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D3.4

Demonstration Scenarios (updated version)

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Abstract: The overall objective of the SEMAFOUR project is to design and develop a unified self-management system for heterogeneous radio access networks, representing the complete environment as one single network towards the operator through a unified view. The objective of WP3 is to visually present the key project results and findings through demonstration activities. This deliverable elaborates the demonstration objectives and approach, and furthermore describes a set of specific demonstration scenarios based on use cases considered in the SEMAFOUR project.

Keywords: Multi-layer, Multi-RAT, Policy Based SON Management, Self-management, SON, SON Coordination, Demonstrations, Demonstration Scenarios, Decision Support System, Traffic Steering, Dynamic Spectrum Allocation, Interference Management, High Mobility, Active Antenna Systems.

Executive Summary

The overall objective of the SEMAFOUR project is to design and develop a unified self-management system for heterogeneous radio access networks, representing the complete environment as one single network towards the operator through a unified view. This deliverable elaborates on the demonstration scenarios and gives an overview of the demonstration platform that has been developed in the SEMAFOUR project. The objective of this platform is to showcase the key project results achieved in WP4 and WP5, and captured in deliverables D4.2 [5], D4.3 [6] and D5.3 [7].

For each SON use case developed within SEMAFOUR, a description of the demonstration objective(s) is given, followed by the specific assumptions and scenarios in which the SON (management) use cases are evaluated. Key demonstration KPIs are defined and a short description of the SON use case is presented, as well as the overall storyline of the specific use case demonstration, highlighting the main benefits.

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List of Acronyms and Abbreviations

3GPP	3rd Generation Partnership Project
BSA	Best Server Area
AAS	Active Antenna Systems
CAC	Composite Available Capacity
DSA	Dynamic Spectrum Allocation
CDR	Call Drop Rate
CDS	Central Demo Server
DSS	Decision Support System
GSM	Global System for Mobile communication
HO	Handover
KPI	Key Performance Indicator
LTE	Long Term Evolution
MD	Monitoring & Diagnosis
OHZ	Outdoor Hot Zone
OAM	Operation, Administration and Maintenance
PBSM	Policy-Based SON Management
QoS	Quality of Service
RE	Resource Efficiency
QoS	Quality of Service
PBSM	Policy-Based SON Management
RAT	Radio Access Technology
SON	Self-Organising Network
SONCO	SON Coordinator
SSR	Short Stay Rate
TS	Traffic Steering
WLAN	Wireless Local Area Network
WP	Work Package

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1 Introduction

The overall objective of the SEMAFOUR project is to design and develop a unified self-management system for heterogeneous radio access networks, representing the complete environment as one single network towards the operator through a unified view. The project is divided into a number of work packages (WPs), including:

- WP2: “Requirements, Use Cases and Methodologies”. In WP2, the self-management use cases are defined, together with their requirements.
- WP3 “Demonstrator”. The objective of WP3 is to communicate the key project results and findings through demonstration activities and to develop a demonstrator platform suitable for these purposes. The outcome of WP4 and WP5 form the input to the demonstration activities in WP3.
- WP4: “SON for Future Networks”. In WP4, SON functions for multi-layer LTE networks, for multi-RAT networks and for integrated multi-RAT and multi-layer networks are developed.
- WP5: “Integrated SON Management”. In WP5, concepts, methods and algorithms for an integrated SON management consisting of policy transformation and supervision, operational SON coordination, and monitoring, are developed.
- WP6: “Dissemination and Exploitation”. In WP6, dissemination and exploitation activities are defined and executed in order to maximise the impact of the project results. An important dissemination instrument is the SEMAFOUR demonstration platform developed in WP3 and discussed in this deliverable.

The WP3 deliverable D3.1 ‘Demonstration Scenarios’ [2] described the high-level demonstration objectives, requirements, the approach, and defined a set of specific demonstration scenarios. These scenarios were based on a subset of the SEMAFOUR use cases as presented in SEMAFOUR deliverable D2.1 [3]. In this deliverable, there is a further elaboration of the demonstration scenarios as well as an overview of the demonstration platform that has been developed to showcase the key project results achieved in WP4 and WP5, and captured in deliverables D4.3 [6] and D5.3 [8]. In contrast to D3.1, we base the scenarios on the final SEMAFOUR WP4 and WP5 results ([5], [6] and [8]) and describe the demonstration of these results using the demonstrator developed [15]. In addition, this deliverable gives an overview of the demonstration platform, including all the subcomponents, which was not included in D3.1.

For the following use cases, scenarios are show-cased in the demonstrator and described in this deliverable:

- Dynamic spectrum allocation and interference management
- Multi-layer LTE/Wi-Fi traffic steering
- Handling users with high mobility
- Active antenna systems
- Policy based SON management and SON coordination
- Decision support system for operational network evolution

For each use case above, a description of the demonstration objective is given, followed by the specific assumptions and scenarios in which the SON (management) features are evaluated. Key demonstration KPIs are defined and a short description of the SON function is presented, as well as the overall storyline of the specific use case demonstration, highlighting the main benefits. The outline of this report is as follows. In Chapter 2, an overview of the demonstration platform is given, followed by specific demonstration scenarios for SON use cases developed in the SEMAFOUR project in Chapters 3-8. This report is concluded by a summary in Chapter 9.

2 Description of the Demonstration Platform

In this chapter we give an overview of the demonstration platform that has been developed in the SEMAFOUR project. This platform supports the demonstration of scenarios that have been developed to showcase the key project achievements, namely: *(i) integrated SON management*, including a Policy-Based SON Management (PBSM) functionality and a SON Coordinator (SONCO); *(ii)* advanced *multi-layer/RAT SON functions*; and *(iii)* a Decision Support System (DSS). We also indicate how content is stored in the form of recorded traces and how the demonstrator is used to manoeuvre through various traces in order to showcase an integrated demonstration scenario. The chapter is organised by the descriptions of the different components of the demonstrator's client-server architecture as visualised in Figure 1.

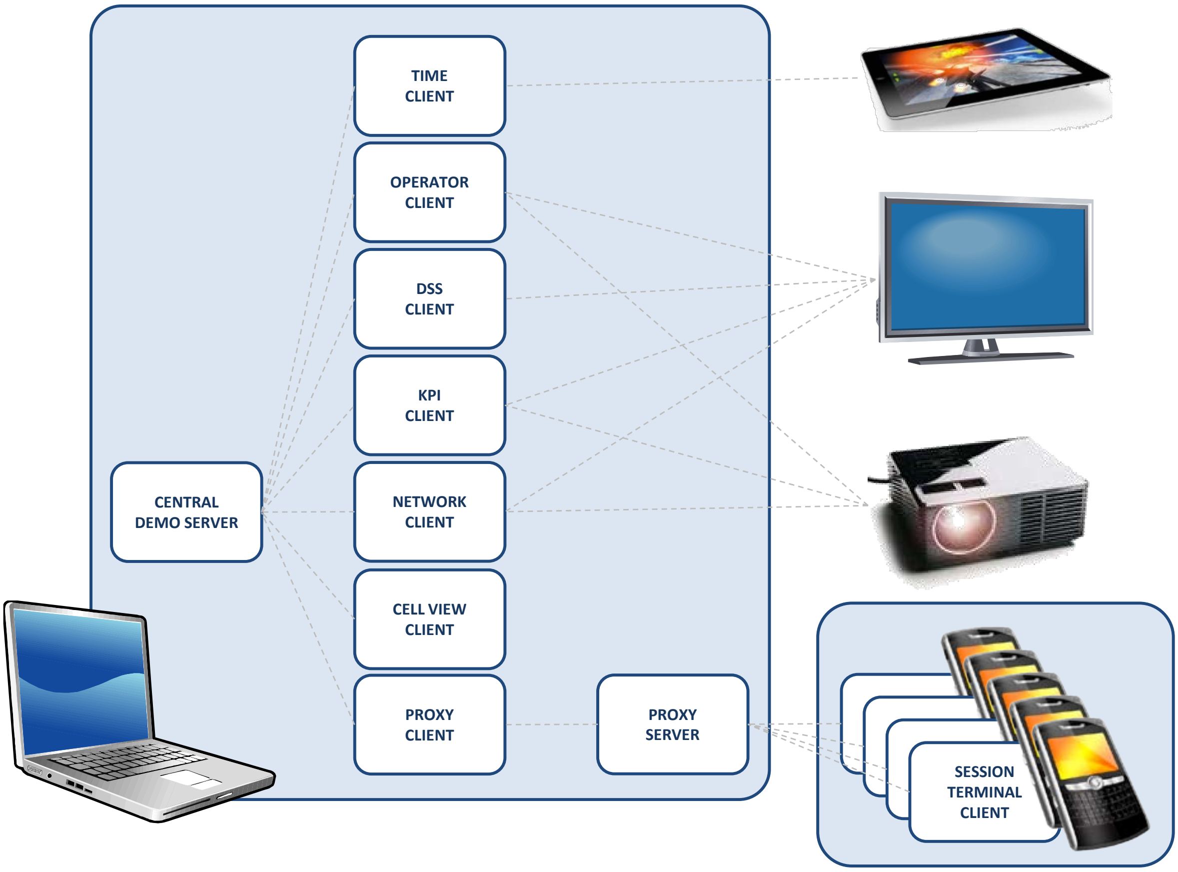


Figure 1: Architecture of the SEMAFOUR demonstrator.

2.1 Central Demo Server

The key roles of the Central Demo Server (CDS) are the authorisation and synchronisation of the different clients, the storage of configuration data, and the storage and playout of recorded simulation traces.

Regarding the latter we note that, since the execution time of these simulations is generally significantly slower than the desired playout speed of the demonstration, it is not supported for the simulations to be executed on-line, i.e. whilst the demonstration is running. Instead, simulations are done off-line, i.e. in advance before the demonstration is made. This makes it obviously impossible to have direct control over the settings of the simulated network, such as SON (management) function configurations, traffic load, etc, during an on-going demonstration. This controllability is provided to the required extent by the possibility to switch between several so-called 'branches', where each such branch is a pre-simulated trace representing a certain network configuration, e.g. with the given SON functionality on/off etc. or with a certain network deployment. All these branches are stored in the

CDS, and manoeuvring through the different branches in order to establish a targeted demonstration storyline is done primarily via the Operator Panel (see below).

2.2 Time Client

The Time Control Panel (see Figure 2) not only shows the demonstration's actual date/time stamp, as also visible on the banners of other clients, it also provides mechanisms to affect the date and time . It provides control of the 'speed of time', i.e. it allows speeding up or slowing down of the demonstrations. This allows the presenter to select an acceleration factor from a pull-down list. Setting it to '1.0' implies that the demonstration runs in real-time, playing out one demonstration minute per wall clock minute, while higher settings effectuate a faster than real-time demonstration. In addition, it provides a mechanism to make the demonstrator jump to the next day. This is for instance used when a change made on the Operator Panel is to be deployed, e.g. regarding the operator's technical objectives, which are assumed to be effectuated overnight when the disruptive effects of such a change are minimal due to light traffic. The Time Control Panel further allows the pause and restart of a running demonstration.

Figure 2: Time Panel.

2.3 Operator Client

The Operator Panel (see Figure 3) serves as the key interface for the network operator to the self-managed multi-layer/RAT network and comprises multiple components. On the *Control* tab of the *Objectives* frame[1], SON (management) functions can be (de)activated and selected options can be deployed in the demonstrated network. More specifically, demonstrations can be configured and hence compared at three distinct levels: *(i)* scenarios with no active SON (management) functions; *(ii)* scenarios with one or more active SON functions; and *(iii)* scenarios with managed SON functions, involving PBSM and SONCO in order to dynamically configure and coordinate active SON functions in line with an operator-selected high-level objective (considered options are 'Optimise Performance' and 'Optimise Robustness'; see also Chapter 7). In a complete demonstration scenario, one would typically first show the network operation and performance for the 'no SON' scenario, subsequently

[1] A 'frame' is a designated area of information on a panel, like a 'subwindow within a window', as immediately understood when looking at e.g. Figure 3.

activate SON functions and observe their induced performance impact, and lastly turn on the SON Management layer and demonstrate how the SON functions are adaptively configured and observe how this optimises the network in line with the selected objective.

These technical objectives are specified in more detail on the *Objectives* tab in the same frame, in terms of the Key Performance Indicators (KPIs) that are of relevance, e.g. user throughput and call drop ratio, with associated target levels and an inter-KPI priority ordering. The relevant KPIs, the target levels and the priority ordering may be set distinctly for different cell classes (defined on the *Classes* tab) based on context, e.g. the environment, the degree of mobility and on whether the cell is currently operating in busy or normal hour traffic conditions.

The *SON Parameters* frame details for each SON function the different SON function Configuration parameter Value (SCV) sets, where each such SCV set provides a distinct configuration of the SON function in terms of, e.g. thresholds and step sizes, that are applied in the self-optimisation algorithm. If the PBSM functionality is active, it will dynamically and on a per cell class basis choose the applied SCV set based on observed context and in line with the selected high-level objective.

During a demonstration, the *Policy & Performance* frame is continuously updated to show for each defined cell class the number of cells that currently fall into the cell class, the SON function-specific SCV set that currently applies as well as the so-called ‘Class Satisfaction’, which indicates the current degree to which the cell-class specific KPI targets are satisfied in the associated cells.

The *Log Messages* frame is included in the Operator Panel in order to provide the network operator some insight into the ‘black box’ of SON (management) which generally comprises confidential vendor-specific algorithms. Upon any decision event for a SON (management) function it is logged *where* (typically: in which cell) a decision was made, what *observation* caused the decision event, and what *decision* was taken.

Finally, in the *DSS Messages* frame the Decision Support System (DSS) issues a message stating that it has performed a predictive analysis of network performance and resource utilization in order to forecast the emergence of bottlenecks. If ‘the analysis indicated no need to initiate network upgrades’ the message is presented in a reassuringly green colour. Alternatively, if ‘the analysis revealed a need to initiate a network upgrade for the continued provisioning of coverage and service quality as targeted in the network-oriented objectives’ the message is presented in an alarming red colour, and the provided buttons can be clicked in order to visualise key insights and recommendations on a separate DSS Panel (see below).

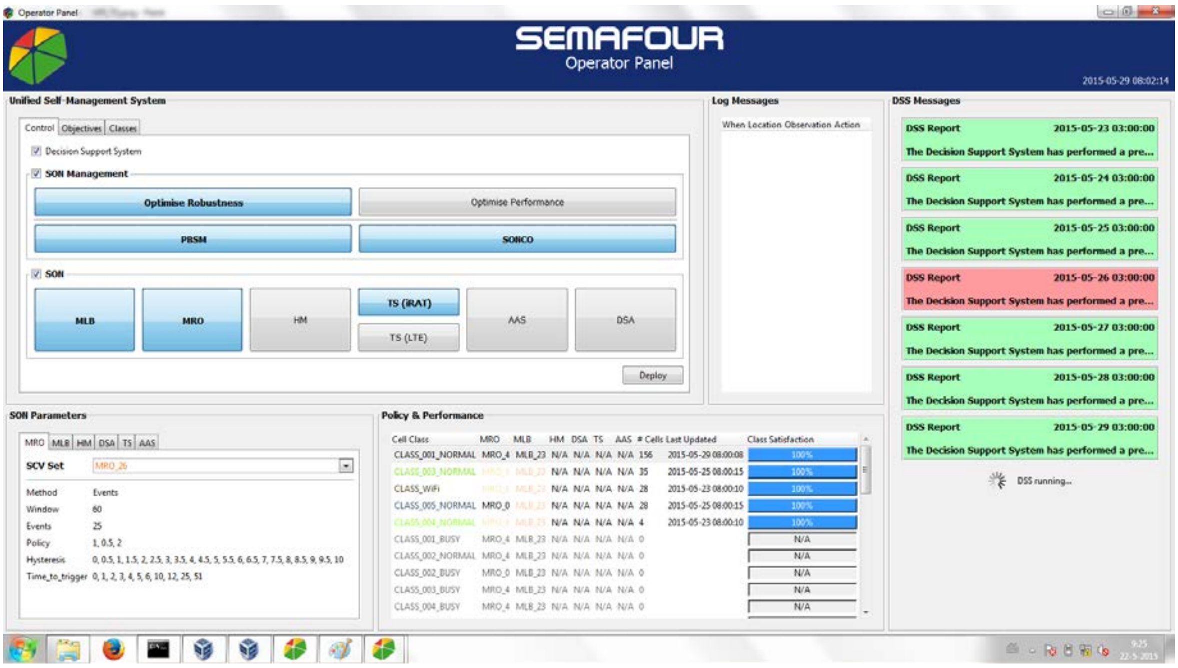


Figure 3: Operator Panel.

2.4 DSS Client

The DSS Panel (see Figure 4) features a red rather than a blue banner in order to stress that we are now no longer looking at the actual evolution of the Hannover network, but rather at predictions of future loads and performance. The panel, displayed upon a click of the ‘Show DSS Panel’ button on the Operator Panel (see above), is designed to visualize the predicted evolution of (over)loads and user throughput performance for a baseline scenario of the given network deployment as well as for up to two additional scenarios with selected network upgrades, e.g. a site addition or the six-sectorization of an existing site, deployed to prevent the predicted load/performance bottleneck from emerging. Such bottlenecks are derived and presented in the form of problem zones, i.e. a geographical area where the predicted network overload leads to an unacceptable high degree of unserved (or unsatisfactorily served) traffic.

In the panel configuration menu, the presenter firstly selects from a pull-down list which of the problem zones is to be addressed, each with its own geographical area and predicted date of emergence, i.e. the date at which the more or less gradually emerging ‘overload area’ is deemed to be a significant problem. With problem zones ordered by their predicted date of emergence, the one listed at the top is the most urgent one and also the zone that triggered the DSS alert on the Operator Panel. Subsequently, the presenter can select up to two network upgrade options from the presented shortlist, while furthermore either ‘overload’ or ‘user throughput’ can be selected as a displayed metric. Once the ‘play’ button is clicked, time starts progressing from the triggering time until beyond the time of the predicted problem zone. On the network maps (one for the baseline scenario and one for each selected network upgrade) at the top of the panel, the area of Hannover surrounding the problem zone is displayed. The selected metric is displayed both at the pixel and at the cell level. Furthermore, the problem zone is shown, as it is predicted to change over time in the different scenarios and, as a non-changing polygon, the problem zone predicted for the time it was deemed a significant problem if no network upgrades were enforced to prevent it. The chart below the network maps show a time-varying curve of the selected metric for each of the three scenarios. These three curves are noted to coincide up until the moment where in the non-baseline scenarios the network upgrade is scheduled to become effective. Beyond that moment, the curves indicate, as do the maps, the extent to which the network upgrades resolve the predicted problem.

Figure 4: DSS Panel.

2.5 KPI Client

The KPI Panel (see Figure 5) displays a number of charts showing the temporal evolution of a set of configurable, scenario-specific KPIs. The panel has the option to show multiple curves per chart/KPI, e.g. for different cell classes or for different RATs or network layers. The comparison of different SON (management) settings, as configured via the Operator Panel, is best done via metrics shown on the KPI Panel. Since such configuration changes are enforced overnight, as explained above, the comparison is effectively a comparison of KPIs over subsequent days, which are readily distinguished by alternating shades of grey for the chart's background colour.

As explained below under 'Proxy Client/Server/Session terminals', one of two ways to emulate representative user-level performance on actual session terminals is to select by right-clicking e.g. the 50th user throughput percentile curve, if indeed displayed on the KPI Panel, and map this metric to one of the attached session terminals. The Proxy Client/Server will then, just like the KPI Panel, retrieve the temporal variations of this metric from the CDS, and use this metric to emulate the median quality experience of video streaming session in the demonstrated scenario. The KPI Panel supports this selection procedure and changes the selected curve to a thicker curve displayed in a colour that matches the thick rim bordering the video image on the associated session terminal. With the option to associate up to four session terminals 'to the KPI Panel' this colour coding enables the audience to know which terminal is matched to which KPI curve and hence what performance level to expect on each session terminal.

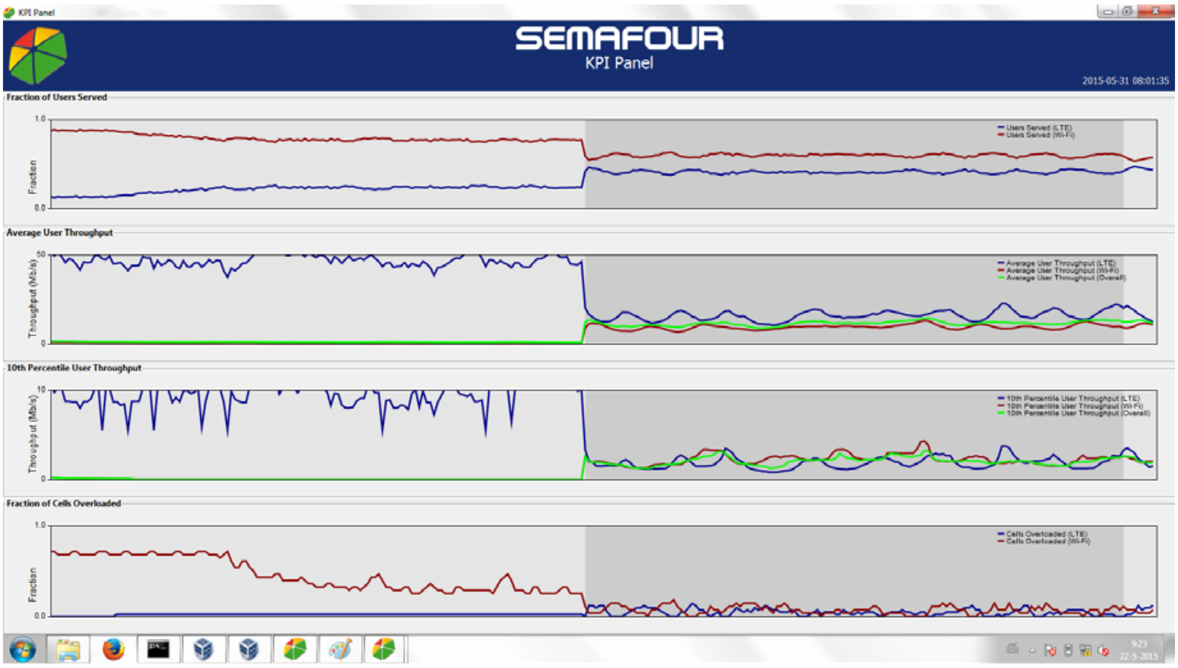


Figure 5: KPI Panel.

2.6 Network Client

The visual centrepiece of the SEMAFOUR demonstrator is the Network Panel (see Figure 6), which displays the multi-RAT/layer mobile network and its users in the realistically modelled city of Hannover, Germany. The network panel is a combined display of multiple, distinctly configurable layers: a Hannover city map, a map showing land use classes, time-varying pixel maps showing scenario-specific spatially displayed information such as Best Server Areas (BSAs) or traffic intensities, sector markers that are coloured based on the time-varying values of selectable KPIs, and user markers that are coloured based on user-specific attributes, e.g. user class (stationary, pedestrian, highway, …) or serving RAT (3G, 4G, Wi-Fi, …).

Besides mouse-driven panning and zooming, the Network Panel also features a set of pre-configured pan/zoom buttons which smoothly bring the displayed part of the network to specific areas of interest within Greater Hannover where relevant demonstrations are given.

As an alternative to the mapping of selected KPI curves to session terminals via the KPI Panel, it is also possible to select individual users from a prepared set of persistent users visible on the Network Panel and map them to session terminals. It is then the user-specific time-varying performance that is retrieved by the Proxy Client / Server and used to emulate the user's quality experience of a video streaming session in the demonstrated scenario. The Network Panel supports this selection procedure, thickens the rim of a selected user and displays it in a colour that matches the thick rim bordering the video image on the associated session terminal. As mentioned above, this colour coding enables the audience to know which terminal is matched to which user on the Network Panel.

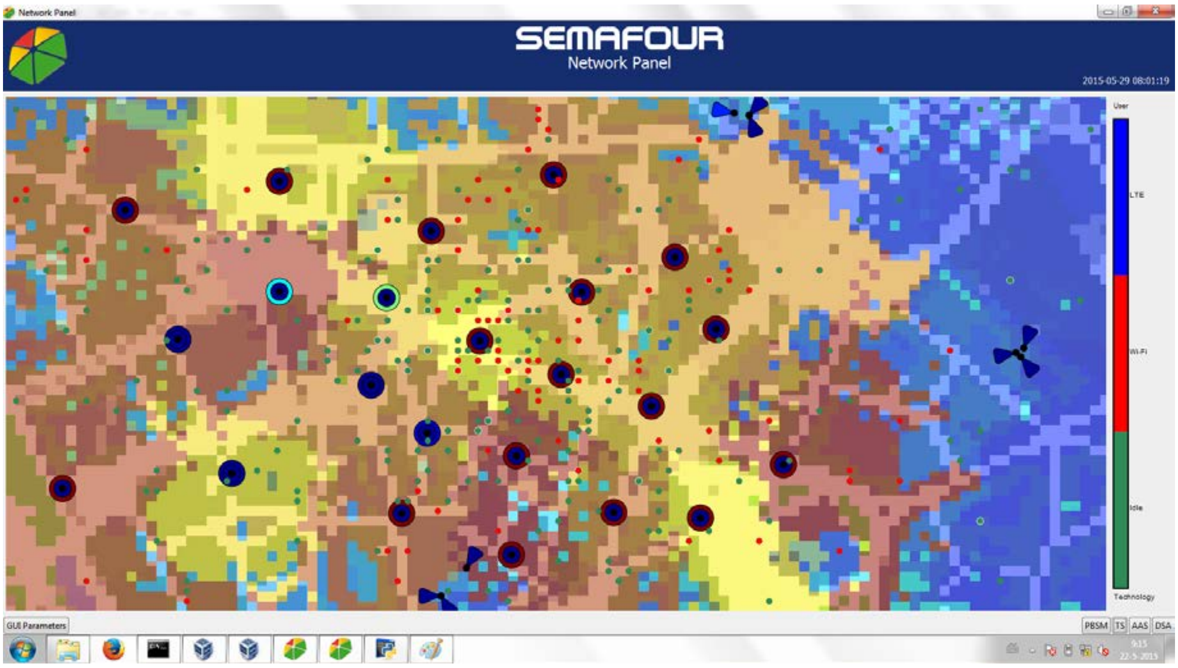


Figure 6: Network Panel.

2.7 Cell View Client

Right-clicking on a cell of any RAT or network layer displayed on the Network Panel, provides the option to open the so-called Cell View Panel (see Figure 7) for that particular cell. The Cell View Panel gives a localised view of the network around the selected cell and details the cell-specific attributes and SON function parameters. Furthermore, the panel presents two separate charts allowing the display of the parallel evolution of a selectable cell-specific KPI and a control parameter, in order to reveal how an automated change of a control parameter responds to an observation of a triggering KPI, while a subsequent observation of this KPI then indeed reflects the intended effects of the control parameter change.

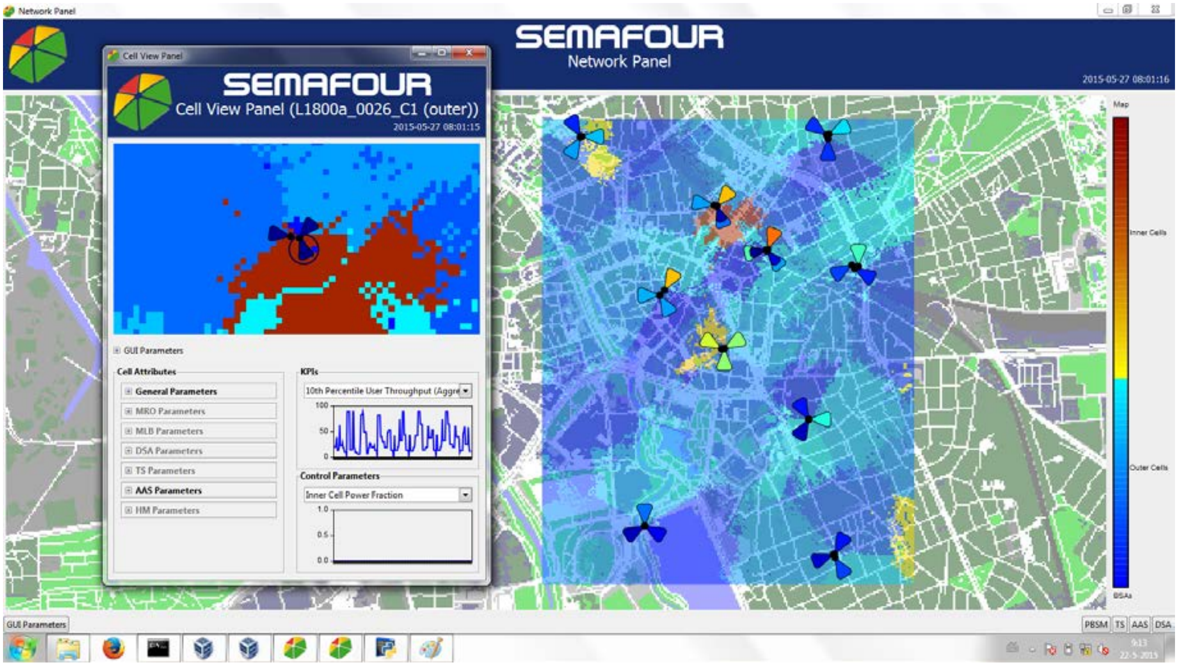


Figure 7: Cell View Panel.

2.8 Proxy Client/Server/Session Terminal Client

As introduced above already, the SEMAFOUR demonstrator also supports the involvement of actual session terminals, on which suitably emulated video streams are shown to illustrate the service quality experienced by either specific users selected on the Network Panel or by at least x% of the users in the entire network, in case e.g. the x^{th} user throughput percentile curve is selected on the KPI Panel. The Proxy Client learns from the Network/KPI Panel which user data or KPI curve is to be associated with which session terminal, retrieves the time-varying performance data from the CDS, and adapts the original video stream by imposing frame errors and freezes in accordance with the retrieved performance data. The Proxy Server then feeds the adapted video stream to the targeted session terminal, where a video player displays the video stream. In order for the audience to understand what performance data is used to adapt the video stream on a given session terminal, a matching colour is used both as a thick rim around the displayed video and as either a thick rim around the corresponding user on the Network Panel or a thickened curve shown on the KPI Panel. See Figure 8 for two examples.

Figure 8: Session terminals.

3 Demonstration Scenario for Dynamic Spectrum Allocation and Interference Management

This chapter describes the visualisation of the Dynamic Spectrum Allocation (DSA) algorithm, introduced in D4.3 [6]. The DSA algorithm controls the use of additional spectrum for LTE, in the event of an overloaded LTE cell. The secondary LTE carrier for the overloaded cell is placed in the same frequency domain as GSM. Thus the impact of the spectrum placement was investigated for LTE and GSM. The DSA visualisation will show how the LTE capacity increases if part of the GSM spectrum is used for LTE.

3.1 Demonstration Objective

The DSA algorithm tries to increase the throughput in an LTE hotspot cell by assigning it additional spectrum in the part of the spectrum which was reserved for GSM carriers transmitting traffic channels only. It might also disable certain GSM carriers in order to decrease the interference to the LTE cell.

The algorithm is triggered by LTE and GSM events in particular exceeding of cell load thresholds. Thus the demonstration presents the reaction of DSA on chosen events. For every hour that is going to be simulated, the improvement of the throughput in the LTE hotspot cell and avoidance of an overload situation will be visualised. In parallel it will be shown that the changes in the network configuration won't affect the GSM performance, i.e. all traffic requests can still be served.

3.2 Settings

This section describes the large scale scenario used for the multi-RAT investigations of DSA. The simulated area has a size of 8x8 km² covers mostly urban areas (see Figure 9). It is fully covered by GSM as well as LTE macro cells. As GSM and LTE cells are co-located the same predictions have been used for both. The difference in terms of reception levels arises from the power spectrum density. For GSM it is assumed that each carrier of 200 kHz is transmitted with 46 dBm transmission power. For LTE the same power is split across 5 MHz. This results into a transmission power of 32 dBm for each 200 kHz LTE bin.

The GSM and the LTE networks are offered the same traffic distribution maps, which is the basis for traffic variations. For GSM, the map it is interpreted as Erlang in contrast for LTE the traffic distribution map is assumed to contain offered traffic in kbps. For both radio access technologies, the traffic is scaled in a way, that the mostly loaded cell has a load of 80% in the busiest hour.

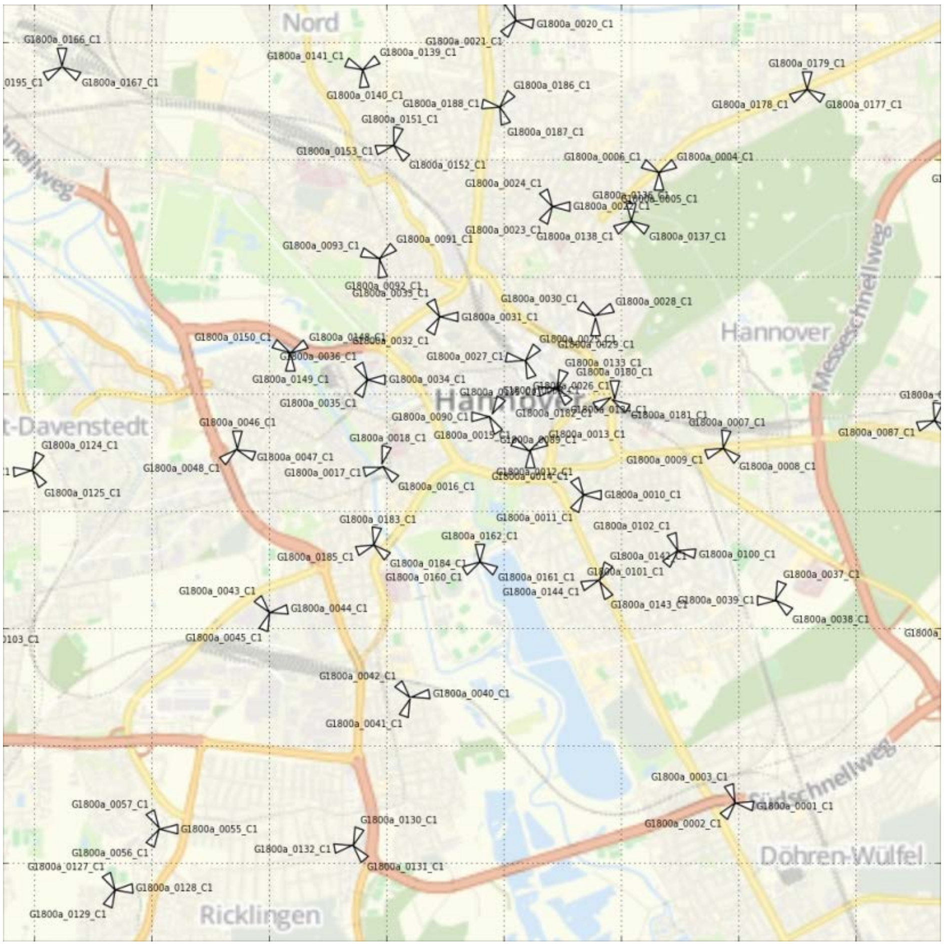


Figure 9: 8x8km² DSA scenario: network layout

3.3 KPIs

For the demonstration the main KPIs are as follows:

- Maximum possible throughput of the secondary LTE carrier in the hotspot cell, related to the time dependent traffic map
- Cell load of the primary and the secondary LTE carrier in the hotspot cell
- Covered area of the secondary LTE carrier as a percentage of the primary LTE carrier
- Cell load of the GSM cells
- Number of active TRXs per GSM cell

3.4 SON Function

The DSA algorithm is triggered by events. The related state diagram is shown in Figure 10. Every hour (‘State 1’) the DSA algorithm will check the cell load of all LTE cells to detect an impending overload situation. If this happens, the LTE carrier with the best estimated LTE throughput performance is activated to increase the cell capacity. The LTE cell then changes to ‘State 2’. Four events are possible when the secondary carrier is activated:

1. If the LTE cell load decreases and the LTE cell is not expected to change into an overload state again, the secondary carrier is deactivated.
2. If the LTE cell load is still in an overload situation after the secondary carrier is enabled, the greatest GSM interferer will be deactivated (if possible) to increase the cell capacity.

3. If one or more GSM interferers are near an overload situation, the DSA algorithm will activate the disabled GSM carrier.
4. If one or more GSM carriers are disabled: If the traffic can be served with the primary cell only and if it is not expected to change into an overload state again, the disabled GSM carrier is switched on again.

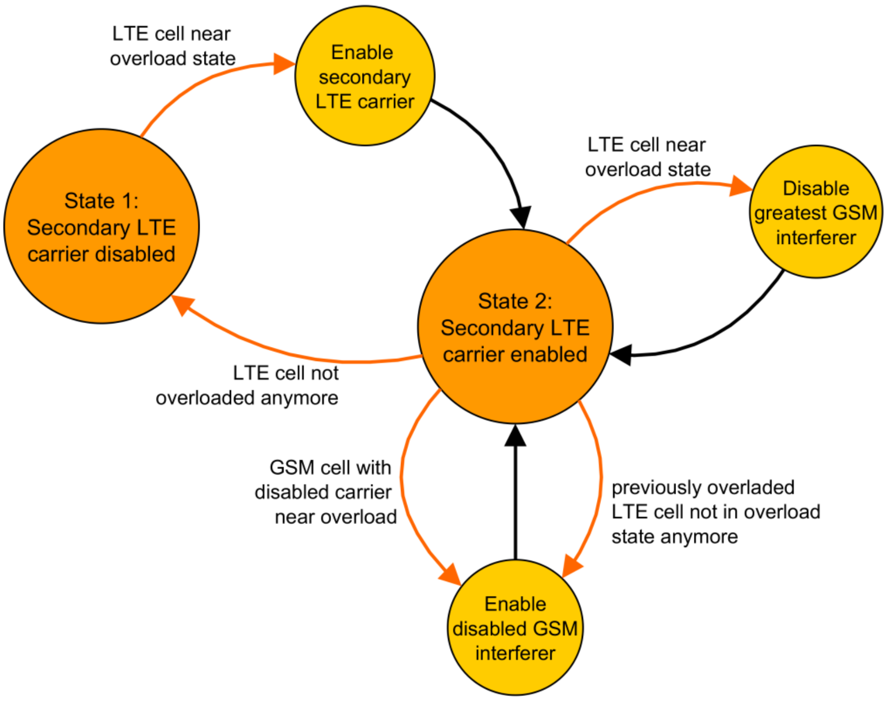


Figure 10: The states and trigger events for the DSA algorithm

3.5 Demonstration Storyline

For the demonstration, one LTE cell is chosen as a hotspot. The traffic map is scaled to produce the described events. The storyline for the simulated day is shown in Figure 11: at 9am, an impending overload situation is detected and the secondary LTE carrier is activated. The load can then be handled by the primary and the secondary LTE carrier. To make this possible, one GSM carrier has to be disabled. This is done by the DSA algorithm. At 1pm, the DSA algorithm, will detect a load for the first and secondary LTE carrier that is under a defined threshold value. The second occurrence of this small load, detected 1h later, will lead the DSA algorithm to undo the network changes: the secondary LTE carrier will be disabled, and the deactivated GSM carrier will be activated again. The same behavior can be observed with an overload situation, starting at 4pm and ending at 6pm, as shown in detail in Figure 11.

For the demonstration, the algorithm will output the detected events and the measures which have been taken into account on the terminal. This provides deep insight into the algorithms input data and its subsequent decisions. There are three charts in the KPI panel that are going to display the impact from the DSA algorithm. In chart number one the load for the LTE hotspot cell is presented. Chart number two shows the load of the GSM cell for which a GSM carrier will be disabled in the course of the demonstration. This will be necessary when enabling the secondary LTE carrier. The cell load will show an inverse proportional behavior to the LTE load as resources are shifted. Chart 3 will show the throughput for the LTE cell: One curve shows the maximum possible throughput that could be processed for every hour by the LTE cell. The second curve will then show the total processed throughput, depending on the offered traffic. After switching on the secondary LTE carrier, the maximum possible traffic will highly increase. This makes it possible to visualize the potential of the DSA algorithm.

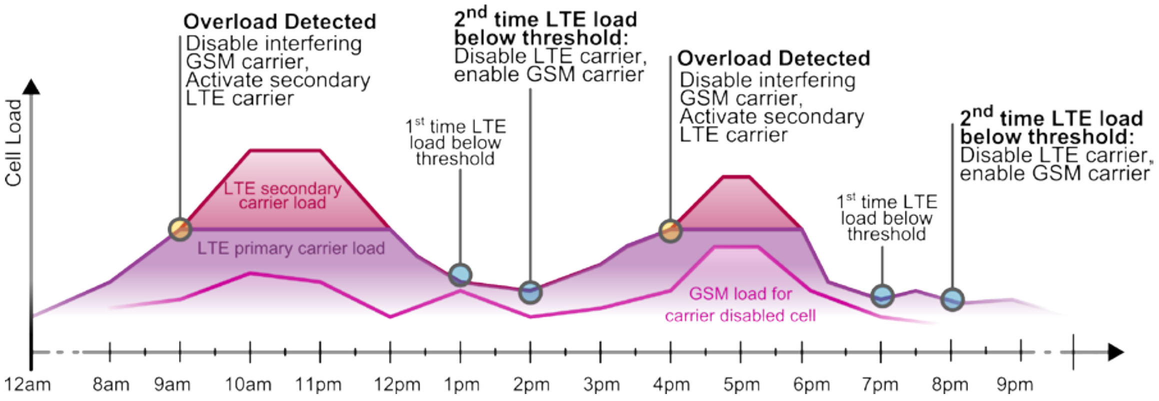


Figure 11: DSA events demonstrating the DSA algorithm.

4 Demonstration Scenario for Multi-layer LTE/Wi-Fi Traffic Steering

This chapter describes the demonstrations designed to visualize the workings and performance of the SEMAFOUR WP4 multi-layer LTE/Wi-Fi Traffic Steering use case [3]. This use case studies the steering of users between LTE base stations and Wi-Fi access points according to the dynamic fluctuations of e.g. network loading, radio link quality, and experienced QoS. A simplified illustration is shown in Figure 12. The targeted mechanisms aim at improving the end user experience and network performance by means of efficient utilization of both Wi-Fi as well as cellular network assets. The tradeoff between the achievable performance gains and the additional network complexity required to enable those gains is one important aspect to consider as well. The design, development, and assessment of multi-layer LTE/Wi-Fi SON-based Traffic Steering (TS) solutions have been extensively described in SEMAFOUR WP4 Deliverables 4.1[4], 4.2 [5], and 4.3 [6].

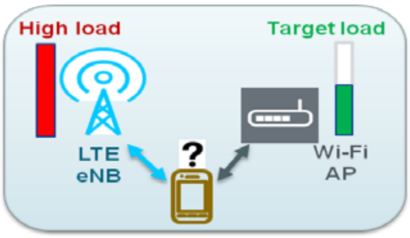


Figure 12 Illustration of LTE/Wi-Fi Traffic Steering

4.1 Demonstration Objective

At a high level the demonstration of SON-based traffic steering between LTE and WLAN aims at achieving the following main objectives:

- The visualization of the main deployment scenario(s), see Section 4.2, where most of the TS investigations have taken place during the project life time. This enables to further explain both the main scenario characteristics and the implications of those for the TS decisions.
- The visualization of the performance gains of the designed TS SON functions over the reference scenario. Additionally, also the performance comparison of the designed TS SON functions with respect to each other is one of the targets. Cf. Section 4.5.
- The visualization of the inner workings of the TS SON functions. The intention is to provide insights on how the SON function adjusts the control parameters based on the evolution of the monitoring KPIs according to the desired SON objective. Cf. Section 4.5.

4.2 Settings

This section describes the main aspects of the Outdoor Hot Zone (OHZ) scenario, a dense urban environment, adopted in the demonstration. This scenario is derived from the OHZ scenario specified in D2.5 [1] and described in detail in D4.2 [5] and D4.3 [6]. Figure 13 illustrates the deployment scenario. The deployment includes 28 co-sited outdoor LTE micros and WLAN APs in addition to 4 LTE macro sites. Omni-directional antennas of the co-sited micro/APs are installed on lampposts at 5 m height. The scenario is visualized during the demonstration in the Network Panel, see Section 2.6.

Non-uniform hot zone traffic is assumed where user traffic is generated by the Poisson arrival of the User Datagram Protocol (UDP) with fixed (large) size file downloading and uploading from stationary users.

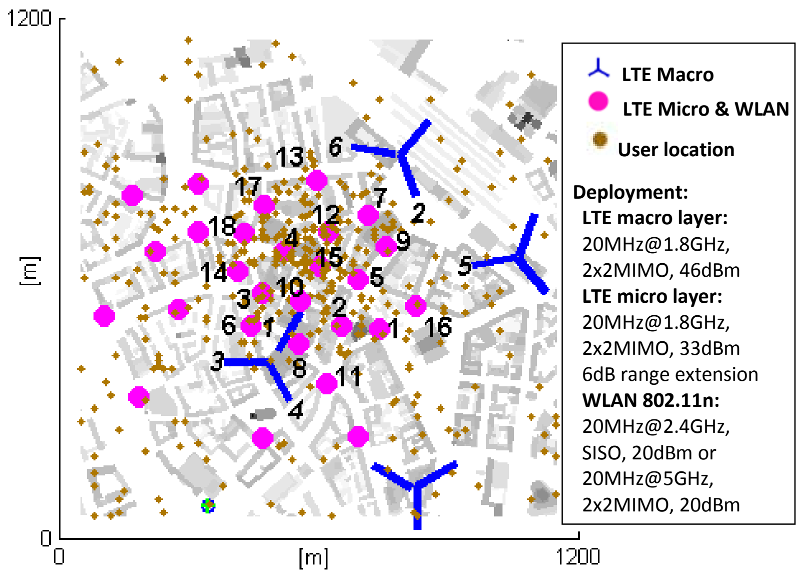


Figure 13: Outdoor hot zone scenario without mobility: Network deployment layout and fixed user locations.

4.3 KPIs

The following performance KPIs have been included in the TS demonstration to illustrate the ability of the studied TS SON functions to reach their objectives, see KPI Panel described in Section 2.5:

- *Session-level statistics*
  - **User throughput**: the average of 10-th percentile and mean of the experienced user throughputs, determined over a certain time window per layer/radio access. Shown as a line plot over time.
  - Besides their presentation on the KPI Panel, the session-level metrics can also be shown on handheld devices as discussed in Section 4.5.1.
- *Network-level statistics*
  - **Carried traffic**: the amount/percentage of traffic/sessions handled by the LTE and Wi-Fi network, respectively. Shown as a line plot over time.
  - **Overloaded and under-utilized cells ratio**: the fraction of the LTE cells and Wi-Fi access points which experience overload / under-utilization, i.e. averaged utilization of resources exceeds / falls below given load thresholds. Shown as a line plot over time.

4.4 SON Functions

Among the TS SON schemes studied within the WP4 activity, we have selected to demonstrate the load-based TS SON schemes which achieve a good compromise between gains and system complexity. The selected schemes are referred to as Received Signal Reference Power (RSRP) based and Received Signal Strength (RSS) based TS SON algorithms in D4.1 [4] and D4.2 [5]. The description in this section is limited to the *main aspects* of the TS SON functions and to the *demonstrated SON schemes* only. Further information about the demonstrated schemes, along with the additional TS SON functions investigated in the WP4 TS use case work, can be found in Deliverables 4.1 [4], 4.2 [5], and 4.3 [6].

Figure 14 illustrates the main blocks of the TS SON function and their inter-relation. The main blocks are: KPIs Monitoring, Evaluation Triggers for starting the traffic steering-related adjustments, the actual Control Parameters Adjustment, and the final Traffic Steering Execution.

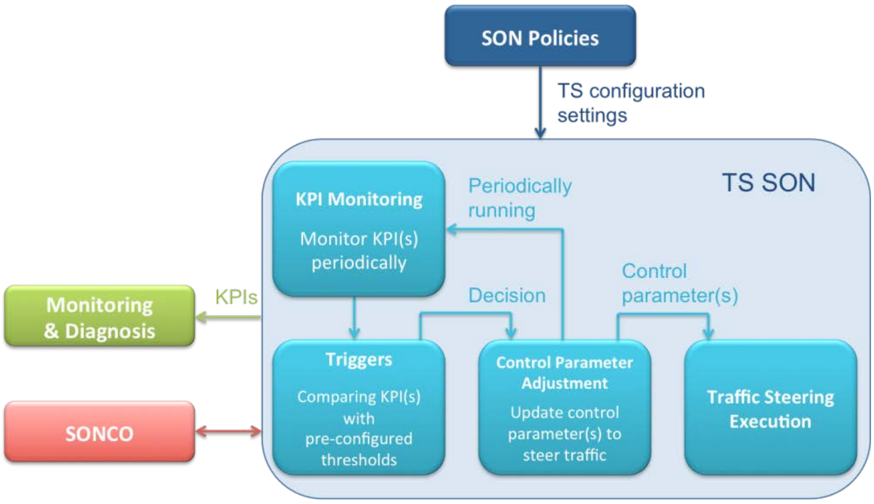


Figure 14: Simplified flow-chart of the closed-loop TS SON function.

The demonstrated load-based SON schemes target to optimally tune the RSRP or RSS threshold settings (adopted control parameters) *per cell and over time* to control LTE - Wi-Fi access network selection. The tuning depends on the evolution over time of the monitoring KPIs which the SON functions observe and may react upon. The adopted KPIs are the Wi-Fi and LTE Cell Saturation Ratio (CSR) load metrics which are defined in D4.2 [5]. The adjustments of the Wi-Fi RSS or LTE RSRP thresholds result in increasing / decreasing the area of the cell where Wi-Fi offload is activated and therefore to a larger / smaller ratio of traffic offloaded to Wi-Fi. The objectives of the SON functions are to keep either the LTE or both LTE and Wi-Fi load levels within the desired target range, and, as a result, to improve UE Quality of Service (QoS). The former objective is referred to as *LTE Load Control* objective. In this case, the SON function can be implemented in the individual LTE eNodeBs, because the SON function uses only local information. The latter objective is referred to as *inter-RAT Load Control* objective which requires information exchange between the two systems as shown in Figure 15. The above-mentioned objectives are mapped to the corresponding TS SON schemes and their configuration in the Operator Panel (see Section 2.3).

Figure 15: Simplified illustration of LTE Load Control and Inter-RAT Load Control TS schemes.

4.5 Demonstration Storyline

This section describes the storyline of the *standalone* TS demonstration. The TS demonstration has been integrated together with other SEMAFOUR use cases in a single demonstration scenario as well. For this description, the interested reader can refer to Chapter 7.

The TS demonstration compares the performance of:

a) The baseline scheme where Wi-Fi network access is prioritized over LTE as long as minimum Wi-Fi coverage is provided, UE RSS > -92 dBm, alike the most common UE behaviour today;

b) The TS SON function where the objective is set as *LTE Load Control*;

c) The TS SON function where the objective is set as *inter-RAT* (*LTE - Wi-Fi) Load Control*.

In particular, the demonstration will show that:

- The end user experience has improved through session-level QoS statistics, e.g. user throughput or video streaming quality.
- Cellular network assets are more efficiently used, shown via network-level statistics such as the decreasing of overloaded and/or under-utilized cells.

Initialisation – We show the operational multi-layer LTE/Wi-Fi network deployed in the dense urban OHZ environment (see Section 4.2), including a visualization on the KPI (session- and network-level statistics) and Network Panel. The baseline scheme "*TS Wi-Fi When Available*" which prioritizes most of the users to select Wi-Fi is active. Obviously, this policy generates Wi-Fi congestion while keeping the LTE network under-utilized.

At some point in time the presenter enables, in the Operator Panel, the first SON traffic steering algorithm "*TS (LTE)", i.e. LTE Load Control based TS,* see Section 4.4. From then the demonstration is given, for the exact same scenario, of the effects derived from the activation of the SON algorithim, both on the KPI and on the Network/Cell View Panel. Overall user-level performance is improved by significantly increasing the subset of the user sessions served in the LTE network compared to the baseline. However, as the algorithm is unware of the Wi-Fi performance / load, Wi-Fi utilization may not be optimal leading to e.g. Wi-Fi congestion in the area with highest traffic demand.

At a later point in time the presenter enables, in the Operator Panel, the second SON traffic steering algorithm "*TS (IRAT)", i.e. IRAT Load Control based TS",* see Section 4.4. Notice that by doing so, the first SON algorithm is disabled. From then the demonstration is given, for the exact same scenario, of the effects derived from the activation of the new SON algorithim, both on the KPI and on the Network/Cell View Panel. Overall user-level performance is further improved by serving more optimally the user sessions in the LTE and Wi-Fi network. Wi-Fi congestion is limited or avoided altogether.

Figure 16 shows the snapshot of the KPI Panel when changing from No TS ("TS Wi-Fi When Available") to TS SON (IRAT LC). The transition between the two schemes can be distinguished by the alternating shades of grey for the chart's background colour. When enabling the TS SON function the user throughput performance significantly increases along with the LTE utilization. At the same time the overload in Wi-Fi (see the fraction of cells overloaded metric) significantly decreases as expected.

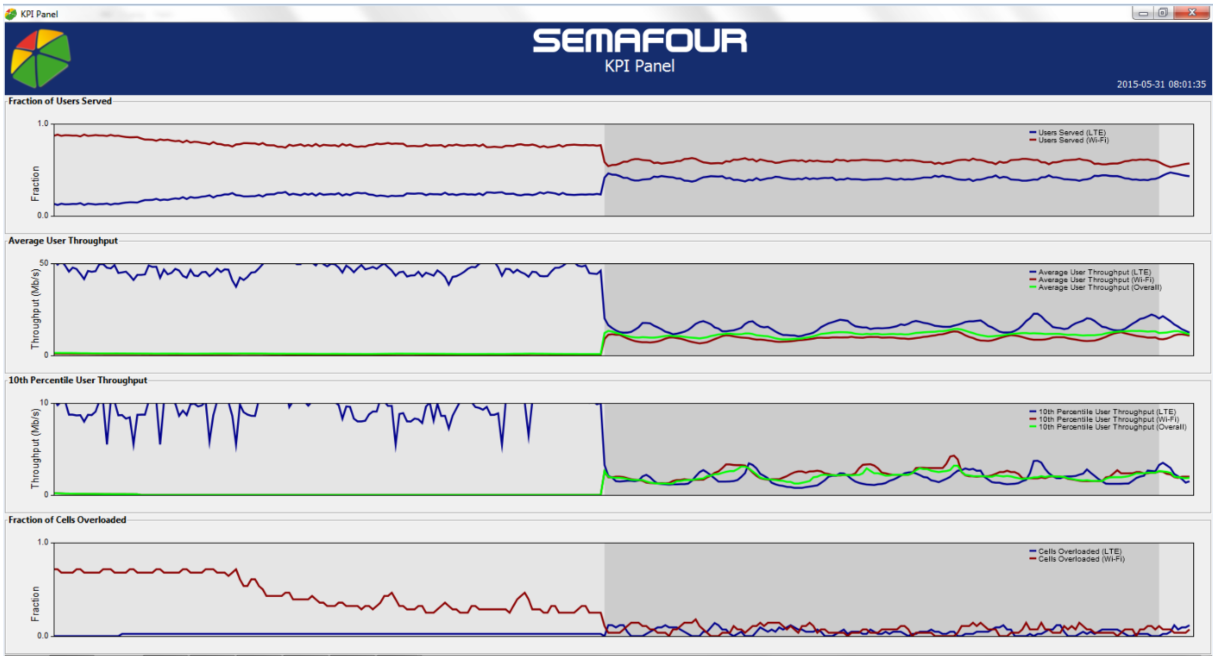


Figure 16: KPI Panel illustrating the time evolution of the performance metrics when changing from "TS Wi-Fi When Available" (chart's background colour is lighter grey) to "TS (IRAT)" (chart's background colour is darker grey).

4.5.1 User Session Terminals

Terminals running individual video streaming sessions have been used in the TS demonstration. The general introduction of session terminals and the detailed description of how the terminals are linked to the demonstration platform are given in Section 2.8. The terminals are used to display the QoS experienced by the represented user(s) as well as which cell the user is connected to such that actions of the traffic steering algorithm can be observed. That is, each session terminal plays-out the video according to the simulated UE experience, i.e. the UE throughput experienced during the demonstration. This throughput figure can be either:

a) Estimated for a selected (actual) UE connected to a given cell based on the UE radio quality and the cell load (via the Network Panel)
b) Assumed equal to any of the available UE throughput percentiles (via the KPI Panel).

Figure 17 illutrates the emulated video stream of a user mapped to the 10th user throughput percentile from the KPI Panel generated when no TS SON is enabled (“TS Wi-Fi When Available”, left) and TS (IRAT) SON is enabled (right). As expected, the snapshots reflect that the experienced video quality is significantly improved when enabling TS SON.

Figure 17: Session terminals for “TS Wi-Fi When Available” (left) and “TS (IRAT)” (right).

5 Demonstration Scenario for High Mobility

The SON function developed in the High Mobility use case aims to tackle the problems that arise when users make frequent handovers. Frequent handovers occur in case of a dense deployment of cells and/or when user velocities are high. These frequent handovers might cause a serious degradation of UE and network performance like a reduced QoS due to a relatively high data outage time in comparison to the cell stay time, an increased number of call drops and an increased signaling and data overhead in the core network. The High Mobility SON function reduces short stays by predicting the mobility behavior of currently active users based on measurements, which were collected by users that were active in the past. Based on these predictions, the SON function aims at refraining from handovers to cells in which the user is likely to stay for only a small amount of time, and at steering the user more appropriately. Users can be steered within the same layer and RAT, but also between different layers (macro, micro, pico cells) and/or RATs (LTE, UMTS, etc.), depending on their mobility behavior and the availability of layers and RATs to steer them to. In this chapter the High Mobility demonstration scenario is described.

5.1 Demonstration Objectives

The goal of the demonstration of the High Mobility SON function is twofold. Firstly to show the benefits of reducing the number of short stays in a cell by applying the High Mobility SON function and to show how the High Mobility SON function reduces the number of short stays by giving insight in the actions that are taken by it.

Secondly to show how the High Mobility SON function can be integrated in the Policy Based SON Management function (see Chapter 7) and how its parameters are adapted by it, depending on the high-level operator goals.

5.2 Settings

As the High Mobility SON function is demonstrated as a part of the Policy Based SON Management demonstration the same demonstration scenario is used. A picture of the demonstration scenario is shown in Figure 18.

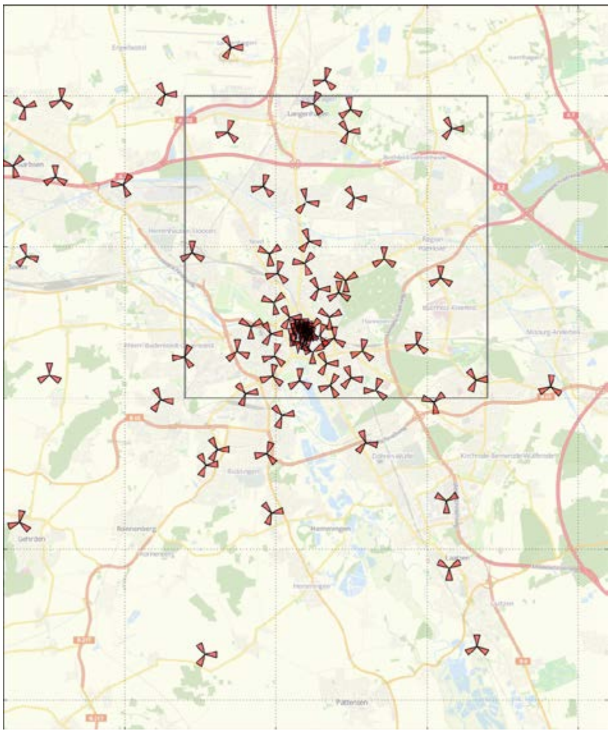


Figure 18: The PBSM scenario in which the High Mobility SON function is demonstrated is indicated by the rectangle.

This scenario contains both macro and micro LTE cells. The High Mobility SON function is enabled in all cells in the considered area. The most relevant traffic steering decisions will however be taken in the city center where there is a dense deployment of both macro and micro cells. The dense deployment of cells will cause frequent handovers even when users have a low velocity. At the same time, this is the location where the High Mobility SON function can steer users between the different macro and micro layers.

The parameters (or SON Configuration Values, SCVs) of the High Mobility SON function are set by the PBSM function depending on the high-level objectives that are set by the operator using the Operator Panel (see Section 2.3). The High Mobility SON function has 3 main parameters: the Tagged User Probability, this is the probability with which a user becomes a tagged user, the Minimum Stay Duration, this is the minimum amount of time that a user has to be able to stay in a cell before this cell is considered to be an eligible target for steering the user to and the Minimum Throughput Fraction, this is the fraction of the throughput of the Serving Cell above which the throughput in the target cell at all times has to lie. The different SCV sets from which the PBSM function can choose are shown in Table 1.

Name	***Tagged User Probability***	***Minimum Stay Duration***	***Minimum Throughput Fraction***
Normal	0.1	10s	0.8
Eager	0.1	5s	0.6
Conservative	0.1	15s	0.9
Investigative	0.2	10s	0.8
Uninvestigative	0.05	10s	0.8

Table 1: The different SCV sets from which the PBSM function can choose.

5.3 KPIs

In the demonstration, the High Mobility SON function is evaluated using two KPIs: the User Throughput and the Short Stay Rate. Both are shown in the KPI panel (see Section 2.5). The **User Throughput** is the average throughput that can be achieved by the users. It is used to assess what the impact of the High Mobility SON function on the throughput experienced by the users is. This is important as the High Mobility SON function aims at keeping users camped longer on the same base station, which might be at the cost of a reduced user throughput.

The **Short Stay Rate** is the number of short stays (i.e., users that stay in a cell for a period that is shorter than a certain amount of time (10 seconds), before being handed over) per user and per unit of time. The Short Stay Rate is used to assess the ability of the High Mobility SON function to reduce the amount of handovers that are made by the users.

5.4 SON Function

The general architecture of the High Mobility SON function is shown in Figure 19. It consists of three main components: the Trajectory Identifier, the Trajectory Classifier and the Traffic Steerer. The **Trajectory Classifier** is the core of the SON function. It is responsible for classifying users according to the trajectory they follow through the cell. It does this by comparing measurement traces that are made by currently active users (active traces) to measurement traces that were made by users that were active in the past (reference traces), and as such identifying matching traces of measurements. The **Trajectory Identifier** is responsible for identifying the traces that will serve as reference traces. The **Traffic Steerer** is responsible for making a traffic steering decision once the Trajectory Classifier has made a sufficiently reliable match of the trajectory of a currently active user onto a reference trace. By assuming that events that occur to one user will also occur to another user that follows a similar trajectory through the cell, the Traffic Steerer can decide whether it is beneficial to hand over the user to another cell or to keep it in the current cell.

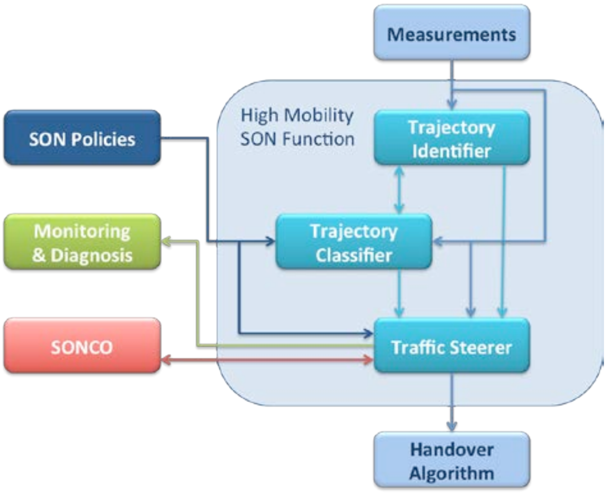


Figure 19: The architecture of the High Mobility SON function.

5.5 Demonstration Storyline

While demonstrating the Policy Based SON Management function at a point where the SON management function has activated and configured the High Mobility SON function, the presenter will point to the reference traces that are drawn on the network panel. Lines that are drawn along the trajectory of the tagged user from which the reference trace originated will indicate these. The presenter will then point to the log window where the actions that have been taken by the High Mobility SON functions are listed. The presenter then explains that the high mobility matches active users on one of the available reference traces. When such a match is made the RSRP that was experienced by the reference users in both the serving cell as well as in the neighbouring cells is projected on the active user by scaling the timing of the reference trace by the ratio of the durations of the active match and the reference match. From the projected RSRP the SINR and consequently throughput in the serving cell as well as the neighbouring cells will be calculated. A user is then steered to a neighbouring cell if it finds periods in the future that satisfy the following conditions:

1. they start at the current time;
2. they have a length that is longer than the Minimum Stay Duration;
3. during these periods the predicted throughput is at no point lower than the Minimum Throughput Fraction of the predicted throughput of the SeNB; and
4. during the periods the average predicted throughput is above the average predicted throughput of the SeNB.

If such a period is found the user will be steered to this NeNB. If multiple of these periods are found, the user will be steered to the NeNB for which the average throughput is the highest.

The benefits of the High Mobility SON function are mentioned with the other results of the PBSM function. The presenter should note in particular that the short stay fraction is reduced.

6 Demonstration Scenario for Active Antenna Systems

The AAS use case aims to investigate the capabilities and potential for performance/capacity enhancement of Active Antenna Systems (AAS), concentrating on the application of Vertical Sectorisation (VS). When VS is applied, a cell is split into an inner and outer sector serving users closer and further away from the eNB respectively. The two sectors utilize the same spectral resources and share the available transmit power of the original cell. The (de)activation of the inner sector and the transmit power split between the sectors are dynamically controlled by a SON function that was developed within the AAS use case. VS is a capacity enhancement measure which increases overall cell and network performance by serving users close to the eNB with very high throughputs while retaining the performance of the users further away from the eNB. More details about VS, its implementation and performance analysis carried out within the context of the SEMAFOUR project can be found in [5], [6], [10] and [11] .

6.1 Demonstration Objective

The objective of demonstrating VS is to show in detail the performance improvement that VS offers as a capacity enhancement measure and on top of that the added performance gains that the advanced SON algorithm developed within AAS offers, in a realistic network deployment. The demonstration is considered user friendly and does not require any extensive technical knowledge on the part of the audience in order for the benefits of SON VS to be understood. The network and cell level performance is going to be evaluated and compared for three different main scenarios, in order to demonstrate the functionality and gains of SON VS:

- **VS OFF** (Baseline scenario): The operation of the network is demonstrated when the VS feature is inactive in all cells. The performance of the network under these normal conditions is used as a benchmark.
- **VS ON** (Full VS): The operation of the network is demonstrated when VS is always active in all the cells of the network, using the same deployment settings. The performance of the network under these conditions is used to determine the benefits of VS when it is deployed with no intelligence (no SON functionality).
- **SON VS**: The operation of the network is demonstrated when VS is activated on a per cell basis and with customized transmit power split between the sectors, based on current network conditions. The performance of the network under these conditions is used to demonstrate the benefits of intelligent, SON based, VS deployment.

Some main KPIs will be used for each of these scenarios (see Section 6.3) to depict the fact that user experienced performance over the network, improves when VS is deployed statically (compared to the baseline scenario) and that further gains are observed when the SON VS algorithm is used.

6.2 Settings

The settings of the scenarios used for demonstration purposes are the same as the settings that were used for performance evaluation simulations and are described in detail in [1]. Here, we highlight the main scenario settings for the sake of the document’s self-containment and note any possible differences to the original scenario settings described in [1].

Figure 20 below depicts the demonstrated network layout and the corresponding traffic intensity per geographical area (color-coded). The area used for the demonstration is depicted within the white rectangle. This is the only difference in settings compared to what is mentioned in [1] . Even though the entire depicted area is used for performance analysis, and the area within the brown rectangle is used for statistics and KPIs collection, the smaller urban area within the white rectangle was selected for demonstration purposes for two main reasons:

- **SON VS suitability**: SON VS is mainly a capacity enhancement measure and as such, it is expected to offer greater benefits in an urban environment. Moreover, the intense interference environment is expected to offer the best circumstances possible for the SON algorithm to depict its added value in a way that is immediately visible to the audience.

- **Demo speed**: The smaller size of the area allows for quicker loading and display of all the relevant data, which will speed up the necessary time for demonstration.

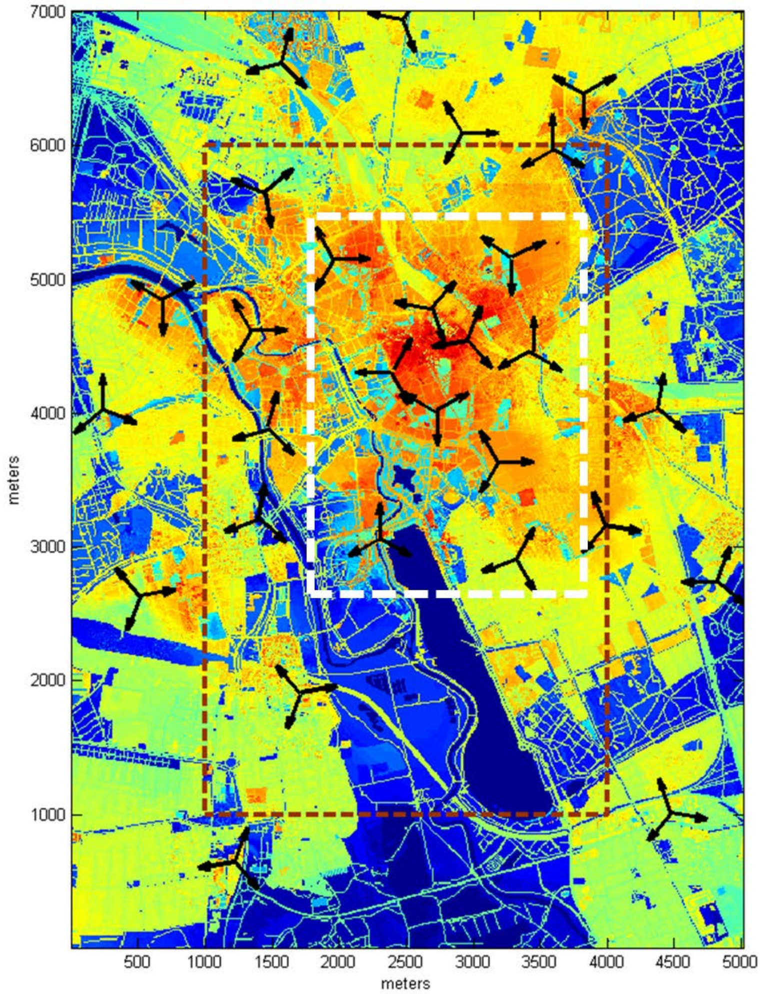


Figure 20: Considered LTE network in Hannover for demonstration purposes and spatial traffic intensity

The depicted AAS demo area (white rectangle) is a 2 x 2,5 km^2 area in the centre of Hannover, including 30 LTE macro cells operating at 1800 MHz with a bandwidth of 20 MHz and a total transmit power per cell of 40 Watts. Each cell is equipped with an active antenna that can be exploited in VS mode, operating with a fixed mechanical downtilt of 4^o and an electrical downtilt denoted θ^e. The assumed antenna model is described in [12] and [13]. For the purposes of the demonstration, the electrical tilt of inner and outer sectors is fixed at 8° and 0° respectively, whenever VS is activated. These values were selected as optimum based on the C&O study presented in [5] and [10].

Traffic is generated according to a spatially heterogeneous Poisson arrival process, with relative traffic intensities depicted in Figure 20. The given relative intensity map is uniformly scaled in order to obtain absolute traffic intensities. A generated session is modelled as a file download with a deterministic size of 16 Mb. Using real three-dimensional building data and applying advanced ray tracing modelling [14], a realistic isotropic propagation model is developed to cover both in- and outdoor pixels, comprising the effects of distance-based path loss, shadowing, diffraction, reflections and building penetration. Antenna masking is done based on the used antenna model and the applied tilt and azimuth settings. The scenario and modeling aspects used both for performance analysis and demonstration purposes are described in more detail in [1], [5] and [10].

6.3 KPIs

Most of the KPIs used for performance evaluation and described in detail in [5] are also used for the demonstration, but some additional KPIs have also been defined just for the needs of the demonstration. A nominal list of all the used KPIs for demonstration is presented here per level of statistics aggregation. For more details on these KPIs the reader is referred to [5] and [6].

<u>*Network level KPIs*</u>

- Throughput : Average and *x*% - where x ∈ {5,10,50,90,95}
- SINR : Average and *x*% - where x ∈ {5,10,50,90,95}
- Load : Average and *x*% - where x ∈ {5,10,50,90,95}
- Number of VS activations / deactivations
- Number of call handovers
- Best Server Area (BSA) map

<u>*Cell level KPIs*</u>

- Status : Active / Inactive (only inner sectors can be '*inactive*')
- Throughput : Average and 10%
- Load : Current instantaneous
- Transmit power : Current instantaneous

<u>*User level KPIs*</u>

- Location (x and y coordinates)
- Arrival / departure time

For the purposes of the demonstration a different class of users was also defined, called '*persistent users*'. The persistent users perform never-ending downloads at different network locations from various cells. These users never move and never change serving cells. The purpose of this user class is to be linked to specific devices which will emulate the experience of performing video streaming. The quality of the video stream is directly linked to the instantaneous user experienced performance of each of these users and varies depending on network conditions and scenarios used. For this purpose, the following KPIs are reported and used:

<u>*Persistent user KPIs*</u>

- Location (x and y coordinates)
- Serving cell ID (can change based on (un)-sectorisation events)
- Instantaneous SINR
- Instantaneous serving cell load

6.4 SON Function

The SON function showcased in the AAS use case demonstrator is described in detail in [5], [6], [10] and [11] and comprises two main functionalities, the (de)activation of VS on a per cell basis taking into account current load distribution information and the instantaneous transmit power split between the inner and the outer sector of a cell based on current traffic distribution information. These two functionalities will be briefly described here for the sake of self-containment of the document.

A decision to (un)sectorise a cell is taken based on the current number of active users (a.k.a. load) that is estimated / calculated for the inner and outer sectors respectively. A calibration procedure [10] indicated that optimum results are obtained by taking this decision on a per call basis (every time a new call arrives or an old call departs from the network). The load estimation process of the SON algorithm can be expressed by the following equation:

$$Load\ Ratio = \frac{N_{outer}^{\tau}}{N_{inner}^{\tau}} \quad (1)$$

where $\mathrm{N}_{\mathrm{inner}}^{\tau}$ and $\mathrm{N}_{\mathrm{outer}}^{\tau}$ are the (measured or estimated) number of data calls served by the inner and outer sectors during a time interval τ, respectively. The SON algorithm then simply becomes:

- *(i)* Calculate the Load Ratio
- *(ii)* Compare the Load Ratio with α
- *(iii)* If Load Ratio $\leq \alpha$ then VS activated
- *(iv)* If Load Ratio $> \alpha\ then\ VS\ deactivated$

The calibration process also revealed that optimum results are obtained when α tends to infinity, meaning that VS should be activated as soon as there is a single call within the inner sector serving area.

The second functionality of the VS SON algorithm is the dynamic adjustment of the power split between the inner and outer sectors based on the current traffic distribution, which is expected to increase performance even more since users are served with more appropriate amounts of power. The research carried out in the AAS use case and presented in [6] and [11] resulted in the following form for the estimation of the optimum power of the inner sector:

$$P_{inner} = \frac{N_{inner} + \omega \cdot N_{interfering}}{N_{inner} + N_{outer} + \omega \cdot N_{interfering}} \cdot P_{total} \quad (3)$$

where N_{inner} is the number of calls served by the inner sector, N_{outer} is the number of calls served by the outer sector and $N_{interfering}$ denotes the number of immediately affected ongoing sessions served by neighbouring cells. ω is a weight ('neighbour coefficient') determining the importance of the neighbouring sessions. P_{outer} is determined by the power conservation condition ($P_{outer} = P_{total} - P_{inner}$). The intention of the demonstration is to depict and quantify the gain of applying the two aforementioned SON functionalities in combination with VS deployment in the Hannover network.

6.5 Demonstration Storyline

The demonstration of the AAS use case is performed according to the following storyline:

<u>*Initialisation*</u>

The operation of the Hannover network is depicted when the SON algorithm is deactivated. Vertical Sectorisation (VS) is enabled and always active, using a 50% -50% power split between the inner and outer sectors, for all the cells in the network. The presenter gives a small overview of the depicted network KPIs which are:

- One chart containing 5 graphs of throughput percentiles - *x*% - where x ∊ {5,10,50,90,95}
- One chart containing 5 graphs of load percentiles - *x*% - where x ∊ {5,10,50,90,95}
- One chart containing the number of VS activations / de-activations (this metric will be zero at this point, since no SON means no activations / de-activations)
- One chart containing the number of Handovers (HO) (this metric will be zero at this point, since no SON means no HOs)

The presenter should also draw the audience's attention to the BSA mapping / colouring in the network panel and to the fact that the best server areas remain constant (no SON means no changes in the BSA map).

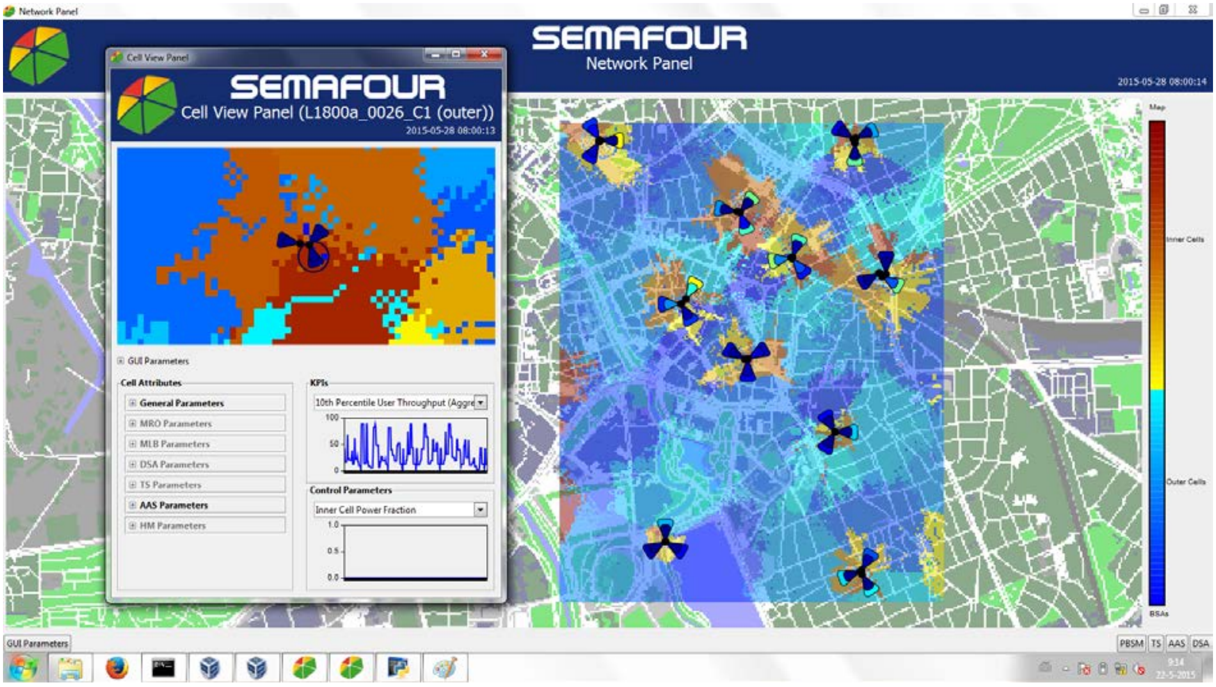


Figure 21: AAS Demo – network panel and cell view panel for the case of SON OFF

<u>Step 1 – Go to the cell view panel</u>

The presenter at this point goes to the cell view panel of a specific cell by clicking on the outer sector icon of the cell (the inner sector should be avoided because the inner sectors can disappear for SON ON which makes them bad for comparison) and gives an overview of the depicted parameters and KPIs which are:

- **Control parameters**: One chart depicting one of two possible control parameters. Which parameter is currently depicted on the chart can be selected by a drop-down list. The two control parameters are:
    - *Cell status*: Active / In-Active – In case of SON OFF all the cells are constantly in Active status
    - *Cell transmit power*: (selection between P_{inner} and P_{outer}) – In case of SON OFF the power of all the cells is always 50% of the original power, a.k.a. 20 Watts per cell
- **KPI chart**: One chart depicting one of possible eight KPIs belonging to three main categories. Which KPI is currently depicted on the chart can be selected by a drop-down list. The KPI possibilities are:
    - *Load Ratio vs α threshold*: The load ratio between the inner and outer sector of that cell is depicted as a graph over time. The parameter α is a fixed value (straight line in the graph) which will separate the graph into two differently coloured areas. The idea is that when the Load Ratio drops below the parameter α threshold then VS will be activated in that cell. In the case of SON OFF, this has no effect on the activation of the inner sector.
    - *Power Ratio*: The power ratio between the inner and outer sectors as defined in [5] also based on the number of neighbouring parameters. This ratio should be directly proportional to the available power in each sector when SON is active. It has no effect when SON is OFF, since the power in that case is fixed.
    - *Throughput KPIs*: Average and 10^{th} percentile user throughput for the inner, the outer and the aggregate cells.
- **Configuration parameters:** Hard printed parameter names and values for the α and ω parameters as defined in [5].

The presenter focuses the audience's attention to the three different throughput graphs for inner, outer and aggregate cells, explains the individual behaviours and reminds them that the BSA area remains steady because the SON algorithm is still deactivated. The presenter also asks the audience to memorize the throughput value for the aggregate cell, since it will be used for comparison with the SON ON case, later on. Figure 21 above depicts the network and cell view panels of the AAS demonstrator for the case that the SON algorithm is OFF. It can be seen that all cells in the area are sectorised, their individual serving areas are color-coded, while the KPIs and control parameters of a cell under investigation are visible in the cell view panel.

Step 2 – Activate SON from the operator panel

The presenter at this point goes to the operator panel and clicks the button that activates the SON function. All the KPIs and charts have moved on to the "next day".

Step 3 – Go to the network panel with SON

The presenter returns to the network panel and draws the attention of the audience to all the changes that are happening on a network level:

- BSA areas are now changing dynamically
- Inner cells are being activated and de-activated
- VS activation / de-activation chart now has values
- HO chart now has values
- A small improvement in network-wide throughput might be visible. In that case the presenter points it out, otherwise he/she moves to the next step.

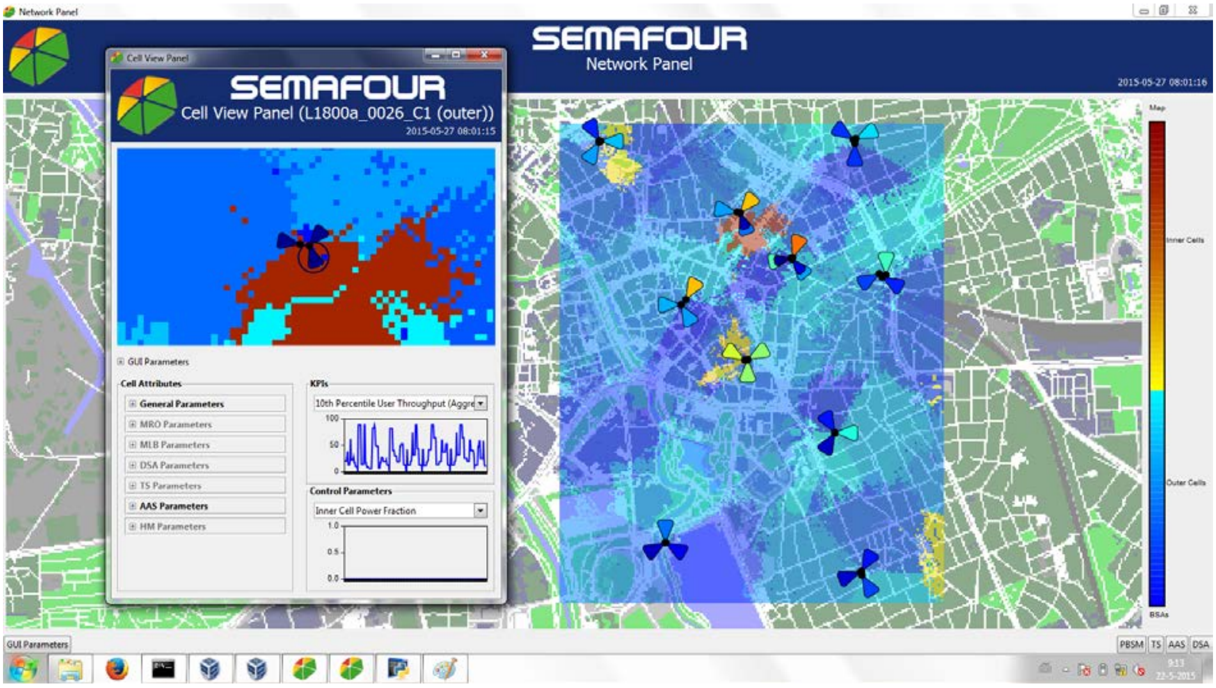


Figure 22: AAS Demo – network panel and cell view panel for the case of SON OFF

Step 4 – Go to the cell view panel with SON

The presenter at this point goes to the cell view panel of the same outer cell that he/she had visited before and points out to the audience all the differences in parameters and KPIs:

- The Active / In-active status of a cell is now affected by the relative position of the Load Ratio compared to the αthreshold.

- The power per sector actually changes according to the P_{inner} and P_{outer} values
- The throughput of the aggregate cell is increased compared to the value that the audience memorized for the SON OFF case

Figure 22 depicts the network and cell view panels of the AAS demonstrator for the case that the SON algorithm is activated (ON). It can be clearly observed that now only a few cells are sectorised (dictated by the SON algorithm – snapshot specific), while others remain un-sectorised. The KPIs and control parameters of the same cell as for the SON OFF case can be seen in the cell view panel, providing a measure of the improvement that the SON algorithm offers.

Step 5 – Further explanations and Q&A

The presenter spends as much time as needed to explain how the SON function works, which parameters and KPIs are affected and answer the audiences questions, while freely moving about the different demonstrator panels.

7 Demonstration Scenario for Policy Based SON Management and SON Coordination

The Policy-Based SON Management (Work Package 5) provides a means for the operator to enable an automated and autonomous configuration of a multitude of individually operating SON functions according to a set of objectives defined by the operator (cf. SEMAFOUR D5.2 [7] and D5.3 [8]). These objectives thereby represent target values for Key Performance Indicators (KPIs), which can furthermore be dependent on a certain network context or status, and which can have a certain weight. The demonstration scenario at first focuses on the operator tooling, where the objectives definition can be performed and the current configuration of the SON system can be acquired from, and secondly on the impact of the Policy-Based SON Management on the active network, where SON function re-configurations and the corresponding impact on the network configuration and performance can be seen.

The actual transformation process from the operator-defined objectives to the SON function configuration is not shown in the demonstrator scenario. This is in line with the expected tooling capabilities in real Operation, Administration and Maintenance (OAM) systems.

7.1 Demonstration Objective

The demonstration on Policy-based SON Management and Operational SON Coordination shall give insight to the new approach of instrumenting and managing a SON-enabled radio access network from the operator’s view. In particular, it shall demonstrate how the operator is enabled to define objectives (i.e., weighted and context-specific targets for dedicated radio network KPIs), deploy these objectives, monitor the impact on SON function configuration and network configuration, and monitor the impact on network performance and the degree of achievement of the objectives. Furthermore, the automated re-configuration of SON functions and the network configuration can be observed in case the network context changes (e.g., when switching from busy hour to normal traffic).

In short, the operator only has to define once his objectives on the network performance and does not need to care anymore about the necessary adaptation of SON functions and network configuration such that these objectives can be achieved.

Besides the SON Management functionality, the “background” working of the SON Coordination can be observed, which ensure a conflict-free operation of simultaneously active SON functions.

The final version of the PBSM demonstrator integrates a number of results from SEMAFOUR WP4. In particular, it allows the automated and autonomous configuration of the High Mobility (see Chapter 5) and Traffic Steering (see Chapter 4) SON functions together with the legacy Mobility Load Balancing and Mobility Robustness Optimisation SON functions. Furthermore, the SON Coordinator functionality has been integrated such that conflicts occurring between simultaneously operating SON functions can be resolved at real-time. Finally, the PBSM demonstrator includes the new concept of continuously adapting / improving SON Function Models by using a simple learning approach as it has been described in D5.3 [8].

7.2 Settings

The PBSM demonstration features a full-fledged multi-layer (macro and micro cells) and a multi-RAT (LTE, Wi-Fi) mobile network scenario. Total of 195 LTE macro cells and 28 LTE micro cells in the city centre are operating at 1800 MHz. The WiFi cells are co-located with the LTE micro cells and are operating at 2400 MHz.

The scenario area comprises an area of 10 by 10 km² in the city of Hannover, Germany (see Figure 24). In this area the main city centre (urban cells), highways (high-speed mobility profile) as well as suburbs and lightly cultivated areas (rural cells) are included.

The simulations relied on individual users which have been generated to cover a time span of two times four hours. The user types include static, pedestrian, vehicular, railway and highway. The first four hours simulation time take place from 8 to 12 o’clock in the morning. The second four hours from

5 to 9 o'clock in the evening. The users themselves produce traffic based on traffic model that differentiate between different services. Such services are voice, audio-, SD-video and HD-video streaming and FTP download sessions. For detailed information regarding the user mobility models, traffic types and network topology see SEMAFOUR D2.5 [1]

7.3 KPIs

The KPIs that are of interest to show to the audience of the demonstrator depend on the considered SON functions to be managed. The KPIs used in the overall PBSM simulation can be categorised in Cell KPIs and User KPIs.

The KPIs that are available from the PBSM simulations are listed below. Those KPIs which have been selected to be shown in the PBSM demonstration scenario (based on the PBSM results as described in SEMAFOUR D5.3 [7] and D5.4 [9]) and can hence be selected within the operator panel are marked **bold**.

- Cell KPIs:
  - Cell Load
  - Cell Throughput (note: this KPI may also indicate "0" in case there is no user in the cell)
  - **Resource Efficiency (RE):** The RE is calculated by dividing the cell throughput (given in Mbps) by the cell load (minus the cell load that accounts for signalling traffic, here 10 %).
  - **Short stay rate (SSR):** If, when a HO is performed (regardless of whether it fails or not), the user has been in the cell it is leaving for less than a certain amount of time (e.g. 10 s) it is counted as a short stay. The SSR is the number of these short stays per amount of time.
  - Handover rate
  - **Call drop rate (CDR):** Call drops are sessions that have been terminated due to lower received user throughputs than required and radio-link-failures due to bad radio conditions (too low signal strengths or bad SINR values). The CDR is the number of these call drops per amount of time.
- User KPIs:
  - (Mean) User SINR
  - (Mean) User Throughput (note: this KPI may also indicate "0" in case there is no user in the cell)
  - **User Satisfaction (US):** A user is fully satisfied if the received data rate is greater than, or equal to the requested data rate. Otherwise the received data rate gets divided by the requested data rate and multiplied by 100 to get a value that represents the US as a percentage. Note: if the user requires no data rate, the satisfaction is 100%.

7.4 SON Management Functions

In general, the functioning of the actual SON Management cannot be shown. However, the cell classes and the objective sets that serve as input to the SON Objective Manager as well as the output, namely the SON Policy and the corresponding SCV Sets, can be demonstrated.

Cell Classes

Each cell belongs to exactly one cell class which is defined by five context parameters:

- Cell location: rural, urban
- Mobility type: high-mobility, normal
- Cell type: micro, macro
- Cell technology: LTE, UMTS, Wi-Fi

- Traffic type: busy-hour, normal-hour

By means of cell classes the audience of the demonstrator can easier understand the configuration of specific cells and how the configurations are related to the class objectives.

Objective Sets

There are four different sets in the demonstrator. The “No-SON” and “Default-SON” sets do not define concrete objectives, since all SON functions are deactivated or running with the default configuration respectively. A third set aims at the robustness of the SON whereas the fourth set aims at achieving a high performance. Objective Sets define KPI targets for each cell class individually and the importance of those KPI targets compared to other KPI targets by means of weights.

SON Policy

The SON Policy shows a list of rules that indicate how cells of certain cell classes should be configured in order to achieve the best results with respect to the KPI targets in the objective sets. That means it shows for each cell class the best possible configurations, i.e., SCV Sets, for all SON functions. The SON Policy reflects the result of combining the cell classes, the objective set and the SON Function Models which is done by the SON Objective Manager function.

SCV Sets

In order to show a technically versed user of the demonstrator the concrete parameterization of specific SON functions, each SCV Set of each SON function can be shown in detail.

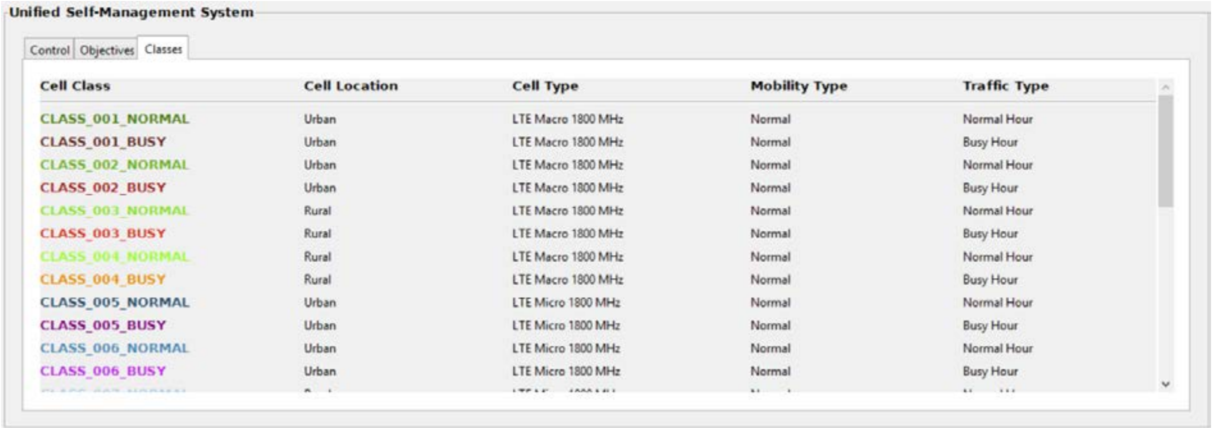
7.5 Demonstration Storyline

The intended storyline for PBSM consists of five steps:

1. Network Context / Cell Classification
2. Network operation with NO SON
3. Network operation with DEFAULT SON
4. Operator process to define new / select objectives
5. Network operation with PBSM / Objective Sets

Network Context / Cell Classification

In the first step, the operator can check for the definition of the context / cell classes as they have been pre-defined, for example, through network planning. This shall give insight towards the demonstrator audience how the network scenario actually looks like, in particular with respect to the different kinds of attributes a cell in the SEMAFOUR Hannover scenario can have. This step can be shown at two parts of the demonstrator: the Operator Panel, where all the definitions (attributes) of the different cell classes are listed (see Figure 23), and in the Network Panel, where the colour code of each cell indicates its cell class (see Figure 24).



Cell Class	Cell Location	Cell Type	Mobility Type	Traffic Type
CLASS_001_NORMAL	Urban	LTE Macro 1800 MHz	Normal	Normal Hour
CLASS_001_BUSY	Urban	LTE Macro 1800 MHz	Normal	Busy Hour
CLASS_002_NORMAL	Urban	LTE Macro 1800 MHz	Normal	Normal Hour
CLASS_002_BUSY	Urban	LTE Macro 1800 MHz	Normal	Busy Hour
CLASS_003_NORMAL	Rural	LTE Macro 1800 MHz	Normal	Normal Hour
CLASS_003_BUSY	Rural	LTE Macro 1800 MHz	Normal	Busy Hour
CLASS_004_NORMAL	Rural	LTE Macro 1800 MHz	Normal	Normal Hour
CLASS_004_BUSY	Rural	LTE Macro 1800 MHz	Normal	Busy Hour
CLASS_005_NORMAL	Urban	LTE Micro 1800 MHz	Normal	Normal Hour
CLASS_005_BUSY	Urban	LTE Micro 1800 MHz	Normal	Busy Hour
CLASS_006_NORMAL	Urban	LTE Micro 1800 MHz	Normal	Normal Hour
CLASS_006_BUSY	Urban	LTE Micro 1800 MHz	Normal	Busy Hour

Figure 23: Screenshot of the Operator Panel showing the definitions (attributes) of the different cell classes

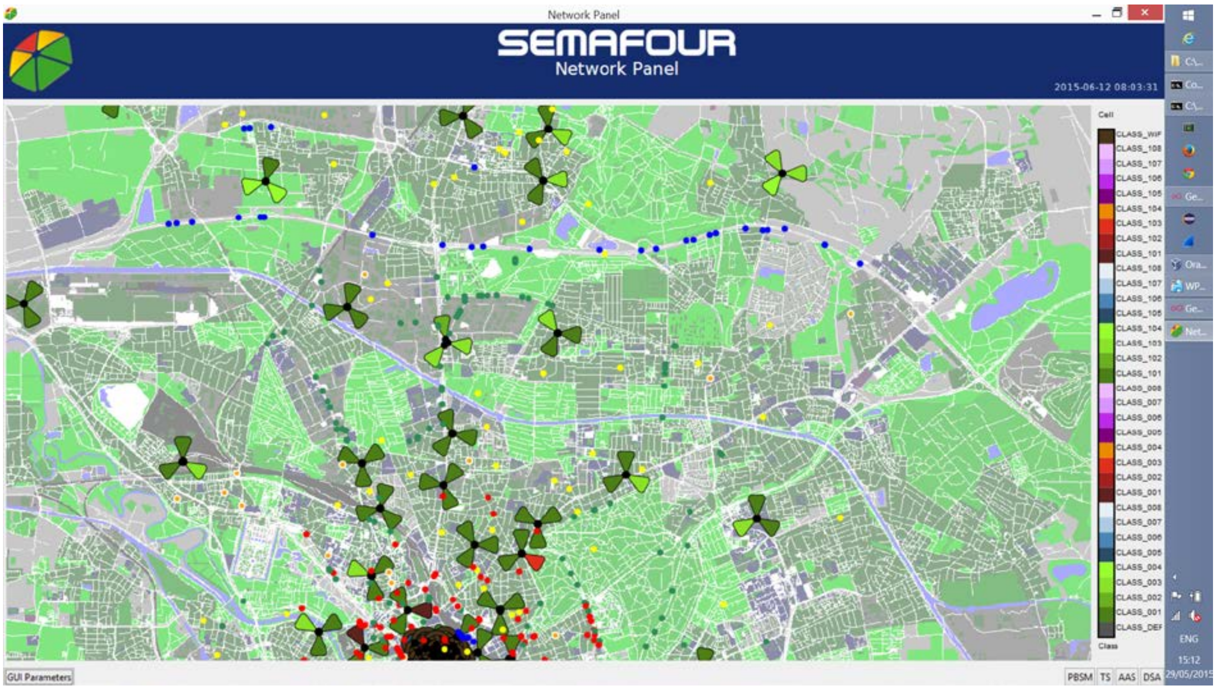


Figure 24: Screenshot of the Network Panel where the color code of each cell indicates the corresponding cell class

For this first step of the storyline, the NO SON case can already be active and running, as the Network Context is also available for this case.

Network Operation with NO SON

The PBSM scenario with NO SON, i.e., there are no SON functions activated, is the default setting when starting PBSM. While all functionality of the network itself is available, including cell classes, user classes etc., none of the SON functions is active. Hence, the scenario shows a completely non-optimised operational network, which should also be visible from the KPIs in the KPI panel, where HO failures, overload situations, and clearly non-optimal resource efficiency and user satisfaction are visible.

Network Operation with DEFAULT SON

The third step within the PBSM demonstrator storyline is represented with the DEFAULT SON scenario. In this scenario, all SON functions available for PBSM are activated. This includes Mobility Load Balancing, Mobility Robustness Optimisation, High Mobility (cf. Chapter 5) and LTE/Wi-Fi Traffic Steering (cf. Chapter 4). While for the High Mobility SON function the original algorithm implementation is used (at least the single-RAT LTE implementation, potentially even the multi-RAT LTE/3G implementation), an implementation with simplified functionality is used for Traffic Steering. The reason for this simplification is founded in the PBSM simulations, where the original MATLAB implementation of Traffic Steering could not be used. Common to all SON functions in this scenario is the fact that they run with their default configuration only (this default configuration has been defined through the PBSM team), and the SON functions are not coordinated by a SON Coordination function.

The intention of this scenario is to show the advantages in terms of network and KPI behaviour compared to the NO SON scenario. However, as the SON functions are not configured automatically through PBSM, and there is no SON Coordinator available, the KPIs are still beyond being optimal, and conflicts occurring between the SON functions may even lead to some KPI malperformance peaks or undesired KPI behaviour, for example in terms of high Call Drop Rate or high Handover Failure rate.

Operator Process to Define / Select Objectives

This step represents the “preparation” for the actual SON Management scenario. It shall provide insight to the demonstrator audience how the process of defining operator objectives looks like, and in which way it could work in a real Operations Support System. While the definition of the available network / cell context is already described in the first step (and this first step is assumed to be pre-defined, for example, through the operator’s network planning department), the current step to define the objectives is intended to be performed through the network operations department of the operator.

Within this step, the operator can define the target values for the KPIs available within the SON management system for each of the defined context / cell classes. Furthermore, the operator can define the weights (i.e., the sequence of importance) for these KPI targets. This definition process is performed within “NEW” tab of the Operator Panel (see Figure 25).

Note that the defined objectives cannot be “deployed”, i.e., they cannot be made the actual objectives used within the network. The reason behind is the architecture of the demonstrator platform (see Chapter 2), where pre-recorded simulation traces are used. An individual, audience-defined set of objectives would first require a simulation, and the simulation results would then need to be put into the demonstrator.

At the end of this step, the demonstrator presenter shall explain to the auditory about the already prepared objective sets (“Optimise Robustness” and “Optimise Performance”, see Figure 26) which are then used in the fifth step.

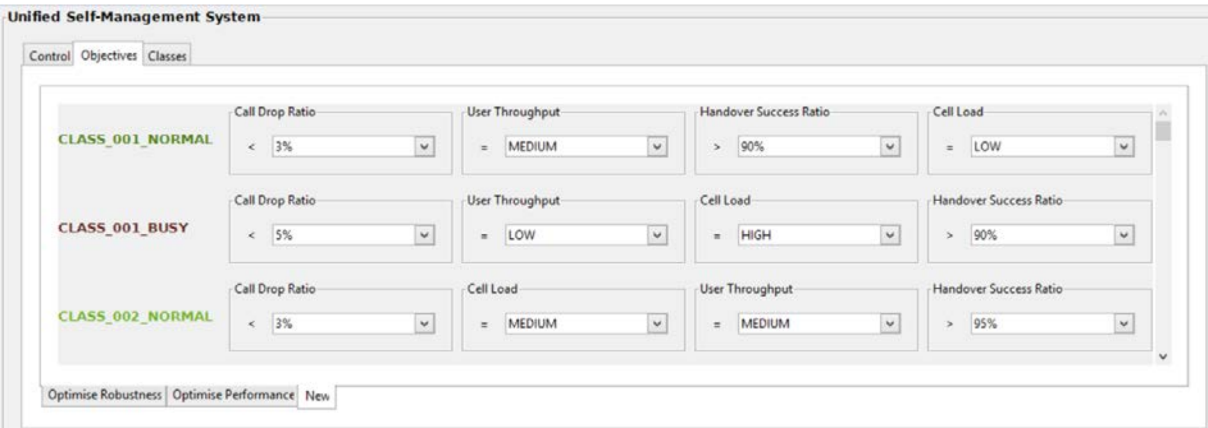


Figure 25: Screenshot of the Operator Panel with Objective Definition tab (NEW Objective)

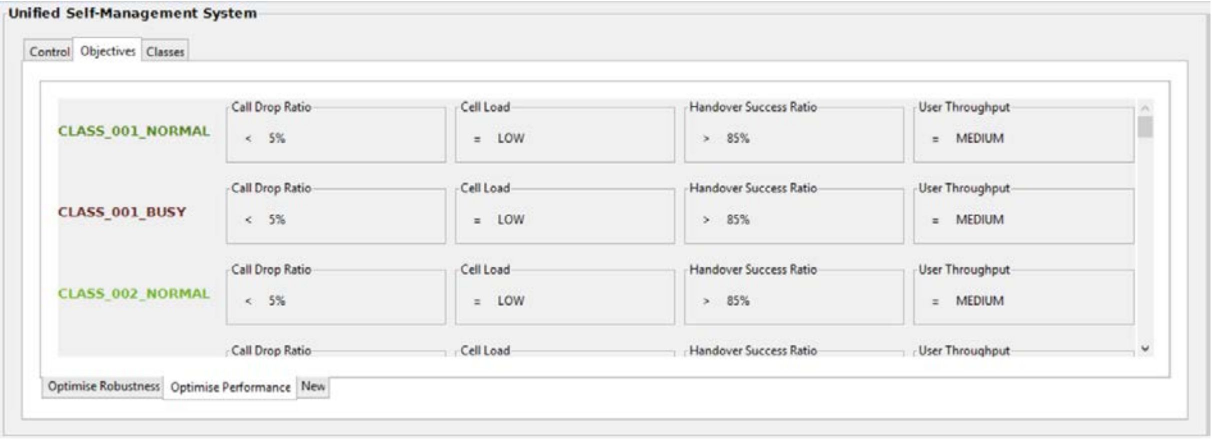


Figure 26: Screenshot of the Operator Panel with Objective Definition tab (Optimise Performance)

Network Operation with PBSM / Objective Sets

This step of the PBSM demonstrator storyline represents the Integrated SON Management approach in its full stage of expansion. All functionality available for Integrated SON Management (i.e., the SON functions, SON Coordinator, and SON Management) is active.

One of the pre-defined Objective Sets is activated by the demonstrator user and then deployed. In the accompanying explanation of this step, the mechanisms of the SON Objective Manager can be explained, where from the Objective definitions (weighted and context / cell class specific KPI targets) and the models of the available SON functions the SON Policy is generated. This SON Policy is displayed in the Operator Panel. When the demonstration is started (Next Day), the Policy System selects for each (available) cell class the appropriate SON function configuration, i.e., the SON Function Configuration Value (SCV) Sets, and configures the SON functions accordingly. The currently active SCV Sets per cell class can be obtained in the Operator Panel, and the demonstrator user can have a closer look at this SON function configuration by clicking on the corresponding SCV Set name (see Figure 27).

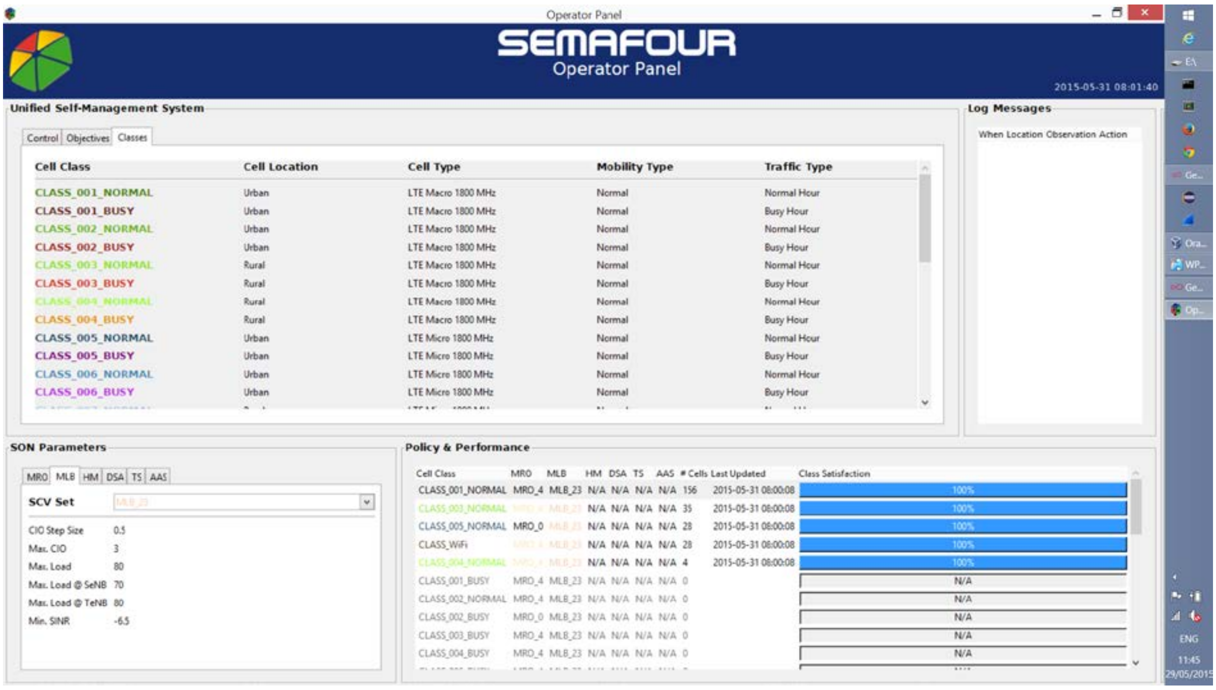


Figure 27: Operator Panel showing the content of SCV Set MLB_23

During the runtime of the demonstration, two types of effects are made visible in the Network, KPI and Operator Panels. First, the change of the cell classes during runtime (caused by the switch between busy hour and normal hour) leads to the corresponding colour change of the cells in the Network Panel, and partially to a selection of different SCV Sets to be deployed to the SON functions depending on the defined Objectives for this cell class. This switch between busy and normal hour hence also impacts the KPIs visible in the KPI panel in case the SCV Sets are different for busy hour and normal hour. Secondly, the functioning of the SON Coordinator can be observed in such way that, in case a conflict occurs between two SON functions concurrently operating in a cell, and the SON Coordinator has to resolve this conflict, a message will be shown in the Operator Panel.

The demonstrator user may switch to a different Objective Set in the Operator Panel. While the switching between busy hour and normal hour remains the same, and hence there is no major difference visible in the cell colour displayed within the Network panel, the KPI targets and their weight are now completely different from those in the first Objective Set. Hence, the impact is clearly visible in the KPIs.

8 Demonstration Scenario for Decision Support System for Operational Network Evolution

This chapter describes the demonstration scenario for the DSS (Decision Support System) use case. The DSS is a set of functionalities aimed at supporting the network operator in making proactive network upgrade decisions, using predictive simulations of future traffic growth and its consequences for network loads, based on the current network configuration and on several configurations including different upgrade options. The demonstration of the DSS functionalities makes use of the Operator Panel and the DSS Panel.

8.1 Demonstration Objective

The demonstration scenario for the DSS use case aims at visualizing both the functionalities developed in the DSS use case and the performance improvements achievable by implementing them. In particular, we want to demonstrate:

- The predicted deterioration of the network performance over time, if the traffic intensity is steadily increasing and no network reinforcements are implemented.
- The early detection of problem zones that are expected to arise within 4 months, based on the predicted traffic intensity maps.
- And the performance improvements corresponding to different network upgrade options, which can be compared both visually and quantitatively using the DSS Panel.

8.2 Settings

Network layout:

The network layout for demonstrating the bottleneck detection functionality is described in [3] and depicted in Figure 28.

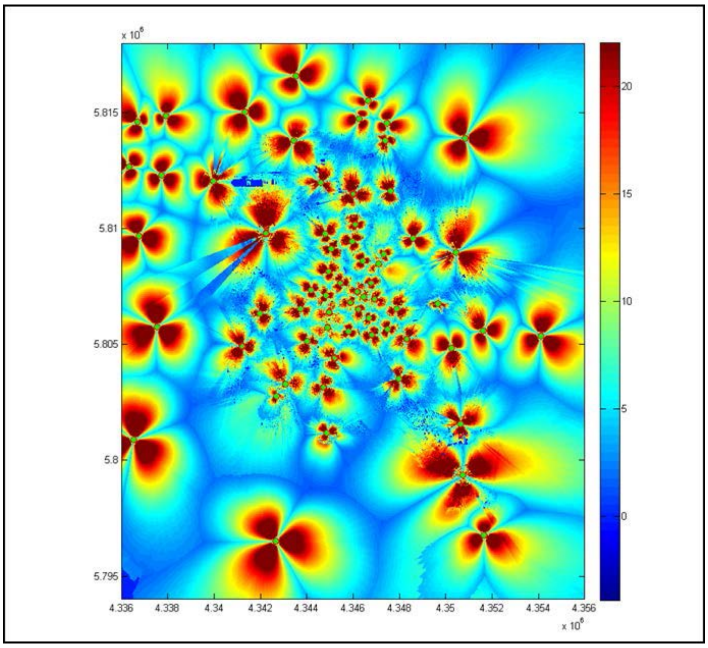


Figure 28: Network Geometry and Throughput map (in Mbps/km^2)

Once the bottleneck detection algorithm has returned a set of problem zones, the network considered in the demonstration is restricted to a smaller area containing all problem zones. The new network, used for finding and comparing different upgrade options, is illustrated in Figure 29.

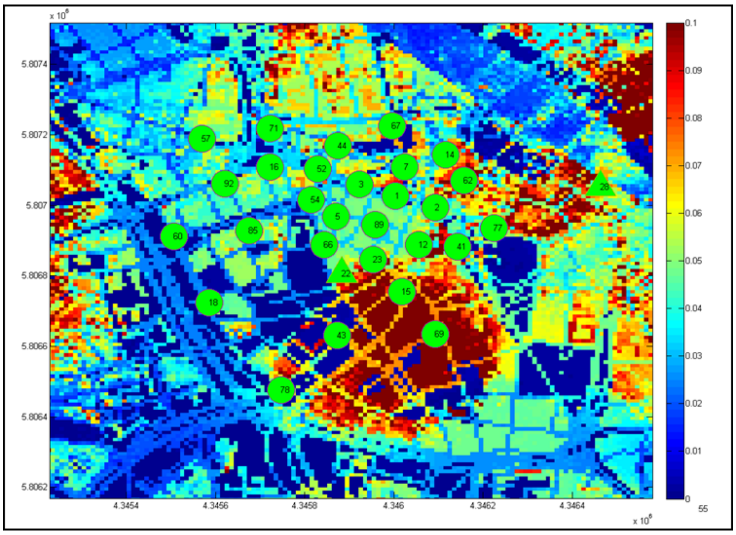


Figure 29: Network geometry: micro (circles), macro (triangles) around problem site 22, and traffic intensity (in Mbps/100m^2)

Propagation environment:

As propagation environment we use the realistic Hannover scenario, as described in [1].

Traffic characteristics:

Based on 4 weeks of historical data and a traffic growth factor of 66% per year, the traffic intensity is predicted for a time horizon of 4 months into the future. This prediction, described in more detail in [1], returns traffic data on a daily basis, for one busy hour per day. Figure 30 illustrates the prediction horizon and the corresponding DSS triggering event.

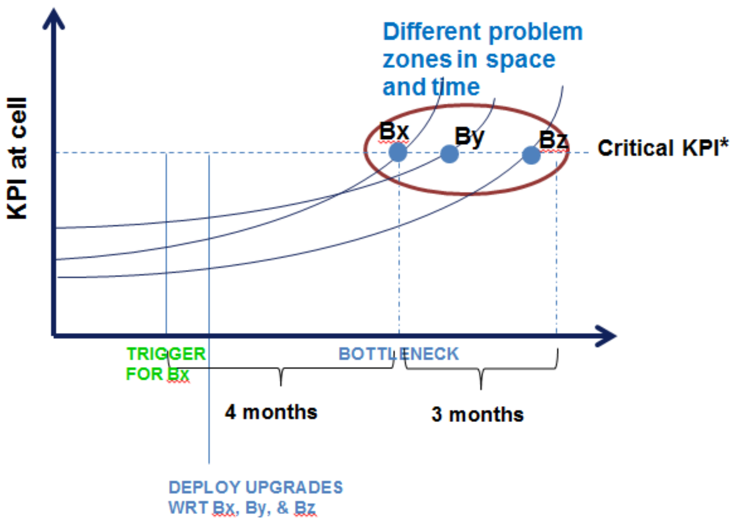


Figure 30: Relation between the timelines of the DSS triggering event, the emergence of the bottleneck Bx, and the deployment of upgrades targeting Bx

Several scenarios can be visualized using the DSS Panel:

- **Baseline scenario:** The expected future evolution of the system with the current network configuration, based on the predicted traffic growth pattern.

- **Upgrade scenarios**: For each problem zone detected in the baseline scenario within the next 4 months, several possible network upgrades (i.e., adding a new micro site or six-sectorizing an existing one) are considered. For each upgrade, the hypothetical future evolution of the system is predicted in the corresponding upgrade scenario.

8.3 KPIs

The demonstration includes the following KPIs:

Network level KPIs:

- *Overload:* This is defined as the total load which exceeds the threshold of 0.6 (i.e., a load of 0.7 corresponds to an overload of 0.1), predicted for areas of $100m^2$.

Cell level KPIs:

- *Cell load:* The load of each active cell.

Problem zone level KPIs:

- *Aggregated overload:* The sum of the overloads in all areas belonging to a given problem zone (this is the triggering metric).

The analysis of possible upgrade options, as shown in the DSS Panel, is triggered once the **aggregated overload within a problem zone** in the baseline scenario is predicted to exceed a given threshold value within 4 months. This KPI is also used for comparing the performance improvements to be expected from different upgrade options.

8.4 SON Functions

The functionalities of the DSS are:

- **Bottleneck detection:** On a daily basis, the system runs an analysis of the predicted future performance and detects whether a significant performance bottleneck is expected to arise. Reports summarizing the results of this analysis can be found in the Operator Panel, under the section DSS Messages.
- **Generation and Evaluation of Upgrade Options:** If an expected future bottleneck is detected, possible network upgrades are generated and analysed. These different upgrades, and their predicted influence on the future performance of the system, are visualized in the DSS Panel. This gives the network operator a detailed insight into the future of the network, and supports the operator in making an informed and proactive decision about network upgrades, well before significant problems arise.

8.5 Demonstration Storyline

We turn to the *Decision Support System* segment of the **Operator Panel**. The DSS is continuously performing predictive analyses of resource utilization and network performance in order to forecast the emergence of bottlenecks. Every night, the DSS issues a report with its findings. Green DSS messages inform the operator that the analysis indicated no need to initiate network upgrades.

If we click on the *Next Day* button of the **Time Control Panel** a few times, however, we see in the **Operator Panel** that the DSS issues a red alert after a few days. As the red coloring of the alert suggests, the DSS message now indicates that the analysis revealed a need to initiate a network upgrade for the continued provisioning of coverage and service quality as targeted in the network-oriented objectives. Upon clicking the *Show DSS panel* button, the key results of the DSS analysis are shown on the **DSS Panel**.

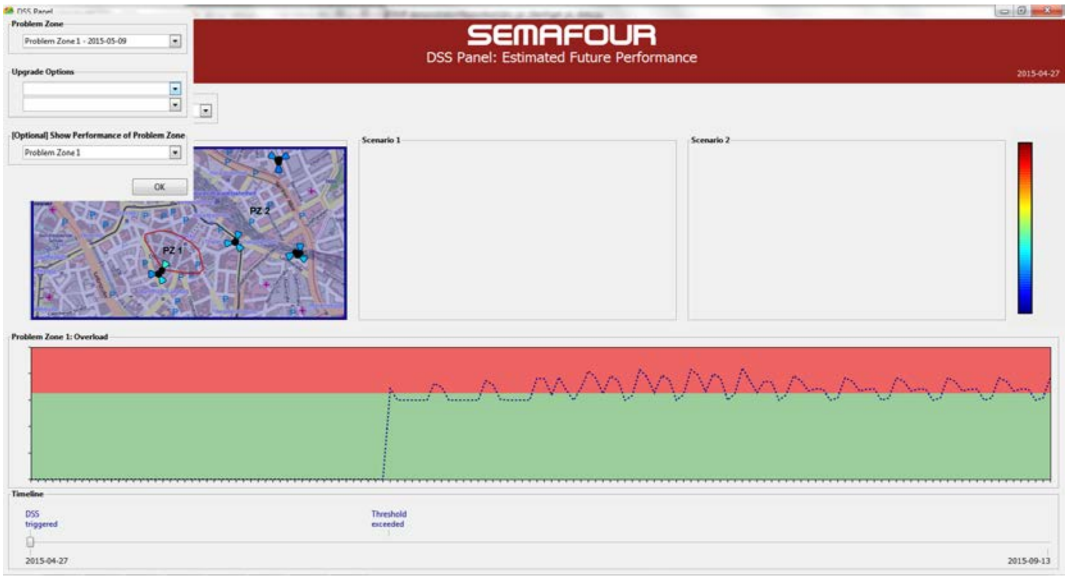


Figure 31: Initial view of the DSS Panel, with the configuration menu open in the upper left corner

The red banner of the **DSS Panel** is different from that of the other panels, in order to stress that we are now no longer looking at the *actual evolution* of the Hannover network, but rather at *predictions* of future performance. Performance or capacity bottlenecks are analyzed in the form of so-called *problem zones*, regions in the network where the predicted loads are deemed too high to allow performance targets to be satisfied. In the configuration menu of the DSS panel a list of such anticipated problem zones is presented, ordered by the date at which they are predicted to arise (see Figure 31). At the time of DSS triggering, three problem zones are predicted to emerge in the considered network region, the first one being Problem Zone 1. This anticipated bottleneck triggered the red DSS alert on the **Operator Panel**. The timing of the DSS alert relative to the predicted time of the emerging problem zone is derived from the assumed longest deployment delay associated with the different network upgrades that are considered to prevent the problem zone from occurring.

For each problem zone, the DSS has compiled a list of recommended network upgrades that may be effectuated to prevent the selected problem zone. This list currently contains several options to deploy new micro sites, in or near the problem zone, as well as the option to upgrade an existing site in the area from having three sectors to having six sectors. The **DSS Panel** is designed to visualize the predicted overload evolutions in the noted problem zones for the baseline scenario and two distinct upgrade scenarios. The final configuration option in the menu allows us to pick, given the chosen network upgrades associated with the selected problem zone, for which of the listed problem zones we would like to animate the predicted evolution of the degree of overload. This is option allows us to also observe the effects of such upgrades on nearby problem zones, which may potentially influence an operator's decision on which upgrade to deploy.

As an example, we compare the baseline scenario, meaning that no upgrades are enforced, with the six-sectorization of the macro site closest to Problem Zone 1 (see Figure 32).

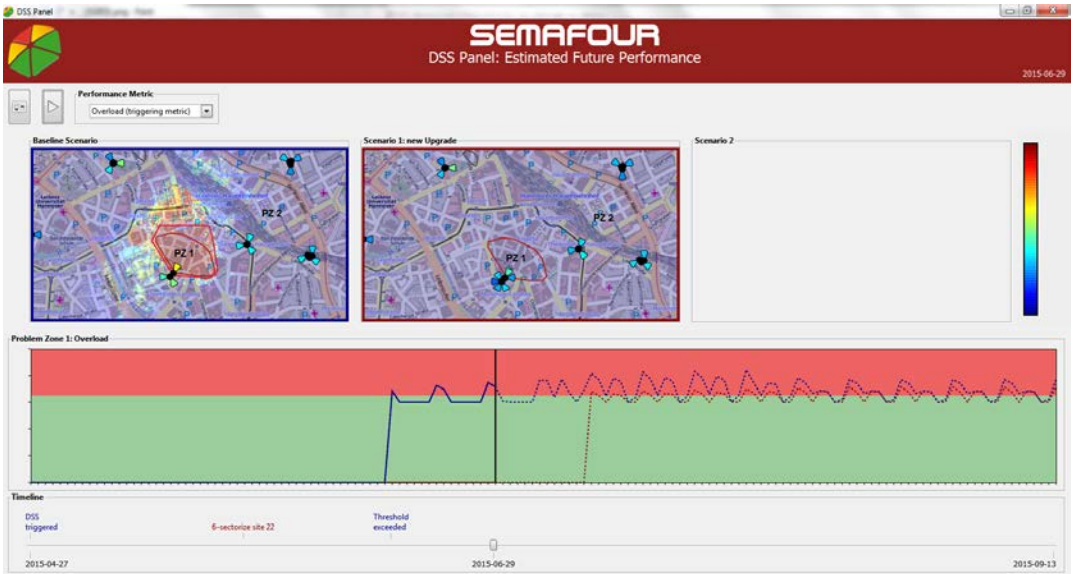


Figure 32: The DSS Panel, showing the effects of a six-sectorization near Problem Zone 1

Once we click the *Play* button, the selected scenarios will be animated on the panel. In the network view of the **DSS Panel**, we see the immediate surroundings of the predicted problem zone, which itself is indicated with a red dashed line polygon. Other predicted problem zones in the vicinity are also shown, but with a gray dashed line polygon. The time-varying background color map shown in each of the views, indicates a predicted overload metric throughout the area. Note from the legend that, as expected, regions of more severe overloads occur in the area of the problem zone. Besides the background map showing the spatial presentation of the overload metric, also the cell markers themselves are colored to indicate their predicted loads.

On the timeline, distinct markers indicate key events, such as the day at which Problem Zone 1 was predicted to emerge, or in other words, the day at which the overload metric for that problem zone was predicted to first exceed some predefined threshold, indicated in the chart by a distinction between the green and red background colors. From this day backwards, the DSS derives for each selected upgrade the day at which the deployment of the upgrade should be *initiated*, considering typical deployment lead times depending on the nature of the upgrade. Furthermore, a safety margin of an additional week is enforced.

In the regional network view of the upgrade scenario, the six-sectorized site is shown, starting from the moment the upgrade is in effect.

In the view for the baseline scenario, at the date where the problem zone is predicted to arise, a red *solid* line polygon is shown, which from then on continues to grow as the increasing traffic worsens the overload in the area and no upgrade is effectuated to resolve this. At all times, the red dashed line polygon remains visible to indicate the anticipated problem zone that triggered the DSS alert.

In the upgrade scenario, we immediately see the effects of the network upgrades in that the load situation is improved by the added network resources. Here the problem zone has completely vanished by the upgrade. Only the dashed polygon marking the triggering problem zone is shown. In the chart we see how for the upgrade scenario the predicted overload curve enters the ‘red zone’ at a later date than was the case for the baseline scenario. This is due to the additional local capacity generated by the six-sectorized site.

Considering these predicted load effects for the different recommended upgrades as well as the different deployment costs associated with each upgrade, the network operator will then make a decision as to which upgrade to deploy in the network. In order to better anticipate future bottlenecks, the operator should inform the DSS of the timing and nature of any planned network upgrades, so that these can be appropriately taken into account.

9 Concluding Remarks

This deliverable gives an overview of the demonstration platform and scenarios used to showcase the key project results achieved in WP4 and WP5, and captured in deliverables D4.3 [6] and D5.3 [7]. The use cases show-cased in the demonstrator and further described in this deliverable are:

- Dynamic spectrum allocation and interference management
- Multi-layer LTE/Wi-Fi traffic steering
- High mobility
- Active antenna systems
- Policy based SON management and SON coordination
- Decision support system for operational network evolution

For each use case above, we have described the demonstration objective, followed by the specific assumptions and scenarios in which the SON (management) features are evaluated. Key demonstration KPIs are defined and a short description of the SON functions is presented, as well as the overall storyline of the specific use case demonstration, highlighting the main benefits.

In conclusion, the SEMAFOUR demonstrator brings together key solutions and findings under one common platform and clearly shows the overall benefit in terms of network performance and management simplification. This is achieved by showcasing the performance of the different SON and management features in realistic scenarios and use cases. Through the demonstrator it is possible to, control (de)activation of SON functions as well as setting parameters of the different SON functions, using the Operator Panel. The KPI Client illustrates performance metrics associated to a particular demonstration case, and together with the Network Client and Cell View Clients it is possible to evaluate spatial network and cell performance. In order to understand the impact of actual user services, the Proxy/Server/Terminal Clients support the involvement of actual session terminals, on which suitably emulated video streams are shown to illustrate the service quality experienced by specific users. The demonstrator will be delivered in D3.5 [15].

10 References

[1] EU FP7 SEMAFOUR, “Definition of Reference Scenarios, Modelling Assumptions and Methodologies (Final Results)”, Deliverable D2.5, February 2015

[2] EU FP7 SEMAFOUR, “Demonstration Scenarios”, Deliverable D3.1, February 2013

[3] EU FP7 SEMAFOUR, “Definition of self-management use cases”, Deliverable D2.1, February 2013.

[4] EU FP7 SEMAFOUR, “SON Functions for Multi-Layer LTE and Multi-RAT Networks (First Results)”, Deliverable 4.1, November 2013.

[5] EU FP7 SEMAFOUR, “SON Functions for Multi-Layer LTE and Multi-RAT Networks (Final Results)”, Deliverable 4.2, August 2014

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