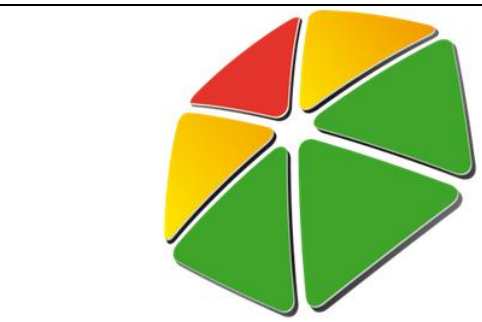

INFSO-ICT-316384 SEMAFOUR

D6.7

Exploitation Roadmap

Contractual Date of Delivery to the EC:	August 31st, 2015
Actual Date of Delivery to the EC:	August 31st, 2015
Work Package	WP6 - Dissemination and Exploitation
Participants:	NSN-D, ATE, EAB, iMinds, FT, TID, TNO, TUBS, NSN-DK
Authors	***Mehdi AMIRIJOO***, Hans van den BERG, Luis Miguel Campoy CERVERA, Andreas EISENBLÄTTER, Thomas KÜRNER, Sana Ben JEMAA, Lars Christoph SCHMELZ, Kathleen SPAEY, Kristina ZETTERBERG
Reviewers	Colin WILLCOCK, Thomas KÜRNER, Kathleen SPAEY
Estimated Person Months:	7
Dissemination Level	Public
Nature	Report
Version	1.0
Total number of pages:	38

Abstract: The SEMAFOUR project has produced novel Self-Organising Network (SON) solutions for networks comprising multiple layers and Radio Access Technologies (RAT), as well as an integrated SON management system, aiming at simplifying network management and increasing network performance. The objective of this deliverable is to identify key results from SEMAFOUR that can be exploited by the SEMAFOUR consortium members, and to describe means taken to achieve efficient internal dissemination and exploitation.

Keywords: SEMAFOUR, SON, Self-organisation, Exploitation, Exploitation Roadmap, Exploitation plans, Exploitable Results, Internal Dissemination

Executive Summary

The SEMAFOUR project has produced novel SON solutions for networks comprising multiple layers and RATs, as well as an integrated SON management system. These results will increase network performance and provide a unified view on the performance of the complex heterogeneous network environment and allow its efficient control and operation. In order to evaluate the solutions developed, the SEMAFOUR project has invested significant effort in developing accurate models and scenarios, as well as, a common simulation infrastructure SON laboratory (SONLAB).

The objective of this deliverable is to identify results from SEMAFOUR that can be exploited by the SEMAFOUR consortium members, and to describe means taken to achieve efficient internal dissemination and exploitation. In creating this document, each partner has analysed the practical benefits obtained and considered how knowledge will be exploited in their operational business. Overall, the network vendors have a better understanding of benefits of new SON features in terms of performance and manageability, and of how to develop new products. The network operators are better able to select the right features at the right time given traffic demand increase and introduction of new services. The consultants are better equipped to advise customers on SON capabilities, and the universities are better able to direct their research. As a whole, the consortium partners have taken significant steps towards increasing their respective capabilities in meeting future challenges in network automation and management.

List of Authors

Partner	Name	E-mail
NSN-D	Lars Christoph Schmelz	christoph.schmelz@nokia.com
ATE	Andreas Eisenblätter	eisenblaetter@atesio.de
EAB	Mehdi Amirijoo Kristina Zetterberg	mehdi.amirijoo@ericsson.com kristina.zetterberg@ericsson.com
iMinds	Kathleen Spaey	kathleen.spsaey@uantwerpen.be
FT	Sana Ben Jemaa	sana.benjemaa@orange.com
TID	Luis Miguel Campoy Cervera	luismiguel.campoycervera@telefonica.com
TNO	Hans van den Berg	j.l.vandenberg@tno.nl
TUBS	Thomas Kürner	kuerner@ifn.ing.tu-bs.de

List of Acronyms and Abbreviations

3GPP	Third Generation Partnership Project
API	Application Programming Interface
CAPEX	Capital expenditure
CDS	Central Demo Server
CM	Configuration Management
CPU	Central Processing Unit
CTO	Chief Technology Officer
DSA	Dynamic Traffic Steering
DSS	Decision Support System
EU	European Union
FP7	Seventh Framework Programme
GUI	Graphical User Interface
ICT	Information and Communications Technology
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
IPR	Intellectual Property Rights
KPI	Key Performance Indicator
LTE	Long Term Evolution
MD	Management & Diagnosis
NGMN	Next Generation Mobile Networks
OPEX	Operating Expenditure
OSS	Operations Support System
PBSM	Policy-Based SON Management
PM	Performance Measurement
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RAT	Radio Access Technology
RFI	Request For Information
RSRP	Reference Signal Received Power
RSS	Received Signal Strength
SME	Small and Medium-sized Enterprise
SON	Self-Organising Network
TS	Traffic Steering
UMTS	Universal Mobile Telecommunications System
WLAN	Wireless Local Area Network
WP	Work Package

Table of Contents

1 Introduction

The objective of this deliverable is to identify those results from SEMAFOUR that can be exploited by the SEMAFOUR consortium partners, and to describe means to achieve internal dissemination and exploitation. The current document covers the exploitation activities, while a report on dissemination is presented in D6.8 [4]. This deliverable mainly focuses on how the specific results of the project are relevant and of value to each of the project partners individually, and on internal dissemination activities within the organisations of the partners. D6.8 [4] on the other hand reports on activities that are mostly of a public nature (presentations at workshops and conferences, publications, organisation of workshops, standardisation activities, etc.) or of benefit to the overall project (cooperation with the advisory board or with the operational department of operators).

Exploitable results from SEMAFOUR can broadly be divided into three main areas. A first set of results involves the development of multi-RAT / multi-layer SON functions. These functions provide a closed control loop for the configuration, optimisation and failure recovery of the network across different RATs, i.e., Universal Mobile Telecommunications System (UMTS), Long Term Evolution (LTE), Wireless Local Area Network (WLAN) and cell layers (macro, micro, pico, femto). Numerous SON functions have been developed and, in addition, a set of SON design principles has been created that facilitate proper operation between SON functions [1].

A second set of results involves the design and development of an integrated SON management system. This system interfaces between operator-defined performance objectives and the set of multi-RAT / multi-layer SON functions. It provides a unified view on the performance of the complex heterogeneous network environment and allows its efficient control and operation. To this end, four areas have been identified that cover the self-management of a radio system [1].

A third set of results addresses means to evaluate the developed functions, where a significant effort has been spent in developing models, scenarios and simulation tools in order to achieve as realistic results as possible, see Deliverable D2.5 [2]. In particular, a complete LTE network has been modelled for the entire city area of Hannover, Germany. This model featuring for example, 3D propagation models using building data and macroscopic traffic and individual user mobility. Further, a common simulation infrastructure SON laboratory (SONLAB) has been developed within the SEMAFOUR project, as well as a demonstrator showcasing the complete SEMAFOUR approach to self-organisation for future networks.

The SEMAFOUR consortium consists of nine partners from six European countries, as shown in Figure 1. The consortium is well balanced among industrial and academic partners. On the industry side the project includes Ericsson (Sweden) and Nokia (Germany, Denmark), as infrastructure manufacturers, and Orange (France) and Telefónica (Spain), as mobile network operators. They have been complemented by the SME atesio (Germany), which brought in its expertise on algorithms for planning and optimisation of large scale radio networks. On the academic / research institutes side the project includes TNO (The Netherlands), iMinds (Belgium), participating through its member universities of Antwerp and Ghent, and TU Braunschweig (Germany).

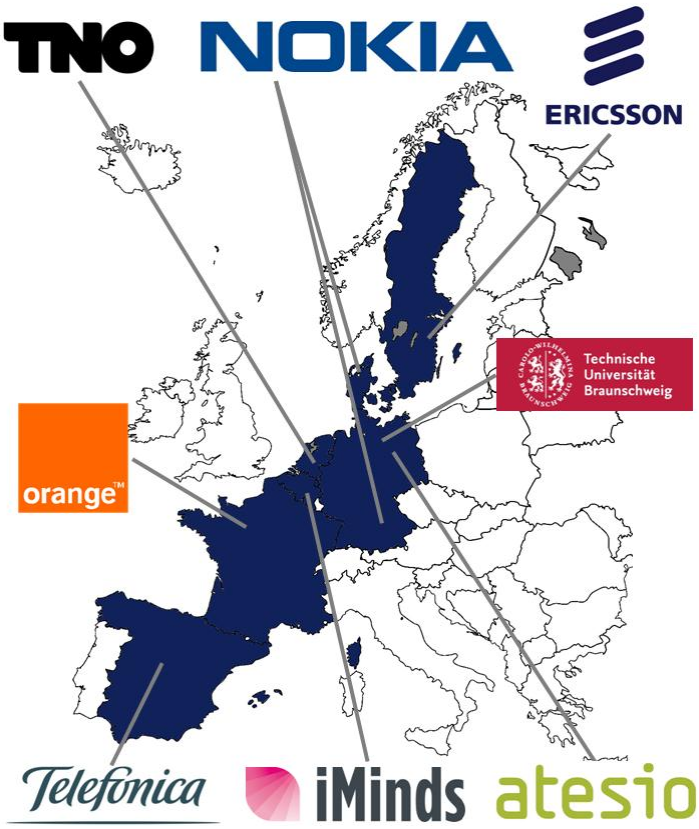

Figure 1: Partners in the SEMAFOUR project.

From the experience and results gained, the SEMAFOUR consortium members are now in a good position to capture results and integrate the above mentioned results into the ongoing work of the corresponding organisations. In creating this document, each partner has analysed the practical benefits obtained and considered how knowledge will be exploited in their operational business.

Overall, the network vendors have a better understanding of benefits of new SON features in terms of performance and manageability, and of how to develop new products. This will be key in determining roadmaps and to guide the internal product development units in designing appropriate features. The network operators are better able to select the right features at the right time given traffic demand, services usage, and quality requirements. The consultants are better equipped to advise customers on SON capabilities, as they have increased their capabilities in simulation tools, algorithms, and standardisation. Universities are better able to direct their ongoing and future research towards areas relevant for the industry. As a whole, the consortium partners have taken significant steps towards increasing their respective capabilities in meeting future challenges in network automation and management.

This document is organised in the following way:

- Chapter 2 presents a high-level description of how the different SEMAFOUR consortium partners plan to exploit the results and knowledge gained in the project in their respective organisations (vendors, operators, SME, and research institutes).
- Chapter 3 lists key solutions and deliverables produced in the SEMAFOUR project, in the three areas mentioned above: (*i*) multi-RAT / multi-layer SON functions, (*ii*) integrated SON management system, and (*iii*) simulators and demonstrators.
- Chapter 4 presents more details about how each of the identified results in the three areas listed above is relevant and of value to each of the consortium partners. In particular, we describe how the capabilities of the respective organisation has advanced by understanding future network management and self-organisation challenges and needs, developing of

algorithms and architectures, carrying out performance evaluations (including modelling and calibration), and implementing demonstrators.

- Chapter 5 then gives an overview of the different internal dissemination activities leading to potential commercial impact, including specific plans for commercial exploitation that are currently under consideration. This chapter only applies to vendors, operators, and SMEs.
- Final conclusions are given in Chapter 6.

2 Exploitation Plans of the Partners

This chapter presents a high-level description of how the different SEMAFOUR consortium partners plan to use and exploit the results and knowledge gained in the project.

2.1 Nokia (Germany and Denmark)

Nokia has, and will exploit, the gained knowledge, and the results achieved within the SEMAFOUR project work in several ways.

At first, the concepts developed within SEMAFOUR, the achieved results, and the knowledge gained during the evaluation of these results provide the basis for further research activities within the Nokia Technology & Innovation department, for example, in terms of continuing and deepening the work on Integrated SON Management (Work Package 5 - WP5) towards cognitive management solutions, or using the results achieved within WP4 as a basis for further research work towards 5G SON. Furthermore, the results of SEMAFOUR will also impact the existing and future research cooperation and project definition with universities, research institutions and industrial research partners. The knowledge and experience gained with the common simulation environment (simulator architecture and simulation scenarios) and the demonstrator environment developed within WP3 will influence the corresponding tooling landscape within Nokia Technology & Innovation.

Secondly, the interaction with the relevant Nokia business units (Mobile Broadband and Operations Support Systems) has already been set up from the beginning of the project. This allowed on the one hand ensuring that the use cases that have been defined and selected in the first phase of SEMAFOUR have a high relevance for the business units, and on the other hand the continuous dissemination of results and findings towards the business units contributed to the SON feature verification and development within the corresponding Nokia products, and to decision making on future product and feature release planning. The composition of the SEMAFOUR consortium considerably supported gaining a high footprint and visibility of the project's results within Nokia.

Thirdly, the results and insights achieved within SEMAFOUR gave and give input to the standardisation work conducted within Nokia. Of considerable impact thereby was the strong interaction between the Nokia people participating in the project and the standardisation delegates, in particular, 3GPP RAN2 and RAN3 groups.

Finally, the results and findings of the SEMAFOUR that were published at international conferences and workshops (for example, VTC, NOMS, IM, ISWCS) supported the international visibility of Nokia's research activities and efforts.

2.2 Atesio

In three domains atesio is already exploiting or intends to exploit results from the SEMAFOUR project. These domains are:

1. SON-light and decision support systems (DSS) for operational (radio) network evolution
2. Policy-based (radio) network management
3. Simulations of SON and SON management in multi-RAT multi-layer networks

In the following paragraphs, the topics and how atesio approaches exploitation are sketched.

SON in particular and, more generally speaking, a high degree of automation of the (radio) network planning, configuration, and optimisation processes have been key concerns for operators and vendors alike. atesio's background is in the automation of network analysis, planning, and optimisation using mathematical / scientific tools. Ideas and methodologies from the SEMAFOUR project related to the Management & Diagnosis (MD) functionality (WP5) as well as the Decision Support System for Operational Network Evolution (DSS-ONE, WP5) are used to strengthen atesio's NGPS platform. In effect, insights from the SEMAFOUR project further enlarge the application domain of NGPS beyond its use for traditional network planning and optimisation tasks. In particular, the tighter linking of functionalities as well as their automated chaining in NGPS is well received by network operators, e.g., on the occasion of the SEMAFOUR poster presentations (Andreas Eisenblätter: Decision support

system: operational network evolution; Ulrich Türke: SonLab - multi-party simulation platform) at the RAN World Event in January 2015.

Policy-Based SON Management (PBSM, WP5) builds on the idea of evaluating the context of cells (local network structure, geography, traffic profile, mobility patterns) before deciding on how to (re-) configure the parameters of (radio) network elements. Based on the context of the cell, for example, and the objectives of the operator, an optimised parameterisation of the cell is determined. This basic approach has been adopted by atesio's NGPS platform and allows for an elaborate definition of rules and policies in the definition of network planning and optimisation tasks. In the context of out-tasking such activities to atesio, operators can specify their expectations for the (automated) processing of such task in great detail. This ability improves the operators' ability to fine-tune the expectations for SON-light functionalities, which take care of network planning and optimisation using, among others, traditional Configuration Management (CM) data, Performance Measurement (PM) data, and radio planning data. In summary, PBSM principles applied to atesio's NGPS platform ease the definition of out-tasking results, which, in turn, fosters the acceptance of the underlying business model.

atesio's SONLAB platform is designed to orchestrate complex, possibly distributed radio network simulations including SON and management functions. The platform supports complex simulation on realistic scenario data. atesio has developed a SONLAB Dashboard in order to support SONLAB users in monitoring simulations (of increasingly high complexity). Features of the dashboard are a geo-referenced display of the network configuration as well as the active users and their cell association (among others). SONLAB is being used extensively within the project, and there are first commercial requests by partners to use SONLAB after the end of the project as well as from outside of the consortium.

The use of the platform is particularly interesting for realistic scenario data (environment models, user mobility, network evolution over time, etc.). The realism reflected in the simulation scenarios goes beyond what is commonly used in R&D. Generating such scenario data is particularly complex, and hardly any such scenario data is commercially available or in the public domain. For the SEMAFOUR project this has largely been accomplished by TUBS with some contributions from atesio. Both partners are jointly pursing activities to commercialise their scenario generation capabilities. (To which extent the SEMAFOUR data can be used outside of the consortium is still subject to negotiations with providers of basic input data (e.g., building structures) that are mandatory for the generation process.

Still in this context, atesio has established a way to display parts of SEMAFOUR demonstration content within websites (basically reusing technologies from the Dashboard). This feature provides the ability to play back simulation traces on a geo-referenced network display. This feature supports interactive panning and zooming in the display while watching the playback. Provided the use of this feature on the SEMAFOUR website will stimulate interest, atesio intends to create a commercial offer around this.

In addition to the above technical/business objectives, the project provides staff at atesio with a strong environment for training and practicing in-depth technical skills, which are hard to acquire during university education.

Finally, competences, tools, and reputation gathered during the project are instrumental to winning operators' and vendors' attention in the acquisition phase. The elaborate demonstration capabilities established within the project (WP3) are used to showcase ideas, approaches, and solutions.

2.3 Ericsson

Ericsson will exploit results from the SEMAFOUR project and knowledge gained during the project in the different steps of the work towards developing SON features and a management system for SON features for future mobile networks.

The knowledge gained and the results and conclusions reached within the SEMAFOUR project will lead the way for product decisions and the development of SON functionality and SON management functionality within Ericsson product development. When it comes to impacting Ericsson features, we have taken a series of measures to disseminate the results to and ensure close interaction with the product units and product managers. This close interaction has enabled input on the selection of

relevant use cases to go forward with in SEMAFOUR, but also for product units LTE and Operations Support System (OSS) to provide input on the feasibility of solutions in the end products. Finally, the close interaction will also take results closer to industrialisation and implementation of the solutions in product releases.

Through the SEMAFOUR project, a network with research organisations and companies working within the SON field is established. This network will be useful also outside the SEMAFOUR project work, enabling research cooperation and contacts important for future standardisation.

The knowledge gained in the SEMAFOUR project will give insights and point the direction for work within standardisation, and standardisation proposals can be given as a result of the findings within SEMAFOUR.

The scenarios and the simulator developed within the SEMAFOUR project will be reused also for internal simulations. Finally, the demonstrator developed within the SEMAFOUR project will provide a means to show the gains of SON and SON management both internally within Ericsson and externally.

Ericsson as a company has also published the results from SEMAFOUR – together with the partners – in internal and external media such as scientific journals and papers and well-positioned conferences, see D6.8 [4]..

Finally, the results from the SEMAFOUR project will also impact and influence future directions taken in Ericsson Research. This is especially important when it comes to future opportunities and features developed at Ericsson. To this end, outcomes from the SEMAFOUR project will be used as input to research studies on SON in multi-RAT and multi-layer, SON management functionality, as well as SON opportunities and solutions for future networks. This will apply for internal research studies, but also for cooperation between Ericsson and academia, such as PhD and master thesis projects.

2.4 iMinds

iMinds exploits the results and knowledge obtained in the SEMAFOUR project mainly in research and educational activities. The iMinds teams involved in the SEMAFOUR project are affiliated with the MOSAIC research group at the University of Antwerp and the IBCN research group at the University of Ghent. Results and experience achieved in the SEMAFOUR project have an immediate positive impact on the research of PhD students working in these teams.

iMinds has gained knowledge on LTE, self-management and SON functions for multi-RAT and multi-layer scenarios in general, and on how to optimise the performance of highly mobile users, on LTE/Wi-Fi traffic steering techniques and on nomadic networks in particular. Further, the SEMAFOUR project enabled the iMinds teams to enlarge their experience with the OMNET++ simulation tool and the simulator developed with it, with the openEPC emulation platform and with the SONLAB tool, and with the development of additional components for these tools. Also expertise in building a distributed demonstration platform and a tool for editing a demonstration video has been gained.

Research results are exploited in papers and by giving presentations at international workshops and conferences (for example VTC, ISWCS, ICWMC). Obtained knowledge and competences, including the increased experience with simulation and demonstration tool development will be further exploited and used for participation in and the definition of new national and European R&D projects, with partners from academia and industry.

Further, the building up of knowledge on the mentioned areas has an immediate impact on teaching activities, and as such on the education of the students that follow the telecommunication courses at the University of Antwerp or the University of Ghent. In particular the content of the courses “Mobile and Wireless Networks” in the master Computer Science at the University of Antwerp and the course “Mobile Broadband Access Networks” in the master Computer Science Engineering at the University of Ghent will be updated with new insights obtained from participation in the SEMAFOUR project. For this last course, also a new lab session has been developed which makes use of the SEMAFOUR demonstrator.

2.5 Orange

Orange Labs intends to benefit from the unified self-management solutions, particularly from the integrated SON management, to simplify the management of its next generation radio access networks, which are increasingly complex. The innovative solutions provided by the project will allow the operator to better control its radio access networks and to control the Quality of Service (QoS) in the next releases of equipments endowed with Self-Organising Network (SON) features.

The SEMAFOUR results will be exploited by Orange Labs as follows:

1. By assessing the performance of evolved SON functions proposed in SEMAFOUR, Orange Labs can determine which SON function will bring a significant gain. SEMAFOUR project results will then help to define the functions that should be required in network equipment as well as the related requirements to be provided to network vendors and to standardisation. The SEMAFOUR activity on Active Antenna Systems has been a valuable input to internal discussions and decisions on this technology. SEMAFOUR results have been presented to anticipation teams and the expertise acquired in the project helped to define/evaluate trials on this technology. Moreover, this activity resulted in two contributions to 3GPP RAN3 standardisation group, cosigned by Orange among other partners of the project.
2. Considering SON coordination and management research activity, Orange will use the expertise gained in the project to ensure that SON functions are used optimally, in a coordinated manner. The unified management framework aims at guaranteeing that the whole SON system fulfils the high level operator objectives and hence is in line with the vision of Orange on SON management. The SEMAFOUR demonstrator has been presented internally to Orange in several occasions, in particular during the 2014 Orange Labs Research Exhibition. The concept of the integrated SON management is supported internally in Orange and two theses on Cognitive Network management for 5G (as an extension of the SEMAFOUR Integrated SON management concept) have been approved and will start in autumn 2015.

2.6 Telefónica I+D

Telefónica I+D provides the most advanced vision on networks technologies evolution, in order to elaborate the Telefónica Group (a main Mobile Network Operator with more than 300 millions customers in 25 countries) network evolutions strategic plans. Also specific developments, adapted to most strategically or differential network deployment and management are directly generated by Telefónica I+D for the Telefónica Group.

Telefónica has, in much of its current regional operations, simultaneously deployed three networks, that constantly need to be monitored and optimised: 2G/3G/4G, with different, generally using more than two vendors in each network. The complexity of managing these networks is increasing (and it is not clear now that 2G end of live will be sooner than 5G deployment), therefore the automation of day-to-day activities are needed to speed up work and reduce errors.

The SEMAFOUR project has provided two types of contributions towards Telefónica's aims of constant improvement of its mobile network efficiency, and cost reduction.

On one hand, the insight into the integrated SON management architecture and procedures will influence the already ongoing SON technology deployment, providing a broader view the full SON framework, and open the possibility of multi-layer multi-RAT approach for current and future radio access networks. Providing a new approach for functional split between current Centralised / Decentralised SON functions, and their interactions.

On the other hand, the decision support system, will be used on current networks as an differential tool for bottle neck detection aiding on network upgrading decisions, so that they are not performed too soon (wasting CAPEX), nor too late (impacting user perceived QoS).

Dissemination of SEMAFOUR achievements and approaches inside the Telefónica group, has raised attention to new SON procedures. Telefónica Global Chief Technology Officer (CTO) has promoted recently (in 2014) a major SON Request For Information (RFI) with many vendors participation. In this RFI integration interfaces enabling multivendor SON solutions have been included, accordingly

with SEMAFOUR approach for integrating different SON functionalities in a common integrated SON framework.

The concept of a Decision Support System has helped to improve Telefónica's in-house dimensioning tool, used by Telefónica business units on the decision making process if network upgrades are required to offer the users the Quality of Experience they are demanding. The new improvements will be applied then in the short/medium term by any Telefónica business unit for optimising the CAPEX, just upgrading the networks where it is really needed (where the users are demanding it).

2.7 TNO

As a non-profit organisation for applied research it is TNO's mission to initiate and support innovations in the Information and Communications Technology (ICT) industry, and in other domains where ICT plays a crucial role, through contract research and consultancy. The SEMAFOUR project has provided an excellent opportunity for TNO to expand its leading-edge expertise on mobile network operations to the promising field of self-management of heterogeneous (multi-layer, multi-RAT) mobile networks. The gained knowledge, both on heterogeneous networking technologies in general and on self-management, will and has already been used to support and advise mobile network operators.

We distinguish roughly three phases in the role of TNO regarding the introduction of self-management in heterogeneous mobile networks.

- Phase 1 (2013-2015): In the past few year we have provided consultancy for network operators regarding the potential benefits and implications of self-management for network operations and regarding the actually available functionalities on the short and medium term based on the state-of-the-art of this technology. Based on this TNO is supporting network operators in taking strategic decisions regarding future investments in network equipment and the organisation of their network operations.
- Phase 2 (2015-2018): In the coming years we will support network operators in making concrete introduction plans, and in preparing tenders and assessing offers from vendors. Simulation tools, assessment methodologies and deep knowledge on self-management concepts and methods as developed in SEMAFOUR will be used here to evaluate and trade-off different scenarios and solutions.
- Phase 3 (2018-2022): Next we will provide consultancy on expansion and optimisation of self-management concepts and functionalities, including decision support systems as developed in SEMAFOUR in WP5 for fully automated generation of plans for network evolution and other major network modifications that require human involvement for actual implementation (building).

As an important spin-off, our research results have been exploited in the form of scientific papers (several additional ones will appear), which are useful for strengthening TNO's technological position.

Finally, besides application to (heterogeneous) mobile networks, some of the generated knowledge and experience will also be applied in the context of other systems and domains where the need for self-management is also emerging (e.g., Cloud infrastructures and Smart Mobility, where we are involved together with our TNO colleagues primarily working in these domains).

2.8 Technische Universität Braunschweig

The main task of Technische Universität Braunschweig is higher education and research. Therefore results from SEMAFOUR are used both in education and research. In education results will be integrated into various courses on Mobile Communications. Already in the summer term 2015 methods and results on traffic modelling and mobility modelling from TUBS' SEMAFOUR activities on setting up realistic scenarios found their way into the lecture "Modeling and Simulation of Mobile Radio Systems". Within the next year a revision of the lectures on "Planning of terrestrial Radio networks" and "Advanced Topics in Mobile Radio Systems" is scheduled targeting the integration of chapters on SON in the syllabus, which will yield further exploitation of SEMAFOUR results in education. Furthermore two Ph.D. students heavily involved in SEMAFOUR are now working

towards their Ph.D. thesis, which will be based significantly on results from SEMAFOUR. On the research side results have been published at international conferences (VTC, and others) and will be submitted to journals (e.g., IEEE Transactions on Vehicular Technolog). Furthermore results knowledge exchange has been done with international bodies e.g., mainly COST IC 1004 and Next Generation Mobile Networks (NGMN) alliance and IEEE 802 to a limited extend. Both the publications and the results knowledge exchange will strengthen the position of TUBS within the scientific communities working on cellular networks. Of specific value is the gained knowledge and the simulation software (SiMoNe – Simulation of Mobile networks) developed at TUBS within the project. The expertise and availability of the software tools form a solid basis for the acquisition and execution of further projects. Already in the third year of SEMAFOUR this tool has been used to execute an industry project with a car-manufacturer and is further used in a collaborative project with the Qatar Mobile Innovations Center funded by the Qatar National Research Fund. Furthermore the availability of software tools and scenario data as developed within the project has been proven as an ideal starting point for final student projects enabling TUBS' students to do projects using cutting edge technology.

3 Overview of Exploitable Results

During the lifetime of the SEMAFOUR project, an inventory of the exploitable results of the project has been made, by way of a living table. The table with the identified results up till the end of Year 2 was already shown in Deliverable 6.5[3]. Table 1 in this chapter shows the identified results for the whole project duration. In Chapter 4, more details about how each of the identified results is relevant and of value to each of the consortium partners are given.

Description of exploitable result / knowledge	**Exploitable product(s) or measure(s) in which the result / knowledge will be used**	**Sector(s) of application**	**Timetable for use**	**Deliverable(s)**	**Owner and other beneficiaries involved**
Extension of existing (LTE) simulation tools	Research studies; verification of concepts and products; consultancy; participation in research projects; PhD theses; SONLAB clients; SiMoNe software	Vendors; mobile network operators; research; education; SON developers	2013 - 2018	D2.5 [2]	NSN-D; ATE; EAB; iMinds; TNO; TUBS; NSN-DK
Extension of simulation platform	SONLAB platform, Central Demo Server (CDS)	Vendors; mobile network operators; research; education; SON developers	2013 - 2020	D2.5 [2], D3.4 [5]	ATE
Knowledge on (integrated) multiple layer and multiple RAT SON	Algorithms; research studies; competence building; ideas for new concepts and solutions; participation in research projects; updates of course material; PhD theses; consultancy	Vendors; mobile network operators; research; education	2013 - 2018	D4.2 [7], D4.3 [8]	NSN-D; ATE; EAB; iMinds; TID; TNO; TUBS; NSN-DK

Knowledge on (self-optimisation of) (multiple layer) LTE/Wi-Fi interworking and traffic steering (TS)	Research studies; competence building; ideas for new concepts, solutions and products; PhD theses; consultancy; algorithms; workshops; research projects; input to standardisation	Vendors; mobile network operators; education; research; standardisation	2013 - 2018	D4.2 [7], D4.3 [8]	EAB; iMinds; TNO; NSN-DK
Knowledge on (self-optimising) dynamic spectrum allocation (DSA) and interference management	Research studies; competence building; ideas for new concepts, solutions and products; algorithms	Mobile network operators; vendors; education; research	2014 - 2018	D4.2 [7], D4.3 [8]	EAB; TNO; TUBS
Knowledge on (self-optimising) active antenna systems using vertical sectorisation and virtual cells	Algorithms; consultancy; research projects; research studies; competence building; ideas for new concepts and solutions; input to standardisation	Mobile network operators; vendors; education; research; standardisation	2014 - 2018	D4.2 [7], D4.3 [8]	EAB; Orange; TNO
Knowledge on (SON functions for) tackling the problem of high-mobility users and on core network handover procedures	Algorithms; updates of course material; PhD theses	Research; education	2014 - 2018	D4.2 [7], D4.3 [8]	iMinds
Knowledge on design principles for SON functions	Research studies; competence building; ideas	Mobile network operators; vendors; research	2014-2018	D4.2 [7], D4.3 [8]	EAB; iMinds; NSN-DK, Orange

	for new concepts, solutions and products; algorithms; research projects				
Knowledge on self-organising network functions for future networks	Research studies; competence building; ideas for new concepts, solutions and products; algorithms; research projects	Mobile network operators; vendors; education; research	2015-2018	D4.4 [9]	EAB; iMinds; Orange; TUBS
Knowledge on integrated policy-driven SON management and its requirements	Consultancy; research studies; competence building; ideas for new concepts and solutions; feedback to business and operational entities as contribution to strategic discussions; research projects; input to standardisation	Mobile network operators; vendors; education; standardisation	2013 - 2018	D5.3 [10]	NSN-D; ATE; EAB; Orange; TID; TNO; TUBS; NSN-DK
Knowledge on the detection and (root cause) analysis of undesired network behaviour (instabilities, oscillations) caused by the operation of a SON system	Consultancy; research studies; competence building; ideas for new concepts and solutions; research projects; input to standardisation	Mobile network operators; vendors; standardisation	2014 - 2018	D5.3 [10]	NSN-D; Orange
Knowledge on decision support systems	Consultancy; input to research studies; competence building; ideas	Mobile network operators; software tool suppliers	2014 - 2018	D5.3 [10]	ATE; EAB; TID; TNO; TUBS; NSN-D

	for new concepts and solutions; participation in research projects				
Knowledge on operators' view on importance and timeline for SON functions and on operators' view on SON management	Competence building; directions for research studies	Vendors	2013 - 2016	Internal document on advisory board questionnaire results	NSN-D; ATE; EAB
Experience on the development of a distributed demonstration platform	Demonstrator; consultancy	Research; mobile network operators	2014 - 2018	D3.4 [5], D3.5 [6]	NSN-D; ATE; EAB; iMinds; TNO; TUBS
Reference scenario for system level simulations	Research using realistic simulation data	Research	2014 - 2018	D2.5 [2]	NSN-D; ATE; TUBS
Improvement of in-house radio dimensioning tools	Consultancy on network upgrades based on traffic / capacity predictions	Mobile network operators	2014 - 2016	D5.3 [10]	ATE; TID
Deployment and experience with OpenEPC platform	OpenEPC testbed; participation in research projects	Research; education	2013 - 2018	D4.2 [7]	iMinds
Experience with the recording of a demonstration video	Participation in research projects	Research	2013 - 2018	D3.5 [6]	iMinds; TNO
Experience on simulator calibration	Competence building on simulator development	Research; education	2013 - 2018	D2.5 [2]	NSN-D; EAB; iMinds; NSN-DK, TUBS

Table 1: Overview table of identified exploitable results.

4 Exploitable Results per Partner

In this chapter the exploitable results that were identified in Chapter 3 are revisited, and it is detailed how they are relevant and of value to each of the project partners.

4.1 Nokia Germany

Description of exploitable result / knowledge	**Detailed explanation**
Extension of existing (LTE) simulation tools	In the context of the activities on realistic network simulations the knowledge on modelling handover procedures and modelling Wi-Fi performance could be extended. Both a handover client and a Wi-Fi client have been integrated into a server / client based platform. The acquired knowledge will be used to improve internal radio network and SON simulation tools that are used for proof-of-concept and demonstration purposes.
Knowledge on (integrated) multiple layer and multiple RAT SON	In the activity of LTE/Wi-Fi Traffic steering we have gained further knowledge from the extensive sensitivity studies on the proposed SON mechanisms. Additionally, we have gained knowledge on the potentials of intra-LTE DSA algorithms.
Knowledge on integrated policy-driven SON management and its requirements	Within the WP5 work on SON management, knowledge regarding the management of a SON system in today's networks has been built up, on the one hand based on the analysis of feedback from network operators, and on the other hand based on the gained knowledge during implementation and evaluation of the Integrated SON Management concepts developed within SEMAFOUR. The input from the operators regarding KPI definition, KPI target values, network context (e.g., cell location, cell type, user classes) and KPI weighting helped to build knowledge required to automatically operate and manage a SON system and hence a SON-enabled network. The acquired knowledge plays an important role regarding concept and solution development for SON management and operation solutions, e.g., definition of technical objectives and network context information. At a first stage this impacts the work within Nokia research, but the findings will thereby also influence the development of corresponding products and services.
Knowledge on the detection and (root cause) analysis of undesired network behaviour (instabilities, oscillations) caused by the operation of a	Within the WP5 work on SON coordination, knowledge has been acquired on means for the avoidance of interactions between SON functions through the appropriate and conflict-free definition of technical objectives, i.e., context-specific and weighted KPI targets. The findings will primarily influence the research work on SON management and SON coordination (including ongoing research projects on SON verification and troubleshooting). Furthermore, the results of this internal research work influence the improvement of existing products for SON coordination.

SON system	
Knowledge on decision support systems	Nokia expects in particular the bottleneck detection components of decision support systems (DSS) to become an important part of future network planning and SON solutions, for example, as part of SON verification tools. The results of the functionalities developed as part of the SEMAFOUR decision support system therefore helped in building knowledge and gaining some experience in what such tooling is capable of, and use this knowledge and experience as a first baseline towards decision making on future products and features.
Knowledge on operators' view on importance and timeline for SON functions and on operators' view on SON management	Within SEMAFOUR WP5 work, the analysis of requirements regarding the management of a SON system, based on feedback from network operators, leads to an improved knowledge on the operator's view on SON management. The acquired knowledge provided input regarding operator's priorities regarding SON implementation, in particular, trust in a SON system and transparency of SON actions. The knowledge has already led to the revision of concepts and approaches on SON management within SEMAFOUR, but also internal research projects.
Experience on the development of a distributed demonstration platform	In the context of planning and developing the SEMAFOUR demonstrator, knowledge and experience has been built up with respect to a modular approach for implementing a common demonstrator platform, and its distributed operation on different physical machines and platforms. This knowledge will also impact the planning, design and implementation of Nokia internal research simulation and demonstration platforms, in particular with respect to modularisation and distributed simulation execution.
Reference scenario for system level simulations	In the context of SEMAFOUR simulation and demonstration integration, knowledge and experience on defining of a set of realistic (real-world) reference scenarios for various independent use cases have been acquired, including the provisioning of these scenarios by means of a central scenario database. The knowledge about the scenario, and the process and definition of reference scenarios for distributed simulations will impact the future design and implementation of Nokia internal simulation environments within research.
Experience on simulator calibration	Nokia uses different tools for its internal research and development purposes. The experience gained within SEMAFOUR on the complexity and the required processes and procedures that are required to align different simulation environments such that the results can be made comparable helped and helps in particular within Nokia's research departments. This experience will influence future decision on the setup of the tooling landscape.

Table 2: Exploitable results relevant to Nokia Germany.

4.2 atesio

Description of exploitable result / knowledge	**Detailed explanation**
Extension of	The complex realistic network scenarios considered within the project require

existing (LTE) simulation tools	extensions of atesio's platform for network analysis / simulation in terms of refined models as well as in terms of extended functionalities. Among others, capabilities for more detailed analysis of intra- and inter-systems handovers are added. The enhanced functionalities as well as the acquired knowledge will improve atesio's tool-based network analyses and consulting competences.
Extension of simulation platform	The SONLAB platform for hosting multi-party multi-RAT multi-layer radio network simulations has been extended and enhanced in response to project needs. Among others, a dashboard has been developed. Through the dashboard simulation participants can administer simulation platforms as well as start and stop simulation runs. Moreover, the dashboard provides (graphical) access to the progress of the simulation, the exchange of information among simulation clients, technical details on communication and processing times / delays. An engine for playing back recorded (SONLAB) simulation traces has been largely improved during the project. This engine has been used as Central Demo Server (CDS) for the project's demonstrator (WP3).
Knowledge on (integrated) multiple layer and multiple RAT SON	Knowing how to plan and optimise the complex (multi-RAT and multi-layer) networks with and without SON is a key competence for operators and their suppliers alike. atesio is acquiring and enhancing such competence, e.g., when conducting or assisting integrated simulations of several SON functions within SONLAB. This competence shall improve atesio's capability to carry out consultancy projects is this domain.
Knowledge on integrated policy-driven SON management and its requirements	It is expected that (operator) policies in combination with SON will become instrumental parts of future network management. atesio is acquiring and enhancing competence, e.g., in the work on the Policy-based SON management use case, in the course of the project. This competence shall improve atesio's capability to carry out consultancy projects.
Knowledge on decision support systems	atesio expects decision support systems (DSS), such as for operational network evolution, to become competing tools to traditional radio network planning tools. In fact, in the long run, DSS may replace traditional planning tools. atesio is therefore building up competences in designing key functionalities for decision support systems in order to make such components available for in-house use, for consultancy projects, and potentially as individual software components in the longer run.
Knowledge on operators' view on importance and timeline for SON functions and on operators' view on SON management	Refining the understanding on what parts of SON operators intend to use and when, helps atesio to adjust the scope and timing of consultancy offers.
Experience on	While designing and developing the SEMAFOUR demonstrator, experience with a

the development of a distributed demonstration platform	modular implementation of a multi-purpose demonstrator platform and its distributed operation on different physical machines and platforms has been gained. This know-how will be leveraged by atesio in the future design and implementation of simulation software (including the further development of SONLAB).
Reference scenario for system level simulations	atesio has keen interest in the establishment of (realistic) reference scenarios that support SON simulations. Such scenarios are known to exhibit more details and variations than typical hexagonal / homogeneous scenarios, which sometimes entail merely modest challenges for SON functions. The establishment and future availability of such scenarios, even under a restricted access regime for internal use only, is therefore already seen as an achievement. It remains desirable, however, to be able to share such scenarios beyond the project consortium.
Improvement of in-house radio dimensioning tools	Cf. the statement on Decision Support Systems above.

Table 3: Exploitable results relevant to atesio.

4.3 Ericsson

Description of exploitable result / knowledge	**Detailed explanation**
Extension of existing (LTE) simulation tools	An existing simulation tool has been extended with Wi-Fi capabilities in a joint effort by SEMAFOUR and internal projects. The simulator will be used also in future studies on co-existence between LTE and Wi-Fi.
Knowledge on (integrated) multiple layer and multiple RAT SON	Understanding of how SON functions interact in an integrated multi-layer and multi-RAT network is gained through numerous studies performed in the project. This knowledge is spread within the organisation and is used as input for further research studies as well as product development. Exposure of these studies through publications and presentations also builds to the perception of Ericsson as a thought leader in the area.
Knowledge on (self-optimisation of) (multiple layer) LTE/Wi-Fi interworking and traffic steering	Understanding of self-optimising access selection/traffic steering and load balancing methods between LTE and Wi-Fi is gained through the use case study on *Multi-Layer LTE / Wi-Fi Traffic Steering*. This knowledge is spread within the organisation and is used as input for further research studies as well as product development. Exposure of these studies through publications and presentations also builds to the perception of Ericsson as a thought leader in the area.
Knowledge on (self-optimising)	Understanding of the potential of dynamically assigning spectrum to different layers in a RAT as well as to different RATs is gained through the use case study on *Dynamic Spectrum and Interference Management*. The knowledge is spread within

dynamic spectrum allocation and interference management	the organisation and is used as input for further research studies as well as product development. Exposure of the results through publications and presentations also builds to the perception of Ericsson as a thought leader in the area.
Knowledge on (self-optimising) active antenna systems using vertical sectorisation and virtual cells	Understanding the potential of self-optimisation of vertical sectorisation for LTE and virtual cells for LTE and future networks is gained through the use case study on *Active/Reconfigurable Antenna Systems*. The knowledge is spread within the organisation and is used as input for further research studies as well as product development. The published results from the SEMAFOUR project have also been used as input for a master thesis project performed within Ericsson. Exposure of the results through publications and presentations also builds to the perception of Ericsson as a thought leader in the area.
Knowledge on design principles for SON functions	Understanding of methods and procedures for analysing coordination needs between SON functions and means to resolve conflicts during the design time of the SON functions is gained through the use case *SON Design Principles*. This knowledge is spread within the organisation and is used as input for further research studies as well as product development. Exposure of these studies through publications and presentations also builds to the perception of Ericsson as a thought leader in the area.
Knowledge on Self-Organising network functions for future networks	Understanding of scenarios and technologies for future mobile networks and needs of self-organising functions is gained through this activity. This knowledge is spread within the organisation and is used as input for further research studies as well as product development. Exposure of these studies through publications and presentations also builds to the perception of Ericsson as a thought leader in the area. Also these results will be used for future research projects.
Knowledge on integrated policy-driven SON management and its requirements	Insights to the operator needs and implementation possibilities for controlling the SON functions through high level policies is gained through the study on *Policy Based SON Management*. The insights are spread within the organisation and are used as inspiration and input for further research studies, as well as a basis for discussions between research and product development departments.
Knowledge on decision support systems	Understanding of the potential of a decision support system advising the operator on potential upgrades is gained through the use case study on *Dynamic Spectrum Allocation and Interference Management*. The knowledge is spread within the organisation and is used as inspiration and input for further research studies, as well as a basis for discussions between research and product development departments. Exposure of the results through publications and presentations also builds to the perception of Ericsson as a thought leader in the area.
Knowledge on operators' view on importance and timeline for SON functions and on operators'	Insights and understanding of operators' views and needs in terms of SON functions and SON management is gained through the study on *State-of-the-art in Radio Network Management* as well as through regular meetings with the SEMAFOUR *Advisory Board* members. The insights are spread within the organisation and are used as inspiration and input for further research studies, as well as a basis for discussions between research and product development departments.

view on SON management	
Experience on the development of a distributed demonstration platform	Experience has been gained with the development of the Time Client [5], involving Graphical User Interface (GUI) programming and interaction with other components. This experience will be used in future projects and for the development of future demos.
Experience on simulator calibration	Understanding of the impact of different simulator models and simulation approaches has been gained through the simulator calibration that has been performed within WP2 and WP4. This experience will be useful for the involved persons in continued work with simulator tools internally within Ericsson.

Table 4: Exploitable results relevant to Ericsson.

4.4 iMinds

Description of exploitable result / knowledge	**Detailed explanation**
Extension of existing (LTE) simulation tools	A dynamic LTE system simulator written using OMNET++ has been extended with extra functionality (to support multiple network layers, with new mobility models and network layouts, with new (SON) algorithms related to high-mobility). Interfacing of the simulator with the SONLAB platform of atesio has been performed, allowing collaborative simulations and the calibration of our simulator with the simulators of other partners. An additional SONLAB client implementing the high mobility SON algorithms was written in Python. Writing the CPU intensive parts in C++ and providing this component as a Python module using the Python/C Application Programming Interface (API) further enhanced the performance of the client. The simulator and the extensions made to it in the SEMAFOUR project, and the experience gained by developing and extending the simulation tools, will be used in PhD research, in future research projects and for master theses.
Knowledge on (integrated) multiple layer and multiple RAT SON	During the course of the SEMAFOUR project, knowledge on multi-layer and multi-RAT SON functions and their integration has been gained. This knowledge will be exploited in PhD research, in future research projects and in education.
Knowledge on (self-optimisation of) (multiple layer) LTE/Wi-Fi interworking and traffic	During the course of the SEMAFOUR project, knowledge on LTE/Wi-Fi interworking and traffic steering and the self-optimisation thereof has been gained. This knowledge will be exploited in PhD research, in future research projects and in education.

steering	
Knowledge on (SON functions for) tackling the problem of high-mobility users and on core network handover procedures	During the course of the SEMAFOUR project, a lot of knowledge on tackling the problem of high-mobility users and on SON functions therefor, as well as on the intra-LTE signalling latency in the core network during handover, has been gained. Also knowledge on Dynamic Time Warping, a technique used in the algorithm development part of this use case, has been gained. This knowledge will be used in PhD research (the work performed in the SEMAFOUR high-mobility use case will be a core part of a PhD thesis at the University of Antwerp), in future research projects and in education.
Knowledge on design principles for SON functions	During the course of the SEMAFOUR project, knowledge on SON design principles has been gained. This knowledge will be exploited in PhD research and in future research projects.
Knowledge on self-organising network functions for future networks	In the SON for future networks activity, knowledge on nomadic networks has been gained. This knowledge will be exploited in future research projects and in education.
Experience on the development of a distributed demonstration platform	During the course of the SEMAFOUR project, experience has been gained with the development of a distributed demonstration platform, with GUI programming, and with the process of developing software that needs to have a uniform look-and-feel together with different partners. This experience will be used in future projects and for the development of future demos. The demonstration platform itself will be used at demonstration events.
Deployment and experience with openEPC platform	During the course of the SEMAFOUR project, knowledge on the Evolved Packet Core in general, and experience with the deployment and operation of the OpenEPC platform, and its features and limitations in particular, has been gained. This experience and knowledge will be used for extending the iMinds FIRE facilities, in future projects, in PhD research and for master theses.
Experience with the recording of a demonstration video	During the course of the SEMAFOUR project, experience with the setup and recording of a multi-screen demo, and with the editing of parallel recordings in a single demonstration video, has been gained. This experience will be used in future projects and for future demonstration video developments.
Experience on simulator calibration	The simulation calibration activity performed in the SEMAFOUR project allowed us to compare and align our LTE system simulator with the simulator tools used by other partners. The experience gained from this activity will be used in the further simulator developments.

Table 5: Exploitable results relevant to iMinds.

4.5 Orange

Description of exploitable result / knowledge	Detailed explanation
Knowledge on (self-optimising) active antenna systems using vertical sectorisation and virtual cells	Knowledge about the active antenna systems and in particular vertical sectorisation is an input for Orange for the evaluation of the potential gain of this feature.
Knowledge on design principles for SON functions	Knowledge on SON design principles has been gained during the project. This knowledge will be useful for the analysis of SON functions, potential conflicts between them and the needs for coordination.
Knowledge on self-organising network functions for future networks	The study on "Self-organizing network functions for future networks" conducted at the end of the SEMAFOUR project helped orienting Orange research activity on SON.
Knowledge on integrated policy-driven SON management and its requirements	Global management of a network with several SON functionalities is one of the main challenges in future (and legacy) networks. Policy driven SON management is an efficient and simple (from the point of view of the operator) way to cope with the increasing complexity of network operation and management tasks. Assessing the feasibility of a policy driven SON management system on a realistic network is an important input for Orange in its long term strategy.
Knowledge on the detection and (root cause) analysis of undesired network behaviour (instabilities, oscillations) caused by the operation of a SON system	During the course of SEMAFOUR, knowledge has been gained on the analysis, the detection and the resolution of conflicts and undesired behaviours due to the simultaneous operation of several SON functions. The experience gained in this activity is used to define mid-term recommendations for the operation of SON functions in Orange networks, and in research activities for the design of an automated SON Coordinator (proof of concept, recommendation for the implementation, etc).

Table 6: Exploitable results relevant to Orange.

4.6 Telefónica I+D

Description of	Detailed explanation

exploitable result / knowledge	
Knowledge on (integrated) multiple layer and multiple RAT SON	Adapting the Telefónica vision of SON functionalities to a full framework of multi-layer and multi-RAT environment. This knowledge will be adapted to the already deployed situation in most of the Telefónia business units.
Knowledge on decision support systems	Telefónica will deploy and use, in the short/medium term the predictive tool deployed under the SEMAFOUR project framework, in order to optimise the CAPEX usage in new deployments. Taking advantage of the prediction tool, Telefónica will be able to evaluate the radio resource usage, as a function of the foreseen traffic demand from users in any specific area.
Knowledge on integrated policy-driven SON management and its requirements	The correct administration of SON functionalities of a Radio Access Network (RAN), needs to be adapted to the high-level targets perceived from the market demands. The understanding of how to proceed on SON functionalities to adapt RAN behaviour to the foreseen needs, will not only increase the final users perceived Quality of Experience (QoE), but also lower the Operating Expenditure (OPEX) needed to maintain it.
Improvement of in-house radio dimensioning tools	Strategic investments in new RAN technology or equipment need to be carefully evaluated, being one of the main strategic decisions on already working, or under deployment, mobile networks. In order to optimise deployment cost and match the investment with the real network needs, the long view forecast being included in the SEMAFOUR project will allow the optimisation of infrastructure investments in Telefónica.

Table 7: Exploitable results relevant to Telefónica I+D.

4.7 TNO

Description of exploitable result / knowledge	**Detailed explanation**
Extension of existing (LTE) simulation tools	A simulation tool has been extended through implementation of several SON functions, small cell layer and enhanced traffic/application models. The simulator will be used for supporting further internal research and in consultancy projects for operators and service providers.
Knowledge on (integrated) multiple layer and multiple RAT SON	The more general knowledge gained on multiple layer and multiple RAT SON has been and will be exploited in consultancy projects, e.g., for operators investigating at a strategic/tactical level the pros and cons of introducing self-management for their heterogeneous networks.
Knowledge on	The obtained results regarding algorithms for traffic load distribution between LTE

(self-optimisation of) (multiple layer) LTE/Wi-Fi interworking and traffic steering	and Wi-Fi have been published at scientific conferences and will be used as a basis for further research in this area. Some material has also been used for courses at university provided by TNO. Knowledge and experience on this topic has also been (and will be) used in consultancy projects, mainly for operators (e.g., assessment of products from different vendors).
Knowledge on (self-optimising) dynamic spectrum allocation and interference management	Knowledge and experience gained on dynamic spectrum allocation and interference management will be used in consultancy projects (e.g., advice to operators on potential benefits of this functionality, feature assessment and benchmarking of products from different vendors, etc.). Further, the obtained results have been published at scientific conferences and will be used as a basis for further research as well as for courses at university provided by TNO.
Knowledge on (self-optimising) active antenna systems using vertical sectorisation and virtual cells	Developed algorithms for self-optimisation of vertical sectorisation by active antenna systems have been implemented in our simulator, which will be used for supporting further research and for consultancy purposes. Results have been published at scientific conferences. The obtained knowledge will also be used for courses at university provided by TNO.
Knowledge on integrated policy-driven SON management and its requirements	The obtained knowledge on integrated policy based SON management (PBSM) will be used in consultancy projects, mainly for network operators. In addition, the generic aspects of PBSM have also been used in other self-management contexts in the ICT domain, e.g., self-management of cloud infrastructures.
Knowledge on decision support systems	The developed concepts, algorithms and knowledge regarding the fully automated decision support system (DSS) serve as a basis for the development of tools that will be used for consultancy (network operators, service providers); we are also considering commercial exploitation of these tools.
Experience on the development of a distributed demonstration platform	The obtained experiences regarding the development of demonstration platforms and giving demonstrations is used in other research projects for promoting their results as well as in consultancy projects for TNO's customers.
Experience with the recording of a demonstration video	Experience with the setup and recording of a multi-screen demo, and with the editing of parallel recordings in a single demonstration video, has been gained. This experience will be used in future research and consultancy projects.

Table 8: Exploitable results relevant to TNO.

4.8 Technische Universität Braunschweig

Description of exploitable result / knowledge	Detailed explanation
Extension of existing (LTE) simulation tools	For system level simulation at TUBS performed within the project, the simulation platform SiMoNe has been established and is further developed by TUBS. This platform is already used in other research projects and final student projects. There is a large potential for licensing this platform to industrial partners, which has been partly realised already in an industry project.
Knowledge on (integrated) multiple layer and multiple RAT SON	The knowledge gained on multiple RAT/multiple layer SON will help TUBS to acquire further projects in this area. The knowledge will be also of interest for consultancy for network operators.
Knowledge on (self-optimising) dynamic spectrum allocation and interference management	The knowledge gained on DSA along with the implemented solutions will help TUBS to acquire further projects in this area. The knowledge will be also of interest for consultancy for network operators, especially in the area of regulations and spectrum issues.
Knowledge on self-organising network functions for future networks	This activity has clearly a large potential for the acquisition of further research projects. Especially the work done on Cognitive PBSM and Device-to-Device Communication are either part of new proposals or already ongoing projects.
Knowledge on decision support systems	The knowledge gained on decision support systems along with the implemented solutions will help TUBS to acquire further projects in this area. The knowledge will be also of interest for consultancy for network operators.
Experience on the development of a distributed demonstration platform	The knowledge gained from this platform can be used to set-up demonstrators in other research projects. The concept of integrated real terminals into the simulator/demonstrator, which was done by TUBS within SEMAFOUR, is currently ongoing for the application in another research project.

Reference scenario for system level simulations	Apart from making parts of the reference data publicly available, which may contribute to the scientific reputation, impact and visibility, the reference scenarios also have a clear potential for commercial exploitation. Talks on both possibilities are ongoing.
Experience on simulator calibration	The simulation calibration activity performed in the SEMAFOUR project allowed us to compare and align our LTE system simulator with the simulator tools used by other partners. The experience gained from this activity will be used in the further simulator developments as well as in education.

Table 9: Exploitable results relevant to Technische Universität Braunschweig.

4.9 Nokia Denmark

Description of exploitable result / knowledge	**Detailed explanation**
Extension of existing (LTE) simulation tools	In the context of the LTE/Wi-Fi Traffic steering activity we have extended our system level simulator with improved WLAN modelling and traffic steering algorithm enhancements.
Knowledge on (integrated) multiple layer and multiple RAT SON	In the activity of LTE/Wi-Fi Traffic steering we have gained further knowledge from the extensive sensitivity studies on the proposed SON mechanisms. Additionally, we have gained knowledge on the potentials of intra-LTE DSA algorithms.
Knowledge on (self-optimisation of) (multiple layer) LTE/Wi-Fi interworking and traffic steering	In the activity of LTE/Wi-Fi Traffic steering we have identified the pros and cons of the proposed SON algorithms for traffic steering between LTE and Wi-Fi. This knowledge has been exploited for supporting the internal Nokia discussion and standardisation activities on 3GPP/WLAN interworking. As an example, the use of LTE RSRP thresholds and WLAN RSS-alike thresholds has been agreed in 3GPP for Release 12.
Knowledge on design principles for SON functions	Insights on how to operate simultaneously multiple SON algorithms has been acquired based on the SON design principles' activity. These insights will impact the future design and implementation of SON functions in particular within the company's research activities.
Knowledge on self-organising network functions for future networks	The insights gained within the study on License Assisted Access LTE helped in understanding the characteristics and requirements for LAA-LTE regarding the channel selection mechanism, and paved the way for further Nokia internal research and evaluation work, and corresponding activities in 3GPP standardisation.
Knowledge on	Knowledge has been gained within the LTE/Wi-Fi Traffic steering activity in terms

integrated policy-driven SON management and its requirements	of policy based management such as “avoiding LTE congestion” in high load conditions, and “prioritising LTE system” in low and medium load conditions. This knowledge has been used for instance in the SEMAFOUR traffic steering demonstration and will furthermore be used within future development work in the area of multi-RAT / multi-layer traffic steering, in particular regarding the upcoming 5G systems.
Experience on simulator calibration	Nokia uses different tools for its internal research and development purposes. The experience gained within SEMAFOUR on the complexity and the required processes and procedures that are required to align different simulation environments such that the results can be made comparable helped and helps in particular within Nokia’s research departments. This experience will influence future decisions on the setup of the tooling landscape.

Table 10: Exploitable results relevant to Nokia Denmark.

5 Internal Dissemination Leading to Potential Commercial Impact

The SEMAFOUR project performs pre-commercial research. The potential for commercial impact is enabled by the presence of relevant stakeholders in the project consortium: Nokia and Ericsson are two of the world's largest mobile communication equipment vendors, Orange and Telefónica are two leading mobile operators, and atesio is an Small and Medium-sized Enterprise (SME) developing support tools for mobile network planning and operations. During the course of the project, these partners performed several internal dissemination activities to communicate SEMAFOUR results internally to operational business units, product managers and system engineers. The goal of these activities is paving the way for commercial exploitation of the SEMAFOUR results. This chapter gives an overview of the different internal dissemination activities.

5.1 Nokia (Germany and Denmark)

Within Nokia there have been several means implemented in order to ensure that the SEMAFOUR work is in line with the interest and strategy of Nokia with respect to research and product generation, and that the results, findings and knowledge gained within SEMAFOUR are disseminated appropriately towards the other research departments and in particular to the relevant business units.

During the requirements and development phases of the project, weekly meetings of the SEMAFOUR team within Nokia (Germany and Denmark) have been held in order to align the different work topics and keep each other on track. During the implementation phase these meetings have been scheduled bi-weekly.

For dissemination of project results and findings inside the company, Nokia has implemented a weekly online lecture series (TechnoForum) where participants from all business units, research, and the technology strategy departments participate. From the SEMAFOUR project this forum has been used several times in order to disseminate the project scope, results, findings, and the estimated impact on standardization and products to a wide auditory. These presentations were:

- January 2013: SEMAFOUR project scope and goals, setup and content in particular of WP4 and WP5, first results on use cases including the Nokia preferences
- September 2013: First insights on building a common simulation environment within SEMAFOUR; in particular the first results on scenario definition and simulation calibration activities conducted as part of WP2 were presented
- December 2013: Short presentation on all WP4 and WP5 use cases, and a detailed presentation of the first results and findings on the Traffic Steering and Policy-based SON Management use cases; furthermore an overview about the status of the SEMAFOUR demonstrator
- January 2015: Detailed dissemination of the concept of Policy-based SON Management (WP5), the corresponding implementation and the acquired knowledge of this work. A focus was also on the expected impact on the SON management processes at the operator in case the developed solutions are implemented
- April 2015: Detailed dissemination of the concept and implementation of the SEMAFOUR demonstrator (WP3)

Each research project within Nokia is controlled through a steering board consisting of managers from the relevant business units. On a regular basis, the project status, results and findings are presented to the steering board members, in order to timely identify and discuss opportunities for Nokia's product and feature portfolio. During the SEMAFOUR project runtime these meetings have been conducted at least at a bi-annual basis, with additional meetings in case major results were delivered. In these meetings, also the project deliverables were presented and discussed. In particular, the steering board was also interested in the results of dedicated activities with the operators involved in the project (project partners as well as advisory board members) – this included, for example, the results of Activity 2.3 on the operators' feedback on SEMAFOUR use cases as well as the activities with Orange and Telefónica in 2014 on operational processes.

In the following a number of additional events are listed where SEMAFOUR results have been disseminated in Nokia internally.

- March 2014: selected results of SEMAFOUR (LTE/Wi-Fi traffic steering, Policy-based SON Management) have been presented during a 2-day seminar organised by the Technology & Innovation department, where managers and developers from the Mobile Broadband and Operations Support Systems business units participated. The results were well received and discussed.
- June 2014: the SEMAFOUR project status and results have been presented and discussed within a workshop at Nokia research; the focus was thereby on the Policy-based SON Management and Monitoring & Diagnosis
- February 2015: the SEMAFOUR demonstrator has been presented to a team of managers and product developers from the OSS business unit, with a scope on the Policy-based SON Management use case. This presentation led to a number of downstream meetings with the responsible OSS business teams.
- March / April 2015: the concept of the Decision Support System has been discussed with managers and developers from Nokia's OSS business units. There was a high interest in particular regarding the results on bottleneck detection.

The status and results of selected topics from the SEMAFOUR project have been described several times in the Technology & Innovation newsletter which is distributed company-wide.

5.2 atesio

atesio is an SME, where information is easily shared among all relevant colleagues. There has been no need for extensive, formal presentations. However, key achievements from the project have been shared regularly during internal status meetings and from time to time in technical seminars. As described in Section **Error! Reference source not found.**, atesio is already exploiting or intends to exploit the results from the project in three domains. The internal dissemination has helped to map ideas and technologies from the SEMAFOUR project to other business domains of atesio as well.

5.3 Ericsson

At Ericsson, there have been a series of measures taken in order to ensure that the selected studies in SEMAFOUR are chosen in accordance with Ericsson interest and strategy, as well, as to disseminate SEMAFOUR results to product units and product management. The following steps have been taken during SEMAFOUR in order to disseminate the results at Ericsson:

During the whole project run time, bi-weekly meetings have been held within the Ericsson SEMAFOUR team, with one invited participant from the systems department. In these meetings, status and solutions have been discussed for all studies where Ericsson is involved, and one in-depth presentation on a specific study area has been given in each meeting.

In September 2012, an overview presentation of the SEMAFOUR project scope and decided studies was held at Ericsson for Network Management research sector.

In October 2013, a presentation on the WP4 work on LTE/Wi-Fi traffic steering was held at Ericsson, to an audience including related research project members as well as product managers and people from the product systemisation organisation with interest in LTE and Wi-Fi interworking. Results from the controllability and observability study were shown, as well as the proposed SON algorithm and algorithm evaluation results.

In November 2013, the SEMAFOUR project was represented in an internal Ericsson workshop on SON, where SEMAFOUR presentations on the WP2 Advisory Board Questionnaire results, as well as results from the WP4 LTE/Wi-Fi Traffic Steering and Dynamic Spectrum Allocation use cases were given. In the audience were research project members, product managers and system engineers working with SON.

During December 2013 and January 2014, two presentations of the SEMAFOUR project scope, as well as WP4 and WP5 results, have been held internally at Ericsson to system engineers and product managers from product organisations working with network management and SON.

In April 2014, the SEMAFOUR project was represented in an internal Ericsson workshop on SON, and a SEMAFOUR status overview as well as the SON management solutions developed within WP5 were presented. In the audience were research project members, product managers and system engineers working with SON.

In June 2014, a presentation on the LTE/Wi-Fi traffic steering study, algorithm proposal and results was given in a WLAN workshop at Ericsson. Participants included researchers, product managers and 3GPP back-office and delegates working within the area.

In December 2014, a presentation summarising the status and results of the SEMAFOUR project was given within the LTE and Multi-Standard RBS Systems Management organisation at Ericsson.

In January 2015, the SEMAFOUR project was represented in an internal Ericsson workshop on SON, where a SEMAFOUR overview was given as introduction, followed by more detailed presentations of results from the WP4 studies on LTE/Wi-Fi Traffic Steering and Active Antenna Systems, and the WP5 study on the Decision Support System. The audience consisted of research project members, product managers and system engineers working with SON.

A cooperation with an Ericsson Research internal research project has been held for the work of developing the simulator used in the LTE/Wi-Fi traffic steering study. The final results have been presented to Ericsson Research, product units, and product managers in April 2015.

In May 2015, the final deliverables of WP4 (D4.3 and D4.4) have been disseminated and presented to key drivers and product managers in the business units. There has been a great interest received from the Business Units Radio and Business Unit Cloud&IP. In addition there has been a seminar arranged based on results from the LTE/Wi-Fi Traffic Steering use case. Further, on May 5, 2015, iMinds has given a telco presentation on the mobility prediction part of the SON function developed in the High Mobility use case towards research engineers from Ericsson interested in applying learning techniques to optimise radio performance.

The progress of the SEMAFOUR project has been described a couple of times in an Ericsson newsletter sent out to all employees of the Ericsson office in Linköping.

Finally, all SEMAFOUR deliverables are stored in the Ericsson document handling system, and release emails are sent out to the Ericsson internal SEMAFOUR interest group upon new deliverable releases. The interest group consists of researchers, system engineers and product managers within the organisation.

In terms of commercial impact, the SEMAFOUR project has studied areas where Ericsson has an interest in both short-term, such as LTE/Wi-Fi traffic steering and Active Antenna Systems (e.g., vertical sectorisation), and long-term such as Multi-RAT Dynamic Spectrum Allocation. As such the choice of the studies in SEMAFOUR overlaps very well with the interest of Ericsson. Given the very close interaction between SEMAFOUR and product managers and development units in Ericsson, there are excellent opportunities for impact on Ericsson future products.

5.4 Orange

The SEMAFOUR demonstrator was the most important tool for disseminating the SEMAFOUR results internally to Orange.

On December 13, 2013, the SEMAFOUR demo has been shown at Orange, to an audience of more than 20 people from Orange Research and Orange Operations.

At Orange, the SEMAFOUR demonstrator was presented in the Orange Labs Research Exhibition (25th to 28th of November 2014). The Research Exhibition is organised at Orange Lab in Issy-les-Moulineaux, and its aim is to offer Orange Group personnel and its partners a condensed view of the recent innovations and a look at future service and technology trends. The 2014 session consisted of 45 demonstrations and more than 1500 visitors from the Orange Group and its partners. The SEMAFOUR demonstration was focused on the PBSM use case. The demonstration attracted around 150 visitors:

- Orange Group attendees were from R&D (with key representatives from Orange Executive Commitee) and operational teams (Orange France, Europe Region optimisation team, Africa and Middle East Region optimization team and some African affiliates representatives, …)
- External visitors: DGA (the army), Thales, French regulator (ANFR), 'Celtic' representatives, vendors (ALU, Huawei), some engineering tools providers (SystemX, Astelia) and some research labs (Supelec, BCOM), …

5.5 Telefónica I+D

Telefónica I+D has promoted the SON activities and approaches carried out by the SEMAFOUR consortium, both in Telefónica Global CTO department and in specific regional business units. This dissemination has helped to shape current and long term view of Telefónica on SON technology, and has had also impact on ongoing RFIs of SON technology.

Also, different interviews on current state of the art of network management have been carried out in the course of SEMAFOUR project, being the outcomes of these interviews incorporated in the SEMAFOUR D5.4.

Telefónica staff involved in the SEMAFOUR project does periodically report, as part of the radio innovation team, to the full radio department inside the Telefónica Global CTO, providing insight in the most relevant outcomes, and on the SEMAFOUR vision of an integrated SON management function with multi-layer and multi-RAT approach.

5.6 Applications for Patents

No patents are filed yet from the SEMAFOUR partners at the moment of writing this deliverable.

6 Concluding Remarks

In this deliverable we have identified results from SEMAFOUR that can be exploited by the SEMAFOUR consortium partners, and in addition the means to achieve internal dissemination and exploitation have been presented.

Contributions and achievements from the SEMAFOUR project include novel solutions for multi-RAT / multi-layer SON functions, as well as an integrated SON management system, which interfaces between operator-defined performance objectives and the set of multi-RAT / multi-layer SON functions. These results will increase network performance and provide a unified view on the performance of the complex heterogeneous network environment and allow its efficient control and operation for increasingly complex networks. In addition, exploitable results also include models and scenarios, as well as a common simulation infrastructure (SONLAB), which are key to evaluate the solutions in realistic conditions.

Each partner has analysed the above mentioned results obtained and considered how knowledge will be exploited in their operational business. A detailed list of exploitable results has been presented as well as how each partner will make full use of those results in order to develop new products and services, create new business opportunities, and provide insight for future research. The industrial partners have taken numerous steps towards disseminating the SEMAFOUR results with internal product development units, through for example workshops, discussion with product managers, and internal consultancy. The SEMAFOUR partners are now in better position to meet future challenges in network automation. In particular, network vendors have a better understanding of benefits of new SON features in terms of performance and manageability, and of how to develop new products, the network operators are better able to select the right features at the right time, the consultants are better equipped to advise customers on SON capabilities, and the universities are better able to direct their research.

7 References

[1] EU FP7 SEMAFOUR, Deliverable D6.6, “Final report on a Unified Self-Management System for Heterogeneous Radio Access Networks”, August 2015.

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

[3] EU FP7 SEMAFOUR, Deliverable 6.5: “Report on Dissemination, Exploitation and Liaison Activities During Year 2”, August 2014.

[4] EU FP7 SEMAFOUR, Deliverable 6.8: “Final Report on Dissemination and Liaison Activities”, August 2015.

[5] EU FP7 SEMAFOUR, Deliverable 3.4: “Demonstration Scenarios (updated version)”, May 2015.

[6] EU FP7 SEMAFOUR, Deliverable 3.5: “Demonstrator (full-fledged, results-oriented version)”, May 2015.

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

[8] EU FP7 SEMAFOUR, Deliverable 4.3: “SON Functions for Integrated Multi-layer and Multi-RAT Networks”, May 2015.

[9] EU FP7 SEMAFOUR, Deliverable 4.4: “SON for Future Networks”, May 2015.

[10] EU FP7 SEMAFOUR, Deliverable 5.3: “Integrated SON Management - Policy Transformation and Operational SON Coordination (final results)”, February 2015.