CORASMA project

COgnitive RAdio for dynamic Spectrum MAnagement

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Plan

- CORASMA project in a few slides
- Simulation and simulator
  - Methodology
  - Basic Waveform
  - Simulator architecture
  - Sensing
  - Radio environment modeling
  - Metrics
- Results of the project
  - Scenarios
  - Cognitive solutions
  - Some more insights about the simulator

CORASMA project in a few slides

CORASMA consortium

Partner	Country
THALES Belgium	Belgium
SUPELEC*	France
THALES Communications &Security S.A. - France – Coordinator	France
Fraunhofer FKIE*	Germany
THALES Defence & Security Systems	Germany
Karlsruhe Institute of Technology*	Germany
CNIT – University of Florence*	Italy
Selex Sistemi Integrati S.p.A.	Italy
Selex Communications	Italy
THALES Italia	Italy
ALMAMATER (University of Bologna)*	Italy
ASSECO POLAND SA*	Poland
Military University of Technology	Poland
RADMOR*	Poland
Tekever Communications Systems	Portugal
Saab AB	Sweden

*sub-contractor

7 countries

9 partners + 7 subcontractors

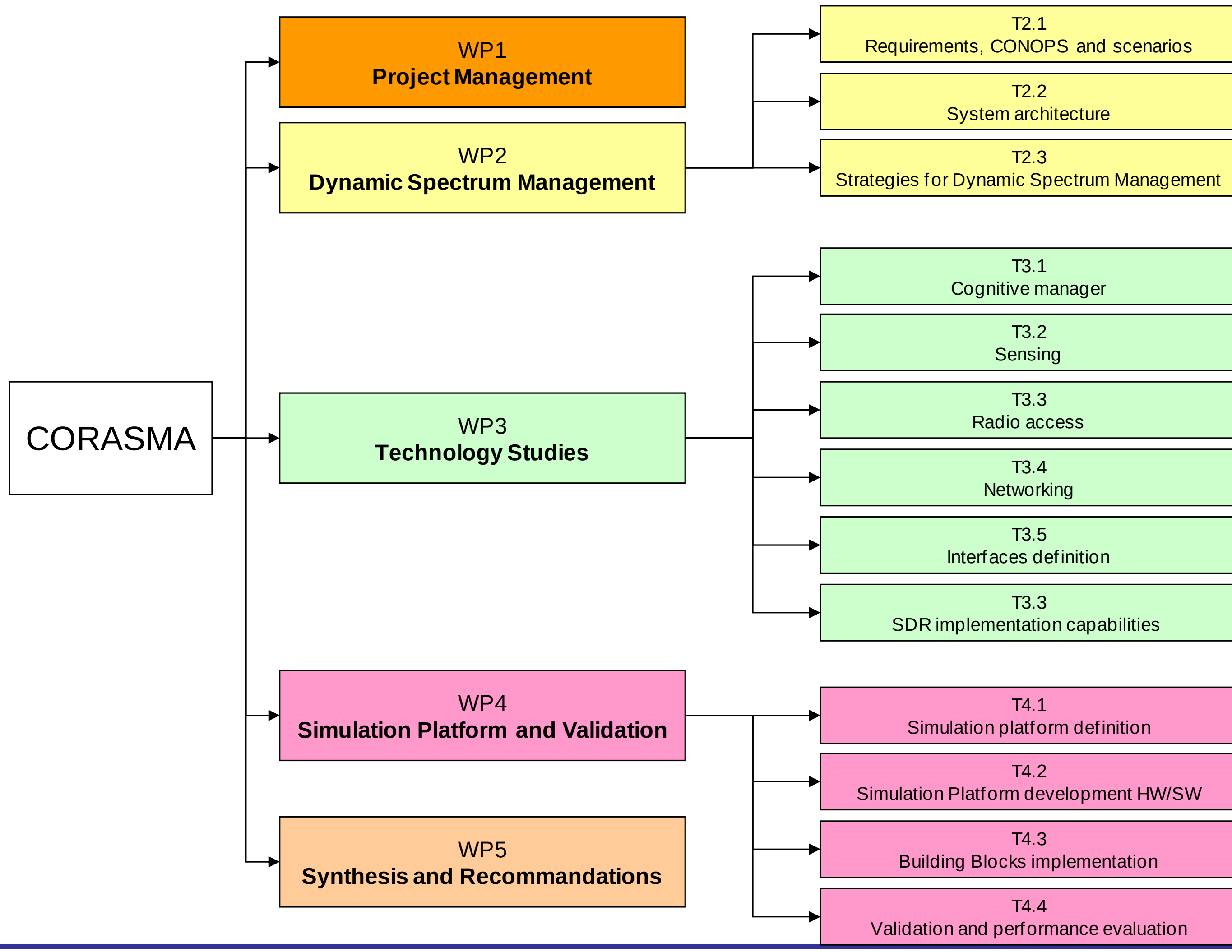
CORASMA project

- Project main objectives
  - Study the application of the Cognitive Radio concept to military radiocommunication systems
  - Achieve HiFi system simulation of a Cognitive Radio system to simulate operational military mobile tactical ad hoc networks

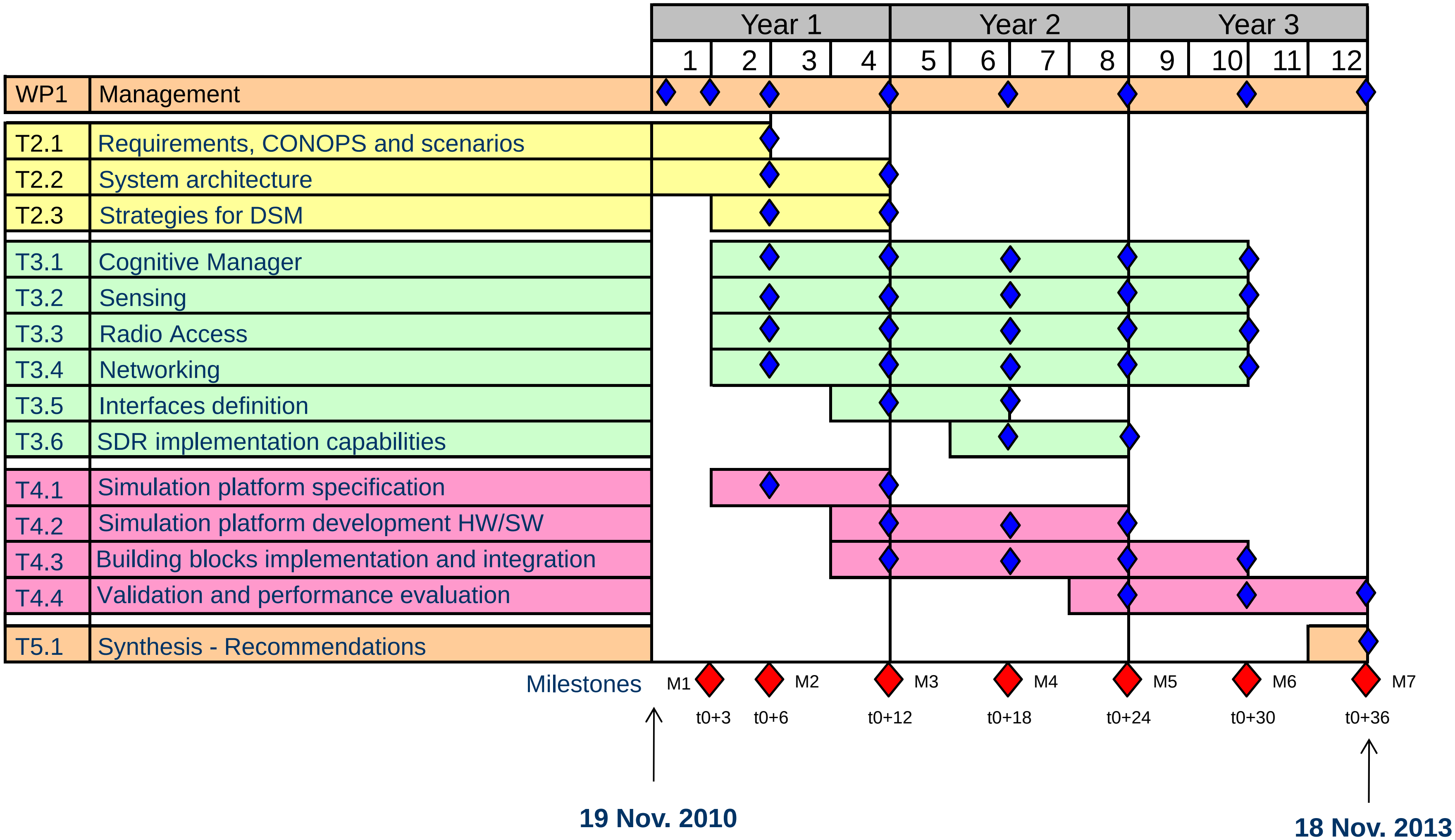
- Cognitive Radio concept is expected to bring two main capabilities
  - Dynamic spectrum allocation, allowing more flexible operations
  - Adaptive link management, improving spectral resource usage

- Cognitive Radio requires a system approach (derived from operational needs) and enabling techniques study: CORASMA intends to address jointly these challenges

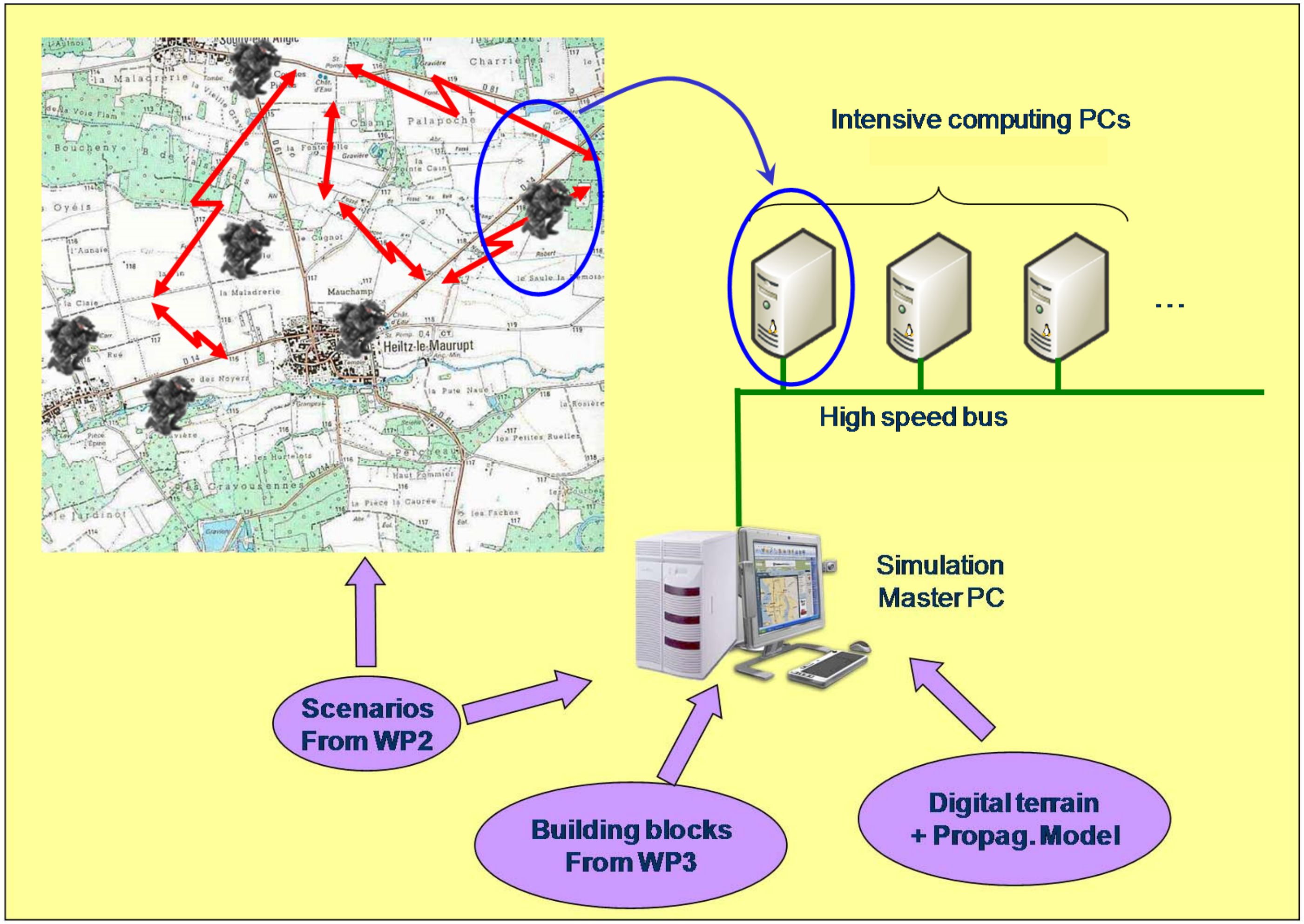
CORASMA WBS


CORASMA
WP1
Project Management
WP2
Dynamic Spectrum Management
WP3
Technology Studies
WP4
Simulation Platform and Validation
WP5
Synthesis and Recommandations
T2.1
Requirements, CONOPS and scenarios
T2.2
System architecture
T2.3
Strategies for Dynamic Spectrum Management
T3.1
Cognitive manager
T3.2
Sensing
T3.3
Radio access
T3.4
Networking
T3.5
Interfaces definition
T3.3
SDR implementation capabilities
T4.1
Simulation platform definition
T4.2
Simulation Platform development HW/SW
T4.3
Building Blocks implementation
T4.4
Validation and performance evaluation

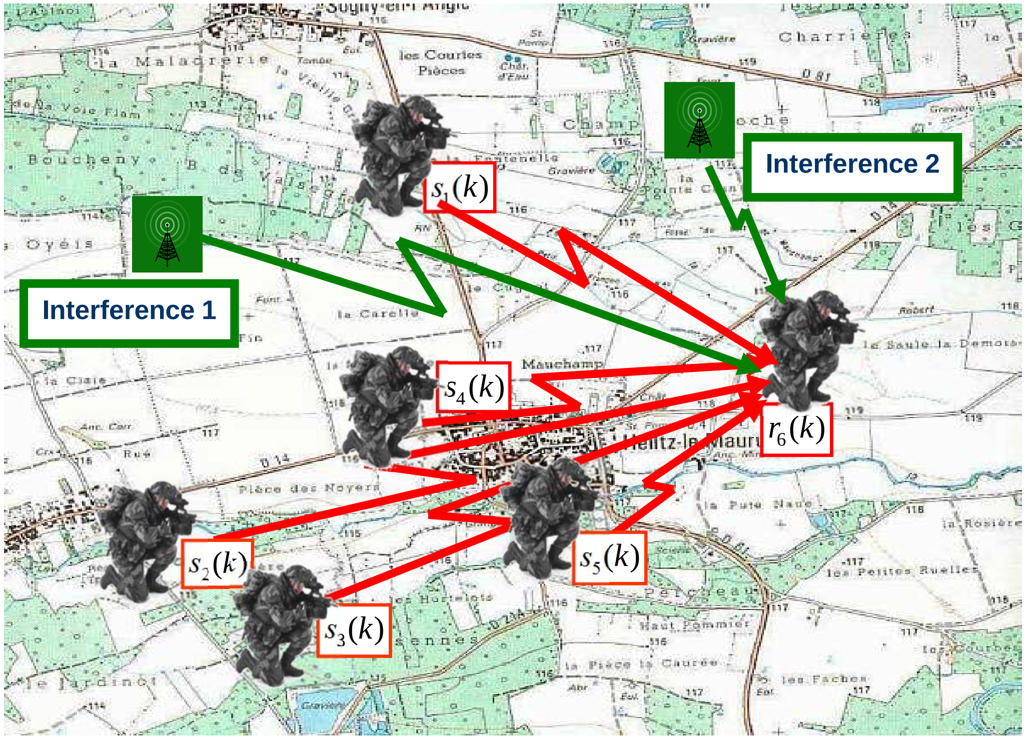
Tasks and time schedule



CORASMA HiFi Distributed Simulation Platform



IQ HiFi simulation



Principle

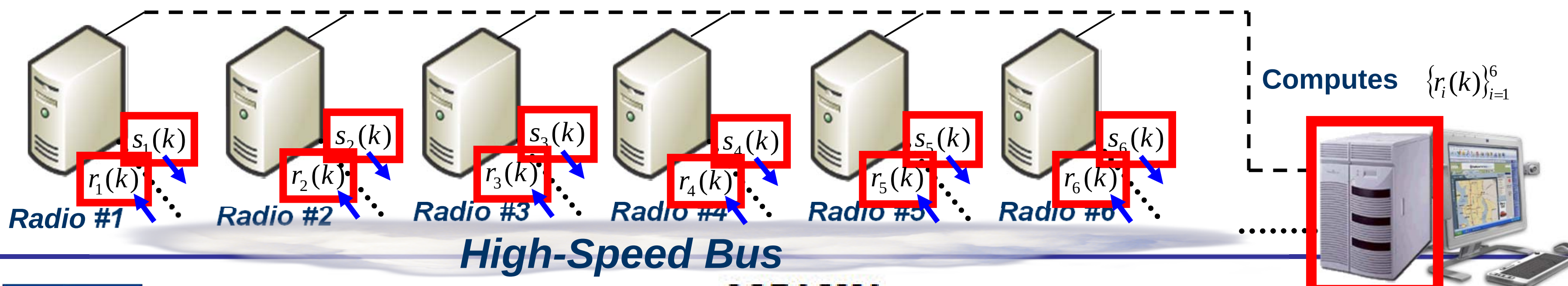
Each node *j* receives the contribution of all other nodes + interferences through propagation:

$$\boxed{r_j(k) = \sum_{\substack{i=1 \\ i \neq j}}^{6} \Gamma_{i,j}\left(s_i(k)\right) + \sum_{n=1}^{N_I} \Gamma_{n,j}\left(I_n(k)\right)}$$

other nodes — jammers

Samples are IQ baseband signals

$\Gamma_{i,j}(\bullet)$ **: propagation filtering function**



EDA

CORASMA

Methodology

Methodology

- How to assess improvements brought by cognitive solutions?

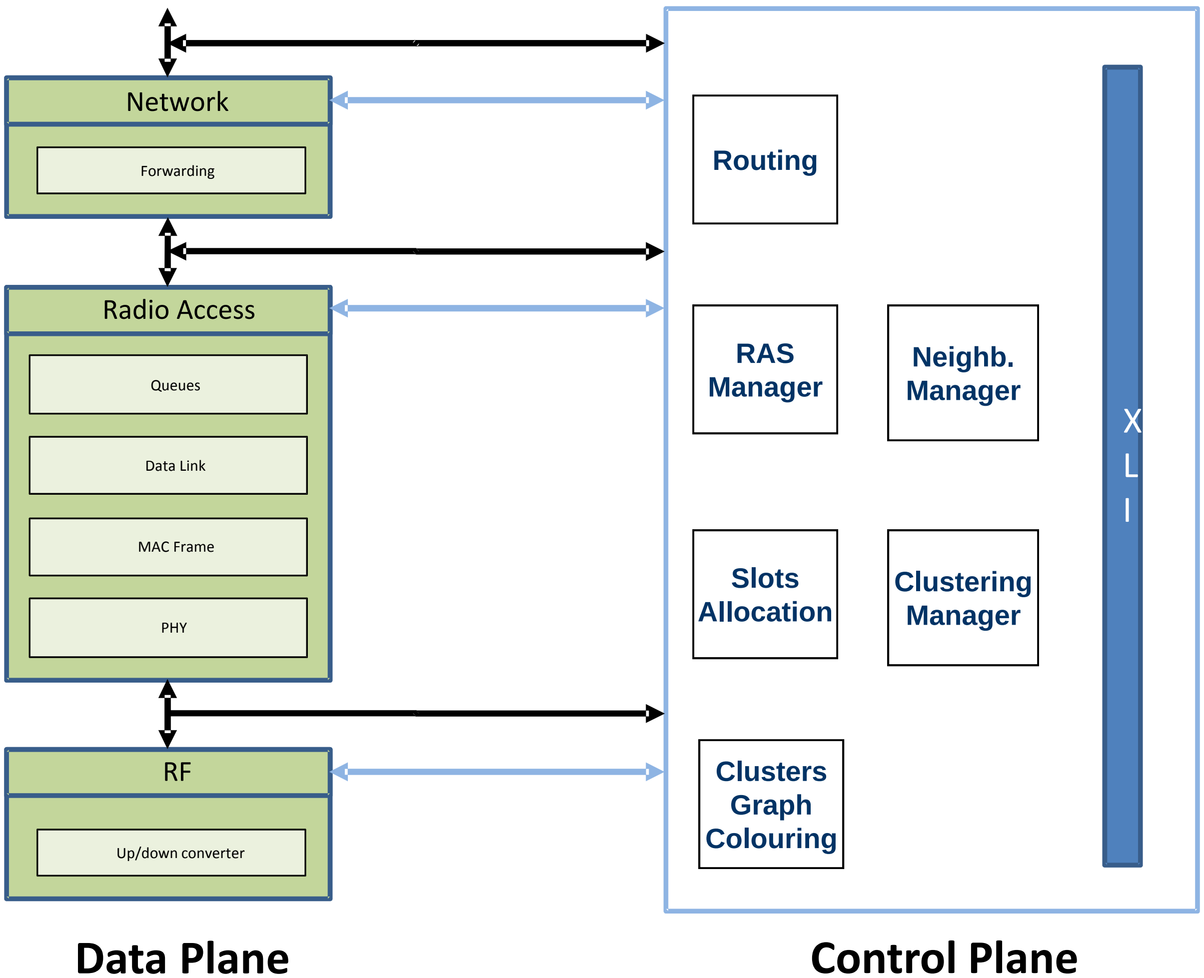
1. Fix a waveform as reference representing SotA
   → Basic Waveform (BW)

2. Study and implement cognitive solutions in the BW

3. Simulate BW and cognitive solutions in operational scenarios

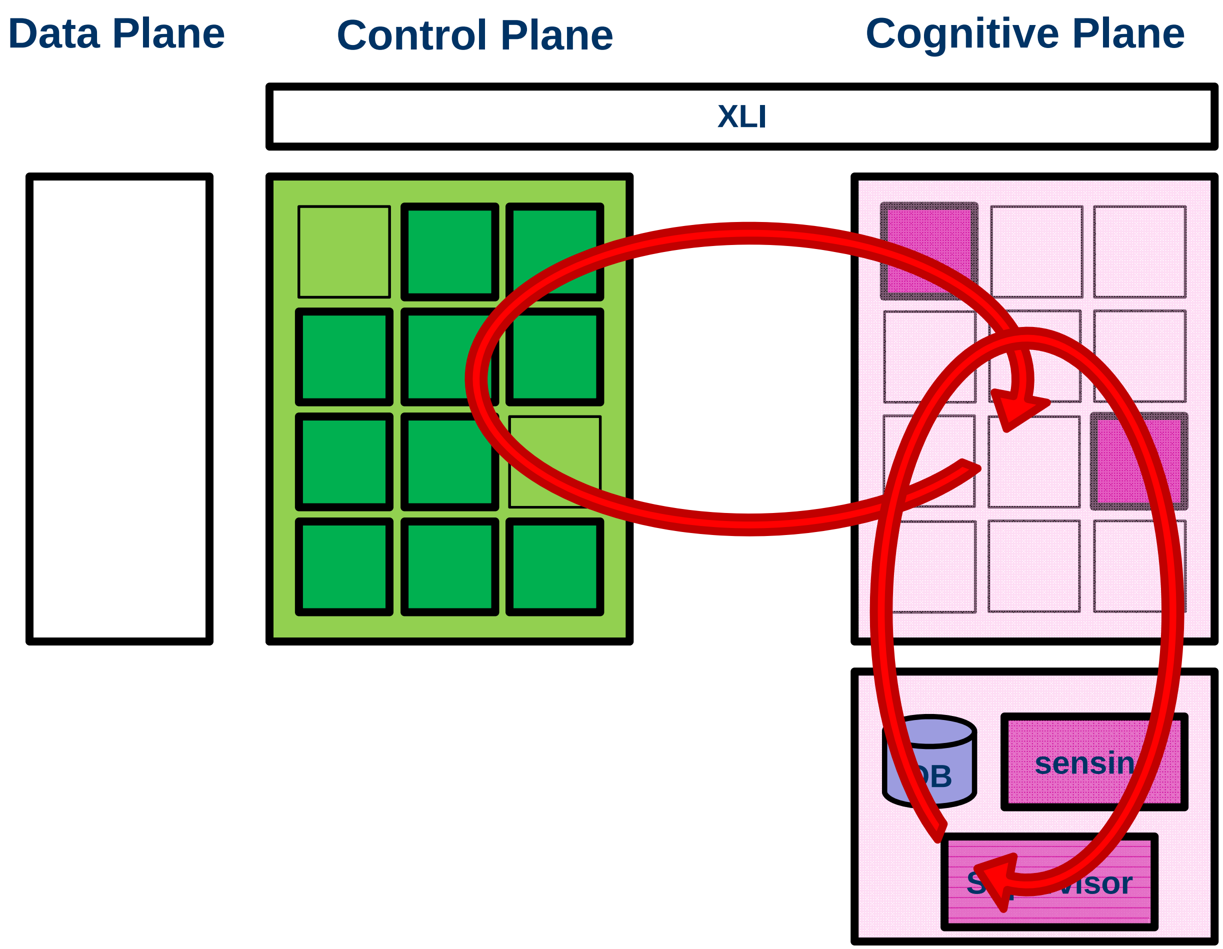
4. Assess improvements at system level

Data plane and control plane of the BW



CORASMA

Cognitive plane



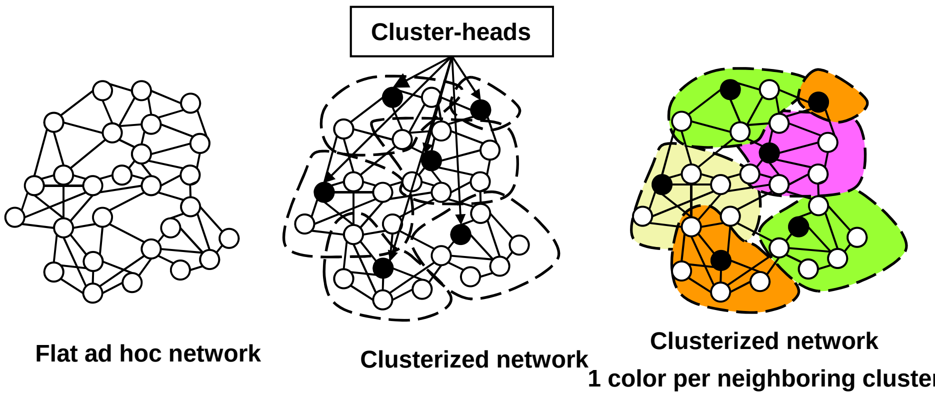
Basic Waveform

Mirror Blocks (BWMB)

Basic Waveform

Basic WF

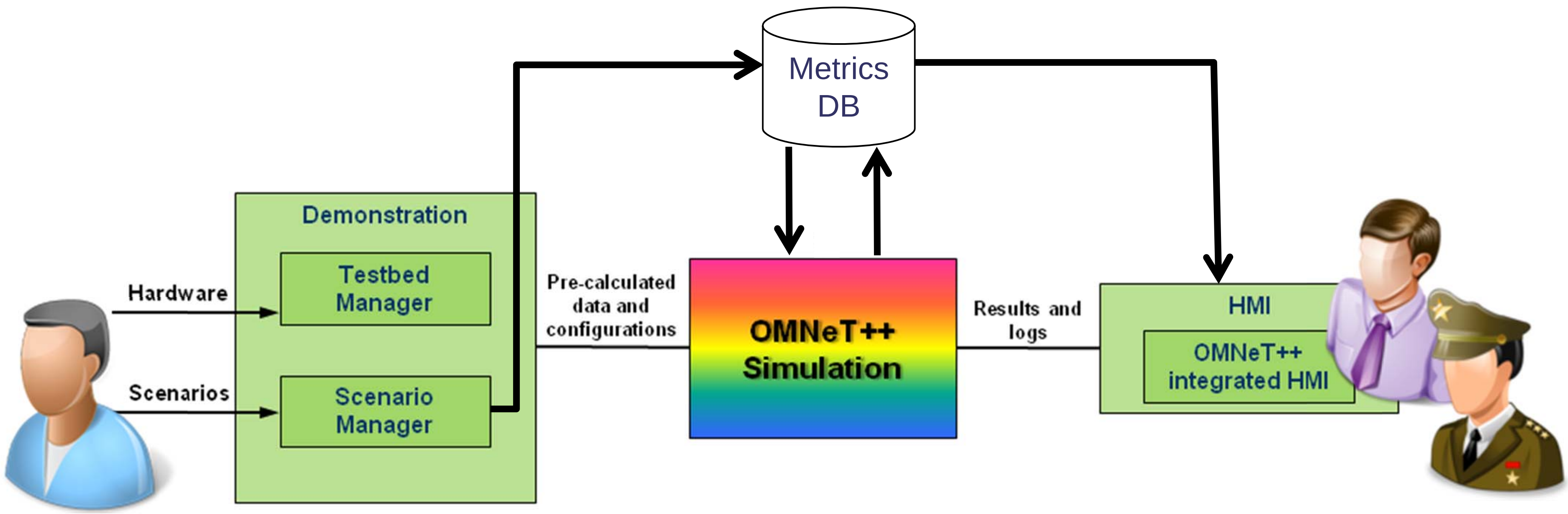
- The basic WF builds and maintains a clustered network
  - Network dynamically organized in clusters through MAC signaling messages exchange
  - Two steps allocation of resources to clusters: graph coloring and intra-cluster resource allocation



- Network layer
  - OLSR tuned to cluster structure
- MAC
  - TDMA/SC-FDMA (multiple access)
  - RRM performs Adaptive Modulation and Coding
- PHY
  - Turbo code
  - SC-FDE / SC-FDMA

Simulator architecture

Simulator architecture



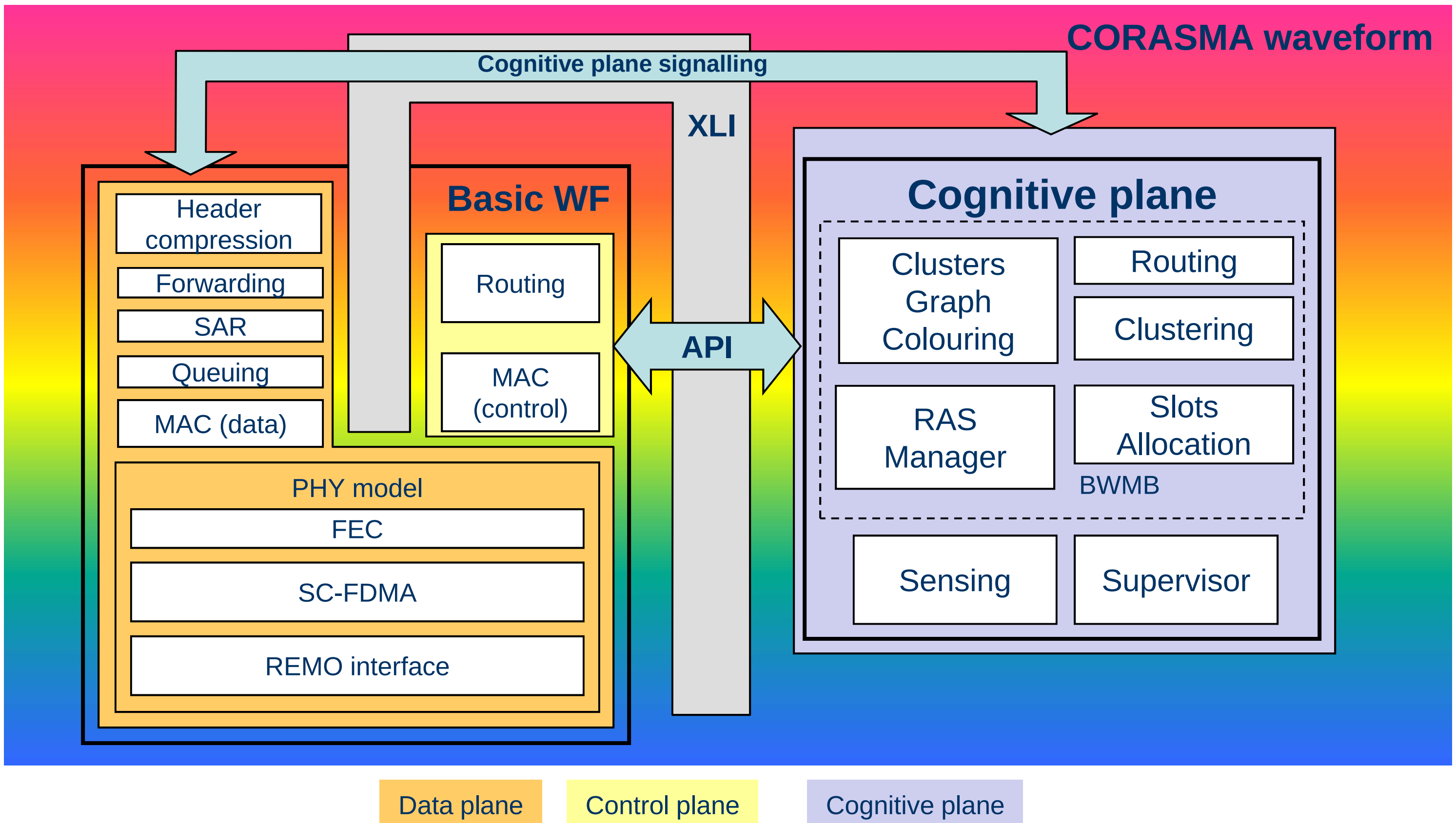
platforms' components designed to be as independent as possible from the CORASMA simulation, **these are not OMNeT++ models**.

Administration user

Technical user

Operational user

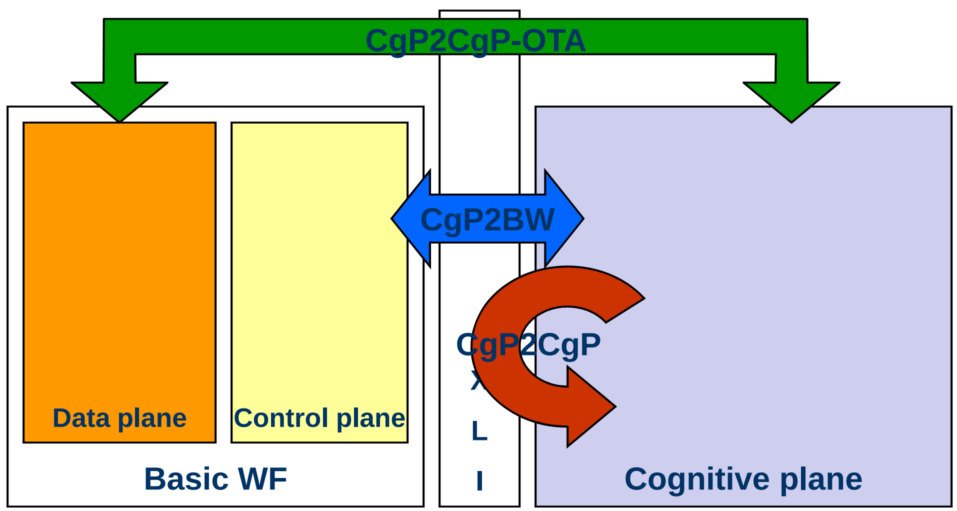
WF model overview



WF model overview: cognitive plane interfaces

- Cognitive Plane to Cognitive Plane interface
  - Local to a node: CgP2CgP
  - Over the air between different nodes: CgP2CgP-OTA

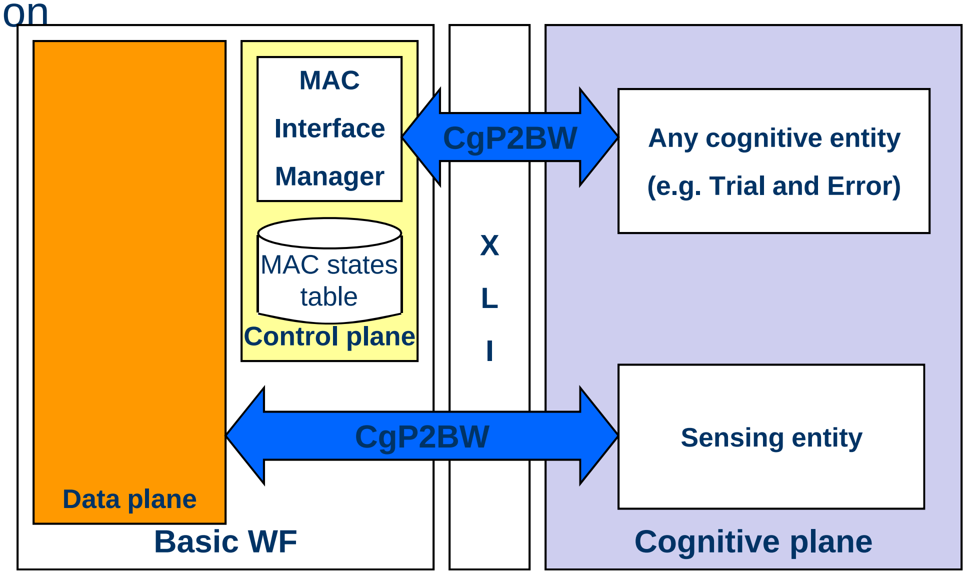
- Cognitive Plane to basic WF interface : CgP2BW



CgP2BW interface

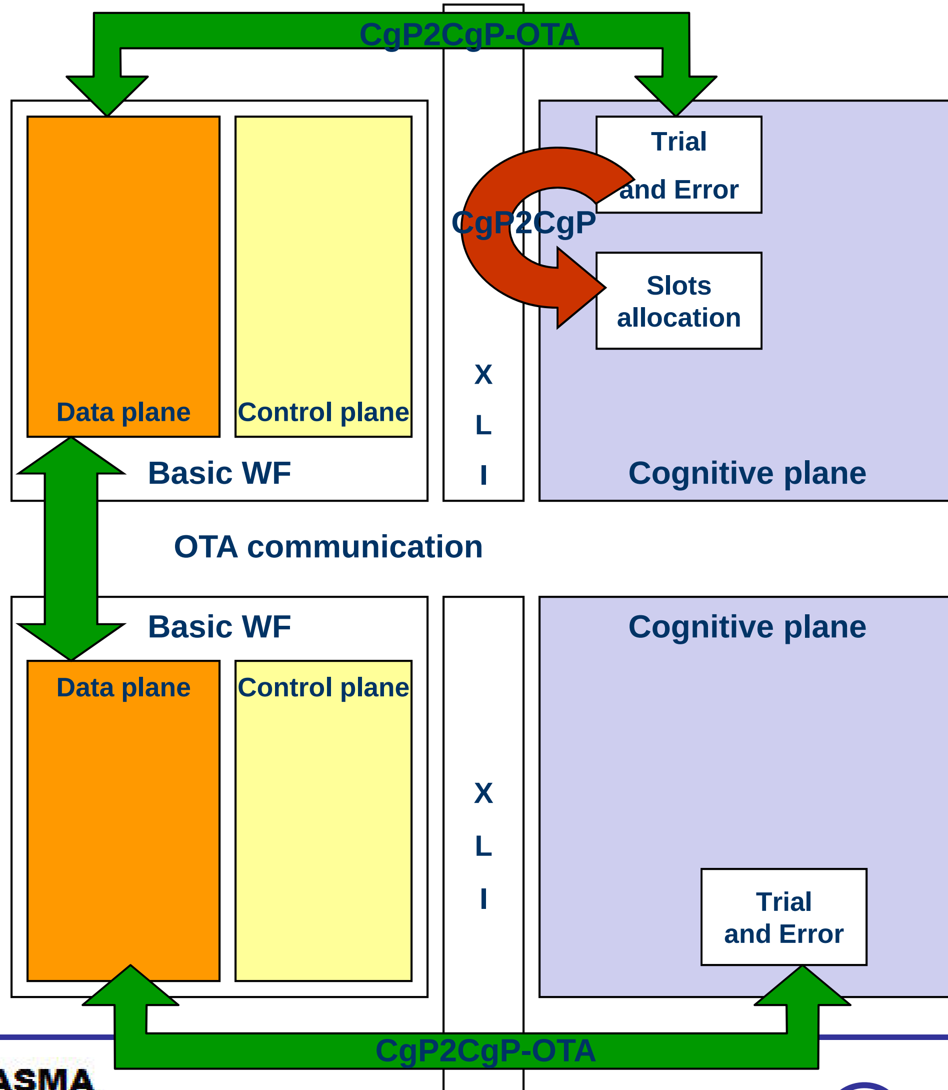
- Signaling exchange between cognitive entities and basic WF on a single node

- Examples
  - TCS cognitive solution needs to know if local node is CH and also uses reception statistics provided by the MAC layer
  - Sensing entity need to get I/Q samples from physical later to perform sensing operation



CgP2CgP-OTA and CgP2CgP interfaces

- CgP2CgP-OTA
  - Signaling exchange between cognitive entities on different nodes
  - Use of “cognitive stub” module
  - Through basic WF data plane
  - Example: within a cluster TCS graph coloring cognitive entities need to transmit feedback information to the cluster head node
- CgP2CgP
  - Local signaling exchange between cognitive entities
  - Example: maximum power information from TCS graph coloring cognitive solution to TCS cognitive slots allocation entity



Sensing

Challenges

- Sensing is embedded inside the waveform
  - Sensing uses radio communication equipment
  - Radio resource is shared between communications and sensing
  - Selection of signal processing algorithms

- The sensing block provides sensing results upon request from cognitive blocks (sensing clients)

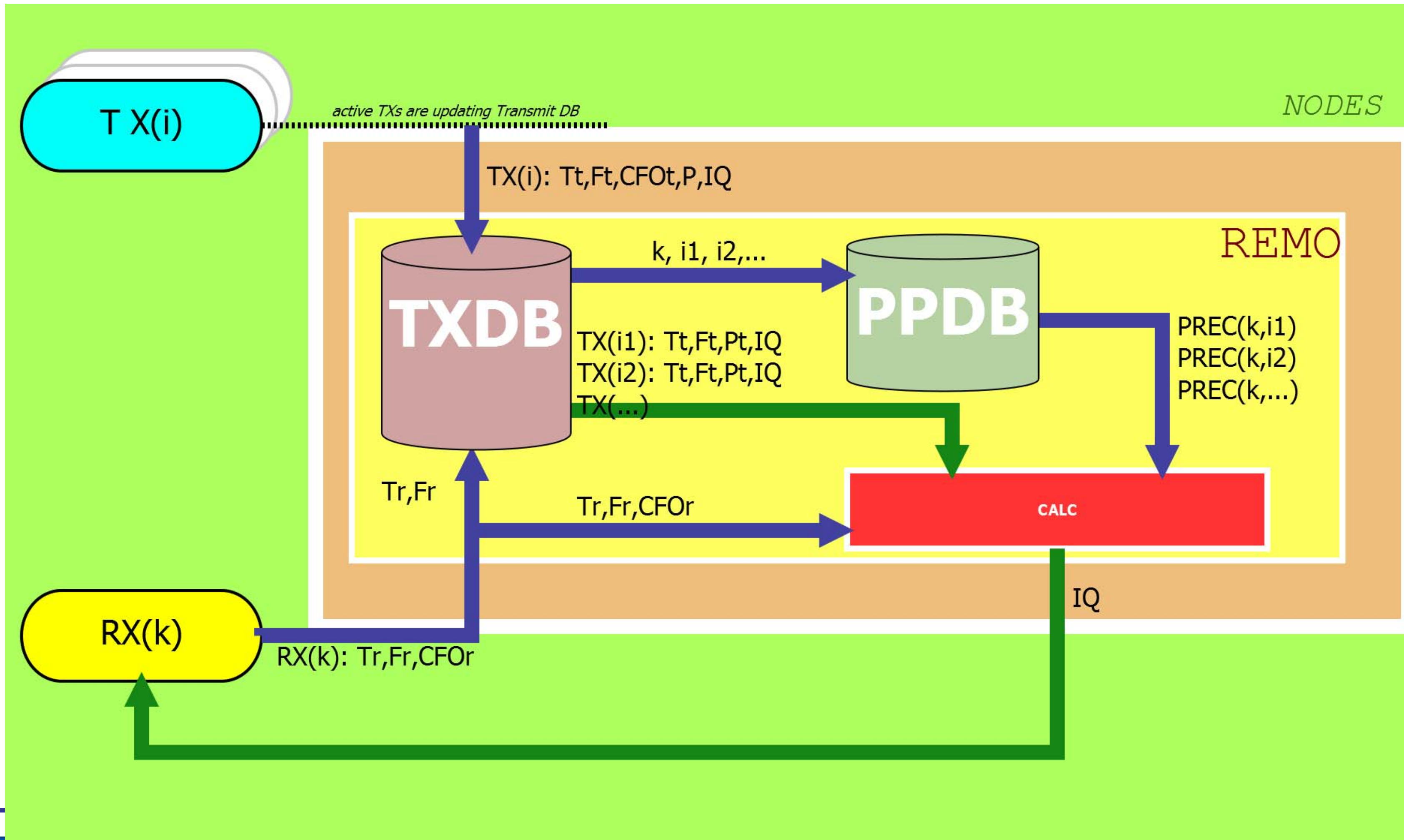
- Study implementation inside the waveform concurrently with the communications
  - Elaborate resource allocation to determine dynamically specific slots for sensing taking into account sensing and communications demands
  - Elaborate protocols to transfer sensing information between nodes using signaling and data capabilities of the waveform

Radio environment modeling

REMO: Radio Environment Model

- Main Characteristics
  - Large Scale Modelling
    - LoS/NLoS – distinction
    - Path profile (incl. buildings and terrain)
    - ITM
    - ITU.R P.1411
  - Small Scale Modelling
    - LoS/NLoS
    - 6 path (tapped delay line)
    - Doppler shift
    - Spatial correlation of the model

REMO - Architecture



Metrics

Metrics – general

- Layer-specific metrics
  - PHY/MAC/NETWORK → Detailed lower layers metrics
  - CM → Cognitive plane specific metrics
  - APPLICATION → Mission oriented metrics
- Metrics category
  - Global
  - s2d (source to destination)
  - Node
  - Link
- Metrics visualization with results display tool
  - Standard 2D graphs
  - Dedicated tables for global mission oriented metrics

Visualization of global mission oriented metrics

Global statistic	Basic Waveform	Cognitive Waveform
Utility functions summary		
Global utility function [%]	45%	86%
Global RT services utility function [%]	40%	70%
Global NRT services utility function [%]	78%	90%
Service summary		
General		
Percentage of services success [%]	55%	90%
NRT services		
VoIP: Attempts/Success (% of success)	27/20 (74%)	27/26 (96%)
VioIP: Attempts/Success (% of success)	5/0 (0%)	5/4 (96%)
PTT: Attempts/Success (% of success)	100/78 (70%)	100/98 (98%)
RT services		
C2m: Sent/Success (% of success)	27/20 (67%)	27/26 (95%)
BFT: Sent/Success (% of success)	140/130 (77%)	140/140 (100%)
Email: Sent/Success (% of success)	10/4 (44%)	10/9 (96%)
Alerts: Sent/Success (% of success)	16/6 (40%)	16/14 (90%)
Chats: Sent/Success (% of success)	10/6 (60%)	10/10 (100%)

Scenarios

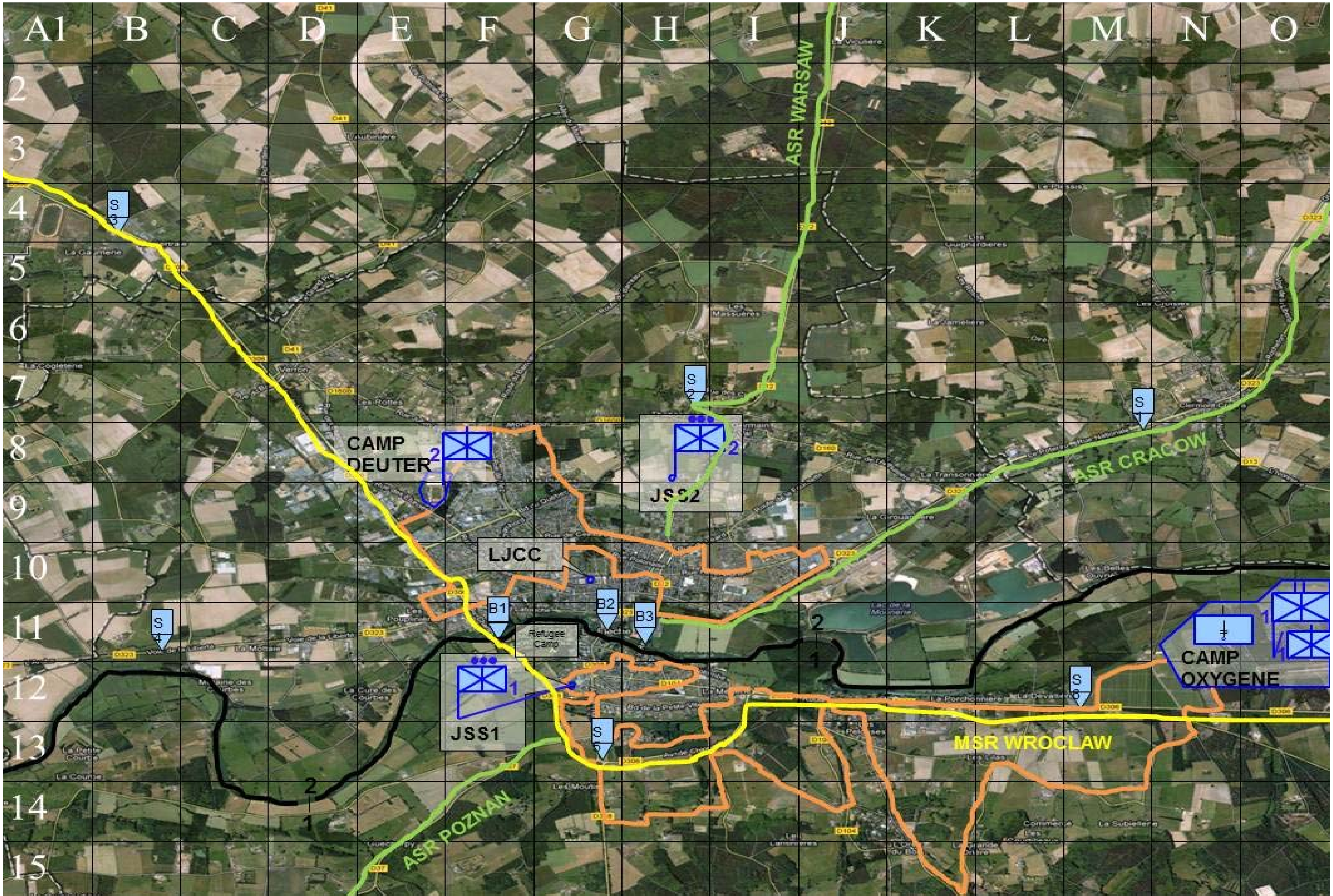
Scenario definition

- Two operational scenarios
  - Convoy attacked in La Fleche (France)
  - Base camp

- Based on hypothetical peace keeping mission and are created to simulate capabilities and functionality of a cognitive radio network
  - Done by MUT (Poland) with the help of military operational people

- Digital terrain provided by DGA-MI (DTED France)

- Above ground available on internet
  - In shapefile format
  - Around La Flèche city (10 km x 10 km)



A1 B C D E F G H I J K L M N O
2 3 4 5 6 7 8 9 10 11 12 13 14 15
ASR WARSAW
ASR CRACOW
ASR POZNAN
MSR WROCLAW
CAMP DEUTER
JSS2
JSS1
LJCC
Refugee Camp
CAMP OXYGENE
B1
B2
B3

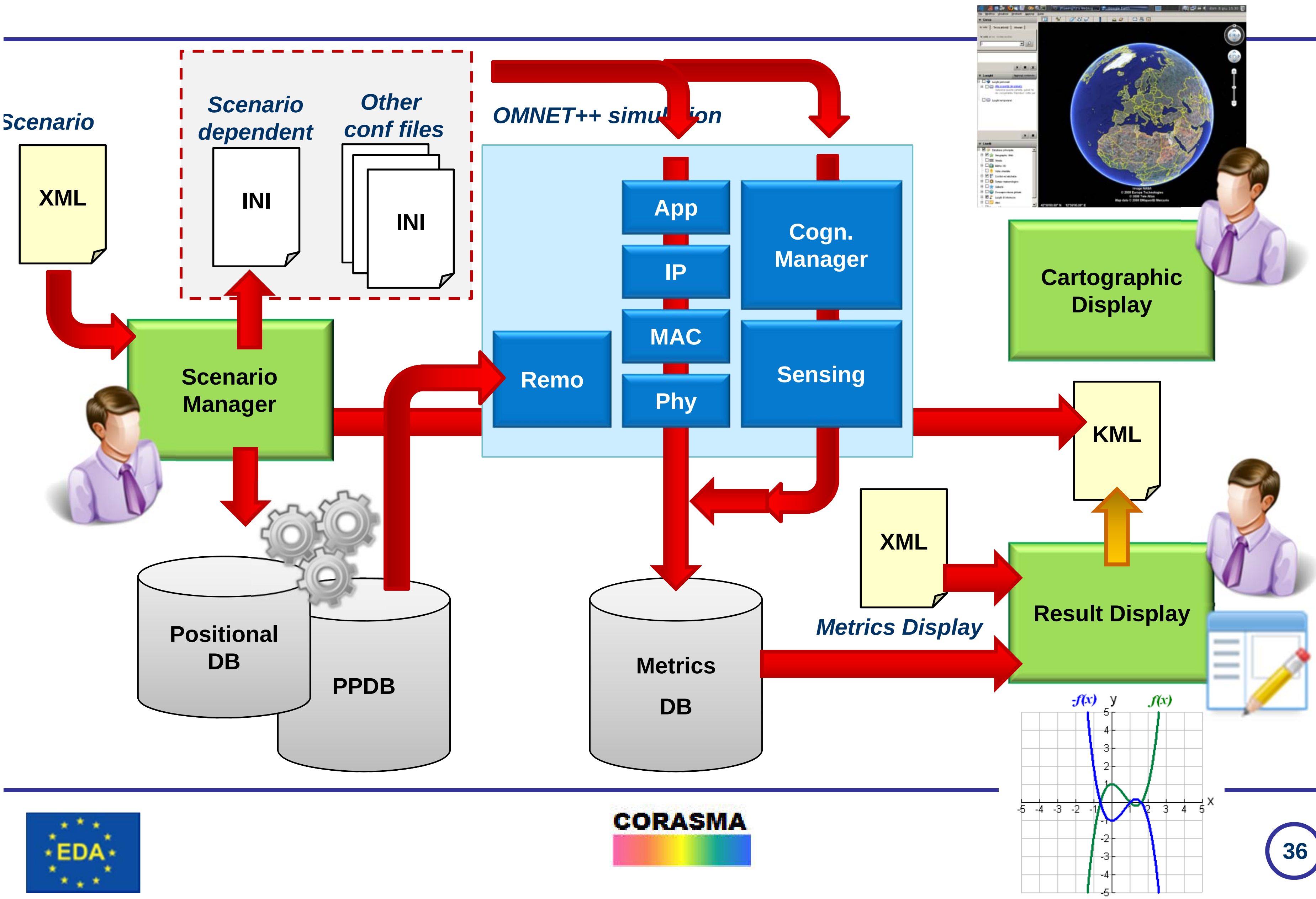
Cognitive solutions

Cognitive solutions Summary

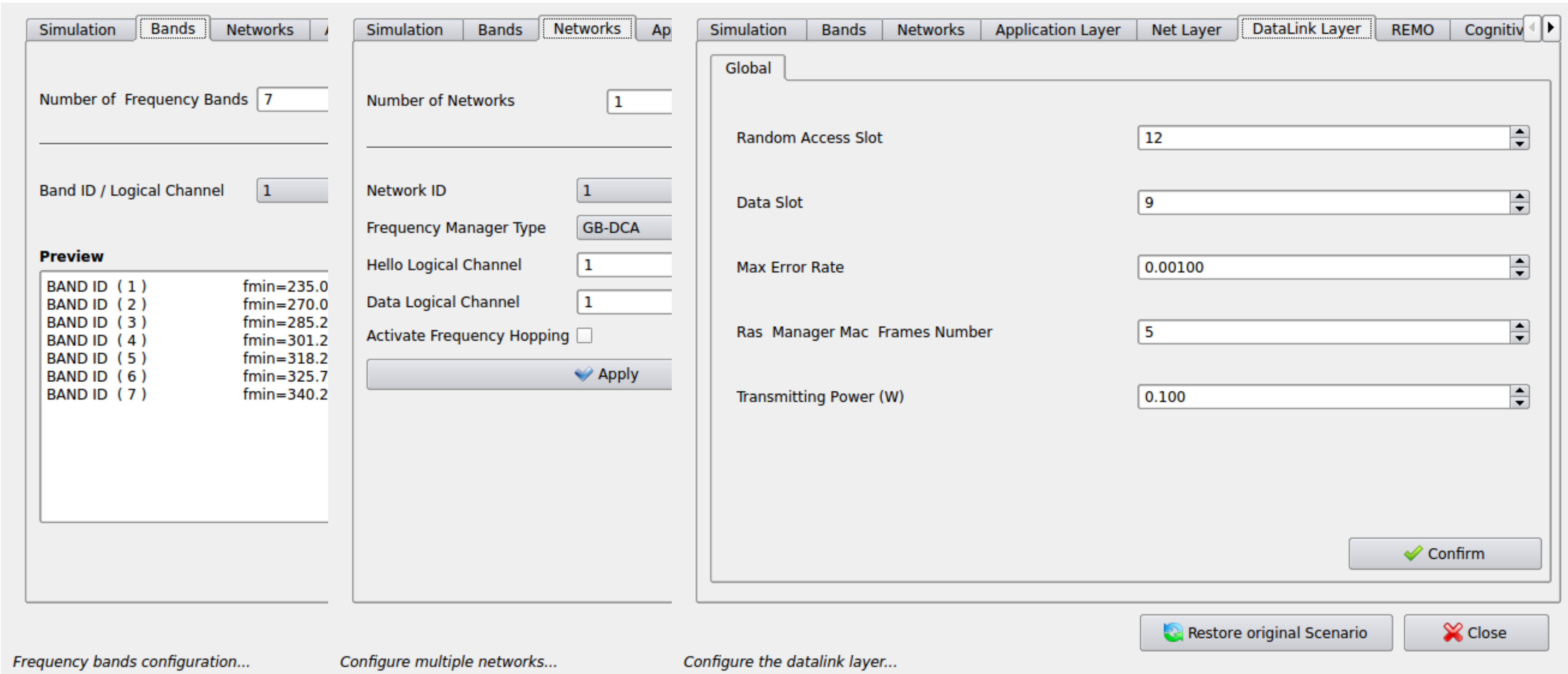
	Slot allocation	Cluster Graph coloring	RAS manager	Routing	Clustering	Header Compres sion
MUT		X			X	
Saab		X				X
SES-G		X				
TBE	X	X				
TCS		X				
TDS						

Some more insights from the simulator

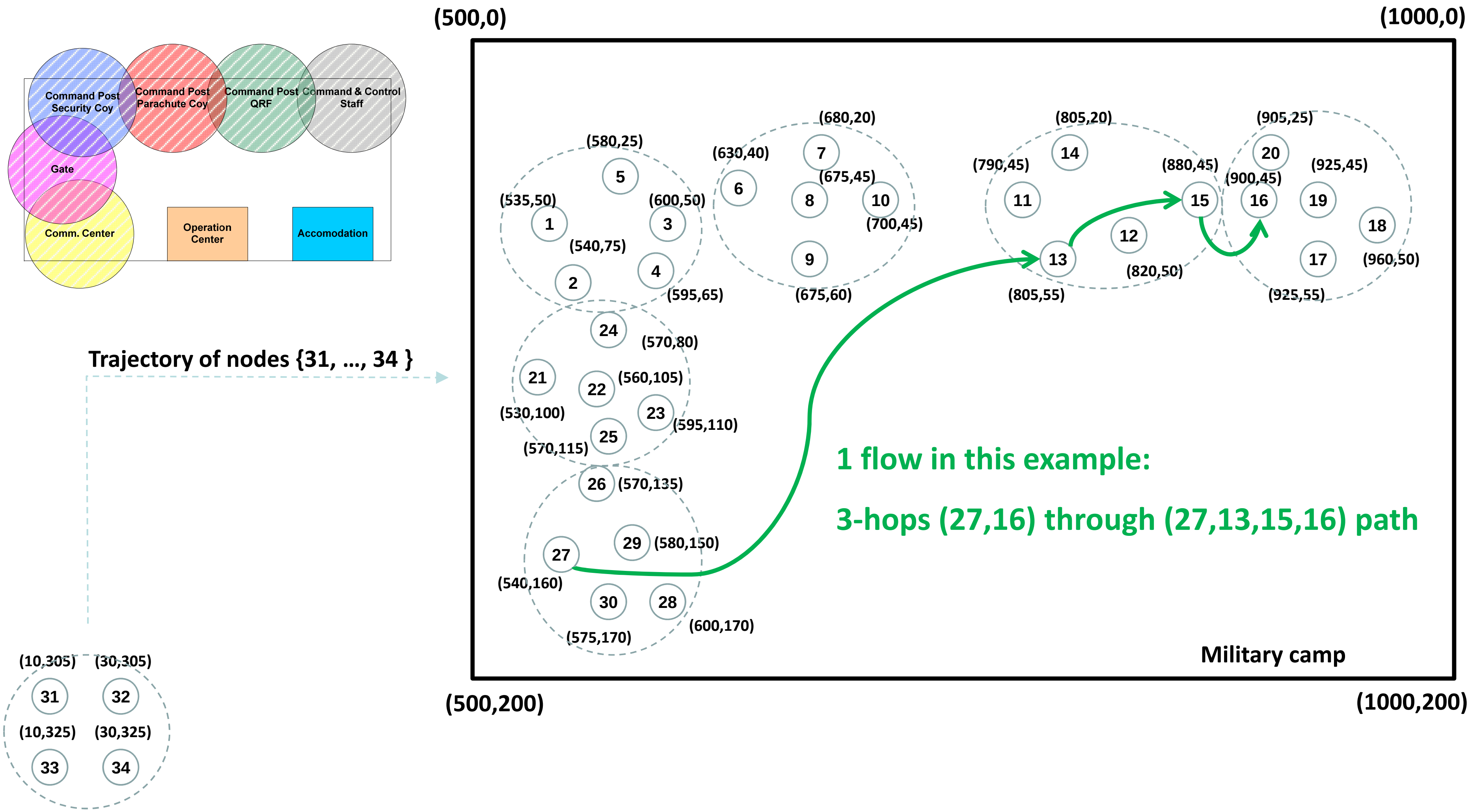
Simulation workflow



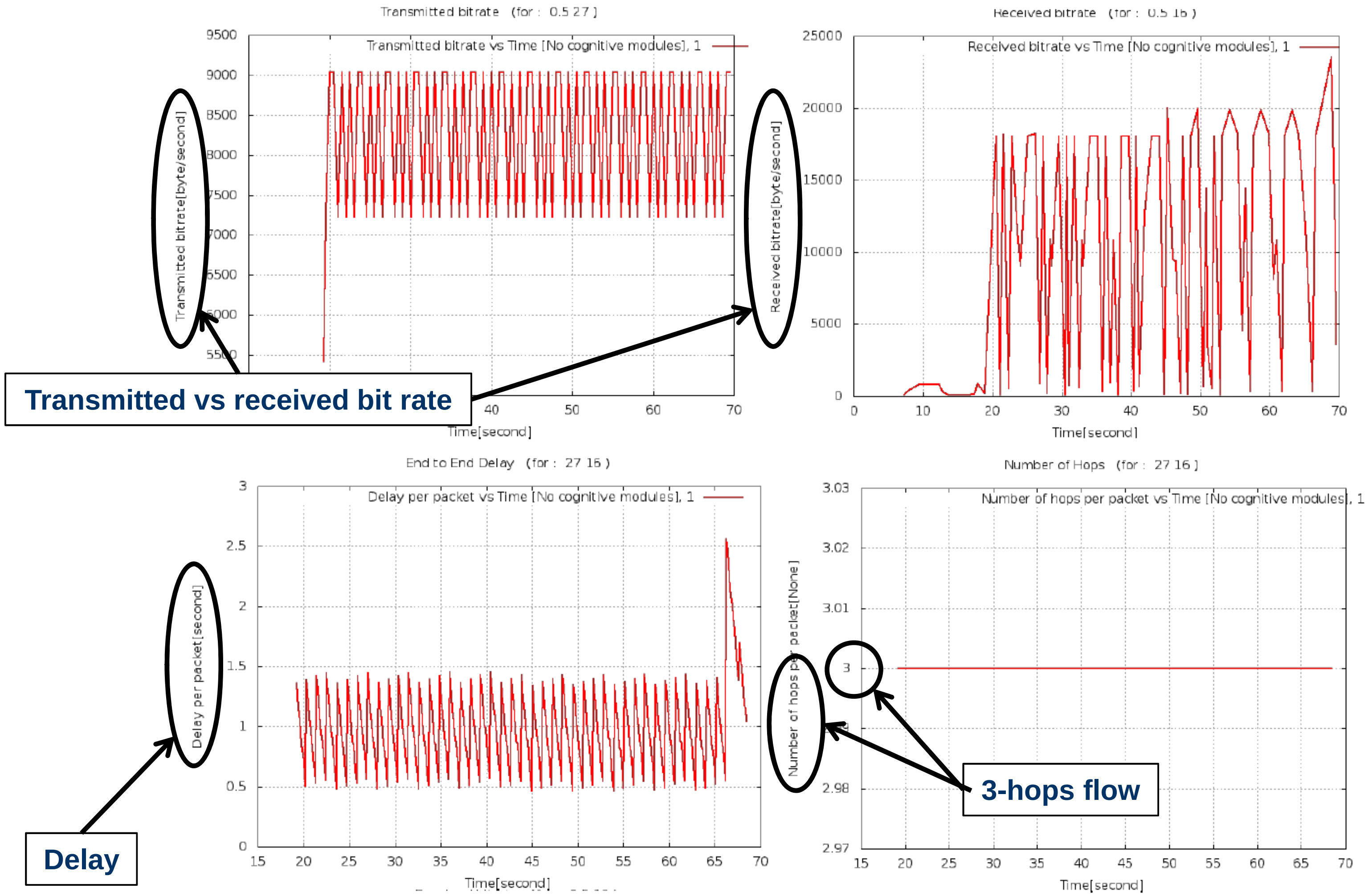
Scenario manager screenshots



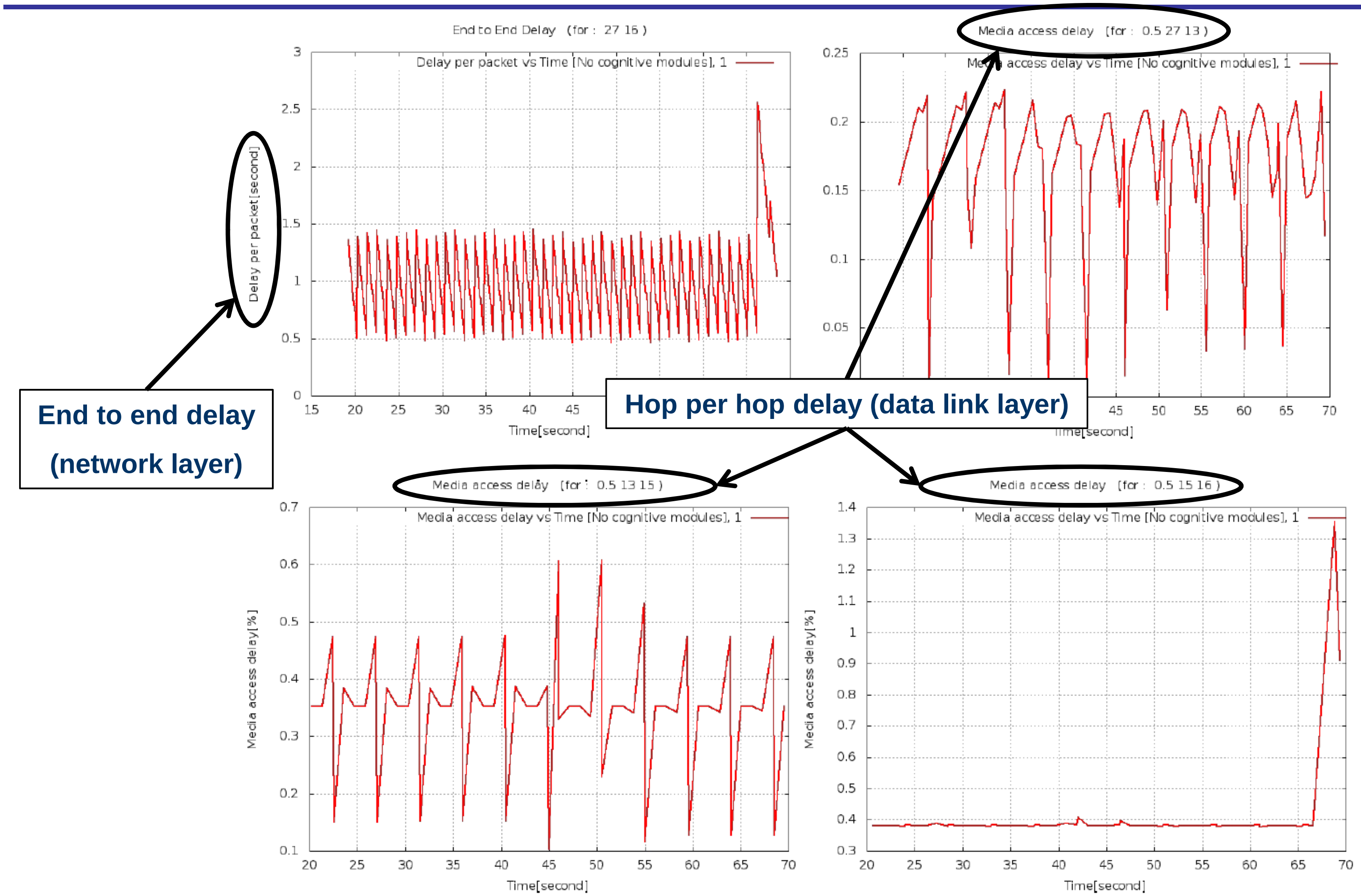
Scenario example (base camps)



Results display screenshots (3-hops flow)



Results display screenshots (3-hops flow)



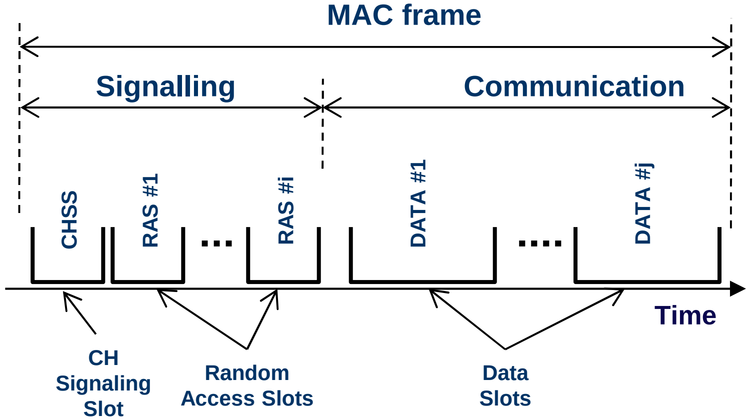
Any question ?

POC: christophe.le_martret@thalesgroup.com

Backup slides

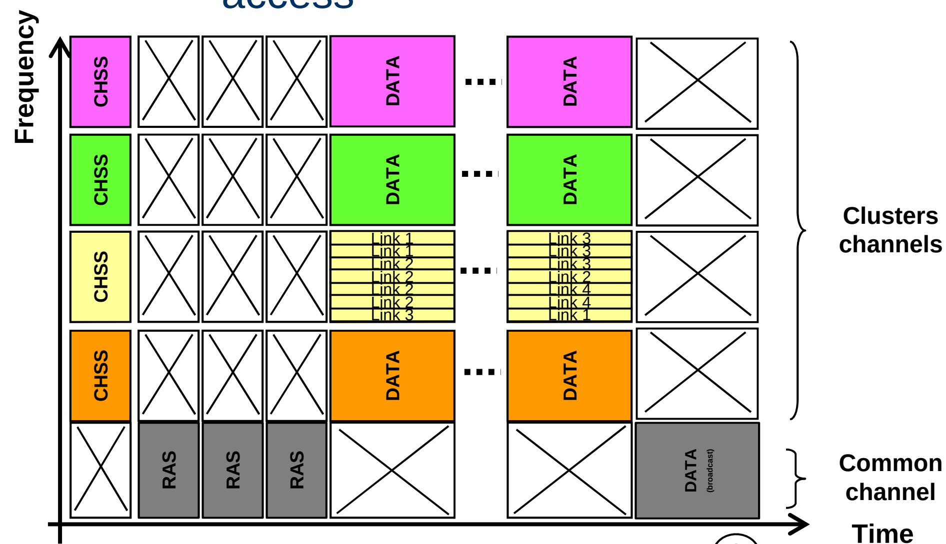
TDMA/SC-FDx radio resource allocation (BUS)

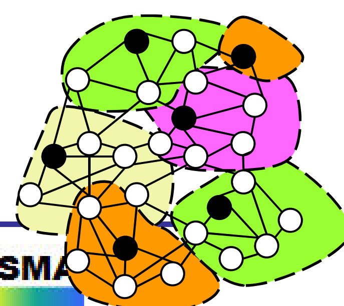
- Access: TDMA in TDD

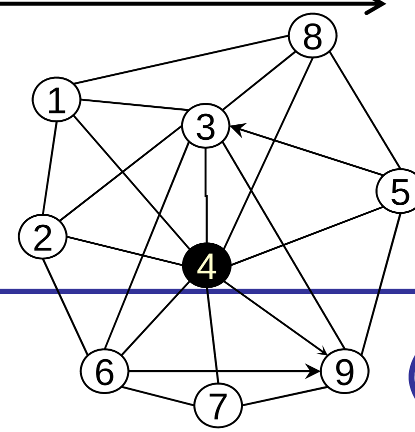


- Signalling phase
  - CH sends MAC-RESSOURCE-RSP to all nodes in the cluster
  - Regular nodes exchange MAC-HELLO and send MAC-RESSOURCE-REQ to their CH
- Communication phase
  - All nodes exchange data with multi-access within each slot

- Radio resource allocation
  - Cluster graph coloring
  - Intra cluster AMC with multiple access







CgP2BW interface (BUS)

Interface messages from CP entities to BW		
Name	**When**	**Purpose**
MAC_ENTITY_ACTIVATE_REQ	[init]	A cognitive plane entity has been activated, deactivate the action of the associated MAC entity
MAC_LINK_INFO_UPDATE_REQ	*	Report link information update
MAC_GRAPH_COLORING_UPDATE_REQ	*	Set the value of local cluster colour (only on CH nodes)
MAC_SLOT_SENSING_ALLOCATION_REQ	* or **	Reserve data slots for use by sensing entity
MAC_SCHEDULING_UPDATE_REQ	*	Set result of resource allocation required to schedule the TDMA
MAC_CLUSTERING_STATES_UPDATE_REQ	*	Set values of clustering parameters
MAC_HOPSET_CHANGE_REQ	*	Update frequency hopping parameters
CP_INFO_CH_BROADCAST_REQ	*	Trigger information broadcast OTA from cognitive entities in the CHSS

Table 3 Messages from cognitive plane to BW (CgP2BW)

Messages only used during initialization are tagged [init].

When: * means beginning of last data slot in the MAC frame. ** means beginning of 3rd data slot in the MAC frame.

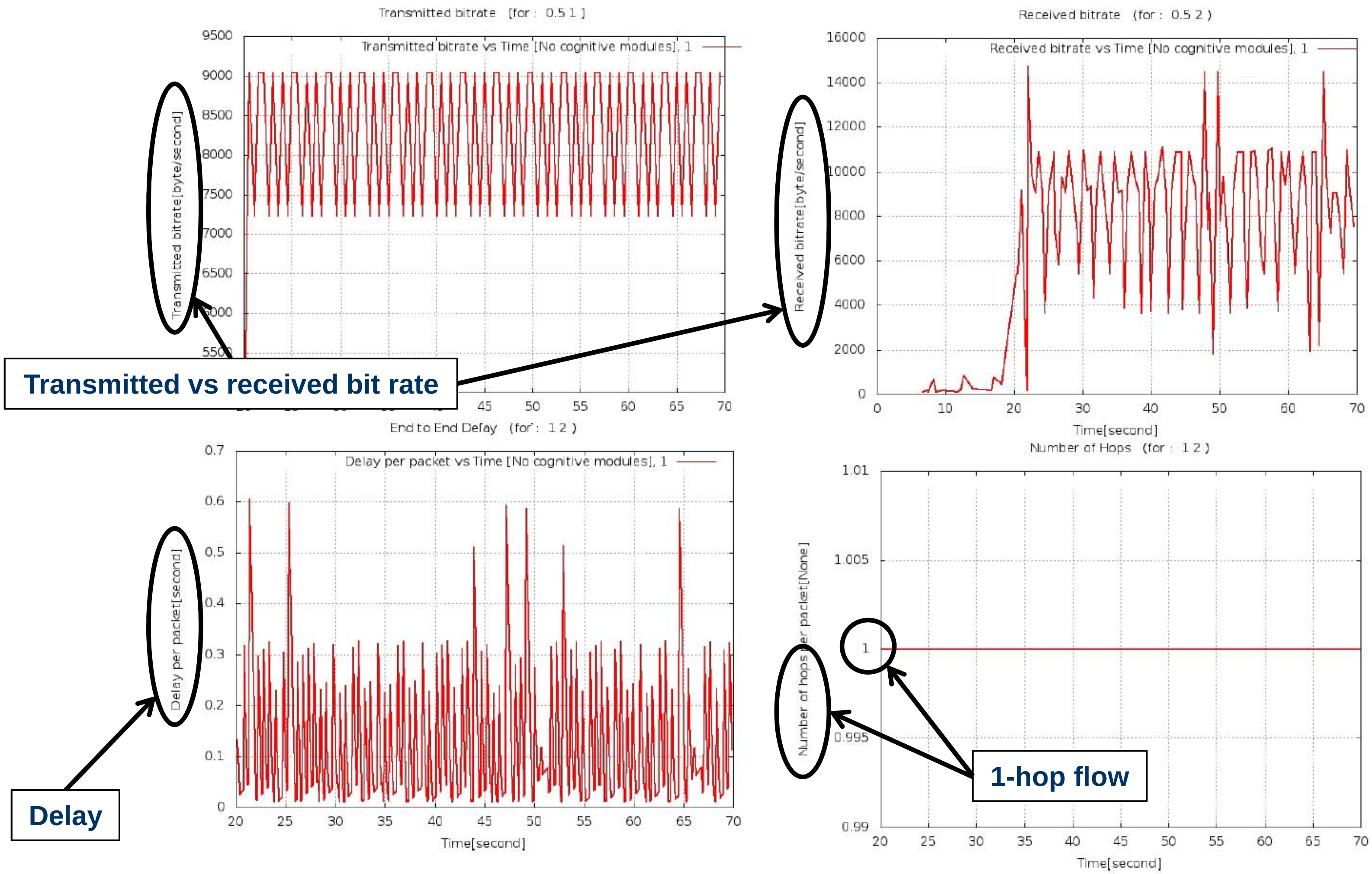
Interface messages from BW to CP entities		
Name	**When**	**Purpose**
MAC_TDMA_PARAMS_INFO	[init]	Report configuration parameters dedicated to TDMA cycle
MAC_FER_THRESHOLD_PARAM_INFO	[init]	Report target frame error rate
MAC_MCS_PARAMS_INFO	[init]	Report about MCS available for resource allocation
MAC_SCFDMA_PARAMS_INFO	[init]	Define parameters dedicated to SC-FDMA communication
MAC_PRIORITIES_NUMBER_PARAM_INFO	[init]	Report about number of available priorities
MAC_LOGICAL_CHANNELS_INFO	[init]	Report initial set of available logical channels (=colours)
MAC_CLUSTERING_STATES_INFO	**	Report clustering parameters update
MAC_NEIGHBOURHOOD_INFO	**	Report neighbourhood information update
MAC_CLOCK_INFO	**	Report that a new MAC frame is starting
MAC_LINK_INFO	**	Report link information update
MAC_RESOURCE_REQUESTS_INFO	**	Report about current resource requests,
MAC_GRAPH_COLORING_INFO	**	Report the colour of local cluster (only on CH nodes)
MAC_NEIGHBOURING_GRAPH_COLORING_INFO	**	Report set of colours used in a one hop cluster neighbourhood around the cluster to which local node belongs
MAC_CUMULATED_CRC_INFO	**	Report cumulated number of CRC OK/KO that happened during last MAC frame
CP_INFO_CH_BROADCAST_INFO	**	Report information received OTA from the local node CH received during the CHSS
MAC_SCHEDULING_INFO	***	To report the resource allocation performed by the RRM-SA entity

Table 4 Messages from BW to cognitive plane (CgP2BW)

When: ** means beginning of 2nd data slot in the MAC frame. *** means beginning of 4th data slot in the MAC frame.

Video

Results display screenshots (1 hop flow) (BUS)



Sensing modes classification (BUS)

- Passive sensing and active sensing
  - Passive sensing
    - Receive only mode (one node)
    - Allows measure spectrum level and to detect “free” bandwidths
  - Active sensing
    - Transmit and receive (two nodes)
    - Allows to assess channel gain to noise plus interference level

- Implicit sensing and dedicated sensing
  - Implicit sensing uses data communications to evaluate SINR per link and thus interference levels -> no extra resource needed (active sensing)
  - Dedicated sensing uses specific resource in place of data communications (passive or active sensing). Two modes:
    - Data slots are preempted for sensing at the beginning of the frame,
    - Opportunistic sensing: uses opportunities left over by data (unused slots)

Sensing interfaces/messages (BUS)

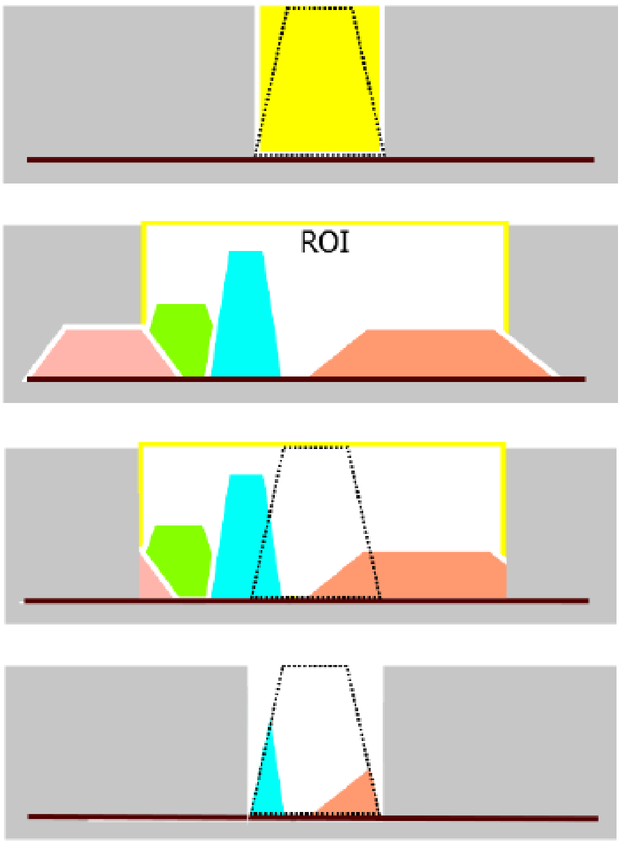
- To allow sending information related to sensing

1. Inside a node between cognitive blocks and the sensing block
   - Specific messages through XLI inside cognitive plane
2. In between nodes inside a cluster
   - Allows nodes to send sensing information (detection, …) to the cluster head for fusion
   - Two different ways:
     - Using CHSS signaling channel, for command messages from the CH to the nodes
     - Using cognitive to cognitive plane over the air messages, uses data plane communications, mainly used to send sensing information from the nodes to the CH

Sensing organization between nodes (BUS)

- Local sensing
  - Each node can perform sensing from its received signal
  - 1/ I/Q samples are sent to the sensing block
  - 2/ Signal processing algorithms are computed in sensing block
- Cooperative sensing
  - The cluster head acts a fusion center
  - 1/ Commands local sensing to nodes in the cluster (through signalling)
  - 2/ Receives the sensing information from nodes (through over the air messages)
- Sensing detection algorithm implemented
  - Energy detection
  - Eigen value
  - …

Simulated bandwidth (BUS)



2 MHz

6 MHz

6 MHz

2 MHz