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D5.10

Measurements, Architecture and Interfaces for Self-organising Networks

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Abstract: The SOCRATES project aims at the development of self-organisation methods for LTE radio networks. In addition to the algorithms required for SON functionality, measurements, architecture and interfaces should also be considered. This document considers these aspects based on SOCRATES results from stand-alone and integration use cases, and work on SON coordination.

Keyword list: Self-organisation, self-optimisation, self-healing, self-configuration, measurements, architecture, interfaces, use cases, SON coordination

Executive Summary

The SOCRATES project is developing solutions for self-organising networks. Development of algorithms is an important part of this. However, the algorithms alone are not sufficient for a complete SON solution. In addition, measurements, interfaces and architecture are required. This document considers these aspects, with the purpose of identifying which measurements, interfaces and architectures need to be implemented for the SON functions that have been considered in SOCRATES, and in addition to identify standards requirements to support this.

Measurements are required as input to the SON algorithm. The umbrella term measurements can be sub-divided into three different categories: radio measurements, statistics and KPIs (key performance indicators). Measurements are considered for all stand-alone and integration use cases, and are presented in tables. A combined table is included showing the required measurements for all stand-alone use cases. Many measurements are required, with some measurements used by multiple use cases.

As SON algorithms often involve more than one network element, interfaces between network elements are important. Two interfaces are most important and standardized: the X2 interface, which is the interface between eNodeBs, and the Northbound Interface (Itf-N), which is the interface between the Element Manager and the Network Manager.

Interface requirements are specified for all stand-alone and integration use cases. A combined table is included, showing all interface requirements for the stand-alone use cases. There are various interface requirements, although the number is considerably less than the number of measurements.

For the implementation of SON algorithms, the architecture is also important, i.e. where in the network the SON algorithm is implemented or located. Particularly important is the impact on architecture of the coordination between SON use cases; the architecture is considered for all SON coordination roles.

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List of Acronyms and Abbreviations

3GPP	3rd Generation Partnership Project
AC	Access Control
AC	Admission Control parameter optimisation
AeNB	Affected eNodeB
AGP	Automatic Generation of initial Parameters for eNodeB insertion
aGW	access GateWay
ANR	Automatic Neighbour Relations
CQI	Channel Quality Indicator
COM	Cell Outage Management
DL	Downlink
DM	Domain Manager
EM	Element Manager
eNB	eNodeB
EPS	Evolved Packet Service
E-UTRAN	Evolved UMTS Terrestrial Radio Access Network
FDD	Frequency Division Duplex
FFS	For Further Study
GBR	Guaranteed Bit Rate
GPS	Global Positioning System
HeNB	Home eNodeB
HNB	Home NodeB
HNB	Self-optimisation of Home eNodeB
HPO	Handover Parameter Optimisation
ICO	Interference Coordination
ID	Identifier
IE	Information Element
Itf-N	Northbound Interface
KPI	Key Performance Indicator
LB	Load Balancing
LTE	Long Term Evolution
MCS	Modulation and Coding Scheme
MDT	Minimization of Drive Tests
MME	Mobility Management Entity
MRO	Mobility Robustness Optimisation
NE	Network Element
NM	Network Manager
NeNB	Neighbour eNodeB
OAM	Operation, Administration, and Maintenance
OSI	Open System Interconnection
OSS	Operational Support System
PBR	Prioritised Bit Rate
PCI	Physical Cell ID
PRB	Physical Resource Block
PS	Packet Scheduling parameter optimisation
QCI	QoS Class Identifier
RACH	Random Access Channel
RAN	Radio Access Network
RAT	Radio Access Technology
RB	Radio Bearer
RL	Radio Link
RLF	Radio Link Failure
RRC	Radio Resource Control
RRM	Radio Resource Management
RSRP	Reference Signal Received Power
RSRQ	Reference Signal Received Quality
RSSI	Received Signal Strength Indicator
SA	Services and System Aspects

SAE	System Architecture Evolution (3G core evolution)
SINR	Signal to Interference and Noise Ratio
SOCRATES	Self-Optimisation and Self-Configuration in Wireless Networks
SON	Self-organising Networks
SUE	Served UE
TDD	Time Division Duplex
Tdoc	Technical document (3GPP)
TNL	Transport Network Layer
TR	Technical Report
TS	Technical Specification
TSG	Technical Specification Group
UE	User Equipment
UL	Uplink
UTRAN	UMTS Terrestrial Radio Access Network
WI	Work Item
WP	Work Package
XME	X-Map Estimation

Table of Contents

1 Introduction

In the SOCRATES project, SON (Self-Organising Networks) functionality has been developed. The SON functionality can be divided into three categories: stand-alone use cases, integration use cases and SON coordination. Stand-alone use cases considered a single SON functionality. Examples of stand-alone use cases considered in SOCRATES are load balancing and cell outage compensation. Integration use cases consider two use cases simultaneously, and the focus is on the interaction and potential conflicts between the two use cases. SON coordination considers an overall framework for the coordination between use cases.

This document considers the measurements, architecture and interfaces that are required to support this SON functionality. The aim of considering these aspects is to understand what measurements, architecture and interfaces need to be implemented to support SON, and in addition what standardisation support is required.

Results are based on work in other SOCRATES work packages, specifically WP3 (Self-optimisation) and WP4 (Self-configuration and self-healing). In these work packages, solutions for self-organising networks have been developed. To support these solutions, measurements, architecture and interfaces are required. As part of the work in these work packages, required measurements, architecture and interfaces have already been identified. In this document, these measurements, architecture and interfaces are summarised and differences and similarities between different use cases are identified. Where appropriate, requirements for 3GPP standardisation are identified, if the necessary standards are not already in place.

Figure 1 shows the general 3GPP scenario layout for Operation, Administration and Maintenance (OAM) with the separation into the different management layers and the interfaces between these layers. This architecture builds the basis for all requirements on measurements, interfaces and architecture described in this document. Only the Itf-N interface between OSS layer (often also called Network Management layer) and Network Element Management (NEM) layer, and the X2 Interface between eNodeBs is standardised, other interfaces are manufacturer specific.

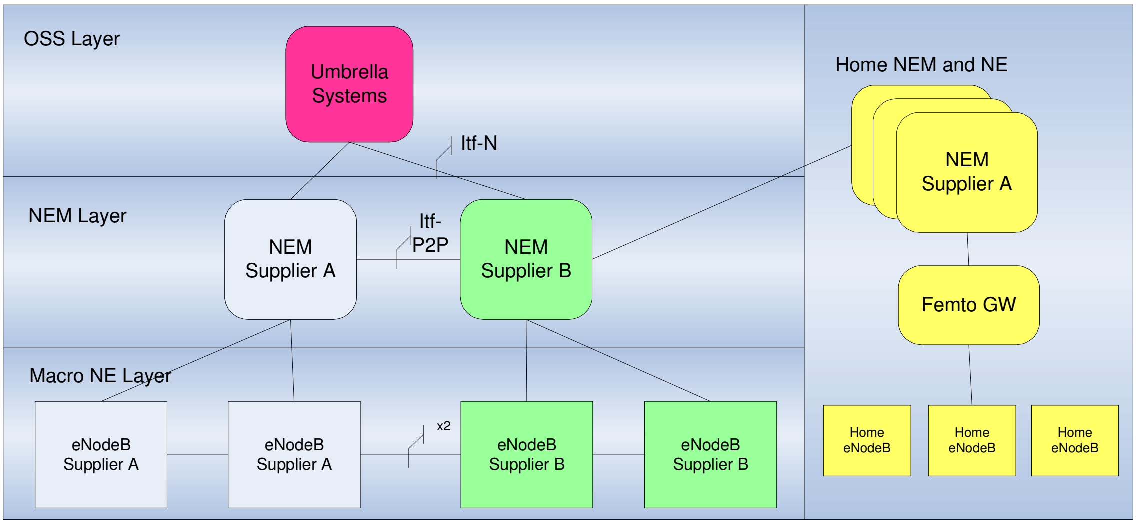

Figure 1: General 3GPP OAM scenario layout – Delegation of responsibilities to different element layers

As background information, chapter 2 provides a high-level overview of the status of SON in 3GPP. Standardisation in RAN2, RAN3 and SA5 is considered, as these are the relevant groups for SON standardisation.

Chapter 3 considers measurements. Measurements are important, as they are used as input to the SON algorithms. The measurements for stand-alone and integration use cases are considered. The detailed tables are included in the appendix in section 8.1. Various tables, listing measurements and their associated attributes, are included. Combined overview tables and analysis of these are included in chapter 3.

In chapter 4, interfaces are considered. Specifically, the focus is on signalling requirements over existing interfaces. Often, use cases require interaction between different network elements. To enable those interactions, signalling is required over the interfaces between these network elements. Detailed tables are included in the appendix in section 8.2. Combined overview tables and analyis of these are included in chapter 4.

In chapter 5, architectural aspects are considered. For the stand-alone and integration use cases, the focus is on whether a centralised, distributed or hybrid architecture is preferred. For SON coordination, the preferred architecture for the functional roles is described.

Finally, in chapter 6, the conclusions and recommendations are presented.

2 High-level overview of 3GPP status

2.1 Introduction

In this chapter, an overview is given of SON standardisation in 3GPP. As this document considers measurements, architecture and interfaces for SON as required by SOCRATES solutions, in the following chapters the requirements from SOCRATES will be compared to what is already standardised. Therefore, it is useful to first provide an overview of the topics that have already been standardised in 3GPP.

The main items of standardisation are highlighted, and briefly summarised. Information is provided on standardisation in RAN2, RAN3 and SA5. Figure 2 shows the high-level architecture of 3GPP LTE and SAE (source: [29]), including the network entities (elements) and interfaces that are of relevance for this document.

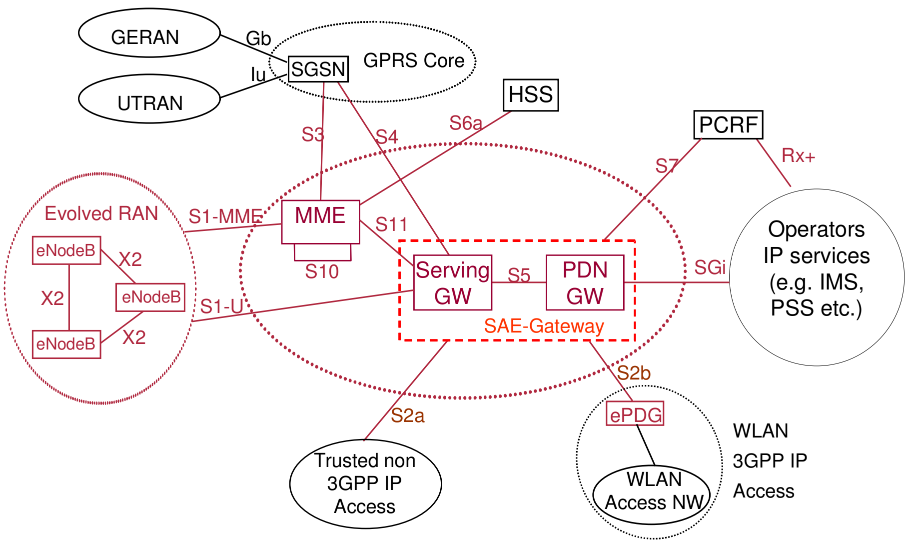

Figure 2: 3GPP LTE and SAE high-level Architecture (Source: [29])

2.2 3GPP RAN2

The Technical Specification Group (TSG) Radio Access Network (RAN) Working Group 2 (WG2) in 3GPP is the group responsible for radio interface architecture and protocols. For SON purposes, it standardised the required signalling between the eNodeB and UE. One of the key aspects of that is retrieval of UE measurements by the eNodeB. In the following sections, an overview is provided of RAN2 SON standardisation in Release 8, 9 and 10.

2.2.1 Release 8

In 3GPP Release 8, UE signalling was standardised to support ANR (Automatic Neighbour Relations) [7]. As part of the ANR process, the eNodeB needs to obtain the global cell ID of the potential neighbour cell that the UE has measured, and signalling for that has been standardised.

2.2.2 Release 9

In 3GPP Release 9, UE signalling was standardised to support RACH optimisation [12]. The eNodeB needs information from the UE to assess the RACH channel performance. This is because if a UE is having problems accessing the RACH channel, the eNodeB may not be aware of that.

To provide the necessary information to the UE, signalling of two measurements was standardised: the number of preambles sent, and whether contention was detected. Signalling of these measurements will be requested by the eNodeB.

Also in Release 9, UE signalling was standardised to support MRO (Mobility Robustness Optimisation) [12]. If Radio Link Failure (RLF) occurs, it is useful for the eNodeB to know what the radio conditions where at the time of RLF. For that purpose, the eNodeB can request the RSRP and RSRQ values at the time of RLF.

2.2.3 Release 10

The most relevant work item related to SON in RAN2 during Release 10 is the ‘Minimization of Drive Tests’ (MDT) activity. This activity considers how to use UE measurements to reduce the need for drive tests. The measurements from the UEs can be used for manual network optimisation, but they can also be used for SON. Note that this topic was a study item in Release 9.

MDT is possible both in connected and idle mode. In connected mode, immediate reporting will be used, i.e. measurements will be transmitted to the eNB directly after they have been taken. In idle mode, logged reporting will be used. This means that measurements will be taken and then stored in a log in the UE. When the UE goes into connected mode, the logged measurements will be transmitted to the eNodeB.

When measurements are reported, the report will include the measurements values, location information and time information.

2.3 3GPP RAN3

The Technical Specification Group (TSG) Radio Access Network (RAN) Working Group 3 (WG3) is responsible for the Overall UTRAN/E-UTRAN architecture and the specification of protocols for the Iu, Iur, Iub, S1 and X2 interfaces. For the SON purposes WG3 mainly works on interfaces and protocols standardisation as many of SON functions require exchange specific information between eNBs in case of distributed approach or with e.g., OAM in case of centralised.

2.3.1 Release 8

In the 3GPP Release 8 tasks related with SON (SON Concepts and requirements, Self-Establishment of eNBs, SON Automatic Neighbour Relations (ANR) List Management) have been worked out by SA5 in SON Work Item (WI). RAN3 group addressed SON related tasks (not part of the Rel. 8 SON WI) like:

- Automatic Neighbour Relation Function (ANR) which enables a cell to maintain information on its neighbours’ and define operates based on information available at an eNB.
- Automated Configuration of Physical Cell Identity that enables a cell to select automatically its PCI from an allowed range and avoids PCIs that are reported from outside
- Load reporting of current load information for radio, Transport Network Layer (TNL) and hardware.

2.3.2 Release 9

In the 3GPP Release 9 WG 3 continued work on SON functions described in Release 8 and also newly defined in Release 9 like:

Mobility load balancing optimization which allow network to force users to HO against the radio condition but due to load situation. Such LB procedure can be executed as an intra LTE HO as well as inter RAT HO. In Release 9, for the purposes of LB, procedures have been defined to negotiate HO settings between eNBs (intra LTE), and procedures to identify appropriate cause values for HO request or signalling have been defined.

Mobility Robustness Optimization (MRO) which allow on automatic detection and correction of wrong HO settings which lead to RLFs

RACH Optimisation which allows UE to report RACH activity to the eNB . The eNB based on received reports is able to optimize RACH resources and synchronise RACH settings with other eNB by exchanging information over X2 and mitigate interference.

Coverage and Capacity optimization, which enables the network to detect capacity and coverage problems (e.g. coverage holes). For the purposes of this function, WG3 defined required information exchanged between eNBs, this task is also related with interference reduction techniques.

2.3.3 Release 10

In 3GPP Release 10 WI SON include continuation of works from Release 9 like, *Mobility Robustness* with the focus on inter-RAT HO, Mobility *Load Balancing* enhancements improving intra and inter RAT procedures and as a new use case *Energy saving* has been added to SON WI.

2.4 3GPP SA5

The Technical Specification Group (TSG) *Services and System Aspects*, work group 5, commonly referred to as SA5, is the 3GPP standardisation group for telecom management. SA5 specifies management framework and requirements, delivers architecture descriptions of the telecommunication management network and coordinates telecom management work across TSGs. The areas in which SA5 have been active within SON are *self-optimisation*, *self-healing, minimisation of drive tests (MDT)* and *energy savings*. In this section, an overview of the SA5 work of most interest for SOCRATES within self-optimisation, self-healing and MDT is given. Energy savings is not considered in SOCRATES.

2.4.1 Release 8

In 3GPP Release 8, SA5 considered one building block[1] within the SON area, called the SON building block. The work tasks[2] considered were SON concepts and requirements, self-establishment of eNBs and SON ANR list management. The ANR work task was the most active one, where the solution was defined in [19].

2.4.2 Release 9

In 3GPP Release 9, SA5 studied SON OAM aspects, self-optimisation management, SON related OAM interfaces for Home NodeB and self-healing of SON. In the self-optimisation management work, requirements for a number of self-optimisation use cases were specified in [20]. Table 1 shows the use cases considered and the standardisation status as given in [21].

Table 1: Self-optimisation use cases and standardisation status

Use Case	Standardisation Status
Monitoring and Management (general requirements)	Requirements have been defined.
Load Balancing Optimization	Optimisation targets have been specified.
Handover (HO) Parameter Optimization	Optimisation targets and suggestions of parameters to be optimised have been specified.
Interference Control	Some requirements specified.
Capacity and Coverage Optimization	Some requirements specified.
RACH Optimization	Some requirements specified.

2.4.3 Release 10

As part of the Operations, Administration, Maintenance & Provisioning feature (OAM&P 10), SA5 currently has one building block within the SON area; the SON-OAM aspects building block, consisting of two active work tasks on self-optimisation and self-healing; namely SON Self-optimization management continuation and SON Self-healing management.

For the self-optimisation management continuation work task, the focus is to specify management aspects of interference control, capacity and coverage optimisation and RACH optimisation. Further, the work considers coordination related with self-optimisation, for example coordination of manual operations and automatic functionalities, or coordination between different self-optimisation use cases. Some additional release 10 requirements have been defined in [22].

[1] In [18], a building block is described as a "*sub-division of a feature, representing a coherent set of technical functionality which would generally be expected to reside in a single system element*".

[2] In [18], a work task is described as a "*sub-division of a building block, representing a self-contained, well-scoped and well-scheduled item of work*".

The SON Self-healing management work task was moved from Release 9 to Release 10. The self-healing requirements specification, [23], is still in draft mode, and hence not tied to a specific release.
The stage 2[3] document for self-healing, [27], is not yet available. It has been agreed to implement Self Healing of Cell Outage in the Self Optimisation Stage 2 document [21]. Table 2 shows the use cases considered for self-healing.

Table 2: Self-healing use cases

Use Case
Self Recovery of NE Software
Self-healing of board faults
Self Healing of Cell Outage; • Cell Outage Detection • Cell Outage Recovery • Cell Outage Compensation • Return from Cell Outage Compensation

In the minimization of drive test area, SA5 has one work item on Management of UE based network performance measurements. Requirements have been included in [24] and [25]. The stage 2 work is ongoing and will be documented in [26].

[3] In [18], "Stage 2" is described as a "*logical analysis, breaking the problem down into functional elements and the information flows amongst them across reference points between functional entities*".

3 Measurements

3.1 Introduction

Measurements are an essential input to Operation, Administration and Maintenance (OAM), and to Radio Resource Management (RRM). With the introduction of SON, the requirements on measurements will change regarding number, accuracy, or timeliness, compared with conventional performance management. Furthermore, there may be additional measurements required by some SON functions.

In this chapter, the measurements required by the SON functions that have been developed within the SOCRATES project are described. A table has been created for each SON function, listing the measurements required by the corresponding algorithm. For each measurement, details regarding measurement type, layer, period, and the status in 3GPP standardisation are given. While some of the measurements required by the use cases are already standardised, others are still discussed in 3GPP. Especially for SON functions that operate directly at the NE, standardisation may not be necessary as the implementation of the SON functions and the required measurements is usually manufacturer specific.

The chapter is organised as follows: Section 3.2 provides an introduction to the measurements types and sources that have been regarded, and furthermore an explanation of the table format that has been used for describing the requirements of the SON functions. Section 3.3 lists the results for the stand-alone SON functions as they have been described in SOCRATES deliverables D2.1 [1] and D2.4 [4], and developed in SOCRATES work packages 3 and 4. Section 3.4 lists the results of the integration SON functions and the SON coordinator as they have been developed in SOCRATES work package 3. An overview of the results from the WP3 and WP4 use cases can be found in SOCRATES deliverable D5.9 [32].

3.2 Definitions and concepts

3.2.1 Measurement types

In the following, all types of data are listed that can serve as input to the SON functions. In this document, we define a measurement as data that is either directly taken from an NE or UE, or that has been calculated from NE or UE data. Note that the definition of measurement used in this document is different from the definition in [28]. In the context of this document, a measurement includes all types of data that can serve as input to a SON function and is not limited to a measured value from an NE or UE. Therefore, the term "Measurement" used in this document includes, if not explicitly noted, all these types of information.

- *Counter:* a counter represents a single value that is maintained by the firmware or software of the Network Element (NE), e.g. eNodeB; an example is an event counter (failure counter) that incrementally counts specific events
- *Key Performance Indicator (KPI):* a KPI uses two or more counters as input and calculates from them a value according to a well-defined algorithm
- *Alarms:* an alarm is emitted by the NE towards the Operation, Administration, and Maintenance (OAM) system, triggered by defined events
- *Timers:* timers are started and stopped by the NE, e.g. to measure the duration of a dedicated process; in case a timer expires this may indicate an exception and cause an alarm
- *Measurements:* a value that is taken by the NE or the User Equipment (UE), which may be event-triggered or periodically, and that represents a certain state of the NE or a connection; examples are temperature, load, and link quality.
- *Statistic:* statistics are accumulated and/or processed values of the above measurement types (e.g. counter, alarms and measurements) over time; they can be calculated at the NE, UE, or the OAM system;

3.2.2 Measurement sources and targets

There are several entities in the network where measurements can be acquired from, or where the acquired measurements can be sent to. As the SON functions that have been developed in SOCRATES have different measurement sources and targets, the possibilities are listed below:

- *Affected eNodeB*: the eNodeB which is affected by the SON use case

- *Neighbouring eNodeB:* eNodeBs that are neighbours of the affected eNodeB, e.g. those with a handover relationship
- *User equipment* served by the affected eNodeB
- *User equipment served by neighbour cells* that still receive and decode information from the affected eNodeB
- *The access gateway(s)* (aGW) to which the eNodeB is connected
- The *OAM fault management* system where alarms are aggregated

Figure 3 shows the different potential sources. The eNodeB1 depicted in the centre symbolises the affected eNodeB (failed or low performing), which serves the three surrounding cells (marked in light orange) and serves user equipment UE1. eNodeB1 has furthermore a connection to the neighbouring eNodeBs 2-4 (dotted line) and is associated to the aGW (dotted line). UE1, which is served by eNodeB1, also receives signals from eNodeBs 2 and 3. UE2 is served by eNodeB2 and also receives signals from eNodeB1.

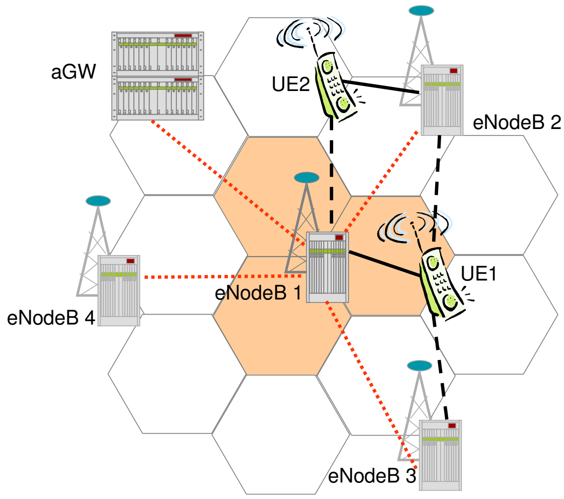

Figure 3: Measurement Sources

3.2.3 Measurement tables format

In this chapter the measurements required by stand-alone use cases, integration use cases, and the SON coordinator, are shown in table format. These tables provide the following information per measurement:

- #: The SON function that requires the measurement
- Name: measurement name (not necessarily a standardised name)
- Type: the measurement type as described in Section 3.2.1
- Layer: the OSI layer where the measurement is taken
- No. of cells: the number of cells per NE (if applicable) where the measurement is to be taken from
- Source: the network element where the measurement is taken from as described in Section 3.2.2
  - Affected eNodeB (AeNB)
  - Neighbour eNodeB (NeNB)
  - User Equipment (UE)
  - Served UE (SUE)
  - Neighbour UE (NUE)
  - Access Gateway (aGW, including SAE-Gateway and MME)
  - OAM system
- Target: the network element where the measurement is sent to (cf. also the descriptions in Section 3.2.2)

  - Affected eNodeB (AeNB)
  - Neighbour eNodeB (NeNB)
  - OAM system
- Period: the time period in which the measurement is taken:
  - ms: milliseconds
  - s: seconds
  - min: minutes
  - hours
  - By trigger: the measurement is taken only on request
- Purpose: description of the intended use of the measurement
- Standard (3GPP): the 3GPP standard document(s) where the measurement is described (if applicable)

3.3 Stand-alone SON functions – combined measurements tables

This section summarises the measurements that are required by the following SOCRATES WP3 and WP4 SON functions (see SOCRATES deliverable D5.9 [32] for an overview of the WP3 and WP4 results):

- Load Balancing (LB, WP3)
- Handover Parameter Optimisation (HPO, WP3)
- Admission Control parameter optimisation(AC, WP3)
- Packet Scheduling parameter optimisation (PS, WP3)
- Interference Coordination (ICO, WP3)
- Self-optimisation of Home eNodeB (HNB, WP3)
- Cell Outage Management (COM, WP4)
- X-Map Estimation (XME, WP4)
- Automatic Generation of initial Parameters for eNodeB insertion (AGP, WP4)

The contents of the following Table 3 and Table 4 have been combined from the individual SON function tables that are provided in Section 8.1. By combining the tables, an overview of the measurement requirements of the different SON functions is created. This enables measurements required by multiple SON functions to be identified, as well as differences in the requirements for different SON functions. Table 3 contains measurements – based on the narrow definition of measurements, i.e. KPIs and statistics are not included in this table. Instead, they are included in Table 4, which considers KPIs and statistics.

In case the same measurement is required by several SON functions with different settings (e.g. measurement period), the measurement is listed only once but with the different characteristics. To identify the SON function from which the requirements come, the acronyms as defined above are used (i.e. HO is handover optimisation). Measurements that are the same or similar are grouped together.

Table 3: Combined table of measurements – stand-alone SON functions

#	Name	Type	Layer	No. of cells	Source	Target	Period	Purpose	Standard (3GPP)
HPO1	RSRP	Measurement	1	21	SUE	AeNB	200ms	UE monitors RSRP from neighboring cells in order to determine a HO target when RSRP from SeNB is degrading	TS 36.214 V8.2.0
LB2	RSRP	Measurement	1	1	SUE	AeNB	200 ms	SINR and load estimation	36.214
HNB4	RSRP	Measurement	1	1	SUE	AeNB	10 seconds	Information on the relative signal strength of different base stations may be useful.	
HNB6	RSRP	Measurement	1	1	AeNB	AeNB	10 seconds	RSRP (DL) from neighbouring base stations measured in the HeNB and used for calculating suitable HeNB transmission power.	Standardized for UE measurements in 36.214. DL receiver in 3G HNBs have been discussed, but not standardized. This is also not standardized for HeNBs. This should however not be needed, as measurements are both performed in and used by the HeNB.
XME2	RSRP	Measurement	1	1	SUE/NUE	TBD	200 ms	Create X-map (localised network performance)	36.214
AGP1	RSRP	Measurement	1	1	SUE	AeNB / OAM	15min	Measurement of the strongest servers (base stations) in the neighbourhood, to identify neighbours of newly installed eNodeBs. If possible, the measurements shall be associated with location information - Input to ANR - Verification of the offline integration model - Load estimations to predict the impact of changes - Adaptation of soft integration parameters, also as input for subsequent parameter self-optimisation	36.214
LB3	RSSI	Measurement	1	1	SUE	AeNB	200 ms	SINR and load estimation	36.214
HNB7	RSSI	Measurement	1	1	AeNB	AeNB	10 seconds	RSSI (DL) from neighbouring base stations measured in the HeNB and used for calculating	Standardized for UE measurements in

								suitable HeNB transmission power.	36.214. DL receiver in 3G HNB has been discussed. This is also not standardized for HeNBs. This should however not be needed, as measurements are both performed in and used by the HeNB.
HPO2	SINR	Measurement	3	1	SUE	SUE	200ms	The SINR is used in the simulations to detect call drops. If the SINR falls below a threshold for a certain time the UE is considered to be dropped from the network	
LB4	DL RS TX power	Measurement	1	1	AeNB,NeNB	AeNB	200 ms	SINR and load estimation	36.214
LB5	Received Interference Power	Measurement	1	1	AeNB	AeNB	200 ms	SINR and load estimation	36.214
COM2	UL inter-cell interference	Measurement	L1	1	NeNB	NeNB	1-15 mins	To determine the setting of uplink target received power P_0	
HB5	UE speed	Measurement	1?	0	SUE/AeNB	AeNB	10 seconds	Different handover settings will be used for UE with different speeds.	
XME1	UE position	Measurement	1(?)	1	SUE/NUE	TBD	200 ms	Geographical reference for desired measurement Comments: - The measurements from neighbour cells are also considered. Thus, an interface to exchange the information between the neighbour cells is required. - X-Map estimation requires a new entity which is most likely best handled in, e.g., the OSS. - The mentioned measurement period of 200ms represents the ideal value. However, longer measurement periods are also possible.	
COM1	User bit rate	Measurement	L2/L3	1	NeNB	NeNB	1-15 mins (educated guess; the	To determine the user quality in own cell, where quality is defined as a percentile. Cell outage compensation runs over several iterations.	

							period may even be shorter)		

Table 4: Combined table of KPIs and statistics – stand-alone SON functions

#	Name	Type	Layer	No. of cells	Source	Target	Period	Purpose	Standard (3GPP)
HPO3	UE history information	Statistic	3	16	SUE	AeNB	Update on handover event	By analyzing the information contained in this list of visited cells and times spent in each of them, we can detect ping-pong HOs. If a call is handed over to a new eNodeB and is handed back to the source eNodeB in less than the critical time (T_crit = 5s) this handover is considered to be a ping-pong handover.	TS 36.300 V8.8.0
HPO4	HO failure ratio	KPI	3	1	AeNB	AeNB	200ms	If the value of this KPI is over a predefined threshold the SON algorithm starts to take actions. Also, if the KPI is under its predefined threshold for a long enough period of time, this threshold can be lowered in order to get even better performance.	
LB8	Handover success ratio	KPI	3	1	AeNB	AeNB	Seconds as a SON period	Observe impact of LB operations on networks performance	
AGP7	HO Success Ratio	KPI	n/a	1	NeNB	AeNB / OAM	15 min	- Verification of the offline integration model - Adaptation of soft integration parameters, also as input for subsequent parameter self-optimisation	36.425
HPO5	Call dropping ratio	KPI	3	1	AeNB	AeNB	10ms	Same as 4	
LB6	Call dropping rate	KPI	3	1	AeNB	AeNB	Seconds as a SON period	Observe impact of LB operations on networks performance	
HNB1	Dropped call ratio (handover	KPI	3	2	AeNB	AeNB	10 minutes	This KPI may be required to identify problems, and to assess whether parameter changes have the desired effect.	

	related)								
AGP5	Call Drop Ratio	KPI	1-3	1	OAM	AeNB / OAM	15 min	see above	
AC1	Fraction of rejected HO calls	KPI	3	1	AeNB	AeNB	Once per minute	AC SON will use this measurement to detect degraded performance (GoS) for handover calls	
AGP6	HO attempts	Statistic / KPI	n/a	1	NeNB	AeNB / OAM	15 min	- Verification of the offline integration model - Adaptation of soft integration parameters, also as input for subsequent parameter self-optimisation	36.425
AC2	Fraction of rejected fresh calls	KPI	3	1	AeNB	AeNB	Once per minute	AC SON will use this measurement to detect degraded performance (GoS) for fresh calls	
AGP4	Call Blocking Ratio	KPI	1-3	1	OAM	AeNB / OAM	15 min	There may be various issues for the rejection / drop of a call / connection setup: - Radio link failures - Admission control - QoS control The reason behind this is to get qualitative values for comparison with neighbouring eNodeBs - Verification of the offline integration model - Adaptation of soft integration parameters, also as input for subsequent parameter self-optimisation	32.425 (RRC / EPS connection counters)
HPO6	Ping-pong HO ratio	KPI	3	1	AeNB	AeNB	10ms	Same as HPO4	
LB7	Ping-pong HO ratio	KPI	3	1	AeNB,	AeNB	Seconds as a SON period	Observe impact of LB operations on networks performance	
HNB2	Ping-pong HO ratio	KPI	3	2	AeNB	AeNB	10 minutes	This KPI may be required to identify problems, and to assess whether parameters changes have the desired effect.	
LB1	Load, PRB usage	Statistic	2	From 1 to all	AeNB,NeNB	AeNB,NeNB	Seconds as a SON period	The measurement is done separately for DL and UL, trigger LB functionality at AeNB and inform AeNB about the available resources at NeNB	36.314
AGP2	UL PRB Usage	KPI	2	1	AeNB	AeNB / OAM	15 min	Physical Resource Block (PRB) usage is an indicator for the cell load. PRB usage can also be calculated for different traffic classes.	36.314

								- Verification of the offline integration model - Adaptation of soft integration parameters, also as input for subsequent parameter self-optimisation	
AGP3	DL PRB Usage	KPI	2	1	AeNB	AeNB / OAM	15 min	Physical Resource Block (PRB) usage is an indicator for the cell load. PRB usage can also be calculated for different traffic classes. - Verification of the offline integration model - Adaptation of soft integration parameters, also as input for subsequent parameter self-optimisation	36.314
HNB3	Cell load	KPI	1	1	AeNB	AeNB/NeNB	1 minute	Cell load is a factor in the decision whether to hand over to a particular cell.	
AC3	Traffic loss ratio of real-time calls	KPI	2	1	AeNB	AeNB	Once per minute	AC SON will use this measurement to detect degraded performance (QoS) for real-time calls	TS 36.314 v9.00 (2009-12), Packet Discard Rate in the DL per QCI, page 13
AC4	Fraction of non real-time calls that do not achieve their required bitrate	KPI	2	1	AeNB	AeNB	Once per minute	AC SON will use this measurement to detect degraded performance (QoS) for non-real-time calls	
XME4	Any desired value	KPI	3	1	AeNB/ NeNB	TBD	200 ms	Create X-map (localised network performance)	

3.4 Integration SON functions

Integrated SON functions are functions that run in parallel in a network and interact with each other regarding the configuration parameters to be changed, or the metrics (measurements) to be influenced. Some of the integrated SON functions might therefore require additional measurements that have not been considered for the corresponding stand-alone functions, or require different settings for these measurements such as the period. This chapter summarises the measurements that are required by the SOCRATES WP3 and WP4 SON integration SON functions [32]:

- Load Balancing & Handover Parameters Optimisation (LB-HPO) both operate by controlling HO parameters and all measurements required by them as a standalone functions are sufficient for proper cooperation between them.
- Measurements utilised by integrated Handover Parameters Optimisation & Admission Control (HPO-AC) functions do not require new measurements but those that have been already used by HPO as a standalone function will be used for integration purposes.
- Home eNodeB HO Optimisation & Macro Handover Parameters Optimisation (HNB-HPO) as well as HPO-AC integrated SON function do not need to define new measurements but those that have been already used by HPO as a standalone function will be used for integration purposes.
- Automatic Generation of initial Parameters for eNodeB Insertion & Handover Parameter Optimisation (AGP-HPO) utilises the same measurements as the corresponding stand-alone functions, without different settings.
- The SON Coordinator does not require new measurements since it is assumed that new measurement required to detect undesirable network behaviour are manufacturer specific according to the type of implemented SON functions.

Table 5 gives an overview of the new measurements required by the different SOCRATES integrated SON functions and the SON coordinator, as well as different usage of measurements that have already been described for standalone functionalities. In case the same measurement is required by several SON functions with different settings (e.g. measurement period), the measurement is listed only once but with different characteristics.

Table 5: Overview of measurements required by integration use cases and SON Coordinator

#	Name	Type	Layer	No. of cells	Source	Target	Period	Purpose	Standard (3GPP)
Load Balancing & Handover Optimisation									
1	New measurements are not required, standalone SON functions measurements are utilised								
Handover Optimisation & Admission Control									
2	Handover failure ratio	KPI	3	1	AeNB	AeNB	180 sec	The HPO SON algorithm considers a weighted sum of these 3 measurements and compares it to the previously obtained weighted sum to decide if the handover parameters TTT and Hys should be changed.	
3	Call dropping ratio	KPI	3	1	AeNB	AeNB	180 sec		
4	Ping-pong handover ratio	KPI	3	1	AeNB	AeNB	180 sec		
Home eNodeB HO Optimisation & Macro Handover Parameters Optimisation									
5	Dropped call ratio (handover related)	KPI	3	2	AeNB	AeNB	10 minutes	This KPI may be required to identify problems, and to assess whether parameter changes have the desired effect.	
6	Ping-pong HO ratio	KPI	3	2	AeNB	AeNB	10 minutes	This KPI may be required to identify problems, and to assess whether parameter changes have the desired effect.	
Automatic Generation of initial Parameters for eNodeB Insertion & Handover Optimisation									
7	New measurements are not required, standalone SON functions measurements are utilised								
SON Coordinator									
8	Operator defined network KPIs	KPI	1-3	n	eNB, UE	OAM	n.a.	The Guard function as it is defined as an optional function within a SON Coordinator, aims at identifying undesirable network behaviour caused by the SON system (oscillation, crossing absolute thresholds) and shall trigger countermeasures to solve the underlying problems. As the definition of undesirable behaviour may be operator or manufacturer specific, and depends on the SON functions implemented in the system, no dedicated measurement can be described here.	

Relevance to standards:

Above listed measurements for the integration use cases are already used in the stand-alone handover use case (and all integration use cases include handover as one of the use cases). Difference in the integrated use case is that the period over which these measurements are collected is now longer than in the stand-alone use case. Also the purpose description is now different, as the handover SON algorithm is different. All measurements are internal to the eNB.

Regarding SON Coordinator, it is likely that all measurements that can be used for identifying undesirable network behaviour already exist, so only a corresponding processing is necessary.

Recommendations:

No standardisation actions required.

3.5 Measurements conclusions

Analysis of the measurements considered in this chapter has resulted in the following:

- Most measurements relate to measurement of radio signals, particularly relating to received power and interference. As most use cases assume a distributed implementation, these measurements are generally used locally in the eNodeB.
- Most KPIs and statistics relate to handover and call drops. Most of these are used locally in the eNodeB, although some are used at OAM level.
- For integration use cases, most measurements are the same as for the stand-alone use cases, with minor differences such as the period over which measurements are collected.

4 Interfaces

4.1 Introduction

An essential part of all radio networks are the interfaces, constituting common boundaries between associated systems or entities. In most cases, SON functionality requires input from other entities in the network than the one the SON function is residing in, or involves more than one entity or system in the SON functionality itself. With the introduction of a new SON function, it is important to assess what signalling is needed, and to evaluate whether this can use existing interfaces, or whether interface updates or new interfaces are required. In case a SON function requires a new interface, or requires the enhancement of an existing interface, this is stated in the result tables in the following sections of this chapter.

This chapter gives an overview of the interfaces needed for the SON functions developed within SOCRATES. The interface usage, status in standardisation and changes needed for the SON functions are described. In Section 4.2, the interfaces for the stand-alone SON functions are given, while the integrated SON functionalities are considered in Section 4.3. Then, in Section 4.4, a proposal that was sent to 3GPP on parameter exchange over X2 for the SOCRATES load balancing solution is briefly described. Finally, some concluding remarks are given in Section 4.5.

4.2 Stand-alone SON functions – combined interfaces table

In this section, the requirements on the interfaces by the stand-alone SON functions are combined. The detailed requirements for each individual SON function are provided in Section 8.2. By combining the requirements of the individual SON functions, an overview has been created in Table 6. This overview also enables the identification of interface requirements that are needed by multiple SON functions, and differences in the requirements for different SON functions.

To identify the use case from which the requirements come, the acronyms as defined in Section 3.3 are used (i.e. HO is handover optimisation). The interface requirements are grouped according to the interface that is involved.

Table 6: Combined table of interfaces for stand-alone SON functions

#	Interface Name	Required/ Optional	Usage	Status in Standardi-sation (including spec. number)	Standard Additions / changes	Expected Change in Signalling
LB1	X2	Required	Load information, P0 and parameter alpha are exchanged between eNBs	36.420 - 424	Procedure of P0 and alpha exchange between eNBs is not yet standardised, only exchange of load information	No significant increase in signalling overhead. Information exchanged on demand.
XME1	X2	Required	To exchange location information measured by UEs between eNodeBs for X-Map calculations.	Interface already specified	Add notifications or messages to be sent via the interface.	None.
LB2	Itf-N	Optional	SON entity in the OAM system sends a list of cells to the eNB with an ordered priority for load balancing purposes.		Idea of centralised support for LB proposed in [31]but only noted	These lists are updated periodically for all cells that have the load balancing functionality

						enabled or on request in case of rapid load changes. Shouldn’t significantly increase signaling overhead
COM1	Itf-N	Required	To specify the user quality degradation during an outage. This is given by the operator and the network then degrades the user quality in order to increase the coverage during an outage	No work has been done; not active	To include the lowest quality level accepted by the operator	
AGP1	Itf-N	Required	To provide the default configuration determined by the network planning system / configuration management to the eNodeB to be installed	No work has been done; not active	To be checked if local eNodeB configuration parameter modifications can be indicated sufficiently fast to the OAM configuration database.	

4.3 Integration use cases

Integrated SON function will run in parallel in a network thus some of them might require to exchange information between them to coordinate their actions thus new interfaces or changes in currently defined might be required. This section summarises the interfaces that are required by the SOCRATES WP3 and WP4 SON integration use cases [32].

- Load Balancing & Handover Parameter Optimisation (LB-HPO) as an integrated SON function do not require new interfaces because of the communication between neighbouring eNBs is the same as for standalone SON functions over X2 interface.
- There is no interfaces affected by integration Handover Parameter Optimisation & Admission Control (HPO-AC) SON functions, since all measurements on which AC SON or HPO SON might react are collected in the eNodeB where the SON algorithms reside.
- In case of integration Home eNodeB HO Optimisation & Macro Handover Parameter Optimisation (HNB-HPO) interface changes are not expected, as the HO parameters are set per eNodeB. In 3GPP signalling for communication over the X2 interface has been standardised. In case a similar solution would be used in HeNBs, X2 (or other interface) would be required between HeNBs, and between macro cells and HeNBs. It has been agreed in 3GPP that the X2 interface will be available for open access HeNBs.
- In an extension of proposed solution, TTT depending on target eNodeB and type (home eNB or macro eNB) could be considered. In that case, additional information (multiple TTT values) might need to be added to the IE MeasConfig, in the Radio Resource Control protocol for the UE-E-UTRAN radio interface.
- Also integration of SON functions: Automatic Generation of initial Parameters for eNodeB Insertion & Handover Parameter Optimisation (AGP-HPO), do not affect currently available interfaces and changes are not required.

- The SON Coordinator concept which is developed to control the interaction between SON functions assumes that the 3GPP Itf-N interface will be required for the specification of high-level performance objectives (Operator Policies) as input to the SON Coordinator resp. the SON system. First activities have been started in 3GPP SA5 on the definition of policies for single SON use cases, but no activities are currently foreseen regarding SON Coordination. As this is highly dependent on the implementation of first and future SON releases, regarding the number of different and interacting SON use cases, and due to the fact that the SON Coordinator concept created within SOCRATES has not been implemented and evaluated within a simulator, no recommendations on further proceeding can be given here. The 3GPP Itf-N interface will be required for transferring feedback on the functioning of the individual SON use cases, but also on the functioning of the SON Coordination functions, if implemented, towards the operator. This feedback will consist of standard performance management information. No further standardisation is required therefore.

4.4 3GPP proposals

Mechanisms for self organising network algorithms are mostly vendor specific solutions and 3GPP standards cover only those areas which are required for a SON function, such as measurements provided by the UE as well as features required for proper cooperation between different devices like interfaces or protocols. As the SOCRATES aim is to develop autonomous solutions, some of the developed SON function might require new input information which is not covered by standards. In such a case, one of the partners which represented in 3GPP can in cooperation with others apply this extension to the standard.

The Load Balancing function proposes a method for load prediction at the TeNB by estimating SINR after LB HO. This method allows the LB algorithm to calculate accurate HO offsets, to achieve load reduction at SeNB by user redistribution over the adjacent cells without performance degradation and HO request rejections. The data required to estimate SINR after HO in downlink can be acquired from the users, but in uplink the additional information P0 and α must be exchanged between eNodeBs which are involved in the LB process. 3GPP RAN3 contribution [30] discusses problems of UL LB and proposes a solution to exchange some additional parameters over the X2 interface, including P0 and α parameters considered in SOCRATES. The document was noted and discussions will come up during the next 3GPP RAN WG3 meetings.

4.5 Interfaces conclusions

The SON functions developed in SOCRATES require communication over X2 and Itf-N. Some SON functions may use both interfaces, while some functions use one, or even no signalling over the considered interfaces. It is expected that existing interfaces can be used for all of the SON functions. An extension of the HeNB optimisation solution to cases where X2 is not available might need a new interface to the HeNB, or extended messages over S1, but this has not been further evaluated within SOCRATES. It is expected that signalling over X2 and Itf-N needs to be extended to include information needed by the SON functions. No need for major changes to the interfaces has however been foreseen.

SOCRATES has identified some additional parameters to be exchanged over the X2 interface, which are beneficial for uplink load balancing.

5 Architecture

5.1 Introduction

The different solution concepts for the implementation of SON functionality in LTE networks and the corresponding OAM systems have been described in detail in [4], [5] and [6]. The three described high-level solutions for a functional OAM architecture that integrate SON functionalities are:

- Distributed solution: self-organisation algorithms run locally on the network elements and communicate with each other via direct links (e.g. the X2 interface between eNodeBs). Decisions are made in a distributed manner.
- Centralised solution: all self-organisation algorithms are executed at a central node, which communicates with the network elements to acquire measurements, process the measurements, and provide new parameter settings
- Hybrid solution: this solution combines the distributed and the centralised solution approaches, i.e., some of the self-organisation algorithms run locally on the NEs and communicate with each other via direct links, but some functions are executed at a central node. An example for the requirement of a hybrid solution may be that the supervision and detection algorithms run locally on the NEs, but the compensation or optimisation algorithms that require processing a large number of measurements in a short timeframe and affecting a large number of NEs run at the central node.

5.2 Stand-alone use cases

In the following, the impact on the architecture from stand-alone SOCRATES use cases out of Activities 3.1, 4.1 and 4.2 is described (see [32] for information about these use cases). For each of the considered stand-alone use cases, a preference regarding the architecture and the reasoning for this preference can be described. These preferences, together with the current status of the work on architectural issues, are shown in Table 7.

Table 7: SOCRATES stand-alone use case architectural preferences

Use case	Preferred Architecture	Reason	Status
Admission Control	Distributed	Admission control and self optimised admission control algorithms both make decisions based on local eNB measurements and measurements from adjacent UEs.	No changes to existing architecture are required.
Automatic Generation of Default Parameters	Centralised (Distributed)	A centralised architecture is the simplest implementation concept regarding the requirements. A distributed solution, however, may provide a higher degree of autonomy.	No changes to the existing architecture are required.
Cell Outage Management	Distributed	Cell outage is seen as a local incident and shall be handled locally. Therefore, regarding the requirements of COM, the algorithms shall run at the eNBs to keep the impact on the whole system small.	No changes to existing architecture are required.
Handover optimisation	Distributed	The handover optimization decisions are independently taken at cell level (eNB) based on cell specific	Signaling over X2 is done as part of the default HO procedure. No changes to the existing architecture concepts

		handover performance indicators. No measurements from other cells are needed for the optimization.	are necessary, and no additional messages are required.
Home eNodeB	Distributed	Due to the potentially huge number of Home eNodeBs, centralised control is impractical.	No architectural issues have yet been handled for this use case.
Interference Coordination	Centralised	It is not clear from the literature what gains inter-cell interference coordination can realise in the ideal case of full information and global control, let alone from local information and distributed control. The former should therefore serve as a reference point with which to compare later attempts.	Initial investigation (algorithm development and simulations) has been with a centralised architecture. As the work on the use case was stopped, no further investigations towards a distributed architecture have been made.
Load Balancing	Hybrid	A distributed architecture is required for direct LB actions as the Source eNBs need to get information about the load currently hosted by the Target eNB and available "space", and decide the amount of load/users to be forced to HO to neighbour cell. This communication will take place between neighbouring cells over the X2 interface. A centralised architecture is required to indicate the direction of load shifting, e.g., by sending a prioritised list of Target eNBs from OAM to eNBs which participate in LB. This is part of SON and not required but desirable.	No changes to existing architecture are required from current point of view. Additional messages for X2 interface are required to support LB procedure in UL.
Packet Scheduling	(Distributed)	Packet scheduling as a local (intra-cell) scope. Therefore a distributed algorithm is preferred to keep the impact on the system small.	There is currently no necessity seen for a self-optimised packet scheduling solution – however, if a solution will be implemented, a distributed architecture seems most appropriate.

5.3 Integration use cases

In the following, the impact on the architecture from SOCRATES integration use cases out of Activities 3.2, 4.1 and 4.2 is described (see [32] for information about these use cases). For each of the considered integration use cases, a preference regarding the architecture and the reasoning for this preference can be described. These preferences, together with the current status of the work on architectural issues, are shown in Table 8.

Table 8: SOCRATES SON integration functions architectural preferences

Use case	Preferred Architecture	Reason	Status
Load Balancing & Handover Optimisation	Distributed (Hybrid only for LB)	A distributed architecture is required for both LB and HO optimisation actions. Load Balancing needs to swap information about the load status with the neighbouring cells as well as new HO offset adjustments with Target cells. In case of HO optimisation coordination with adjacent cells is needed. This communication will take place between neighbouring cells over the X2 interface. Both algorithms may operate in parallel and conflicts can be solved at eNB level. A centralised architecture could be applied to support LB decision to indicate the direction of load shifting. This is part of SON and not required but desirable. Centralised approach is not needed for HO optimisation	No changes to existing architecture are required from current point of view except those mentioned for standalone LB.
Handover Optimisation & Admission Control	Distributed	The admission control, self-optimised admission control and self-optimised handover algorithms make decisions based on local eNB measurements and measurements from adjacent UEs. In the handover procedure, serving and target eNodeB communicate with each other via the X2 interface.	No changes to existing architecture are required.
Home eNodeB HO Optimisation & Macro HO Optimisation	Distributed	The control parameters are set locally, per eNodeB.	No changes to the existing architecture are necessary.

5.4 SON coordinator

SOCRATES has developed a high-level functional approach for the coordination of SON use cases by introducing a set of interacting functional roles. These functional roles, further on denoted as SON Coordinator functions, and the SON functions together form the SON system.

The *Policy function* converts the operator's high-level performance objectives into SON function specific policies and into policies for the other functions of the SON Coordinator. These policies are required to define the functioning of SON, i.e., how a SON (Coordinator) function acts on incoming measurements and triggers, and for a certain network status. Therefore, the Policy function provides the interface between operator and the SON system, which also includes defining the feedback from SON (Coordinator) functions towards the operator. The *Alignment function* is responsible for the detection and resolution of conflicting configuration change requests coming from SON functions, and for taking counteractions in case of undesirable behaviour of the SON system. The *Autognostics function* collects and processes performance, fault and configuration data coming from the entities of the network subsystem (for example, network elements and user equipment, or fault / performance management functions of OAM) as input to the SON functions and functions of the SON Coordinator. The instructions on which data is to be acquired and how this data is to be processed, comes from the SON functions and the Guard function. The *Guard function* is responsible for detecting extreme or undesirable network behaviour by analysing data coming from the Autognostics function, and triggers the Alignment function to take countermeasures. The Autognostics, Guard and Alignment functions provide feedback towards the operator on their functioning. Figure 4 shows a simplified functional architecture of the developed SON Coordinator framework with its functions.

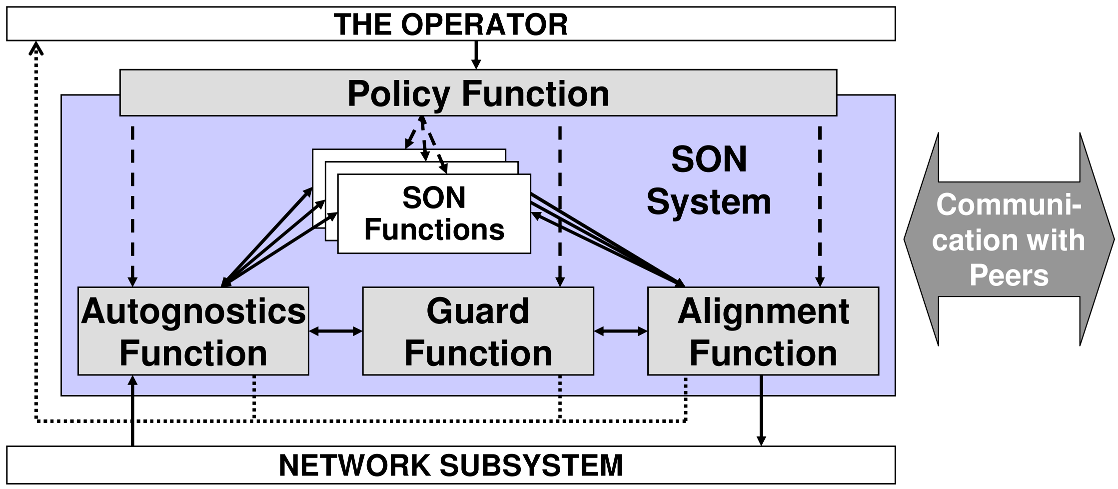

Figure 4: SON Coordinator functional framework

However, the necessity of these functional roles depends on the operator- and manufacturer-specific implementation of SON, and on the number and type of implemented SON use cases, in particular on the interaction between the implemented use cases. The coupling and the conflicts between SON functions depend on various factors, for example, the choice of control parameters, time-scale, target and objective of the SON functions, input measurements, etc. As such, the need or benefit of SON coordination depends on various properties of the SON functions in operation, where a careful design of the SON functions may result in no coupling or dependencies at all, and as such, the need of coordination may be obsolete. Considering the sheer number of options in designing SON functions it is difficult to generally foresee the need for or gain of coordination.

To give a general statement and recommendations on the architectural impact of the different SON Coordinator roles, the functional approach required at least an experimental implementation, together with a set of SON use cases. Therefore, in Table 9, the minimum impact of the functional roles on the architecture is described. As SON coordination in general is a rather new topic in standardisation, and it is currently unclear how far it will be required at all, since the number of SON use cases to be implemented is rather small in current releases, the impact described in Table 9 only reflects the current status in research. Future consolidated findings and technical expertise from first SON deployments may considerably change the requirements.

Table 9: SOCRATES SON Coordinator: minimum architectural impact by functional roles

Use case	**Preferred Architecture**	**Reason**	**Status**
Policy Function	Implemented at different layers (NM,DM,eNB)	The definition of high-level operator policies is required at network management level, while the enforcement of these policies is required at domain management or network element level	The discussion of this topic has just started in standardisation (Release 10).
Autognostics Function	Implemented at different	The Autognostics function collects and processes	The SOCRATES SON Coordinator concept foresees

	layers (NM,DM,eNB)	performance, fault and configuration data required by SON use cases, but also SON Coordinator functions. Depending on the level where SON use cases are implemented, it is likely that an Autognostics function is necessary at the same level	using standardized performance, fault and configuration management mechanisms for the purpose of Autognostics. No additional standardisation efforts are required.
Guard Function	Implemented at different layers (NM,DM,eNB)	Undesirable performance caused by SON functions may occur and therefore be detected at every level where SON functions are implemented. Undesirable performance may even be detectable only at the level where it occurs since the required performance information is only available there.	The SOCRATES SON Coordinator concept foresees using standardized performance and fault management mechanisms for the collection of input data to the Guard function, but also regarding the output of the Guard function. No additional standardisation efforts are required.
Alignment Function	Implemented at different layers (NM,DM,eNB)	A centralised approach (at network management level only) is reasonable if only a small number of SON functions is implemented and the number of configuration change requests that have to be processed is small. If many SON functions are implemented at several levels (network and domain management level, and network element level) a distributed implementation at least at network and domain management level is more appropriate to reduce the load caused by configuration change requests on the interfaces, but may cause considerable complexity in the coordination between several alignment functions.	The SOCRATES SON Coordinator concept foresees using standard configuration management mechanisms for the collection of input data to the Alignment function, and for the output of the Alignment function (notifications for the requests of SON functions, and standard CM changes for the alignment results). No additional standardisation efforts are required.

5.5 3GPP proposals

In the distributed architecture for Load Balancing purposes, overloaded eNodeBs acquire knowledge of the load situation of adjacent cells via X2 load reports. The obtained information is sufficient to redistribute excessive load between adjacent cells, but from the perspective of the larger environment, i.e., from the perspective of neighbours of the neighbours, this choice for LB handovers may be not optimal. There may, for example, be a collision with LB operations from the outer ring of neighbouring cells. Thus, support for the LB decision from a centralised SON entity in the OAM system is proposed, which can send the neighbour's prioritised list to the eNodeBs that are currently within a LB process. The cell with the highest priority may not be the lowest loaded neighbour cell but shifting load there will be most favourable decision in point of view wider network area.

This idea of Load Balancing optimisation improvement has been presented at the 3GPP SA WG5 meeting #67 [31]. The document was noted and the conclusion was that this idea needs more discussion.

6 Conclusions and recommendations

6.1 Conclusions

Based on the content presented in this report, it has been found that there are many requirements for measurements, interfaces and architecture for SON. In terms of measurements, the following has been found:

- Most measurements relate to measurement of radio signals, particularly relating to received power and interference. As most use cases assume a distributed implementation, these measurements are generally used locally in the eNodeB.
- Most KPIs and statistics relate to handover and call drops. The majority are used locally in the eNodeB, although some are used at OAM level.
- For integration use cases, most measurements are the same as for the stand-alone use cases, with minor differences such as the period over which measurements are collected.

For the interfaces, the conclusions are:

- It is expected that existing interfaces can be used for all of the SON functions. An extension of the HeNB optimisation solution to cases where X2 is not available might need a new interface to the HeNB, or extended messages over S1, but this has not been further evaluated within SOCRATES.
- It is expected that signalling over X2 and Itf-N needs to be extended to include information needed by the SON functions. No need for major changes to the interfaces has however been foreseen.

Relating to architecture, the conclusions are:

- The architectural requirements vary between use cases, with the possibilities being distributed, centralised or hybrid.
- For the SON Coordinator functional roles, all of these need to be implemented at different layers in the network.

In most cases, it has been found that the required measurements, architecture and interfaces have already been standardised. However, SOCRATES has not considered all aspects of the practical implementation of the considered use cases, so it is possible that there are further standardisation requirements for these use cases.

6.2 Recommendations

Based on the content presented in this document, the following is recommended:

- It is important to ensure that measurements as required by the SOCRATES solutions are available timely and with the right frequency.
- SON solutions should support the architectural requirements of the SON coordinator function.

As SOCRATES has not considered all aspects of SON, the following further work is recommended:

- Further SON standardisation work should be monitored, especially relating to requirements from integration use cases and the SON Coordinator.
- For SON use cases interaction and SON coordination, there are still some open issues that have not been studied under real network conditions. Further analysis and research is required for that.
- Feedback to the operator on the functioning of SON use cases and the SON coordinator has not been considered in SOCRATES, but will become an important issue as the number of SON deployments increases. This needs further investigation and conceptual work, and may have an impact on standardisation.
- SOCRATES has considered only LTE, but Multi-RAT SON is also relevant for standards. Further study on standardisation for Multi-RAT SON is recommended.

7 References

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[17] 3GPP TS 36.413: Evolved Universal Terrestrial Radio Access (E-UTRA); S1 Application Protocol (S1AP)

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[21] 3GPP TS 32.522 V9.0.0 (2010-03), Technical Specification, 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Telecommunication management; Self-Organizing Networks (SON) Policy Network Resource Model (NRM) Integration Reference Point (IRP); Information Service (IS) (Release 9)

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8 Detailed tables

8.1 Measurements tables

8.1.1 WP3 stand-alone SON function analysis

8.1.1.1 Handover optimisation

#	Name	Type	Layer	No. of cells	Source	Target	Period	Purpose	Standard (3GPP)
1	RSRP	measurement	1	21	SUE	AeNB	200ms	UE monitors RSRP from neighboring cells in order to determine a HO target when RSRP from SeNB is degrading	TS 36.214 V8.2.0
2	SINR	measurement	3	1	SUE	SUE	200ms	The SINR is used in the simulations to detect call drops. If the SINR falls below a threshold for a certain time the UE is considered to be dropped from the network	
3	UE history information	statistic	3	16	SUE	AeNB	Update on handover event	By analyzing the information contained in this list of visited cells and times spent in each of them, we can detect ping-pong HOs. If a call is handed over to a new eNodeB and is handed back to the source eNodeB in less than the critical time (T_crit = 5s) this handover is considered to be a ping-pong handover.	TS 36.300 V8.8.0
4	HO failure ratio	KPI	3	1	AeNB	AeNB	200ms	If the value of this KPI is over a predefined threshold the SON algorithm starts to take actions. Also, if the KPI is under its predefined threshold for a long enough period of time, this threshold can be lowered in order to get even better performance.	
5	Call dropping ratio	KPI	3	1	AeNB	AeNB	10ms	Same as 4	
6	Ping-pong HO ratio	KPI	3	1	AeNB	AeNB	10ms	Same as 4	

Relevance to standards:

All measurements are either already standardised, or are internal to the eNB.

Further work in standards on measurements for intra-LTE mobility robustness optimisation is not expected.

Recommendations:

No standardisation actions required.

8.1.1.2 Load balancing

#	Name	Type	Layer	No. of cells	Source	Target	Period	Purpose	Standard (3GPP)
1	Load, PRB usage	Statistic	2	From 1 to all	AeNB,NeNB	AeNB,NeNB	Seconds as a SON period	The measurement is done separately for DL and UL, trigger LB functionality at AeNB and inform AeNB about the available resources at NeNB	36.314
2	RSRP	measurement	1	1	SUE	AeNB	200 ms	SINR and load estimation	36.214
3	RSSI	measurement	1	1	SUE	AeNB	200 ms	SINR and load estimation	36.214
4	DL RS TX power	measurement	1	1	AeNB,NeNB	AeNB	200 ms	SINR and load estimation	36.214
5	Received Interference Power	measurement	1	1	AeNB	AeNB	200 ms	SINR and load estimation	36.214
6	Call dropping rate	KPI	3	1	AeNB	AeNB	Seconds as a SON period	Observe impact of load balancing (LB) operations on networks performance	
7	Ping-pong HO ratio	KPI	3	1	AeNB,	AeNB	Seconds as a SON period	Observe impact of LB operations on networks performance	
8	Handover success ratio	KPI	3	1	AeNB,	AeNB	Seconds as a SON period	Observe impact of LB operations on networks performance	

Relevance to standards:

All measurements are either already standardised, or are internal to the eNB.

Further work in standards on measurements for intra-LTE load balancing is not expected.

Recommendations:

No standardisation actions required.

8.1.1.3 Self-optimisation of Home eNodeB

#	Name	Type	Layer	No. of cells	Source	Target	Period	Purpose	Standard (3GPP)
1	Dropped call ratio (handover related)	KPI	3	2	AeNB	AeNB	10 minutes	This KPI may be required to identify problems, and to assess whether parameter changes have the desired effect.	
2	Ping-pong HO ratio	KPI	3	2	AeNB	AeNB	10 minutes	This KPI may be required to identify problems, and to assess whether parameter changes have the desired effect.	
3	Cell load	Measurement	1	1	AeNB	AeNB/NeNB	1 minute	Cell load is a factor in the decision whether to hand over to a particular cell.	
4	RSRP	Measurement	1	1	SUE	AeNB	10 seconds	Information on the relative signal strength of different base stations may be useful.	
5	UE speed	Measurement	1?	0	SUE/AeNB	AeNB	10 seconds	Different handover settings will be used for UE with different speeds.	
6	RSRP	Measurement	1	1	AeNB	AeNB	10 seconds	RSRP (DL) from neighbouring base stations measured in the HeNB and used for calculating suitable HeNB transmission power.	Standardized for UE measurements in 36.214. DL receiver in 3G HNBs have been discussed, but not standardized. It has also not been standardized for HeNBs. This should however not be needed, as measurements are both performed in and used by the HeNB. However, standardisation may be required if a more “intelligent” form of transmit power control

									is needed, i.e. that HeNBs communicate their RSRPs to other (neighbouring) HeNBs and this is used to adjust transmit powers of all HeNBs accordingly.
7	RSSI	Measurement	1	1	AeNB	AeNB	10 seconds	RSSI (DL) from neighbouring base stations measured in the HeNB and used for calculating suitable HeNB transmission power.	Standardized for UE measurements in 36.214. DL receiver in 3G HNBs have been discussed, but not standardized. It has also not been standardized for HeNBs.This should however not be needed, as measurements are both performed in and used by the HeNB.

Relevance to standards:

Most measurements are either already standardised, or are internal to the eNB. Exchange of cell load between HeNBs and macro, or other HeNBs may be considered for standardisation.

There is a WI in 3GPP Release 10 on H(e)NB mobility enhancements, which may included some relevant activities on HeNB handover optimisation.

Recommendations:

Monitor activities in the H(e)NB mobility enhancements WI, and identify opportunities for SOCRATES to contribute.

8.1.1.4 Admission control parameter optimisation

#	Name	Type	Layer	No. of cells	Source	Target	Period	Purpose	Standard (3GPP)
1	Fraction of rejected HO calls	KPI	3	1	AeNB	AeNB	Once per minute	AC SON will use this measurement to detect degraded performance (GoS) for handover calls	
2	Fraction of	KPI	3	1	AeNB	AeNB	Once per	AC SON will use this measurement to detect	

	rejected fresh calls						minute	degraded performance (GoS) for fresh calls	
3	Traffic loss ratio of real-time calls	KPI	2	1	AeNB	AeNB	Once per minute	AC SON will use this measurement to detect degraded performance (QoS) for real-time calls	TS 36.314 v9.00 (2009-12), Packet Discard Rate in the DL per QCI, page 13
4	Fraction of non real-time calls that do not achieve their required bitrate	KPI	2	1	AeNB	AeNB	Once per minute	AC SON will use this measurement to detect degraded performance (QoS) for non-real-time calls	

Relevance to standards:

All measurements are internal to the eNB.

Recommendations:

No standardisation actions required.

8.1.1.5 Other

There were two other stand-alone WP3 SON functions in SOCRATES:

- Packet scheduling parameter optimisation
- Interference coordination

For both these use cases, it was not considered worthwhile to provide a measurements table, as these use cases did not provide SON algorithm results, and therefore it does not make sense to specify measurements.

8.1.2 WP4 stand-alone SON function analysis

8.1.2.1 Cell Outage Management

#	Name	Type	Layer	No. of cells	Source	Target	Period	Purpose	Standard (3GPP)
1	User bit rate	measurement	L2/L3	1	NeNB	NeNB	1-15 mins (educated	To determine the user quality in own cell, where quality is defined as a percentile. Cell outage	

							guess; the period may even be shorter)	compensation runs over several iterations.	
2	UL inter-cell interference	measurement	L1	1	NeNB	NeNB	1-15 mins	To determine the setting of uplink target received power P_0	

Relevance to standards:

Most measurements are either already standardised, or are internal to the eNB.

Recommendations:

Cell Outage Management is a topic for LTE Release 10 standardisation. It is therefore recommended to monitor the corresponding activities and contribute from SOCRATES in case there are measurement related issues to be solved.

8.1.2.2 X-Map Estimation

#	Name	Type	Layer	No. of cells	Source	Target	Period	Purpose	Standard (3GPP)
1	UE position	measurement	N/A	1	SUE/NUE	TBD	200 ms	Geographical reference for desired measurement Comments: - X-Map estimation requires a new entity which is most likely best handled in, e.g., the OSS. - The mentioned measurement period of 200ms represents the ideal value. However, longer measurement periods are also possible.	
2	RSRP	measurement	1	1	SUE/NUE	TBD	200 ms	Create X-map (localised network performance)	36.214
3	RSRQ	measurement	1	1	SUE/NUE	TBD	200 ms	Create X-map (localised network performance)	36.214
4	any desired value	KPI	3	1	AeNB/ NeNB	TBD	200 ms	Create X-map (localised network performance)	

Relevance to standards:

UE positioning is being considered as part of the Minimization of Drive Tests (MDT) activity in RAN2, and is necessary to create the measurement-specific map of the desired value (e.g., to create a coverage map using SINR measurements).

Recommendations:

The availability of UE measurements for SON and OAM purpose is still a difficult topic in 3GPP standardisation. Depending on the standardisation success of other UE measurements (such as UE history) it is also recommended to contribute with the UE position related measurements.

8.1.2.3 Automatic Generation of Default Parameters for eNodeB Insertion

#	Name	Type	Layer	No. of cells	Source	Target	Period	Purpose	Standard (3GPP)
1	RSRP	radio measurement	1	1	SUE	AeNB / OAM	15min	Measurement of the strongest servers (base stations) in the neighbourhood, to identify neighbours of newly installed eNodeBs. If possible, the measurements shall be associated with location information - Input to ANR - Verification of the offline integration model - Load estimations to predict the impact of changes - Adaptation of soft integration parameters, also as input for subsequent parameter self-optimisation	36.214
2	UL PRB Usage	KPI	2	1	AeNB	AeNB / OAM	15 min	Physical Resource Block (PRB) usage is an indicator for the cell load. PRB usage can also be calculated for different traffic classes. - Verification of the offline integration model - Adaptation of soft integration parameters, also as input for subsequent parameter self-optimisation	36.314
3	DL PRB Usage	KPI	2	1	AeNB	AeNB / OAM	15 min	Physical Resource Block (PRB) usage is an indicator for the cell load. PRB usage can also be calculated for different traffic classes. - Verification of the offline integration model - Adaptation of soft integration parameters, also as input for subsequent parameter self-optimisation	36.314
4	Call Blocking Ratio	KPI	1-3	1	OAM	AeNB / OAM	15 min	There may be various issues for the rejection / drop of a call / connection setup: - Radio link failures - Admission control - QoS control The reason behind this is to get qualitative values	32.425 (RRC / EPS connection counters)

								for comparison with neighbouring eNodeBs - Verification of the offline integration model - Adaptation of soft integration parameters, also as input for subsequent parameter self-optimisation	
5	Call Drop Ratio	KPI	1-3	1	OAM	AeNB / OAM	15 min	see above	
6	HO attempts	Statistic / KPI	n/a	1	NeNB	AeNB / OAM	15 min	- Verification of the offline integration model - Adaptation of soft integration parameters, also as input for subsequent parameter self-optimisation	36.425
7	HO Success Ratio	KPI	n/a	1	NeNB	AeNB / OAM	15 min	- Verification of the offline integration model - Adaptation of soft integration parameters, also as input for subsequent parameter self-optimisation	36.425

Relevance to standards:

All measurements that have been identified up to now are already standardised. As the AGP soft integration concept does not foresee new self-optimisation procedures but builds on other self-optimisation functions (e.g., Load Balancing, Handover Optimisation, Automatic Neighbour Relation) there might be a relevance for standardisation coming from these functions.

Recommendations:

Some AGP related functions (e.g. ANR) are already standardisation topics. It is recommended to monitor standardisation activities on automated radio configuration during the ongoing AGP concept development and simulation activities to identify potential contributions to 3GPP regarding measurements.

8.2 Interfaces tables

8.2.1 WP3 stand-alone SON function analysis

8.2.1.1 Handover optimisation

No interface requirements specified.

Relevance to standards:

Further work in standards on measurements for intra-LTE mobility robustness optimisation is not expected.

Recommendations:

Signalling over interfaces has been standardised in 3GPP. It should be clarified why no signalling is required for the SOCRATES solution.

8.2.1.2 Load balancing

#	Interface Name	Interface Reference Points (in case of new interface)	Required/ Optional	Usage	Status in Standardization (including specification number)	Standard Additions/changes	Expected Change in Signalling
1	X2		Required	Load information, P0 and parameter alpha are exchanged between eNBs	36.420 - 424	Procedure of P0 and alpha exchange between eNBs is not yet standardised, only exchange of load information	No significant increase in signalling overhead. Information exchanged on demand.
2	S1		Optional	SON entity in the OAM system sends a list of cells to the eNB with an ordered priority for load balancing purposes.		Idea of centralised support for LB proposed in S5-093243 but noted	These lists are updated periodically for all cells that have the load balancing functionality enabled or on request in case of rapid load changes. Shouldn't increase significantly signaling overhead

Relevance to standards:

Release 9 SON activities are still ongoing in SA5, so there may be potential to contribute ideas on load balancing.

Recommendations:

Push SOCRATES interface requirements for load balancing into SA5 and RAN3. Identify most appropriate approach for achieving that.

8.2.1.3 Self-optimisation of Home eNodeB

No interface requirements specified.

Relevance to standards:

There is a WI in 3GPP Release 10 on H(e)NB mobility enhancements, which may included some relevant activities on HeNB handover optimisation.

Recommendations:

Further study the need for additional interfaces or interface signalling.

8.2.1.4 Admission control parameter optimisation

No interface requirements specified.

Relevance to standards:

No relevant standards activities.

Recommendations:

No standardisation action required.

8.2.1.5 Other

There were two other stand-alone WP3 use cases in SOCRATES:

- Packet scheduling parameter optimisation
- Interference coordination

For both these use cases, it was not considered worthwhile to provide an interfaces table, as these use cases did not provide SON algorithm results, and therefore it does not make sense to specify interfaces.

8.2.2 WP4 stand-alone SON function analysis

8.2.2.1 Cell Outage Management

#	Interface Name	Interface Reference Points (in case of new interface)	Required/ Optional	Usage	Status in Standardization (including specification number)	Standard Additions/changes	Expected Change in Signalling
1	Itf-N		Required	To specify the user quality degradation during an outage. This is given by the operator and the network then degrades the user quality in order to increase the coverage during an outage	No work has been done; not active	To include the lowest quality level accepted by the operator	

Relevance to standards:

Itf-N is the 3GPP SA5 standardised interface.

Recommendations:

No standardisation action required from SOCRATES.

8.2.2.2 X-Map Estimation

#	Interface Name	Interface Reference Points (in case of new interface)	Required/ Optional	Usage	Status in Standardization (including specification number)	Standard Additions/changes	Expected Change in Signalling
1	X2		Required	To exchange location information measured by UEs between eNodeBs for X-Map calculations.	Interface already specified	Add notifications or messages to be sent via the interface.	None.

Relevance to standards:

The X2 interface is the 3GPP standardised interface between LTE eNodeBs.

Recommendations:

To establish the exchange of geo-location information between eNodeBs an additional message type on the X2 interface is to be added. A corresponding contribution to standardisation can be started if X-Map estimation shall be supported.

8.2.2.3 Automated Generation of Default Parameters for eNodeB Insertion

#	Interface Name	Interface Reference Points (in case of new interface)	Required/ Optional	Usage	Status in Standardization (including specification number)	Standard Additions/changes	Expected Change in Signalling
1	Itf-N		Required	To provide the default configuration	No work has been done; not active	To be checked if local eNodeB configuration	

				determined by the network planning system / configuration management to the eNodeB to be installed		parameter modifications can be indicated sufficiently fast to the OAM configuration database.	

Relevance to standards:

Itf-N is the 3GPP SA5 standardised interface. Itf-N includes to major means for providing configuration information from the OAM system to the eNodeB (single parameter changes, and bulk Configuration Management for bundling several parameter changes). Since AGP foresees an eNodeB local adaptation of configuration parameters during the soft integration also an update of the configuration database at the OAM system is required.

Recommendations:

It is to be checked in standardisation if a sufficient method to update the OAM database in case of local eNodeB parameter changes is available.