Context based configuration management of plug & play LTE base stations

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Abstract— **In second and third generation cellular networks the rollout of base stations needs to be conscientiously prepared, because their radio configuration should match with the coverage provided by existing cells in their neighborhood. The detailed radio planning for every new cell requires considerable human resources and time. This paper proposes a framework for 3G Long Term Evolution (LTE) that can perform a dynamic radio configuration of a base station when powered on, which is adaptive to the current network topology context and does not require human intervention. This function enables the deployment of base stations and new cells in an ad hoc manner, reduces OPEX and contributes to the concept of a self-configuring network.**

Keywords- configuration management, self-configuration, auto-commissioning, radio access network, LTE

I. INTRODUCTION

The need for data rates (up to 100 Mbit/s) and new services for mobile users have set the scene in 3GPP for the standardization of the 3G Long Term Evolution (LTE). The LTE cellular network consists of an Evolved Packed Core (EPC) and an Evolved Universal Terrestrial Radio Access Network (E-UTRAN). The E-UTRAN uses a new radio interface and is based on a flat architecture only consisting of base stations (eNodeB – evolved NodeB), each serving a set of cells [4]. The E-UTRAN will be characterized by equal or smaller cell sizes than those of predecessor third generation radio access networks. As a consequence thousands of new radio nodes will need to be installed and properly configured in these mobile networks.

In order to reduce the rollout costs of eNodeBs, manufacturers and operators are working together in research [2] and standardization [3] to enable the introduction of self-configuration mechanisms. Self-configuration is the process of bringing a new network element or network element parts into service with minimal human operator intervention. The process encompasses several steps illustrated in Figure 1. After the base station has been installed and switched on, the auto-connectivity setup function establishes a secure connection between the eNodeB and the network element management system [1]. Auto-commissioning includes the automated provisioning and testing of the software and database configuration according to the installed hardware, operator's expected features and the site location [3].

The transport and radio configuration of legacy base stations is completely based on a careful planning which needs to be conducted by the network operator prior to the installation, using a planning toolset. In this paper it is proposed that a subset of the radio parameters would be assigned dynamically, when the eNodeB is powered up for the first time in the field. For this purpose the Dynamic Radio Configuration Function (DRCF) is appended to the self-configuration process.

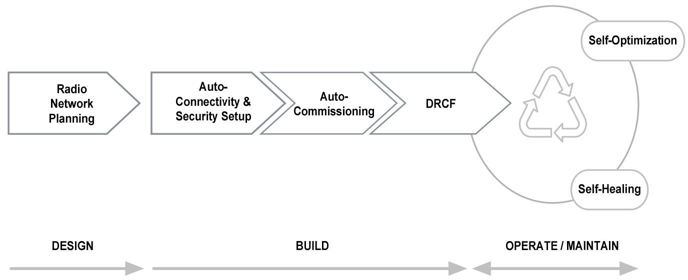


Figure 1. Scope of the DRCF

When incrementally building up the network without SON functions one can either perform a labor intensive radio planning step every time a new network element is inserted or perform periodic radio planning updates anticipating the new eNodeB insertions within the next time frame. In the former case the insertion order of the base stations must proceed exactly as planned. In the latter case one needs to accept that the planning is not representative for the operational network at a certain point in time. Without a representative planning the newly inserted eNodeB and its neighbors will not have an optimal configuration matching the current network topology. When using dynamic configuration this trade-off disappears. The DRCF will configure the new eNodeB/cell and its neighbors in such a way that the best possible coverage and capacity is achieved given the existing intermediate network topology.

A second benefit of the DRCF is a reduction of the planning activities. Although it is still needed to perform a dimensioning and capacity planning for selecting the sites and deciding on the HW resources to be installed, the detailed radio planning can be omitted since the assignment of the corresponding parameters is shifted to the DRCF. Where off-line radio planning tools completely rely on input provided by the operator (e.g. expected geographic traffic distribution), DRCF algorithms can make use of measurements and already optimized parameters of operational neighbors.

When shipping an eNodeB to another site than originally planned or relocate it to another site it is not longer necessary to re-run the radio planning. This aspect is crucial for indoor deployments where a tight site dependent radio planning prior to the installation cannot be followed.

II. DRCF Functionality

Radio parameters are classified in two major groups [5]:

1) **Class A** parameters do not have an influence on the configuration of the adjacent cells or vice versa. Since their assignment is independent from the existing network topology, they are out of scope for the DRCF.

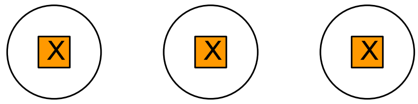
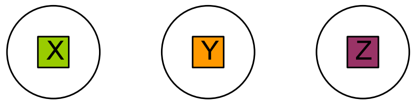
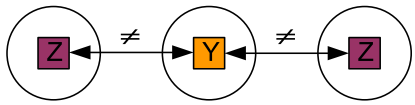
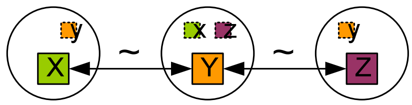
2) To configure ***Class B*** parameters correctly, the knowledge of the relationships and the configuration of adjacent cells is needed (including direct neighbors, neighbors of the neighbors or even all cells in a large geographical area). Since these parameter values are dependent on the current network context, it may be necessary to assign them dynamically. Class B parameters are further divided in subclasses defined by Table 1. From the sub-classification following conclusions can be derived:

- Class B1 parameters need to be assigned for an entire network. Hence this class is out of scope of the DRCF. Examples are Public Land Mobile Network Identity (PLMN ID), frequency band, E-UTRA Absolute Radio Frequency Channel Number (EARFCN) etc.
- Class B2 parameters should be assigned by the DRCF. Examples are Evolved Global Cell Identity (EGCI) and eNodeB name.
- Class B3 parameters should be assigned dynamically, but not all parameters are needed when an eNodeB is switched on. Examples are Physical Cell Identity (PHY-CID), Physical Random Access Channel (PRACH) root sequence index, Root Sequence Cyclic Shift (RS CS).
- Also class B4 parameters need a dynamic assignment. Examples are initial Neighbor Relationships (NR), quality offset for cell reselection, Tracking Area Code (TAC) and Transmitter Power.

The activity diagram below (Figure 2) illustrates the individual algorithms executed by the DRCF, their intermediate outputs and their interdependencies. The algorithms build further on (intermediate) results of previous algorithms. Intermediate results are not directly configuration parameters for the eNodeB, but essential inputs for self-configuration algorithms. All activities in the diagram map to a single self-configuration algorithm.

At the left hand side of the diagram the inputs of the DRCF are listed. A high level grouping of these parameters can be made as follows:

Table 1: Class B Parameters

Subclass	***Definition***
B1	Parameters of class B1 need to be configured with a uniform value in all cells of a large part or even the complete network. 
B2	The value of class B2 parameters needs to be unique in scope of the complete network. 
B3	The value of class B3 parameters need to be configured collision free. This means that the same parameter of a direct neighbor cell cannot be configured with the same value. 
B4	The value of a class B4 parameter needs to be aligned with the configuration of an adjacent cell. 

1) Equipment Parameters (Inventory Management): This group of parameters collects equipment properties of the installed eNodeB, like the HW configuration, the type and manufacturer of the different HW components and related properties like the antenna gain, or power amplifier limitations. The HW configuration to be installed on a site is an outcome of the network dimensioning planning activity.

2) Installation Measurements: Measurements performed while installing the eNodeB, either automatically or manually by the installer. The measurements can be either stored in the eNodeB or in some central repository. Typical examples are the geo-location and the feeder loss.

3) Site and Environment Parameters: These parameters comprise properties of the site where the eNodeB is installed. Examples are the site ID and the clutter type. Some of these parameters may be assigned automatically (e.g. extract the clutter type from a digital surface map), but often these are configured manually.

4) Network Topology, State and Performance: The geographic locations, operational states and performances of the existing cells in the network. These inputs are representing the context of the network and are essential in the incremental network growth scenario.

5) General Configuration Parameters: These include class A configuration parameters of the new cell, but also of already operational cells in the network. For the new cell(s) these are typically configuration parameters which are derived from the planning during the auto-commissioning phase, like the frequency band, channel bandwidth, etc.

6) Operator Inputs: Inputs provided by the remote commissioner in order to control the self-configuration process.

Algorithms for the assignment of the following intermediate outputs and parameters are included in the workflow:

1) Coverage area: includes the calculation of the coverage of the newly inserted cells as well as the reassessment of the coverage area of already operational cells. The coverage area calculation can be based on matching the link budget with the path loss estimated by a radio propagation model, like applied for the detailed radio planning by off-line planning tools. The algorithm should also calculate the related downlink transmission power, Remote Electrical Tilt (RET) and – if supported by the eNodeB – Remote Azimuth Steering (RAS). They need to be defined in such a way that an optimum overlap with the neighboring cells is achieved at minimum power radiation. When the dimensioning planning shows that the coverage of the cell should be capacity limited this shall be handled as an extra constraint for the algorithm.

In case cells are inserted between already existing cells, the coverage area of these neighbors is reduced, their radio parameters are recomputed and these eNodeBs are reconfigured accordingly.

2) Pre-operational Neighbor Relation Table (NRT): The pre-operational NRT contains the potential neighbor cells of the inserted cells. The DRCF needs to construct a NRT in pre-operational phase because this is an essential input for further self-configuration algorithms and for the inter-eNodeB connection setup (3GPP X2 interface). This function is complementary to the Automated Neighbor Relationship function (ANR) which is intended for defining handover neighbor relations [4]. ANR is based on user equipment measurements and may be used to optimize the NRT while a cell is in operational state.

The algorithm for assembling the pre-operational NRT's could rely on the coverage area assessment of the new cell and all cells within an arbitrary geographic distance of that cell. A neighbor relationship is then identified based on the cell coverage area overlap between two cells.

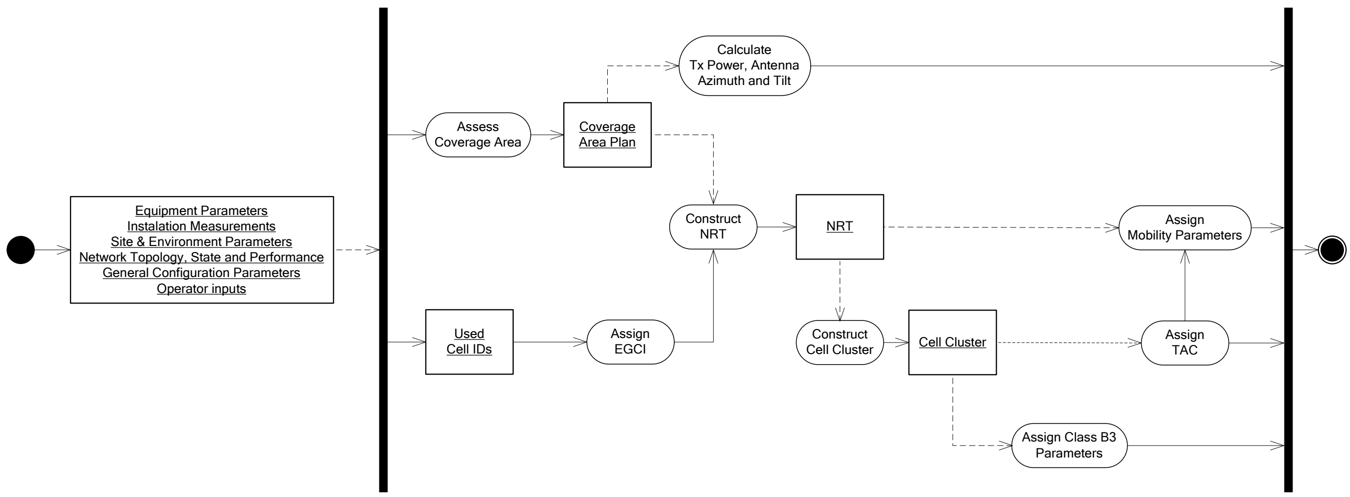


Figure 2: DRCF Activity Diagram

3) Cell cluster: A cell cluster consists of the newly inserted cell, all neighbors of this cell and all neighbors of the neighbors of this cell. The latter are called second tier neighbors. All cells in the cell cluster are identified by the EGCI and PHY-CID. Each cell is given an additional qualifier to identify it as a first, second or third tier cell.

The cell cluster is a typical intermediate result, as the eNodeB will not be configured with the cell cluster, but it is an essential input for other self-configuration algorithms requiring information from remote cells, like the PHY-CID assignment algorithm. Depending on the implementation of those algorithms even the 3rd or nth tier neighbors may be added. The cell cluster is constructed starting from the NRT of the inserted cell (containing the first tier neighbor cells) and going through the NRT's of the neighbor cells until the expected level of neighbors has been collected.

4) Class B3 parameters: Class B3 parameters have a restricted value range. Therefore the same value needs to be assigned to multiple cells throughout the network. All class B3 parameters need to be configured collision free (Table 1), which means that the configured value of the parameter needs to be different from the values configured in all the neighboring cells. An example for the Physical Cell ID (PHY-CID) assignment is explained in [6].

5) Tracking Area: In order to maintain the location of mobiles for paging purposes the E-UTRAN is divided in contiguous Tracking Areas (TA). Every cell must be assigned a Tracking Area Code (TAC). Usually tracking areas are assigned manually by planning experts, based on traffic behavior knowledge in the area.

The size of a TA is constrained by a trade-off between the paging signaling load and location update load. There exist several proposals to perform location area planning automatically by means of mobility and traffic prediction models. These models aim to compute cell border traversal frequency and paging load to assign location areas for optimum signaling cost. Typical inputs are a geographic map of cells and high capacity routes, the population distribution, user mobility behavior, paging traffic model and relative resource cost of paging and location updates.

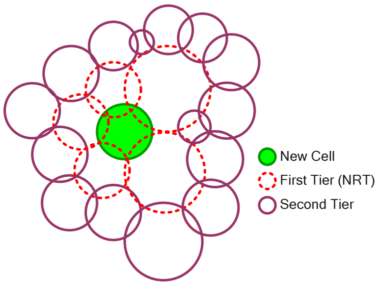


Figure 3: Cell Cluster Example

Alternatively a *provisional assignment* algorithm could be used. For example, a new cell could be allocated to a TA of a neighbor cell while maintaining a TA size limit. Because an incremental assignment may create a sub-optimal location of tracking area borders, a periodic TA self-optimization should be foreseen. The optimization should also take care of reconfiguring other affected cells, since a TA re-configuration may propagate through a large part of the network.

While the outlined DRC vision contains "instantaneous" reconfiguration, in a real system there may be constraints: a reconfiguration of existing cells triggered by the above algorithms may need to be postponed until low traffic hours. For example, reconfiguring tracking areas may cause location update storms and temporary paging failures in the area. Modification of an operational radio configuration might also induce a reboot of HW modules, resulting in temporary service outages. In principle a new cell should not be brought into operation until all adjacent cells affected by the insertion are adapted, subject to operator's policy. Therefore a coordination function is required to control reconfigurations of existing cells and the operational state of new cells.

The human operator will take a different role than with the traditional base station enrollment, where often a (remote) commissioner is involved to provision the planned radio configuration on the access nodes. With self-configuration, the remote commissioner primarily monitors progress of base station rollouts and the performance of the dynamic configuration algorithms on the basis of event notifications, respectively Key Performance Indicators gathered after entering operational state.

The operator should also be able to control the DRCF through policies. This can include the selection of a self-configuration algorithm, fine-tuning of algorithm parameters, defining constraints on parameter values, configuring reconfiguration schedules, failure handling etc. Only in exceptional cases the human operator should be alarmed and take over control to initiate corrective actions on the input data or the policies of the DRCF.

It would be technically feasible to integrate the dynamic radio configuration functions on any management layer, ranging from a centralized solution on NMS level up to a distributed solution implemented on the eNodeBs only. In general, for achieving minimum complexity and considering the requirements of the different algorithms on scalability, input data collection, coordination, performance etc., it is recommended to handle those functions in a centralized way.

III. SUMMARY

A framework is presented for a dynamic radio configuration of new base stations or cells, allowing for ad-hoc deployments in cellular networks with minimal planning overhead. These functions primarily consist of a set of algorithms to compute the radio parameters automatically and coordination functions to collect the necessary input parameters, to configure the new cells and to reconfigure neighbor cells. Altogether these functions are activated in a (usually centralized) workflow according to a predefined order while taking into account operator policies. Algorithms can be derived from those available in the conventional network planning & configuration tool chain, yet have to be adapted to the dynamic (incremental) way of execution.

The concept enables a transition path from a "static" infrastructure network where all parameters are pre-planned before deployment to an entirely "dynamic" infrastructure network where *only* the site of deployment for a network element is pre-planned. For the presented E-UTRAN the solution will still be not the fully dynamic one, however it is now possible to continue research towards that scenario.

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