Online Automated Tuning of RRM Parameters of UMTS Networks: Uplink Load Factor Threshold

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Abstract — This article addresses the automated tuning of RRM parameters in UMTS networks. It presents a generic functional architecture and the envisaged approach for the tuning of the uplink load factor threshold. In order to maintain the network stability, auxiliary mechanisms (dimensionless matrix calculation) were also implemented. The conducted simulations showed the feasibility of the present approach and a significant improvement in the network performance in terms of Quality of Service (QoS) and capacity.

1. INTRODUCTION

Traffic fluctuations and user mobility can cause impairment of the network performance and of the quality of service. Nowadays mobile network operators have fixed and usually uniform settings for their network parameters. This static configuration is not able to adapt automatically to the changes that occur in the network. A fixed parameter setting then gives a non-optimal solution for the network optimisation process and thus the utilisation of the radio interface is not maximized. Therefore, research work is needed for automation of the optimisation process of mobile networks in order to cope with the different conditions.

Optimisation of the radio access network is a complex process that the operator needs to perform periodically and manually. After network deployment, network performance and quality characteristics are monitored and possible hard (e.g. antenna tilt) and soft parameters (related with the RRM mechanisms) have to be tuned. These optimisations are needed due to traffic fluctuations, service changes, user mobility, etc. The goal of the automated tuning is to adjust dynamically these parameters (only soft parameters considered) in a continuous way without human intervention, which is only required in the definition of the reference QoS.

Optimisation of mobile networks has been gaining growing interest in the research community. The first studies focused on the automated fault detection and automated tuning of GSM networks, and later on of UMTS networks. Different algorithms, primarily based on the control of a single parameter were proposed. The control of parameters such as handover windows [1], total received interference target [2], total cell transmission power target and radio link power maximums [3], Eb/N0 in the UL/DL for data traffic [4] and common pilot channels powers [5] were proposed in several papers and books [6]. Later on, the concept of multi-parameter optimisation, where a set of key RRM parameters is optimised simultaneously with an automatic control method, was introduced [7] [8]. These studies have show the feasibility of automated optimisation of single or multiple RRM parameters and demonstrated a significant increase in network capacity in comparison with default parameter settings.

Depending on the required reaction, time two different strategies can be devised for the optimisation: offline (based on long term averaged indicators) and online (based on short term indicators). Due to the large number of parameters involved and large optimisation areas, the first type of optimisation often tends to be very complex and time-consuming. Thus, stochastic optimisation algorithms, such as genetic algorithms, are often used to perform offline optimisation. On the other hand, online optimisation has as a goal optimisation of the controller in a functioning network. Due to its online nature, high speed convergence is required for this type of optimisation. Here usually simple but resilient optimisation algorithms/processes are used. Most of the algorithms for online optimisation of controller presented in the literature are based on a set of rules (rule based algorithms) [2].

This paper addresses the problem of automated optimisation of the load factor threshold (LFT) of the admission control algorithm of a UMTS network based on the key performance indicators (KPI), call dropping and blocking ratio. Furthermore, it proposes in the following section a general functional architecture for the tuning system. Section III describes the control method for the LFT. Simulation topics and results are presented in section IV.

II. AUTOMATED TUNING FRAMEWORK

This section presents a functional architecture for the system that performs the tasks related with the automated tuning process. A conceptual representation of a generic automated tuning system (ATS) is depicted in Fig. 1. It consists of three main blocks (Control algorithm, Learning & Memory and Monitoring) and two interfaces (RAN and reference). The Radio Access Network (RAN) provides access to the RRM parameters and gives the values of the event counters, which can be grouped into a single parameter (key performance indicator - KPI) to give a better understanding of the real state of the network. The reference
source provides the operator’s concept of quality of service and network performance (reference KPIs).

![Diagram of Automated Tuning System](image)

**Fig. 1 – Automated Tuning System**

The automated tuning system creates a statistical feedback loop between network measurements and the RRM parameters. The network is constantly monitored; selected indicators are placed into memory for statistical analysis and compared with the reference source. When any of the cells does not meet the reference criteria, the tuning algorithm is started, and parameters are possibly changed. Thus, radio network optimisation process becomes an automatic process.

The functional architecture having been presented, each of the constituting blocks will be explained in more detail. The ATS can be sub-divided into three smaller blocks:

- **Monitoring**: For each cell a set of input measurements is constantly monitored and an alarm is triggered when a KPI is not met. This alarm is passed to the algorithm entity, which takes the adequate measures to put the QoS within the target defined by the operator or to improve the performance of the network.

- **Learning & Memory**: This block can be seen as a database that accumulates statistical information concerned with the network performance (memory). It is also responsible for finding out trends and network behaviour regarding different traffic and radio aspects (learning). This entity can also be used to adjust the rules or the steps of the control algorithm.

- **Control Algorithm**: This block can also be called intelligent control algorithm. It receives the alarm from the monitoring block and with the help of the information provided by “Learning & Memory” decides on the actions to take (subsystem, parameter and value). This action usually compromises the change of one or several RRM parameters. It may occur that no change is required since network operator would not benefit. In this situation the process is stopped and, for example, a new subsystem to tune is chosen.

### III. LOAD FACTOR THRESHOLD TUNING

This section presents the tuning of a parameter related with the admission control algorithm. The optimisation is performed on a cell basis. Reference [7] shows that this approach results in a superior network performance compared to cell cluster based optimisation because optimal values are obtained for each cell. Prior to any parameter modification it is compulsory to predict the impact that this event will have on the network in terms of interference.

#### A. Selected optimisation parameter and quality indicators

The UTRAN provides several statistics concerned with the radio interface obtained from the node-B or the RNC. In order to overcome the instantaneous radio channel and traffic fluctuations this performance indicators are then filtered using sliding windows. Besides, it is necessary to calculate the KPI. The selected KPI should tell clearly whether the network performance is improving or deteriorating. The following KPIs were chosen:

- **Call Blocking rate (CBR)** – due to maximum cell load
- **Call Dropping rate (CDR)** – due to insufficient MS power
- **Load factor (LF)**, defined by the following equation:

\[
LF = \frac{I_{\text{intra}} + I_{\text{inter}}}{I_{\text{intra}} + I_{\text{inter}} + N}
\]

In the above equation \( I_{\text{intra}} \) stands for intra-cell interference, \( I_{\text{inter}} \) for other-cell interference and \( N \) for receiver noise.

Corrective actions are related to tuning of RRM parameters in the RAN. These values are set by the control algorithm and constitute the ATS output. The present approach focuses on the tuning of the load factor threshold (LFT) of the admission control algorithm in the uplink direction.

#### B. Trade-offs

There are two limiting factors for an uplink capacity limited scenario: cell load and interference. When the maximum uplink cell load is reached, no more users can access the network, which brings about the blocking of new users. On the other hand, a mobile’s not having enough transmission power to access the network service accounts for call dropping.

When tuning the load factor threshold, it is mandatory to understand how the KPIs (CDR/CDR/LF) vary accordingly. If the LFT is increased, more users will be allowed to access the network and, consequently, the CBR will decrease, however, at the expense of higher CDR or lower quality for data traffic. On the other hand, if a cell is allowed to accept less traffic (decrease load factor threshold), a higher blocking probability for voice and queuing probability for data will result. Therefore, there is a trade-off between the load factor threshold and call dropping/blocking rate. Fig. 2 presents the evolution of the quality indicators (CBR/CDR) with respect to different load factor thresholds. The CBR and CDR curves intersect at the optimum point, where these quantities and the cost function are minimum.
C. Learning & Memory

In UMTS all cells share the same frequency. Hence, prior to the tuning of RRM parameters, in order to insure network stability, it is mandatory to implement support analysis mechanisms that analyse the impact on the neighbouring cells and other sub-systems. These perform statistical estimations, based on the information provided by the Learning & Memory block, in order to determine whether the impact on the system as a whole is acceptable. If automated tuning might cause system instability, the process is interrupted.

The devised approach currently focuses on the estimation of the impact in terms of interference in the neighbouring cells, which will occur due to the tuning of the LFT parameter. This method is based on a night learning scheme and online calculation of the dimensionless interference flow matrix ($\alpha$). The matrix is regularly constructed online based on relative path losses between the cell where it is being executed and all the neighbouring cells. After obtaining this matrix, it is possible to predict the load factor in the neighbouring cells.

D. Control Algorithm

This control algorithm is based on known facts and knowledge acquired from the experience of a radio engineer, associated with reasoning methods to make conclusions. Decisions are taken on the base of a set of imperfect set of input data. A set of rules, specifying the conditions of the application of a rule and the action to take under these conditions, was produced from the known facts.

The load factor threshold of a cell is tuned according to the filtered quality indicators measurements (KPIs). The input variables (CBR/CDR) are compared against the references REF1 and REF2 respectively. The network quality indicators may be considered degraded if they are above the target value set by the network operator. Taking into account the existing trade-offs, and the specific set of inputs, the following actions are allowed:

- **No Action (NA)** - Tuning is not necessary or may degrade network performance;
- **Increase LFT (INC.)** - Increase the load factor threshold in order to decrease the call blocking and improve network capacity;
- **Decrease LFT (DEC.)** - Decrease the load factor threshold further limits the allowed interference in the system, which makes call dropping rate decline (but compromising the system maximum throughput) or improve network coverage.

Optimisation should only be performed ensuring that the impact on other subsystems or cells is acceptable (NC). In the case when both values are above their references (CV), we consider more important to ensure the planned cell capacity and to bring the system faster into a stable state then to improve the capacity.

As a result, a set of conditions/action(s) was constructed, as is presented in the matrix form in Fig. 3.

![Fig. 2– LFT setting vs. quality indicators](image)

![Fig. 3 – Decision Matrix](image)

<table>
<thead>
<tr>
<th>CDR</th>
<th>$&lt;$ REF1</th>
<th>$\geq$ REF1</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBR</td>
<td>$&lt;$ REF1</td>
<td>NA DEC.</td>
</tr>
<tr>
<td>CBR</td>
<td>$\geq$ REF1</td>
<td>INC. DEC.</td>
</tr>
<tr>
<td>(NC)</td>
<td>(CV)</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 3 – Decision Matrix

IV. SIMULATIONS

In order to prove the feasibility of the presented approach a set of simulations was carried out using a semi-static WCDMA radio network simulator. Since the control algorithm deals with the tuning of the UL load factor threshold, only the uplink iteration will be performed. The simulation parameters are included in Table I.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial number of UEs (antenna type)</td>
<td>1000/4000 (Omni)</td>
</tr>
<tr>
<td>Number of BSs (antenna type)</td>
<td>19 (Omni)</td>
</tr>
<tr>
<td>Service (Bit Rate)</td>
<td>Voice (8kbps)</td>
</tr>
<tr>
<td>Initial Load Factor (Scenario I/II)</td>
<td>0,6 / 0,5</td>
</tr>
<tr>
<td>Path Loss Model</td>
<td>Okumura Hata</td>
</tr>
<tr>
<td>Shadow fading deviation (db)</td>
<td>7</td>
</tr>
<tr>
<td>Ref1,Ref2 (%) (Scenario I/II)</td>
<td>5,5 / 2,5</td>
</tr>
<tr>
<td>LFT Tuning step</td>
<td>0,1</td>
</tr>
<tr>
<td>Test cell</td>
<td>BS1</td>
</tr>
</tbody>
</table>

A. Learning & Memory

Firstly, the interference flow matrix ($\alpha$) was calculated based on the relative path losses. It was observed that the bigger values correspond to the first tier around the test cell (mean 0,2166; std 0,0453) followed by the second tier (mean 0,0510; std 0,0273) mainly due to better propagation conditions. Thus not all cells are affected equally when a parameter is changed; the second tier being significantly less
affected. The user distribution and propagation conditions determine the values contained in the interference flow matrix.

The second step was to predict new load factors in the neighbouring cells. Fig. 4 presents some of the values predicted using the alfa method and the measured values in the simulation scenario and shows the error involved in the calculation of the load factor for different thresholds and for different BSs. The error values reaches at the most 1.5 %, which proves that the proposed calculation method is feasible and highly accurate.

![Fig. 4 – Measured vs. predicted load factor](image)

**B. Control Algorithm**

Fig. 5 illustrates the variation of the CDR and CBR with respect to the simulation time of scenario I. The KPIs vary according to the rules that were stated previously. Before increasing the LFT in the test cell, the impact in the neighbouring cells was also analysed and the tuning would be done if the KPIs of the neighbouring cells would stay below their reference limit. The simulation stopped when the measured CBR and CDR met the required requirements.

![Fig. 5 – LFT Tuning](image)

Table II presents the network statistics prior and after the start of the automated tuning process for scenario II. As expected, with the increase of the LFT, the call blocking rate decreases and subsequently more users are allowed to access the network. As a consequence, an increase of the average throughput for the test cell (BS1) and, at a smaller rate, of the average network throughput is observed. For some neighbouring cells the throughput may decrease slightly due to the additional interference, even though the performance of the network as a whole surely becomes better. Another issue to address is the grade of service (GoS). As can be seen from Table II, with the increase of the LFT the network GoS increases. This allows us to conclude that network performance in terms of throughput and QoS improves with the automated tuning process, and, consequently, the radio access network can be used more efficiently.

![Table II - Network statistics](image)

**REFERENCES**