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D2.2

Requirements for Self-Organising Networks

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Abstract:

The SOCRATES (Self-Optimisation and self-ConfiguRATION in wirelEss networkS) project aims at the development of self-organisation methods for LTE radio networks. Self-organisation comprises self-optimisation, self-configuration and self-healing. In this document the requirements on solutions for self-organisation are described, categorised into general and use-case specific technical requirements, business requirements, and requirements on the simulation environment for the evaluation of self-organisation solutions.

Keyword list:

Self-organisation, self-configuration, self-optimisation, self-healing, LTE, E-UTRA, radio interface, use cases, requirements, simulation

Executive Summary

Self-organisation, comprising self-configuration, self-optimisation, and self-healing, is expected to substantially reduce the necessary human intervention in network operations, aiming at a significant reduction in operational expenditure (OPEX) and an improvement in network quality. The SOCRATES (Self-Optimisation and self-ConfiguRATion in wirelEss networkS) project develops self-organisation methods for LTE radio networks.

While a large number of use cases for self-organisation have been described in the first SOCRATES deliverable (D2.1, see [23]), the present deliverable describes the requirements put on the solutions to be developed. These solutions for self-organisation will consist of algorithms and the underlying management and network architecture and interfaces. Specifying requirements will ensure that appropriate solutions are developed.

Three main categories of requirements are distinguished in this deliverable, which are addressed in some more detail below: technical requirements, business requirements and simulation requirements.

First, general *technical requirements* are listed that apply for all use cases, followed by detailed use case specific technical requirements. The technical requirements are categorised according to a set of criteria, including performance and complexity, stability, robustness, timing (time scale of operation), interaction with other functionalities, architecture and scalability, and the required inputs (counters, measurements).

Next, the *business requirements* are addressed. The business requirements include requirements related to cost efficiency, and requirements for ensuring optimal benefit when applying solutions for self-organisation during the deployment of LTE networks.

Finally, *simulation requirements* are considered, i.e., requirements for the simulation tools to be developed within the project for testing and evaluation of the methods and algorithms for self-organisation. Following a common scheme, use case specific simulation requirements are determined, which will be used (in WP3 and WP4) as a basis for the development of appropriate simulation models of the particular SON functionalities described in the use cases. Further, a number of more general requirements concerning a.o. traffic modelling, user mobility modelling, and network size and topology are addressed. Also the LTE network specific modelling requirements are discussed, including the Layer 1 and Layer 2 characteristics, mobility management, etc.

The requirements in the present deliverable, together with the use case descriptions in D2.1 and the assessment criteria which are currently specified in Activity 2.3 (to be reported in D2.3 [24], due in Month 6), are important ingredients for the development of the self-optimisation framework in Activity 2.4 (to be reported in D2.4 [25], due in Month 7). Establishment of this framework will conclude the first phase of the project and will form the basis for the actual development of methods and algorithms for self-organisation in wireless networks in the next phase, in WP3 (“Self-optimisation”) and WP4 (“Self-configuration and self-healing”).

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List of Acronyms and Abbreviations

3GPP	Third Generation Partnership Project
aGW	Access Gateway
ARQ	Automatic repeat-request
ATM	Asynchronous Transfer Mode
BCH	Broadcast CHannel
BLER	BLock Error Rate
BS	Base Station
BTS	Base Transceiver Station
C/I	Carrier to Interference ratio
CN	Core Network
CQI	Channel Quality Indicator
DHCP	Dynamic Host Configuration Protocol
DL	DownLink
DoS	Denial of Service
EDGE	Enhanced Data Rates for GSM Evolution
EESM	Effective Exponential SINR Mapping
eNB	eNodeB
eNodeB	E-UTRAN NodeB
EPC	Evolved Packet Core
E-UTRA	Evolved Universal Terrestrial Radio Access
E-UTRAN	Evolved Universal Terrestrial RAN
FDD	Frequency Division Duplex
FFS	For Further Study
GBRRB	Guaranteed Bit Rate Radio Bearer
GERAN	GSM EDGE RAN
GoS	Grade of Service
GPS	Global Positioning System
GSM	Global System for Mobile communications
HARQ	Hybrid ARQ
HII	High Interference Indicator
HO	HandOver
HSPA	High-Speed Packet Access
HW	HardWare
ICIC	Inter Cell Interference Cancellation
ID	IDentity
IP	Internet Protocol
KPI	Key Performance Indicator
LA	Location Area
LTE	Long Term Evolution (of 3 rd Generation mobile networks)
MA	Movement Area
MAC	Media Access Control
MCS	Modulation and Coding Scheme
MIMO	Multiple Input Multiple Output
MME	Mobility Management Entity
MOC	Mobile Originated Call
MTC	Mobile Terminated Call
NE	Network Element
NEM	Node Element Manager
NGMN	Next Generation Mobile Network
NodeB	Base station
O&M	Operations and Maintenance
OAM	Operations, Administration, and Maintenance
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency-Division Multiple Access
OMC	Operations and Maintenance Centre
OPEX	OPerational EXpenditure
OSS	Operations Support System
PA	Paging Area

PBCH	Physical Broadcast CHannel
PCFICH	Physical Control Format Indicator CHannel
PDCCH	Physical Downlink Control CHannel
PDCP	Packet Data Convergence Protocol
PDSCH	Physical Downlink Shared CHannel
PHICH	Physical Hybrid ARQ Indicator CHannel
PKI	Public Key Infrastructure
PM	Performance Measurement
PMCH	Physical Multicast CHannel
PRACH	Physical Random Access CHannel
PRB	Physical Resource Block
PUCCH	Physical Uplink Control CHannel
PUSCH	Physical Uplink Shared CHannel
QoS	Quality of Service
RA	Routing Area
RACH	Random Access CHannel
RAN	Radio Access Network
RAT	Radio Access Technology
RB	Radio Bearers
RLC	Radio Link Control
RP	RACH Parameters
RRC	Radio Resource Control
RRM	Radio Resource Management
RS	Reference Signal
RSRP	Reference Signal Received Power
RSRQ	Reference Signal Received Quality
RSSI	Received Signal Strength Indicator
SAE	System Architecture Evolution
SCH	Synchronisation CHannel
SCM	Spatial Channel Model
S-GW	Serving GateWay
SINR	Signal to Interference and Noise Ratio
SOCRATES	Self-Optimisation and self-ConfiguRATion in WirelEss NetworkS
SON	Self Organising Network
SRS	Sounding RS
SW	SoftWare
TA	Tracking Area
TAC	TA Code
TAI	TA Identity
TAP	TA Parameters
TAU	TA Update
TDD	Time Division Duplex
TTI	Transmission Time Interval
UE	User Equipment
UL	UpLink
UMTS	Universal Mobile Telecommunications System
UPE	User Plane Entity
URA	User Registration Area
VLA	Virtual LA
WCDMA	Wideband Code Division Multiple Access
WWW	World Wide Web

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1 Introduction

In SOCRATES deliverable D2.1 “*Use Cases for Self-Organising Networks*” (cf. [23]) a set of (twenty-four) use cases has been defined, forming a basis for a common and clear view among the partners in SOCRATES on self-organising networks. The use case descriptions themselves list functionalities to be made self-organising and points out what solutions should achieve.

The present document focuses on the requirements needed to be successful in developing the functionalities described for each use case, meaning developing new methods and algorithms, adding measurements, etc.

The requirements are divided into three parts:

- *Technical Requirements*, giving guidance and specifics for each use case (Chapter 2). The following technical requirement categories are defined: performance and complexity, stability, robustness, timing, interaction, architecture and scalability, and required input.
- *Business Requirements*. Special business constraints that will influence the prioritisation of the use cases (Chapter 3).
- *Simulation Tool Requirements*. Since most of the verification of new functionality will be done by means of simulation, a number of simulation requirements will be specified (Chapter 4).

The document is then finalized with some concluding remarks (Chapter 5).

This document contains detailed use case specific information on technical and simulation tool requirements. For the purpose of better readability, the corresponding detailed tables are provided in the appendices: Appendix A for the use case technical requirements, and Appendix B for the simulation tool requirements.

These requirements are an important part for the definition of a self-organisation framework, since together with the use case descriptions of SOCRATES deliverable 2.1 ([23]) they build the base for the definition of key parameters and parameter groups, both required for the initial development of self-organisation methods and algorithms. This framework for the development of self-organisation methods will then be described in SOCRATES deliverable 2.4 [25].

2 Technical Requirements

For each use case, a number of technical requirements have to be specified. These requirements shall give guidance and specifics for the development of new algorithms and functionalities. The intention is to have the same way of describing the technical requirements for each and every use case, and the network characteristics described below are the most important when it comes to network performance and self-organisation.

This chapter describes the technical requirements that self-organisation solutions for the use cases described in [23] should meet. In Section 2.1 general requirements that apply for all use cases are described. Section 2.2 contains the importance analysis of the technical requirements for each of the use cases. The detailed description of the technical requirements per use case is provided in Appendix A.

For each use case the following requirements are addressed:

- *Performance and complexity*: Special requirements needed to handle performance and complexity issues.
- *Stability*: Stability issues are mentioned here. For the reason of stability the proposed algorithms should always find a solution that works. This is especially important since many of the self-organising algorithms will run completely automatic and without the possibility for manual intervention. It is not acceptable for a SON algorithm to come into a state of non execution.
- *Robustness*: Robustness requirements applied on the use case are mentioned. In case there are inaccuracies in for example the input data the functionality should perform in such a way that the performance is still satisfactory.
- *Timing*: Special timing constraints are mentioned here. For example, how often should a specified algorithm run and the constraints around that, how fast must an algorithm react when triggered. At least two different timing requirements are described:
 - Time scale of operation, i.e., the time frame that is regarded for the (continuous) analysis of the measurements.
 - Speed of adjustment: required time scale for an algorithm to converge to a solution with a new parameter set after having been triggered
- *Interaction*: Requirements on interaction with other functionalities that will have an impact on the function and performance of the use case.
- *Architecture and scalability*: Special constraints on architecture and scalability of the implementation of SON functionalities are listed here. Will the algorithms be centralised or decentralised, and what requirements will that bring in terms of architecture, interfaces, and scalability.
- *Required inputs (performance counters and measurements)*: What input is required by the algorithms, e.g., counters, measurements, is described.

The requirements are listed in a table for each use case. This table contains three columns: the requirement category, the requirement description, and the requirement importance. The third column in the table indicates the importance for each of the listed requirements. For the importance, three levels have been defined:

- Low (L) = No requirements, or requirements are easily satisfied
- Medium (M) = Important requirements
- High (H) = Requirements that are crucial for the success of an algorithm

2.1 General Requirements

Performance and complexity requirements

For all use cases, key requirement is that an appropriate balance should exist between the performance gains established by adding self-optimisation, self-configuration or self-healing, and the implementation complexity, which is a clear trade-off.

Implementation complexity can thereby be measured at least with the following indicators:

- Signalling overhead caused by self-X algorithms and required measurements

- Calculation effort for algorithms, required computing power and memory
- Storage requirements
- Load on the radio link, especially for user equipment measurements

Stability requirements

For all use cases it is required that they converge to a stable state, or solution, respectively, within the given timing requirements.

Robustness requirements

Missing, wrong or corrupted input (measurements) should be detected or compensated by the algorithms so they still provide satisfying output parameters.

Timing requirements

No general timing requirements can be given. Each use case has individual requirements, ranging from milliseconds to hours or days.

Interaction requirements

Especially for self-optimisation, it is necessary to establish coordination between those use cases that modify the same parameter settings as output of the algorithms.

Architectural and scalability requirements

For several use cases (usually with a scope on several network elements, network parts, or the entire network), centralised monitoring, data storage, and data analysis entities are required.

For several use cases (usually with a scope on single network elements, or few network elements), appropriate computing power, memory and storage capacity at the network element are required.

For all use cases, in case of multi-vendor equipment deployment in the network, a set of performance measurements and counters will have to be standardised.

Required inputs (performance counters and measurements)

Each use case has individual input requirements.

2.2 Requirements per Use Case

Detailed technical requirements for each use case can be found in Appendix A. The fact that these requirements are in an appendix does not indicate that they are not important. They are in fact a very important part of the SOCRATES project. However, a lot of requirements are provided for a large number of use cases, and the appendix is an appropriate place to include this information.

In this section, a high-level overview of the use case technical requirements is provided. For each use case the importance of each category of requirements is provided. This indicates where the emphasis will be when developing solutions. The requirements tables for self-configuration, self-optimisation and self-healing are included respectively in Table 1, Table 2 and

Table 3.

**Table 1 Importance of the requirements categories for the self-configuration use cases
light blue = low (L), yellow = medium (M), red= high (H)**

	Performance and complexity	Stability	Robustness	Timing	Interaction	Architecture and scalability	Required inputs
Intelligently selecting site locations	M	H	L	L	L	M	H
Automatic generation of default initial parameters for NE insertion	M	H	M	M	H	H	H

Network Authentication	H	M	M	M	M	M	L
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Table 2 Importance of the requirements categories for the self-optimisation use cases
light blue = low (L), yellow = medium (M), red= high (H)

	Performance and complexity	Stability	Robustness	Timing	Interaction	Architecture and scalability	Required inputs
Interference Coordination	H	M	M	H	H	M	H
Self-optimisation of physical channels	H	L	H	M	L	M	H
RACH optimisation	H	L	H	M	M	L	H
Self-optimisation of home eNodeB	H	H	M	M	H	H	H
Admission control parameter optimisation	M	H	M	L	H	M	H
Congestion control parameter optimisation	M	H	M	L	H	M	H
Packet scheduling parameter optimisation	M	H	M	H	H	M	H
Link level retransmission scheme optimisation	H	H	M	M	L	M	H
Coverage hole detection	M	L	M	M	H	M	H
Handover parameter optimisation	M	H	M	H	H	M	H
Load balancing	M	H	M	H	H	M	H
Reduction of energy consumption	H	M	M	M	H	M	H
Tracking areas	H	L	H	M	M	M	H
TDD UL/DL switching point	H	M	M	H	H	M	H
Management of relays and repeaters	H	H	M	H	H	H	H
MIMO	H	M	M	H	H	M	H

Table 3 Importance of the requirements categories for the self-healing use cases
light blue = low (L), yellow = medium (M), red= high (H)

	Performance and complexity	Stability	Robustness	Timing	Interaction	Architecture and scalability	Required inputs
Cell outage prediction	M	H	H	L	L	M	H
Cell outage detection	H	L	H	M	L	M	H
Cell outage compensation	H	M	M	H	M	M	H

3 Business Requirements

One of the main objectives of the SOCRATES project is to reduce OPEX related to LTE network deployment, maintenance, and optimisation. Therefore, in addition to considering the technical requirements, it is also important to consider the business requirements. The objective of defining business requirements is so that they can be considered when developing solutions. Solutions that are good purely from a technical point of view will not necessarily meet business requirements. The business requirements are divided into two parts:

- *Cost efficiency*: This is a very important factor determining the success of a network technology. Operator, vendor, and end user should benefit from cost efficiency, and SON solutions are supposed to significantly contribute to this efficiency.
- *LTE deployment*: When deploying new network technologies like LTE, SON functionality should support the process and meet the requirements of reducing OPEX. Another important aspect is timing, that is, the time when a SON function is introduced should carefully be selected so that it matches the current state of the network, in terms of traffic load and expansion plans.

3.1 Cost efficiency

Cost efficiency is an important factor in determining the success of a network technology. If the cost of rolling out a network is too high, it becomes difficult to provide a profitable consumer service on the network. Both operators and vendors benefit from cost efficiency. Operators benefit as costs are lower for rolling out a network.

In turn, this leads to more demand for network equipment, from which vendors will benefit. This leads to the following requirements:

- *SON solutions should reduce OPEX*: Significant manual effort is required to roll-out and operate a network. By reducing this manual effort, OPEX will be reduced.
- *SON solutions should reduce CAPEX*: By more efficiently using radio resources, less base stations will be required (it is expected that OPEX reductions will be more significant than CAPEX reductions).

Adding SON functionality will potentially increase the cost of equipment, due to the need for additional hardware and/or software. Therefore, SON impact on costs of all parts of the mobile network should be considered, including:

- *Terminals*: functionality to support SON could increase hardware or software costs, and potentially decrease battery life.
- *Base stations*: additional hardware or software could increase costs
- *O&M systems*: additional hardware or software could increase costs

3.2 LTE deployment

When considering SON, it is also necessary to consider how LTE networks will be deployed. In areas with high traffic, there will be a large number of cells with a small size. If the operational effort per cells remains the same, then the total effort required to roll-out and optimise this network will be very high. Therefore it is important to reduce the operational effort per cell.

Some operators have plans to deploy LTE by 2010, while others deployments will be several years later. Availability of vendor products supporting SON should be in line with this. Availability of functionality should also match with the requirements of the stage of roll-out. In the initial stage, the networks will have a low load. At that point, easy deployment of the network is the most important. As load on the network increases, it becomes more important to have functionality that efficiently handles high load. Vendor roadmaps should match operator requirements, and SOCRATES should support vendor roadmaps.

Deployment trends should also be considered, i.e. important aspects of how networks are deployed. For example, network sharing (between different operators) is becoming increasingly common, and this should be taken into account when developing SON solutions.

This leads to the following requirements

- *SON solutions should speed up roll-out of LTE networks:* When a new network is first rolled out, there are usually many problems to solve before satisfactory performance is achieved. SON solutions should reduce these problems, and reduce the time required before cells go live.
- *SON solutions should simplify processes:* Solutions should be aligned with operational processes used by operators, and solve real problems occurring in real networks.
- *SON solutions should not introduce other manual efforts:* Set up and operation of SON solutions should be straightforward, and should not require significant manual effort.
- *Easy deployment of new services:* New services may have new QoS requirements, and SON solutions should be able to support these, with minimum configuration required.
- *End user benefits:* Users should experience high Grade-of-Service and Quality-of-Service.

4 Simulation Tool Requirements

The goal of SOCRATES is to develop SON functionalities for LTE that (are expected to) perform well in a real network environment. At this early stage of the LTE development, a live test of algorithms in the field is not yet possible. The new functionality will thus need to be evaluated by means of software simulations.

The verification of new algorithms and functionalities will first be done by means of simulation. Therefore, a number of simulation tool requirements are defined within the SOCRATES project. The ambition is to define a set of “rules” to be agreed upon among the SOCRATES partners so that the work in WP3 and WP4 will be based on the same platform. This will in turn provide a good basis when comparing results from different partners. The simulation tool requirements are divided into three parts:

- *A Template for Use Case Profiles:* In order to get a common way of describing Use Case profiles a template was created. The template is used for definition of the requirements criteria for each and every use case.
- *Requirements for Computer Simulations:* A number of common requirements for computer simulations are defined here:
 - Level of simulations (dynamic or static)
 - Time resolution
 - Mobility modelling
 - Traffic modelling
 - Type of network scenarios
- *LTE Simulation Model Requirements:* The two goals of this section are to establish which LTE functionalities need to be modelled in the simulators used by SOCRATES and to determine the requirements and desired properties of these models. This section contains:
 - Layer 1 models
 - Measurements and reports
 - Layer 2 models
 - Radio resource control models
 - Mobility management models
 - Other Radio resource management models, such as link adaptation, admission control, congestion control and scheduling
 - Architecture
 - Quality of Service models

This chapter addresses the requirements for an assessment of SON functionality based on simulations. In order to derive reasonable simulation tool requirements, firstly, the requirements on a potential field trial are worked out (Section 4.1). The general test environment is described and the requirements of the individual use cases are classified. Based on the results obtained in Section 4.1.4, the simulation tool requirements are classified in Section 4.2, aggregated in a table. The detailed requirements per use case are available from Appendix B. Section 4.3 then provides the detailed LTE simulation model requirements.

4.1 A Template for Use Case Profiles

Ideally, SON functionalities would be evaluated in a test-bed that allows for emulating a variety of network environments and user behaviours. Such an approach is, however, not viable within the SOCRATES project. Computer simulations will need to serve as a substitute. Nevertheless, in a first step the focus shall be on how some SON functionality could be benchmarked in a test-bed. In a second step, the findings shall be used to assess which specific simulations are needed for the various use cases under consideration.

This document applies a top-down approach for identifying the simulation requirements. This allows deferring the discussion of many details. The results obtained in this chapter as well as the results on the simulation framework described in SOCRATES Deliverable D2.4 [25], establish a basis for the bottom-up discussions at the definition phases of SOCRATES WP3 and WP4. It will be identified what items on the “wish list” for simulations results can be provided by existing tools, and which extensions are required. In the end, the mixture of top-down and bottom-up shall provide a clear understanding of what is desired to have and what can be achieved within SOCRATES.

4.1.1 Test Environment

A possible architecture of a test environment is presented in Figure 1. The different algorithms developed for the individual use cases access the network (including mobiles attached to the network) via a well-defined SON test application programming interface (SON test API). The goal of this API is to allow for a fair comparison of algorithms as the interfaces need to be uniform to all algorithms of one use case. Via the interfaces, algorithms obtain measurements from the network (or simulator) and attached mobiles and trigger control parameter changes. Note that Figure 1 does not impose a network architecture, but rather illustrates the architecture of a test environment, where different SON algorithms are evaluated. In reality, the interface between SON algorithms and network functionalities (RRM etc.) may be located in the eNodeB itself (between, e.g., SON and RRM functionality), between the eNodeBs (via the X2 interface), or between the eNodeBs and domain managers.

For each use case, the impact of applying SON functionality is to be observed on the basis of the regular performance indicators in the network. If a use case aims at performance improvements (such as all self-optimisation use cases), then a difference should be traceable there. If, on the other hand, a use case does not primarily aim at influencing network quality, then there should be benefits in network configuration or operation. These benefits as well as CAPEX/OPEX savings cannot be observed in the test environment, but have to be derived elsewhere. The details of how the impacts of the various use cases will be assessed are described in SOCRATES Deliverable D2.3 [24].

For the purpose of this document, the use cases need to be analysed with respect to the impact they can have on network performance. As performance is judged on a whole array of quality measures, the use cases need to be analysed with respect to the measures they affect. Moreover, some of the measures may improve, others deteriorate (slightly). It will not always be obvious what would be a desirable trade-off among the various affected quality indicators. In some cases, this may even depend on the operator strategy. The assessment criteria are discussed in detail in SOCRATES Deliverable D2.3 [24].

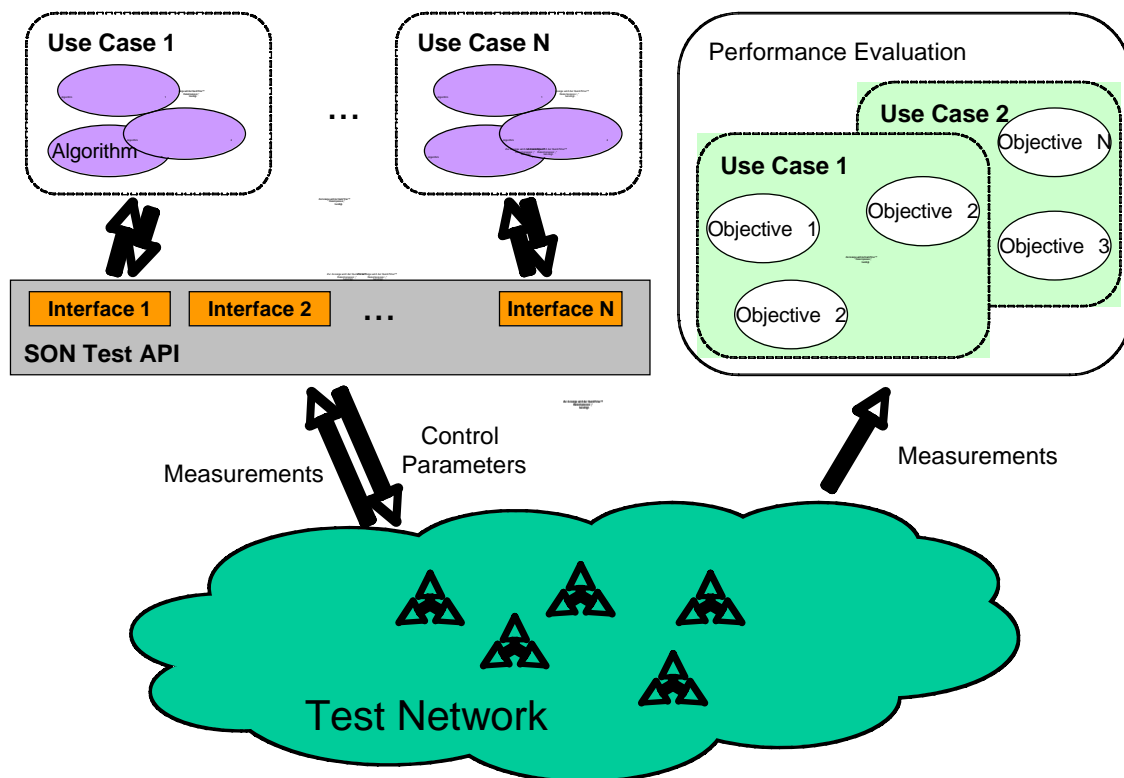


Figure 1: SON test environment

4.1.2 Requirement for Reference Networks

The evaluation of most of the SON-functionality strongly depends on the specific realisations of the network:

- Network topology and environment
- LTE system standard
- Vendor specific realisations (e.g., radio resource management)

The first point will be addressed by the reference scenarios, which are described in SOCRATES Deliverable D2.3 [24]. The reference scenarios will cover a variety of different network topologies and radio environments. The second and third point adhere a large amount of details that need to be addressed in SOCRATES WP3 and WP4. In this document the main requirements are described.

The LTE standard has not yet been finalised and assumptions regarding a variety of technological aspects will need to be taken (at least at the beginning of the project). Vendor specifics are even more difficult to address. The following may serve as an example. The majority of RRM algorithms such as resource scheduling, admission control, congestions control will not be standardised, but will be vendor specific. These algorithms, however, greatly impact the SON functionalities. A possibility for addressing these issues within SOCRATES is to agree on one or multiple reference system implementations, against which the developed SON algorithms are tested. These issues will be addressed in detail in WP3 and WP4.

4.1.3 Structure of Use Case Profiles

In order to understand the requirements of the individual use cases, a use case profile has been developed. The use case profiles are used in this document to categorise the use cases with respect to their simulation requirements, but are also highly useful to capture information at later stages of the project (i.e. in WP3 and WP4). In the following the sections of the profile are described.

Scope of Algorithm

The section in general describes how many network elements are subject to the algorithm, and how the algorithm interacts with the network. In detail:

1. How many cells are controlled by one instance of the functionality, how do these cells relate to each other (e.g., are they neighbours)?
2. How much do decisions / changes carried out by the functionality impact other (neighbouring) cells?
3. How much and by which means do other cells impact the controlled cells?
4. Where is the algorithm located: locally with the cell's eNB, centrally, or distributed over several eNBs?
5. What are the relevant BTS Types: macro, micro, indoor/home?

Information Exchange

Besides measurements and control parameters, which are defined below, some functionalities require additional information to be exchanged. What information and at what frequency information needs to be exchanged is therefore specified:

- Between network elements (information that are not subject to the SON functionalities, e.g., standardized control information between RRM algorithms)
- Between (instances of) SON functions (e.g., triggers for the coordination of SON functionalities)
- Across the SON API

Required Measurements

In this section all measurements required for the SON functionalities to base decisions on are listed.

- Which measurements are required?
- How often are measurements taken?
- Status of standardisation of measurements
 - Fully standardised?
 - Is (or could become) topic of standardisation?
 - Standardisation not foreseen?
- OSI-layer(s), measurements are coming from / referring to?
- Measurement data from how many cells is required?
- Required statistical significance

Control Parameters

Control parameters are defined as the parameters that can be changed by the functionality in order to optimize the network:

- What control parameters exist?
- Status of standardisation of parameters
 - Fully standardised?
 - Is (or could become) topic of standardisation?
 - Standardisation not foreseen?
- Parameter ranges:
 - Min / max values?
 - Relation / dependencies of parameters?
- Parameter updates:
 - Scale of adaptation (“small scale vs. large scale updates”)?
 - Frequency of adaptation (order of seconds, minutes, hours, days)?

Algorithm Assessment

This section describes the measurements and objectives the evaluation of the functionality is based on:

- Which measurements need to be evaluated in order to assess an algorithm?
 - From which OSI-layer are these measurements?
- For how long do / how many measurements need to be taken to yield statistical significance of results?
- Variety of scenarios the assessment needs to be carried out for
- How is the performance evaluated / compared:
 - Generation / aggregation of ratings according the objectives
 - Dominance among objectives

Traffic Profile and Users’ Mobility

This part of the use case template states the relevance of mobility and traffic for the assessment of the algorithm:

- To which extent is mobility of relevance for assessment of algorithm?
- To which extent is the type of traffic (e.g. traffic mix, spatial traffic distribution, flow arrival process, burstiness) of relevance for the algorithm?

Relation to Other Control Mechanisms

- Which other SON functionalities have an impact on the considered algorithm?
- Which other SON functionalities does the considered functionality have an impact on?

Dependency on System Implementation Specifics

- Dependency on LTE standardisation uncertainties
- Dependency on vendor specific implementations

4.1.4 Use Case Profile – Example (Link Level Retransmission Scheme Optimisation)

Use Case	Link-level retransmission scheme optimization			Classification	self-optimisation
I Scope	Location of Algorithm			No. of Controlled / Considered Cells	Impact w.r.t. other cells
	local	centralised	distributed		
	X			1	minor (interference)
	Relevant BTS Types		Macro	Micro	Indoor/Femto

		X	X	X ¹			
II Information Exchange	Between network elements			Frequency	Status w.r.t. standardisation		
	none			n.a.			
	Between (instances) of SON functions			Frequency	Status w.r.t. standardisation		
	None			n.a.			
	Across SON API			Frequency	Status w.r.t. standardisation		
	None			n.a.			
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurements	Status w.r.t. standardisation
	1	BLER	1	UE/eNB	1	ms	??
	2	Packet delay (MAC,RLC)	2	“	1	ms	??
	3	No. of retransmissions	2	“	1	ms	??
IV Control Parameters	#	Name	Layer	Range	Updates		Status w.r.t. standardisation
					scale	freq.	
	1	BLER target	1	0.1%-20%	small	mins/ hours	??
2	Maximum number of retransmissions	2	0-10	“	“	??	
V Mobility And Traffic	How does mobility impact the algorithm?				0 (low) ... 9 (high)	3 ²	
	How much do traffic characteristics impact the algorithm?				0 (low) ... 9 (high)	8 ³	
VI Algorithm Assessment	List of evaluated measurements						
	#	Name	Layer	Period of evaluation			
	1	Packet delay per service	2	Aggregated over observation window			
	2	Residual BLER	1	Aggregated over observation window			
	3	Resource efficiency	1	Aggregated over observation window			
	List of Objectives						
	#	Name	Aggregation		Relation w.r.t. other objectives (e.g. dominance)		
	1	Resource efficiency	Aggregation of multiple measurements		Appropriate balancing w. #2,3		
	2	Packet delay	Aggregation of multiple measurements		Appropriate balancing w. #1,3		
	3	Residual BLER	Aggregation of multiple measurements		Appropriate balancing w. #1,2		

¹ Although the use case is relevant for femto-cell scenarios, its investigation need not be necessarily be done for femto-cell scenarios.

² Via the effects of multipath fading, not directly due to location changes.

³ E.g. service type affects control parameters.

	List of network topologies to be evaluated						
	#	Description				Environment	
	1	Single cell rural/suburban/urban/indoor scenario				standard propagation models	
2	Single cell rural/suburban/urban/indoor scenario				real world propagation info		
VII Relation to other Control Mechanisms	Use cases that have an impact on this use case						
	Weak relation with load balancing, admission control parameter optimization, packet scheduling parameter optimisation, handover parameter optimisation, congestion control parameter optimisation.						
	Use cases that this use case has an impact on						
	Same as above.						
VIII Dependency on System Implementation Specifics	Dependency on		Rating 0 (low) ... 9 (high)		Description		
	LTE standardisation uncertainty		2		Only basic parameters / measurements		
	Vendor specific implementations		0		Interfaces need to be provided		
Use Case	Link-level retransmission scheme optimization				Classification	self-optimisation	
I Scope	Location of Algorithm			No. of Controlled / Considered Cells		Impact w.r.t. other cells	
	local	centralised	distributed				
	X			1		minor (interference)	
	Relevant BTS Types			Macro	Micro	Indoor/Femto	
			X	X	X		
II Information Exchange	Between network elements				Frequency	Status w.r.t. standardisation	
	None				n.a.		
	Between (instances) of SON functions				Frequency	Status w.r.t. standardisation	
	None				n.a.		
	Across SON API (cf. Section 4.1.1)				Frequency	Status w.r.t. standardisation	
	None				n.a.		
...							
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurements	Status w.r.t. standardisation
	1	BLER	1	UE eNB	1	< 1ms	??
	2	Packet delay	2	“	1	“	??
	3	No. of retransmissions	2	“	1	“	??
IV Control Parameters	#	Name	Layer	Range	Updates		Status w.r.t. standardisation
					scale	freq.	
	1	BLER target	1	?	incr.	mins/ hours?	??
2	Maximum number of retransmissions	2	?	“	“	??	
V Mobility And Traffic	How does mobility impact the algorithm?				0 (low) ... 9 (high)		To be clarified
	How much do traffic characteristics impact the algorithm?				0 (low) ... 9 (high)		8

VI Algorithm Assessment	List of evaluated measurements			
	#	Name	Layer	Period of evaluation
	1	Packet delay per service	2	Aggregated over observation window
	...			
	List of Objectives			
	#	Name	Aggregation	Relation w.r.t. other objectives (e.g. dominance)
	1	Resource efficiency	Aggregation of multiple measurements (To be clarified)	Appropriate balancing with #2
	2	Packet delay	Measurement #1	Appropriate balancing with #1
	List of network topologies to be evaluated			
	#	Description	Environment	
1	Simple, regular scenarios	hexagon		
2	Real world scenarios	rural, urban, indoor		
VII Relation to other Control Mechanisms	Use cases that have an impact on this use case			
	Load balancing, admission control parameter optimization, packet scheduling parameter optimisation, ...			
	Use cases that this use case has an impact on			
	Same as above?			
VIII Dependency on System Implementation Specifics	Dependency on	Rating 0 (low) ... 9 (high)	Description	
	LTE standardisation uncertainty	2	Only basic parameters / measurements	
	Vendor specific implementations	0	Interfaces need to be provided	

Table 4: Use Case Profile – Example (Link level retransmission scheme)

4.2 Requirements for Computer Simulations

SON functionalities take account of mid-term or long-term changes (self-optimisation) or special events (self-healing, self-configuration). Computer simulations that are conducted to assess SON functionalities need to, firstly, model these changes, and, secondly, need to allow for a detailed assessment of the impact of the SON functionalities with respect to the changes. Within SOCRATES, a distinction is made between a *macroscopic simulation model* for the modelling of long-term traffic changes as well as special events and a *microscopic simulation model* for the detailed assessment of the network quality. The macroscopic simulation model is use case specific and will be defined within the individual work-packages. In this section, requirements on the microscopic simulation model are described.

Based on the use case profiles—the previous section gives two examples—the use cases are categorized with respect to different criteria. First the different criteria are described, and second the categorisation is carried out.

4.2.1 Criteria

Level of Simulation

The level of simulation describes the type of simulation to be applied. Three types of simulations are distinguished:

1. *Dynamic simulations* carry out an event- or time-driven simulation of the networks. Dynamic simulations simulate the system over a period of time with a typically high time resolution.

2. *Static simulations* evaluate the network quality based on one or multiple static states of the network. They are usually used for simulations in network planning.
3. While dynamic simulations allow a detailed and accurate assessment of the network quality at the expense of lengthy simulation runs, the accuracy and level of detail of static simulations is limited. As a compromise, *short-term-dynamic* simulations have been established. With short-term dynamic simulations the network is simulated based on a static snapshot of the system over a short period of time. Short-term-dynamic simulations are typically carried out at a lower time resolution than dynamic simulations.

The required level of simulation strongly depends on the time-resolution to be applied and the level at which mobility needs to be considered.

Time Resolution

The time resolution describes the temporal resolution of events considered in simulations. The required time resolution mainly depends on the modelling of users, i.e. traffic and mobility modelling, as well as the modelling of the propagation environment. For a very detailed simulation of networks, e.g. including multi-path fading, the time resolution is in the order of less than a millisecond.

Mobility Modelling

In general, the mobility of users has a significant impact on the performance of radio networks. The level at which users' mobility needs to be considered in simulations strongly depends on the algorithm under investigation. If, for example, a handover parameter optimisation is to be carried out, a very realistic modelling of mobility is required. For other use cases, users' mobility does not have a significant impact or can be considered without modelling the individual users' behaviour. In the example of optimising tracking areas, it is sufficient to consider the handover rates among cells.

Traffic Modelling

Similar to the mobility modelling, the traffic modelling is a crucial parameter in the simulation of radio networks. Two basic modelling approaches are distinguished: (a) modelling individual user's traffic, i.e. the source models, and (b) modelling spatial traffic distribution. If, for the example, a packet scheduler is to be simulated, realistic source models are of great relevance. On the other hand, for the (automatic) selection of site locations the realistic modelling of the spatial traffic distribution is essential.

Type of Network Scenarios

The size and topology of networks to be considered for the assessment of functionalities is use case specific as well. In the following, three main requirements are distinguished: the size of the networks, the topology of networks to be considered, and whether femto-cells are of relevance.

The two network topology types are discriminated: hexagonal and realistic. The network topology can be of low importance for the performance evaluation of the methods developed in some use cases. In these cases, the simulation of hexagonal network topologies is considered sufficient. In contrast, if the performance of the functionalities under investigation is expected to depend on the network topology, realistic network layouts as described in [24] are to be applied.

The size of the networks to be analysed depends on two main criteria: the number of cells that are controlled by the investigated functionality and its sensitivity towards interference. In general, the size of the network needs to be large enough so that all relevant interference effects can be captured in the cells controlled by the functionality.

The consideration of femto-cells put additional requirements on the simulations. The combined simulation of femto- and macro-cells presupposes complex simulation models with respect to both propagation and traffic models. The consideration of femto-cells can be either direct, if femto cells are subject to the SON functionality itself, or indirect if only their impact, e.g., regarding interference, needs to be modelled.

4.2.2 Categorization of Use Cases

Based on the use case profiles, the individual use cases are categorized with respect to the abovementioned criteria. The result is listed in Table 5. The requirements in the table constitute minimum requirements. A more detailed modelling is obviously feasible.

The requirements of the individual use cases vary considerably in level of detail and size of networks to be considered. Typically, either the simulation of large-scale networks with lower complexity concerning dynamics or the simulation of small scenarios with higher dynamics is required. For the use cases

“Network Authentication” and “Cell Outage Prediction” no simulation requirements has been defined, because no simulation models are known. If these use cases are considered to be relevant for the project, the simulation environment will need to be defined at a later stage of the project. The detailed description of the requirements per use case is available in Appendix B.

Use Case	Level of Simulation	Time Resolution	Mobility	Traffic	Scenario			Comments
					Type	Size	Indoor / Femto	
Intelligently selecting site locations	static	n.a.	static mobility patterns	realistic traffic distribution	real world scenarios	N x 100 cells	yes	
Automatic generation of default parameters for NE insertion	dynamic	ms	full mobility	realistic traffic mix	real world scenarios	N x 100 cells	yes	dynamic simulations are required as parameter sets are generated for most of the use cases
Network authentication	TBD							currently no simulation models known for this UC
Interference coordination	short-term-dynamic	ms	none	realistic traffic mix	real world scenarios	N x 10 cells	no	
Self-optimisation of physical channels	short-term-dynamic	ms	none	not traffic type specific	hexagonal	1 cell + surrounding cells	yes	
RACH optimisation	short-term-dynamic	ms	none	simple traffic models	real world scenarios	1 cell + surrounding cells	no	
Self-optimisation of home eNodeB	dynamic	ms	mobility between macro and indoor layer	not traffic type specific	real world scenarios	N x 10 cells	yes	requirements will differ depending on the different parts of the use case
Admission control parameter optimisation	dynamic	ms	full mobility	different traffic types, heterogeneous traffic distribution	hexagonal	N x 10 cells	no	
Congestion control parameter optimisation	short-term-dynamic	ms	full mobility	different traffic types, heterogeneous traffic distribution	hexagonal	N x 10 cells	no	
Packet scheduling parameter optimisation	short-term-dynamic	ms	none	different traffic types, heterogeneous traffic distribution	hexagonal	1 cell + surrounding cells	no	
Link level retransmission scheme optimisation	short-term-dynamic	ms	none	different traffic types, heterogeneous traffic	hexagonal	1 cell + surrounding cells	no	
Coverage hole detection	static	n.a.	static mobility patterns	realistic traffic distribution	real world scenarios	N x 100 cells	yes	
Handover parameter	dynamic	~1 s	realistic mobility	realistic traffic	real world scenarios	N x 10 cells	yes	

optimisation			patterns	distribution				
Load balancing	dynamic or short-term-dynamic	sec	Handover traffic	different traffic types, heterogeneous traffic distribution	hexagonal	N x 10 cells	(no)	it might be required to assess this use case in a real NW scenario -> decision at a later project stage
Reduction of energy consumption	static	n.a.	none	realistic traffic distribution	real world scenarios	N x 10 cells	no	dynamic simulations might be required at a later phase of the project
Tracking areas	static	n.a.	realistic mobility patterns	realistic traffic distribution	real world scenarios	N x 1000 cells	no	
TDD UL/DL switching point	dynamic (TDD)	ms	none	realistic traffic mix		> 2 cells	yes	details of scenario will be decided at later project phase
Management of relays and repeaters	static	n.a.	none	realistic traffic distribution	hexagonal	N x 10 cells	no	
Cell outage prediction	TBD							currently no simulation models are known for this use case
Cell outage detection	static	n.a.	none	realistic traffic distribution	real world scenarios	N x 100 cells	yes	
Cell outage compensation	static	n.a.	none	realistic traffic distribution	real world scenarios	N x 100 cells	yes	

Table 5: Categorization per use case

4.3 LTE Simulation Model Requirements

The goal of this section is to establish which LTE functionalities need to be modelled in the simulators used by Socrates and to determine the requirements and desired properties of these models. Actual details regarding the structure of the models and their level of abstraction will be handled in WP3 and WP4 as the needs of the models becomes more apparent. Note that the level of detail of the models listed below depends on the actual use case. In general for dynamic simulations (see Section 4.2.1) more accurate models are needed while for static simulations a simplified view is often sufficient. Further, it may not be necessary to implement all models listed below. For example, if a particular physical channel is not the focus of a study, then a model of this channel may be omitted in order to reduce the simulator complexity and to decrease simulation time.

This section presents a set of requirements for models of

- base station and UE radio transmission and reception,
- layer 1 aspects,
- measurements and reports,
- layer 2 aspects,
- radio resource control,
- mobility,
- other radio resource management,
- architecture, and
- quality of service

Note that in some cases models may be based on relevant 3GPP specifications, while in other cases where algorithms or techniques are vendor specific, models need to be based on a set of reference algorithms that need to be designed and agreed on within SOCRATES.

4.3.1 Base Station and UE Radio Transmission and Reception

UE and base station transmitter and receiver characteristics should follow specifications [18][19]. This includes, e.g., frequency bands that can be used, channel spacing, channel bandwidth, maximum output power, and performance requirements for physical channels.

4.3.2 Layer 1

The following layer 1 (physical layer) models are considered.

Frame Structure and Physical Resources

The time-domain structure should follow frame structures type 1 (FDD) according to specification [4]. In case TDD is to be modelled then the structure should follow type 2 according to specification [4]. Physical resources including physical resource elements and physical resource blocks (PRBs) and related parameters for the uplink and downlink should be modelled according to specification [4].

Physical Channels and Signals

Uplink physical channels, i.e., PUSCH, PRACH, and PUCCH should be modelled according to specification [4]. Downlink physical channels, e.g., PDSCH, PBCH, PDCCH, and PHICH should be modelled according to specification [4]. Other downlink physical channels, e.g., PMCH may need to be modelled. Downlink and uplink reference signals should be modelled according to specification [4].

Physical channel procedures involving, e.g., CQI reporting, ACK/NACK procedures, and random access should be modelled according to specification [6].

Synchronisation Procedures

Cell search is the process of identifying and obtaining downlink synchronization to cells, so that the broadcast information from the cell can be detected. This procedure is used both at initial access and at handover. Synchronisation including cell search and timing synchronisation should be modelled according to specification [6]

Modulation and Coding Scheme

Link adaptation with various modulation schemes and channel coding rates is applied to the shared data channel. The modulation and coding scheme (MCS) is selected based on channel quality, buffer content, acceptable delay, etc. Modulation for the physical channels should follow specification [4]. Schemes up to 64QAM should be modelled.

Power Control

Uplink power control determines the transmit power of the different uplink physical channels. Uplink power control for PUSCH, PUCCH, and PRACH should be modelled according to specification [6]. Downlink power control will most likely be proprietary and vendor specific. A reference algorithm needs to be designed. As a default model, the data channel power is distributed uniformly over the scheduled PRBs (i.e., no power control is used for downlink). This will still allow for downlink interference control as UEs at cell edges can be scheduled on different PRBs and, thus, avoid or minimize downlink interference.

Random Access Procedure

Before commencing services or during handover a UE needs to perform random access in order to register at the network and to determine timing advance. The random access procedure should be modelled according to specification [6] (at layer 1 level) and [12] (at MAC level).

Link to System

Link to system models from SINR to Block Error Probability (BLEP) should be supported, see Figure 2. Geometry and channel conditions are determined at system-level and BLEP is computed using link-level models (based on pre-computed tables).

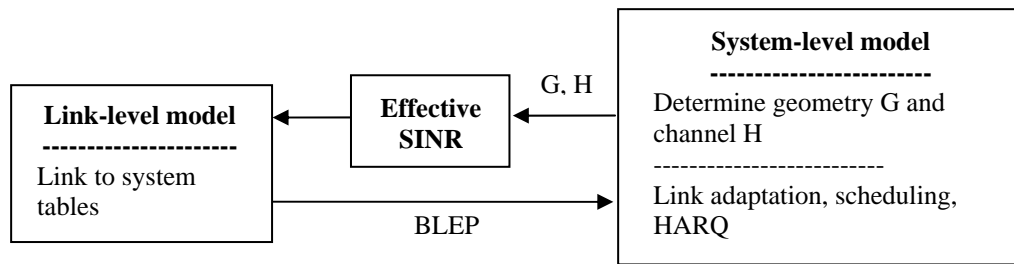


Figure 2 Link to system simulation methodology

The Effective Exponential SINR Mapping (EESM) as explained in [5] should be used to derive the effective SINR given the UE geometry and instantaneous channel. The mapping from effective SINR to BLEP should follow the results found in [5].

4.3.3 Measurements and Reports

Measurements done at the UE and by the network in order to support operation in idle mode and connected mode should follow specifications [7][16]. UE measurements procedures should be modelled as described in specification [8]. Measurements should follow the requirements (e.g., accuracy) for UE and eNodeB as described in specification [8]. For measurements within E-UTRAN at least the following basic UE measurement quantities should be supported, namely, reference symbol received power (RSRP), carrier received signal strength indicator (RSSI), and reference signal received quality (RSRQ). This is required in, e.g., mobility management.

To support fast channel dependent link adaptation and channel dependent time and frequency domain scheduling the UE may be configured to report the Channel Quality Indicator (CQI). Typically, the UE bases the CQI reports on measurements on the downlink reference signal. CQI reporting should follow the procedure given in specification [6]. Uplink buffer status reports (BSR) are needed to provide support for QoS-aware packet scheduling and models of BSR should follow specifications [9][12].

4.3.4 Layer 2

Layer 2 is split into Medium Access Control (MAC), Radio Link Control (RLC), and Packet Data Convergence Protocol (PDCP) [9]. Layer 2 interfaces Layer 1 (physical layer) and provides radio bearers to higher layers. Services provided by MAC include HARQ, scheduling, transport format selection, and random access procedure. The RLC layer supports segmentation and concatenation of IP packets (depending on the scheduler decision), is also responsible for correcting residual HARQ errors by operating another ARQ protocol above MAC, and performs in-sequence delivery. PDCP carries out IP header compression, provides security, and handles prioritization of packets during handover.

MAC should be modelled according to specifications [9][12]. For requirements on the scheduler model refer to Section 4.3.7. The random access procedure including initialization, resource selection, and preamble transmission should be modelled according to specification [12]. The operation of HARQ should be modelled according to specification [12].

RLC may need to be modelled in case services provided by RLC (see above) are needed or affect evaluation results. The ARQ protocol of RLC should be modelled according to specification [13]. PDCP may need to be modelled in case services provided by PDCP (see above) are needed or affect evaluation results. PDCP models should follow specification [14].

4.3.5 Radio Resource Control

In LTE, the RRC protocol includes the following functions: broadcast of system information, connection control and reconfiguration (e.g., paging, management of radio bearers), intra-frequency, inter-frequency, and inter-RAT mobility, radio configuration control (including assignment/modification of ARQ configuration, HARQ configuration, and DRX configuration), recovery from radio link failure, random access, measurement configuration control and reporting, and security.

RRC encompasses a wide variety of functions. As such it may be necessary to model some aspects of RRC especially those related to, e.g., mobility, measurements, random access, and paging. In such circumstance the models must adhere to specification [11]. The RRC states (RRC_IDLE and RRC_CONNECTED) or a subset of the states (e.g. RRC_CONNECTED) should be modelled and follow specification [11].

4.3.6 Mobility Management

A user equipment (UE) can be in the RRC states RRC_IDLE and RRC_CONNECTED. The state RRC_IDLE involves cell (re)selection, which may be modelled if needed and in that case the model should follow specifications [8][9][11]. Tracking area management may be modelled and should follow specifications [9][17].

Mobility management in RRC_CONNECTED is network controlled and involves all necessary steps for relocation/handover procedures, e.g., processes that precede the final HO decision on the source network side (control and evaluation of UE and eNB measurements), preparation of resources on the target network side, commanding the UE to the new radio resources, random access, and finally releasing resources on the (old) source network side. Models of mobility management in RRC_CONNECTED, involving all procedures mentioned above, should follow specifications [8][9][11]. Inter-RAT mobility may be modelled if needed and in that case the model should follow specifications [9][11]. Some parts of mobility in RRC_CONNECTED are likely to be proprietary and vendor specific, e.g., HO decision and admission control. As a default model, a HO decision algorithm based on handover margin may be assumed, see e.g., [15]. Details regarding admission control are given in Section 4.3.7.

4.3.7 Other Radio Resource Management

A list of radio resource management (RRM) functionalities is given below. These RRM functions are likely not to be standardized and, hence, they will most likely be vendor specific. The notion of load will be a central aspect of these RRM algorithms and a proper definition of load will be necessary.

Link Adaptation

In link adaptation a suitable modulation and coding scheme (MCS) is chosen based on, e.g., channel quality (CQI feedback) and buffer content. Link adaptation is closely coupled with the scheduler (see Section 4.3.7 below) and will most likely be proprietary and vendor specific. A reference algorithm needs to be designed. As a default model, it should be assumed that link adaptation uses CQI reports and buffer content to set the proper MCS.

Admission Control

The task of radio admission control is to admit or reject the establishment requests for new radio bearers. Admission control will most likely be proprietary and vendor specific. A reference algorithm needs to be designed. The reference algorithm should take into account the overall cell load, and the QoS requirements and the priority of in-progress sessions.

Congestion Control

The objective of the congestion control mechanism is to monitor the network load and get the system quickly but in a controlled fashion back to a feasible load situation in case of overload. Congestion control will most likely be proprietary and vendor specific. A reference algorithm needs to be designed. The reference algorithm should decrease the load stepwise by rejecting new service requests, alter bit rates, and as a final resort controlled service dropping.

Scheduling

The scheduler should take into account of the traffic volume and the QoS requirements of each UE and associated radio bearers, when sharing resources between UEs. Schedulers may assign resources taking into account the radio conditions at the UE identified through measurements made at the eNB and/or reported by the UE. Scheduling should be modelled and follow specifications [9][12].

Some aspects of the scheduler, e.g., resource allocation, will most likely be proprietary and vendor specific. As a default model, round robin in time with full bandwidth allocation can be assumed, i.e., a UE is allocated the entire bandwidth at a time. An extended model of the scheduler should schedule in time and frequency, be frequency selective, and consider the QoS requirement of admitted services.

4.3.8 Architecture

The radio network architecture models should follow specifications [9][10][11]. The E-UTRAN consists of eNodeBs, providing the E-UTRA user plane and control plane protocol terminations towards the UE. The eNodeBs are interconnected by means of the X2 interface. Models of the X2 interface should follow specification [20]. The eNodeBs are also connected by means of the S1 interface to the Evolved Packet Core (EPC), consisting of Mobility Management Entity (MME) and Serving Gateway (S-GW). Models of the S1 interface should follow specification [21].

4.3.9 Quality of Service

In LTE there will be different types of radio bearers defined and a radio bearer model should conform to the relevant specifications, e.g. [9][22]. A basic QoS model consisting of two types of bearers, namely, Guaranteed Bit Rate Radio Bearer (GBRRB) and Non-Guaranteed Bit Rate Radio Bearer (Non-GBRRB) should be used. The latter is equal to a best effort service. Each radio bears is characterized by a guaranteed bit rate (applies only to GBRRB), maximum bit rate, and allocation and retention priority. The primary purpose of the allocation and retention priority is to decide whether a bearer establishment and/or modification request can be accepted or needs to be rejected, alternatively, to drop radio bearers in case of overload.

5 Concluding Remarks

In this document, focus has been on the requirements to be met by successful implementations of the functionalities described for each use case. The word “implementation” is here understood in a broad sense, including developing new methods and algorithms, adding measurements, and defining a management architecture and interfaces.

The requirements have been divided into three parts: **Technical Requirements, Business Requirements and Simulation Tool Requirements.**

By defining these requirements for the future work within the SOCRATES project, the following has been achieved:

- Well-defined technical **requirements for each use case** have been determined, specifying performance and complexity requirements, stability and robustness requirements, etc. This has been done in a uniform way.
- It was found that many use cases have similar technical requirements. This is to be expected, as they are based on similar principles, even if their specific objectives are different. However, details of these requirements often differ between use cases.
- The document also elaborates on **business requirements**. The general conclusion is that cost efficiency will be in focus. Therefore, when prioritising use cases, SOCRATES should consider when prospective solutions will become available in relation to the further standardisation process as well as in relation to expected network deployment schedules.
- Since most of the verification of new functionality will be done by means of simulation, a number of **simulation tool requirements** have been specified. This includes the description of LTE simulation model requirements.
- The document contains **use case profiles**. This is a uniform way of defining requirements criteria for each use case. Initially, the use case profiles have been used to determine simulation tool requirements, but the information in the use case profiles will also be useful for further work in the project, e.g. for a more detailed analysis of the use cases in WP3 and WP4..

We believe that the definition of requirements done in this document forms a sound basis for the continuation of the project. But it is also understood that further analysis of the requirements will be needed when the projects moves into WP3 and WP4 and the actual development of methods and algorithms for self-organisation for the different use cases starts.

6 References

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Appendix A Detailed Requirements per Use Case

This appendix contains the detailed requirement tables per use case. Section A.1 contains the requirements imposed by self-configuration use cases, Section A.2 contains the requirements imposed by self-optimisation use cases, and Section A.3 requirements imposed by self-healing use cases. An explanation of the requirement categories and a concluded overview about the importance of the respective requirements per use case are provided in Chapter 2.

A.1 Requirements per Use Case – Self-configuration

This section contains a detailed description of the requirements per use case, with a focus on the requirements on the algorithms. The detailed descriptions for each use case are available from [1].

A.1.1 Intelligently selecting site locations

Use case outline

Intelligently selecting site locations describes the task to automatically calculate the ideal or topology specific location for a new base station in case of bad coverage or required bandwidth enhancements.

Category	List of requirements	Importance
Performance and complexity	<ol style="list-style-type: none"> 1. The determination of a new site for a network element (site selection) is a highly complex task, requiring parameters from different sources (measurements from installed network elements, measurements from mobiles, geographical information etc.) as input and a policy-driven analysis and computation system for the selection of the new site location. Therefore, adequate computing power is required. 	Medium
Stability	<ol style="list-style-type: none"> 1. The algorithm for calculating a new site has to ensure that a newly implemented network element integrates well with the existing infrastructure. The recommendation for such an ideal location has to be stable. 2. Since the ideal location determined by the algorithm may not be feasible w.r.t. the installation of the hardware equipment, the algorithm should provide at least an area for the installation that also respects the boundary conditions of the installed infrastructure and technical boundaries of the new hardware (e.g. spatial conditions, available power supply, air conditioning, etc.) to be installed. In case topology or geographical information is available and shall be used to determine the location (including information about buildings, streets, potential antenna sites etc.) the algorithm may also provide a list of potential new sites. 	High
Robustness	<ol style="list-style-type: none"> 1. In case of missing input (e.g. measurements, geographical / topology information) the algorithm should either request a manual input by the human operator or terminate with a corresponding failure message. 	Low
Timing	<ol style="list-style-type: none"> 1. <i>Time scale of operation</i> – The use case is incidentally triggered by other use cases such as coverage hole detection – therefore no dedicated time scale can be given. 2. <i>Speed of adjustment</i> – The determination of the optimum site location should be completed as soon as possible. However, it depends on the demands of the operator how fast this is to be completed, since the calculation of the site parameters will usually be the least time consuming part of the whole process. Therefore, the recommendation for the speed of adjustment is to converge within hours. 	Low

Interaction	<ol style="list-style-type: none"> 1. This use case is not continuously running but incidentally triggered by other use cases, e.g. by Coverage Hole Detection. Therefore a corresponding trigger parameter between these use cases is required. 	Low
Architecture and scalability	<ol style="list-style-type: none"> 1. Site selection is a use case that is strongly related to network planning tools and shall take over some of the tasks currently still performed manually. Site selection requires access to a multitude of input data (see below) and requires access to measurements from network elements of the respective network area. Furthermore site selection is an infrequently performed task. Therefore, the execution of the use case in a central entity is recommended. 2. Site selection needs interfaces to network planning tools, e.g. for retrieving topology or geographical information. Furthermore, an interface to the network configuration database is required, where the configuration information about all network elements is stored. Site selection also needs an interface to performance management from where a mid- to long-term evaluation of the performance measurements in the affected network area is available. This is especially necessary in case site selection has been triggered by coverage hole detection or by performance management, in case of a detected undersupply of a certain area. 3. Regarding the implementation in multi-vendor environments it is necessary to standardise the format and interfaces of the input data, the triggers as well as the format and interface of the output data. The realisation of the required interfaces is not necessarily subject to standardisation. 	Medium
Required inputs	<p>The function has a strong interface to network planning and needs similar data as input:</p> <ul style="list-style-type: none"> • Current radio configuration parameters of surrounding network elements and cells • Performance information and measurements of surrounding network elements and cells • Topology and geographical data • Network usage patterns of the network section • Measurements of mobiles 	High

A.1.2 Automatic generation of default initial parameters for NE insertion

Use case outline

In case a new network element shall be installed, it has to be configured such that it can start working in the operational network. Therefore especially the radio configuration has to be adapted to the site specific conditions. For some of these parameters self-optimisation mechanisms can be adapted, but it is non-trivial for self-optimisation to start from zero. Thus for these parameters it is useful to generate a set of default values that represent the average of the corresponding values of the installed base. From these default initial values self-optimisation can calculate the ideal values.

Category	List of requirements	Importance
Performance and complexity	<ol style="list-style-type: none"> 1. The automatic generation of default initial parameters for NE insertion is a non-real-time use case, i.e., the data required for the generation of a default initial configuration set need not be acquired in real time. The analysis and calculation of one or several default initial parameter profiles does, however, require an adequate computing 	Medium

	<p>power.</p> <ol style="list-style-type: none"> In case of a new network element being introduced, the necessary default initial parameters need to be available quickly, to prevent from long start-up procedures. Since the use case requires the collection, storage and analysis of a large amount of data, corresponding data management and storage is required.. 	
Stability	<ol style="list-style-type: none"> To start a network element with default initial parameters may cause the risk of conflicts with the running system, e.g. regarding transmission power level, etc. Therefore it is necessary to consider a security margin for the default initial parameters, i.e. to modify the default values from the calculated ideal average such that the potential of conflicting with the running system is reduced to a minimum. This security margin should either be a standard offset of the calculated average values, or also be based on empirical values from previous cases, i.e. the gap between the default initial parameter values and the optimised final parameter values. 	High
Robustness	<ol style="list-style-type: none"> When a new network element is inserted, the default initial parameters should be available quickly to keep the start-up procedure short. However, in case the default initial parameter entity is unreachable, a fallback solution is required. This could e.g. be achieved by the duplication of the default initial parameter entity. 	Medium
Timing	<ol style="list-style-type: none"> <i>Time scale of operation</i> – For the acquisition of the optimised parameters from successfully inserted network elements there are no special timing requirements. Most reasonably the data is requested during time periods with low network load, e.g. during night time. <i>Speed of adjustment</i> – For the provisioning of default initial parameter settings in case of network element insertion, the response time of the default initial parameter entity should be in the area of few seconds. 	Medium
Interaction	<ol style="list-style-type: none"> For the provisioning of default parameters to a newly inserted network element interaction between default parameter entity and the network element is required. 	High
Architecture and scalability	<ol style="list-style-type: none"> The calculation of default initial parameters is most reasonable performed in a central entity, to ensure a large, network-wide “knowledge base”. For large networks, this could also be distributed to several interacting entities. To be able to assign the default initial parameters to the newly installed network element it is necessary to establish an interface between the default initial parameter entity and the network element during the installation / start-up procedure. For the generation of the default initial parameters, it is necessary to collect the corresponding parameters from the network elements after initial optimisation. Therefore, the default initial parameter entity needs either a direct interface to the network elements, or an interface to the network configuration management system. 	High
Required inputs	<p>For this use case no actual performance data is required but configuration data from the network elements.</p> <p>Depending on the required extent of the default initial configuration this may include parameters for:</p> <ul style="list-style-type: none"> Physical channels 	High

	<ul style="list-style-type: none"> • Transmitting power • QoS / GoS <p>Apart from the parameters listed above it is necessary to acquire additional information about the network elements:</p> <ul style="list-style-type: none"> • Type of network element (e.g. macro eNodeB, home eNodeB) • Number of associated cells • Number of neighbours • Network environment (urban / suburban / rural) <p>With this data the acquired parameters can be associated with a dedicated scenario, allowing the generation of scenario-specific default parameter profiles.</p>	
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A.1.3 Network Authentication

Use case outline

Network authentication describes those tasks necessary to ensure the authentication of newly installed network elements towards the installed base, and vice versa. Furthermore it describes the tasks necessary to ensure a secure data transfer between network elements and the management system for the purpose of self-organisation.

Category	List of requirements	Importance
Performance and complexity	<ol style="list-style-type: none"> 1. This use case is independent from all other described use cases since it describes a precondition for networking per se. 2. Authentication between network elements usually has to be performed only once before an interface is established. Especially in time-critical cases this has to complete quickly. 3. For the data encryption on the interfaces between network elements, the additional bandwidth and the processing power for en- and decryption has to be taken into account. 4. While data encryption is based on standard protocols (e.g., IPSec), there exist several options for the implementation of network element authentication with different security levels. A Public Key Infrastructure (PKI) with mutual authentication represents the most complex, but also most secure option, implementations with a non-mutual authentication reduce the complexity w.r.t. availability of certificate authorities, corresponding update processes, etc. 	High
Stability	<ol style="list-style-type: none"> 1. Apart from general stability requirements, especially for network element authentication, a clear process how to proceed in case of failed authentication is required. 	Medium
Robustness	<ol style="list-style-type: none"> 1. A fallback solution is required w.r.t. network element authentication, in case required entities for authentication fail. 	Medium
Timing	<ol style="list-style-type: none"> 1. <i>Speed of adjustment</i> – the completion of an authentication procedure should be completed within seconds to keep delay low in case of network element installation or network re-configuration 	Medium
Interaction	<ol style="list-style-type: none"> 1. Depending on the implementation, for network element authentication an interface between a certificate server and the network elements is required. In a multi-vendor environment, this interface needs either to be standardised, or a solution where each supplier provides its own certificate 	Medium

	<p>server is required.</p> <p>2. For data encryption, each network element has to be IPsec enabled.</p>	
Architecture and scalability	<p>1. The implementation of an infrastructure for network element authentication needs at least one central entity e.g. for the storage and administration of certificates. In case of a multi-vendor solution this entity requires a standardised interface for the exchange of authentication information, and a standard format for certificates.</p> <p>2. A solution for network element authentication must be able to handle several 100.000 network elements. This is mainly important for the centralised parts of the solution such as certificate servers.</p> <p>3. For data encryption, each network element has to be IPsec enabled.</p>	Medium
Required inputs	None	Low

A.2 Requirements per Use Case – Self-optimisation

A.2.1 Interference Coordination

Use case outline

The self-optimisation algorithm for the interference coordination should optimally manage interference levels, taking into account signalling and measurement limitations.

Category	List of requirements	Importance
Performance and complexity	<p>1. An appropriate balance between the performance gains established by adding self-optimisation and the implementation complexity is required.</p> <p>2. Optimal balance between overall cell performance and fairness for individual users should be kept. Methods that result in a large gain in cell performance should only be considered if they fairly distribute the gain over all users. Similar considerations apply for fairness between cells – a high gain in one cell should not result in decreased performance in neighbouring cells.</p>	High
Stability	<p>1. The stability requirement is that the interference coordination solution should intelligently handle signalling messages such that stable configurations are achieved.</p>	Medium
Robustness	<p>1. In the event that there are inaccuracies in either the input data or the signalling messages, the interference coordination should still be parameterised such that it performs satisfactorily. For example, if the source eNodeB causing interference is identified incorrectly, an interference problem will not be resolved.</p> <p>2. Possible disturbance sources should be identified, and measures to deal with these should be implemented.</p>	Medium
Timing	<p>1. The interference coordination should operate on a timescale to match changes of propagation environment (scale of ms) and traffic variations (scale of seconds or minutes)</p> <p>2. Speed of adjustment of controlled parameters can be on the order of hours.</p>	High
Interaction	<p>1. Actions of the interference coordination should be aligned (or at least do not conflict) with the actions of other algorithms in the cell itself or surrounding cells. Hence the</p>	High

	<p>associated self-optimisation algorithms should always set the mechanisms' parameters such that their operations are in agreement.</p> <p>2. Potential interactions are foreseen with the following mechanisms:</p> <ul style="list-style-type: none"> ○ Algorithms related to GoS/QoS optimisation such as admission and congestion control. Interference coordination is dealing with a situation where the network is highly loaded, and aims to effectively manage that load. Admission and congestion control have different functionality, but are also mechanisms to deal with a high load. ○ Self-optimisation of physical channels: Interference from other cells will also play a role in the self-optimisation of physical channels. 	
Architecture and scalability	<ol style="list-style-type: none"> 1. The distributed implementation in the eNodeBs implies that it will be required that the interfaces between the eNodeBs (X2 interface) carry signalling messages (Overload Indicator (OI) and High Interference Indicator (HII)). 2. If a centralised implementation is assumed, signalling messages and interference measurements are required to be exchanged with central SON entity. 3. In case of multi-vendor equipment deployment, it might even be required that the definition and interpretation of some of the performance counters and part of the coordination mechanism are standardised. Potential risk for instability and efficiency loss are the cases of multi-vendor deployments when neighbour cells from different vendors execute interference coordination algorithms that take different measures/actions based on the same input conditions. 4. The interference coordination should work independent of whether there are a small number of adjacent cells, or whether a large area is being covered with many cells. 	Medium
Required inputs	<ul style="list-style-type: none"> • User QoS (throughput, delay, packet loss) • User location (how close to cell edge based on path loss measurement) • Interference level for each resource block • Load/Interference indicator from other cells • Statistics of HII, OI, and DL power setting information 	High

A.2.2 Self-optimisation of physical channels

Use case outline

The self-optimisation of physical channels mechanism should keep the physical channel parameters appropriately and timely tuned to the environment and traffic properties.

Category	List of requirements	Importance
Performance and complexity	<ol style="list-style-type: none"> 1. An appropriate balance between the performance gains established by adding a self-optimisation layer and the implementation complexity is required. 2. Limits on number of measurements, and signalling of measurements, should be determined, and solutions should take into account those limits. Limits on UE measurements are particularly important, as these have to be signalled over 	High

	the radio interface.	
Stability	<i>No stability requirements</i>	Low
Robustness	<ol style="list-style-type: none"> 1. In the event that there are inaccuracies in either the input data or the signalling messages, the self-optimising algorithm should still perform satisfactorily. For example, if a faulty UE is reporting incorrect measurements, this should be detected, and measurements from this UE should be discarded. 2. Possible disturbance sources should be identified, and measures to deal with these should be implemented. 	High
Timing	<ol style="list-style-type: none"> 1. Measurements should be gathered over a sufficiently long period to ensure that statistically significant measurement data is obtained. 2. Speed of adjustment can be on the order of hours or days. 	Medium
Interaction	<ol style="list-style-type: none"> 1. Actions of the self-optimisation of physical channels algorithm should be aligned (or at least not conflict) with the actions of other algorithms in the cell itself or surrounding cells. Hence the associated self-optimisation algorithms should always set the mechanisms' parameters such that their operations are in agreement. 2. Interactions with the following mechanism should be considered: <ul style="list-style-type: none"> ○ Interference coordination: Interference from other cells has an impact on the physical channels 	Low
Architecture and scalability	<ol style="list-style-type: none"> 1. The architecture should support the ability to obtain information on parameter settings of other cells. If a centralised implementation is assumed, the following will be required: <ul style="list-style-type: none"> ○ Configuration parameters from an eNodeB can be sent to the central O&M server ○ Configuration parameters from other eNodeBs, stored in the O&M server, can be sent the eNodeB 2. In case of multi-vendor equipment deployment, it should be possible to identify which configuration parameters apply to multiple vendors, and which configuration parameters are only used by one vendor. 3. The algorithm should work independent of whether there are a small number of adjacent cells or whether a large area is being covered with many cells. 	Medium
Required inputs	<ul style="list-style-type: none"> • Information on configuration of physical channels for neighbouring cells • Traffic forecasts • eNodeB location • eNodeB hardware configuration <ul style="list-style-type: none"> ○ Antenna height, pattern • Feedback from UEs making calls on the cell <ul style="list-style-type: none"> ○ DL RSRP (Reference Signal Received Power) ○ DL BLER performance for various channels • Measurements on UL channels 	High

A.2.3 RACH optimisation

Use case outline

The self-optimisation algorithm for the RACH optimisation mechanism should keep the number of blocked access attempts low especially for high traffic load [1] and improve the operating grade of the RACH.

Category	List of requirements	Importance
Performance and complexity	<ol style="list-style-type: none"> 1. An appropriate balance between the performance gains established by adding a self-optimisation layer and the implementation complexity is required. 2. User requests that could be handled should not be blocked because of inappropriate RACH parameter configuration. 	High
Stability	<ol style="list-style-type: none"> 1. The iterations to derive the optimized parameter values should converge to a solution. 2. Any time the measurement procedures determine that the number of blocked access attempts is high compared with the traffic and traffic channel load, the algorithm should be able to determine new RACH parameter settings that correspond to the new load situation. The optimal regime should be mainly impacted by trends, i.e. input parameters (e.g., blocked access attempts, load of traffic channel) should be such that only significant changes trigger recalculation of the parameter settings. 	Low
Robustness	<ol style="list-style-type: none"> 1. In the event that there are inaccuracies in either the input data or the signalling messages associated with the self-optimisation, the RACH optimisation should still be parameterised such that it performs satisfactorily. For RACH optimisation, it is possible that the load of a cell is incorrectly determined, which could lead to an incorrect RACH optimisation decision. Possible disturbance sources should be identified, and measures to deal with these should be implemented. 	High
Timing	<ol style="list-style-type: none"> 1. The self-optimisation algorithm is triggered by other algorithms or measurements. It is not processed automatically. Therefore the time scale of operation depends on the network situation. 2. The self-optimisation algorithm should determine new parameter settings sufficiently fast when the relevant traffic, mobility and environment characteristics undergo significant changes. It typically depends on the abruptness of such changes how soon new parameter settings need to be derived. For the RACH optimisation algorithm, changes are expected to occur within minutes; hence parameter self-optimisation should be done within seconds. 	Medium
Interaction	<ol style="list-style-type: none"> 1. The most important issue is that the actions of the RACH optimisation algorithm are aligned (or at least do not conflict) with the actions of other radio resource management mechanisms in the cell where the RACH optimisation is triggered and adjacent cells. Hence the associated self-optimisation algorithms should always set the mechanisms' parameters such that their operations are in agreement. 2. Changes to the network configuration by the tracking area optimisation, load balancing and handover parameter optimisation might lead to traffic load changes for the corresponding cells. The RACH optimisation should be informed about these changes. 	Medium

	3. Since the cell outage compensation includes major changes in the network the RACH optimisation needs to be informed about the changes. It might become necessary to start the RACH optimisation due to high traffic load for the cells that cover the area of the cell in outage.	
Architecture and scalability	<ol style="list-style-type: none"> 1. RACH optimisation will be implemented locally. Hence no standardisations due to multi-vendor equipment deployment will be necessary. 2. Since the algorithms for the RACH optimisation will not collaborate with mechanisms in other eNodeBs there are no special scalability requirements for this use case. 	Low
Required inputs	<ul style="list-style-type: none"> • Mobile Originated Calls (MOC's) • Mobile Terminated Calls (MTC's) • Blocked access attempts • Incoming handovers • Tracking Area Updates • Load of TCH 	High

A.2.4 Self-optimisation of home eNodeB

Use case outline

The self-optimization of home eNodeB use case should update the neighbour relation lists and control handover conditions, optimize the home eNodeB coverage area and minimize the interference caused by the eNodeB.

Category	List of requirements	Importance
Performance and complexity	<ol style="list-style-type: none"> 1. The neighbour lists should be handled in such a way that UEs are not handed over to a home eNB if it is not likely that they will stay for a while in its cell, in order to avoid unnecessary handovers and signalling overhead. This requires appropriate criteria for when to hand over the UE and when to keep the UE in the macro cell. 2. An appropriate balancing of the coverage provided by the home eNodeB and the interference it causes is required. 3. An appropriate balance should exist between the performance gains established by adding a self-optimisation layer and the implementation complexity, which is a clear trade-off. 4. The number of messages that need to be exchanged between the nodes involved should be minimal. 	High
Stability	<ol style="list-style-type: none"> 1. The iterations to derive optimized parameters should converge to a solution. 2. Any time the measurement procedures determine that the interference, performance or user movement characteristics have migrated to significantly different values than desired, the self-optimisation algorithms should be able to determine new control parameters that correspond to those desired values. 3. The optimized parameters should not change significantly upon small changes of the statistical equilibrium. 	High
Robustness	<ol style="list-style-type: none"> 1. In the event that there are inaccuracies in either the input data or the signalling messages associated with the home eNodeB self-optimization algorithms, the mechanisms should still be parameterised such that it performs 	Medium

	<p>satisfactorily. Missing or inaccurate interference reports could cause too high interference and inaccurate or missing input to the neighbour relation mechanism could lead to dropped calls.</p> <ol style="list-style-type: none"> 2. Possible disturbance sources should be identified, and measures to deal with these should be implemented. 	
Timing	<ol style="list-style-type: none"> 1. The function for setting up the home eNodeB neighbour relations should be working within the same time scale as the function of setting up any neighbour relation. 2. The classification of the node in regards to in which situations a handover is suitable and in which situations it is not, should be based on statistics collected over a time window during a number of hours in order to take daily variations into consideration. 3. The configurations performed by the optimization mechanism should be implemented within the range of minutes once the basic statistical data is collected. 4. The coverage optimization algorithm should be based on statistics collected over a time window during a number of hours. The configurations based on the statistical data should be implemented during the time range of hours or even days in order not to change the interference situation drastically. 5. Configurations due to interference should be implemented in a smaller time scale, i.e. minutes. 	Medium
Interaction	<ol style="list-style-type: none"> 1. The measures taken by the home eNodeB management mechanisms should not conflict with measures taken by other SON mechanisms and radio resource management functions. This means that the neighbour relation management and mechanisms for the home eNodeB must be aligned with and work together with the general Automatic Neighbour Relation mechanism and that any changes of handover parameters must be aligned with the handover parameter optimization function. For example, the handover optimization algorithm must consider any neighbour relations settings indicating that one of the eNodeBs in a neighbour relation is a home eNodeB and set parameters appropriate for such relation. 2. The measures that are taken in order to optimize the coverage area for the home eNodeB must not conflict with measures taken by for example the interference coordination mechanism or the mechanisms for optimization of physical channels. 	High
Architecture and scalability	<ol style="list-style-type: none"> 1. Since the self-optimization of home eNodeBs should be executed in a limited area of a home eNodeB and its vicinity and since the number of home eNodeBs in a network is expected to be large a distributed solution is necessary. The X2 interface can be used for interchange of information, such as interference measurement reports, neighbour relation requests etc. between different eNodeBs. In case of multi-vendor solutions the information exchanged over X2 may need to be standardized. 2. The self-optimization mechanism in one home eNodeB should be able to collaborate with mechanisms in other eNodeBs in its vicinity, including other home eNodeBs. 3. The mechanism should be able to handle a large number of eNodeBs in the same area 4. The mechanism should be able to operate within given 	High

	<p>interference restrictions, for example by using input from the interference coordination mechanisms.</p> <p>5. The self-optimization mechanism in one home eNodeB should not collaborate with mechanisms in eNodeBs that are not in its radio vicinity or within the range of neighbours and neighbours' neighbours.</p>	
Required inputs	<ul style="list-style-type: none"> • Failed handover ratio • Dropped call ratio • Interference measurements made by UEs, the serving eNodeB and neighbouring eNodeBs • Signal strength (RSRP) measurements made by UEs • UE speed and UE position • Coverage hole information from the coverage hole detection mechanism • Information from the interference coordination function <p>Some of the information may not be needed for the optimization, depending on the implementation of the optimization algorithms. This is for further study.</p>	High

A.2.5 Admission control parameter optimisation

Use case outline

The self-optimization of the admission control algorithm should timely tune the admission thresholds according to the current traffic mix (e.g. real-time vs. non-real-time traffic), resource utilization, and mobility characteristics (e.g. handover rate and/or mobiles' velocity) without deteriorating the QoS levels of existing sessions. Appropriate balance should exist between the performance gains established by adding a self-optimisation layer and the implementation complexity. Performance gains can be expressed in terms of, e.g., blocking and dropping probabilities, quality of service of existing connections, resource utilization, etc.

Category	List of requirements	Importance
Performance and complexity	<ol style="list-style-type: none"> 1. The performance requirement for the self-optimized admission control algorithm is that there is a non-zero gain in at least one of the performance measures such as blocking and dropping probabilities, quality of service of existing connections, resource utilization, etc. when compared to an admission control algorithm without the self-optimization functionality. 2. The self-optimisation functionality for the admission control algorithm should not introduce additional operational complexity for the operator and should reduce the workload for the admission control optimization. A measure for the implementation complexity involves e.g. the required signalling and measurements, calculation effort, etc. 	Medium
Stability	<ol style="list-style-type: none"> 1. The iterations to derive the optimized parameter values should converge to a solution considering the timing requirements. 2. If at a given time the measurement procedures have determined that GoS/ QoS characteristics in a cell have migrated to a significantly different statistical equilibrium then the self-optimisation algorithm should be able to determine new admission control thresholds that correspond to that new statistical equilibrium. The optimal regime should be mainly impacted by trends, i.e. should be such that only significant changes in e.g. traffic mix, resource 	High

	utilization, handover rate, etc. trigger recalculation of the optimal admission thresholds.	
Robustness	<ol style="list-style-type: none"> 1. In the event of inaccuracies in the input data or the signalling messages (associated with the self-optimisation algorithm or with the admission control mechanism itself), the admission control mechanism should still be parameterised such that it performs satisfactorily. For the admission control, it is possible that the load level and traffic mix, handover rate or remaining capacity are incorrectly determined, which could lead to an incorrect decision. 2. Possible disturbance sources should be identified, and measures to deal with these should be implemented. It should be avoided that due to the inaccurate input for the self-optimisation of the admission control algorithm the GoS/QoS performance of the system is deteriorated. 	Medium
Timing	<ol style="list-style-type: none"> 1. Depending on how fast traffic and mobility conditions change in a given cell (minutes, hours), the self-optimisation algorithm associated with the admission control mechanism needs to converge to a solution in a similar amount of time or less. 2. The self-optimisation algorithm should be triggered at a varying time scale depending on the times at which significant changes occur of those traffic and mobility characteristics that affect the mechanism's parameters. Typically, such changes occur at a time scale which is at least one order higher than that at which the mechanism itself operates. Hence for the admission control mechanism, which typically operates at a time scale of seconds/minutes (depending on the arrival and handover rate), self-optimisation should operate at a time scale of few minutes to hour. 3. The self-optimisation algorithm should determine new parameter settings sufficiently fast when traffic mix, resource utilization, handover rate, etc., undergo significant changes. It typically depends on the abruptness of such changes and how soon new parameter settings need to be derived. It is expected that these changes occur or are noticed at a time scale of minutes, hence self-optimisation of admission control settings within one minute should be feasible. 	Low
Interaction	<ol style="list-style-type: none"> 1. Actions of the admission control algorithm should be aligned (or at least do not conflict) with the actions of other radio resource management mechanisms in the cell where the admission control is triggered and surrounding cells. Hence the associated self-optimisation algorithms should always set the mechanisms' parameters such that their operations are in agreement. 2. Potential interactions are foreseen with the following radio resource management mechanisms: <ul style="list-style-type: none"> o Packet scheduling parameter optimisation: it should be avoided that users are admitted in a cell requesting a given QoS level while the packet scheduling is not able to meet the demands of these users due to conflicting or misaligned optimisations of the parameters of the self optimisation packet scheduling algorithm. o Misalignments should not occur also with other algorithms related to GoS/QoS optimisation such as congestion control, load balancing, coverage hole 	High

	<p>detection algorithms, etc.</p> <p>3. Self-optimisation should ensure that different radio resource management algorithms should not take conflicting actions, as described above, the same applies to the self-optimised parameter settings of a given radio resource management algorithm in adjacent cells.</p>	
Architecture and scalability	<p>1. The self-optimisation of the admission control algorithm can be based on the local measurements in the cell and therefore distributed implementation in the eNodeBs is envisaged. However, due to the fact that conflicting or misaligned admission control optimisations should be avoided at neighbouring cells the interfaces between the eNodeBs (X2) should convey self-optimization of admission control related information such as resource utilization, remaining capacity, blocking and dropping probabilities, new admission control settings, etc.</p> <p>2. The self-optimisation of the admission control should work properly if new services and/or service classes are added or the set of neighbour cells is extended.</p>	Medium
Required inputs	<ul style="list-style-type: none"> • Experienced service- or subscriber class-specific blocking probabilities; • Experienced service- or subscriber class-specific dropping probabilities; • Resource utilization total, per service or subscriber class, new or handover sessions; • QoS levels of all on-going calls; • Handover rates outgoing, incoming. 	High

A.2.6 Congestion control parameter optimisation

Use case outline

The congestion control algorithm detects overload situations, evaluates the degree and urgency of the overload conditions, and takes appropriate counter measures to resolve the overload situation. The self-optimization of the congestion control parameters should maximise resource utilisation subject to a maximum allowed degree of congestion-induced service quality degradation in light of the uncontrollable uncertainties due to e.g. user mobility, signal propagation effects and the impact of the varying load in neighbouring cells.

Category	List of requirements	Importance
Performance and complexity	<p>1. An appropriate balance should exist between the performance gains achieved by adding a self-optimisation layer on top of the congestion control algorithm and the implementation complexity. Performance gains can be expressed in terms of QoS level of existing connections, blocking and dropping probabilities, resource utilization, etc. A measure for the implementation complexity involves the required signalling and measurements, the required calculation effort, etc.</p>	Medium
Stability	<p>1. The iterations to derive the optimized parameter values should converge to a solution within the timing requirements.</p> <p>2. If at a given time the measurement procedures determine that GoS/ QoS characteristics, resource utilization, percentage of time in uplink/downlink congestion, amount of congestion induced QoS degradation, etc., in a cell have migrated to a significantly different statistical equilibrium,</p>	High

	<p>the self-optimisation algorithm should be able to determine new congestion control parameters that correspond to that new statistical equilibrium.</p> <p>3. The optimal regime should be mainly impacted by trends, i.e. should be such that only significant changes trigger recalculation of the optimal parameter settings.</p>	
Robustness	<p>1. In the event of inaccuracies in the input data or the signalling messages (associated with the self-optimisation algorithm or with the congestion control mechanism itself), the congestion control mechanism should still be parameterised such that it performs satisfactorily. For congestion control, it is possible that the measured load, available capacity, service quality, etc., are incorrectly determined, which could lead to an incorrect decision. Possible disturbance sources should be identified, and measures to deal with these should be implemented.</p>	Medium
Timing	<p>1. Depending on how fast traffic conditions change in a given cell (minutes, hours), the self-optimisation algorithm associated with the congestion control mechanism needs to converge to a solution in a similar amount of time or less.</p> <p>2. The self-optimisation algorithm should be triggered at the time scale at which significant changes occur in the GoS/QoS levels, resource utilization, amount of time in congestion mode, etc., that affect the congestion control parameters. Typically, such changes occur at a time scale that is at least one order higher than that at which the mechanism itself operates. Hence for the congestion control mechanism, which the time of operation is in order of seconds/minutes, the self-optimisation should operate at a scale of few minutes to hour.</p> <p>3. The self-optimisation algorithm should determine new parameter settings sufficiently fast when the GoS/QoS levels, resource utilization, amount of time in congestion mode, etc., undergo significant changes. It typically depends on the abruptness of such changes how soon new parameter settings need to be derived. It is expected that these changes to occur or be noticed at a time scale of minutes, hence self-optimisation of congestion control settings within one minute should be feasible.</p>	Low
Interaction	<p>1. Actions of the congestion control algorithm should be aligned (or at least do not conflict) with the actions of other radio resource management mechanisms in the cell where the congestion control is triggered and surrounding cells. Hence the associated self-optimisation algorithms should always set the mechanisms' parameters such that their operations are in agreement.</p> <p>2. Potential interactions are foreseen with the following radio resource management mechanisms:</p> <ul style="list-style-type: none"> ○ Misalignments should not occur also with other algorithms related to GoS/QoS optimisation such as admission control, packet scheduling parameter optimisation, load balancing, coverage hole detection algorithms, etc. <p>3. No conflicting actions of the self-optimised parameter settings of a given radio resource management algorithm in adjacent cells.</p>	High
Architecture and scalability	<p>1. The congestion control monitors, detects and consequently resolves a congestion situation on cell level, which implies distributed implementation in the eNodeBs. The load and</p>	Medium

	<p>congestion situation could be impacted from the load in neighbour cells and therefore it is envisaged that, similarly as it is the case for admission control, congestion control relevant information is exchanged between neighbour eNodeBs (X2) in order to obtain status information or align congestion control measures.</p> <p>2. The self-optimisation of the admission control should work properly if new services and/or service classes are added or the set of neighbour cells is extended.</p>	
Required inputs	<ul style="list-style-type: none"> • Time fraction the network is congested; • QoS level of all on-going calls; • Amount of congestion induced QoS degradations • Load level per service- or subscriber class • Experienced service- or subscriber class-specific blocking probabilities; • Experienced service- or subscriber class-specific dropping probabilities. 	High

A.2.7 Packet scheduling parameter optimisation

Use case outline

The algorithm for packet scheduling parameter optimisation should appropriately tune the packet scheduling parameters in such a way that the packet scheduling algorithm makes optimal use of the channel resources and offers a balanced QoS to all users. Typical scheduling parameters to tune are absolute/relative differentiation threshold, scheduling weights, resource reservations and channel-awareness (fairness) parameter.

The optimisation algorithm should also adapt the packet scheduling parameters appropriately and timely in case problems related to packet scheduling, like a significant QoS imbalance or diminished resource utilisation, are identified.

Category	List of requirements	Importance
Performance and complexity	<ol style="list-style-type: none"> 1. It is required that packet scheduling related performance is higher with the self-optimisation algorithm activated than with this algorithm not activated (performance gain). 2. A key requirement is that an appropriate balance should exist between the performance gains established by activating the self-optimisation algorithm and the implementation complexity of this algorithm, which is a clear trade-off. <ul style="list-style-type: none"> ○ Performance gains can be expressed in terms of number of users that can be accommodated and the increased QoS for the offered services. ○ Measures for implementation complexity are e.g., the signalling overhead, the required calculation effort and the required calculation memory. 	Medium
Stability	<ol style="list-style-type: none"> 1. The iterations to derive the optimised parameter values should converge to a solution. 2. Any time the measurement procedures determine that the QoS balance between users or the resource utilisation factor changed significantly, the self-optimisation algorithm should be able to determine new packet scheduling parameters that correspond to the new situation. The triggering of the optimisation algorithm should be such that only significant changes trigger the recalculation of the 	High

	optimal packet scheduling parameters.	
Robustness	<ol style="list-style-type: none"> 1. In the event that there are inaccuracies in either the input data or the signalling messages associated with the self-optimisation algorithm or with the packet scheduling mechanism itself, the packet scheduling mechanism should still be parameterised such that it performs satisfactorily. 2. Possible disturbance sources should be identified and measures to deal with these should be implemented. 	Medium
Timing	<ol style="list-style-type: none"> 1. The packet scheduling parameter optimisation algorithm needs to converge (speed of adjustment) to a solution in a similar amount of time or less than the time in which changes in the traffic pattern, mobility pattern, service mix or propagation and interference characteristics occur. 2. Further the algorithm needs to be triggered (time scale of operation) at the time scale at which <i>significant</i> changes of these characteristics occur. <ul style="list-style-type: none"> ○ <i>Time scale of operation:</i> Since significant changes of the characteristics mentioned above typically occur in the order of minutes to hours, the packet scheduling parameter optimisation algorithm should also operate on the time scale of minutes to hours. In times of problems related to packet scheduling or unwanted events, caused by fast changing conditions, the packet scheduling parameter optimisation algorithm may need to be triggered more frequently. ○ <i>Speed of adjustment:</i> In case of triggering the packet scheduling parameter optimisation algorithm, the time the algorithm needs to converge should be in the order of minutes or less, since the service mix, traffic patterns and mobility patterns will typically change over a time frame in the order of minutes. In case of triggering the algorithm by the identification of problems related to packet scheduling or unwanted events, caused by fast changing conditions like propagation or interference characteristics, the algorithm needs to converge to a solution in a time of the same order of magnitude as the fast changing conditions, or less. 	High
Interaction	<ol style="list-style-type: none"> 1. The most important issue is that the actions of the packet scheduling mechanism are aligned (or at least do not conflict) with the actions of other mechanisms in the cell or in neighbouring cells. Hence the associated self-optimisation algorithms should set the parameters of the mechanisms such that their operations are in agreement. For packet scheduling, potential influence is foreseen from load balancing optimisation and algorithms related to GoS/QoS optimisation (admission control, congestion control). These mechanisms optimise, and thus change the parameters of algorithms that might have an influence or change the service mix, traffic patterns and mobility patterns, after which the packet scheduling parameter optimisation algorithm might need to be triggered. 2. Combined actions taken by all these parameter optimising algorithms should ensure optimal QoS levels for all users and an efficient resource utilisation at the same time, but if the actions of these algorithms are not coordinated, there is a risk that exactly the opposite occurs. 3. A similar requirement applies to the self-optimised parameter settings of the packet scheduling mechanism in neighbouring cells: information on load, channel quality, 	High

	<p>QoS requirements and effective user locations should be exchanged to ensure that packet scheduling parameter settings in one cell do not conflict with packet scheduling parameter settings in a neighbour cell.</p> <p>4. The risk of interaction problems is higher in case of multi-vendor equipment deployment in neighbouring cells. In such cases it may be required that there is a kind of coordination mechanism between neighbouring self-optimisation algorithms to ensure stability, and that part of this coordination mechanism is standardised.</p>	
Architecture and scalability	<ol style="list-style-type: none"> 1. In case the optimisation algorithm is implemented locally in a cell, no real architectural and scalability requirements apply. 2. The distributed implementation of the packet scheduling parameter optimisation algorithm in the eNodeBs implies that it will be required that <ul style="list-style-type: none"> o The interfaces between the eNodeBs carry self-optimisation related information and performance counters. o Some of the information that needs to be exchanged is standardised. 3. In case of multi-vendor equipment deployment, it might be required that the definition and interpretation of some of the performance counters are standardised. 4. The packet scheduling mechanism should work independently of whether there are a small or a large number of neighbour cells. 	Medium
Required inputs	<ul style="list-style-type: none"> • Traffic mix • Required QoS per on-going call • Experienced QoS per on-going call (throughput , delay, BLER, QoS vs. traffic load) • Resource efficiency • Packet marking 	High

A.2.8 Link level retransmission scheme optimisation

Use case outline

The self-optimisation algorithm for the link level retransmission scheme optimisation mechanism should keep the link level retransmission scheme optimisation parameters appropriately and timely tuned to the traffic.

Category	List of requirements	Importance
Performance and complexity	<ol style="list-style-type: none"> 1. An appropriate balance should exist between the performance gains established by adding a self-optimisation layer and the implementation complexity, which is a clear trade-off. Performance gains can be expressed in terms of e.g. resource efficiency and packet delay/loss statistics (mean, percentiles). For example, if the experienced packet delays, number of retransmissions of a call and residual BLER target are well within the associated service's performance requirements, e.g. because the user's multi-path fading process (~ mobility, propagation environment) is more favourable than estimated so far, the self-optimisation scheme may decide to increase the BLER target and/or the maximum number of allowed retransmissions to enhance 	High

	<p>resource efficiency. A measure for the implementation complexity involves e.g. the signalling/measurement load and the required calculation effort. As the link level retransmission scheme is foreseen to be self-optimised on a per call basis and within a few milliseconds (see also ‘Timing requirements’ below), obvious restrictions exist on the allowed complexity. Further elaboration on the performance gains and complexity measures will be available in SOCRATES deliverable 2.3 [24] on assessment criteria.</p>	
Stability	<ol style="list-style-type: none"> 1. The iterations to derive the optimized parameter values should converge to a solution. 2. When the measurement procedures determine that the traffic, mobility and environment characteristics of a call are of or have migrated to a significantly different nature than what the current (or default) link level retransmission scheme parameters are optimised for, the self-optimisation algorithm should be able to determine those new link level retransmission scheme parameters that correspond to that new nature of the traffic, mobility and environment characteristics. The optimal regime should be mainly impacted by trends, i.e., input parameters should be such that only significant changes trigger recalculation of the optimal parameter settings. 	High
Robustness	<ol style="list-style-type: none"> 1. In the event that there are inaccuracies in either the input data or the signalling messages, associated with the self-optimisation algorithm or with the link level retransmission mechanism itself, the link level retransmission mechanism should still be parameterised such that it performs satisfactorily. For the link level retransmission mechanism, the applied BLER target and maximum number should always be set to reasonable values. For example, it should not occur that due to false measurements or corrupted signalling messages, the BLER target for a specific bearer type is set to a low (e.g. < 0.1%) or high (> 30%) value; an excessively high BLER target in combination with an excessively high number of allowed reattempts may be rather harmful for the flow performance and the resource efficiency. Possible disturbance sources should be identified, and measures to deal with these should be implemented. 	Medium
Timing	<ol style="list-style-type: none"> 1. Depending on how fast traffic conditions change in a given cell (minutes, hours), the self-optimisation algorithm associated with the link level retransmission scheme needs to converge to a solution in a similar amount of time or less. 2. The self-optimisation algorithm corresponding to a radio resource management mechanism should be triggered at the time scale at which significant changes occur of those traffic, mobility and environment characteristics that affect the mechanism’s parameters. Typically, such changes occur at a time scale which is at least one order higher than that at which the mechanism itself operates. Hence for the link level retransmission mechanism, which operates at a time scale of milliseconds, the self-optimisation should operate at a time scale of seconds. 3. The self-optimisation algorithm should determine new parameter settings sufficiently fast when the relevant traffic, mobility and environment characteristics undergo significant changes or can be estimated to differ from the default assumption applied at the beginning of a call. For the link 	Medium

	level retransmission algorithm, changes are expected to occur or be noticed at a timescale of seconds, hence parameter self-optimisation within a few milliseconds should be feasible.	
Interaction	<ol style="list-style-type: none"> The actions of the link level retransmission scheme should be aligned (or at least do not conflict) with the actions of other radio resource management mechanisms associated with the call. Hence the associated self-optimisation algorithms should always set the mechanisms' parameters such that their operations are in agreement. Potential interactions could exist on other radio resource management mechanisms that perform link adaptation, e.g. power or rate control: whenever the optimisation algorithm associated with the link level retransmission scheme decides to adjust the applied BLER (and SINR) target, the selected transmit power or rate should be chosen according to the adjusted target BLER/SINR, which is a very straightforward mapping. 	Low
Architecture and scalability	<ol style="list-style-type: none"> Since both the link level retransmission scheme and its self-optimisation involve only a single call and its serving eNodeB, few issues of relevance exist here. In terms of architectural requirements, it is important that the UE is able to understand signalling messages in which an eNodeB tells it to adapt its BLER target (in case of uplink transmissions). Since the self-optimisation algorithm must ideally perform on such a small timescale and respond quickly to identified changes, its implementation should be well-integrated in the eNodeB architecture, rather than implemented elsewhere. In terms of scalability, it is important that the self-optimisation algorithm associated with the link level retransmission scheme is relatively simple, in order to allow its use for great numbers of calls that be handled concurrently by a given eNodeB. 	Medium
Required inputs	<ul style="list-style-type: none"> Experienced packet delays; Experienced packet losses; Experienced residual BLER. 	High

A.2.9 Coverage hole detection

Use case outline

The algorithm for coverage hole detection should timely and correctly detect coverage holes, based on the analysis of coverage related parameters like call drops or failures on random access channel. As a result of running coverage hole detection and the triggering of appropriate solutions, users in an area with little/no network access will thus be provided with services and a better QoS.

Category	List of requirements	Importance
Performance and complexity	<ol style="list-style-type: none"> Coverage holes should be detected timely and accurately. There should be a balance between gains derived from using this algorithm and its complexity. Performance gains can be expressed in terms of reduced number of call drops or number of failed connection setups. 	Medium
Stability	<p>While there is no stability problem generated by this use case, the following 2 aspects must be kept in mind:</p> <ol style="list-style-type: none"> If constructed properly, the coverage hole detection algorithm will accurately detect the coverage holes present and their location (at sub-cell level if possible). 	Low

	<ol style="list-style-type: none"> 2. There should be something of “intelligence” associated with this algorithm that will properly identify the coverage holes; for example, if a large number of call drops is observed, it will first check if this is not related to load balancing or handover parameters and only then determine there is indeed a coverage hole in the cell. 	
Robustness	<ol style="list-style-type: none"> 1. Even in the event of not having access to a sufficient amount of input information, the parameters of the coverage hole detection algorithm should have default values which will still allow satisfactory performance. 2. Possible disturbance sources should be identified and measures to deal with these should be implemented. 	Medium
Timing	<ol style="list-style-type: none"> 1. The detection of a coverage hole needs to be done as fast as possible. 2. If this use case is triggered based on a timer, it is up to the operator to set it to an initial value (e.g., 1, x days). If coverage related problems in a specific area have been identified, then the value of the timer may be modified to a lower value (e.g., hours) as to insure the timely detection of future problems. 	Medium
Interaction	<ol style="list-style-type: none"> 1. The coverage hole detection algorithm should be aligned with the other mechanisms that are triggered in case of lack of coverage (such as handover or load balancing, etc.) in such a way that they do not give mixed commands or a hierarchy is set in place between different commands from different mechanisms. 2. The relationship between this use case and the cell outage detection and compensation use cases needs to be kept in mind since all of these algorithms tend to solve the same end problem (no coverage in a certain area). 	High
Architecture and scalability	<ol style="list-style-type: none"> 1. The distributed implementation in the eNodeBs implies that it will be required that <ul style="list-style-type: none"> ○ The interfaces between the eNodeBs (X2-interface) carry self-optimisation related information and performance counters. ○ Some of the information that needs to be exchanged is standardised. ○ There is a kind of coordination mechanism between neighbouring self-optimisation algorithms to ensure stability. 2. In case of multi-vendor equipment deployment, it might be required that the definition and interpretation of some of the performance counters and part of the coordination mechanism are standardised. 	Medium
Required inputs	<ul style="list-style-type: none"> • Number of call drops per cell; • Timing advance before call drops; • Number of failures on random access channel; • Statistical information regarding the received pilot signal strength per neighbour; • Measurements from mobiles; • Number and targets of handover failures; 	High

A.2.10 Handover parameter optimisation

Use case outline

The algorithm for handover parameter optimisation should timely and appropriately adapt the handover parameters, like neighbour specific thresholds and hysteresis parameters, to changing mobility patterns and to changing load of the cell and of neighbour cells. This potentially includes the appropriate adaptation of these parameters such that UEs will be handed over to non-optimal cells (w.r.t. signal strength), to harness spare capacity in neighbouring cells.

The optimisation algorithm should also adapt the handover parameters appropriately and timely in case problems related to handover, like call drops or too many handover failures, are identified.

Category	List of requirements	Importance
Performance and complexity	<ol style="list-style-type: none"> 1. Handover related performance should be higher with the self-optimisation algorithm activated than with this algorithm not activated (performance gain). 2. An appropriate balance should exist between the performance gains established by activating the self-optimisation algorithm and the implementation complexity of this algorithm, which is a clear trade-off. <ul style="list-style-type: none"> ○ Performance gains can be expressed in terms of reduced handover failure rate, reduced call drop rate and less frequent occurrence of ping-pong handovers. ○ Measures for implementation complexity are, e.g., the signalling overhead, the required calculation effort, and the required calculation memory. 	Medium
Stability	<ol style="list-style-type: none"> 1. Any time the measurement procedures determine that the load, mobility or environment characteristics have changed significantly, the self-optimisation algorithm should be able to determine new handover parameters that correspond to the new situation. 2. The triggering of the optimisation algorithm should be such that only significant changes trigger the recalculation of the optimal handover parameters. 	High
Robustness	<ol style="list-style-type: none"> 1. In the event that there are inaccuracies in either the input data or the signalling messages associated with the self-optimisation algorithm or with the handover mechanism itself, the handover mechanism should still be parameterised such that it performs satisfactorily. 2. Possible disturbance sources should be identified and measures to deal with these should be implemented. 	Medium
Timing	<ol style="list-style-type: none"> 1. The handover parameter optimisation algorithm needs to converge (speed of adjustment) to a solution in a similar amount of time or less than the time in which load, mobility or environment conditions typically change. <ul style="list-style-type: none"> ○ In case of triggering the handover parameter optimisation algorithm for load balancing reasons, the time the algorithm needs to converge should be in the order of minutes or less, since the traffic load will typically change over a time frame in the order of minutes. ○ In case of triggering the algorithm by the identification of problems related to handover or unwanted events, caused by fast changing conditions, the algorithm needs to converge to a solution in a time of the same order of magnitude as the fast changing conditions or less. 2. The algorithm needs to be triggered (time scale of operation) 	High

	<p>at the time scale at which <i>significant</i> changes of load, mobility or environment conditions occur. Such changes typically occur in the order of minutes to hours, thus the handover parameter optimisation algorithm should also operate on the time scale of minutes to hours. In times of problems related to handover or unwanted events, caused by fast changing conditions like for example radio conditions, the handover parameter optimisation algorithm may need to be triggered more frequently.</p>	
Interaction	<ol style="list-style-type: none"> 1. The actions of the handover mechanism should be aligned (or at least should not conflict) with the actions of other mechanisms in the cell or in neighbouring cells. Hence the associated self-optimisation algorithms should set the parameters of the mechanisms such that their operations are in agreement. Potential interactions are foreseen with <ul style="list-style-type: none"> o Load balancing: it should be avoided that the handover mechanism moves users towards neighbouring cells because of handover reasons, and then the same users are moved back to the original cell by the load balancing algorithm, or vice versa. o Algorithms related to GoS/QoS optimisation: it should be avoided that when the handover mechanism moves users towards a non-optimal cell (w.r.t. signal strength) to harness spare capacity in this cell, a QoS optimisation algorithm moves these users back, or vice versa. 2. Handover parameter settings in one cell should not conflict with handover parameter settings in a neighbour cell, to avoid undesirable ping pong effects or uncontrolled ripple effects. 3. In case of multi-vendor equipment deployment in neighbouring cells, it may be required that there is a kind of coordination mechanism between neighbouring self-optimisation algorithms to ensure stability, and that part of this coordination mechanism is standardised. Multi-vendor deployments are a potential risk for instability and efficiency loss when neighbouring cells execute handover parameter optimisation algorithms that take different actions based on the same input. 	High
Architecture and scalability	<ol style="list-style-type: none"> 1. The distributed implementation of the handover parameter optimisation algorithm in the eNodeBs implies that it will be required that <ul style="list-style-type: none"> o The interfaces between the eNodeBs carry self-optimisation related information and performance counters. o Some of the information that needs to be exchanged is standardised. 2. In case of multi-vendor equipment deployment, it might be required that the definition and interpretation of some of the performance counters are standardised. 3. The handover mechanism should work independently of whether there are a small or a large number of neighbour cells. In case of a large number of cells, it is possible that one cell is asked to accept users from several neighbouring cells at the same time. The self-optimisation algorithm should set the handover parameters such that the handover algorithm is able to handle this situation. 	Medium
Required inputs	From the cell and its neighbours:	High

	<ul style="list-style-type: none"> • How many handovers are performed, and for which reason (mobility or load balancing) they are performed. • How often handovers fail, what the reasons for the failures are, and what the reason (mobility or load balancing) to perform the handovers were. • How often calls are dropped, and what the reasons for the call drops are. • The throughput before and after handover. • The received signal strength values. • The average C/I (Carrier to Interference Ratio). • When there is a ping-pong handover (requirement to be able to identify ping-pong handovers), how often ping-pong handovers occur, what the reasons for the ping-pong handovers are, and for which reason (mobility or load balancing) the handovers involved in the ping-pong were performed. 	
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A.2.11 Load balancing

Use case outline

Depending on the coverage area of the cell and the spatial distribution of the offered traffic, it can occur that some cells in the network are more heavily loaded than their neighbours (load imbalance). In these situations it can be beneficial to shift the traffic from a heavily loaded cell towards a more lightly loaded cell. This is referred to as load balancing. If the shifting of the traffic is done automatically, load balancing itself is already a self-optimisation action. Another self-optimisation aspect of the load balancing use case is the automatic adjustment of the load balancing parameters. Based on the measurement history from the network regarding the load conditions (amount of traffic and traffic mix), the load balancing parameters should be kept appropriately and timely tuned to the traffic.

Category	List of requirements	Importance
Performance and complexity	<ol style="list-style-type: none"> 1. An appropriate balance should exist between the performance gains established by the load balancing algorithm and its implementation complexity. Performance gains can be expressed in term of, e.g. blocking probability, while measures for the implementation complexity involved are, e.g., the signalling/measurement load and the required calculation effort. 	Medium
Stability	<ol style="list-style-type: none"> 1. Any time the measurement procedures determine that the traffic, mobility and environment characteristics have migrated to a significantly different statistical equilibrium, the self-optimisation algorithm should be able to determine the new load balancing parameters that correspond to that new statistical equilibrium of the traffic, mobility and environment characteristics. 2. The optimal regime should be mainly impacted by trends, i.e., input parameters (e.g., step size, number of iterations) should be such that only significant changes trigger the recalculation of the optimal parameter settings. 	High
Robustness	<ol style="list-style-type: none"> 1. In the event that there are inaccuracies in either the input data or the signalling messages, associated with the self-optimisation of the load balancing parameters or with the load balancing mechanism itself, the load balancing mechanism should still be parameterised such that it performs satisfactorily. 2. Possible disturbance sources should be identified, and 	Medium

	measures to deal with these should be implemented.	
Timing	<ol style="list-style-type: none"> 1. The load balancing algorithm should determine new parameter settings sufficiently fast when the relevant traffic, mobility and environment characteristics undergo significant changes (speed of adjustment). It typically depends on the abruptness of such changes how soon new parameter settings need to be derived. For the load balancing algorithm, changes are expected to occur no faster than, say, within an hour or so, hence parameter self-optimisation within a number of minutes should suffice. 2. The self-optimisation of the parameters corresponding to a radio resource management mechanism should be triggered at the time scale at which significant changes occur of those traffic, mobility and environment characteristics that affect the mechanism's parameters (time scale of operation). Typically, such changes occur at a time scale which is at least one order higher than that at which the mechanism itself operates. Hence for the load balancing mechanism, which operates at a time scale of seconds or minutes, the self-optimisation of its parameters should operate at a time scale of hours or days. 	High
Interaction	<ol style="list-style-type: none"> 1. The actions of the load balancing algorithm should be aligned (or at least should not conflict) with the actions of <i>other radio resource management mechanisms</i> in the cell where the load balancing is triggered and in surrounding cells. Hence the self-optimisation should always set the mechanisms' parameters such that their operations are in agreement. Potential interactions between load balancing and the following radio resource management mechanisms are foreseen: <ul style="list-style-type: none"> ○ Handover parameter optimisation algorithm: it should be avoided that <ul style="list-style-type: none"> ▪ The load balancing algorithm shifts users towards neighbour cells and then the same users are transferred back to the original cell by the handover algorithm. ▪ The load balancing mechanism is triggered when some users already moved to a different cell (due to their mobility patterns), thus decreasing the load of the current cell. ○ Algorithms related to GoS/QoS optimisation such as admission and congestion control. The misalignment with admission control is most likely less problematic as the load balancing algorithm aims to shift traffic towards lightly loaded cells. Regarding congestion control, if this algorithm is triggered at the same time as the load balancing, then there might be a loss of efficiency if the actions between these two algorithms are not coordinated. 2. Load balancing parameters settings in adjacent cells should not conflict. 3. In case of multi-vendor equipment deployment in neighbouring cells, it might be required that there is a kind of coordination mechanism between neighbouring load balancing algorithms to ensure stability. 	high
Architecture and scalability	<ol style="list-style-type: none"> 1. The distributed implementation in the eNodeBs implies that it will be required that 2. The interfaces between the eNodeBs (X2) carry self-optimisation related information and performance counters 	Medium

	<p>such as current load (of real time and non real time traffic), resource utilisation, remaining capacity, etc.</p> <ol style="list-style-type: none"> 3. Some of the information that needs to be exchanged is standardised, e.g., current (and trends of) load, resource utilisation, and remaining capacity, etc. 4. In case of multi-vendor equipment deployment, it might even be required that the definition and interpretation of some of the performance counters and part of the coordination mechanism between neighbouring load balancing algorithms are standardised. There is a potential risk for instability and efficiency loss in the cases of multi-vendor deployments when neighbour cells from different vendors execute load balancing algorithms that take different measures/actions based on the same input conditions. 5. The load balancing should also work independently of whether there are a small number of adjacent cells, or whether a large area is being covered with many cells. In the case of many cells, it is possible that one cell will receive requests to take load from several neighbours at the same time. The load balancing algorithm should be able to handle this and it should also be able to decide which new users it will accept and which ones it will not accept. 	
Required inputs	<ul style="list-style-type: none"> • The current (and trend of the) cell load • The current (and trend of the) load of neighbours • An estimation of the remaining capacity of the cell and of the neighbouring cells • Resource utilisation • In case of introducing a “ripple effect”, the maximum number of hops allowed 	High

A.2.12 Reduction of energy consumption

Use case outline

The self-optimisation algorithm for the reduction of energy consumption mechanism should carefully limit resource utilisation (eNB, Transmitter antennas, and Transmitter power) considering required QoS and coverage.

Category	List of requirements	Importance
Performance and complexity	<ol style="list-style-type: none"> 1. An appropriate balance between the energy reductions and other gains established by adding self-optimisation, and the implementation complexity is required. 	High
Stability	<ol style="list-style-type: none"> 1. The stability requirement is that the reduction of energy consumption algorithm should converge to situation where unused or low loaded eNBs are switched off and affected users are served by neighbouring cells. Smooth and transparent to user handover, without impact on QoS, has to be assured. 2. Procedure of selecting resources to be switched off has to converge in a stable way - avoiding the state when many eNBs want to switch off simultaneously that can lead to a continuous exchange of messages between affected eNBs. 3. As mechanism is strongly dependent on cell load, it should be assured that algorithm would not react on short term traffic variations. Otherwise it could go to uncontrolled, 	Medium

	repeating switching on and off process.	
Robustness	<ol style="list-style-type: none"> 1. In the event that there are inaccuracies in either the input data or the signalling messages, the reduction of energy consumption mechanism should still be parameterised such that it performs satisfactorily. For example, it is possible that the load of a cell is incorrectly determined, which could lead to an incorrect switch on/off decision. 2. Possible disturbance sources should be identified, and measures to deal with these should be implemented. 	Medium
Timing	<ol style="list-style-type: none"> 1. The self-optimisation algorithm corresponding to energy savings mechanism should operate at the time scale at which significant changes of load and traffic affect the mechanism's parameters. Typically, such changes occur at a time scale of minutes / hours. Hence for the reduction of energy consumption mechanism, similar time scale of operation is required. 2. Speed of adjustment can be on the order of hours. 	Medium
Interaction	<ol style="list-style-type: none"> 1. The actions of the reduction of energy consumption should be aligned (or at least do not conflict) with the actions of other algorithms in the cell itself or surrounding cells. Hence the associated self-optimisation algorithms should always set the mechanisms' parameters such that their operations are in agreement. 2. Potential interactions are foreseen with the following mechanisms: <ul style="list-style-type: none"> o Handover optimisation and load balancing algorithms - it should be avoided that the users shifted towards neighbour cells due to e.g. ongoing eNB shut down are transferred back to the original cell by the handover optimisation or load balancing algorithm. o The load balancing mechanism can potentially go into general state of conflict with energy savings algorithm, as load balancing would rather tend to assure balanced status whereas reduction of energy consumption can benefit from unbalanced load between cells. o Interference coordination should remain in cooperation with energy savings algorithm, as potential actions can be beneficial for both mechanisms e.g. switching off eNB, Tx antenna or lowering the Tx power lead apart from energy savings to interference reduction. 	High
Architecture and scalability	<ol style="list-style-type: none"> 1. The distributed implementation in the eNodeBs implies that it will be required that the interfaces between the eNodeBs (X2 interface) carry signalling messages of eNB load status, ongoing actions (e.g. switching off). 2. If a centralised implementation is assumed, signalling messages are required to be exchanged with central SON entity. 3. In case of multi-vendor equipment deployment, it might even be required that the definition and interpretation of some of the performance counters and part of the coordination mechanism are standardised. Potential risk for instability and efficiency loss are the cases of multi-vendor deployments when neighbour cells from different vendors execute reduction of energy consumption algorithms that take different measures/actions based on the same input conditions. 4. The reduction of energy consumption algorithm should also work independently of whether there are a small number of 	Medium

	adjacent cells or whether a large area is being covered with many cells.	
Required inputs	<ul style="list-style-type: none"> • Load measurement from given and neighbouring cells • User QoS (throughput, delay, packet loss) • Traffic statistics from the past • Coverage data – from planning tool or specified measurement 	High

A.2.13 Tracking areas

Use case outline

The self-optimisation/self-configuration algorithm for the Tracking Area Parameter (TAP) optimisation/configuration (cf. [23]) should keep the TAPs appropriately and tuned to keep the average signalling traffic consisting of traffic area updates (TAU) and paging balanced and, by all means, below a certain threshold. This threshold is defined by capacity margins existing for all network elements plus a tolerance space (soft margin (Figure 3)).

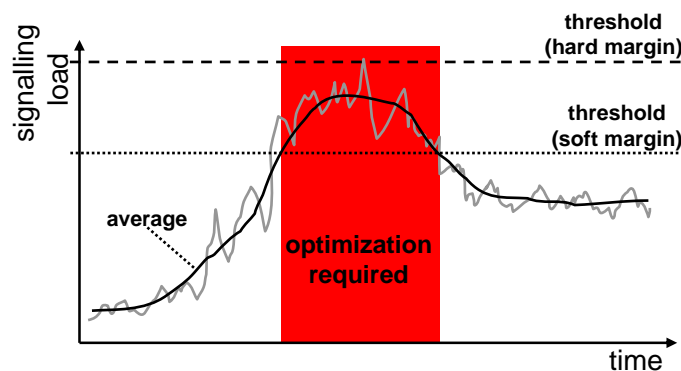


Figure 3: Time of required optimisation

Category	List of requirements	Importance
Performance and complexity	<ol style="list-style-type: none"> 1. An appropriate balance between the performance gains established by adding a self-optimisation layer and the implementation complexity is required. Performance gains can be expressed in terms of reduced TAU and paging signalling. Measures for implementation complexity are e.g. the required signalling overhead to adapt the TAPs in the UEs, the calculation effort and the number of iterations. 	High
Stability	<ol style="list-style-type: none"> 1. The iterations to derive the optimised parameter values should converge to a solution. 2. Any time the measurement procedures determine that the traffic, mobility and environment characteristics have migrated to a significantly different statistical equilibrium (to be expected in terms of weeks and months for the whole network or isolated in a certain areas), the self-optimisation algorithm should be able to determine those new TAPs that correspond to that new statistical equilibrium of the traffic, mobility and environment characteristics to find an appropriate new balance of paging and TAU. However, the triggering should be such that mainly significant changes, which violate given thresholds, trigger recalculation of the optimal parameter settings. 	Low
Robustness	<ol style="list-style-type: none"> 1. In the event that there are inaccuracies in either the input data or the signalling messages, associated with the self-optimisation algorithm or with the TAP assignment 	High

	<p>mechanism itself, the TAP assignment mechanism should still be parameterised such that it performs satisfactorily. For TAP assignment, it is possible that the signalling load of a set of cells is incorrectly determined, which could lead to an incorrect TAP assignment. Possible disturbance sources should be identified, and measures to deal with these should be implemented.</p>	
Timing	<ol style="list-style-type: none"> 1. Generally speaking, the self-optimisation algorithm corresponding to a radio resource management mechanism should operate at the time scale at which significant changes occur of those traffic, mobility and environment characteristics that affect the mechanism's parameters. Typically, such changes occur at a time scale which is at least one order higher than that at which the mechanism itself operates or the changes can be detected (measured). Hence for the TAP assignment mechanism, for which measurements could only be taken and processed hourly or daily, the self-optimisation should operate or triggered at a time scale of days, only. 2. The self-optimisation algorithm should determine new parameter settings sufficiently fast when the relevant traffic, mobility and environment characteristics undergo significant changes. It typically depends on the abruptness of such changes how soon new parameter settings need to be derived. For the TAP algorithm, changes are expected to be detected no faster than, say, within an hour or so, hence parameter self-optimisation within a number of minutes should suffice. Furthermore, it depends on the assignment mechanism, because all TAP values have to be signalled and changed in the UEs. 	Medium
Interaction	<ol style="list-style-type: none"> 1. The most important issue is that the actions of the TAP algorithm are aligned (or at least do not conflict) with the actions of other radio resource management mechanisms in the cells for which the TAP assignment is triggered and their surrounding cells. Hence the associated self-optimisation algorithms should always set the mechanisms' parameters such that their operations are in agreement. 2. TAP optimisation has an impact on RACH optimisation, because a UE requests resources for a TAU message via a RACH. However, TAP optimisation aims at a minimisation of TAUs (and paging), so that this means also a gain for RACH optimisation. 3. Other mechanisms like the adjustments of neighbourhood lists and handover parameters lead to a change of input variables for TAP optimisation. Therefore, TAP optimisation should be informed about these changes for interpretation of given performance counter measurements. 	Medium
Architecture and scalability	<ol style="list-style-type: none"> 1. TAP optimisation will be implemented centralised. In case of multi-vendor equipment deployment, it is required that the definition and interpretation of all performance counters and part of the coordination mechanism are standardized. Potential risks for instability and efficiency loss are the cases of multi-vendor deployments when neighbour cells from different vendors execute HO, but result in incommensurable values. 2. The algorithm is expected to become more complex when the number of involved cells increases due to the increasing amount of signalling traffic and number of relations between the cells. Any algorithm to be developed should be able to 	Medium

	handle the large amount of calculations to be expected.	
Required inputs	<ul style="list-style-type: none"> • Statistics about UE mobility patterns according to the requirements given in [1] (sufficiently large number of UEs, history report of mobility events with the granularity of cells uncorrelated of the result of prior optimisation and configuration of E-UTRANs), • Number of TAU per cell, • Number of triggered HO, measured per cell relation, • Number of paging request per paging area, • Number of paging responds of the UEs per cell (called Mobile Terminated Calls – MTC – in GERAN), • Number of signalling attempts that use the same channel as TAU and/or paging, • Parameters obtained in optimisation of handover parameters and neighbourhood lists. 	High

A.2.14 TDD UL/DL switching point

Use case outline

The self-optimisation algorithm for the TDD UL/DL switching point mechanism should keep TDD UL/DL split relevant parameters appropriately and timely tuned to the traffic and interference level.

Category	List of requirements	Importance
Performance and complexity	<ol style="list-style-type: none"> 1. An appropriate balance between the performance gains established by adding self-optimisation and the implementation complexity is required. 	High
Stability	<ol style="list-style-type: none"> 1. The iterations to derive the optimized parameter values should converge to a solution. 2. Any time the measurement procedures determine that the traffic, mobility and environment characteristics have migrated to a significantly different statistical equilibrium, the self-optimisation algorithm should be able to determine those new TDD UL/DL parameters that correspond to that new statistical equilibrium of the traffic, mobility and environment characteristics. 3. The optimal regime should be mainly impacted by trends, i.e. input parameters (e.g. step size, number of iterations) should be such that only significant changes trigger recalculation of the optimal parameter settings. 	Medium
Robustness	<ol style="list-style-type: none"> 1. In the event that there are inaccuracies in either the input data or the signalling messages, associated with the self-optimisation algorithm or with the TDD UL/DL mechanism itself, the TDD UL/DL mechanism should still be parameterised such that it performs satisfactorily. For TDD switching point, it is possible that the UL/DL load of a cell is incorrectly determined which could lead to an incorrect switching point setting decision. 2. Possible disturbance sources should be identified, and measures to deal with these should be implemented. 	Medium
Timing	<ol style="list-style-type: none"> 1. The TDD UL/DL should operate on a timescale to match changes of local area propagation environment (scale of seconds) and traffic variations (scale of seconds or minutes) 2. Speed of adjustment of controlled parameters can be on the order of hours. 	High

Interaction	<ol style="list-style-type: none"> 1. The actions of TDD UL/DL switching point optimization algorithm should be aligned or at least do not conflict with the actions of other radio resource management mechanism in given cell itself or neighbour cells. Hence the associated self-optimisation algorithms should always set the mechanisms' parameters such that their operations are in agreement. 2. Potential interactions are foreseen with the following mechanisms: <ul style="list-style-type: none"> o Load balancing can perform its actions simultaneously with switching point updates in competitive way (e.g. user can be transferred to other cell due to high load in given cell by load balancing mechanism when TDD UL/DL will tend to change switching point setting). o QoS/GoS related algorithms such as e.g. admission and congestion control can limit efficiency of UL/DL switching point mechanism without proper coordination. 	High
Architecture and scalability	<ol style="list-style-type: none"> 1. The distributed implementation in the eNodeBs implies that it will be required that the interfaces between the eNodeBs (X2) carry signalling messages of eNB load status, interference levels or UL/DL switching point settings 2. If a centralised implementation is assumed, signalling messages and measurements are required to be exchanged with central SON entity. 3. In case of multi-vendor equipment deployment, it might even be required that the definition and interpretation of some of the performance counters and part of the coordination mechanism are standardised. Potential risk for instability and efficiency loss are the cases of multi-vendor deployments when neighbour cells from different vendors execute UL/DL switching point updates that take different measures/actions based on the same input conditions. 4. TDD UL/DL switching point algorithm should also work independent of whether there are a small number of adjacent cells, or whether a larger area is being covered with many cells. 	Medium
Required inputs	<ul style="list-style-type: none"> • User QoS (throughput, delay, packet loss) • User location (how close to cell edge) • Interference level for each resource block • Load/Interference indicator from other cells • Switching point configuration of neighbours cells 	High

A.2.15 Management of relays and repeaters

Use case outline

The goal of relays and repeaters in a telecommunication network is to increase coverage and/or capacity of a cell in a cost-efficient way. Self-organisation algorithms for relays or repeaters aim at enhancing the coverage and/or capacity obtained when using relays or repeaters, automating configuration, and identifying situations where there is a gain in using relays or repeater.

Category	List of requirements	Importance
Performance and complexity	<ol style="list-style-type: none"> 1. An appropriate balance should exist between the performance gains established by adding a self-optimisation layer and the implementation complexity, which is a clear 	High

	<p>trade-off.</p> <ol style="list-style-type: none"> 2. The coverage and/or capacity obtained when using self-optimization algorithms should be the same or greater than the coverage and/or capacity obtained without self-optimisation. 3. The interference caused by the relay or repeater should be minimized. 4. The relay or repeater should configure itself with minimal operator intervention. 5. Self-organisation algorithms should in as many cases as possible correctly determine whether there will be a gain in using relays or repeaters. 6. The number of messages that need to be exchanged between the nodes involved (e.g., the relay and the eNodeB) should be minimal. 7. Self-optimisation algorithms should require minimal storage and processing. 	
Stability	<ol style="list-style-type: none"> 1. Any time the measurement procedures determine a drop in coverage and/or capacity, the self-optimisation algorithms should be able to determine new control parameters that mitigate the decrease in coverage and/or capacity. 2. Actions taken to enhance coverage and/or capacity may execute over several iterations, where each iteration results in a new set of radio parameters and altered capacity and/or coverage. The output of each iteration should converge to the final, ideally optimized, solution. For example, in each iteration the repeater or relay power may be changed. The number of iterations should be finite and the power should converge to a final value, which results in optimised coverage and/or capacity. 	High
Robustness	<ol style="list-style-type: none"> 1. In the event that there are inaccuracies in either the input data or the signalling messages associated with the self-optimisation algorithm the self-optimisation should still perform satisfactorily. Inaccuracies may be present in estimates of, e.g., uplink and downlink interference and UE measurements, resulting in the relay to generate unnecessarily high interference, thus, decreasing the capacity of the cell or cells in its vicinity. 2. Possible disturbance sources should be identified, and measures to deal with these should be implemented. 	Medium
Timing	<ol style="list-style-type: none"> 1. Depending on how fast traffic conditions change in a given cell (minutes, hours), the self-optimisation algorithm associated with the relay or repeater self-optimisation mechanism needs to converge to a solution in a similar amount of time or less. More specifically: 2. <i>Time scale of operation</i> – For the capacity and/or coverage optimisation mechanism, which operates at a time scale of seconds or minutes, the self-optimisation should operate at a time scale of minutes or hours. 3. <i>Speed of adjustment</i> – For the coverage and/or capacity optimisation algorithm, changes are expected to occur no faster than, say, within an hour or so, hence parameter self-optimisation within a number of minutes should suffice. 	High
Interaction	<ol style="list-style-type: none"> 1. The measures taken by the relay and repeater management mechanisms should not conflict with measures taken by other SON mechanisms and radio resource management functions. 	High

	<ol style="list-style-type: none"> 2. The power control and beam forming mechanisms of the self-optimisation algorithm must communicate with the interference coordination mechanism so that the interference caused by relays or repeaters is not too high and so that the measures taken by the interference coordination, such as power decreases, are not only implemented in the serving eNodeB but also in the relay/repeater. 	
Architecture and scalability	<ol style="list-style-type: none"> 1. Relays and repeaters are not necessarily known by other entities than the eNB they are connected to, and the management of them should therefore be handled locally in the eNB. In case there are different vendors for the eNB and the relays an interface between these might need to be standardized. 2. The relay/repeater management mechanism should be scalable in the sense that it will work in cells with numerous relays/repeaters. Since the mechanism is local, it is however not effected by the network size or number of nodes in the network, other than through the interaction with the interference coordination mechanism. 	High
Required inputs	<ul style="list-style-type: none"> • Relay signal strength measurements in the eNodeB • Measurements of the total signal strength deriving from a UE (with or without relaying) performed by the serving eNodeB • Measurements of the signal strength from a UE performed by the relay • Measurements of the received signal strength in the UE (RSRP) • DL interference measurements performed by the UE • UL interference measurements performed by the relay • UL interference measurements performed by the serving eNodeB • UL interference measurements performed by surrounding eNodeBs • Information from the interference coordination mechanism, for example maximum allowed power 	High

A.2.16 MIMO

Use case outline

The self-optimisation algorithm for the MIMO schemes control should optimally manage MIMO techniques to obtain minimized interference levels, optimal antennas utilization and high spectrum efficiency, taking into account signalling and measurement limitations.

Note: the detailed description of this use case is not available in [23]. This description will be available in SOCRATES deliverable 2.5, which is to be released in December 2008.

Category	List of requirements	Importance
Performance and complexity	<ol style="list-style-type: none"> 1. An appropriate balance between the performance gains established by adding self-optimisation and the implementation complexity is required. 2. Optimal balance between overall cell performance and fairness for individual users should be kept. Methods that result in a large gain in cell performance should only be considered if they fairly distribute the gain over all users. Similar considerations apply for fairness between cells – a 	High

	high gain in one cell should not result in decreased performance in neighbouring cells.	
Stability	<ol style="list-style-type: none"> 1. Any time the measurement procedures determine that the traffic, mobility and environment characteristics have migrated to a significantly different statistical equilibrium, the self-optimisation algorithm should be able to determine those new MIMO schemes control parameters that correspond to that new statistical equilibrium of the traffic, mobility and environment characteristics. 2. The optimal regime should be mainly impacted by trends, i.e. input parameters (e.g. step size, number of iterations, etc.) should be such that only significant changes trigger recalculation of the optimal parameter settings. 3. The stability requirement is that MIMO schemes control solution should intelligently handle signalling messages such that stable configurations are achieved. 	Medium
Robustness	<ol style="list-style-type: none"> 1. In the event that there are inaccuracies in either the input data or the signalling messages, associated with the self-optimisation algorithm or with the MIMO schemes control mechanism itself, the control mechanism should still be parameterised such that it performs satisfactorily. For advanced MIMO schemes, especially beam forming, it is possible that the channel state measurement is incorrectly determined which could lead to an incorrect scheduling and link adaptation setting decision. 2. Possible disturbance sources should be identified, and measures to deal with these should be implemented. 	Medium
Timing	<ol style="list-style-type: none"> 1. The MIMO schemes control should operate on a timescale to match changes of propagation environment (scale of ms) and traffic variations (scale of seconds or minutes) 2. Speed of adjustment of controlled parameters can be on the order of hours. 	High
Interaction	<ol style="list-style-type: none"> 1. Actions of the MIMO schemes control should be aligned (or at least do not conflict) with the actions of other algorithms in the cell itself or surrounding cells. Hence the associated self-optimisation algorithms should always set the mechanisms' parameters such that their operations are in agreement. 2. Potential interactions are foreseen with the following mechanisms: <ul style="list-style-type: none"> ○ Interference coordination – MIMO schemes control should strongly cooperate with interference coordination mechanism, as in fact it is also additional layer of interference coordination. ○ Algorithms related to GoS/QoS optimisation such as admission and congestion control. MIMO schemes control is also dealing with a situation where the network is highly loaded, and aims to effectively manage that load by enhancing layers of data transmission. Admission and congestion control have different functionality, but are also mechanisms to deal with a high load. ○ Self-optimisation of physical channels: Interference (also caused by MIMO) from other cells and additional layers of data channels will also play a role in the self-optimisation of physical channels. ○ Optimal management of MIMO schemes can cause energy savings. 	High

Architecture and scalability	<ol style="list-style-type: none"> 1. The distributed implementation in the eNodeBs implies that it will be required that the interfaces between the eNodeBs (X2 interface) carry signalling messages (Overload Indicator (OI), High Interference Indicator (HII)) and also beam coordination information. 2. If a centralised implementation is assumed, signalling messages and measurements are required to be exchanged with central SON entity. 3. In case of multi-vendor equipment deployment, it might even be required that the definition and interpretation of some of the performance counters and part of the coordination mechanism are standardised. Potential risk for instability and efficiency loss are the cases of multi-vendor deployments when neighbour cells from different vendors supports different MIMO schemes and execute coordination algorithms that take different measures/actions based on the same input conditions. Algorithm should also work in cases where some cells may not support MIMO at all. 4. The MIMO schemes control should work independent of whether there are a small number of adjacent cells, or whether a large area is being covered with many cells. 	Medium
Required inputs	<ul style="list-style-type: none"> • User QoS (throughput, delay, packet loss) • User location (how close to cell edge based on path loss measurement) • MIMO scheme indicator and/or beam indicator per resource block • Interference level for each resource block • Load/Interference indicator from other cells • Statistics of HII, OI, and DL power setting information 	High

A.3 Requirements per Use Case – Self-healing

Cell outage management outline

Self-healing comprises cell outage management, which is an umbrella use case that covers the whole process of cell outage mitigation from the prediction and detection phase to the cell outage compensation where appropriate actions are taken to counteract a cell outage. We define that a cell is in outage when the UEs, in the coverage area of the cell, cannot establish and/or maintain *all or only a limited set of* the Radio Bearers (RBs) via that particular cell due to hardware and/or software failures at the eNodeB. The cell outage prediction function gives an early warning and assists to speed up the actual cell outage detection and also to start preparation actions in the cell outage compensation function in the system. The cell outage detection confirms that at the current time an outage has occurred and triggers the cell outage compensation function to take appropriate actions.

A.3.1 Cell outage prediction

Use case outline

The cell outage prediction algorithm weighs the inputs (traffic levels, eNodeB measurements, known/scheduled outage events) in some way (i.e. via a mapping function) in order to derive the cell outage likelihood. These weights could be self-optimised based on automatic correlation analysis between the inputs, the predicted outage likelihood and actually detected outage events.

Remark: Changes of the cell outage prediction characteristics (which should trigger the self-optimisation) will usually take place at a relatively large time scale and may be quite well ‘predictable’ (e.g. introduction of new type of eNodeB or (re)placement of (new) elements in eNodeB). So, it may be likely that most updates of the parameters (e.g. weights of the mapping function) are triggered and performed ‘manually’.

Category	List of requirements	Importance
Performance and complexity	<ol style="list-style-type: none"> Appropriate balance should exist between the performance gains established by adding a self-optimisation layer and the implementation complexity, which is a clear trade-off. What is deemed appropriate is for further study. Performance gains can be expressed in terms of the timeliness and ‘accuracy’ of the predictions (location, scope and likelihood of forthcoming cell outages), i.e. not too many “wrong” predictions. 	Medium
Stability	<ol style="list-style-type: none"> Any time the cell outage prediction characteristics have significantly changed, the self-optimisation algorithm should be able to determine those new cell outage prediction parameters (e.g. new values of the weights of the mapping function mentioned above) that correspond to that new situation. Utilization, handover rate, etc. trigger recalculation of the optimal admission thresholds. 	High
Robustness	<ol style="list-style-type: none"> In the event that there are inaccuracies in the input data of the self-optimisation algorithm the cell outage prediction should still be parameterised such that it performs satisfactorily. Possible disturbance sources should be identified, and measures to deal with these should be implemented. 	High
Timing	<ol style="list-style-type: none"> The self-optimisation algorithm associated with the cell outage prediction needs to converge to a solution in a similar amount of time or less than the time in which significantly changes in the cell outage prediction characteristics take place. Note that changes of the cell outage prediction characteristics (which should trigger the self-optimisation) will usually take place at a large time scale and may be quite well ‘predictable’ (e.g., introduction of new type of eNodeB or (re)placement of (new) elements in eNodeB). So, it may be likely that most updates of the parameters (e.g., weights of the mapping function) are triggered and performed ‘manually’. 	Low
Interaction	<ol style="list-style-type: none"> The interaction with other mechanisms and with the cell outage prediction in other cells is very limited. The main requirements are that the output of the cell outage prediction is passed to the cell outage detection, and that the output of the cell outage detection is fed back to the cell outage prediction (this information may be used as input for the self-optimisation of the cell outage prediction). 	Low
Architecture and scalability	<ol style="list-style-type: none"> The cell outage prediction (and its optimisation) will be mainly based on local information, which motivates distributed implementation. Some measurements (e.g., cell traffic and resource utilisation) and the interfaces for information transfer should be standardized. The cell outage prediction algorithm should work properly if new software/hardware modules/versions are installed in the eNodeB or other network nodes higher up in the network architecture that control/interact the eNodeB. 	Medium
Required inputs	<p>The cell outage prediction should be primarily ‘informed’ about relevant changes in the eNodeB hard- and software that are planned in future (i.e. scheduled/known events). Next to this “a priori” known input the following information can be used for the cell outage prediction:</p> <ul style="list-style-type: none"> ○ Hardware status reports (e.g. CPU load, temperature, malfunctioning alarms, etc); 	High

	<ul style="list-style-type: none"> ○ Software status reports (e.g. stalled processes, conflicts, etc) ○ Cell performance indicators; ○ History of outage predictions with corresponding likelihood; ○ Log of previously detected outage events. <p>The ‘historical’ data is required on used inputs for the cell outage prediction, the predicted outage likelihood (based on these inputs) and the actually detected events because correlations analysis of the used inputs and past cell outage predictions can be used to self-optimize the parameters of the cell outage prediction.</p>	
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A.3.2 Cell outage detection

Use case outline

The goal of cell outage detection is to find the cells in outage, to determine the scope of the outage and to identify the outage type.

Category	List of requirements	Importance
Performance and complexity	<ol style="list-style-type: none"> 1. An appropriate balance between the performance gains established by adding a self-optimisation layer and the implementation complexity is required. 2. Since the cell outage detection triggers the cell outage compensation, which causes major changes in the whole network configuration, the probability of successful cell outage detection should be as close to 100% as possible. There are two measures which will have to be considered here: if an outage occurs in the network it should be detected (high detection rate) and if an outage is detected by the algorithm this information should be correct (low false alarm rate). 	High
Stability	<ol style="list-style-type: none"> 1. The iterations to decide if a cell outage occurred should converge to a solution. 2. Any time the measurement procedures determine that the interferences and performance indicators have migrated to a significantly different statistical equilibrium or the number of error reports increases significantly, the self-healing algorithm should be able to determine if a cell outage occurred or not. The optimal regime should be mainly impacted by trends, i.e., input parameters (e.g., HO failures, performance indicators) should be such that only significant changes trigger the cell outage detection. 	Low
Robustness	<ol style="list-style-type: none"> 1. In the event that there are inaccuracies in either the input data or the signalling messages, associated with the self-healing algorithm, the cell outage detection should still perform satisfactorily. Inaccuracies may be present in estimates of, e.g., load, uplink and downlink interference, and UE measurements. This may have an effect of the performance of the cell outage detection. Outage detection due to data inaccuracies has to be avoided. Possible disturbance sources should be identified, and measures to deal with these should be implemented. 	High
Timing	<ol style="list-style-type: none"> 1. The self-healing algorithm is considered to be ‘always on’ to be able to detect the cells in outage timely, i.e. it can be triggered by failure reports or measurements and could be activated periodically as well. Hence the time scale of 	Medium

	<p>operation depends on the actual network situation.</p> <ol style="list-style-type: none"> The self-healing algorithm should detect cells in outage sufficiently fast after an outage occurred when the relevant interference and performance characteristics undergo significant changes or the number of error reports increases significantly. The algorithm should be able to detect a cell outage within minutes. 	
Interaction	<ol style="list-style-type: none"> Since the cell outage detection algorithm does not change any parameter settings the interaction requirements are limited. The algorithm only interacts with the cell outage compensation, which is triggered if an outage occurred, and with the cell outage prediction to enhance the performance of that algorithm. 	Low
Architecture and scalability	<ol style="list-style-type: none"> The cell outage detection algorithm will be distributed in the network. In case of multi-vendor equipment deployment, it is required that the definition and interpretation of all performance counters and part of the coordination mechanism are standardized. Since the algorithm is distributed in the network there will be a significant collaboration with mechanisms in other eNodeBs. Furthermore it is necessary to exchange information, e.g. failure reports, UE measurements, between the eNodeBs to detect the cell(s) in outage. The cell outage detection algorithm should also work independently from the amount of signalling between the eNodeBs and number of cells in outage. 	Medium
Required inputs	<ul style="list-style-type: none"> • UE neighbour measurement reports • Downlink interference reported by UE • Hardware and Software error reports • HO failure rate • Cell performance indicators • Radio link failure rate/call drops in the cell • Uplink interference reported by eNodeBs • Timing advance before call drops • Timing advance at certain signal strength threshold • Relative load indicator 	High

A.3.3 Cell outage compensation

Use case outline

The goal of cell outage compensation is to mitigate the negative effects of a cell outage, e.g., loss in coverage and number of served UEs.

Category	List of requirements	Importance
Performance and complexity	<ol style="list-style-type: none"> Given that a cell is in outage, the coverage obtained when using cell outage compensation should be greater than the coverage obtained without cell outage compensation. Number of served UEs should be greater when using cell outage compensation compared to the case when compensation is not used. The actions taken by cell outage compensation may have negative effects on bit rates of cells that are not in outage. The actions produced by cell outage compensation should not overly influence the rest of the network negatively. 	High

	<ol style="list-style-type: none"> 4. The number of eNodeBs, involved in cell outage compensation, should be kept to a minimum. 5. The number of messages that need to be exchanged between the nodes involved should be minimal. 6. Cell outage compensation algorithms should require minimal storage and processing. 	
Stability	<ol style="list-style-type: none"> 1. A coordinated campaign to mitigate the effects of cell outage may execute over several iterations, where each iteration updates the values of related radio parameters. The output of each iteration should converge to a final, ideally optimised, solution. For example, in each iteration the antenna tilt may be changed for one or several cells around the cell in outage. The number of iterations should be finite and, e.g., the antenna tilt, should converge to the final value. 2. Cell outage compensation should not propagate to a large area but should be limited in the area around the cell(s) that are in outage, e.g., one or two levels of neighbours. 	Medium
Robustness	<ol style="list-style-type: none"> 1. Inaccuracies in, e.g., load, uplink and downlink interference, and UE measurements may have a negative effect on the performance of the compensation mechanism. Possible disturbance sources should be identified, and measures to deal with these should be implemented. 	Medium
Timing	<ol style="list-style-type: none"> 1. The compensation algorithm should determine new parameter settings sufficiently fast when the relevant information from cell outage detection becomes available. Parameter changes should occur in the order of minutes from the time compensation is triggered. 2. The number of iterations required to reach a converged state should be minimized, i.e., the time it takes to converge should be minimized. 	High
Interaction	<ol style="list-style-type: none"> 1. Actions of the compensation algorithm must be aligned (or at least do not conflict) with the actions of other radio resource management mechanisms in the cell where the cell outage compensation is triggered. 2. Interactions with the following mechanism should be considered: <ul style="list-style-type: none"> ○ Algorithms related to optimisation of physical channels, since one way to compensate for outage is to increase the transmit power of surrounding cells and this needs to be coordinated with the function optimising the physical channels. ○ Algorithms related to neighbour cell list automation, since a cell may obtain new neighbours when compensating for another cell in outage, e.g., by increasing its coverage. ○ Interference control since changes to radio parameters, e.g., antenna tilt or transmit power, may increase the interference and, thus, trigger interference control. ○ Algorithms related to GoS/QoS optimisation such as e.g. admission and congestion control. During an outage it may be necessary to admit more UEs at the cost of degrading the QoS level of admitted UEs. Admission and congestion control may be configured to allow such a temporary change in their operation. 	Medium
Architecture and scalability	<ol style="list-style-type: none"> 1. A cell outage compensation approach should scale with the network and be able to handle multiple outages occurring at the same time. The distributed implementation in the eNodeBs implies that it may be required to use the interface 	Medium

	<p>between the eNodeBs (X2) carrying self-healing related information. The usage of this interface should adhere to related specifications.</p> <ol style="list-style-type: none"> 2. The self-healing algorithm should avoid creating a “ripple” through the network, i.e., when multiple levels of neighbours are affected by a cell outage. The compensation should be confined to one or two levels of neighbours of the cell in outage. 3. An eNodeB may need to compensate outage for several neighbours. In this case changes to the radio parameters of the eNodeBs (e.g., tilt, power) might need to be coordinated among the eNodeBs in the vicinity of the cell(s) in outage in order to handle issues such as capacity (in order to avoid one cell being overloaded when it aims at compensating for outages of several cells). 	
<p>Required inputs</p>	<ul style="list-style-type: none"> • List of cells in outage • List of cells that can be reconfigured (consisting of the group of cells that are affected by the outage or can contribute to compensate / reduce the impact of the outage) • Scope of the outage i.e. the whole cell or only a limited set of RBs are not supported, the geographic area with low performing RBs (if possible) • Type of the outage i.e. hardware or software malfunctioning, radio or transport part, etc. • UE measurement reports, e.g., RSRP measurements of neighbours and downlink interference, • Cell performance indicators, e.g., capacity, • Load information • Uplink interference reported by neighbour • HO statistics, e.g., HO success ratio 	<p>High</p>

Appendix B Use Case Profiles for Simulation Requirements

This chapter contains the detailed simulation requirements per use case. The merged requirements are provided in Table 5. The sequence of the use case profile tables is equivalent to the sequence of the use cases in Chapter 2.

For some of the content of the tables, it was found that further detailed analysis would be required to provide this content. In those cases, where appropriate, these details will be addressed in SOCRATES work packages 3 and 4.

B.1 Self-configuration use case profiles

Use Case	Intelligently selecting site locations					Classification	self-configuration
I Scope	Location of Algorithm			No. of Controlled / Considered Cells		Impact w.r.t. other cells	
	local	centralised	distributed				
		X		± 10		major (reconfiguration)	
	Relevant BTS Types			Macro	Micro	Indoor/Femto	
		X		X	X		
II Information Exchange	Between network elements					Frequency	Status w.r.t. standardisation
	none					n.a.	
	Between (instances) of SON functions					Frequency	Status w.r.t. standardisation
	Yes					Event triggered	not stand.
	Across SON API (cf. Section 4.1.1)					Frequency	Status w.r.t. standardisation
	Yes – with other use cases (see VII)					Event triggered	not stand.
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurements	Status w.r.t. standardisation
	1	none					
IV Control Parameters	#	Name	Layer	Range	Updates		Status w.r.t. standardisation
					scale	freq.	
	1	To be discussed					
	2						
V Mobility And Traffic	How does mobility impact the algorithm?					0 (low) ... 9 (high)	0
	How much do traffic characteristics impact the algorithm?					0 (low) ... 9 (high)	0
VI Algorithm Assessment	List of evaluated measurements						
	#	Name	Layer	Period of evaluation			
		none					
	List of Objectives						
	#	Name	Aggregation			Relation w.r.t. other objectives (e.g. dominance)	

	1			
	2			
	List of network topologies to be evaluated			
	#	Description		Environment
	1	Simple scenarios with several NEs		rural, urban, indoor, suburban
	2	Extensive testing in real world scenarios		rural, urban, indoor, suburban
VII Relation to other Control Mechanisms	Use cases that have an impact on this use case			
	Coverage hole detection, Cell outage detection			
	Use cases that this use case has an impact on			
	Hardware / capacity extension, management of relays and repeaters, reduction of energy consumption, RACH optimization, self-optimization of physical channels, self optimization of home eNodeB, management of relays and repeaters			
VIII Dependency on System Implementation Specifics	Dependency on		Rating 0 (low) ... 9 (high)	Description
	LTE standardisation uncertainty		2	Only basic parameters / measurements
	Vendor specific implementations		0	Interfaces need to be provided

Use Case	Automatic generation of default parameters				Classification	self-configuration	
I Scope	Location of Algorithm			No. of Controlled / Considered Cells	Impact w.r.t. other cells		
	local	centralised	distributed		none		
	Relevant BTS Types			Macro	Micro	Indoor/Femto	
				X	X	X	
II Information Exchange	Between network elements				Frequency	Status w.r.t. standardisation	
	none				n.a.		
	Between (instances) of SON functions				Frequency	Status w.r.t. standardisation	
	none				n.a.		
	Across SON API (cf. Section 4.1.1)				Frequency	Status w.r.t. standardisation	
	Yes – at least with database				Event triggered	not stand.	
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurements	Status w.r.t. standardisation
	1	none					
IV Control Parameters	#	Name	Layer	Range	Updates		Status w.r.t. standardisation
					scale	freq.	
	1	at least all self-optimisation related parameters	--				??

	2					
V Mobility And Traffic	How does mobility impact the algorithm? 0 (low) ... 9 (high)					0
	How much do traffic characteristics impact the algorithm? 0 (low) ... 9 (high)					0
VI Algorithm Assessment	List of evaluated measurements					
	#	Name	Layer	Period of evaluation		
		none				
	List of Objectives					
	#	Name	Aggregation	Relation w.r.t. other objectives (e.g. dominance)		
	1	Accuracy of generated default values compared with final optimised values	Observation window			
	2					
	List of network topologies to be evaluated					
	#	Description			Environment	
	1	Simple scenarios with several NEs			rural, urban, indoor, suburban	
2	Extensive testing in real world scenarios			rural, urban, indoor, suburban		
VII Relation to other Control Mechanisms	Use cases that have an impact on this use case					
	Use cases that this use case has an impact on					
VIII Dependency on System Implementation Specifics	Dependency on		Rating 0 (low) ... 9 (high)	Description		
	LTE standardisation uncertainty		0	Interfaces need to be provided		
	Vendor specific implementations		7	Interfaces need to be provided For multi-vendor implementations affected settings to be harmonised		

Use Case	Network authentication			Classification	self-configuration
I Scope	Location of Algorithm			No. of Controlled / Considered Cells	Impact w.r.t. other cells
	local	centralised	distributed		
	X	X		1 NE	none
	Relevant BTS Types			Macro	Micro
			X	X	X
II Information Exchange	Between network elements			Frequency	Status w.r.t. standardisation
	Yes – for X2 interface setup			Event triggered	??

	Between (instances) of SON functions					Frequency	Status w.r.t. standardisation
	none					n.a.	
	Across SON API (cf. Section 4.1.1)					Frequency	Status w.r.t. standardisation
	Yes – for OAM IF setup, S1 IF setup					Event triggered	??
...							
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurements	Status w.r.t. standardisation
	1	none					
IV Control Parameters	#	Name	Layer	Range	Updates		Status w.r.t. standardisation
					scale	freq.	
1	none						
V Mobility And Traffic	How does mobility impact the algorithm?					0 (low) ... 9 (high)	0
	How much do traffic characteristics impact the algorithm?					0 (low) ... 9 (high)	0
VI Algorithm Assessment	List of evaluated measurements						
	#	Name	Layer	Period of evaluation			
		none					
	List of Objectives						
	#	Name	Aggregation		Relation w.r.t. other objectives (e.g. dominance)		
	1	No. of rejected interface / connection setups	Observation window / alarm list				
	2						
	List of network topologies to be evaluated						
	#	Description				Environment	
	1	Simple scenarios with several NEs				rural, urban, indoor, suburban	
2	Testing with large number of NEs and high network reconfiguration rate				rural, urban, indoor, suburban		
VII Relation to other Control Mechanisms	Use cases that have an impact on this use case						
	Neighbour cell list						
	Use cases that this use case has an impact on						
	Neighbour cell list						
VIII Dependency on System Implementation Specifics	Dependency on		Rating		Description		
			0 (low) ... 9 (high)				
	LTE standardisation uncertainty		7		Type of authentication (PKI etc.)		
Vendor specific implementations		7		Type of authentication (PKI etc.)			

B.2 Self-optimisation use case profiles

Use Case	Interference coordination				Classification	self-optimisation	
I Scope	Location of Algorithm			No. of Controlled / Considered Cells	Impact w.r.t. other cells		
	local	centralised	distributed		2-10	High: load, handovers, interference level	
	Relevant BTS Types			Macro			Micro
				X	X	X	
II Information Exchange	Between network elements				Frequency	Status w.r.t. standardisation	
	Overload Indicator (OI)				tens of ms	In advanced standardization process	
	High Interference Indicator (HII)				tens of ms	“	
	Between (instances) of SON functions				Frequency	Status w.r.t. standardisation	
	Across SON API (cf. Section 4.1.1)				Frequency	Status w.r.t. standardisation	
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurements	Status w.r.t. standardisation
	1	Received Signal Received Power	1	UE	1	ms	Standardised, new trigger for ICIC proposed by Ericsson
	2	Channel Quality Indicator (CQI)	1	UE	1	ms	Standardised
	3	Channel State Indicator (CSI)	1	eNB	1	ms	Standardised
	4	Interference plus Thermal	1	eNB	1	ms	Proposed by NSN as measurement for OI
	5	No. of call drops	2/3	eNB	1	minutes	Performance monitoring standardisation currently ongoing
	6	Cell throughput	2/3	eNB	2	seconds	Performance monitoring standardisation currently ongoing
	7	User throughput	2/3	eNB	2	seconds	Performance monitoring standardisation currently ongoing
IV Control	#	Name	Layer	Range	Updates	Status w.r.t. standardisation	

				Scale	freq.	
	1	Physical Resource Block utilization	1	-	sec/ mins	Implementation specific
	2	Sub band Tx powers	1	-	“	Implementation specific
	3	Re – use factor	1	1,3	mins	Implementation specific
	4	Antenna tilting	1	-	mins/ hours	Implementation specific
V Mobility And Traffic	How does mobility impact the algorithm? 0 (low) ... 9 (high)					3
	How much do traffic characteristics impact the algorithm? 0 (low) ... 9 (high)					8
VI Algorithm Assessment	List of evaluated measurements					
	#	Name	Layer	Period of evaluation		
	1	Packet delay per service	2	Aggregated over observation window		
	2	User throughput	2/3	Aggregated over observation window		
	3	Cell throughput	2/3	Aggregated over observation window		
	List of Objectives					
	#	Name	Aggregation	Relation w.r.t. other objectives (e.g. dominance)		
	1	Number of satisfied users	Satisfied user criterion based on Measurement #1 and Measurement #2	Appropriate balancing with #2, but #1 is dominant		
	2	Resource efficiency	Aggregation of multiple measurements (To be clarified)	Appropriate balancing with #1		
	3	Impact on coverage area and load ⁴	Per cell, aggregated over observation time			
	List of network topologies to be evaluated					
	#	Description			Environment	
	1	Simple, regular scenarios			Hexagon	
2	Real world scenarios			Rural, urban		
VII Relation to other Control Mechanisms	Use cases that have an impact on this use case					
	Load balancing, energy saving, handover optimization					
	Use cases that this use case has an impact on					
	Load balancing, GoS/QoS related parameter optimisation, energy saving, handover optimization					
VIII Dependency on System Implementation Specifics	Dependency on		Rating 0 (low) ... 9 (high)		Description	
	LTE standardisation uncertainty		3		Inter Cell Interference Coordination is in standardization process now, some points remains open	
	Vendor specific implementations		9		High impact of scheduling policy	

⁴ power and antenna tilt optimization should not lead to ping-pong HO during the process or dramatic changes in coverage area / load; a measure could be the relative change in coverage area

Use Case	Self-optimisation of physical channels					Classification	Self-optimisation
I Scope	Location of Algorithm			No. of Controlled / Considered Cells		Impact w.r.t. other cells	
	local	centralised	distributed				
	X	X		1		Minor: potential interference impact	
	Relevant BTS Types			Macro	Micro	Indoor/Femto	
	X			X		X	
II Information Exchange	Between network elements				Frequency		Status w.r.t. standardisation
	None						
	Between (instances) of SON functions				Frequency		Status w.r.t. standardisation
	None						
	Across SON API (cf. Section 4.1.1)				Frequency		Status w.r.t. standardisation
Physical channel parameters of neighbour cells				Event based: when new sites are added		Not considered in standards	
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurements	Status w.r.t. standardisation
	1	Number of attempts to decode P-BCH	1	UE	1	FFS	Submitted in RAN2 contribution
	2	Number of H-ARQ retransmissions on DL-SCH	1	UE	1	FFS	Submitted in RAN2 contribution
	3	BLER for BCCH on DL-SCH	1	UE	1	FFS	Submitted in RAN2 contribution
	4	Number of times no UE transmission when resource has been allocated	1	eNB	1	FFS	Submitted in RAN2 contribution
	5	BLER (potentially for various physical channels)	1	UE eNB	1	FFS	Not considered in standards
	6	C/I ratio (potentially for various physical channels)	1	UE eNB	1	FFS	Not considered in standards
IV Control Parameters	#	Name	Layer	Range	Updates		Status w.r.t. standardisation
					scale	freq.	
	1	Physical channel transmit power	1	0-40 dBm	1 dB	Event-based	Transmit power range is defined in standards
2	Physical channel parameters	1			Event-based	Parameters are defined in standards	

V Mobility And Traffic	How does mobility impact the algorithm?	0 (low) ... 9 (high)	4	
	How much do traffic characteristics impact the algorithm?	0 (low) ... 9 (high)	2	
VI Algorithm Assessment	List of evaluated measurements			
	#	Name	Layer	Period of evaluation
	1	Physical channel BLER performance	1	Aggregated over observation window
	List of Objectives			
	#	Name	Aggregation	Relation w.r.t. other objectives (e.g. dominance)
	1	Successful call setup	Measured over several hours	
	2	Successful call completion	Measured over several hours	
	List of network topologies to be evaluated			
#	Description	Environment		
1	Real world scenarios	Rural, urban, indoor		
VII Relation to other Control Mechanisms	Use cases that have an impact on this use case			
	Interference coordination. Many other use cases have similar objectives in terms of improving call quality, but this does not impact on the control mechanisms			
	Use cases that this use case has an impact on			
	Interference coordination			
VIII Dependency on System Implementation Specifics	Dependency on	Rating 0 (low) ... 9 (high)	Description	
	LTE standards	8	Strongly dependent on details of LTE specification	
	Vendor specific implementation	3	Properties and parameters of channels are mainly standardised.	

Use Case	RACH optimisation			Classification	self-optimisation
I Scope	Location of Algorithm			No. of Controlled / Considered Cells	Impact w.r.t. other cells
	local	centralised	distributed		
	X			1	None
	Relevant BTS Types		Macro	Micro	Indoor/Femto
		X	X	? ⁵	
II Information Exchange	Between network elements			Frequency	Status w.r.t. standardisation
	None			n.a.	?
	Between (instances) of SON functions			Frequency	Status w.r.t. standardisation

⁵ It depends on the understanding of Indoor/Femto BTS if the RACH optimisation should be included into these cells. For BTS's that are located in airports or are installed temporarily for an exhibition, the algorithms should be included but for Home BTS's they are probably not needed.

	Trigger from Tracking areas		Event based		?		
	Trigger from Handover parameter optimisation		Event based		?		
	Trigger from Cell outage compensation		Event based		?		
Across SON API (cf. Section 4.1.1)			Frequency		Status w.r.t. standardisation		
None			n.a.		?		
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurements	Status w.r.t. standardisation
	1	Blocked access attempts	3	UE eNB	1	Event based	?
IV Control Parameters	#	Name	Layer	Range	Updates scale freq.		Status w.r.t. standardisation
	1	Number of access attempts before blocking	?	?	?	min.	?
	2	Time delay before next access attempt	?	?	?	min.	?
	3	Number of RACH	?	?	?	sec.	?
	4	Preamble Split	?	?	?	min.	?
V Mobility And Traffic	How does mobility impact the algorithm?				0 (low) ... 9 (high)		2
	How much do traffic characteristics impact the algorithm?				0 (low) ... 9 (high)		9
VI Algorithm Assessment	List of evaluated measurements						
	#	Name	Layer	Period of evaluation			
	1	Blocked access attempts	3	Aggregated over observation window			
	List of Objectives						
	#	Name	Aggregation		Relation w.r.t. other objectives (e.g. dominance)		
	1	Reduction of Blocked access attempts	Measurement #1				
	List of network topologies to be evaluated						
	#	Description				Environment	
	1	Simple, regular scenarios				hexagon	
	2	Real world scenarios				rural, urban, indoor	
VII Relation to other Control Mechanisms	Use cases that have an impact on this use case						
	Tracking areas, Handover parameter optimisation, Cell outage compensation, Interference coordination						
	Use cases that this use case has an impact on						
	Congestion Control, Admission Control						
VIII Dependency on System Implementation Specifics	Dependency on		Rating 0 (low) ... 9 (high)		Description		
	LTE standardisation uncertainty		4		The one measurement that is required needs to be standardized		
	Vendor specific implementations		5		There will probably be some room for vendor specific solutions		

NOTE: For this use case there is a need to discuss whether it should be simulated separately or if the different aspects and optimization mechanism should be included in the corresponding “macro use cases” simulations.

Use Case	Self-optimisation of home eNodeBs				Classification		self-optimisation
I Scope	Location of Algorithm			No. of Controlled/ Considered Cells	Impact w.r.t. other cells		
	local	centralised	distributed		Minor (interference, neighbour relations)		
	Relevant BTS Types			Macro	Micro	Indoor/Femto	
						X	
II Information Exchange	Between network elements				Frequency		Status w.r.t. standardisation
	From home eNodeB to central node: Neighbour relation information.				Event based		Might be needed
	Home eNodeB to central node: registration upon start up.				Event based		Might be needed
	Central node to home eNodeB: Configurations of the home eNodeB.				Event based		Might be needed
	From eNodeB to home eNodeB: Interference information from neighbouring eNodeBs.				Minutes		Might be needed
	From UE to home eNodeB: PCI and signal strength of serving and surrounding eNodeB				Event based		Ongoing
	From home eNodeB to UE: Request for GCI of new found neighbour				Event based		Ongoing
	From UE to home eNodeB: GCI of new found neighbour				Event based		Ongoing
	From UE to home eNodeB: Downlink interference reports				Milliseconds		Needed
	Possibly geographical position from UE to home eNodeB				Minutes		Might be needed
	Possibly UE speed from UE to home eNodeB				Minutes		Might be needed
	Between (instances) of SON functions						Status w.r.t. standardisation
	None						
	Across SON API (cf. Section 4.1.1)				Frequency		Status w.r.t. standardisation
None							
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurement	Status w.r.t. standardisation
	1	Failed handover ratio	3	eNB	1	Event based	
	2	Uplink interference	2	eNB	1	Milliseconds	
	3	Ratio of dropped calls	3	eNB	1	Hours	
	4	Downlink interference	2	UE	1	Milliseconds	
	5	Signal strength from serving home eNodeB	1	UE	1	Milliseconds	Standardized

	6	Signal strength from surrounding eNodeBs	1	UE	>100	Milliseconds	Standardized
	7	Geographical position of the UE	3	UE	1	Seconds	
	8	UE speed	3	UE	1	Seconds	
	9	Interference measurements	2	Neighbouring	>100	Milliseconds	Needed
IV Control Parameters	#	Name	Layer	Range	Updates scale freq.		Status w.r.t. standardisation
	1	Neighbour relations	3	n/a	n/a	n/a	Might need to standardize special indicator for home eNBs
	2	Cell Power	1	?	?	?	Ongoing
	3	PCI	1	1-504, might be only a subset of these	n/a	Event based	Standardization on update procedure ongoing
	4	HO Parameters	3	Parameter dependent			
V Mobility And Traffic	How does mobility impact the algorithm?					0 (low) ... 9 (high)	8
	How much do traffic characteristics impact the algorithm?					0 (low) ... 9 (high)	2
VI Algorithm Assessment	List of evaluated measurements						
	#	Name	Layer	Period of evaluation			
	1	Failed handover ratio	3	Days			
	2	Cell coverage area	1	Days			
	3	Dropped calls	3	Days			
	4	Interference measurements	2	Days			
	List of Objectives						
	#	Name	Aggregation		Relation w.r.t. other objectives (e.g. dominance)		
	1	Dynamic update of the neighbour relation list and seamless handovers	Measurement #1 and #3		High importance		
	2	Optimized coverage area for the home eNodeB in relation to the user needs	Measurement #2.		Medium importance		

	3	Minimized interference on other eNodeBs	Measurement #4.	High importance
	List of network topologies to be evaluated			
	#	Description		Environment
	1	Simple scenario with macro cells and home eNodeBs		highway
	2	Real world scenarios with macro cells and home eNodeBs		rural, urban
VII Relation to other Control Mechanisms	Use cases that have an impact on this use case			
	Interference coordination, Handover parameter optimisation, Coverage hole detection			
	Use cases that this use case has an impact on			
	Neighbour list optimisation, Interference coordination, Handover parameter optimisation.			
VIII Dependency on System Implementation Specifics	Dependency on		Rating 0 (low) ... 9 (high)	Description
	LTE standardisation uncertainty		8	A fair amount of measurements needs to be standardized.

Use Case	Admission Control				Classification	Self-optimisation	
I Scope	Location of Algorithm			No. of Controlled / Considered Cells	Impact w.r.t. other cells		
	local	centralised	distributed		Major impact: affects interference and service quality levels in other cells		
	X			1			
	Relevant BTS Types			Macro	Micro	Indoor/Femto	
II Information Exchange	Between network elements			Frequency	Status w.r.t. standardisation		
	No.			--	--		
	Between (instances) of SON functions			Frequency	Status w.r.t. standardisation		
	Exchange of information like load, quality of service levels, etc. Congestion control can trigger the closing of the admission gate. Information can be exchanged with SON handover parameter optimisation function.			seconds	--		
	Across SON API			Frequency	Status w.r.t. standardisation		
	--			--	--		
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurements	Status w.r.t. standardisation

	UL noise rise	1	eNB	1	ms	Is topic of standardisation	
	DL transmit power	1	eNB	1	ms	Is topic of standardisation	
	UL/DL Shared channel utilisation	2	eNB	1	ms	Is topic of standardisation	
	Hardware utilisation	--	eNB	1	ms	Standardisation not foreseen	
IV Control Parameters	#	Name	Layer	Range	Updates scale freq.		Status w.r.t. standardisation
		UL noise rise threshold	1	70 % to 90 %	Incr.	Hours/days	Standardisation not foreseen
		DL transmit power threshold	1	70 % to 90 %	Incr.	Hours/days	Standardisation not foreseen
		UL/DL shared channel utilization	2	70 % to 90 %	Incr.	Hours/days	Standardisation not foreseen
		Hardware utilization	--	70 % to 90 %	Incr.		Standardisation not foreseen
V Mobility And Traffic	How does mobility impact the algorithm? 0 (low) ... 9 (high)					4	
	How much do traffic characteristics impact the algorithm? 0 (low) ... 9 (high)					8	
VI Algorithm Assessment	List of evaluated measurements						
	#	Name	Layer	Period of evaluation			
		Blocking probability	3	Aggregated over observation window			
		Dropping probability	3	Aggregated over observation window			
		Quality of service	1,2	Aggregated over observation window			
	List of Objectives						
	#	Name	Aggregation		Relation w.r.t. other objectives (e.g. dominance)		
	1	Maximize GoS (minimize blocking/dropping)	Aggregated over observation window		Generation / aggregation of ratings according the objectives		
	2	QoS requirements should be met.	Aggregated over observation window		Generation / aggregation of ratings according the objectives		
	3	Maximize UL/DL resource utilization	Aggregated over observation window		Generation / aggregation of ratings according the objectives		
	List of network topologies to be evaluated						
	#	Description				Environment	
	1	Simple, regular, multi-cellular scenarios				Rural, urban	
	2	Real world scenarios				Rural, urban	
VII	Use cases that have an impact on this use case						

	Handover parameter optimisation, congestion control parameter optimisation, coverage hole detection, packet scheduling parameter optimisation, load balancing, neighbour cell list.		
	Use cases that this use case has an impact on		
	Handover parameter optimisation, congestion control parameter optimisation, coverage hole detection, packet scheduling parameter optimisation, load balancing, neighbour cell list.		
VIII Dependency on System Implementation Specifics	Dependency on	Rating 0 (low) ... 9 (high)	Description
	LTE standardisation uncertainty	2	Only basic measurements are required. Only basic traffic handling procedures are needed.
	Vendor specific implementations	8	Admission control is vendor-specified.

Use Case	Congestion Control				Classification	Self-optimisation	
I Scope	Location of Algorithm			No. of Controlled / Considered Cells	Impact w.r.t. other cells		
	local	centralised	distributed				
	X			1	Major impact: reduces interference levels and improves service quality levels in other cells		
	Relevant BTS Types			Macro	Micro	Indoor/Femto	
			X	X	--		
II Information Exchange	Between network elements				Frequency	Status w.r.t. standardisation	
	No.				seconds	--	
	Between (instances) of SON functions				Frequency	Status w.r.t. standardisation	
	Exchange of measurements information, e.g. open/close admission gate, handover signalling, packet scheduling information, data rate reduction.				seconds	--	
	Across SON API				Frequency	Status w.r.t. standardisation	
	--				--	--	
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurements	Status w.r.t. standardisation
		Uplink noise rise	1	eNB	1	ms	Is topic of standardisation
		Downlink transmission power	1	eNB	1	ms	Is topic of standardisation
		UL/DL Shared channel utilization	2	eNB	1	ms	Is topic of standardisation
		Service quality (BLER)	1/2	eNB	1	ms	Is topic of standardisation
		Delay	3	eNB	1	ms	Standardisation not foreseen

	Packet Loss	3	eNB	1	ms	Standardisation not foreseen	
IV Control Parameters	#	Name	Layer	Range	Updates scale freq.		Status w.r.t. standardisation
		Maximum time the network is congested	--	In the order of seconds	--	Hours/days	Standardisation not foreseen
		Target load level	1,2	70 % to 90 %	--	Hours/days	Standardisation not foreseen
		Prioritization of services	--	--	--	Hours/days	Standardisation not foreseen
		Step size for congestion resolution	--	0% to 5%	--	Hours/days	Standardisation not foreseen
V Mobility And Traffic	How does mobility impact the algorithm? 0 (low) ... 9 (high)					7	
	How much do traffic characteristics impact the algorithm? 0 (low) ... 9 (high)					7	
VI Algorithm Assessment	List of evaluated measurements						
	#	Name	Layer	Period of evaluation			
		Time it takes to resolve congestion	--	Aggregated over observation window			
		Service QoS level (BLER, delay, etc)	1,2, 3	Aggregated over observation window			
		GoS i.e. blocking and dropping	3	Aggregated over observation window			
	List of Objectives						
	#	Name	Aggregation		Relation w.r.t. other objectives (e.g. dominance)		
	1	Minimize congestion induced dropping	Aggregated over observation window		Generation / aggregation of ratings according the objectives		
	2	Minimize time in congestion	Aggregated over observation window		Generation / aggregation of ratings according the objectives		
	3	Minimize QoS degradation	Aggregated over observation window		Generation / aggregation of ratings according the objectives		
	4	Maximize UL/DL shared channel utilization	Aggregated over observation window		Generation / aggregation of ratings according the objectives		
	List of network topologies to be evaluated						
	#	Description				Environment	
	1	Simple, regular, multi-cellular scenarios				Rural, urban	
	2	Real world scenarios				Rural, urban	
VII Relation to other Control	Use cases that have an impact on this use case						
	Handover parameter optimisation, admission control parameter optimisation, coverage hole detection, packet scheduling parameter optimisation, load balancing, neighbour cell list.						

	Use cases that this use case has an impact on		
	Handover parameter optimisation, admission control parameter optimisation, coverage hole detection, packet scheduling parameter optimisation, load balancing, neighbour cell list.		
VIII Dependency on System Implementation Specifics	Dependency on	Rating 0 (low) ... 9 (high)	Description
	LTE standardisation uncertainty	2	Only basic measurements are required. Only basic traffic handling procedures are needed.
	Vendor specific implementations	8	Congestion control is vendor-specified.

Use Case	Packet scheduling				Classification	Self-optimisation	
I Scope	Location of Algorithm			No. of Controlled / Considered Cells	Impact w.r.t. other cells		
	local	centralised	distributed				
	X		X	1 (local) / about 10 (distributed)	Medium impact; affects interference (variability) levels in other cells		
	Relevant BTS Types			Macro	Micro	Indoor/Femto	
II Information Exchange	Between network elements				Frequency	Status w.r.t. standardisation	
	Local version: none. Distributed version: load, channel qualities, QoS requirements, information on effective user location ⁶				n.a. / (milli)seconds	Is subject of standardization (see Overload Indicator)	
	Between (instances) of SON functions				Frequency	Status w.r.t. standardisation	
	Possible trigger from congestion control to reduce rates.				seconds	Standardization not foreseen	
	Across SON API (cf. Section 4.1.1)				Frequency	Status w.r.t. standardisation	
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurements	Status w.r.t. standardisation
	1	Channel quality	1	UE/eNB	1 / 10	ms	Is subject of standardization
	2	QoS (delays, BLER, throughput)	1,2	UE/eNB	1 / 10	ms	Is subject of standardization
	3	Load	1,2,3	eNB	1 / 10	ms	Is subject of standardization
	4	Effective user location info	1	UE/eNB	1 / 10	seconds	Is subject of standardization
IV Control	#	Name	Layer	Range	Updates	Status w.r.t. standardisation	

⁶ In an advanced packet scheduler, neighbouring cells may for instance coordinate which users are served when, also depending on the user location, in order to maximise channel quality and hence bit rates.

					scale	freq.	
	1	Scheduling weights (w.r.t. services and/or locations)	2	[0,1]	Incr.	Hours/ days	Standardization not foreseen
	2	Resource reservations	2	[0%,10 0%]	Incr.	Hours/ days	Standardization not foreseen
	3	Channel-awareness (fairness) parameter	2	[0,1]	Incr.	Hours/ days	Standardization not foreseen
	4	Absolute vs relative differentiation threshold	2	[0,1]	Incr.	Hours/ days	Standardization not foreseen
V Mobility And Traffic	How does mobility impact the algorithm? 0 (low) ... 9 (high)						7
	How much do traffic characteristics impact the algorithm? 0 (low) ... 9 (high)						8
VI Algorithm Assessment	List of evaluated measurements						
	#	Name	Layer	Period of evaluation			
	1	Experienced QoS (throughput, delay, BLER) and QoS versus offered traffic load	2,3	Aggregated over observation window			
	2	Maximum supportable offered traffic, still satisfying all QoS/GoS requirements	3	Aggregated over observation window			
	List of Objectives						
	#	Name	Aggregation		Relation w.r.t. other objectives (e.g. dominance)		
	1	Maximise experienced QoS (throughput, delay, BLER) and QoS versus offered traffic load	Aggregated over observation window		Depends on operator policy i.e. fairness, cell edge throughput, etc.		
	2	Maximise supportable offered traffic, still satisfying all QoS/GoS requirements	Aggregated over observation window		Most important of the two		
	List of network topologies to be evaluated						
	#	Description				Environment	
	1	Simple, regular, multi-cellular scenarios				Rural, urban	
	2	Real world scenarios				Rural, urban	
VII Relation to other Control Mechanisms	Use cases that have an impact on this use case						
	Particularly admission control parameter optimisation, and also to some extent load balancing and congestion control parameter optimisation.						
	Use cases that this use case has an impact on						
	Same as above.						
VIII Dependency on	Dependency on		Rating 0 (low) ... 9 (high)		Description		

	LTE standardisation uncertainty	2	Only basic measurements are required. Only basic traffic handling procedures are needed. For very advanced packet schedulers, however, the rating may be higher, since very specific measurement information may be needed.
	Vendor specific implementations	7	Packet scheduling is vendor-specified.

Use Case	Link-level retransmission scheme optimization				Classification	self-optimisation	
I Scope	Location of Algorithm			No. of Controlled / Considered Cells	Impact w.r.t. other cells		
	local	centralised	distributed				
	X			1	minor (interference)		
	Relevant BTS Types			Macro	Micro	Indoor/Femto	
		X	X	X ⁷			
II Information Exchange	Between network elements				Frequency	Status w.r.t. standardisation	
	none				n.a.		
	Between (instances) of SON functions				Frequency	Status w.r.t. standardisation	
	None				n.a.		
	Across SON API				Frequency	Status w.r.t. standardisation	
	None				n.a.		
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurements	Status w.r.t. standardisation
	1	BLER	1	UE/eNB	1	ms	??
	2	Packet delay (MAC,RLC)	2	“	1	ms	??
	3	No. of retransmissions	2	“	1	ms	??
IV Control Parameters	#	Name	Layer	Range	Updates		Status w.r.t. standardisation
					scale	freq.	
	1	BLER target	1	0.1%-20%	small	mins/hours	??
2	Maximum number of retransmissions	2	0-10	“	“	??	
V Mobility And Traffic	How does mobility impact the algorithm?				0 (low) ... 9 (high)		3 ⁸
	How much do traffic characteristics impact the algorithm?				0 (low) ... 9 (high)		8 ⁹

⁷ Although the use case is relevant for femto-cell scenarios, its investigation need not be necessarily be done for femto-cell scenarios.

⁸ Via the effects of multipath fading, not directly due to location changes.

⁹ E.g. service type affects control parameters.

VI Algorithm Assessment	List of evaluated measurements			
	#	Name	Layer	Period of evaluation
	1	Packet delay per service	2	Aggregated over observation window
	2	Residual BLER	1	Aggregated over observation window
	3	Resource efficiency	1	Aggregated over observation window
	List of Objectives			
	#	Name	Aggregation	Relation w.r.t. other objectives (e.g. dominance)
	1	Resource efficiency	Aggregation of multiple measurements	Appropriate balancing w. #2,3
	2	Packet delay	Aggregation of multiple measurements	Appropriate balancing w. #1,3
	3	Residual BLER	Aggregation of multiple measurements	Appropriate balancing w. #1,2
	List of network topologies to be evaluated			
#	Description		Environment	
1	Single cell rural/suburban/urban/indoor scenario		standard propagation models	
2	Single cell rural/suburban/urban/indoor scenario		real world propagation info	
VII Relation to other Control Mechanisms	Use cases that have an impact on this use case			
	Weak relation with load balancing, admission control parameter optimization, packet scheduling parameter optimisation, handover parameter optimisation, congestion control parameter optimisation.			
	Use cases that this use case has an impact on			
	Same as above.			
VIII Dependency on System Implementation Specifics	Dependency on	Rating 0 (low) ... 9 (high)	Description	
	LTE standardisation uncertainty	2	Only basic parameters / measurements	
	Vendor specific implementations	0	Interfaces need to be provided	

Use Case	Coverage hole detection			Classification	self-optimisation
I Scope	Location of Algorithm			No. of Controlled/ Considered Cells	Impact w.r.t. other cells
	local	centralised	distributed		
	X		X	1/± 10	None (only detection)
	Relevant BTS Types		Macro	Micro	Indoor/Femto
		X	X	X	
II Information Exchange	Between network elements			Frequency	Status w.r.t. standardisation
	Between neighbour cells via X2 interface			Event based ¹⁰	??
	Between (instances) of SON functions			Frequency	Status w.r.t. standardisation

¹⁰ Event based in information such as drop calls, etc.

	Handover parameter optimization, load balancing				Event based	??	
	Across SON API (cf. Section 4.1.1)				Frequency	Status w.r.t. standardisation	
	none				n.a.		
	...						
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurement	Status w.r.t. standardisation
	1	Received pilot strength per user	1	UE	± 10	Order of ms	??
	2	No. of failures on random access channels	2	eNB	± 10	ms (RACH attempts) to seconds (call initiation)	??
	3	No. of call drops	2/3	eNB	± 10	seconds	??
	4	Timing advance before call drops	(1)	eNB	± 10	ms	??
IV Control Parameters	#	Name	Layer	Range	Updates scale freq.		Status w.r.t. standardisation
		Setting threshold for III	--				??
	1	Received pilot strength per user and neighbour	--	?	Incremental	hours/days	??
	2	No. of failures on random access	--	5% to 20%	Incremental	hours/days	??
	3	No. of call drops	--	1%	Incremental	hours/days	??
	4	Timing advance before call drops	--	Microseconds, milliseconds	Incremental	hours/days	??
V Mobility And Traffic	How does mobility impact the algorithm?				0 (low) ... 9 (high)	9 ¹¹	
	How much do traffic characteristics impact the algorithm?				0 (low) ... 9 (high)	5 ¹²	
VI Algorithm Assessment	List of evaluated measurements						
	#	Name	Layer	Period of evaluation			
		Miss detection	--	Over observation window			
		False alarms	--	Over observation window			
	List of Objectives						
	#	Name	Aggregation			Relation w.r.t. other objectives (e.g. dominance)	
		Percentage of coverage holes that should have been detected timely	Over observation window			No relation	

¹¹ Mobility is very important as coverage holes increase call drops

¹² Coverage depends on service type.

	List of network topologies to be evaluated		
	#	Description	Environment
	1	simple scenarios with multiple cells	rural, urban, indoor, suburban
2	Extensive testing in real world scenarios	rural, urban, indoor, suburban	
VII Relation to other Control Mechanisms	Use cases that have an impact on this use case		
	Cell outage detection, reduction of energy consumption, RACH optimization, self-optimization of physical channels, self optimization of home eNodeB, management of relays and repeaters, (handover parameter optimization), ...		
	Use cases that this use case has an impact on		
	Cell outage detection, reduction of energy consumption, RACH optimization, self-optimization of physical channels, self optimization of home eNodeB, management of relays and repeaters, (handover parameter optimization), ...		
VIII Dependency on System Implementation Specifics	Dependency on	Rating 0 (low) ... 9 (high)	Description
	LTE standardisation uncertainty	6	A fair amount of measurements needs to be standardized
	Vendor specific implementations	7	Depends on Vendor implementations

Use Case	Handover parameter optimisation				Classification	self-optimisation	
I Scope	Location of Algorithm			No. of Controlled / Considered Cells	Impact w.r.t. other cells		
	local	centralised	distributed				
			X	10 neighbour cells	Major on neighbour cells		
	Relevant BTS Types		Macro	Micro	Indoor/Femto		
		X	X	X			
II Information Exchange	Between network elements				Frequency	Status w.r.t. standardisation	
	eNBs via X2. Information regarding load, QoS requirements, etc.				seconds	??	
	Between (instances) of SON functions				Frequency	Status w.r.t. standardisation	
	None. Stand-alone operation. However, joint optimisation with e.g., load balancing and GoS/QoS parameter optimisation could be useful.				-	??	
	Across SON API				Frequency	Status w.r.t. standardisation	
	-						
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurements	Status w.r.t. standardisation
	1	Signal strength	1	UE	10	>>1 ms, < 1s	??
	2	Number of triggered HOs	3	eNB	10	Seconds	R3-080530
	3	Number of completed HOs	3	eNB	10	Seconds	R3-080530

	4	Number of dropped calls	3	eNB	10	Seconds	??
	5	Number of TA (timing advance) updates in a certain time period ¹³	3	eNB	10	Seconds	Proposed in NGMN, not yet discussed in detail ¹⁴
	6	Throughput before/after HO	2	eNB	10	Seconds	R3-080530
IV Control Parameters	#	Name	Layer	Range	Updates scale freq.		Status w.r.t. standardisation
	1	Neighbour specific thresholds	2	?		Min / hours	??
	2	Hysteresis parameter	2	?			??
V Mobility And Traffic	How does mobility impact the algorithm?					0 (low) ... 9 (high)	9
	How much do traffic characteristics impact the algorithm?					0 (low) ... 9 (high)	8
VI Algorithm Assessment	List of evaluated measurements						
	#	Name	Layer	Period of evaluation			
	1	Handover failure rate	3	Aggregated over observation window			
	2	Call drop rates	3	Aggregated over observation window			
	3	QoS indicator	3	Aggregated over observation window			
	4	Number of ping-pong HOs	3	Aggregated over observation window			
	5	Throughput before/after HO	2	Aggregated over observation window			
	List of Objectives						
	#	Name	Aggregation		Relation w.r.t. other objectives (e.g. dominance)		
	1	Handover efficiency	Measurement #2 and #3		Appropriate balancing with objective #2		
	2	GoS/QoS	Measurement #4		Appropriate balancing with objective #1		
	3	Network capacity	Measurement #6				
	List of network topologies to be evaluated						
	#	Description				Environment	
	1	Simple, regular scenarios				hexagon	
2	Real world scenarios				rural, urban		
VII	Use cases that have an impact on this use case						

¹³ This measurement is meant for identifying the occurrence of ping-pong

¹⁴ Archive of the NGMN Self-Organising Networks Project 12 mailing list, March 12, 2008.

	Load balancing, neighbour cell list, tracking areas, admission control parameter optimization, packet scheduling parameter optimisation, ...		
	Use cases that this use case has an impact on		
	Load balancing, neighbour cell list, tracking areas, admission control parameter optimization, packet scheduling parameter optimisation, ...		
VIII Dependency on System Implementation Specifics	Dependency on	Rating 0 (low) ... 9 (high)	Description
	LTE standardisation uncertainty	3	Only basic parameters / measurements
	Vendor specific implementations	5	Interfaces need to be provided

Use Case	Load balancing				Classification	Self-optimisation	
I Scope	Location of Algorithm			No. of Controlled / Considered Cells	Impact w.r.t. other cells		
	local	centralised	distributed				
			X	10 neighbour cells	major		
	Relevant BTS Types			Macro	Micro	Indoor/Femto	
		X	X	X			
II Information Exchange	Between network elements				Frequency	Status w.r.t. standardisation	
	Share load information between neighbour eNodeBs via X2 interface				Seconds	??	
	Between (instances) of SON functions				Frequency	Status w.r.t. standardisation	
	None, stand-alone operation. However, joint optimisation with e.g., handover and admission control could be useful.				-	??	
	Across SON API				Frequency	Status w.r.t. standardisation	
	-						
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurements	Status w.r.t. standardisation
	1	UL/DL load measurements	1,2,3	eNB	10	Seconds	??
	2	Resource utilisation	1,2,3	eNB	10	Seconds	??
	3	Achieved QoS	2	eNB	10	Seconds	??
	4	Achieved GoS	3	eNB	10	Seconds	??
	5	Load estimation	1,2,3	eNB	10	Seconds	??
IV Control Parameters	#	Name	Layer	Range	Updates		Status w.r.t. standardisation
					scale	freq.	
	1	Threshold(s)	1,2,3		Incr.	Hours/days	??
	2	Time duration(s)	1,2,3		Incr.	Hours/days	??
3	Step size(s)	1,2,3		Incr.	Hours/days	??	
V Mobility And Traffic	How does mobility impact the algorithm?				0 (low) ... 9 (high)		6
	How much do traffic characteristics impact the algorithm?				0 (low) ... 9 (high)		8

VI Algorithm Assessment	List of evaluated measurements			
	#	Name	Layer	Period of evaluation
	1	Achieved GoS	3	Aggregated over observation window
	2	Call dropping/blocking rate	2	Aggregated over observation window
	3	Throughput	2	Aggregated over observation window
	List of Objectives			
	#	Name	Aggregation	Relation w.r.t. other objectives (e.g. dominance)
	1	Achieved GoS	Aggregated over observation window	Dropping more critical than blocking
	2	Network capacity	Measurement #3	
	List of network topologies to be evaluated			
#	Description		Environment	
1	Simple, regular, multi-cellular scenarios		Rural, urban, indoor	
2	Real world scenarios		Rural, urban, indoor	
VII Relation to other Control Mechanisms	Use cases that have an impact on this use case			
	Handover parameter optimisation, admission control parameter optimisation, coverage hole detection, congestion control parameter optimisation, neighbour cell list.			
	Use cases that this use case has an impact on			
	See above.			
VIII Dependency on System Implementation Specifics	Dependency on		Rating 0 (low) ... 9 (high)	Description
	LTE standardisation uncertainty		2	Only basic measurements are required. Only basic traffic handling procedures are needed.
	Vendor specific implementations		7	Load balancing is vendor-specified.

Use Case	Reduction of Energy Consumption			Classification	self-optimisation
I Scope	Location of Algorithm			No. of Controlled / Considered Cells	Impact w.r.t. other cells
	local	centralised	distributed		
	X	X	X	10-100 ¹⁵	High: load, handovers, interference
	Relevant BTS Types		Macro	Micro	Indoor/Femto
II Information Exchange	Between network elements			Frequency	Status w.r.t. standardisation
	Load information			mins/seconds	
	Request for network element state change			Event based	

¹⁵ Depends on location of algorithm

	Between (instances) of SON functions					Frequency	Status w.r.t. standardisation
	Across SON API (cf. Section 4.1.1)					Frequency	Status w.r.t. standardisation
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurements	Status w.r.t. standardisation
	1	Load	1,2,3	eNB	10-100	seconds	Performance monitoring standardisation currently ongoing
	2	QoS	2	eNB	10-100	“	Performance monitoring standardisation currently ongoing
	3	Received power from current and neighbour cells	1	UE	10-100	statistics over months/days period	Standardised
	4	No of call drops	2/3	eNB	10-100	seconds	Performance monitoring standardisation currently ongoing
IV Control Parameters	#	Name	Layer	Range	Updates		Status w.r.t. standardisation
					scale	freq.	
	1	eNB state		On/off		hours/ mins.	
	2	Transmit power and antenna tilt	1			“	Implementation specific
	3	No of Tx antennas	1			“	Standardized, optional feature
4	Handover thresholds	1			sec.	??	
V Mobility And Traffic	How does mobility impact the algorithm?				0 (low) ... 9 (high)		4
	How much do traffic characteristics impact the algorithm?				0 (low) ... 9 (high)		7
VI Algorithm Assessment	List of evaluated measurements						
	#	Name	Layer	Period of evaluation			
	1	Energy Saving		Aggregated over observation window			
	2	No of call drops	2/3	Aggregated over observation window			
	List of Objectives						
	#	Name	Aggregation			Relation w.r.t. other objectives (e.g. dominance)	

	1	Minimized number of unused resources	Measurement #1	With respect to #2 and power efficiency/cost models of eNB
	2	No increase in number of call drops	Measurement #2	Appropriate balancing with #1
	List of network topologies to be evaluated			
	#	Description		Environment
	1	Simple, regular scenarios		Hexagon, rural, urban
VII Relation to other Control Mechanisms	Use cases that have an impact on this use case			
	Load balancing, coverage hole detection, interference reduction			
	Use cases that this use case has an impact on			
	Load balancing, coverage hole detection			
VIII Dependency on System Implementation Specifics	Dependency on		Rating 0 (low) ... 9 (high)	Description
	LTE standardisation uncertainty		4	Use case defined in TR 36.902 and power efficiency highlighted as requirement in RAN Workshop on LTE-A
	Vendor specific implementations		5	Both standardized and vendor-specific implementation possible (even concurrently)

Use Case	Tracking Areas				Classification	self-optimisation/ self-configuration	
I Scope	Location of Algorithm			No. of Controlled/ Considered Cells	Impact w.r.t. other cells		
	local	centralised	distributed			All or closed subset	None
	Relevant BTS Types			Macro	Micro	Indoor/Femto	
			X	X	X	X	
II Information Exchange	Between network elements				Frequency	Status w.r.t. standardisation	
	None				n.a.		
	Between (instances) of SON functions				Frequency	Status w.r.t. standardisation	
	Trigger RACH optimisation Triggered by new site configuration				Event based Event based		
	Across SON API (cf. Section 4.1.1)				Frequency	Status w.r.t. standardisation	
None				n.a.			
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurement	Status w.r.t. standardisation
	1	UE mobility patterns	??	UE	All or closed subset	Hourly/daily	??

	2	Number of TAU per cell	??	OMC	All or closed subset	Daily	??
	3	Number of triggered HO, measured per cell relation	??	OMC	All or closed subset	Daily	??
	4	Number of paging request per paging area	??	OMC	All or closed subset	Daily	??
	5	Number of paging responds of the UEs per cell	??	OMC	All or closed subset	Daily	??
	6	Number of signal attempts using the same channel as TAU and/or paging	??	OMC	All or closed subset	Daily	??
IV Control Parameters	#	Name	Layer	Range	Updates scale freq.		Status w.r.t. standardisation
	1	TAC (list) per cell	??	??	Small/ large ¹⁶	Days	??
	2	Distance threshold ¹⁷	??	??	Small/ large	Days	??
V Mobility And Traffic	How does mobility impact the algorithm?					0 (low) ... 9 (high)	9 ¹⁸
	How much do traffic characteristics impact the algorithm?					0 (low) ... 9 (high)	7 ¹⁹
VI Algorithm Assessment	List of evaluated measurements						
	#	Name	Layer	Period of evaluation			
	1	Number of TAU per cell	??	Aggregated over observation window			
	2	Number of paging request per paging area	??	Aggregated over observation window			
	List of Objectives						
	#	Name	Aggregation		Relation w.r.t. other objectives (e.g. dominance)		
	1	Number of TAU beyond threshold	Measurement #1		Appropriate balance to #2		
	2	Number of paging request beyond threshold	Measurement #2		Appropriate balance to #1		
	3	Blocked call rate					
	List of network topologies to be evaluated						

¹⁶ Depends on introduction of a single site or re-planning of part of or the whole network

¹⁷ Depends on the standard

¹⁸ Mobility of very high importance, as every UE in idle mode performs TAU at TA borders

¹⁹ Traffic of high importance, as every connection process that requires finding a UE leads to paging messages

	#	Description	Environment
	1	Extensive testing in real world scenarios	Rural (macro), urban (micro), indoor
VII Relation to other Control Mechanisms	Use cases that have an impact on this use case		
	Self optimization of home eNodeB, management of relays and repeaters, (handover parameter optimization), (every use case that reconfigures site or antenna parameters)		
	Use cases that this use case has an impact on		
	RACH optimisation		
VIII Dependency on System Implementation Specifics	Dependency on	Rating 0 (low) ... 9 (high)	Description
	LTE standardisation uncertainty	7	Measurement of UE mobility patterns needs to be standardized
	Vendor specific implementations	9	Interfaces to performance counters need to be provided

Use Case	TDD UL/DL switching point				Classification	self-optimisation	
I Scope	Location of Algorithm			No. of Controlled / Considered Cells	Impact w.r.t. other cells		
	local	centralised	distributed		2-10	High: load, handovers, interference level	
	Relevant BTS Types			Macro			Micro
						X	
II Information Exchange	Between network elements				Frequency	Status w.r.t. standardisation	
	Overload Indicator (OI)				Tens of ms	In advanced standardization process	
	High Interference Indicator (HII)				Tens of ms	“	
	Switching point configuration				Event based	Not standardized	
	Between (instances) of SON functions				Frequency	Status w.r.t. standardisation	
	Across SON API (cf. Section 4.1.1)				Frequency	Status w.r.t. standardisation	
	...						
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurements	Status w.r.t. standardisation
	1	UL/DL Load	1,2,3	eNB	2-10	seconds	-
	2	UL/DL QoS	3	eNB/UE	2-10	seconds	-
	2	Channel Quality Indicator (CQI)	1	UE	1	ms	Standardized
	3	Channel State Indicator (CSI)	1	eNB	1	ms	Standardized
4	Interference plus	1	eNB	1	ms	Proposed by	

	Thermal					NSN as measurement for OI	
IV Control Parameters	#	Name	Layer	Range	Updates		Status w.r.t. standardisation
					scale	freq.	
	1	Physical Resource Blocks utilization	1	?		mins	Implementation specific
	2	Sub band Tx powers	1	?	“	“	Implementation specific
	3	Switching point configuration	1	?		“	Implementation specific
V Mobility And Traffic	How does mobility impact the algorithm? 0 (low) ... 9 (high)					2	
	How much do traffic characteristics impact the algorithm? 0 (low) ... 9 (high)					9	
VI Algorithm Assessment	List of evaluated measurements						
	#	Name	Layer	Period of evaluation			
	1	Packet delay per service	2	Aggregated over observation window			
	2	User throughput	2/3	Aggregated over observation window			
	3	Cell throughput	2/3	Aggregated over observation window			
	List of Objectives						
	#	Name	Aggregation		Relation w.r.t. other objectives (e.g. dominance)		
	1	Number of satisfied users	Satisfied user criterion based on Measurement #1 and Measurement #2		Appropriate balancing with #2, but #1 is dominant		
	2	Resource efficiency	Aggregation of multiple measurements (To be clarified)		Appropriate balancing with #1		
	List of network topologies to be evaluated						
	#	Description				Environment	
	1	Simple, regular scenarios				office, room-corridor deployment	
2	Real world scenarios				real office, shopping mall		
VII Relation to other Control Mechanisms	Use cases that have an impact on this use case						
	Load balancing, GoS/QoS related parameter optimisation						
	Use cases that this use case has an impact on						
	Load balancing, GoS/QoS related parameter optimisation						
VIII Dependency on System Implementation Specifics	Dependency on		Rating 0 (low) ... 9 (high)		Description		
	LTE standardisation uncertainty		8		LA TDD is going to be standardised in next releases		
	Vendor specific implementations		7		High impact of scheduling policy		

Use Case	Management of relays and repeaters	Classification	Self-configuration and self-optimisation
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I Scope	Location of Algorithm			No. of Controlled/ Considered Cells	Impact w.r.t. other cells		
	local	centralised	distributed				
	X						
	Relevant BTS Types		Macro	Micro	Indoor/Femto		
		X					
II Information Exchange	Between network elements			Frequency	Status w.r.t. standardisation		
	From surrounding eNBs to serving eNB: Measured interference			Minutes	Needed		
	From UE to relay/eNB: Received signal strength			Milliseconds	Standardized		
	From UE to relay/eNB: DL interference			Milliseconds	Needed		
	Between (instances) of SON functions				Status w.r.t. standardisation		
	From relay to eNB: Received signal strength from UE			Milliseconds	Not needed		
	From relay to eNB: Measured interference			Milliseconds	Not needed		
	Across SON API (cf. Section 4.1.1)			Frequency	Status w.r.t. standardisation		
	None						
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measuremen	Status w.r.t standardisation
	1	Relay signal strength	1	eNB	1	Milliseconds	Needed
	2	Total signal strength deriving from a UE (with or without relaying)	1	eNB	1	Milliseconds	Standardized(?)
	3	Signal strength from a UE	1	Relay	1	Milliseconds	Not needed
	4	Received signal strength.	1	UE	1	Milliseconds	Standardized
	5	DL Interference	2	UE	1	Milliseconds	Needed
	6	Interference	2	Relay	1	Milliseconds	Not needed
	7	Interference	2	Serv- ing and surro- und- ing	~30	Milliseconds	Needed
IV Control Parameters	#	Name	Layer	Range	Updates		Status w.r.t. standardisation
					scale	freq.	

	1	Configuration parameters	2/3	Parameter dependent			
	2	Relay/repeater power	1	?	?	?	Ongoing
	3	Beam forming parameters	2	Parameter dependent			
V Mobility And Traffic	How does mobility impact the algorithm? 0 (low) ... 9 (high)					6	
	How much do traffic characteristics impact the algorithm? 0 (low) ... 9 (high)					4	
VI Algorithm Assessment	List of evaluated measurements						
	#	Name	Layer	Period of evaluation			
	1	Capacity	3	Days			
	2	Cell coverage area	2/3	Days			
	3	Error rate	2	Days			
	4	Dropped calls	2	Days			
	List of Objectives						
	#	Name	Aggregation	Relation w.r.t. other objectives (e.g. dominance)			
	1	Optimized coverage area	Measurement #2 and #4..	Appropriate balancing with #2			
	2	Minimized interference caused by the relays	Measurement #1 and #3.	Appropriate balancing with #1			
	List of network topologies to be evaluated						
	#	Description			Environment		
	1	Simple scenario with macro cells			rural, urban		
2	Real world scenarios			rural, urban			
VII Relation to other Control Mechanisms	Use cases that have an impact on this use case						
	Interference control						
	Use cases that this use case has an impact on						
	Interference control						
VIII Dependency on System Implementation Specifics	Dependency on		Rating 0 (low) ... 9 (high)	Description			
	LTE standardisation uncertainty		9	Relays have been discussed, but no specifications have yet been presented for approval.			

Use Case	MIMO scheme control			Classification	self-optimisation
I Scope	Location of Algorithm			No. of Controlled / Considered Cells	Impact w.r.t. other cells
	local	centralised	distributed		

	X	X	X	2-10	medium, interference level, load		
	Relevant BTS Types		Macro	Micro	Indoor/Femto		
			X	X	X		
II Information Exchange	Between network elements			Frequency	Status w.r.t. standardisation		
	MIMO scheme indicator			ms	Not standardized		
	MIMO scheme coordination info ²⁰			ms	Not standardized		
	Overload Indicator (OI)			ms	In advanced standardization process		
	High Interference Indicator (HII)			ms	In advanced standardization process		
	Between (instances) of SON functions			Frequency	Status w.r.t. standardisation		
	Across SON API (cf. Section 4.1.1)			Frequency	Status w.r.t. standardisation		
	...						
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurements	Status w.r.t. standardisation
	1	Received Signal Received Power	1	UE	1	ms	Standardized, new trigger for ICIC proposed by E//
	2	Channel Quality Indicator ²¹	1	UE	1	ms	Standardised
	3	Channel State Indicator (CSI)	1	eNB	1	ms	Standardised
	4	Interference plus Thermal	1	eNB	1	ms	Proposed by NSN as measurement for OI
	5	No. of call drops	2/3	eNB	1	minutes	Performance monitoring standardisation currently ongoing
	6	Cell throughput	2/3	eNB	2	seconds	Performance monitoring standardisation currently ongoing
	7	User throughput	2/3	eNB	2	seconds	Performance monitoring standardisation currently ongoing

²⁰ Information to stabilize inter-cell interference caused by spatial processing, e.g. co-ordinated beam switching in case of beamforming

²¹ Should be measured over different MIMO layers, beams (in case of beamforming), critical measurement

	#	Name	Layer	Range	Updates		Status w.r.t. standardisation
					scale	freq.	
IV Control Parameters	1	MIMO antenna configuration	1	1-8 antennas		sec/mi ns	Optional feature Implementation specific
	2	Multiplexing scheme	1/2	1-8 streams, SDMA		“	Optional feature Implementation specific
	3	Physical Resource Block utilization	1			”	Implementation specific
	4	Tx powers	1			“	Implementation specific
	5	Antenna tilting				mins./h ours	Implementation specific
	6	MIMO Scheme Use	1			ms	Implementation specific
V Mobility And Traffic	How does mobility impact the algorithm?					0 (low) ... 9 (high)	3
	How much do traffic characteristics impact the algorithm?					0 (low) ... 9 (high)	8
VI Algorithm Assessment	List of evaluated measurements						
	#	Name	Layer	Period of evaluation			
	1	Packet delay per service	2	Aggregated over observation window			
	2	User throughput	2/3	Aggregated over observation window			
	3	Cell throughput	2/3	Aggregated over observation window			
	List of Objectives						
	#	Name	Aggregation		Relation w.r.t. other objectives (e.g. dominance)		
	1	Number of satisfied users	Satisfied user criterion based on Measurement #1 and Measurement #2		Appropriate balancing with #2, but #1 is dominant		
	2	Resource efficiency	Aggregation of multiple measurements (To be clarified)		Appropriate balancing with #1		
	3	Impact on coverage area and load ²²	Per cell, aggregated over observation time				
	4	Stability of Interference / Reliability of CQI/CSI	Per cell; CDF of reported SINR vs. real SINR when feedback is applied (i.e. at scheduling)				
	List of network topologies to be evaluated						
	#	Description				Environment	
	1	Simple, regular scenarios				hexagon	
2	Real world scenarios				rural, urban		

²² power and antenna tilt optimization should not lead to ping-pong HO during the process or dramatic changes in coverage area / load; a measure could be the relative change in coverage area

VII Relation to other Control Mechanisms	Use cases that have an impact on this use case		
	Interference coordination, load balancing, energy saving, HO optimization, Relaying		
	Use cases that this use case has an impact on		
	Interference coordination, Load balancing, GoS/QoS related parameter optimisation, energy saving, HO optimization, Relaying		
VIII Dependency on System Implementation Specifics	Dependency on	Rating 0 (low) ... 9 (high)	Description
	LTE standardisation uncertainty	6	MIMO is optional for implementation, there are no standardized interfaces for MIMO coordination, collaborative MIMO is proposed for LTE-A technologies
	Vendor specific implementations	8	High impact of scheduling policy

B.3 Self-healing use case profiles

Use Case	Cell Outage Prediction				Classification	self-healing	
I Scope	Location of Algorithm			No. of Controlled / Considered Cells	Impact w.r.t. other cells		
	local	centralised	distributed				
			X	± 10 neighbour cells	Minor ⁽¹⁾		
	Relevant BTS Types		Macro	Micro	Indoor/Femto		
		X	X	X			
II Information Exchange	Between network elements				Frequency	Status w.r.t. standardisation	
	Yes, inform neighbours (see above) of outage prediction				Event based ⁽²⁾	??	
	Between (instances) of SON functions				Frequency	Status w.r.t. standardisation	
	Likelihood prediction function				Event based ⁽²⁾	??	
	Across SON API (cf. Section 4.1.1)				Frequency	Status w.r.t. standardisation	
	??					??	
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurements	Status w.r.t. standardisation
	1	Hardware and Software utilization	--	eNB	± 10	seconds, minutes	??
	2	Temperature	--	eNB	± 10	minutes	??
	3	Traffic	2	eNB	± 10	second, minutes	??
	4	Resource utilization	2	eNB	± 10	second, minutes	??
IV Control Parameters	#	Name	Layer	Range	Updates		Status w.r.t. standardisation
					scale	freq.	
	1	Setting threshold for III	--	?	Incremen tal	Days/ weeks	??

	2	Weighted average of III	--	?	Incremental	Days/weeks	??
V Mobility And Traffic	How does mobility impact the algorithm? 0 (low) ... 9 (high)					0	
	How much do traffic characteristics impact the algorithm? 0 (low) ... 9 (high)					2	
VI Algorithm Assessment	List of evaluated measurements						
	#	Name	Layer	Period of evaluation			
	1	All the required measurements	--	Aggregated over observation window			
	List of Objectives						
	#	Name	Aggregation		Relation w.r.t. other objectives (e.g. dominance)		
	1	Percentage of actual cell outages should have been predicted timely	over observation window		No relation		
	List of network topologies to be evaluated						
	#	Description				Environment	
1	Single and multiple cells, simple scenario ⁽³⁾				standard propagation models		
VII Relation to other Control Mechanisms	Use cases that have an impact on this use case						
	None or with very weak relations						
	Use cases that this use case has an impact on						
	Outage detection, outage compensation						
VIII Dependency on System Implementation Specifics	Dependency on		Rating 0 (low) ... 9 (high)		Description		
	LTE standardisation uncertainty		0		--		
	Vendor specific implementations		7		Depends on vendor specific subjects such as hardware and software failures; room temperature (refrigeration); handling traffic and resource utilization, etc.		

Use Case	Cell Outage Detection			Classification	self-healing
I Scope	Location of Algorithm			No. of Controlled / Considered Cells	Impact w.r.t. other cells
	local	centralised	distributed		
			X	10	Major ⁽¹⁾
	Relevant BTS Types			Macro	Micro
		X	X	X	(X)
II Information	Between network elements			Frequency	Status w.r.t. standardisation

Exchange	No.				--	--	
	Between (instances) of SON functions				Frequency	Status w.r.t. standardisation	
	Yes, informed by cell outage prediction; ⁽²⁾ Yes, cell outage compensation is triggered. ⁽²⁾				Event based ⁽³⁾	Standardization not foreseen	
	Across SON API (cf. Section 4.1.1)				Frequency	Status w.r.t. standardisation	
--				--	--		
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurements	Status w.r.t. standardisation
	1	Neighbour measurement reports	1	UE	10	ms	Is subject of standardization
	2	Downlink interference	1	UE	10	ms	Is subject of standardization
	3	Hardware and software	--	eNB	1	Event based	Standardization not foreseen
	4	HO failure rate	3	eNB	10	s	Is subject of standardization
	5	Cell capacity (e.g. number of ongoing sessions), downlink/uplink	3	eNB	1	s	Is subject of standardization
	6	Calls blocked, dropped	3	eNB	1	s	Is subject of standardization
	7	Uplink interference	1	eNB	1	ms	Is subject of standardization
	8	Timing Advance	1	eNB	1	ms	Is subject of standardization
	9	Relative load indicator	1	eNB	10	s	Is subject of standardization
IV Control Parameters (via Cell outage compensation)	#	Name	Layer	Range	Updates		Status w.r.t. standardisation
					scale	freq.	
	1	Antenna tilt	--	Tbd	Incremental	Min.	Standardization not foreseen
	2	Power DL signalling channels + RACH	1	Tbd	Incremental	Min.	Standardization not foreseen
	3	LTE Handover parameters	--	Tbd	Incremental	Min	Standardization not foreseen
	4	Inter-RAT Handover parameters	--	Tbd	Incremental	Min	Standardization not foreseen
	5	LTE Cell (re)selection parameters	--	Tbd	Incremental	Min	Standardization not foreseen
	6	Inter-RAT Cell (re) selection parameters	--	Tbd	Incremental	Min	Standardization not foreseen
7	Load balancing parameters	--	Tbd	Incremental	Min	Standardization not foreseen	
V Mobility And Traffic	How does mobility impact the algorithm? 0 (low) ... 9 (high)					7 ⁽⁴⁾	
	How much do traffic characteristics impact the algorithm? 0 (low) ... 9 (high)					2	
VI Algorithm Assessment	List of evaluated measurements						
	#	Name	Layer	Period of evaluation			

	1	All the required measurements	--	Aggregated over observation window
	List of Objectives			
	#	Name	Aggregation	Relation w.r.t. other objectives (e.g. dominance)
	1	The cell ID(s) for the cell(s) in outage	Over observation window	No relation
		The scope of the outage (i.e. the whole cell or only a limited set of RBs are not supported); the geographic area with low performing RBs.	Over observation window	No relation
		The type of the outage (i.e. hardware, software malfunctioning, radio or transport part, etc.)	Over observation window	No relation
	List of network topologies to be evaluated			
	#	Description		Environment
	1	Single and multiple cells, simple scenario		standard propagation models
	2	Real world scenarios		Rural, urban.
VII Relation to other Control Mechanisms	Use cases that have an impact on this use case			
	Cell outage prediction and compensation. ⁽⁵⁾			
	Use cases that this use case has an impact on			
	Cell outage compensation.			
VIII Dependency on System Implementation Specifics	Dependency on		Rating 0 (low) ... 9 (high)	Description
	LTE standardisation uncertainty		0	--
	Vendor specific implementations		7	--

Use Case	Cell outage compensation			Classification	self-healing
I Scope	Location of Algorithm			No. of Controlled / Considered Cells	Impact w.r.t. other cells
	local	centralised	distributed		
		(X)	X	neighbour cells	Major
	Relevant BTS Types		Macro	Micro	Indoor/Femto
		X	X	(X) ²³	
II Information Exchange	Between network elements			Frequency	Status w.r.t. standardisation
	Between eNodeB and eNodeB: radio link failure rate			minutes	Might be needed

²³ It is still to be clarified if indoor/femto cells will be considered for this use case

	Between eNodeB and eNodeB: Uplink interference				minutes	Might be needed	
	Between eNodeB and eNodeB: Downlink interference				minutes	Might be needed	
	Between eNodeB and eNodeB: Cell load				minutes	Might be needed	
	Between eNodeB and eNodeB: signal strength of served eNodeBs (reported by UEs)				minutes	Might be needed	
	From UE to eNodeB: Downlink interference				minutes	Needed	
	From UE to eNodeB: PCI and signal strength of serving and surrounding eNodeB				minutes	Ongoing	
	Between (instances) of SON functions				Frequency	Status w.r.t. standardisation	
	Trigger from Cell outage detection				Event based	Might be needed	
	Across SON API				Frequency	Status w.r.t. standardisation	
	None						
III Required Measurements	#	Name	Layer	Entity	No. of measured cells	Frequency of measurements	Status w.r.t. standardisation
	1	Signal strength (from serving and neighbors)	1	UE	>1	ms	Standardised
	2	Cell load	2	eNB	1	s	Might require standardisation
	3	Downlink interference	2	UE	>1	ms	
	4	Uplink interference	2	eNB	1	ms	
	5	HO failure rate	3	eNB	1	event based	Might require standardisation
	6	Radio link failure rate	3	eNB	1	event based	Might require standardisation
	7	Number of served UEs	3	eNB	1	s	
	8	Relative Coverage Indicator ²⁴	TBD	eNB	> 1	s	Might require standardisation
IV Control Parameters	#	Name	Layer	Range	Updates		Status w.r.t. standardisation
					scale	freq.	
	1	Cell power and pilot power	1	-	-	min	Ongoing
	2	Antenna tilt	1	-	-	min	
	3	Intra/inter-RAT handover parameters	3	-	-	min	
	5	Neighbour lists	3	n/a	n/a	min	
	6	Tracking areas	3	n/a	n/a	min	
	7	Load balancing parameters	3	-	-	min	
V Mobility	How does mobility impact the algorithm?				0 (low) ... 9 (high)	0	

²⁴ It could help to evaluate the performance of the algorithm and to decide whether further changes have to be done or not. The relative coverage indicator should provide information about how much of the uncovered area (after the cell outage) is covered again during/after the compensation. It should be related to a theoretical maximal possible coverage dependant on site-to-site distances, etc.

And Traffic	How much do traffic characteristics impact the algorithm? 0 (low) ... 9 (high)			3
VI Algorithm Assessment	List of evaluated measurements			
	#	Name	Layer	Period of evaluation
	1	Hand over failure rate	3	Minutes
	2	Radio link failure rate	3	Minutes
	3	Cell coverage area	1	Minutes
	4	Cell capacity	2	Minutes
	5	Number of served UEs	3	Minutes
	6	Relative coverage indicator	TBD	Minutes
	List of Objectives			
	#	Name	Aggregation	Relation w.r.t. other objectives (e.g. dominance)
	1	Larger coverage area than before compensation	Measurement #3 and #6	high
	2	More users supported than before compensation	Measurement #5	medium
	3	Grade of service should increase when compensating	Measurement #1 and #2	medium
	4	Capacity should not decrease	Measurement #4	low
List of network topologies to be evaluated				
#	Description	Environment		
1	Simple, regular scenarios	hexagon		
2	Real world scenarios	rural, urban		
VII Relation to other Control Mechanisms	Use cases that have an impact on this use case			
	Cell outage detection, cell outage prediction			
	Use cases that this use case has an impact on			
Self-optimisation of physical channels, interference control, GoS/QoS related parameter optimisation, handover parameter optimisation, RACH optimization				
VIII Dependency on System Implementation Specifics	Dependency on	Rating 0 (low) ... 9 (high)	Description	
	LTE standardisation uncertainty	5	Some measurements needs to be standardized	
	Vendor specific implementations	5	There will probably be some room for vendor specific solution	