Self-organisation in wireless networks: use cases and their interrelations

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Self-organisation in Wireless Networks – Use Cases and their Interrelation

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***Abstract*—This paper presents some selected use cases for self-organisation in wireless networks, namely on self-optimisation (Home eNodeB and Load Balancing) and self-healing (Cell Outage Management). Furthermore an approach to identify interrelationships between these use cases is presented and an example for parameter correlation is given. The paper thereby provides results that have been achieved within the EU FP7 project SOCRATES.**

***Index Terms*—Self-organisation, self-optimisation, self-healing**

I. Introduction

THE standardisation body 3rd Generation Partnership Project (3GPP) has finalised the first release (Release 8) of the UMTS successor named Evolved UTRAN (E-UTRAN), commonly known as 3rd Generation Long Term Evolution (3G LTE). With the introduction of LTE there will be many wireless network operators having several mobile network technology generations running in parallel, namely 2nd generation networks (e.g., GSM), 3rd generation networks (e.g., UMTS) and LTE networks. Already with two wireless network technology generations running simultaneously, operators have to spend considerable effort in planning, configuring, optimising, and maintaining their networks. These efforts consume a substantial part of their operational expenditure (OPEX). Consequently, an important E-UTRAN requirement from the operators' side is a significant reduction of the manual effort in the deployment, configuration and optimisation activities for LTE.

One possibility for achieving this requirement is the introduction of self-organisation functionalities into the E-UTRAN. Self-organisation functionalities do not only reduce the manual effort involved in network management, but they also enhance the performance of the wireless network. Self-organisation can thereby be subdivided into several tasks. This includes *self-optimisation* of radio parameters, which can also be denominated as automatic real-time control of radio parameters. *Self-healing* is another important self-organisation task, with the goal of minimising the impact on network performance caused by failures. *Self-configuration* as the third task enables automatically deriving sensible initial configuration for network equipment as part of the installation process.

In this paper we present three self-organisation use cases, namely Cell Outage Management (self-healing), Load Balancing (self-optimisation) and Optimisation of Home eNodeBs (self-optimisation).

II. The SOCRATES Project

There are several international research projects concentrating on Self-organising Networks (SON). Among these projects is the project SOCRATES (Self-Optimisation and self-ConfiguRATion in wirelESs networks, cf. [1], [2]) in which two large vendors (Ericsson, Nokia Siemens Networks), a leading mobile network operator (Vodafone), a vendor and consultant for network optimisation tools (Atesio), and several European research and consultancy institutes (IBBT, Technical University of Braunschweig, TNO ICT) are involved. This project is funded by the European Union in the 7th Framework Program and will run until December 2010.

The main goals are the development, evaluation and demonstration of methods and algorithms for self-configuration, self-optimisation and self-healing, where the 3GPP E-UTRAN has been selected as the radio access technology of focus. In addition, the impact on standardisation, network operations and service provisioning is investigated. The project approach comprises three phases. Firstly, the 'Requirements phase' includes the identification of use cases and requirements for mechanisms that are to become self-organising in (future) wireless access networks (case-based approach), and furthermore the definition of a self-organisation framework. The framework thereby includes technical and business requirements for self-organisation, furthermore some assessment criteria, a methodology and reference scenarios for the development of solution algorithms, and an architectural framework for the implementation of self-organisation solutions. This framework provides the basis for the next step, the 'Development phase', where detailed solutions, i.e. methods and algorithms for self-optimisation, self-configuration and self-healing will be developed and assessed. In the final phase, the 'Integration phase', these solutions will be integrated with the previously defined framework, the benefits and implications of the solutions will be demonstrated, and the project results will be disseminated via standardisation contributions and workshops.

While 3GPP and NGMN (Next Generation Mobile Networks) provide the definitions of use cases and interfaces for self-organisation, SOCRATES aims at providing dedicated solutions, i.e., methods and algorithms, as a step towards the implementation into future wireless access networks.

The ‘Requirements phase’ of SOCRATES has already been completed, with a definition of twenty-four use cases and a subsequent selection of ten use cases (cf. [3] and [4]) that are now worked out in detail, including, e.g., triggers, input sources, parameter and measurements list, architectural aspects and interfaces, standardisation aspects, and the expected gain from implementation. The algorithm development and simulations for some of these use cases have already been started, and first results are expected in mid-2009.

Table 1: SOCRATES selected use cases

Use Case Title	Self-organisation area
Self-optimisation of Home eNodeB	Self-optimisation
Load Balancing	Self-optimisation
Interference Coordination	Self-optimisation
Packet Scheduling	Self-optimisation
Handover	Self-optimisation
Admission & Congestion Control	Self-optimisation
Coverage Hole Detection & Compensation	Self-optimisation
Cell Outage Management	Self-healing
Management of Relays & Repeaters	Self-configuration, Self-optimisation
Automatic Generation of Default Parameters for NE Insertion	Self-configuration

In the following, three of the selected use cases are explained in more detail.

III. USE CASES

A. Home eNodeB

In 3G LTE an extensive use of home base stations, also referred to as home eNodeBs, is expected. The home eNodeBs will typically be used in order to extend coverage and/or capacity in limited areas, such as inside a house or in an office area. The home eNodeB will be physically installed by the customer and may be physically inaccessible for the operator. Due to the limited physical access and the presumed large number of home eNodeBs, self-optimisation of home eNodeBs is foreseen to be beneficial.

While it is desired that the home eNodeB covers the intended area (e.g. inside a building), meaning that there should be no coverage holes in the area and that even the edge of the intended area is covered, the interference caused by the home eNodeB should also be kept low, resulting in a trade-off problem. The possibility to have closed access home eNodeBs adds an extra challenge to the problem.

Further, a seamless mobility to and from home eNodeBs is desired. Due to small coverage areas a handover to a home eNodeB is not always favourable, especially for User Equipment terminals (UEs) moving fast, that may leave the home eNodeB coverage area after only being served by the home eNodeB for a very short time. In the case where the home eNodeB and the macro eNodeB operate on different frequencies it may be beneficial to encourage or discourage a handover in order to decrease interference.

Home eNodeB interference and coverage as well as mobility to and from home eNodeB cells have been identified as possible objectives for self-optimisation and selected by SOCRATES for further studies.

In the work with developing home eNodeB self-optimisation algorithms, measurements to be used as input, and parameters that may be used to control the objectives of the self-optimisation, have been identified (cf. [7]). Identified control parameters for the coverage area as well as the interference are the downlink power, the uplink power and sub-band assignments for the home eNodeB. The self-optimisation of home eNodeB handovers may be controlled by changing thresholds, hysteresis, offsets and possibly also the downlink power. Changes of the latter should however be coordinated with the interference and coverage optimisation.

As different operators may have different marketing priorities and performance targets, a method to reflect these priorities in the self-optimisation has been developed in order for the radio access network to be tuned accordingly. A number of scenarios have also been defined that will be evaluated in simulations and in further work, effects and gains from changing the identified control parameters and possibilities to measure and capture these effects in the network will by evaluated in a controllability and observability study. Based on the results from this study algorithms for the self-optimisation of home eNodeBs will be developed.

B. Load Balancing

Load imbalance is a common problem in communication networks where a large number of independent users are served. In a mobile communication network with unequal user deployment distribution, heavily loaded cells may be in the neighbourhood of lightly loaded cells. For some of the users that are located closely together within one cell, the required quality can not be achieved and neighbouring resources are wasted at the same time. Load Balancing (LB) algorithms aim at reducing undesirable effects of imbalance. Shifting load from highly or overloaded parts of the network to the lightly loaded cells can improve network quality parameters that are of importance for operators, for example, Quality of Service (QoS), Grade of Service (GoS), and resource utilisation.

To handle the common occurrence of imbalance problems in communication networks, many solutions were proposed and implemented in existing mobile systems so far. Contemporary LB solutions are related to the corresponding systems’ features, and due to differences between these systems, LB solutions can not be simply transferred. For example, GSM Base Transceiver Stations (BTS) are fully controlled by Base Station Controllers (BSC) which also control other BTS within one Base Station Subsystem (BSS) and can be treated as central entity for Load Balancing within this BSS. UMTS networks have a less centralised architecture regarding the control domain and include specific mechanisms like Soft Handover, which can also be used for smooth load transfer between NodeBs. 3G LTE radio access networks, which are the scope of the SOCRATES project, are a new technology generation for mobile communication and require new solutions for Load Balancing.

The LB use case group aims at developing methods and functions for network self-optimisation by equal load distribution amongst neighbouring cells. Considered are neighbouring cells with the same Radio Access Technology (RAT) and frequency or with the same RAT but different frequency. Different RATs are assumed to be a possible solution as well but not investigated in detail in SOCRATES. For LTE, cell overlaying is desired, and coverage modifications may be needed. In this case the adjustment of antenna parameters is assumed, for example, Transmitter (Tx) power or antenna tilt. Not only a cell overload alarm may trigger LB functionalities, this may also be the case for QoS improvement requests or energy saving requirements, e.g., in case the cell load is much lower than typically. Cell load status information is periodically exchanged between eNodeBs via the X2 interface, but due to limited resources, a compromise between message exchange frequency and message size is required. Reduction in control information may be achieved by setting load thresholds to trigger LB functionalities. As it is shown in Figure 1, reports may be transmitted if the cell load exceeds Value X, and the LB handover procedure starts when load exceeds Value Y. The energy saving procedure is triggered in case the load is below Value Z.

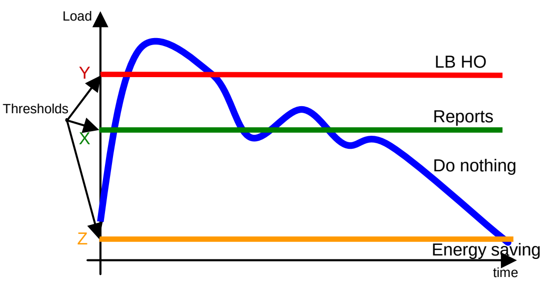

Figure 1: Load Balancing Thresholds

In Figure 2, a rough draft of the Load Balancing algorithm is presented. In case the cell load is between Values X and Y, the eNodeB starts preparation for LB handover by determining the best LB handover direction. To avoid the handover to an overloaded neighbour cell, the required information is received from a central entity which monitors all cells and provides reports from those cells with a load higher than X.

In case the cell load is higher than Value Y, the LB handover procedure is launched, and the cell with the highest priority and a group of users intended to LB handover is chosen. In case no applicable group of users dedicated to a LB handover in best direction can be found, the next target cell in order and another users group are considered.

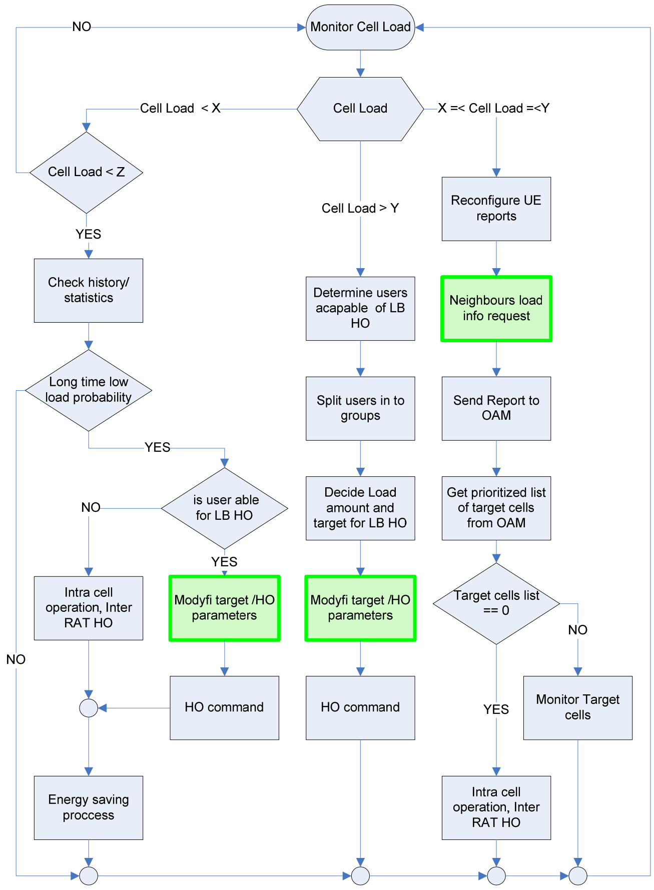

Figure 2: Load Balancing Draft Algorithm

The Energy Saving branch is activated for a load lower than Value Z, but the LB handover procedure can be triggered only for high “long time low load” probability, for which a eNodeB power reduction will be beneficial. “Low load time” is derived from load statistics and load history. For example, eNodeB power reduction and LB handover may be profitable during night hours for one area, but during weekends for another area.

The proposed LB algorithm will be developed and advanced in accordance to the results of simulation and the corresponding analysis of results. A corresponding LB algorithm is currently under development, including the results of ongoing simulations. The proposed LB solution should improve QoS, accessibility, and resource utilisation within the whole mobile network rather than only on a simple base of neighbour cell relations.

C. Cell Outage Management

One aspect that benefits from self-organisation is the management of cell/site outages, which can be divided into two parts, namely, the detection of an outage and the compensation of the detected outage.

There are multiple reasons for a cell outage, e.g., hardware and software failures (radio board failure, channel processing implementation error, etc.), external failures such as power supply or network connectivity failures, or even erroneous configuration. While some cell outage cases are detected by Operations Support System (OSS) functions through performance counters and/or alarms, some may not be detected for hours or even days. It is often through long term performance analysis and subscriber complaints that these outages are detected. Currently, discovery and identification of some errors involves considerable manual analysis and may require unplanned site visits, which makes cell outage detection rather costly. It is the task of the cell outage detection function to timely inform the operator about the occurrence of an outage and the cause of the outage.

In the event of the detection of a cell outage, appropriate compensation methods are triggered to alleviate the degraded performance due to the resulting coverage gap and loss in throughput 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.

The goal of cell outage compensation is to minimise the network performance degradation when a cell is in outage. This is done by automatic adjustment of network parameters in order to meet the operator's performance requirements based on coverage and other quality indicators, e.g., throughput. It is realised that performance requirements may not be achieved during an outage and, as such, the goal of the compensation function is to meet performance requirements to the largest possible extent. Cell outage compensation algorithms may, for example, alter the antenna tilt and azimuth, or the cell transmit power, in order to cover the area that is in outage.

Altering the radio parameters of the neighbouring cells means that some of the UEs served by neighbouring cells may be affected. For example, if the coverage area of a neighbouring cell increases, this implies that more UEs will be served by this cell and, consequently, the per-UE throughput may decrease. This should be taken into account and an appropriate balance between coverage and other quality indicators (e.g. throughput) should be achieved. This balance is indicated by means of an operator policy that governs the actions taken by the cell outage compensation function.

Figure 3 shows the components and workflow of cell outage management. Various measurements are gathered from the UEs and the eNodeBs. The measurements are then fed into the cell outage detection function, which detects whether at the current time an outage has occurred and triggers the cell outage compensation function to take appropriate actions.

In order to monitor and evaluate the actions taken by the cell outage compensation algorithm, there is a need to estimate e.g. coverage and attainable throughput in the vicinity of the outage area. This is provided by the so-called X-map estimation function, which continuously monitors performance metric 'X', e.g. coverage, accessibility, throughput, packet loss, etc., by means of measurements and possibly prediction data.

Key activities pursued for this use case include a controllability and observability study, the development of cell outage management algorithms, the definition of scenarios that capture relevant case studies for the application and evaluation of cell outage management solutions, and methods and criteria for assessing the impact and performance of cell outage detection and compensation algorithms.

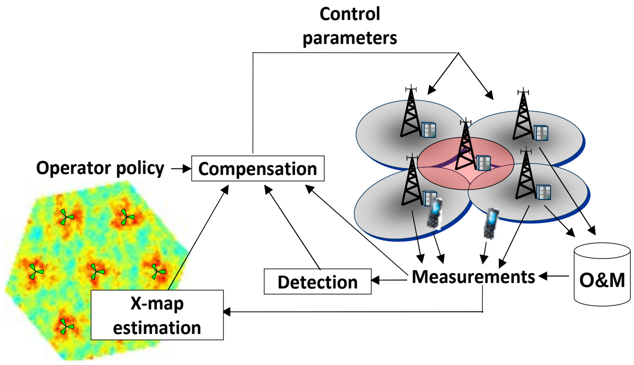

Figure 3: Cell outage management components. The center site is in outage. Red area indicates the coverage previously offered by the outage cell (Source: [5])

IV. INTERRELATION OF USE CASES

The SOCRATES project has identified 24 self-organisation use cases, from which 10 have been selected for further investigation (cf. Table 1). Each of these SON functionalities such as Load Balancing or Interference Coordination modifies a set of configuration parameters in the corresponding network elements, to achieve the intended self-configuration, -optimisation or -healing goals. However, given that several SON use cases are running in parallel, multiple SON functionalities alter the same configuration parameters, and the all over system performance depends on potentially conflictive parameter adjustments (cf. Figure 4).

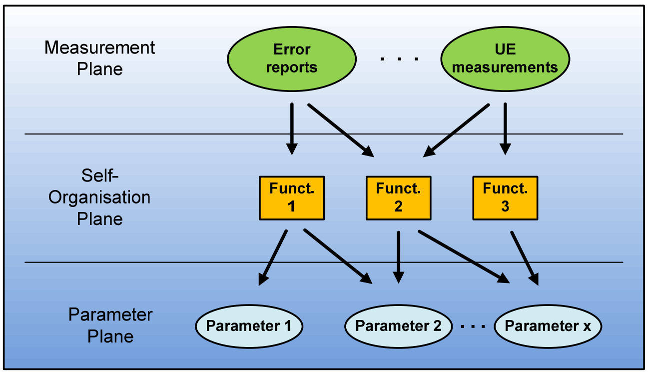

Figure 4: Interaction of SON functionalities

Therefore, it is necessary to analyse the interaction of the SON functionalities based on the control parameters and interaction with other use cases that follow the same purpose, to identify the functionalities that need to be coordinated and simulated together.

To identify those SON functions and use cases that have an interrelationship, three terms are introduced: a *Goal* describes a high-level target of self-organisation, such as "minimise inter-cell interference" or "maximise capacity". A *Parameter* describes a dedicated configuration setting at the network element, such as "transmission power" or "antenna settings". A *Contributor Relation* describes the correlation between a given parameter and one or several goals. For each use case, there exists a description of the goals and the required parameters. To identify those parameters that need to be coordinated, since they influence the goals of several use cases, the goals are put into *Groups*, whereby all goals coupled together by contributor relations are put into one group, together with the related parameters (see Figure 5: Parameter Group A is independent of Parameter Group B). As a result, parameters within one group do not affect goals in other groups, and different groups remain uncoupled. A coordination of parameter settings/adjustments is therefore only required within groups but not between different groups.

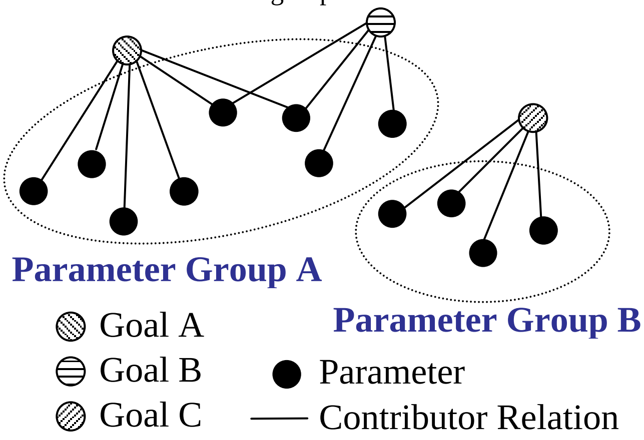

Figure 5: Configuration Parameter Grouping (Source: [6])

As an example, these goals and parameter groups can be defined for the use cases described in Section III. In Table 2, three of the major (common) goals for self-organisation use cases are shown. “Minimise Interference” describes the reduction of the all over interference within the mobile radio system. “Balance Load” aims at a well-adjusted distribution of user traffic between the eNodeBs, to prevent from one eNodeB being fully loaded and neighbouring eNodeBs being only marginally loaded. “Maximise / Optimise Coverage” aims at reducing areas to a minimum where no sufficient radio signal reception is available and the probability of e.g. call drops is rather high. For the (configuration) parameters listed in Table 2 only those are mentioned that have been considered as most important for a self-organisation solution.

Table 2: Identification of Goals and Parameters

Goal	**Parameters**
Minimise interference	• Radio bearer transmit power • Radio bearer assignment • Antenna parameters • Channel Quality Indicator thresholds for schemes switching
Balance load	• Radio bearer transmit power • Antenna parameters • Handover parameters • Cell re-selection parameters
Maximise / Optimise coverage	• Radio bearer transmit power • Antenna parameters

Taking the identified parameters as described in Table 2 it becomes clear that all three mentioned goals have at least two common configuration parameter, namely “Radio bearer transmit power” and “Antenna parameters” (which can include, for example, radio beam forming parameters or antenna tilt). Therefore, in case the solutions developed for all three use cases are jointly implemented in a mobile radio network self-organisation solution, it is necessary to coordinate the corresponding self-optimisation and self-healing actions to prevent from unpredictable and instable behaviour of the whole system.

V. Conclusions

The presented SOCRATES use cases give a brief insight into the diversity of self-organisation, and make clear that each single use case requires considerable effort regarding the analysis of input data, measurements and configuration parameters, the development of the solution algorithms, architecture, integration and deployment scenarios and concepts, and simulations to evaluate the self-organisation gain compared with existing methods.

Furthermore, it becomes clear that self-organisation in mobile radio networks cannot simply be split into a set of independent use cases that provide configuration, optimisation, or healing tasks. Since especially the optimisation of one radio parameter usually has a clear influence on the behaviour of other radio parameters, self-optimisation by default has to be seen as a whole, and the interaction between different use cases, their respective goals and the corresponding configuration parameters has to be taken into account from the very beginning of research and development activities. This is a clear goal of the SOCRATES project, not to only develop solutions for single self-organisation use cases, but to aim for an integrated solution.

Acknowledgment

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