Use Cases, Requirements and Assessment Criteria for Future Self-Organising Radio Access Networks*

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Abstract. Self-organisation (self-optimisation, self-configuration, and self-healing) methods are a promising concept to automate wireless access network planning, deployment and optimisation. This paper contains a mind setting exercise. First the mechanisms for which self-organisation is anticipated to be effective and feasible are identified. Then technical and non-technical requirements that need to be taken into account for the successful development of self-organisation functionalities are discussed. Furthermore, a set of metrics and appropriate reference cases (benchmarks) are presented, which allow to do on one hand a quantitative comparison of the different algorithms developed for a given use case, and on the other hand to evaluate the gains from self-organisation by comparing self-organisation solutions with the case of manual network operations.

1. Introduction

As recognised by the standardisation body 3rd Generation Partnership Project (3GPP) [1] and the operators' lobby Next Generation Mobile Networks (NGMN) [2], future wireless access networks, such as the 3GPP Long Term Evolution (LTE) radio access, will exhibit a significant degree of self-organisation. The principal objective of introducing Self-Organising Network (SON) functionalities in wireless access networks is to reduce the costs associated with network operations, while enhancing network performance. By improving the effectiveness of manual effort in network operational tasks, significant Operational Expenditure (OPEX) reductions are expected, while because of the better adaptation to changing network characteristics and failures, it is anticipated that SON features will enhance the global network capacity, coverage and service quality experienced by the users.

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Before starting on detailed technical work and the development of SON methods for future wireless access networks, it is essential to first perform a mind setting exercise to identify the mechanisms for which self-organisation is anticipated to be effective, to obtain a clear view on the (non-)technical requirements put on SON solutions, and to define criteria that can be used to evaluate the feasibility and performance of the developed SON methods. This is the topic of the current paper. All presented material is developed within the context of the European FP7 research project SOCRATES (Self-Optimisation and self-ConfiguRATion in wirelEss networkS) [3,4]. A main objective of SOCRATES is providing dedicated SON solutions, i.e., methods and algorithms, as a step towards the implementation of SON functionality into future wireless access networks, where 3GPP Evolved UTRAN (E-UTRAN), which is the 3GPP LTE radio access, has been selected as the technology of focus.

2. Use Cases and Requirements for Self-Organising Access Networks

Use cases are an established means of describing what a solution to a particular problem shall achieve. Within the SOCRATES project, over twenty-five use cases that focus on self-organisation in 3GPP E-UTRAN have been identified. These include for example the self-configuration use cases 'intelligently selecting site locations' and 'automatic generation of default parameters for network element insertion', the self-optimisation use cases 'packet scheduling optimisation', 'interference coordination', 'admission control parameter optimisation' and 'load balancing', and the self-healing use case 'cell outage management'. See [5] for an extensive description of these and the other use cases.

The classification of the use cases in the three categories, i.e., self-configuration, self-optimisation and self-healing, is in line with the framework SOCRATES envisions regarding the use of self-organisation methods in future radio networks [3,4]. Newly added NEs (Network Elements) like e.g., base stations (eNodeBs), *self-configure* in a 'plug-and-play' fashion, while existing NEs continuously *self-optimise* their operational algorithms and parameters in response to changes in network, traffic and environmental conditions. The adaptations are performed in order to provide the targeted service availability and quality as efficiently as possible. In the event of a cell or site failure, *self-healing* methods are triggered to alleviate the performance effects due to the resulting coverage/capacity gap by appropriately adjusting radio parameters in surrounding sites. In general, human involvement shall only be triggered when absolutely necessary, e.g., when manual repairs are needed.

For the successful development of SON functionalities, various *technical requirements* must be considered. In [6], we present several technical requirement categories: performance and complexity, stability, robustness, timing, interaction, architecture and scalability, and required inputs (performance counters and measurements). As the same principles apply to many use cases, while the details vary, these requirement categories are discussed in general, but also in detail for every identified use case.

Since solutions that are good from a purely technical point of view may not necessarily meet *business requirements*, it is also important to consider these requirements.

They comprise cost efficiency requirements (e.g., SON solutions should reduce OPEX and CAPEX (Capital Expenditure)) and LTE deployment requirements (e.g., the roll-out of LTE networks should be sped up, new services should easily be deployed, the end user should benefit). For more details, we again refer to [6].

3. Assessment criteria for self-organising access networks

In future SOCRATES will develop self-organisation methods and algorithms. An adequate assessment of the benefits from developed self-organisation methods requires a set of well-defined metrics and appropriate reference cases (benchmarks). With regard to the reference cases, on one hand different self-organisation algorithms may be compared with one another, while on the other hand an appropriate 'manual reference case' needs to be defined to allow evaluation of the gains from self-organisation with respect to contemporary and manually operated networks.

3.1 Metrics

Key metrics that are relevant in the assessment of self-organisation methods are [7]:

• **Performance metrics:** These metrics express the service level experience from the user perspective and include *grade of service (GoS)* metrics, e.g., call blocking ratio, call dropping ratio, and *quality of service (QoS)* metrics, e.g., packet delay statistics, packet loss ratio, throughput statistics, mean opinion score, fairness.

• **Coverage metrics:** Different coverage metrics exist, e.g., the *service coverage*, i.e., the fraction of area where a given service can be supported with adequate service quality and the *data rate coverage*, i.e., the fraction of area where a user can experience at least some specified data rate.

• **Capacity metrics:** Cell (or network) capacity is not unambiguously defined and different sensible perspectives are applied in the literature, such as maximum number of concurrent calls, maximum supportable traffic load, and spectrum efficiency.

• **CAPEX:** In general, CAPEX encompasses the investments needed in order to create future benefits, including e.g., radio and core network elements. An approach we propose to estimate CAPEX is to determine the number of network elements that is needed to cover a certain service area with pre-specified GoS and QoS requirements, and multiply this with the corresponding costs. Given a certain service demand per km^2, the required number of network elements can be determined by maximising the cell radii such that traffic demand per cell and cell capacity are sufficiently well balanced to meet the GoS and QoS requirements.

An additional aspect to consider is that the introduction of self-organisation features themselves may lead to an increase in equipment cost (per unit). This additional CAPEX is hard to estimate, but depends on the nature and complexity of the self-organisation algorithm, the transmission bandwidth requirements that may be higher due to increased signalling overhead, and additional costs related to needed site equipment, e.g., electrical antenna tilt and additional circuitry for enabling power savings.

• **OPEX:** The costs associated with the network operations and, in particular, the reduction of these costs due to the introduction of self-organisation functionalities, are rather difficult to assess. Noting that actual OPEX reductions depend on the degree of self-organisation that is deployed, in an extreme implementation, all OPEX related to manual adjustment of a given parameter set (associated with a use case) is removed. In order to develop an approach to assess the OPEX level, we distinguish between three main phases in effectuating parameter adjustments, i.e., gathering input data, e.g., via performance counters, drive tests or planning tools; determining new parameter settings, using (some combination of) manual adjustments and/or computer-aided adjustments using planning tools or advanced simulation models; and applying new parameter settings, which may be done remotely or requires a site visit.
Depending on the applied methods, a use case-based estimation of the human effort in man hours involved in the three distinct phases can be made by the operator[†]. Multiplying this by the effective cost per expert hour, the number of times per year such a parameter adjustment is needed and a multiplication factor that reflects the number of cells (or cell classes) for which separate parameter adjustments need to be made, yields the OPEX per year for the considered use case.
In case self-organisation functionalities are applied, their specific impact on the above-mentioned distinct components that contribute to OPEX should be assessed, based on the properties of the developed solutions. Note that for some components the required human effort is significantly reduced, while for others it remains unchanged.

3.2 Benchmarking

A key objective in the development of methods for self-organisation is to do a quantitative comparison of different methods developed for a given use case, and to compare their achieved performance, capacity and cost to a case with manual network operation. Below we describe an approach for such benchmarking. The approach is primarily outlined from the perspective of a self-optimisation use case, although it is readily converted to cover self-configuration and self-healing use cases as well.

Starting point is a specific scenario in terms of e.g., the propagation environment, service mix, traffic characteristics and spatial traffic distribution. For such a scenario, the achievements of the different self-optimisation algorithms can be expressed in terms of the metrics mentioned in Section 3.1, including an estimation of the optimisation effort that is based on the observed number of automatic parameter adjustments per time unit. Note that if the optimisations were done manually, this would indicate the OPEX level.

Example values of the metrics obtained at the end of simulation studies are shown in Figure 1‡. Observe that e.g., self-optimisation algorithm SO_A achieves the highest performance, which can be exploited to achieve the lowest CAPEX, but in order to

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[†] Note that this depends on the operator policy: a cost-driven operator is likely to spend less effort on network planning and optimisation than a quality-driven operator.

[‡] Note that all figures shown in this section are only speculative examples to illustrate and explain the developed benchmarking approach.

achieve this, a large optimisation effort is required. In contrast, algorithm SO_D is significantly less complex but consequently achieves worse performance and CAPEX.

In general, it is hard to compare the different self-optimisation schemes given the conflicting performance objectives. One possible approach to enforce a strict overall ranking is to weigh/combine the different measures into some utility function and rank the algorithms based on the obtained utility values.

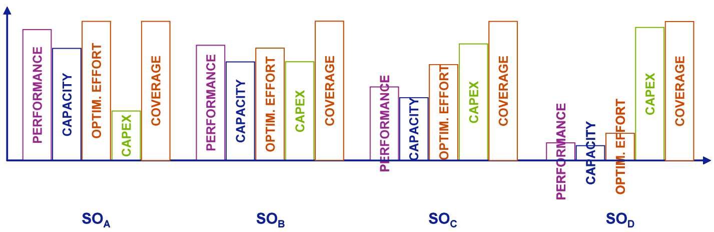

Figure 1. Example values of obtained metrics.

Whereas the above discussion outlines an approach to compare different self-optimisation algorithms, a more difficult challenge is to compare a self-optimisation algorithm with a case of manual optimisation. In an extreme case, one could assume that a 'manual operator' freezes permanent settings of his radio parameters, which should then be chosen such that the overall performance of a given scenario is optimised. In practice, however, a network operator will upon observed need or sensibility adjust the radio parameters. Depending on the operator's policy this may happen more or less frequently: a quality-oriented operator is likely to do more frequent adjustments than a cost-oriented operator. In order to model this in a reasonable way, we propose to define 'manual optimisation algorithms' MO_A through MO_D (continuing the above example) such that they manually adjust radio parameters at the same time and to the same values as would the corresponding self-optimisation algorithms with the same label. Figure 2 visualises an example comparison of SO_A with MO_D, concentrating on CAPEX and OPEX related measures.

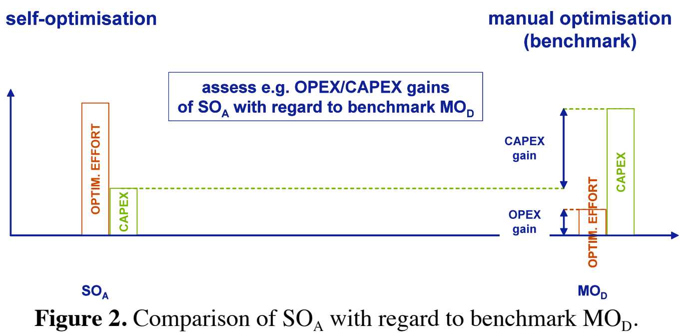

Figure 2. Comparison of SO_A with regard to benchmark MO_D.

Assuming that self-optimisation reduces OPEX to zero (which may be too extreme, but is fine for illustrative purposes), the OPEX and CAPEX gains are indicated in Figure 2. Note that the OPEX gain is determined by the optimisation effort that applies in the manual case. Continuing this approach for different combinations of SO_X and MO_Y we could generate tables such as Table 1, where the '+', '-' and '0's are just qualitative indicators; actual numerical values should be determined via simulations.

Observe that introducing self-optimisation in the network of a quality-oriented operator is likely to establish the highest OPEX gains, but the lowest CAPEX gains.

Table 1. Comparing self-organisation algorithms with manual algorithms.

		CAPEX GAINS				OPEX GAINS			
		SO_A	SO_B	SO_C	SO_D	SO_A	SO_B	SO_C	SO_D
quality oriented operator	MO_A	0	-	--	---	++++			
	MO_B	+	0	-	--	+++			
	MO_C	++	+	0	-	++			
cost oriented operator	MO_D	+++	++	+	0	+			

4. Concluding remarks and future work

In this paper we have identified use cases, requirements and assessment criteria for future self-organising radio access networks. Within the SOCRATES project, these will form the basis of a framework for the development of self-organisation methods and algorithms, which describes among other things the relation and dependencies between the different components of SON. As future work, SON algorithms for the use cases will be developed, while the identified requirements will be taken into account. The proposed assessment criteria will then be used to evaluate the developed algorithms and solutions. As at this early stage of LTE development, a live test of developed SON algorithms in the field is not yet possible, the actual comparison and assessment of the different developed SON solutions will be done by performing simulation studies. The future work also includes the integration of the developed SON solutions, to ensure consistent behaviour when the developed algorithms are operated simultaneously.

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