Multi-Layer LTE / Wi-Fi Access Network Selection - results from the SEMAFOUR project

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Outline

- **What is the SEMAFOUR project?**
- **SEMAFOUR Vision**
- **Results achieved within SEMAFOUR‘s LTE/WLAN Traffic Steering use case**

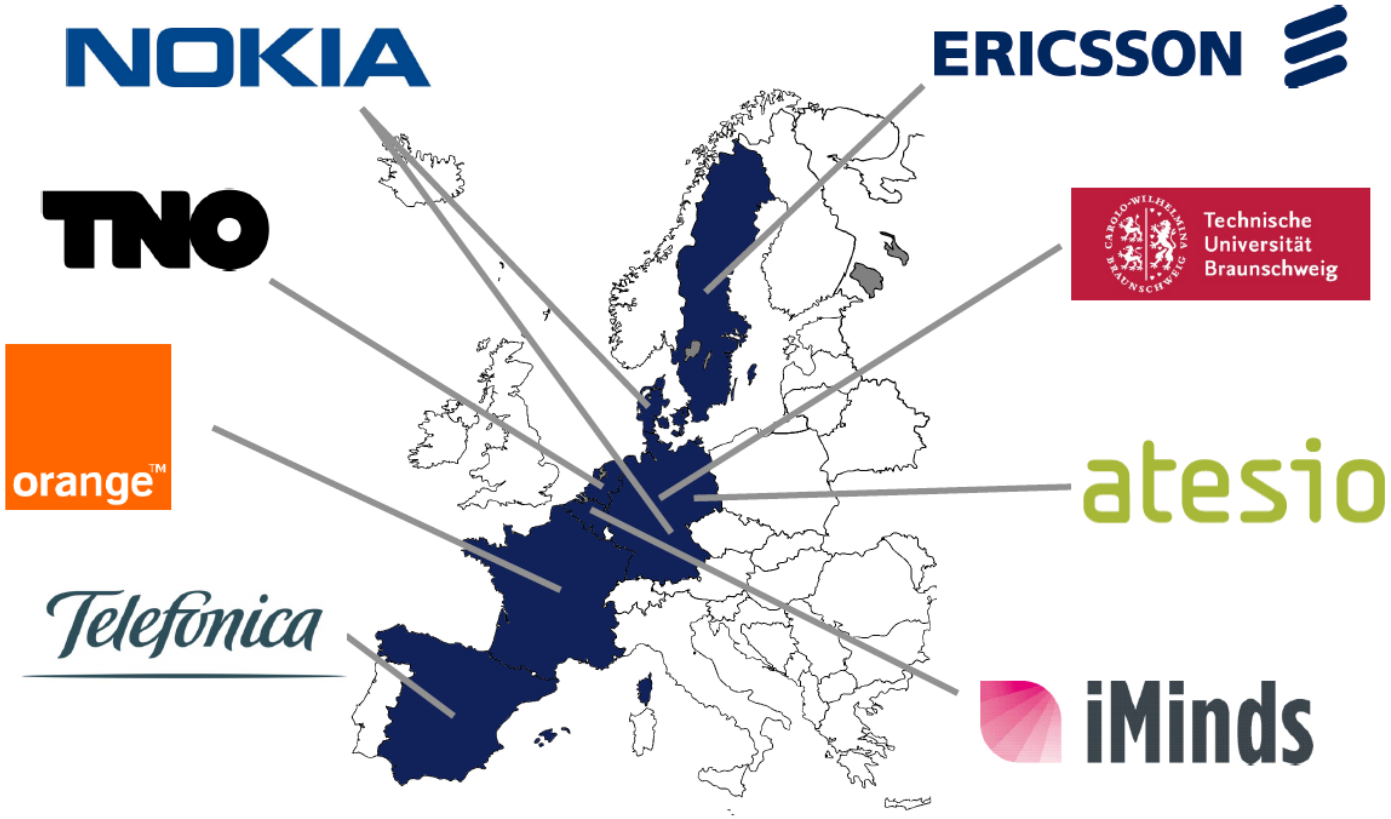
What is SEMFOUR ?

- SEMAFOUR is a collaborative research project funded by the European Commission within its seventh framework programme
- The goal of SEMAFOUR is to develop a Unified self-management system efficiently operating a heterogeneous mobile network comprising a multitude of radio access technologies and layers
- SEMAFOUR mainly has concentrated on 3GPPP radio technologies, but has considered IEEE 802.11 as well

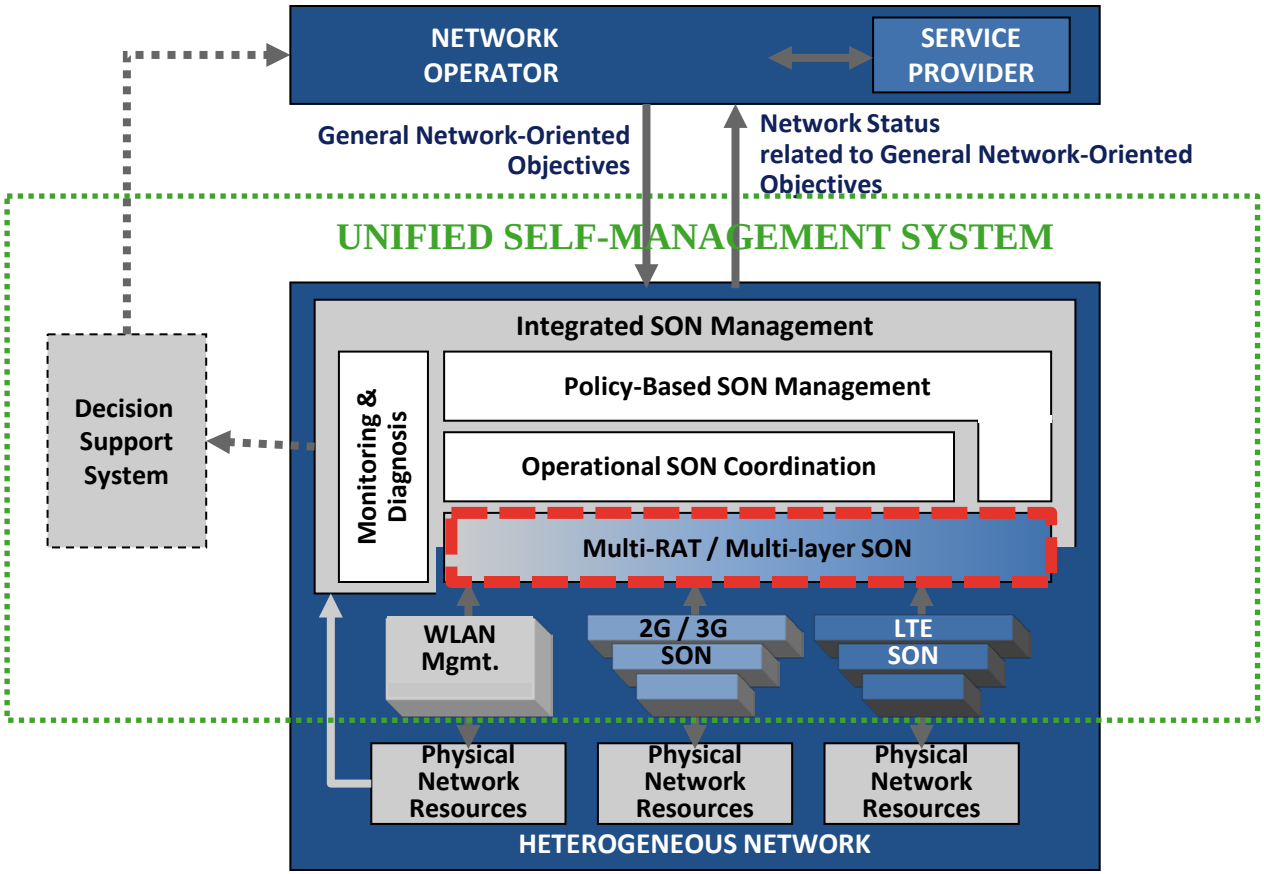
SEMAFOUR Key Facts

- Website: www.fp7-semafour.eu
- Scheme: EU FP7 STREP (No. 316384)
- Duration: 09/2012 – 08/2015
- Effort: 500 Person Months
- Budget: 6.1 M€ (total), 3.8 M€ (funding)
- Coordinator: Dr. Colin Willcock (Nokia, Germany)

SEMAFOUR Partners

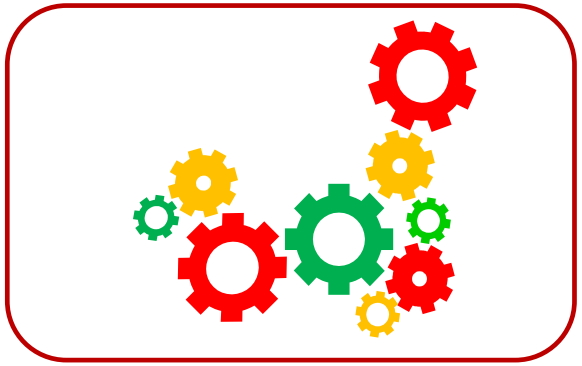


SEMAFOUR Vision

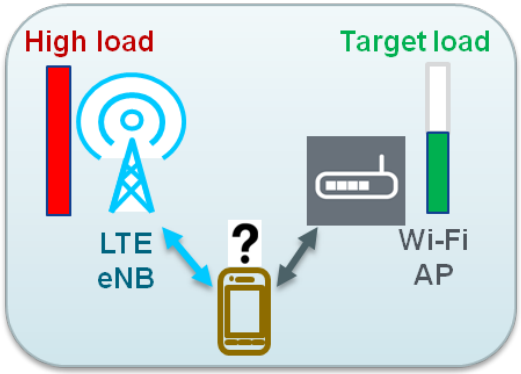


SON Functions for Multi RAT and Multi Layer Networks

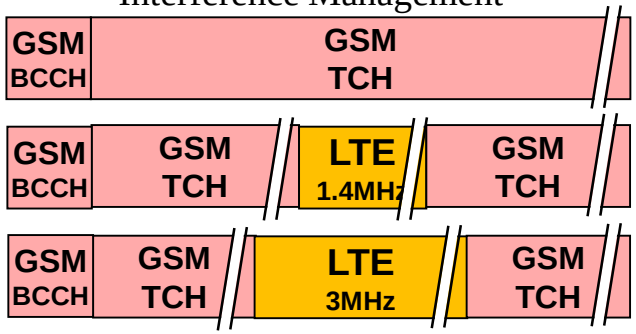
SON Design Principles



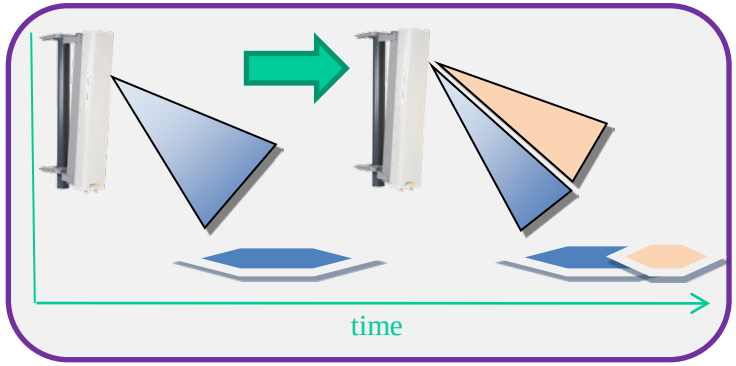
Multi-layer LTE/Wi-Fi TS



Dynamic Spectrum Allocation and Interference Management



Active Antenna Systems



High Mobility

- In the remaining part of this presentation is on the Multi-layer LTE/Wi-Fi Traffic Steering use case, where the partners Ericsson, Nokia, iMinds and TNO have worked on.
- The following slides are an extented version from:

  http://www.fp7-semafour.eu/media/cms_page_media/20/6-Wang-SEMAFOUR%20Workshop%202014-Traffic%20Steering.pdf

Multi-Layer LTE / Wi-Fi Access Network Selection

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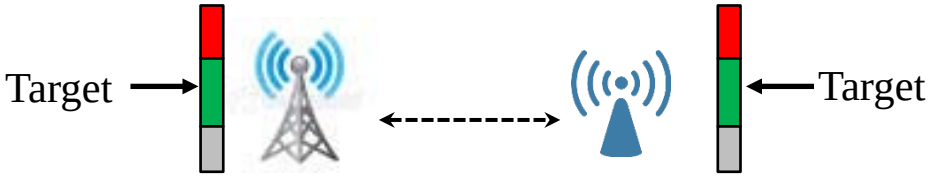
Objective (1/2)

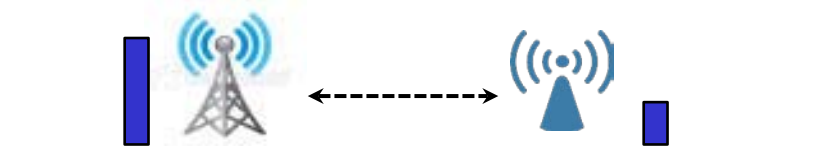
- Objective:
  - **Access network selection between multi-layer LTE and Wi-Fi in dense urban deployments to improve user experience and network efficiency**
- Implemented SON functions:
  - Threshold based SON functions
    - SON for LTE load control
    - SON for Inter-RAT LTE/Wi-Fi load control
  - Throughput based SON functions
    - QoS-oriented access network selection, e.g. based on a per user throughput metric

Objective (2/2)

SON for LTE load control



SON for Inter-RAT LTE/Wi-Fi load control



Throughput based SON function

SON Function Design – Monitoring KPIs

- **LTE load**
  - Average raw percentage of physical resource blocks (PRBs) utilization
  - Average fraction of required PRBs in a cell to serve connected UEs with a certain minimum bit rate

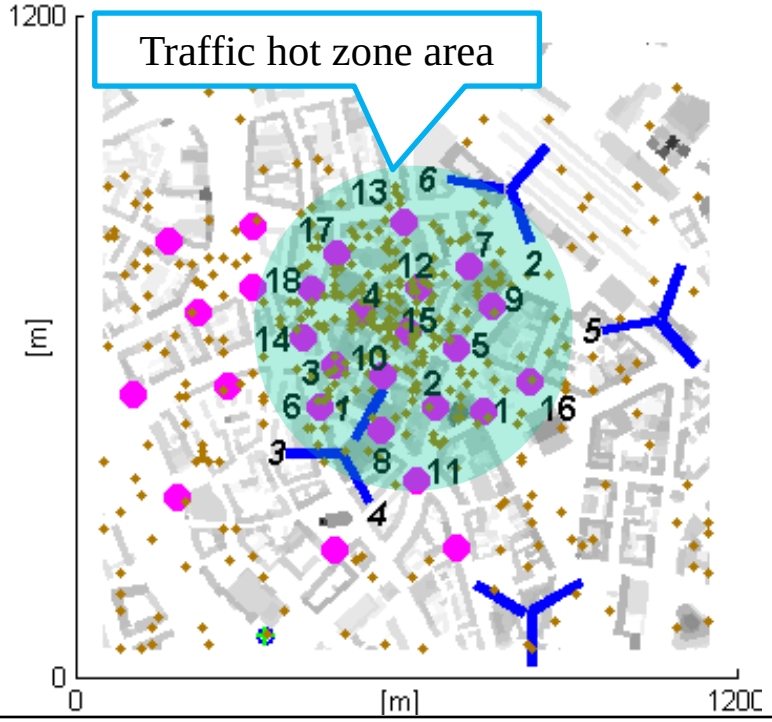
- **Wi-Fi load**
  - Average percentage of channel busy time of a Wi-Fi AP
  - The channel is considered as busy if there is at least one active connection associated to the AP and the AP or a UE is transmitting

- How fast the SON functions can change configuration parameters which determine access network selection of UEs
  - **Observation & Adjustment period (**0.5 – 2 seconds**)**
  - **Control parameter step size** (0.5 – 5 dB)

SON Function Evaluation - Scenario

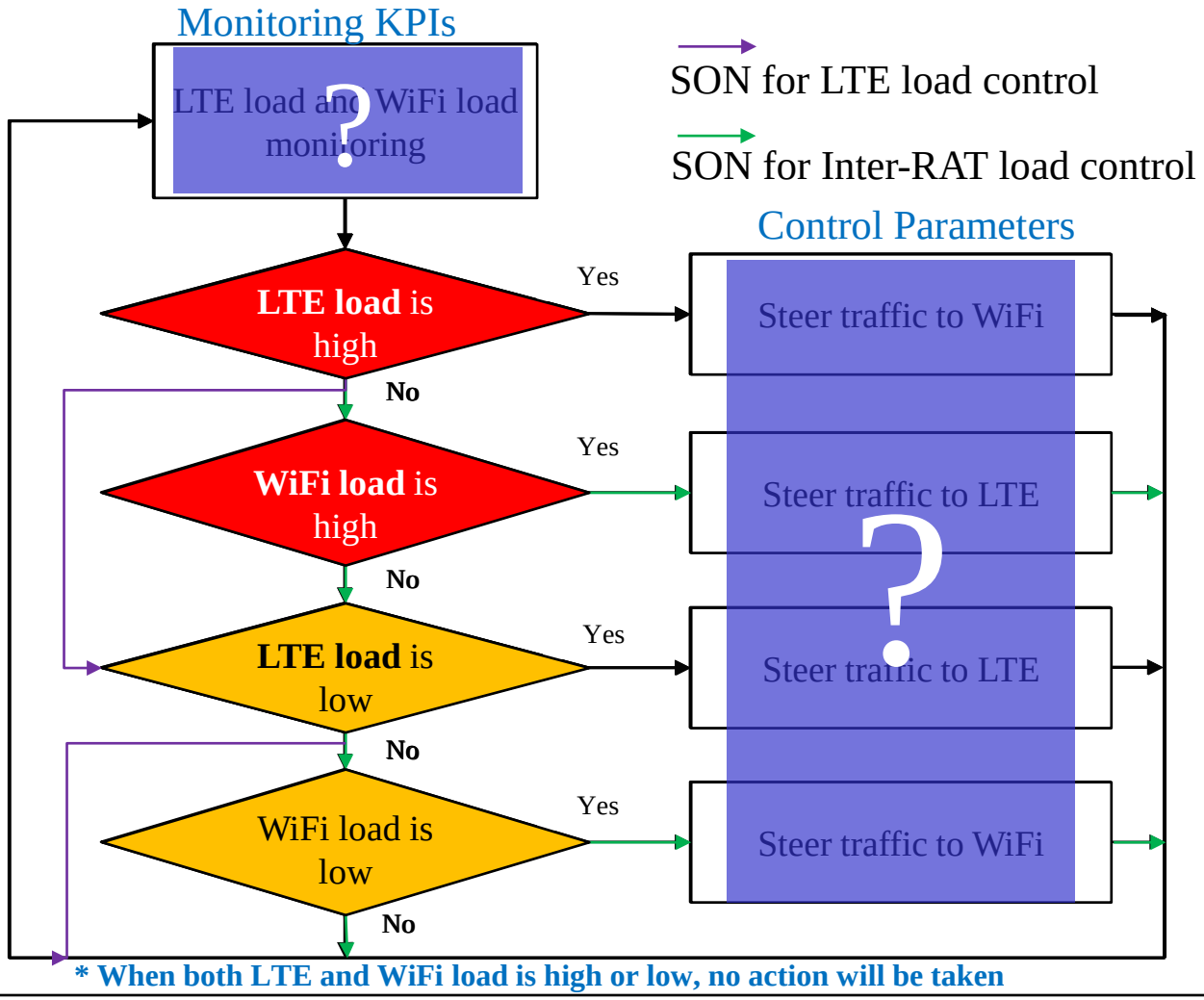
- Realistic dense urban environments
- Dense WiFi deployment
- Outdoor & Indoor

Outdoor Hot Zone



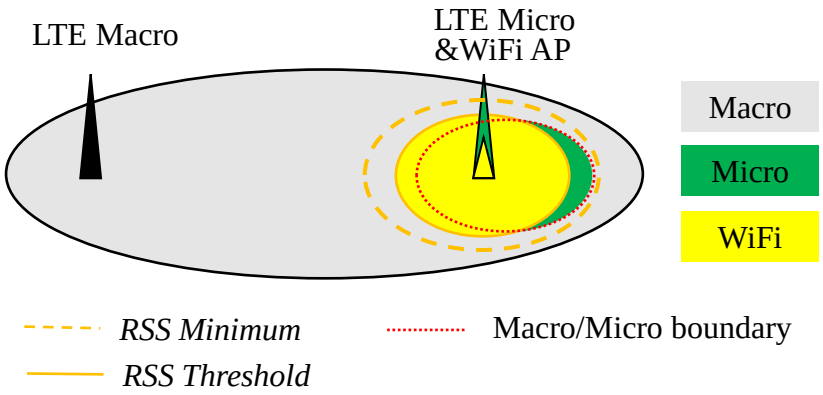
Threshold based SON Functions

SON Function Design for the Access Network Selection

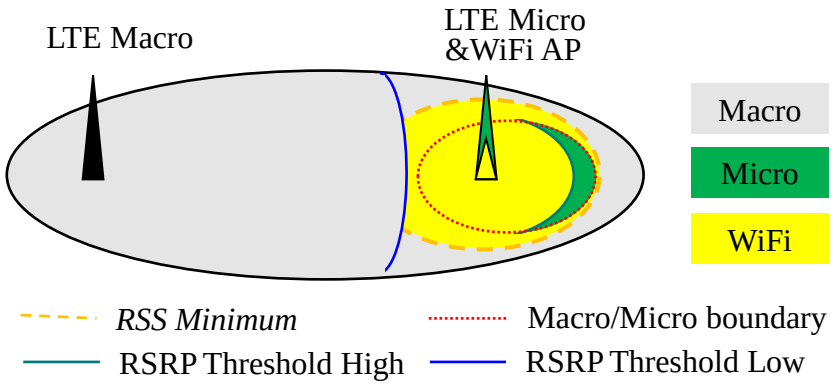


SON Function Design – Control Parameters

WiFi RSS Threshold



LTE RSRP High & RSRP Low Thresholds



To steer more traffic to WiFi

- Decrease WiFi RSS Threshold
- Decrease RSRP High Threshold
  Increase RSRP Low Threshold

SON Function Evaluation - Overview

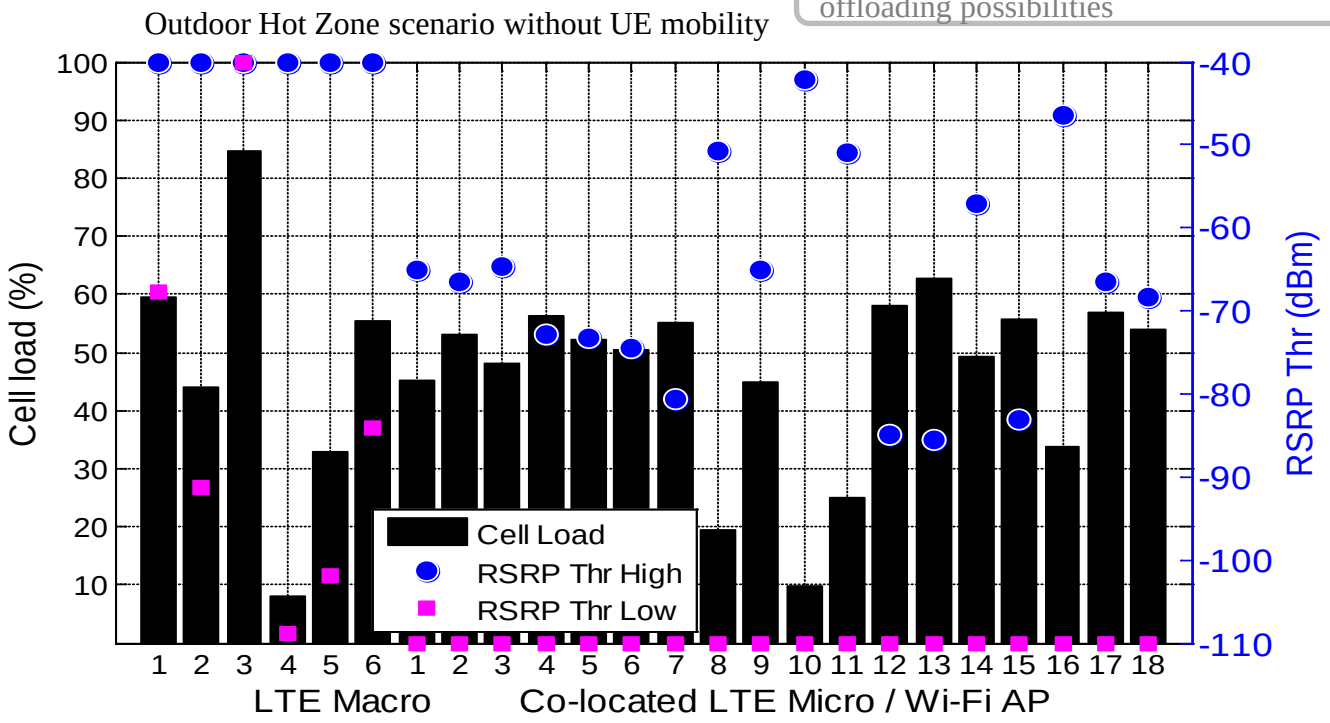
Objective	LTE Load Control	Inter-RAT Load Control
Control Parameter	RSS Threshold	RSRP Thresholds
Environment	Indoor	Outdoor
Mobility	Static Users	Mobile Users

- Presented in this presentation:
  - LTE Load Control + RSRP Thresholds + Outdoor + Static Users
  - Inter-RAT Load Control + RSS Threshold + Outdoor + Static Users

SON Function Evaluation – LTE Load Control

- **RSRP Threshold Low (macros) and RSRP Threshold High (micros) are properly adjusted to meet the objective, i.e. keep LTE cell load within target range (60-80%)**

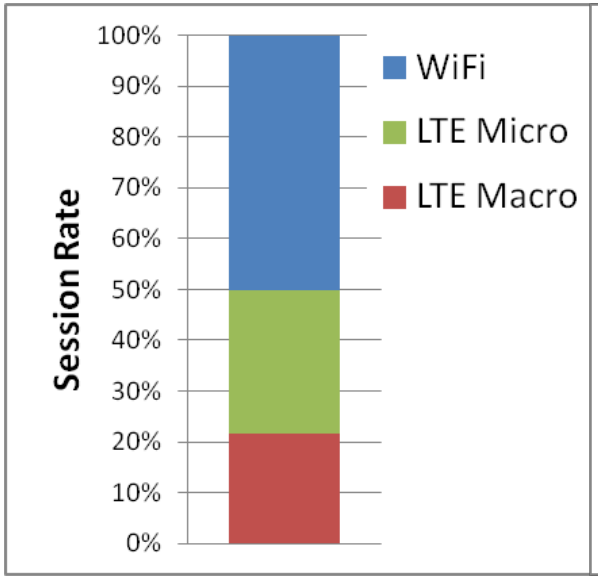
High load in macro#3 due to limited offloading possibilities

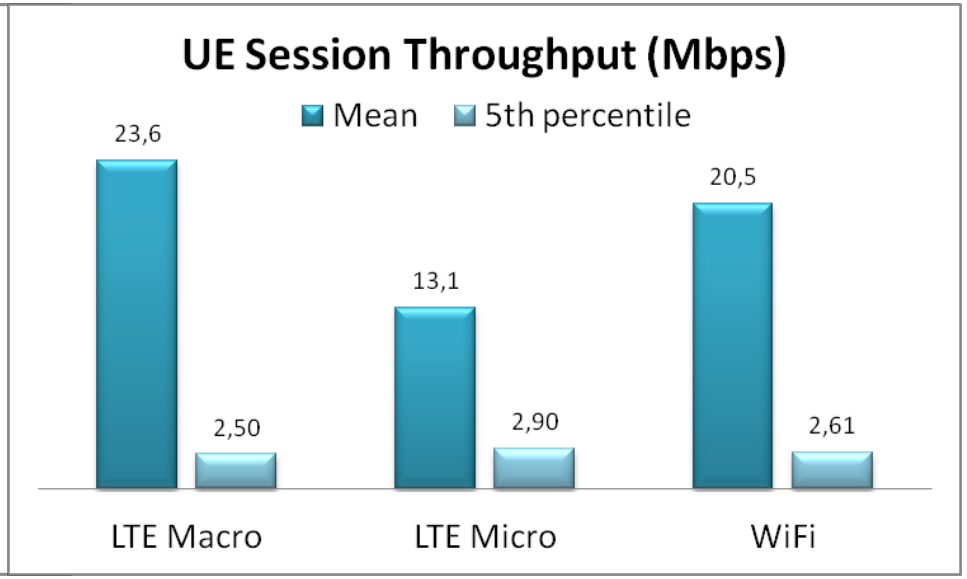


SON Function Evaluation – LTE Load Control cont'

- **The SON configuration results in 50% offload to Wi-Fi while good Wi-Fi throughput is achieved, i.e. 5th-ile throughput of 2.6 Mbps**
- **Overall good performance is achieved, avg UE throughput=19.1 Mbps**
  - vs. Baseline "Wi-Fi if coverage" with mean UE throughput = 10.5 Mbps
- **Micro performance lower than macro due to presence of cell-edge UEs**

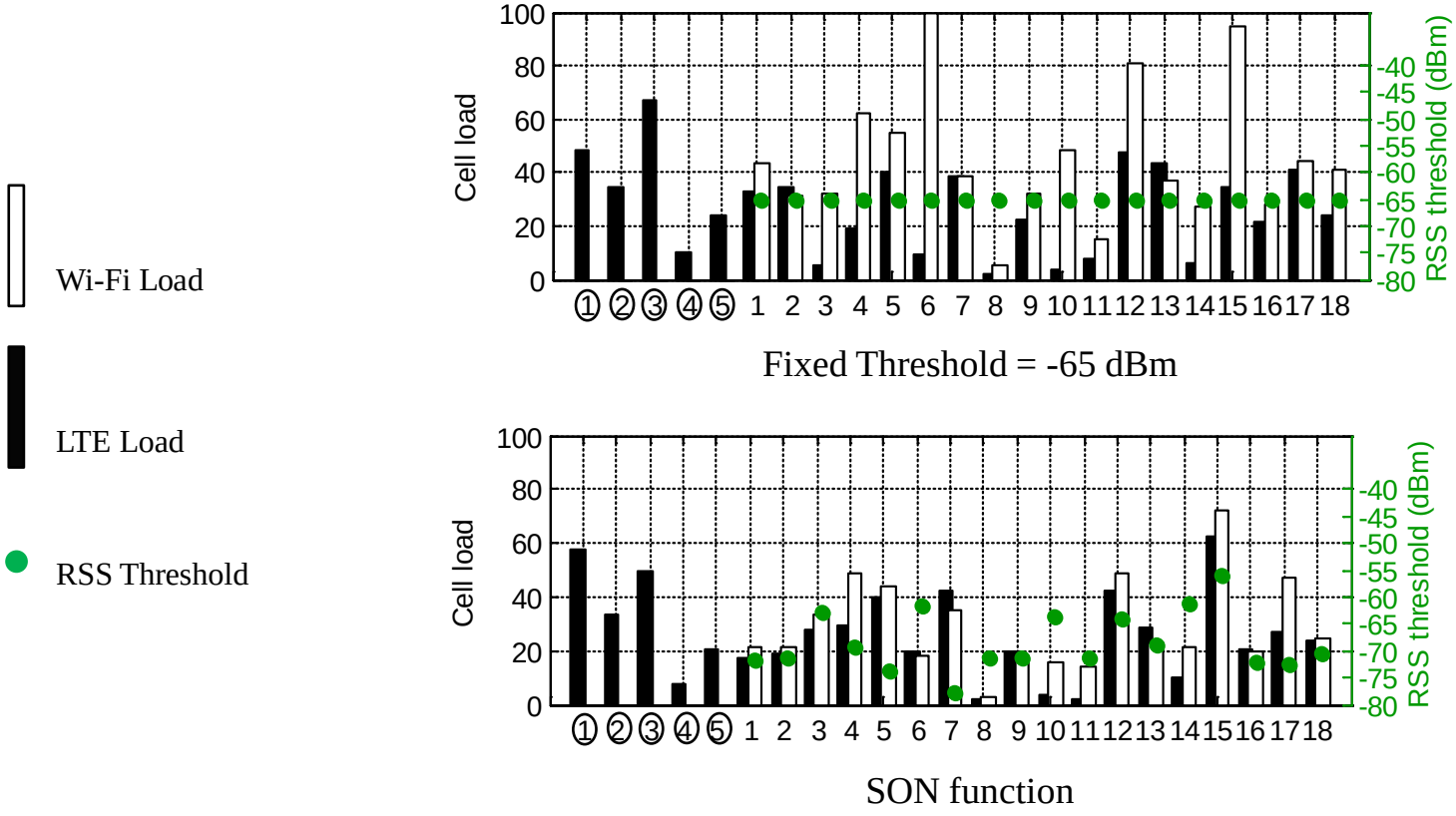
Outdoor Hot Zone scenario without UE mobility





SON Function Evaluation – Inter-RAT Load Control

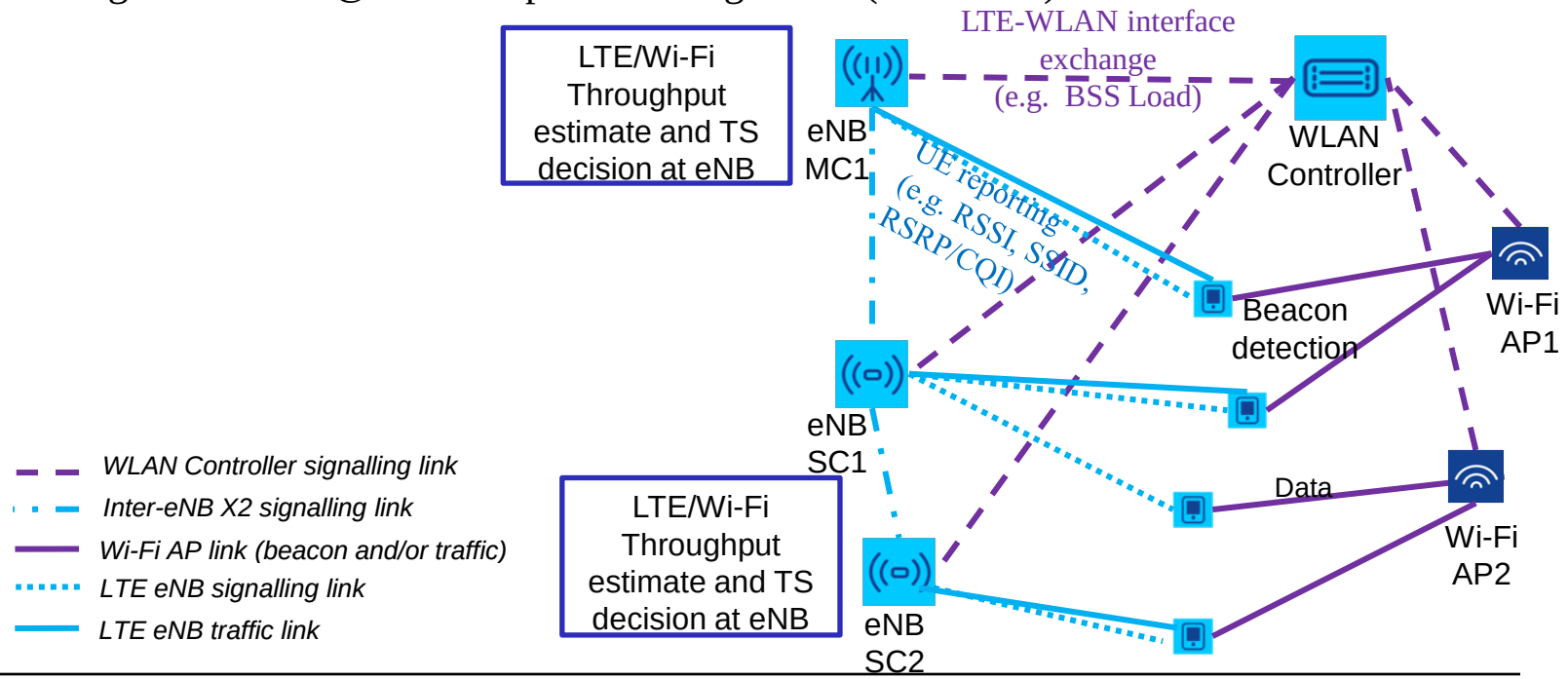
- RSS Thresholds are properly adjusted to meet the objective, i.e. balance the load between LTE and Wi-Fi



Throughput-based SON Functions

Principle of Throughput based Traffic Steering

- Throughput based Traffic Steering between LTE and Wi-Fi is based on predicted/measured user throughput in LTE and Wi-Fi
- A user session is served by the RAT (LTE or Wi-Fi) which provides the highest throughput (plus a hysteresis to minimize IRAT handovers)
- The algorithm runs @Call Setup and During a Call (if enabled)

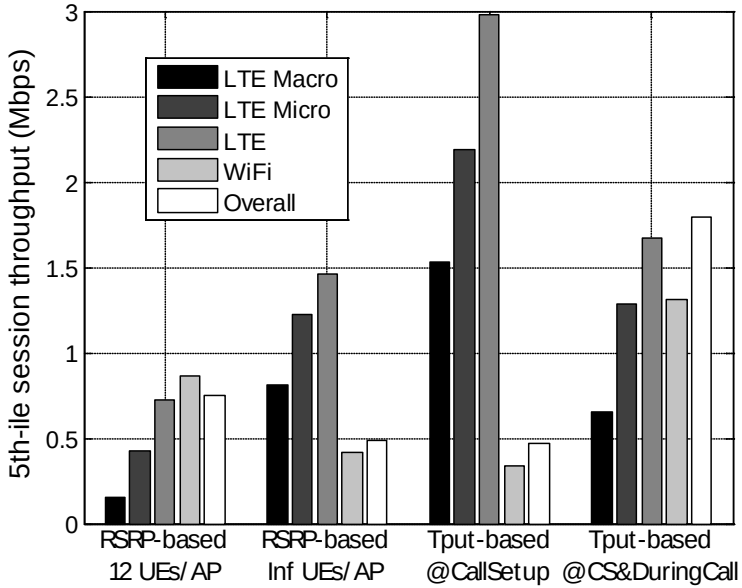


Results from Throughput basd SON functions

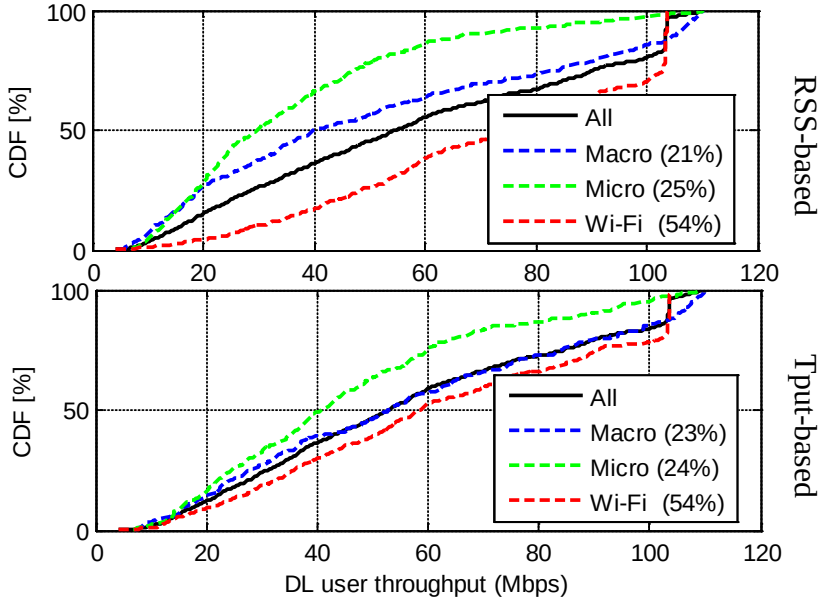
- Throughput based SON function outperforms the threshold based functions
  - Gains of 25%-240% for the 5th percentile user throughput depending on scenarios
  - More balanced user throughput among the network layers

Throughput based SON function example

Outdoor dense urban with UE mobility



Outdoor dense urban without UE mobility



SON Function Implementation

- **The proposed SON functions are intended to be implemented in a distributed manner**
  - Control parameters are updated every few seconds
- **Implementation of the access network selection rules**
  - **Executed in terminals assisted by the network**: Control parameter thresholds are sent to terminals via broadcasted or dedicated signalling channels being standardized in 3GPP (RAN2 R12)
  - **Controlled by the network**: Control parameters are monitored at a network node and the node controls the access network selection
- **Information exchange between LTE and WiFi**
  - Standardization of such an interface is being discussed in 3GPP (Release 13 work item RP151114 “LTE-WLAN Radio Level Integration and Interworking Enhancement” covers the LTE-WLAN exchange (between the LTE eNB and the WT (WLAN Termination function)) and the UE reporting of WLAN measurements required for implementing the presented schemes
  - Proprietary interfaces
  - Terminals as relays

Summary

- **SON functions for LTE and WI-Fi traffic steering have been designed, evaluated and demonstrated in realistic dense urban scenarios**
- **The effectiveness of the SON functions was proved with controlled load levels and improved user throughput**
- **We found the performance of the SON functions were most sensitive to the control parameter updating pace, i.e. the step size and period**
- **Throughput-based SON outperforms threshold-based SON in user throughput and improved manageability at the cost of further complexity (throughput prediction)**
- **Among other findings, the study unveiled the importance of information exchange between LTE and Wi-Fi**