CASE STUDY – PART I

SON and SON collaboration according to operator policies

Abstract

Through the SON and SON collaboration case study, this document describes the activities and research axes aiming at fully benefitting from the SON paradigm and allowing large scale deployment of SON features in LTE and LTE-Advanced networks:

- Design novel SON functionalities for future radio access networks, e.g. for heterogeneous LTE-Advanced networks (HetNets), or for home networks,
- Design solutions for coordinated operation of SON functionalities, and
- Integrate SON operation in a Unified Management Framework (UMF) developed in the UniverSelf project.

The innovations in SON presented in this case are expected to further simplify the network management, reduce its cost of operation and increase its performances and perceived quality of service.

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CONTENT

STORY LINE

Future radio access networks, e.g. those compliant with the Long Term Evolution (LTE) and LTE-Advanced (LTE-A), will be empowered by self-organizing network (SON) mechanisms that aim at automating the network management, at reducing the cost of network operation, and at increasing its efficiency (performance and Quality of Service/Experience levels). 3GPP standardization activities in recent years have given an important momentum to the SON technology, and a closer look at this activity sheds light on future trends, requirements and challenges to enable its massive deployment [1].

SON features in the first 3GPP Release 8 of LTE have focused on self-configuration such as set-up of transport interfaces between network nodes, and the neighbor cell identification via the Automatic Neighbor Relation (ANR) feature. These features aim at facilitating the network rollout. First self-optimization features include Inter-Cell Interference Coordination (ICIC) and intra (LTE) system load balancing. The following Releases (9-11) of the standard focus mainly on self-optimization features (functionalities) such as

- Inter-system load balancing
- Mobility robustness optimization (MRO)
- Random Access Channel (RACH) optimization
- Energy saving functionalities
- Minimization of Drive Test (MDT, paving the way to off-line self-optimization / healing)
- Cell outage compensation
- Parameter optimization in troubleshooting
- Coordination between MRO and mobility Load Balancing (MLB)

Based on this background, three research avenues have been identified within the “SON and SON collaboration” case study to fully benefit from the SON paradigm and to allow large scale deployment of SON features in LTE and LTE-Advanced networks:

- Design novel SON functionalities for future radio access networks, e.g. for heterogeneous LTE-Advanced networks (HetNets), or for home networks,
- Design solutions for coordinated operation of SON functionalities, and
- Integrate SON operation in a unified management framework (UMF) developed in the UniverSelf project.

Three research avenues are identified to fully benefit from the SON paradigm and to allow large scale deployment of SON features in LTE and LTE-Advanced networks:

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Figure 1 presents a network empowered by SON functionalities. The figure can correspond to the following story line: The business and operation teams of the operator foresee a traffic peak in the LTE cellular network that may lead to severe traffic saturation. This traffic forecast may lead to the following undesired results:

- Massive loss of served traffic and associate revenues
- Degradation of “DashBoard Global KPIs” (dropped and blocked calls, …)
- Loss of coverage due to excess of interference (related to high station loads)

Via a governance tool, the network operation expert launches a policy that triggers coordinated SON functionalities (e.g. load balancing between LTE and HSPA, traffic offloading via hybrid/open access femtocells, relays and small cells, ICIC, coverage and capacity optimization) aiming at absorbing the excess of traffic.

Coordination and conflict resolution of SON functionalities is a key enabler for large scale deployment of the SON technology. SON coordination is among the central activities of this case study.

The SON paradigm will impact all network phases, from the green field deployment of a new radio access network (e.g. LTE, LTE-Advanced), through the operation and optimization phase, and to the densification phase.

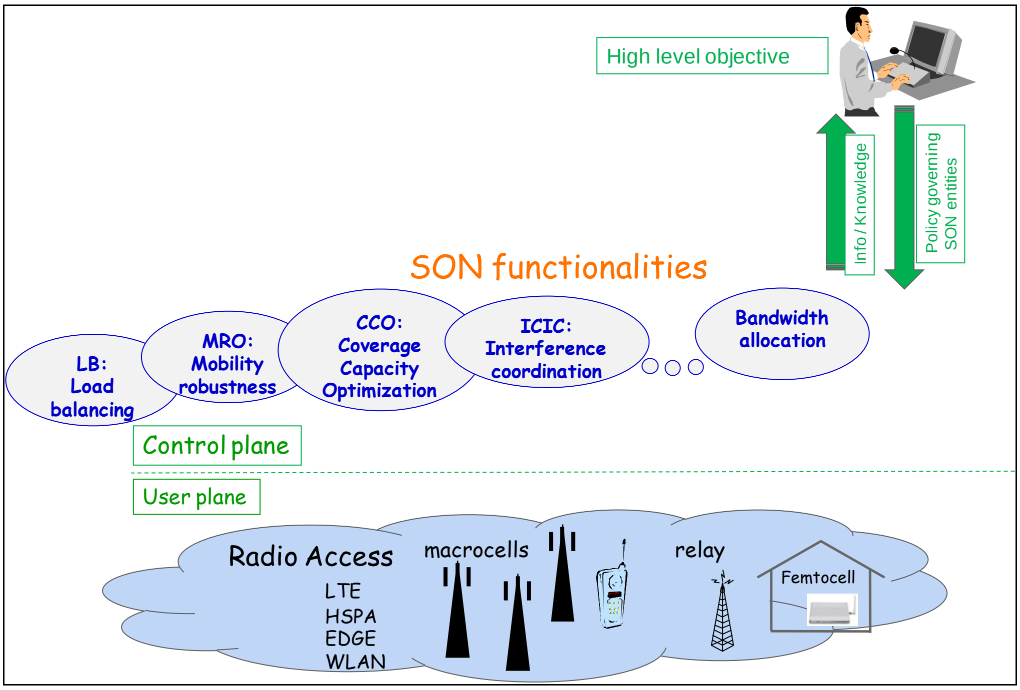

Figure 1: Management goals enforced by coordinated SON functionalities.

SON use cases

Among the use cases studied for the SON and SON coordination study are [2]:

- Handover parameter self-optimization (LTE)
- Interference self-management (LTE)
- Cell outage self-configuration and healing (WLAN)
- Coverage self-optimization in (femto/small cell network)

Coordination use cases:

- Self-optimization of mobility and load balancing (LTE)
- Coverage capacity optimization and Inter-Cell Interference Coordination (CCO), (LTE)
- Load balancing and CCO in macro-relay heterogeneous (HetNet) LTE-Advanced network (LTE)

Examples of parameters involved in the SON processes: mobility parameters consist of handover margin (HM), cell individual offset (CIO) and time to trigger (TTT); load balancing parameters are the pilot power or the HM; coverage parameters are the pilot power and antenna tilt.

Network topology

The case study targets end-to-end topology in Radio Access Network (RAN) segment, covering from the human console in the OA&M/OSS down to the wireless-mobile end-user device. The network entities / nodes involved are:

- Heterogeneous (macro / small cell / relay /femto cells) networks
- Multi-system mobile network
- Home network
- Multi-hop network
- OA&M/OSS supporting SON operation

Heterogeneous network is a central contribution of LTE-Advanced, introduced in 3GPP Release 10. It aims at providing high capacity all over the cell area by means of low power nodes (pico, femto, relays).

Multi-system network is part of the mobile network, which in the project's scope covers 3G (HSPA), LTE and LTE-A, and Wifi hotspots. In this context, load balancing and energy saving mechanisms are both of particular importance.

Home network technology covers LTE femtocell technology as well as Wifi (WLAN 802.11) technology.

Multi-hop network technology covers LTE-A/WiMax macro cell technology, and relay deployment covers LTE-A/WiMax microcell technology.

OA&M/OSS is considered here in the context of invoking high level policies and other activities related to network governance.

PROBLEM STATEMENT

The problem addressed in this case study is summarized as follows:

Managing radio access networks by means of SON entities operating in a coordinated manner to enforce high level operator goals

This problem can be translated into a list of sub problems:

Problem 1: *Design of novel SON functionalities for future radio access networks to efficiently manage network resources*

The introduction of new radio access networks and their evolutions calls for new SON functionalities of self-configuration, self-optimization and self-healing. As an example, new self-optimization functionalities are needed to operate heterogeneous networks with femo or relay stations.

Problem 2: *Design of SON algorithms which are both scalable, stable and robust*

SON solutions should be scalable to allow deployment of the SON functionalities in many network nodes. Furthermore, SON solutions should be stable and robust, with predefined limited performance degradation during any learning and self-optimization phase. Good operation of the SON functionalities should be achieved in the presence of noisy measurement and in different conditions of operation (propagation, traffic etc.)

Problem 3: *Coordinate SON functionalities*

Certain SON functionalities will operate simultaneously, in the same or in neighboring nodes. Different operation scenario can be envisaged: the SON functionalities share the same or different (possibly conflicting) performance or QoS objectives, and act upon the same or different parameters. Coordinated operation is necessary to achieve the performance gain from the different SON functionalities, while avoiding instabilities.

Problem 4: Integrate SON operation in a general operator-governed self-management framework

SON functions should be part of the management entity of the operator. The operator should be able to trigger SON entities to achieve certain high level management goals. To this end, the operator should be capable of

- Introducing operation or business goals. The goals should be high level ones, and provide performance objectives, constraints, priorities
- Translate high level goals to low level triggers of SON entities by means of policies. Policies should be derived
  - to account for the network operator priorities and objectives
  - to trigger the right SON entities (including activation/deactivation)
  - to account for constraints, conflicting goals

Problem 5: *Assurance*

The problem of assurance is central to convince operators to adopt/trust future autonomic solutions and to allow the operator to govern its networks. To this end, monitoring of the entire process involving SON entities is needed:

- Monitoring running policies
- Monitoring running SON entities
- Monitoring SON coordination
- End-to-end evaluation of the entire process

- Provisioning of a “panic mode”, allowing to shut down a SON functionality, and to automatically fall back to default parameters

Problem 6: *Proof of concept*
Evaluation/assessment of the case study via simulations/emulations, and project prototypes. The case study evaluation should encompass different building blocks defined by the Unified Management Framework (UMF) developed in the project.

The requirements coming out from the previous problem statement have been regrouped in Deliverable D41 [3].

MODELLING

The modelling of the case study is presented here. The different modelling approaches for SON coordination in the case study are also addressed. The case study lifecycle is decomposed in several phases each of which corresponds to a specific task that is performed within the case study. Triggers that enable the case study functionality and the actor, who interacts with the functionalities of this case study, are also identified.

Actor(s)

The actor of SON and SON collaboration case study is the operator. The operator should have the possibility to govern its networks and intervene in the autonomic process to enforce its high level policies.

Trigger(s)

The operator needs to express its business goals and requests via a friendly human to network interface, thus shifting from network management to network governance. Triggers for the operator consist of:

- New business goals, e.g. the deployment of a new service
- Business and operation teams of the operator foresee specific conditions to be handle, such as a traffic peak in the LTE cellular network that may lead to severe traffic saturation (described in the story line section)
- Conversely, a notification to the operator about an assurance functionality that there are major problems in the self-managed operation or a realistic risk for performance degradation.

Phases

Based on the previous problem statement, four main phases may be identified:

- Phase A - Determination of involved SON entities: the objective is to determine the involved SON entities/functionalities and their location based on the operator targets. Novel SON functionalities for future radio access networks, such as those stated in Problem 1, may be also exploited. This phase is also related to Problem 2.
- Phase B – Policy derivation: the objective is to generate specific policies of the SON entities based on the information about the involved SON entities and the operator targets. Hence, a policy-based framework is required for translating those business level goals/requests (high level policies) to low level policies and configuration commands. This phase has a strong relationship to Problem 4.
- Phase C – SON coordination: the objective is to coordinate the SON entities to allow efficiently enforcing policies. Moreover, different network performance problems are tackled through the coordinated SON entities. This phase represents Problem 3.
- Phase D – Assurance: the objective is to monitor the whole process and react, when degradation occurs, by triggering re-optimizations or by notifying the operator. This phase represents Problem 5.

The previous modelling analysis including actor, triggers and phases are depicted in Figure 2.

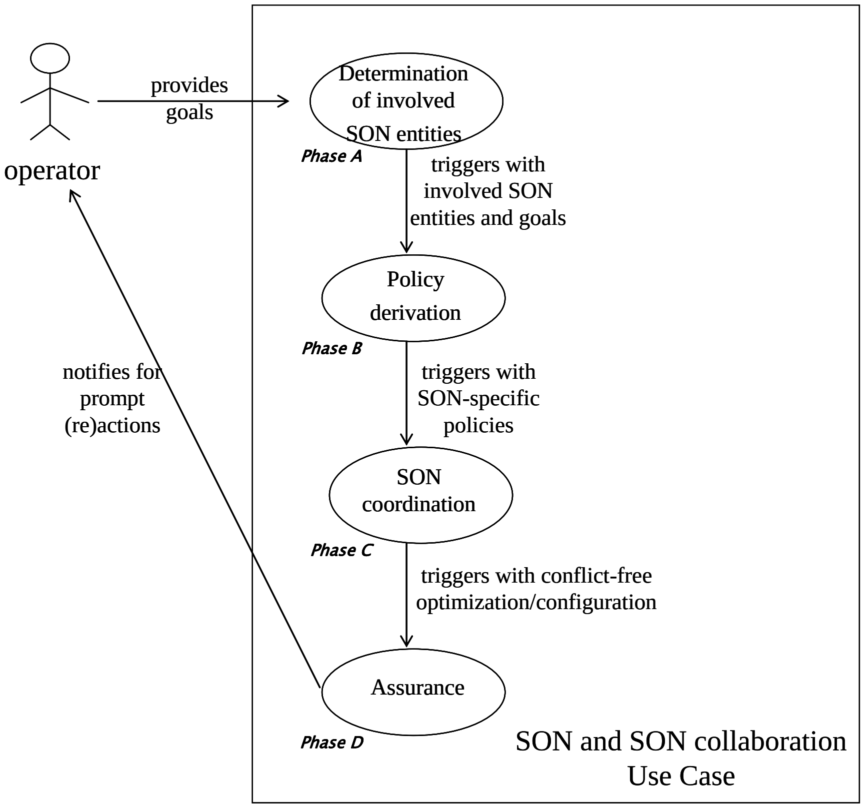

Figure 2. Case study diagram

Since Phase C and SON coordination problem is the main phase/problem of the case study, to which the demonstration/prototypes will be also related, the rest of the modelling analysis will focus on it.

The SON coordination problem is studied by means of a set of use cases, each of which involves two or more SON functionalities which need to be coordinated to ensure scalable and stable operation (see list of use cases in the Story line Section). Figure 3 presents an example of a use case. It consists of a heterogeneous LTE-Advanced network with macro- and (in band) relay stations. Three self-optimizing mechanisms are considered: 1. (Self-) optimize resource allocation between the (wireless) backhaul and the direct (eNode B and relay stations to users) links to increase the network capacity; 2. Adapt relay coverage; and 3. Coordinate interference.

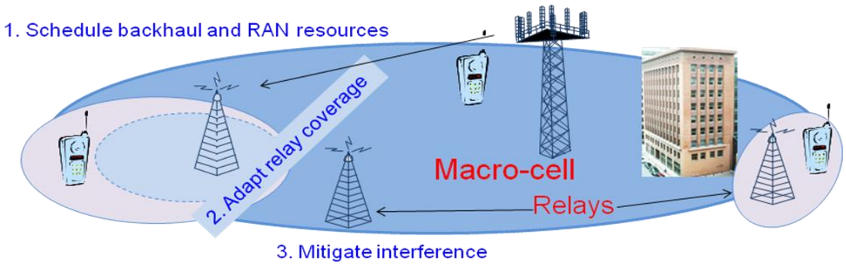

Figure 3. Heterogeneous network (HetNet) with macro and relay stations.

Concept Maps

To gain intuition on the interaction between the different control loops, to simplify the design of the coordinated SON functions and the detection of conflicts, a powerful graphical tool is utilized, namely the Concept Map (CM) [4]. The CM allows representing reasoning about the interactions of SON use cases. Figure 4 shows the CM for the HetNet use case (Figure 3).

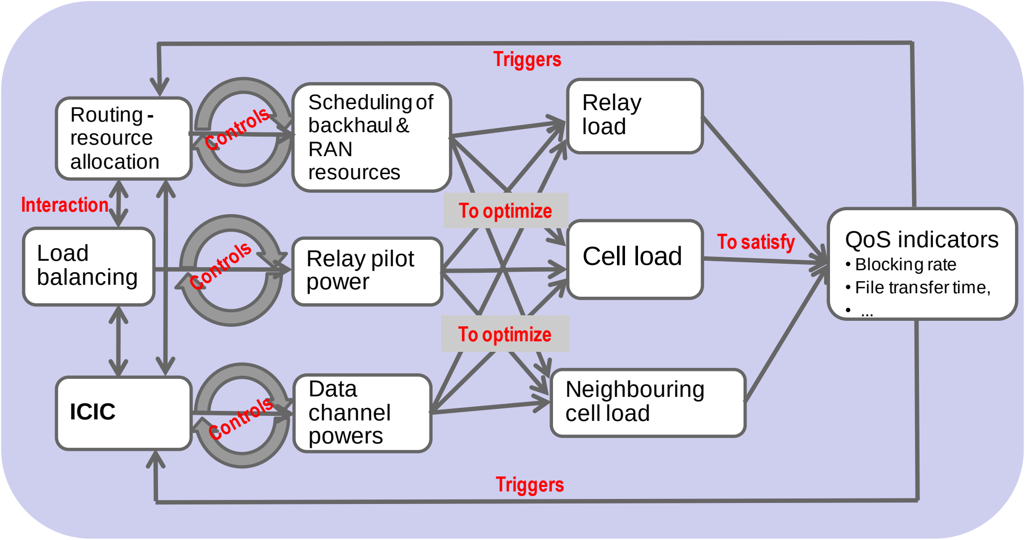

Figure 4. Concept Map for the HetNet use case with eNode B and relay stations.

Coordination approaches

The coordination model is an important enabler for the success of large scale deployment of SON functionalities. SON functionalities can differ in time scale, in the parameter they act upon and in the KPI they impact. For this reason different coordinating schemes are required, rather than a "generic" model. For example, coordination can be performed in an on-line (distributed) or off-line (centralized) manner according to the desired time scales. Another example is the serial or parallel operation of SON functionalities. Three models for SON coordination are developed and experimented within the project:

(i) Off-line coordination based on optimization

(ii) On-line coordination based on control theory

(iii) Conflict avoidance approach based on "policy conflict avoidance"

(iv)

(i) Optimization approach

The optimization approach targets centralized off-line implementation of the coordination process of the SON functionalities. Each SON is considered as one optimization process. The optimization is handed in a centralized manner, with less strict timing constraints depending on the SONs under consideration. We consider I SON functionalities acting upon I parameters, $\theta = (\theta_1,\cdots,\theta_I)$. In the optimization approach the objectives (utilities) of the different SON functionalities are integrated into one objective function $F(\theta) = [f_1(\theta), f_2(\theta),..., f_I(\theta)]^T$. In this way, the common objective function implicitly handles conflicts of the possibly competing objectives. Constraints related to KPIs or parameter values are typically added as part of the optimization problem. The operator can also include policies in the common objective function in terms of priorities (weights) and desired targets. The optimization approach gives rise to multi-objective optimization which can be handled both via the utility aggregation and addition of constraints.

(ii) Control theory approach

Control theory approach considers SON functionalities as control loops [5]. Control theory models are of interest when on-line, distributed SON processes are considered, and parameters are modified in small time scales. The entire system including the control loops and the coordination mechanisms are described as an Ordinary Differential Equation (ODE). In the context of control theory the design of a coordination mechanism corresponds to the concepts of *controllability* and *state feedback synthesis*. We consider I >1 control loops, each of which is in charge of controlling one parameter θ_i, and the set of the SON parameters are denotes as

$\theta = (\theta_1,\cdots,\theta_I)$. The ODE describing the system is modelled as: $\dot{\theta} = F(\theta)$. To simplify the design, the control model is linearized. Linearization is valid when small interval of variation for the parameters θ_i are considered**.** Hence the ODE is represented in the following form: $F(\theta) = A\theta + b$, with A being a matrix and θ and b - vectors. Control theory provides straightforward mathematical tools for assessing stability of the controlled system: stability condition requires that the location of the eigenvalues of the controlled system A have negative real part. Hence by measuring and processing certain KPIs one can deduce whether the system is stable. Stabilizing the control system is performed using a simple algorithm which modifies the matrix A [5]. Furthermore, the existence of the solution can be verified rigorously. Measurements are corrupted with noise due to different sources (e.g. propagation phenomena, signal sampling and discretization etc.). The validity of the control model in the presence of additive noise is analyzed using stochastic approximation theorems [6].

(iii) Conflict Avoidance

The conflict avoidance approach is based on the extended policy domain approach described in [7]. A separation in time strategy is used based on utilities and performance objectives to derive a triggering sequence for the SON functionalities. The process operates as follows: all SON functionalities exchange their expected utilities per time interval (e.g. time slot); expected utilities per time interval are ordered decrementally. The possible actions for a given parameter are {Decrease, Neutral, Increase} and are denoted as *predicate modalities*. In the next time slot the SON functionality to be triggered is selected following two conditions: predicate modalities for the present and for the previous time interval are the same AND the expected utility of an action chosen based on the previous time slot was the highest in the ordered list. This approach allows to avoid certain type of conflicts; the invocations of mechanisms are self-orchestrated based on relevant frequencies associate to each SON functionality.

Triggering of SON functionalities

Triggering SON functionalities is associated with a certain cost. The criteria for re-configuration and re-optimization should be well defined, and the question of *when* to re-optimize should account for the tradeoff between the benefits from the optimization and the associated cost. Optimization processes can be dependent on yet other optimization processes, so there has to be some way to take this aspect into account as well.

Different strategies can be envisaged to trigger SON processes: One is to trigger related optimization processes upon an initial re-optimization (*trigger strategy*), and another one is to separate optimization processes in different time domains in order to separate them from each other (*separation in time strategy*).

The *trigger strategy* does not impose any restrictions in terms of when to re-optimize. This means that a re-optimization can be performed whenever statistically meaningful. In this case, Hidden Markov Models in combination with the Viterbi algorithm can be used [8]. It is assumed that the fact whether a re-optimization makes sense or not is hidden and can only be derived from observing whether the key performance indicator is above or below a certain threshold.

The *separation in time strategy* assumes that re-optimizations can only be performed at certain pre-defined time instants. Here the question is not *when* to re-optimize, but rather *whether* to re-optimize at all. More specifically, the question here is how to choose a threshold for the relevant key performance indicator so that above this threshold re-optimizations should not be carried out and that below this threshold re-optimizations are actually statistically meaningful and not based on noise [8].

INNOVATION

Enabling concepts and mechanisms

Empowering the network by means of SON enabled entities introduces several problems and challenges:

- Design of stable and scalable SON solutions: a SON entity within a network node should be capable of learning in an environment of other learning nodes
- Design of coordinating SON entities. The SON entities can have the same or different (conflicting) objectives and can act on the same or on different parameters
- Design of a management framework, compatible with the UniverSelf UMF, allowing to enforce operator objectives within the OA&M by means of governance tools, e.g. policies which trigger coordinated SON entities

Differentiation from the state of the art

Progress with respect to the state of the art is carried out in several areas listed below. Contributions in these areas will definitively allow pushing further away the state of the art frontier of SON:

- SON functionalities for new technologies, e.g. for heterogeneous LTE-Advanced networks
- Scalability, stability and robustness of SON solutions,
- Triggers, coordination and conflict resolution for SON functionalities,
- Introduction of SON solutions for the radio access domain within UMF which provide the following benefits: simplifying the introduction of new SON functionalities; providing means for governing the network empowered by SON functionalities; guiding and coordinating SON functionalities using policies and UMF coordination mechanisms
- Proof of concept of the novel solutions via project demonstrators

Impacts and benefits

Impacts of the use cases are related to performance, competitiveness, OPEX and CAPEX:

- *Performance*: coordinated SON functionalities can improve network performance (e.g. capacity, coverage) and QoS (e.g. blocking rate, file transfer time)
- *Competitiveness*: performance and QoS gain improve the operator ranking
- *OPEX*: reduction of (additional) costs and efforts related to network operation activity of LTE and LTE-Advanced technology to configure, parameterize and optimize the network. Assessment of OPEX savings in future networks can be performed by comparing network management of currently deployed networks (e.g. HSPA) to SON enabled networks (e.g. LTE and LTE-Advanced).
- *CAPEX* – performance gains in certain cases can be translated into reduction or delay of investment in infrastructure. Capacity gain brought about by different SON functionalities are studied in the case study.

TO BE CONTINUED

This document is the first part in a series covering the introduction, general description, problem statement and innovation of the case study on Self-diagnosis and self-healing for IMS VoIP and VPN services. Subsequent and complementary parts will be published in the near future, during the lifetime of the project with even more information, results and innovations.

Keep in touch to get premium access to these future reports!

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