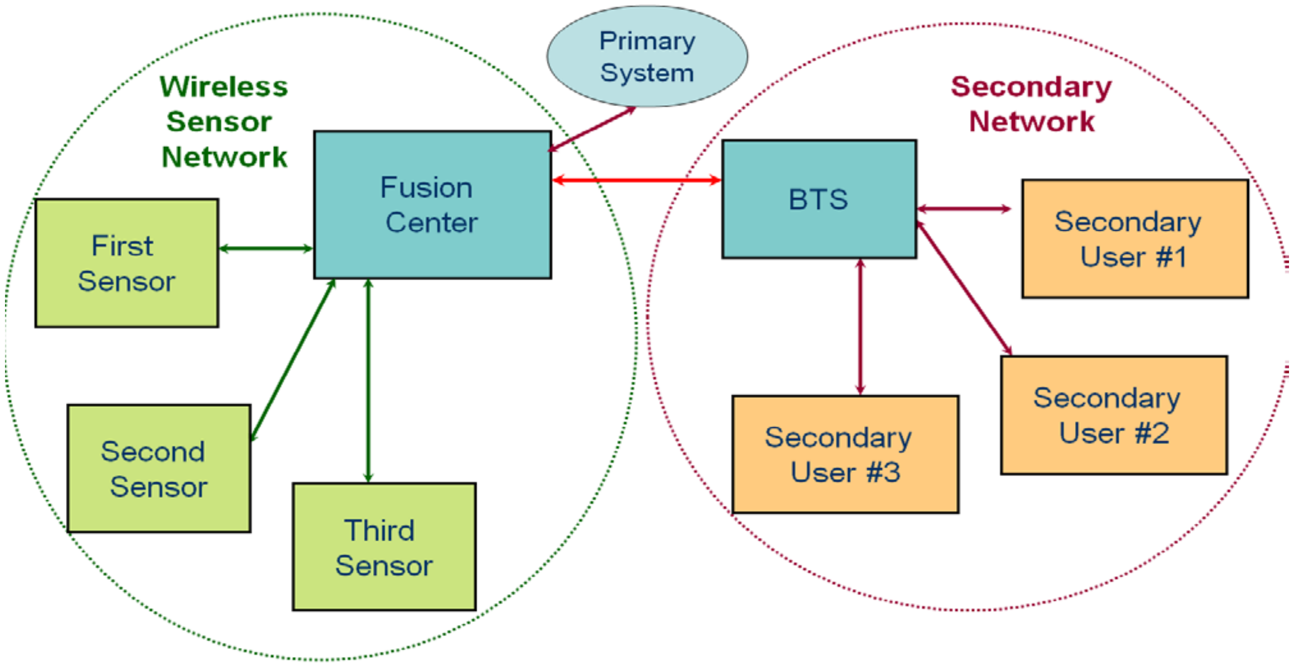

Figure 1: WSN aided CR centralized scenario

The primary system is a WiFi system and WiFi communications are considered as primary user communications. A sensor network is deployed in the area to detect the spectrum usage in the corresponding frequency band. The sensor nodes (S) have detection capability and communicate their detection results through a wired connection to a Fusion Centre entity that aggregates the information coming from the different sensors and proposes an interface with global spectrum monitoring. A secondary network (Base Station (BTS) + Secondary Users (SUs)), deployed in the area, takes advantage from this interface provided by the Fusion Centre entity to perform communications in an opportunistic manner. If primary user transmissions are detected by the Sensor Network in the corresponding band, the Fusion Centre shall receive the information and forward it to the Secondary Network. The Secondary nodes shall adapt their transmissions to avoid harmful interferences generated to the primary users.

2.2. SYSTEM DEMONSTRATION SCENARIO #2

The second system demonstration scenario shall demonstrate a secondary network providing the users with a cognitive nomadic broadband access using a WSN aided Cognitive Radio technology.

In this scenario, the Secondary Network integrates the Wireless Sensor Network: secondary communicating nodes have sensing capabilities, they perform the spectrum sensing in a distributed manner, compute transmission opportunities and adapt their communications to take advantage of these opportunities without interfering harmfully with the primary technologies.

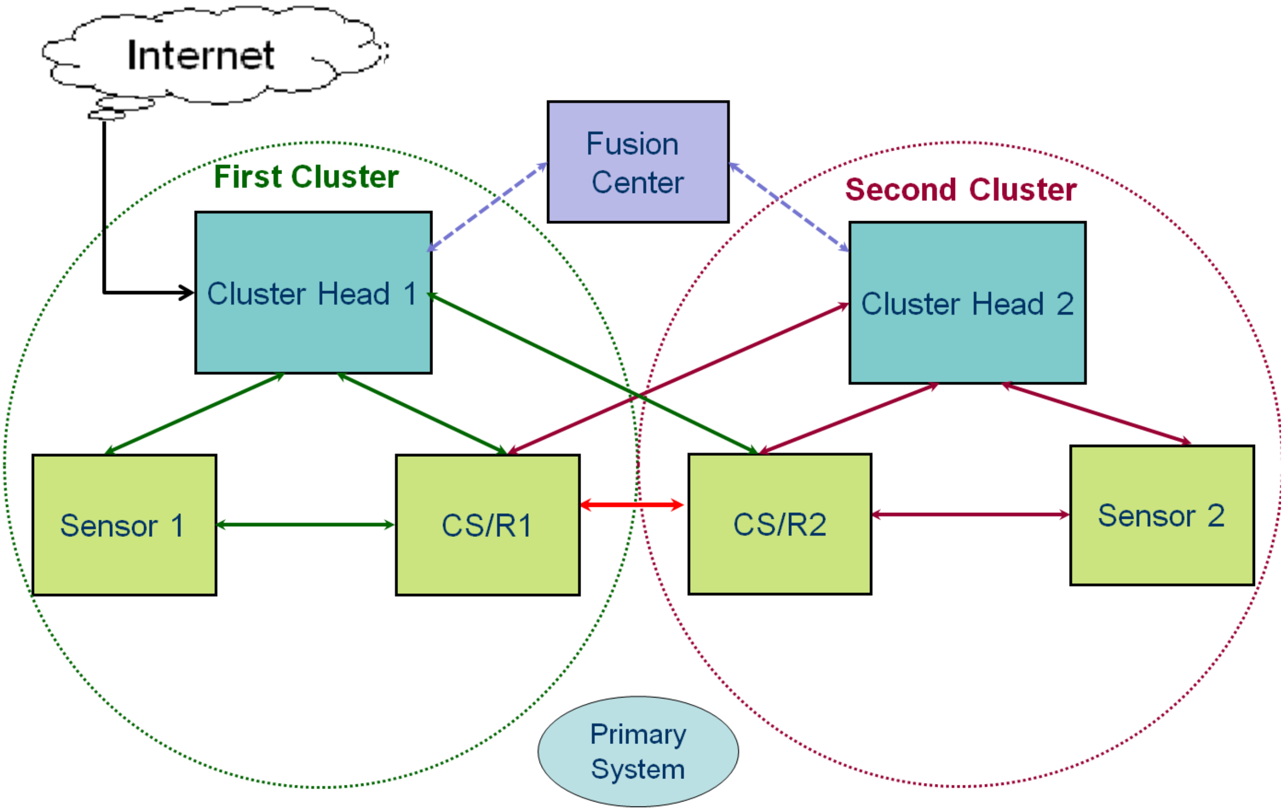

Figure 2: Cognitive Ad Hoc Net Scenario

The system demonstration scenario #2 is represented on Figure 2. As in demonstration scenario #1, the primary system is a WiFi system. An ad hoc secondary network is deployed in the area. The secondary nodes have sensor capabilities to detect the spectrum usage and communicate their detection results between each other on a dedicated narrow band channel. There are 6 nodes in total, out of which 4 have communication and sensing capabilities (CS) and 2 nodes only have sensing capabilities (S). The WSN is organized in two clusters. Cluster 1 consists of cluster head 1 (CH1), sensor 1 (S1), and secondary nodes (R1 and R2). CH1 is supposed to be directly connected to a Fusion Centre over a wired connection, which should be mandatory in a real system to ensure a global spectrum management, as depicted in D2.1 "Scenarios and system requirements" document. The second cluster is formed by CH2, S2, R1 and R2. According to the result of this sensing phase, the secondary nodes perform cognitive communications in a channel that they have detected as free. The secondary nodes shall adapt their transmissions if they detect any primary user transmissions in the corresponding channel to avoid harmful interferences. We consider a centralized channel allocation scenario where all sensing results are collected by the cluster heads, and the cluster heads control the channel assignment upon a request from a secondary node.

3. SENDORA DEMONSTRATION PLATEFORM: MODULES IMPLEMENTATION AND INTEGRATION

This section describes the progress of the implementation of the different components of the SENDORA system for both demonstration scenarios defined in previous WP7 deliverables.

3.1. PRIMARY SYSTEM MODULE

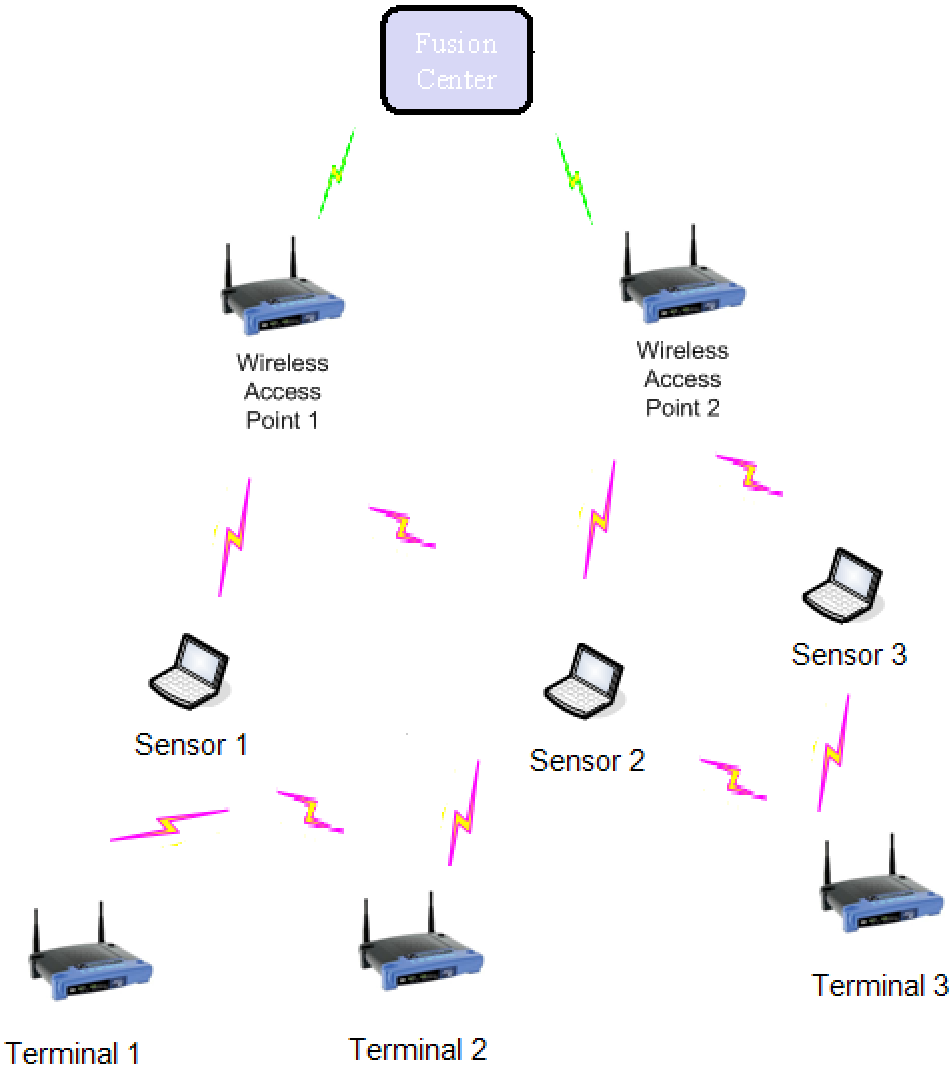

Figure 3: Primary system network in SENDORA demonstration

For the first step of the demonstration based on the emulation, we had to implement the following environment for the primary system, given by Figure 3.

The primary Wi-Fi like system is composed of two access points (AP) working on two different frequencies F1 and F2 and three terminals [LCN09]. We consider that each access point manages the three mobile nodes. The sensor module contains the algorithm (Energy Detector (ED) [U67]) in charge of scanning the spectrum in the bands specified by the Fusion Centre and reports the measurements in a proactive manner as specified by higher layers.

The Fusion Centre sends commands to each sensor with the following control information: the central frequency, the bandwidth, the granularity of sensing (i.e. the number of sub-bands to sense and there bandwidth), the detector (threshold), the sensing start time and the sensing duration. Each node detects the spectrum usage in the corresponding frequency band and communicates their detection results through a wired connection to the Fusion Centre that aggregates the information coming from the different sensors.

In the following, we describe the modelling of this primary system for emulation purpose.

Assume the 3 nodes are distributed in a two-dimensional plane. The distances, d_{j,AP_1}, from the first AP to the terminal j, and, $d_{i,j}$, between a pair of Ts, are [P01]:

$$d_{j,AP_1} = \sqrt{(x_{AP} - x_{T_j})^2 + (y_{AP} - y_{T_j})^2}$$

$$d_{i,j} = \sqrt{(x_{T_i} - x_{T_j})^2 + (y_{T_i} - y_{T_j})^2}$$

Using equivalent complex envelopes in the baseband, the received signal at the node, j, corresponding to the transmitted packet, $\imath$, from the node, i, is [P01]:

$$\mathbf{y}_{j\imath} = |g_{ij}| \exp^{j\psi_{ij}} a_{\imath i}\mathbf{x}_{i\imath} + \mathbf{w}_\imath$$

The channel attenuation, $|g_{ij}|$, represents a free-space path loss, ψ_{ij} is a random channel phase shift, $a_{\imath i}$ sets the transmitter power, $\mathbf{x}_{i\imath}$ is the transmitted packet, and $\mathbf{w}_\imath$ denotes an additive white Gaussian noise (AWGN). The channel attenuations are modeled as

$$|g_{ij}|^2 = \left(\frac{4\pi 100}{\lambda}\right)^{-2} \left(\frac{d_{ij}}{100}\right)^{-\mu} s_{ln}$$

where d_{ij} is the distance from the transmitter antenna (in meters), $\lambda = 3\ 10^8/f_c$ is the carrier wavelength, f_c is the carrier frequency, μ is the path loss exponent, and where, $1.5 \leq \mu \leq 4.0$, for the typical line-of-sight outdoor channels. A log-normal distributed random variable, s_{ln}, models the path loss variations, and we assume that it can be neglected. Note that the channel attenuation is symmetric in both directions between the nodes, i, and, j.

The Wi-Fi system is generated by using different combinations of parameters given in Table 1 and Table 2 [LCN09].

	APs	**Terminals**
Transmit power	20 dBm	20 dBm
Data rate	10 Mbps ~ 10 MHz	10 MHz
Noise figure	10 dB	13 dB
Thermal noise	-175 dBm/Hz	-175 dBm/Hz
Minimum SNR	1 dB	3 dB
Packet size	2304	2304
Maximum number of packets	400	400
Measurement bandwidth	22 MHz	22 MHz

Table 1: AP and Terminal's parameters

	AP1	**AP2**
Carrier frequency	2432 MHz	24574 MHz
System bandwidth	22 MHz	22 MHz
Sampling frequency	48/7 MHz	48/7 MHz
OFDM symbol duration	373.3	373.3
Frequency resolution	1 MHz	1 MHz
Number of samples	1600	1600

Table 2: Wi-Fi system parameters

3.2. WSN CENTRALIZED COGNITIVE RADIO (SCENARIO #1)

The implementation of demonstration scenario #1 has followed the specification of message exchanges described in deliverable D7.4 (Figure 9 and 10). The channels, messages and their scheduling have been implemented in the different modules of the system.

All nodes of the system including Fusion Centre, Secondary Network nodes and WSN nodes are based on the modified OpenAirInterface architecture adapted for the purpose of the project.

Generally speaking all protocol stack modules are implemented for Scenario #1.

3.2.1.Fusion Centre Module

The Fusion Centre module architecture is described below:

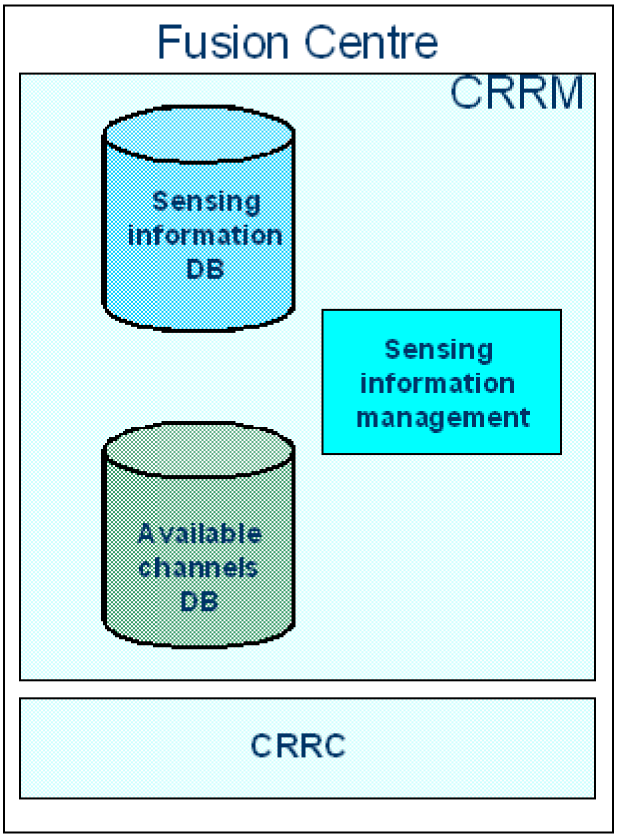

Figure 4: Fusion Centre architecture

The Fusion Centre module receives the sensing information from sensor nodes through the $CSCH_i$ and stores it in a database. It performs a fusion of the information received and decides what channels are available for secondary operation. This information is stored in another database to be conveyed by the CPCH towards the SN upon request.

The initial fusion algorithm is based on the detection of primary activity by the different sensors as follows: if a majority of the sensors detects the channel as occupied, the Fusion Centre decides that the channel is occupied.

The Fusion Centre implementation also manages the sensing process as specified, piloting the initialization, scan and monitoring.

This module is fully implemented and has been validated in the OpenAirInterface framework. With respect to the message exchanges specified in deliverable D7.4 (Figures 9, 10 and 12), the “Initiate MON” message have been removed as it was not necessary. Hence the monitoring of the channels allocated to the Secondary Network is performed by the Fusion Centre using information periodically received from sensors.

3.2.2. Sensor Network modules

The abstraction model was developed at EURECOM to emulate the sensor unit and allow the validation of the protocol stack using the emulator.

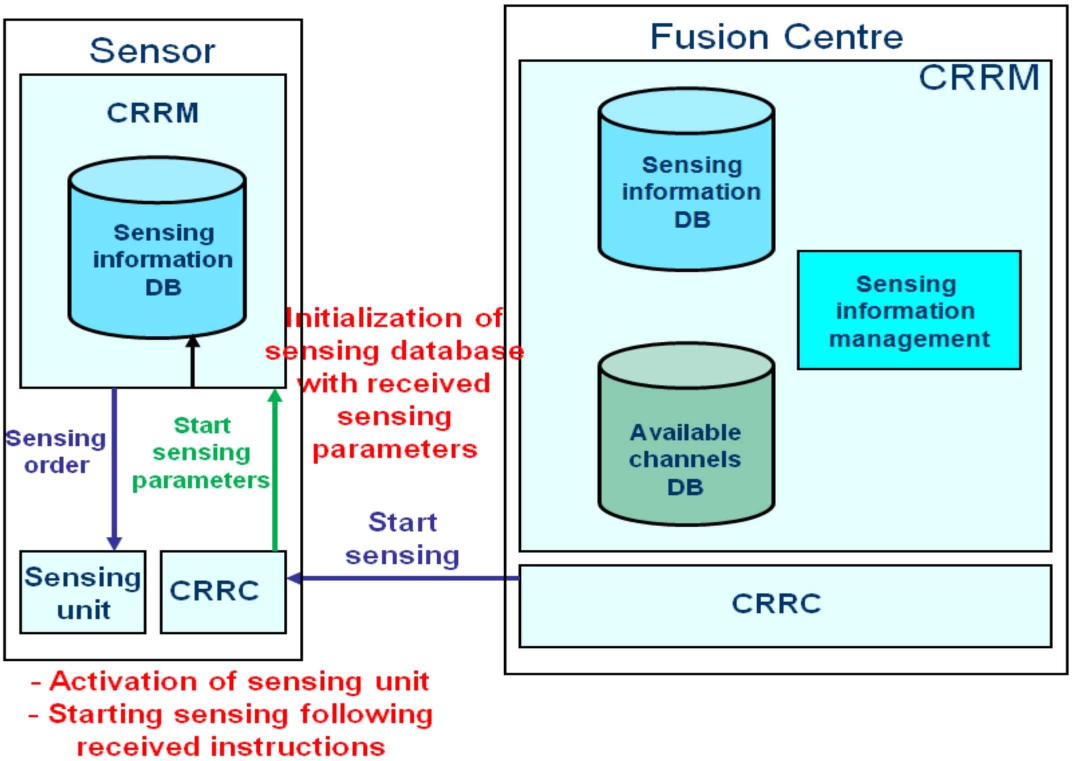

Figure 5: Sensing initialization

Figures 5, 6 and 7 describe the communication phases between the sensor node and the Fusion Centre. The first step in the sensor network module is the initialization of the sensing database with received sensing parameters to start the sensing operation. The Inputs to Sensing block are:

- Start frequency (GHz)
- Stop frequency (GHz)
- Measurement bandwidth (MHz)
- Measurement time per carrier (s)
- Number of subbands (integer)
- Overlap factor (%)
- Sampling frequency (Ms/s)
- Averaging policies
  - Long-term average window (m0) duration (samples)
  - Short-term average window (m1) duration (samples)

The Outputs of sensing unit (sufficient statistics) are:

- Ambiant noise power (dBm)
- Average signal power (dBm) over long-term period (m0),
- Maximum signal power (dBm) over short-term period (m1),
- Statistics

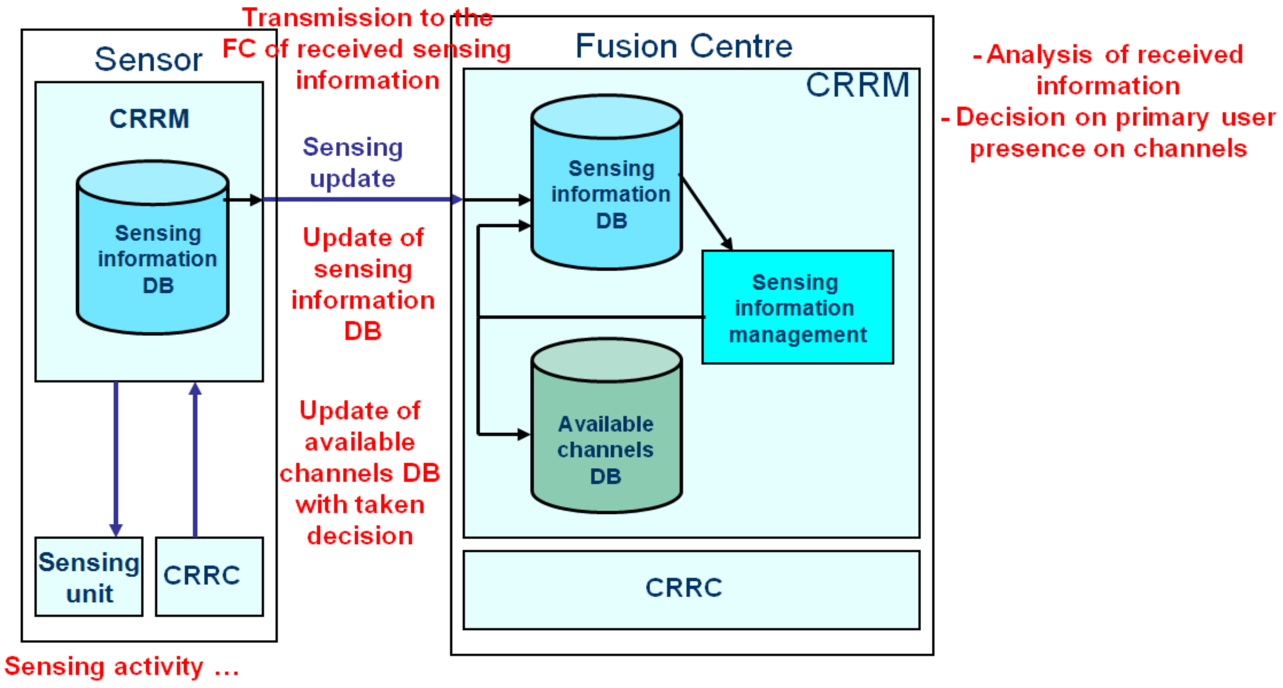

Figure 6: Sensing information update

The second step is the transmission of received sensing information's from each sensor to the Fusion Center. Then we update the sensing information Data Base and the available channels Data Base and we stop the sensing operation.

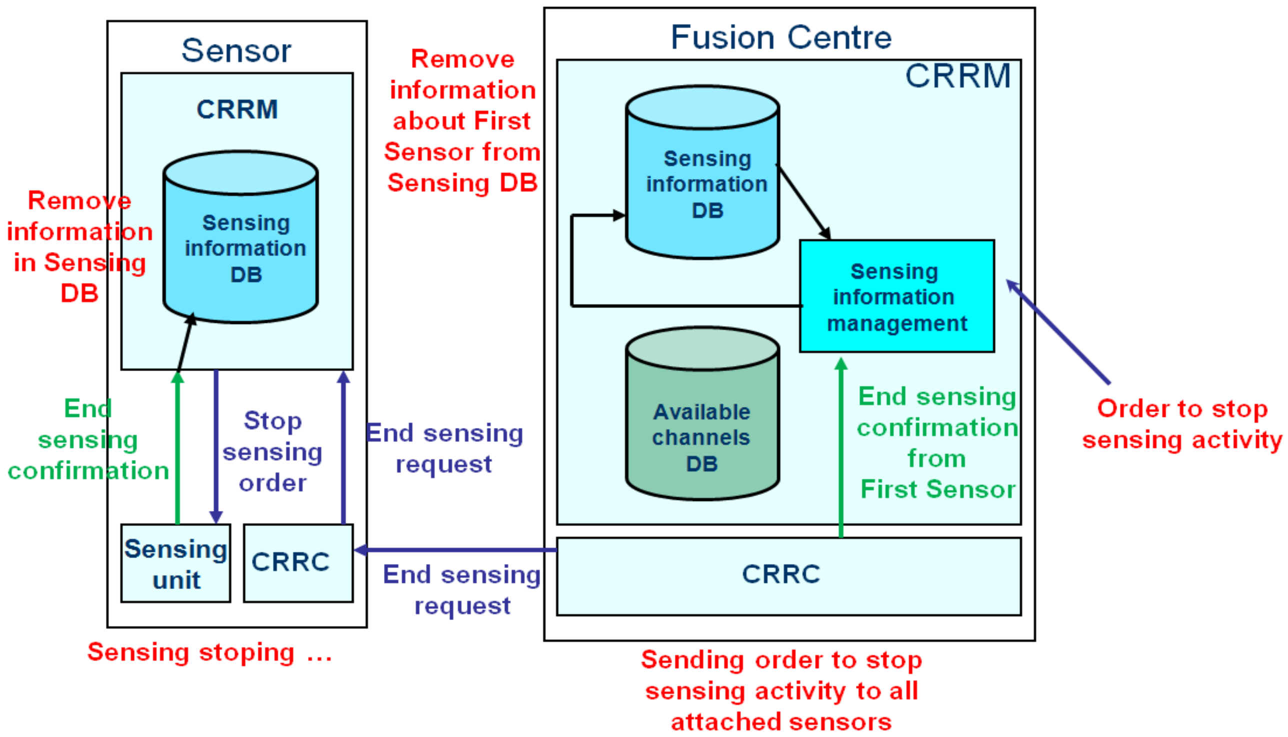

Figure 7: Stop sensing activity

3.2.3. Secondary Network modules

The Secondary Network (SN) modules are of two types: the Base Station (BTS) and the Secondary Users, attached to the BTS, forming together a cell.

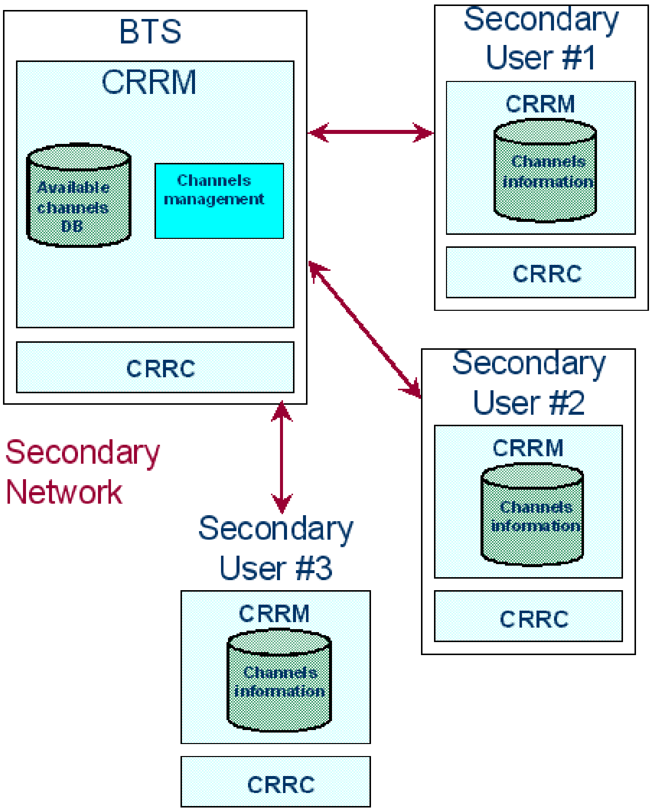

Figure 8: Secondary Network architecture

The exchange of messages between the BTS and the Fusion Centre has been implemented also on BTS side. The BTS is able to request free channels and update its database accordingly:

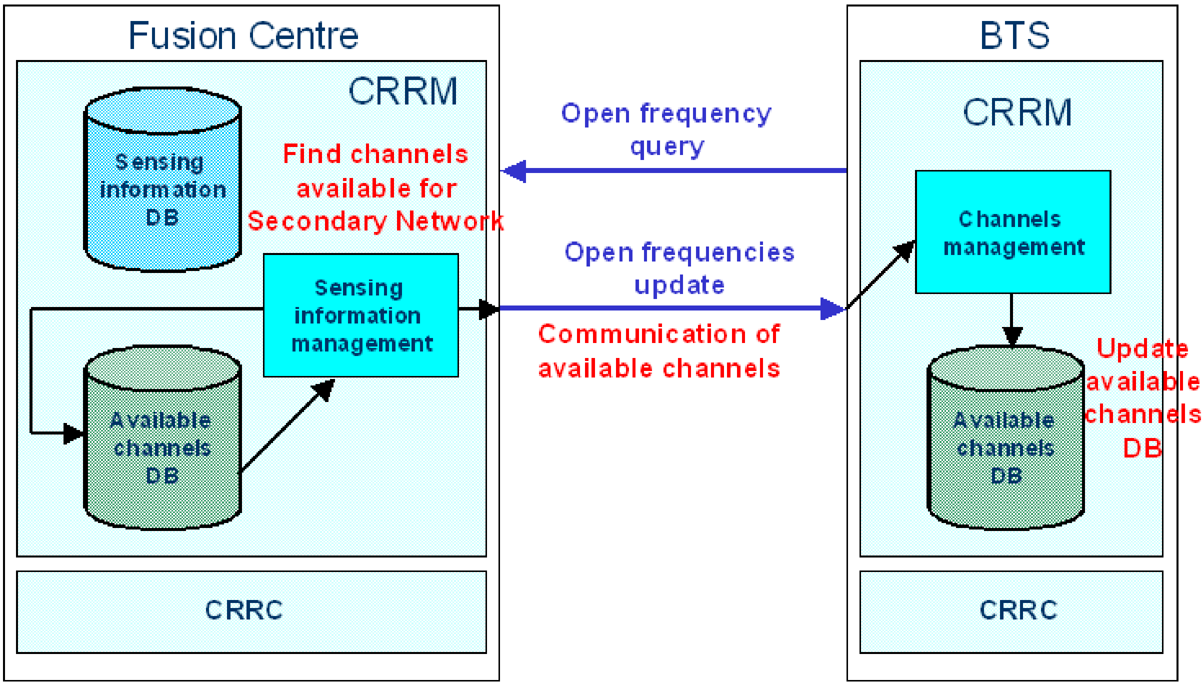

Figure 9: BTS - Fusion Centre exchange for channel request.

Then, according to expected needs of secondary users, it can select a certain number of channels for the Secondary Network. The selected channels are reported to the Fusion Centre. The procedure is represented in the following figure:

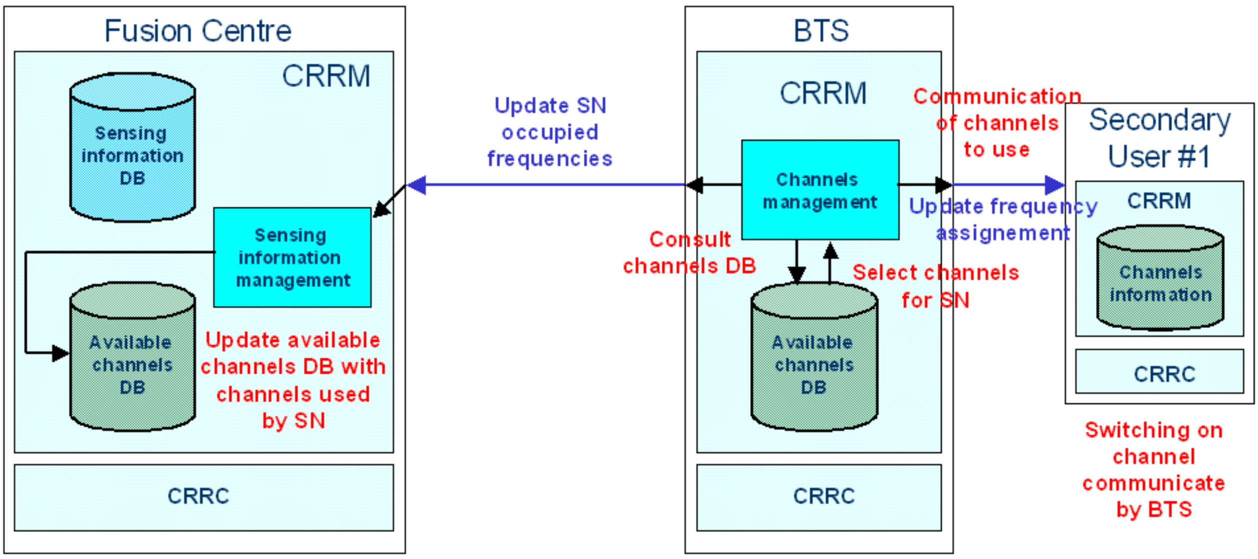

Figure 10: SN channel attribution

This module is fully implemented and has been validated in the OpenAirInterface framework. It follows the message exchanges specified in deliverable D7.4 (Figures 9,10 and 12) as depicted above.

3.3. COGNITIVE AD HOC NETWORK SCENARIO (SCENARIO#2)

The implementation of scenario #2 is almost performed. The message exchanges between the several modules of the architecture have been implemented on the dedicated channels as specified in deliverable D7.4. The procedures to allow the collaborations between clusters during sensing phase have been implemented as well.

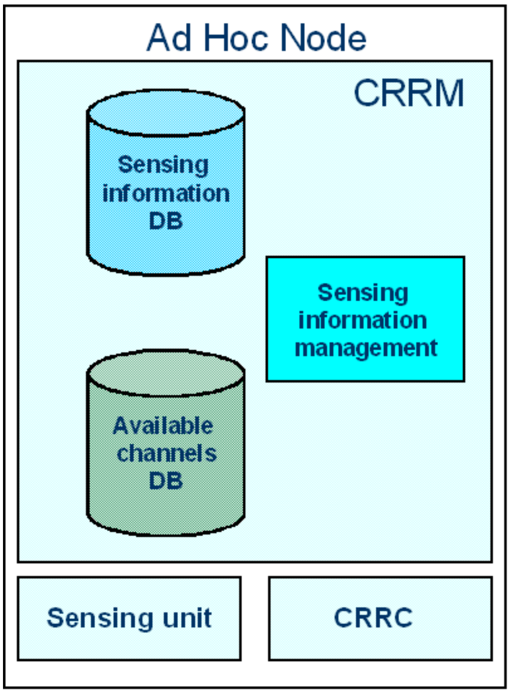

Figure 11: Ad Hoc node

The implementation of the ad hoc node (both sensor and secondary node) is mostly based on the implementation of the sensor node and of the secondary node in scenario #1. The ad hoc node includes a sensing module that provides information stored in a local sensing database and also sent to the Cluster Head. As for Secondary Users of previous scenario, a channel database is present in the ad hoc node to store available channels.

4. INTEGRATION PLAN

Step 1: WSN aided Cognitive Radio architecture validation using the emulator

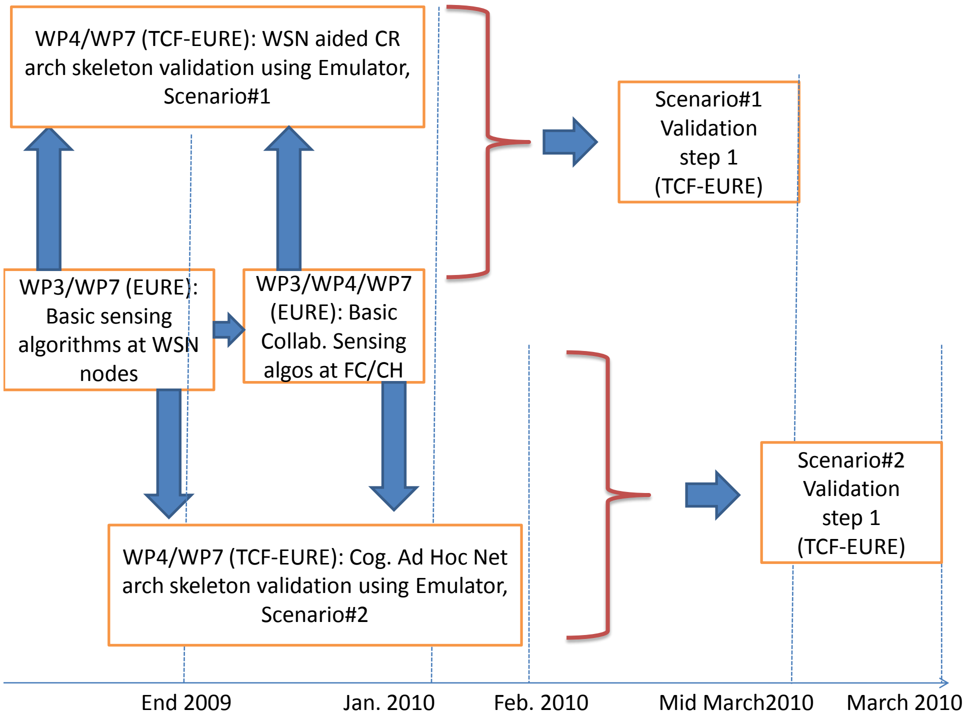

Figure 12: Validation roadmap of Step 1

- Scenario#1 was fully validated.
- Scenario#2 is under validation (will be validated by September 2010).

Step 2: Selected algorithms enabling WSN aided cognitive radio concept implementation and validation using the architecture validated in step 1.

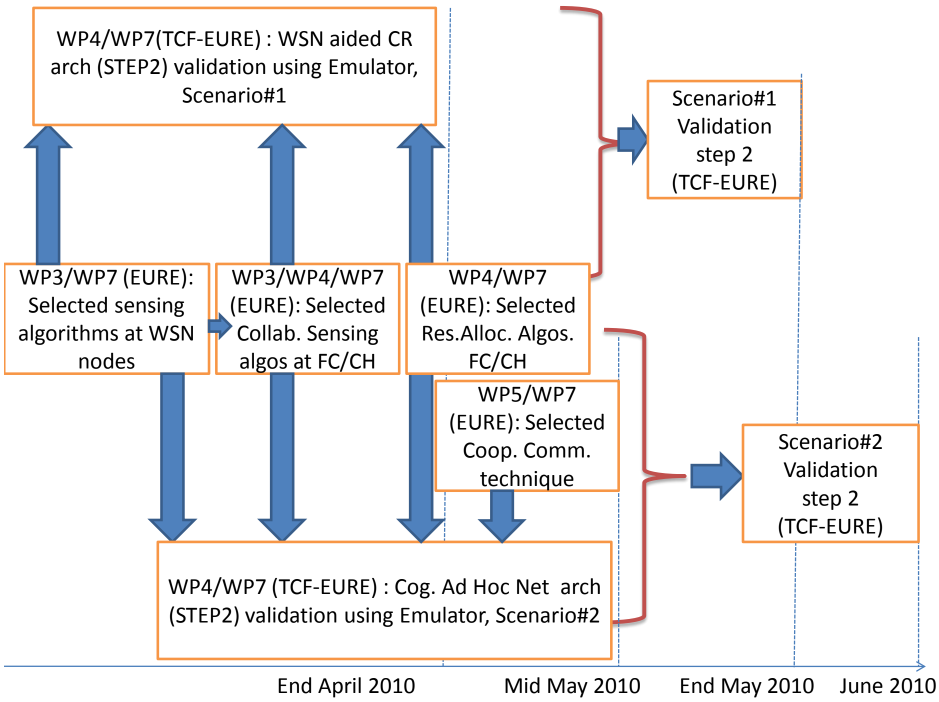

Figure 13: Validation roadmap of Step 2

- Scenario#1 was fully implemented in the OpenAirInterface framework based on emulation version [ABKK08] [KGKAB10].
- Scenario#2 is under implementation.
- The implementation of cooperative communication technique is in well progress and will be validated by September.

5. CONCLUSION

In this deliverable, we described the status on the progress of the implementation of the different modules for architecture demonstration scenario#1 and scenario#2 described in previous WP7 deliverables. We provided a summary of the two system demonstration scenarios and described the progress of the demonstration activities. We prepared a preliminary demonstration which includes the primary Wi-Fi system module, the fusion centre module, the WSN modules and the secondary network module. These modules are fully implemented and have been validated in the OpenAirInterface framework based on emulation version. This preliminary demonstration (in emulation) was performed at CrownCom 2010 conference in Cannes during 09-11 June 2010 [crowncom2010] and Future Network and Mobile Summit 2010 in Florence, June 16-18, 2010 [futurenetworksummit2010].

D7.8 will be the final report on demonstrations activities and will update this document, including results. Coming work will be dedicated to the complete validation of scenario#1 including over-the-air demonstrations. The effort dedicated to scenario#2 will mainly focus on the validation using the emulator.

6. REFERENCE

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