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

Author: Thomas Kürner
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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

- NOKIA
- ERICSSON
- TNO
- orange™
- Telefonica
- atesio
- Technische Universität Braunschweig
- iMinds
SEMAFOUR Vision

UNIFIED SELF-MANAGEMENT SYSTEM

Integrated SON Management

Policy-Based SON Management

Operational SON Coordination

Multi-RAT / Multi-layer SON

WLAN Mgmt.

2G / 3G SON

LTE SON

Physical Network Resources

Physical Network Resources

Physical Network Resources

HETEROGENEOUS NETWORK
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 extended version from:

Multi-Layer LTE / Wi-Fi Access Network Selection

Yu Wang†, Daniela Laselva*, István Z. Kovács*, Per-Henrik Michaelsen*, Relja Djapicφ, Pieter Willemen^, Kathleen Spaeyx, Bart Sasx, Dries Naudts^, Andreas Bergström+

†Ericsson Research, Stockholm, Sweden; *Nokia, Aalborg, Denmark; φTNO, Delft, Netherlands; ^iMinds/Ghent University, Ghent, Belgium, x iMinds/University of Antwerp, Antwerp, Belgium
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

Predicted LTE throughput

Predicted 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 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

Traffic hot zone area

Deployment:
- LTE Macro
- LTE Micro & WiFi
- User location

LTE macro layer:
- 20MHz@1.8GHz, 46dBm

LTE micro layer:
- 20MHz@1.8GHz, 33dBm
- 6dB range extension

WiFi 802.11n:
- 20MHz@2.4/5GHz, 20dBm
Threshold based SON Functions
SON Function Design for the Access Network Selection

* 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

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<th>Objective</th>
<th>LTE Load Control</th>
<th>Inter-RAT Load Control</th>
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<tr>
<td>Control Parameter</td>
<td>RSS Threshold</td>
<td>RSRP Thresholds</td>
</tr>
<tr>
<td>Environment</td>
<td>Indoor</td>
<td>Outdoor</td>
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<tr>
<td>Mobility</td>
<td>Static Users</td>
<td>Mobile Users</td>
</tr>
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- 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

![Graph showing cell load versus RSS threshold for Wi-Fi and LTE, with a fixed threshold of -65 dBm.](image)
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 based 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
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