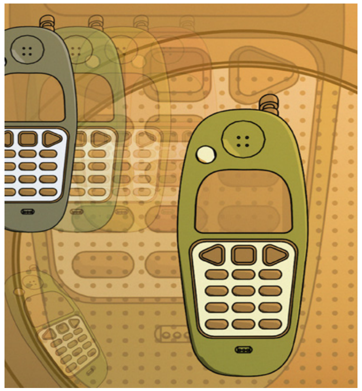
“Cognitive Context Acquisition and Subcarrier Assignment Strategies in LTE”



Mr. Aggelos Saatsakis

Dr. Kostas Tsagkaris

Mr. Marios Logothetis

Dr. George Dimitrakopoulos

Pr. Panagiotis Demestichas

University of Piraeus Research Center (UPRC)

E3 Presentation outline

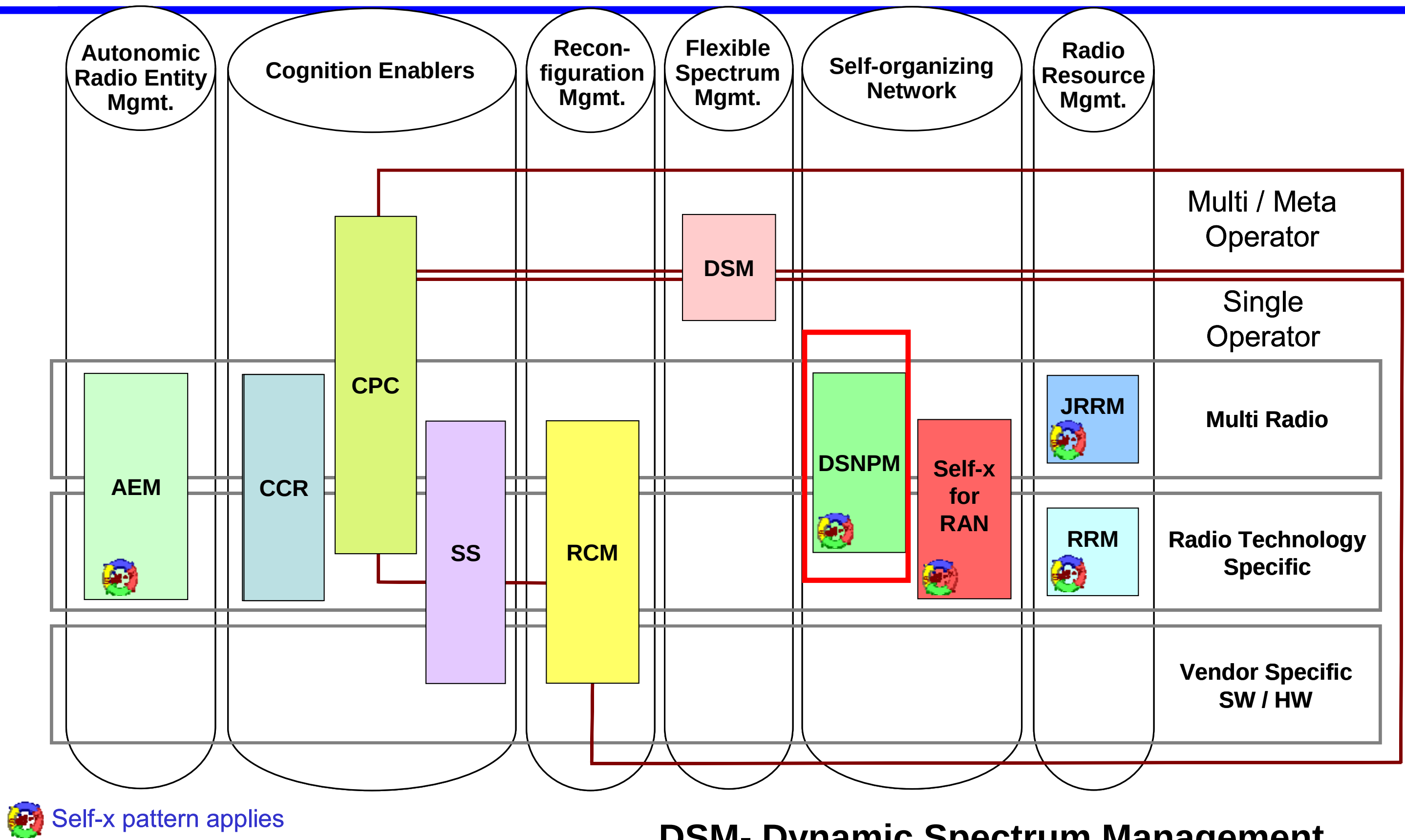
- E3 Project targets and Functional architecture
- Dynamic Self-organizing Network Planning and Management (DSNPM) functional block
- Context Matching Algorithm (CMA)
- Enhancing DSNPM with DSA technique for OFDMA
- OFDMA learning algorithms in DSNPM
- Latest achievements
- Future steps

E^3 – Overview

E^3 is an European Project on End-to-End-Efficiency under the 7th Framework Program of the European Commission, addressing the core of the strategic objective "The Network of the Future"

- Introducing Reconfigurable, Cognitive Systems in the B3G world:
  - ⇒ Reconfigurable Base Stations and Reconfigurable Terminals
  - ⇒ Self-Management and Self-Optimisation of
    - Radio Network Infrastructure
    - Cognitive Devices
  - ⇒ Cognition Support Mechanisms
  - ⇒ Dynamic Spectrum Management
  - ⇒ Joint Multi Standard Radio Resource Management

E3 Functional Architecture



AEM - Autonomic Entity Management

CCR - Cognitive Control Radio

CPC- Cognitive Pilot Channel

SS - Spectrum Sensing

RCM - Reconfiguration Control Module

DSM- Dynamic Spectrum Management

Self-x-for-RAN - Self-x for Radio Access Netw.

DSNPM - Dynamic Self-organizing Network Planning & Management

JRRM - Joint Radio Resource Management

RRM - Radio Resource Management

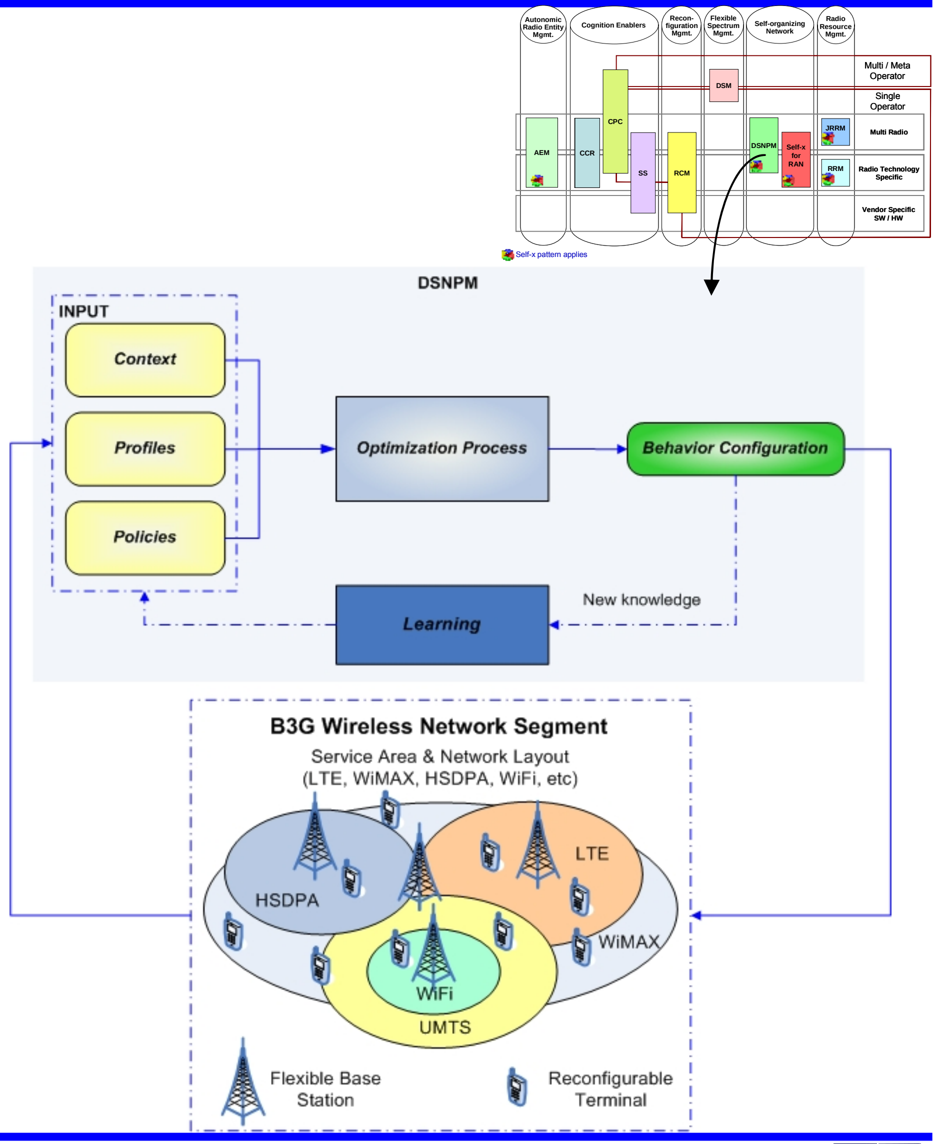
E3 Dynamic Self-organizing Network Planning and Management (DSNPM)

Input:

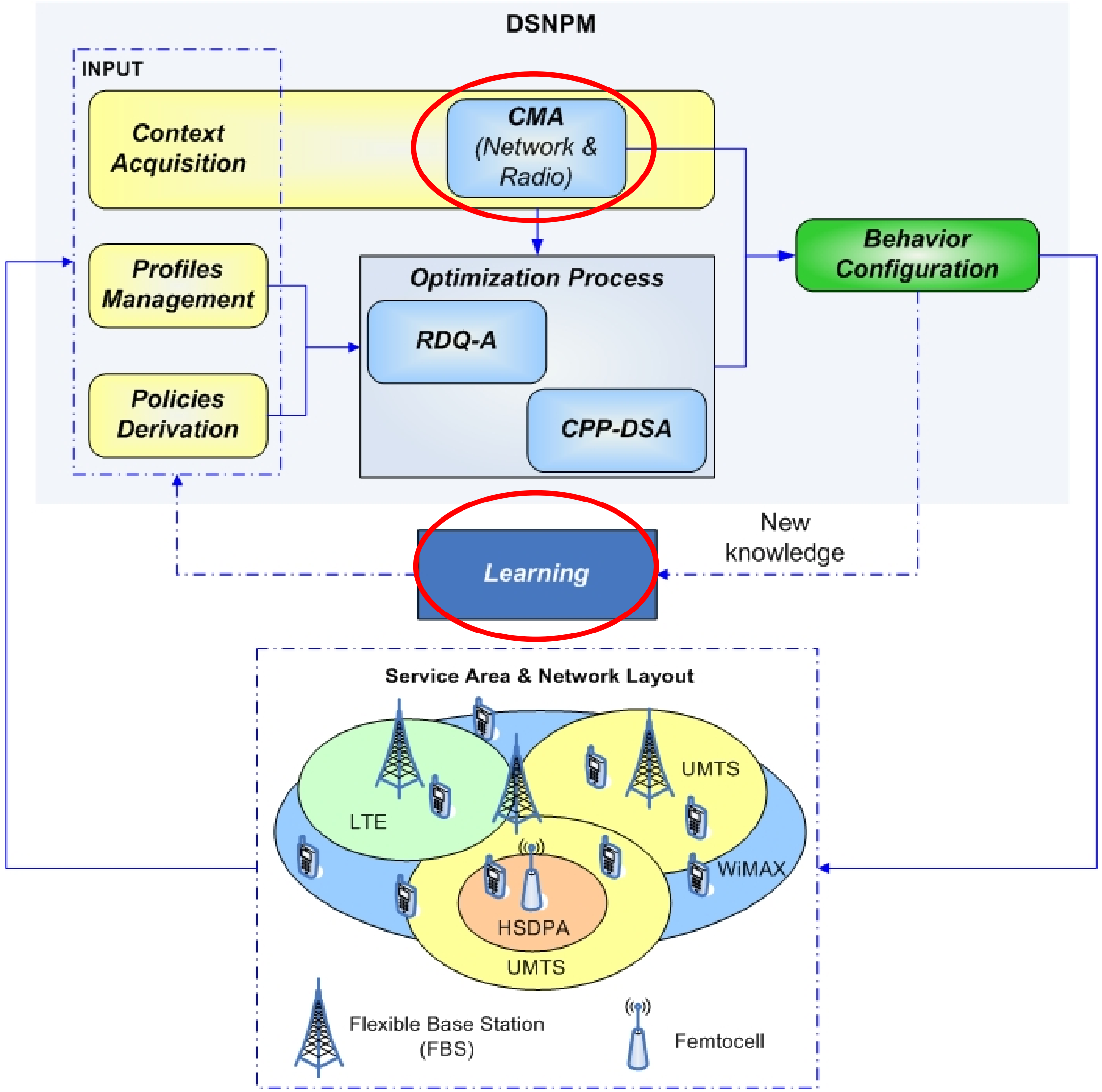
- **Context: traffic, mobility, interference, element status**
  - ⇒ Change of element status, e.g., fault of some component like TRX→ trigger for self-healing mechanisms
- **Profiles: equipment, application, user requirements and preferences**
- **Policies: optimization objectives, strategies, constraints**

Optimization mechanisms:

- **Algorithms for various time scales, optimal or near-optimal**
- **Short time scale: greedy, online**
- **Mid-term: simulated-annealing, taboo search, genetic algorithms**



E3 DSNPM functional entities in detail



E3 DSNPM: Learning the context

1. Network segment status retrieved;

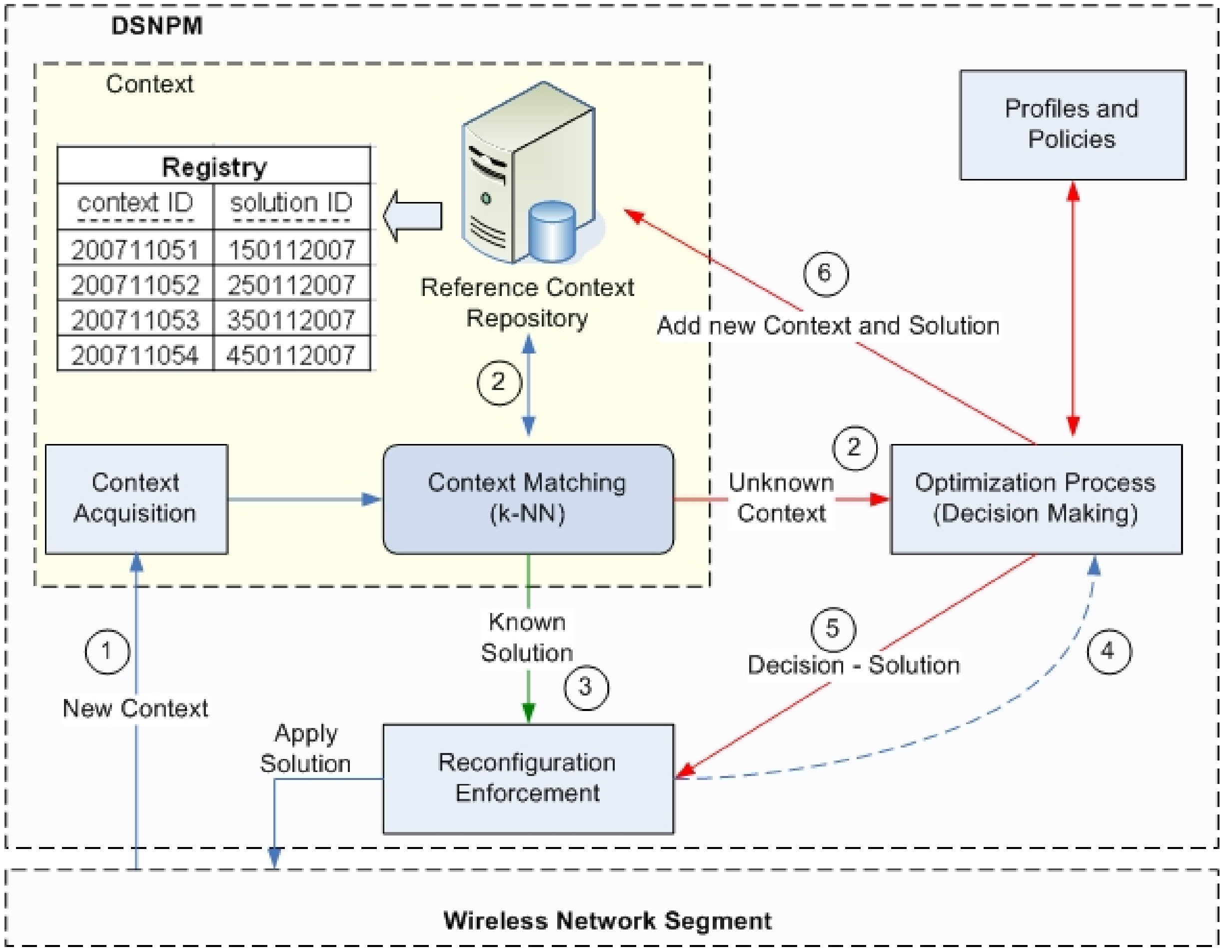
2. Context Matching. Optimization modules are triggered in parallel;

3. Context Matching passes the control to the Reconfiguration Enforcement or to the Optimization modules if a match is found or if no reference context is close to the new context respectively;

4. Reconfiguration Enforcement passes the control to the Optimization module in case the solution proposed by the Context Matching module cannot be applied;

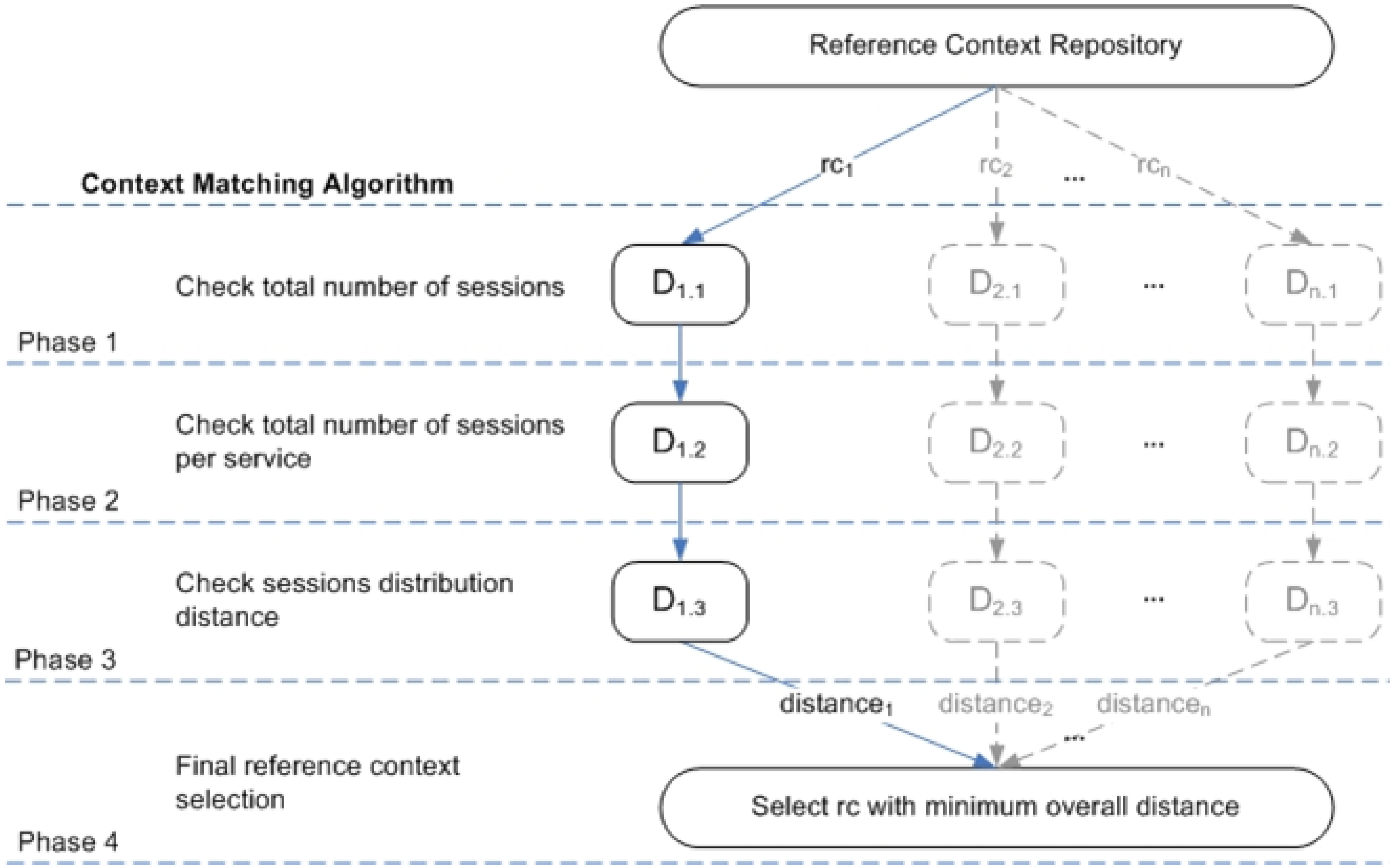
5. The Optimisation module will ask the Reconfiguration Enforcement module to apply the derived configuration to the network segment;

6. The new context and its solution are sent to the repository.

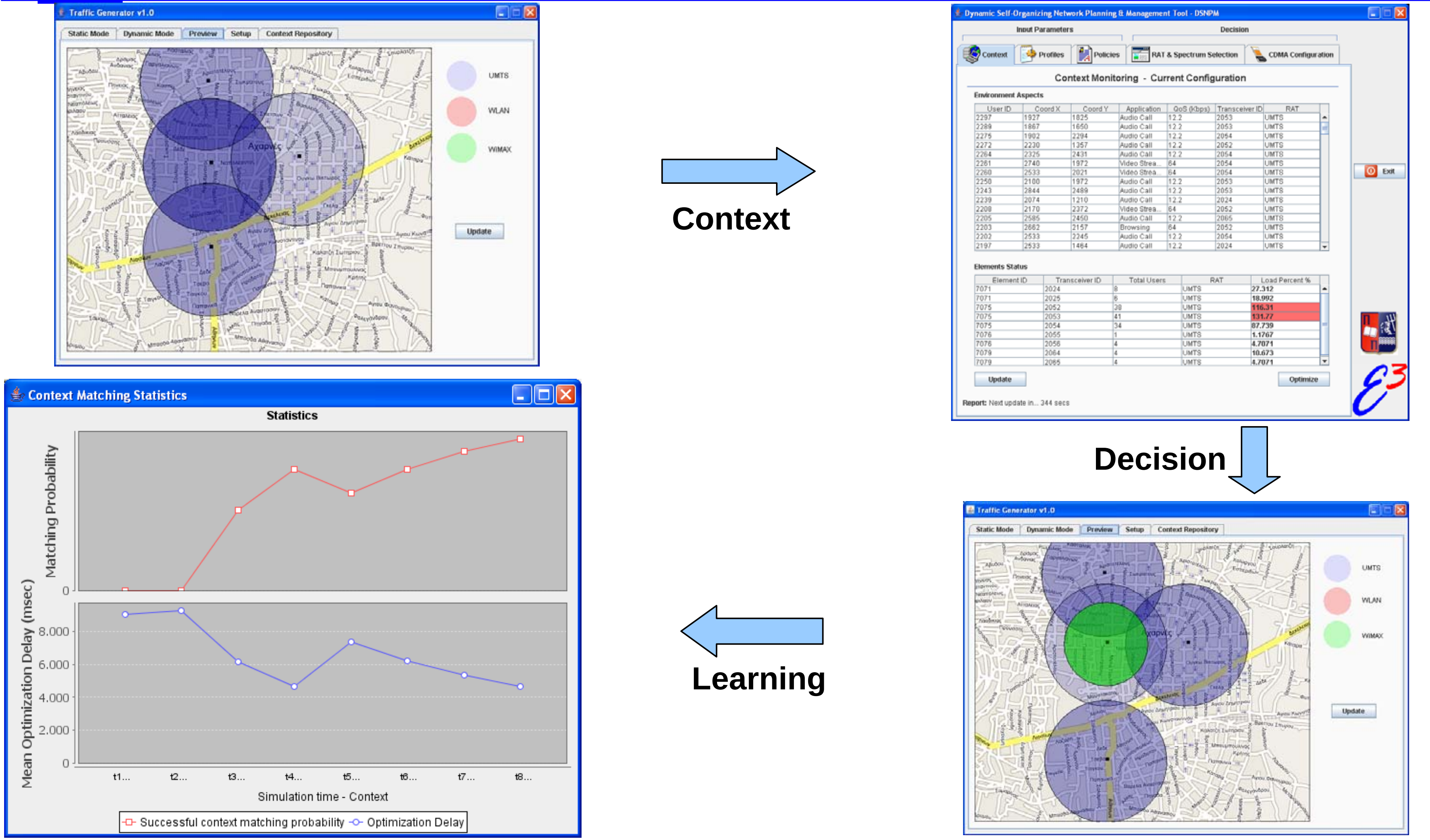


E3 Context Matching Algorithm

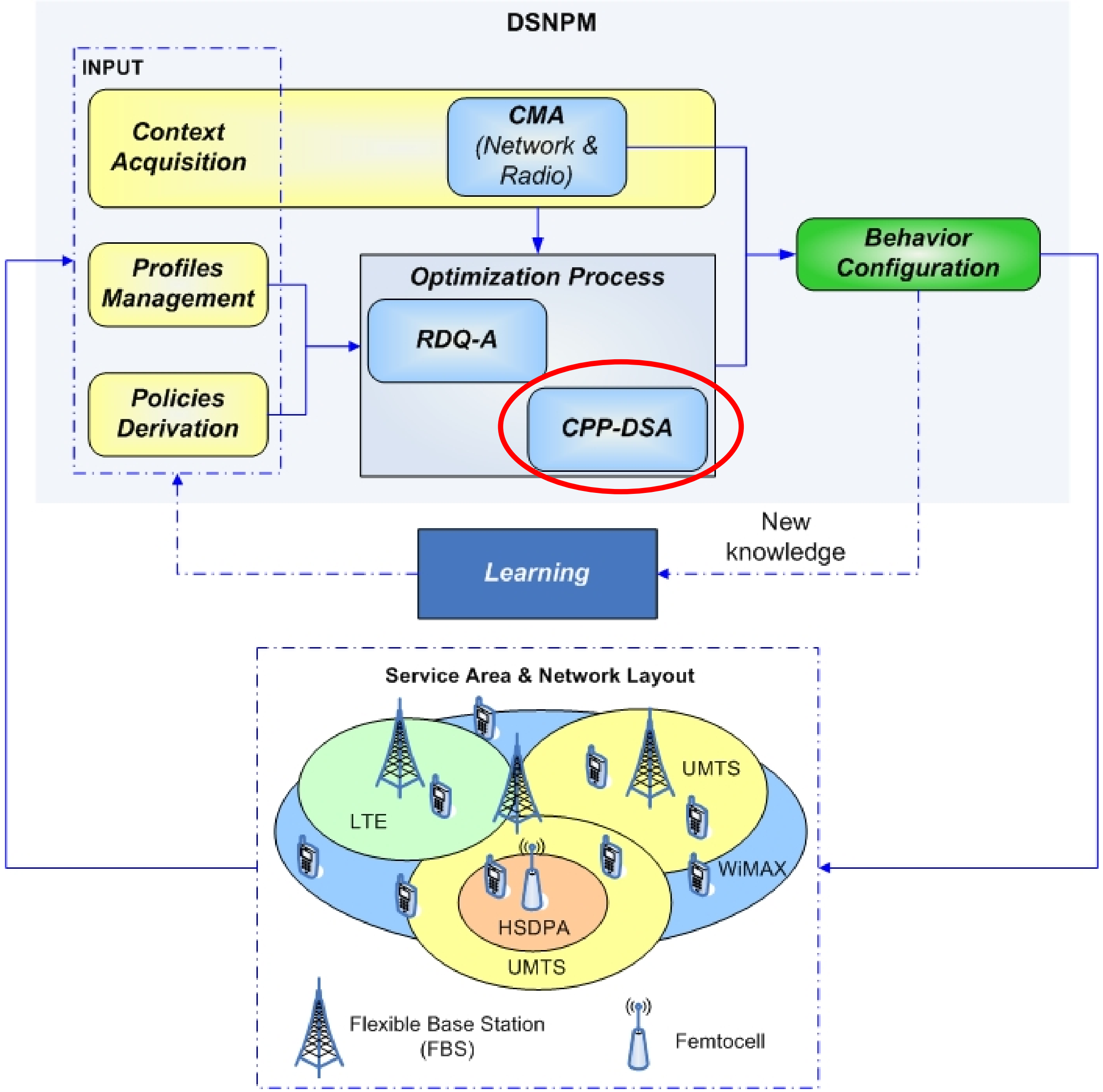
CMA is based on K-NN algorithm and it is targeted for past contexts identification.



E3 DSNPM learning simulations



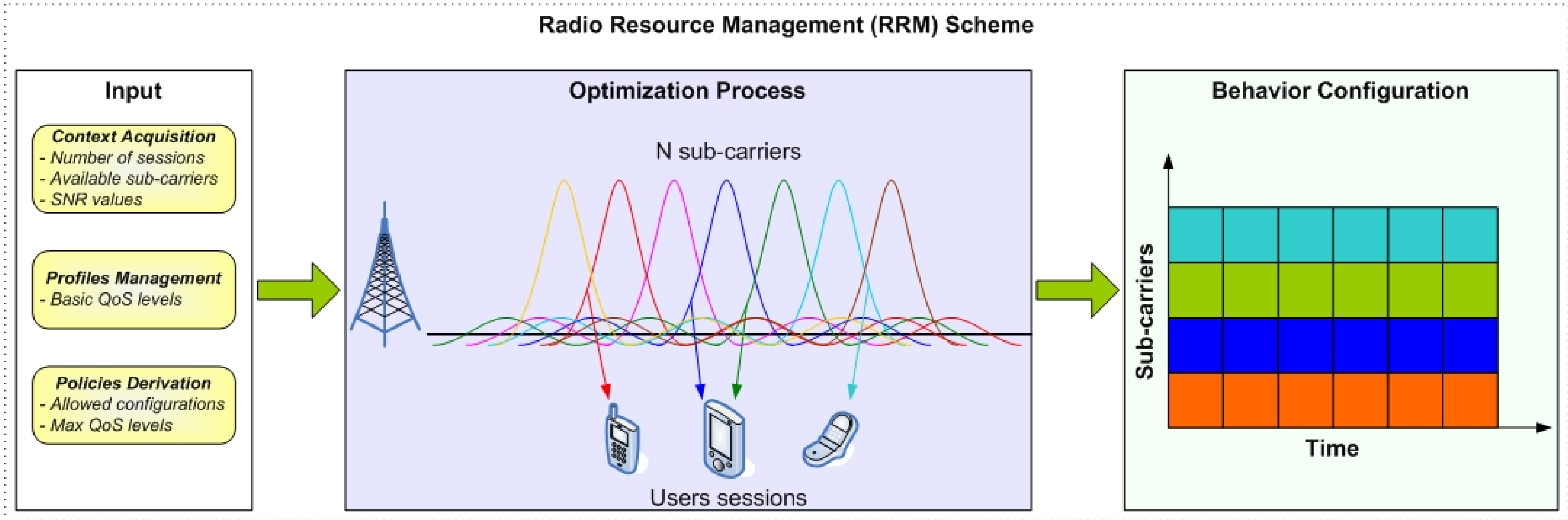
E3 DSNPM functional entities in detail



E3 Enhancing the decision making process of DSNPM with DSA techniques

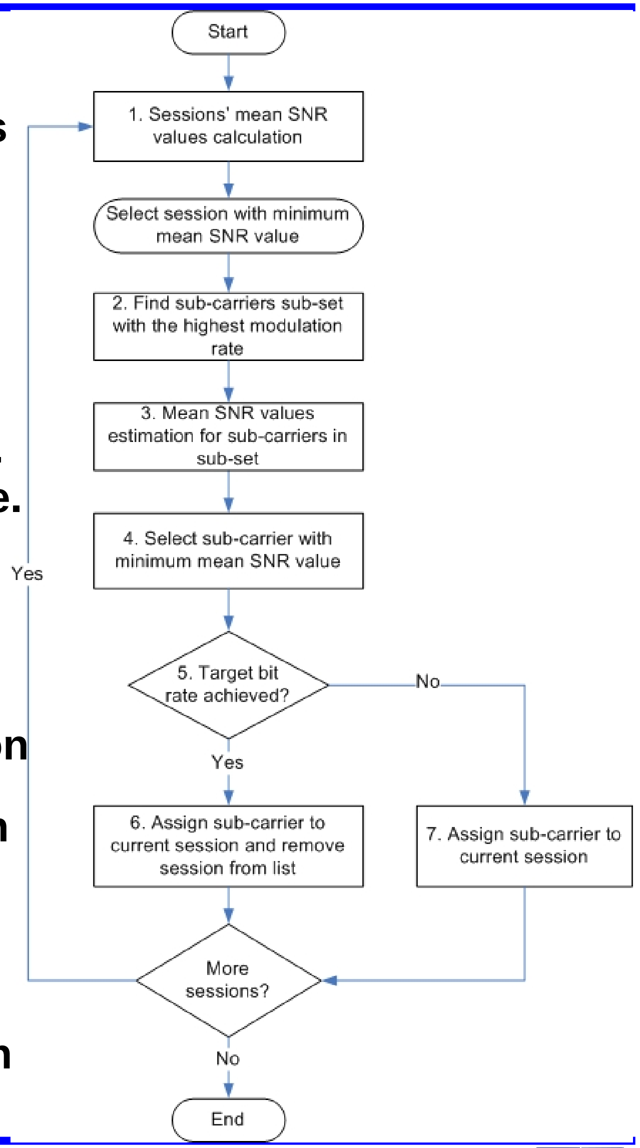
A Dynamic Sub-carrier Assignment (DSA) algorithm for OFDMA based networks is introduced, named CPP-DSA, considering:

- Active user sessions, requested services, available sub-carriers
- Channel quality information reflected by sub-carriers SNR values
- High level management information: Context, Profiles and Policies (CPP)



E3 CPP-DSA algorithm steps

- The selection of the next session to assign a sub-carrier to is based on the session's mean SNR value for all the available sub-carriers to this session. The algorithm selects the session with the minimum mean SNR value in order to guarantee that sessions with few or less available sub-carriers will be selected for sub-carrier assignment first, compared to the other sessions.
- The selection of the most appropriate sub-carrier will be based on the minimum mean SNR value but in this case it will be estimated from the sessions' SNR values of the sub-carriers capable of achieving the maximum possible bit rate. Thus, the sub-carrier mean SNR value won't be estimated for all the sub-carriers of the selected session but only for the sub-carriers where the maximum data rate can be achieved.
- Information from profile management and policies derivation entities are considered so as to estimate the target bit rate for each session that must be achieved. Thus, each session can be assigned with one or more sub-carriers.
- The algorithm will finish either when
  - ⇒ all sub-carriers are assigned to sessions
  - ⇒ there are no more sessions to be further assigned with the remaining sub-carriers.



E3 Simulation scenario – CPP-DSA for LTE

- Active sessions in the service area: 100
- User profiles: Basic, Bronze, Silver and Gold

LTE channel (MHz)	Total sub-carriers
5	*225*
10	*450*
15	*675*

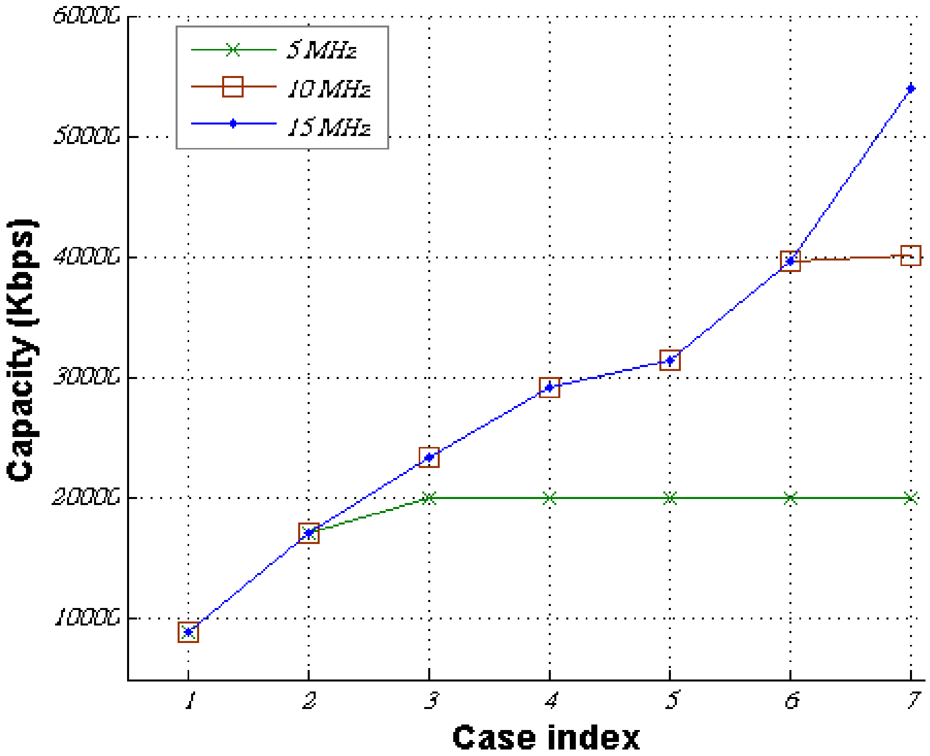
User profile	Bit rate (Kbps)
Basic	*64*
Bronze	*128*
Silver	*384*
Gold	*512*

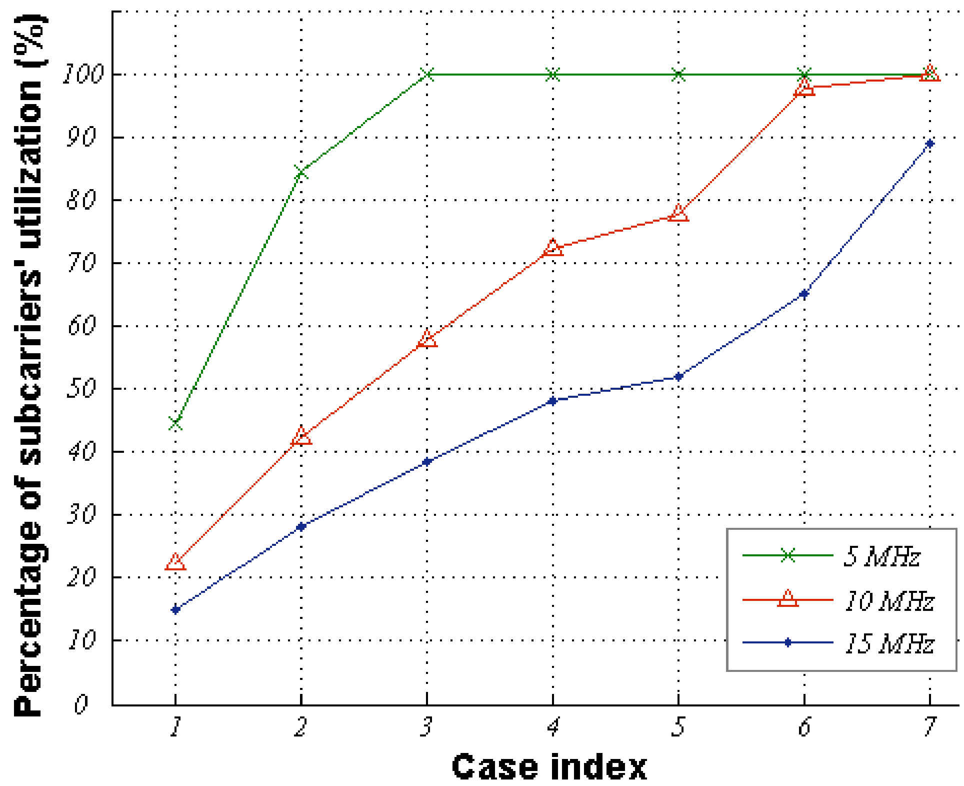
Case	Basic (%)	Bronze (%)	Silver (%)	Gold (%)
1	*100*	*0*	*0*	*0*
2	*10*	*90*	*0*	*0*
3	*40*	*30*	*20*	*10*
4	*24*	*32*	*27*	*17*
5	*0*	*50*	*50*	*0*
6	*10*	*20*	*30*	*40*
7	*0*	*0*	*0*	*100*

Mod. Scheme	bits/symbol	SNR range	bit rate (kbps)*
8-QAM	*3*	$a \le SNR < b$	*45*
16-QAM	*4*	$b \le SNR < c$	*60*
64-QAM	*6*	$d \le SNR < e$	*90*

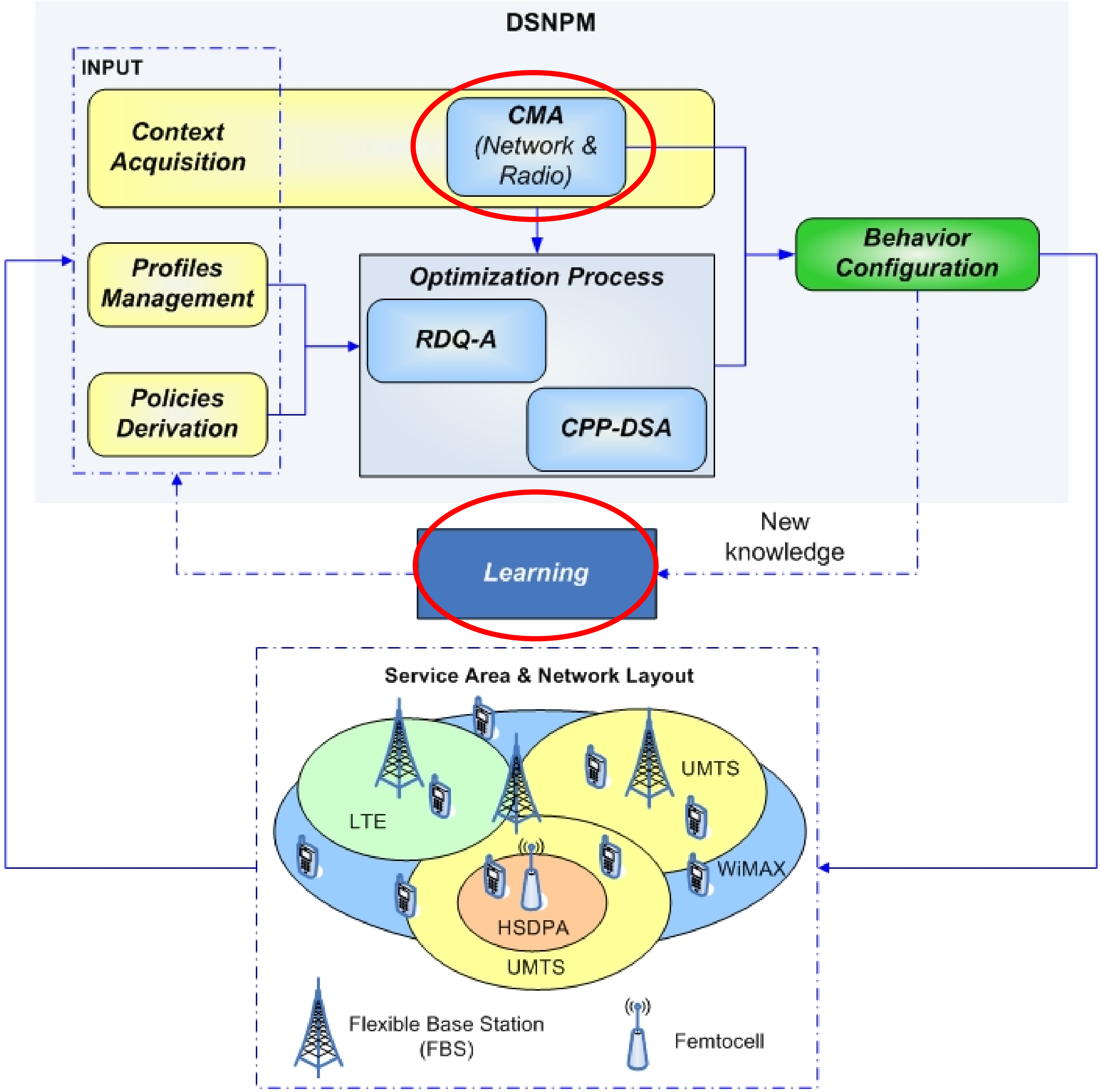
* LTE symbol length 66.7 μs

E3 Main simulation results per case





E3 DSNPM functional entities in detail



E3 OFDMA and learning in the context of DSA technique (1/2)

- **Goal to be achieved**
  - ⇒ Exploit knowledge, gained from past interactions of the management system with the network environment, for sub-carriers assignment and/or channel assignment
- **Algorithms and procedures**
  - ⇒ Context Profile and Policies – DSA (CPP-DSA) algorithm provides sub-carriers assignment to users' sessions close to the optimum (compared to Hungarian algorithm) and in timely manner (due to its low complexity)
  - ⇒ Having CPP-DSA algorithm available in DSNPM, knowledge on past assignments and channel selection is feasible
  - ⇒ *Algorithms for identification of the past or similar context characteristics (traffic, mobility, radio parameters) are necessary in order to skip optimization procedures*

E3 OFDMA and learning in the context of DSA technique (2/2)

The following approaches are considered

- *Learning on sub-carriers assignment*
  - ⇒ Past context information as well as the corresponding assignment set, provided by CPP-DSA algorithm, can be stored in "Reference Context Repository" in order to be available in the future
  - ⇒ A matching algorithm for the similarity of radio environment conditions between contexts is necessary in order to be able to identify whether a past assignment can be used for the current captured context skipping the execution of CPP-DSA algorithm
- *Channel segregation*
  - ⇒ Given the number of available sub-carriers for each channel, CPP-DSA algorithm will provide the best possible assignment sets
  - ⇒ Learning can be introduced by rating the channel appropriateness for each captured context in the past
  - ⇒ A matching algorithm for contexts similarity is necessary. Channel selection for network segments can be based on the higher appropriateness rate for the captured context

E3 Latest achievements

- A. Saatsakis, P. Demestichas, “*Enhanced context acquisition mechanisms for achieving self-managed cognitive wireless network segments*”, Wireless Personal Communications journal, September, 2009, doi:10.1007/s11277-009-9807-z
- A. Saatsakis, K. Tsagkaris, P. Demestichas, "*Exploiting Context, Profiles and Policies in Dynamic Sub-carrier Assignment Algorithms for Efficient Radio Resource Management in OFDMA Networks*", submitted to Annals of Telecommunications Journal.
- A. Saatsakis, P. Demestichas, V. Merat, C. Le Page, T. Loewel, K. Nolte, "*Femtocell and Flexible Base Station Cognitive Management*", accepted for presentation in Indoor and outdoor femtocell workshop (in conjunction with PIMRC 2009)
- W. Koenig, K. Nolte, J. Gebert, P. Demestichas, V. Stavroulaki, A. Saatsakis, "*Introducing Cognitive Systems in the B3G world*", accepted for presentation in CogCloud workshop (in conjunction with PIMRC 2009)
- A. Saatsakis, N. Koutsouris, K. Tsagkaris, P. Demestichas, K. Nolte, F. Noack, C. Lange, T. Loewel, “*Cognitive Management of Reconfigurable Infrastructures and Equipment*”, demo proposal accepted in SDRF, December 2009, Washington
- P. Demestichas, A. Saatsakis, W. Koening, "*An Approach for Realizing Future Internet with Cognitive Technologies*", Proc. Crowncom Conference, Hannover, Germany, 2009

E3 Future steps

- **Journal paper preparation**
  - ⇒ A. Saatsakis, K. Tsagkaris, P. Demestichas, "*Knowledge Based Dynamic Sub-carrier and Channel Assignment for OFDMA Systems*"
- **Enhance DSA algorithm with learning capabilities**
  - ⇒ Introduce suitability rating in order to reward sub-carriers and modulation types configurations where the optimum network performance is achieved
- **Enhance DSA algorithm with reinforcement learning capabilities**
  - ⇒ Based on the reconfigurations performed in the past, suitability rating will be used in order to:
    - select faster the appropriate sub-carriers in the service area
    - select the appropriate channel configuration for each network segment in the service area (Channel Segregation)

Thank you!

Acknowledgement

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