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
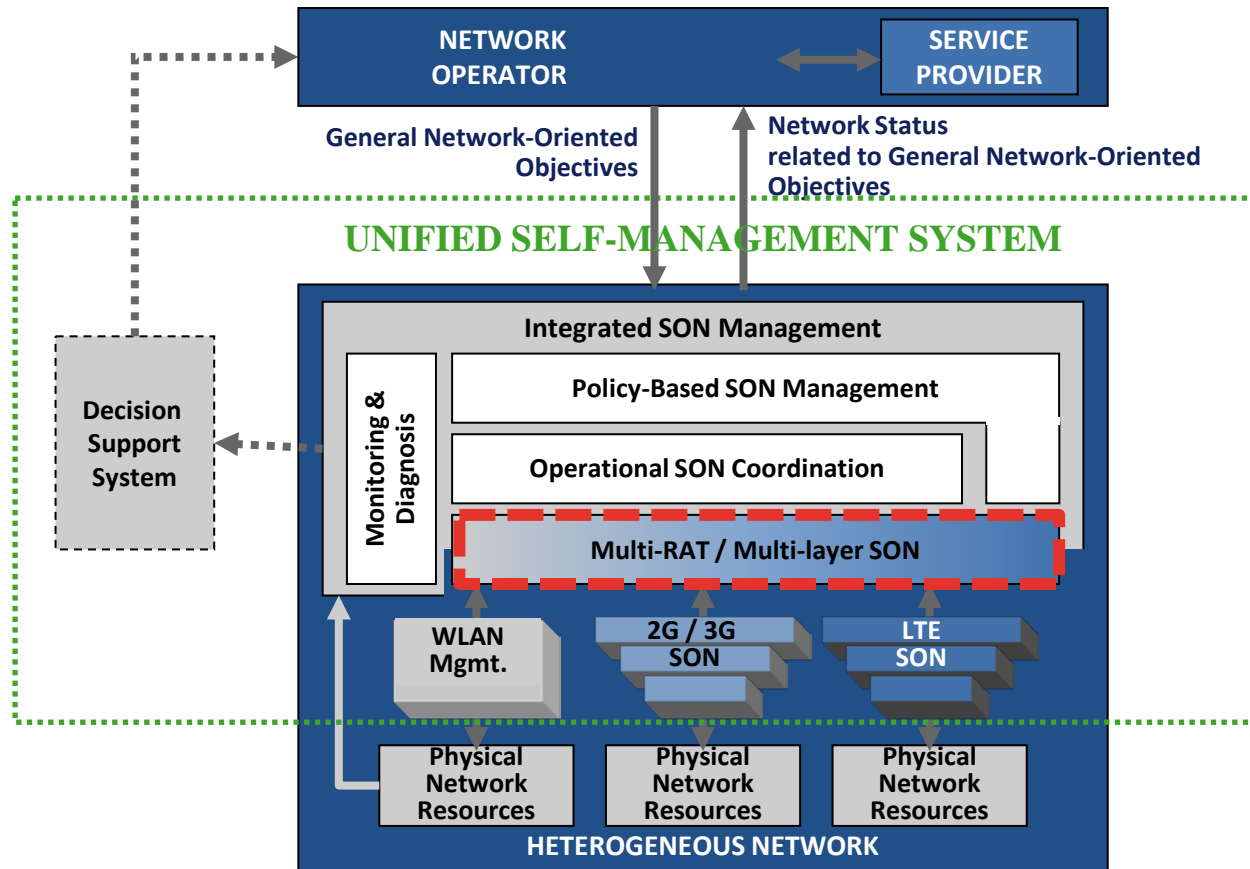
SEMAFOUR Key Facts

- 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)
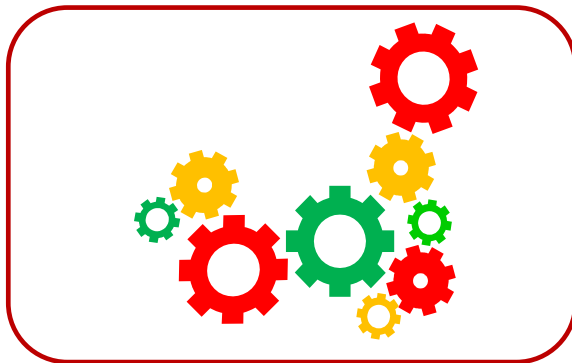
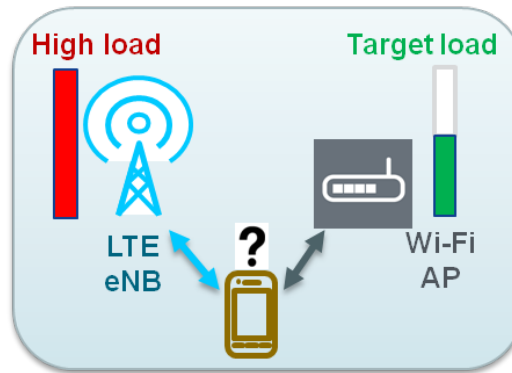# SEMAFOUR Partners
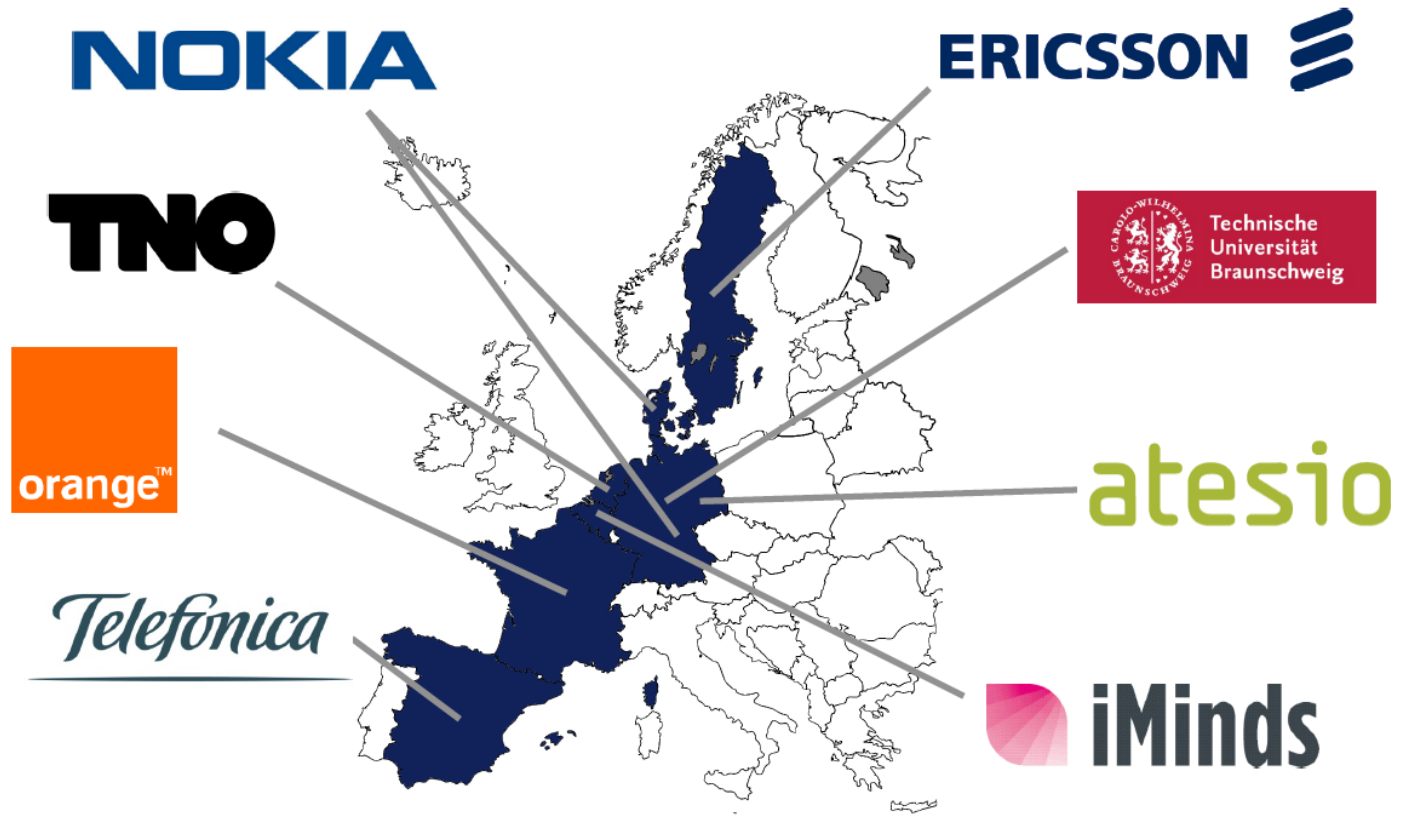
SEMAFOUR Vision

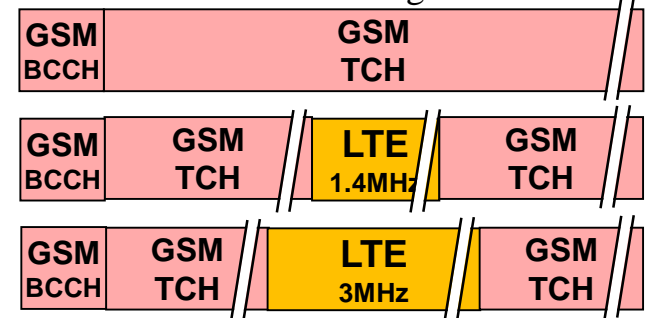# SON Functions for Multi RAT and Multi Layer Networks
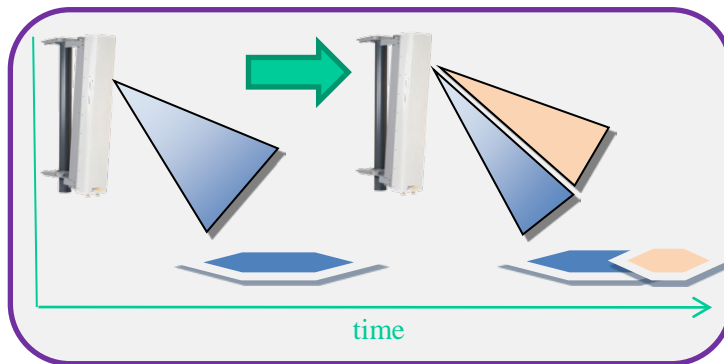
SON Design Principles

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

Yu Wang[+], Daniela Laselva[*], István Z. Kovács[*], Per-Henrik Michaelsen[*], Relja Djapic[φ], Pieter Willemen[^], Kathleen Spaey[x], Bart Sas[x], Dries Naudts[^], Andreas Bergström[+]

[+]Ericsson Research, Stockholm, Sweden; [*]Nokia, Aalborg, Denmark; [φ]TNO, Delft, Netherlands; [^]iMinds/Ghent University, Ghent, Belgium, [x] iMinds/University of Antwerp, Antwerp, Belgium

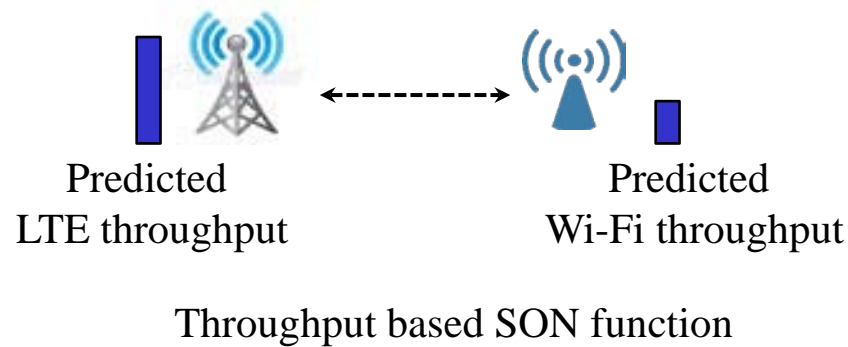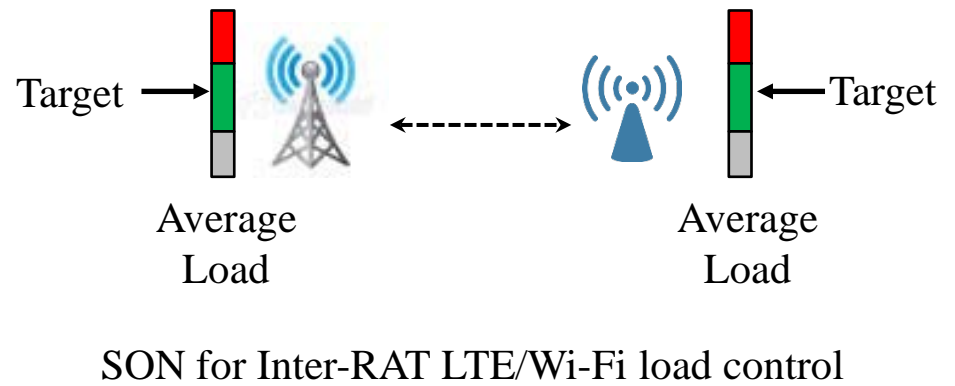# Why SON for LTE/WiFi Access Network Selection?

- **Operators are using Wi-Fi for offloading**
  - "Carrier grade Wi-Fi"

- **Great interests in integrating cellular and Wi-Fi networks**
  - WiFi Alliance: Hotspot 2.0 Release 1/2
  - 3GPP: IP session continuity, ANDSF, Radio interworking

- **One key technology component: access network selection**
  - Today behaviour: "*Wi-Fi If Coverage*".

- **SON for access network selection**
  - SON: proved working in related areas, e.g. load balancing
  - A good candidate to address the LTE/Wi-Fi access network selection in dynamic radio and traffic environments
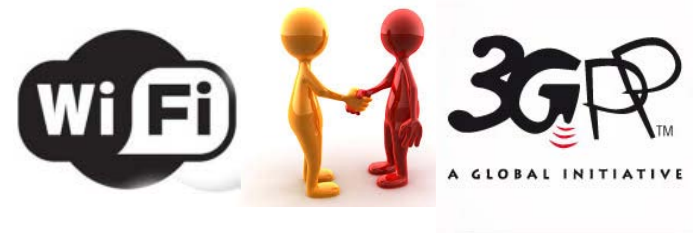
Objective (1/2)

- 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)

Target →

Average
Load

SON for LTE load control

Target →   ← Target

Average   Average
Load   Load

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

Predicted   Predicted
LTE throughput   Wi-Fi throughput

Throughput based SON function
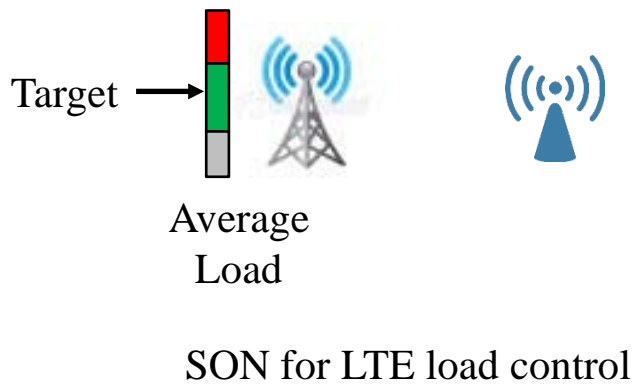
SON Function Design – Monitoring KPIs

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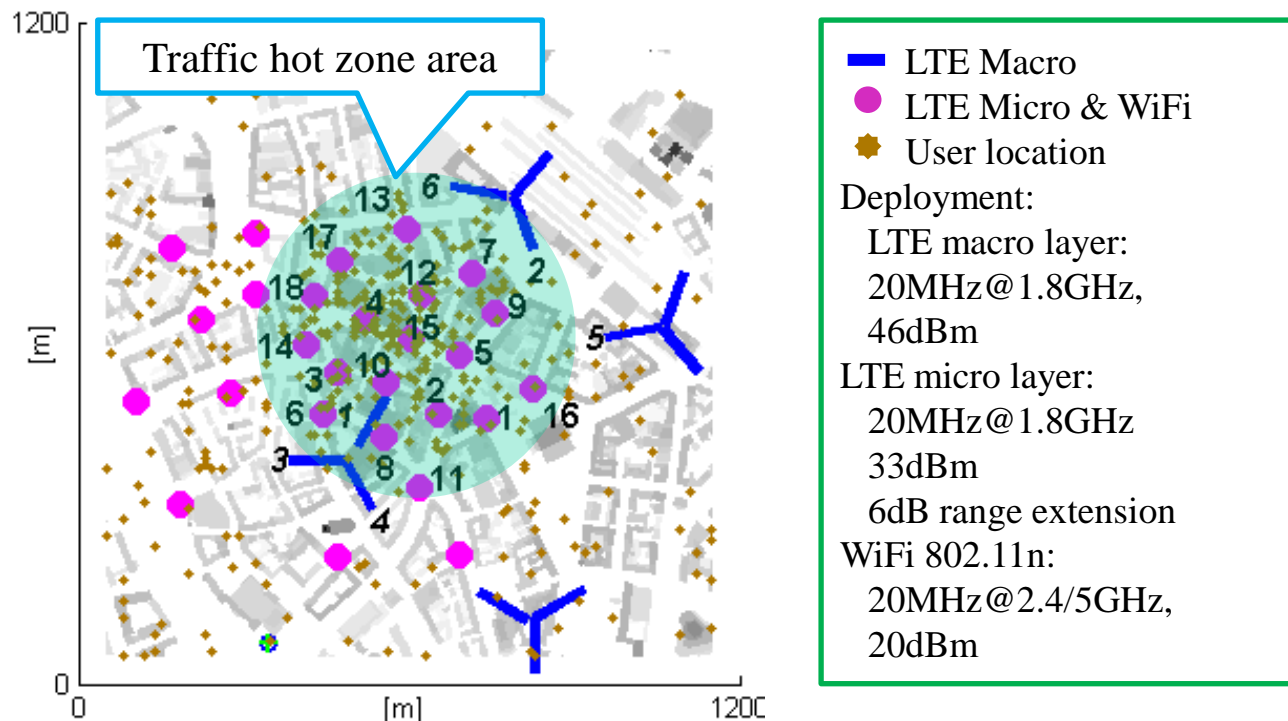
- **Wi-Fi load**
  - Average percentage of channel busy time of a Wi-Fi AP
  - The channel is considered as busy if there is at least one active connection associated to the AP and the AP or a UE is transmitting

- 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)
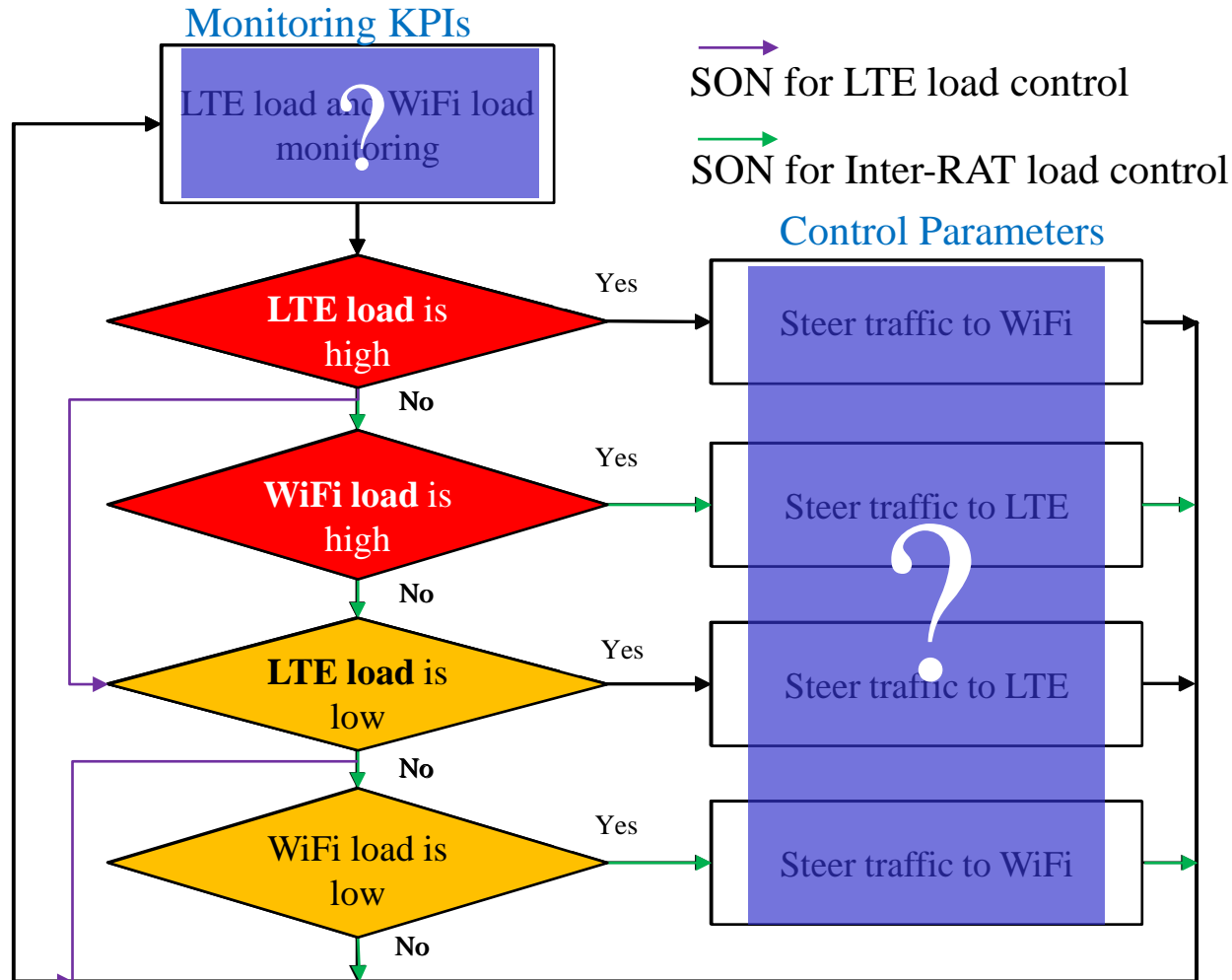
SON Function Evaluation - Scenario

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

Outdoor Hot Zone

Threshold based SON Functions

SON Function Design for the Access Network Selection

Monitoring KPIs

LTE load and WiFi load monitoring

SON for LTE load control

SON for Inter-RAT load control

Control Parameters

LTE load is high — Yes → Steer traffic to WiFi

No

WiFi load is high — Yes → Steer traffic to LTE

No

LTE load is low — Yes → Steer traffic to LTE

No

WiFi load is low — Yes → Steer traffic to WiFi
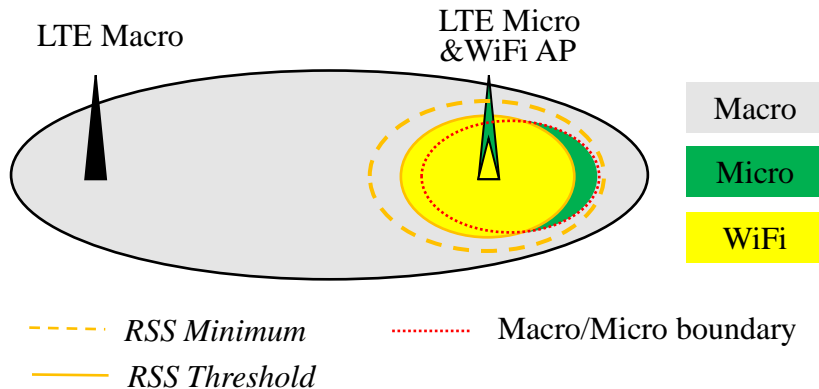
No

* When both LTE and WiFi load is high or low, no action will be taken

SON Function Design – Control Parameters

WiFi RSS Threshold　　　　**LTE RSRP High & RSRP Low Thresholds**
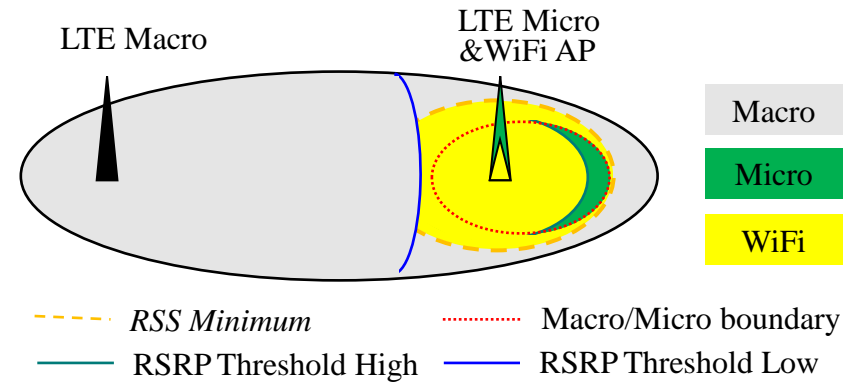
To steer more traffic to WiFi

– 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

Outdoor Hot Zone scenario without UE mobility
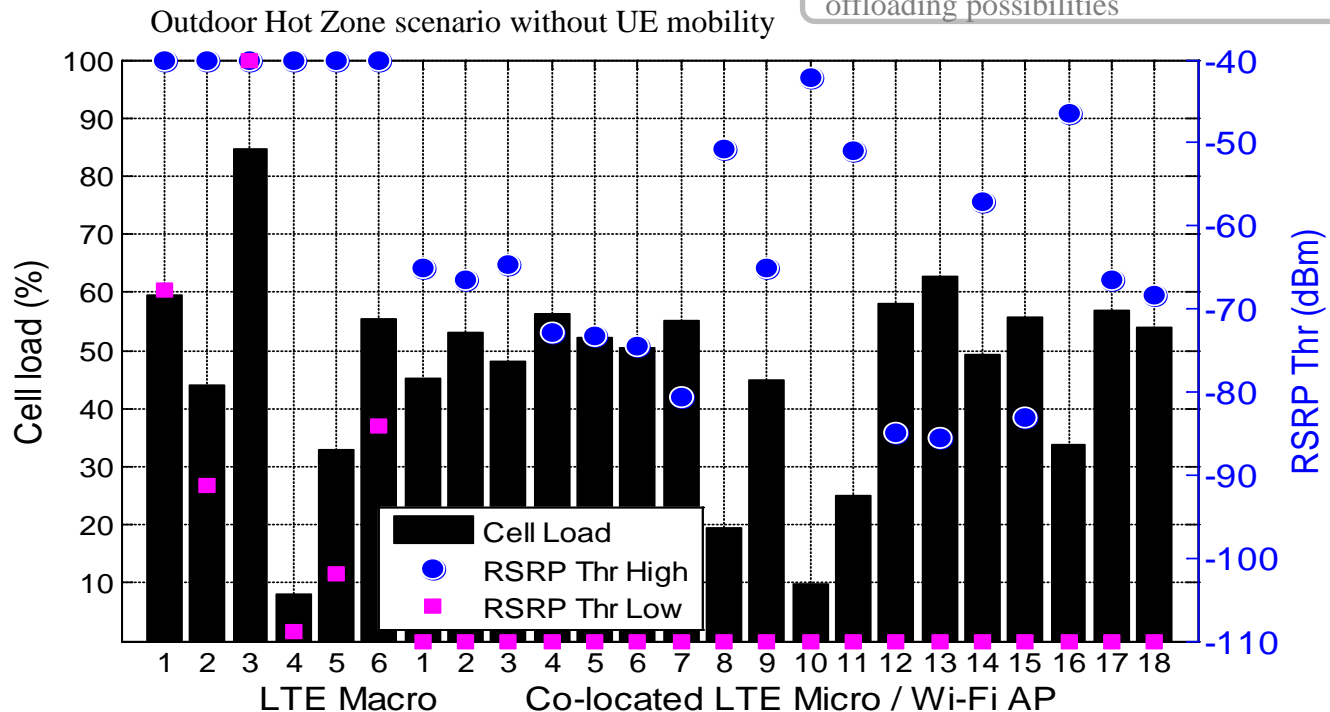
# SON Function Evaluation – LTE Load Control cont'

- **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
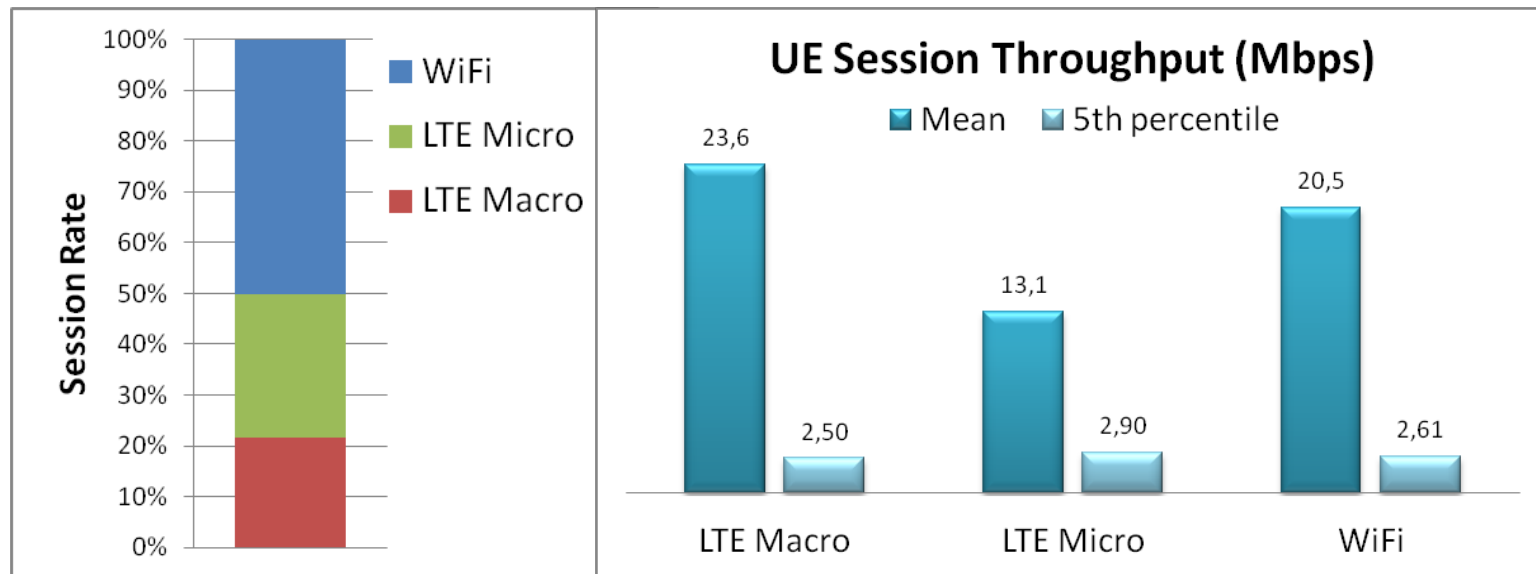
# SON Function Evaluation – Inter-RAT Load Control

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

Wi-Fi Load

LTE Load

● RSS Threshold

Fixed Threshold = -65 dBm
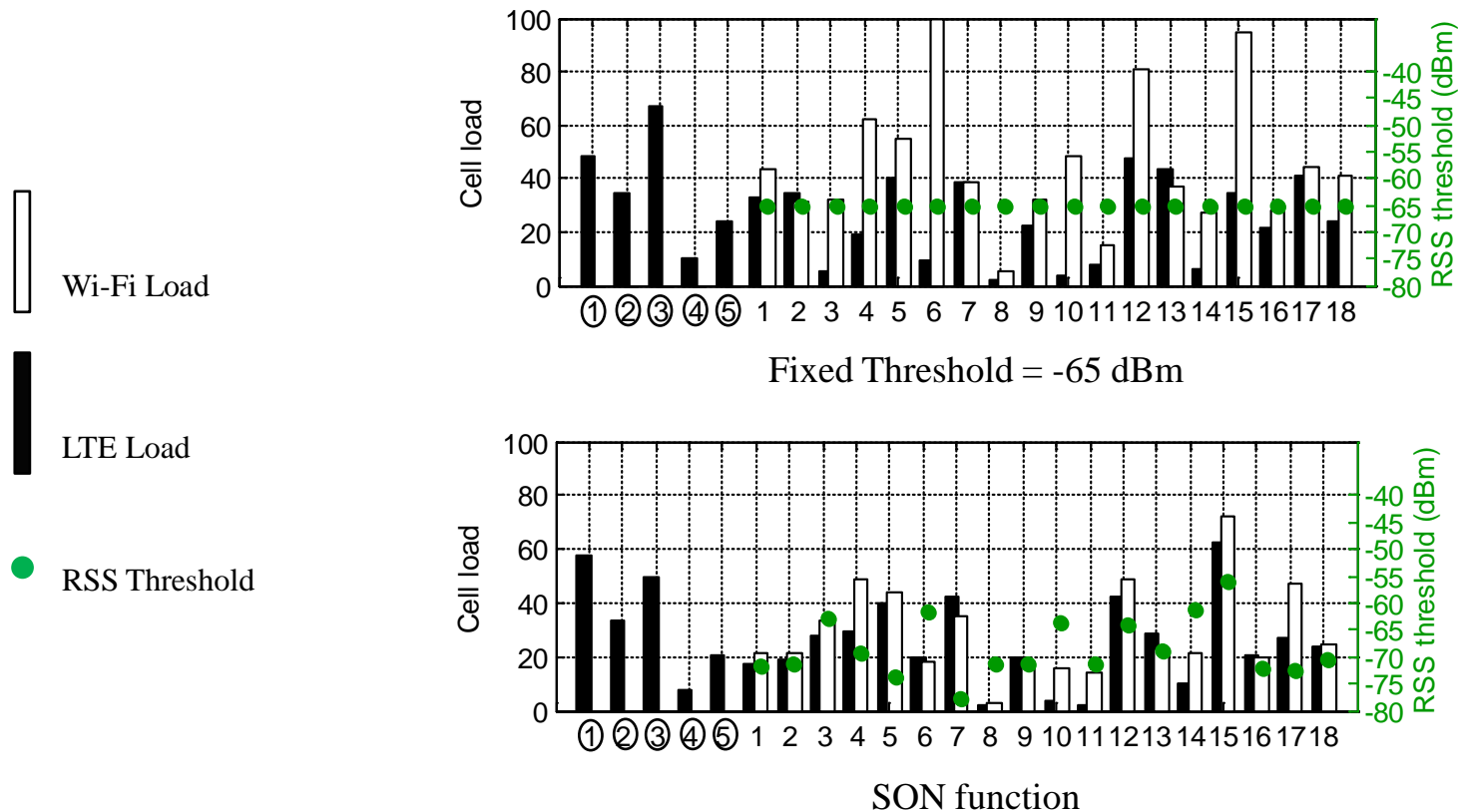
SON function

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)
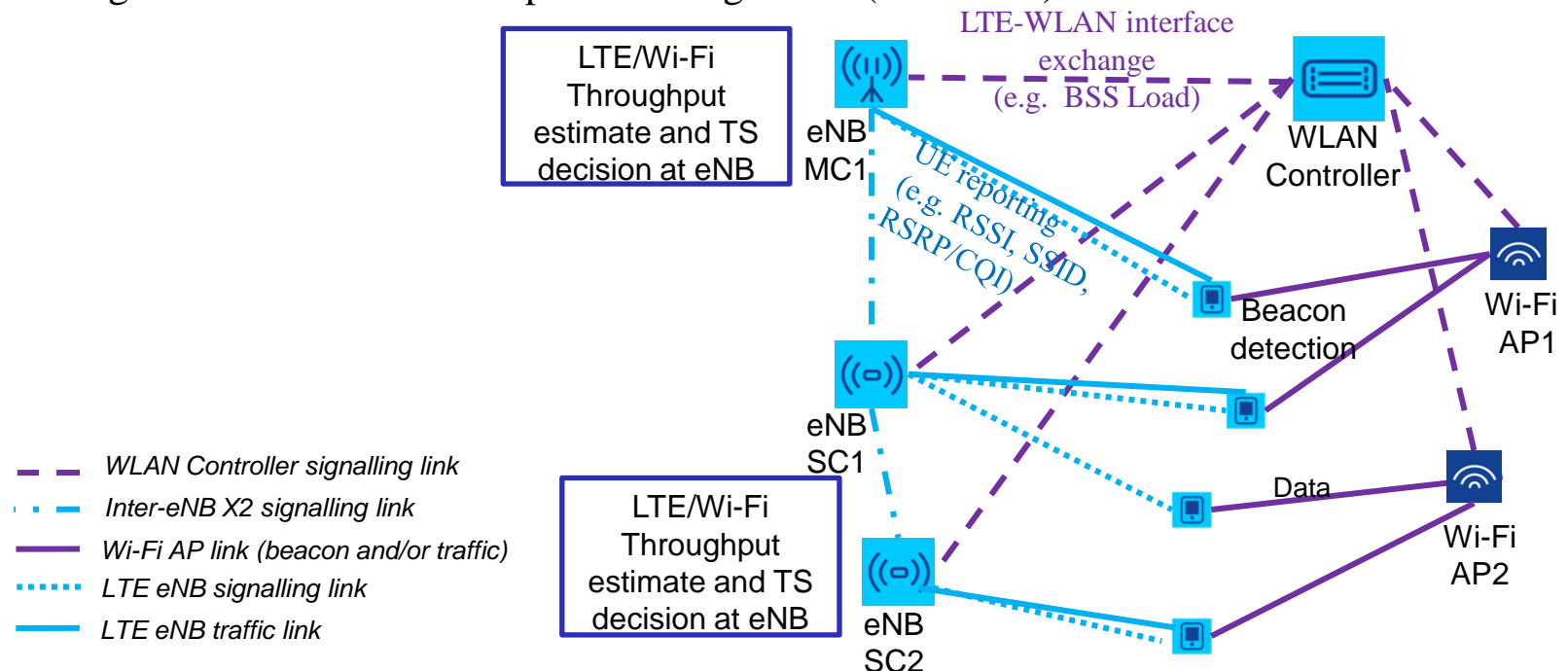
Results from Throughput basd SON functions

- 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
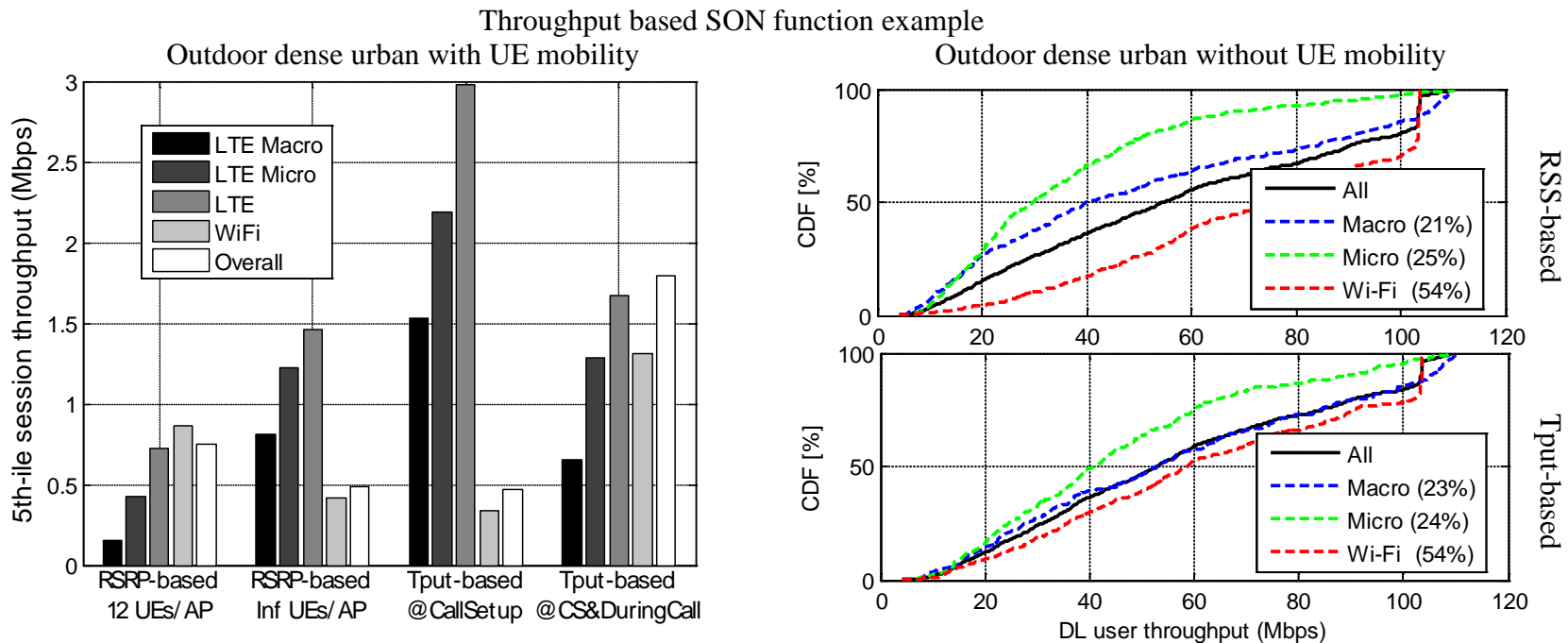
SON Function Implementation

- **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**