A New Methodology for RF Failure Detection in UMTS Networks

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***Abstract*— The optimization of third-generation mobile communication systems has become an important aspect for network operators. This paper proposes a new methodology for RF failure detection in UMTS networks based on Key Performance Indicators (KPI) which are obtained by measuring certain parameters at different network entities. With the proposed methodology possible uplink problems are identified. The proposed method has been validated with data extracted from a real UMTS network.**

Keywords: UMTS, Key Performance Indicator, RF failure detection, uplink interference.

I. Introduction

Third-generation (3G) mobile communication systems (e.g. UMTS, CDMA2000) have seen widespread deployment around the world. There are 395 commercial 3G operators in 135 countries with a total of around 477 million 3G subscribers as of June 2007 [1]. 3G Operators must run radio networks that can introduce new services with high added-value without compromising network quality and can rapidly react to constant dynamic changes into the operation conditions, which in turn are every time more and more difficult to predict.

Wireless cellular systems need continuous monitoring due to the inherent network dynamism, with multiple sources of randomness such as propagation conditions, mobility, traffic behaviour, etc. This monitoring requirement is emphasized in WCDMA-based networks such as UMTS because these variations directly influence the radio network quality. As a result, 3G networks can only be effectively optimized through automated, self-adaptive processes based on data dynamically drawn from the network. The optimization engine would monitor network performance continuously, evaluate actual QoS (Quality of Service) and dynamically set relevant parameters. Operators should target 3G optimization in a timely manner in order to gain progressively insight into the problem. Otherwise the envisaged WCDMA enhancements may complicate filling the gap with actual 2G optimization engineering skills.

WCDMA networks are intrinsically interference limited, with many coupling effects between cells of the network, so that the modification of a given parameter in one cell can directly impact the performance of other cells elsewhere in the network [2]. UMTS network optimization turns out to be a tricky and complex task because the target objectives in terms of coverage, capacity and quality tend to be contradictory (e.g. capacity may be increased at the expense of a coverage or quality reduction). Additionally, the number of tuneable parameters in a WCDMA network is significantly higher than that of a 2G TDMA-based one.

In such complex scenarios, an efficient network management becomes prime important in order to guarantee the QoS requirements to the subscribed users. In the last years, operators are showing an increasing interest in automating this network management tasks in order to increase operational efficiency. An intensive effort has been done by operators and investigators in the field of automated optimization [3][4][5][6]. Two different phases can be distinguished in the optimisation of a 3G system [7]. The first phase is RF optimization, whose objective is to guarantee the required coverage, avoiding excessive pilot pollution, cell overlap or cell overshoot by optimizing the setting of RF parameters such as pilot power, antenna down-tilt, etc. The second phase is service parameters optimisation. This includes the setting of admission and congestion control thresholds, maximum downlink power per connection, events to change to compressed mode and channel switching, etc.

One of the most important steps in network optimization is troubleshooting (i.e. fault management). It consists on detecting network problems, identifying the cause of that problem and providing an adequate solution. Fault detection in the Radio Access Network has been studied for different wireless systems. As an example, in [8] an automatic fault management methodology based on the correlation of different alarms is proposed for GSM/GPRS systems. Other works such as [9] deal with troubleshooting for WLAN. In the framework of UMTS, [10] proposes a neural network algorithm that makes possible to perform a more efficient troubleshooting and optimization of the cell parameters. On the other hand, a methodology for automated fault management tasks based on Bayesian Networks is proposed in [11]. Within this context, this paper presents an approach for RF failure detection for UMTS, which can eventually be used by an automatic optimization tool. By using a symptom matrix, the possible RF problems are identified according to several Key Performance Indicators (KPI). In particular, this paper proposes a new methodology to identify uplink interference problems and determine the possible cause of these problems. Within this context, section 2 provides the general description of the proposed methodology. Section 3 presents a detailed description of the methodology based on a flow diagram and the comparison of different KPIs with certain thresholds adjusted according to real measurements. Finally, section 4 provides some results obtained from real data in a real network and the conclusions are summarised in section 5.

II. General Description of the Proposed Optimization Methodology

Evaluating RF performance requires the identification of RF quality metrics based on the measurements specified in [12] for the uplink and downlink in both dedicated and common channels. In addition to these RF measurements, some other KPIs obtained by measuring certain network parameters at different network entities (namely the Node-B or the RNC) and related with e.g. load levels, users in soft/softer handover, etc., can also be used so that a more accurate network characterization is obtained and then proper decisions of network reconfiguration can be done. Two levels of optimization can be defined:

- *Limited information.* In this case, it is considered that certain UE measurements (such as UE transmitted power, received CPICH power, received E_c/N_o, path loss, etc.) are not available for optimization. The proposed solution in the limited information case will be based on substituting those unavailable KPIs by other statistics or combination of measurements that may reflect the same problems and are available at the network management entity.
- *Complete information.* In this case, it is considered that UE measurements are available for optimization. Clearly, this case may provide more precise results in the detection of the RF problems.

A complete diagnosis requires a multidimensional lookup matrix which takes into account as much as possible KPIs. Table 1 shows a simplified matrix for symptoms covering only three metrics: CPICH E_c/N_o (Common Pilot Channel per chip over total received power), CPICH *RSCP* (Received Signal Code Power of the pilot channel) and UE transmitted power. In most cases, these are sufficient to identify RF issues [7].

III. Case 1: Detailed Description

This section proposes a methodology for the detection of possible problems and the identification of its causes for the case 1 (see Table 1). This methodology can be divided in two phases: Detection of the problem and identification of the possible causes that may have generated that problem.

A.- Detection of the problem

This section presents a flow diagram to determine case 1 problems. The other seven cases of Table 1 can be detected by adding new branches in the flow diagram in Figure 1. In case of complete information, case 1 is detected provided that CPICH E_c/N_o, UE transmitted power and CPICH *RSCP* are above certain thresholds as shown in Figure 1. In case of limited information, new KPIs which may detect the same problem are proposed. In the following a description of these KPIs is given.

Table 1.- RF Failure Symptom Matrix

High CPICH E_c/N_o	High UE transmitted power	High *RSCP*	**CASE 1:** UL interference and no DL problems
		Low *RSCP*	**CASE 2:** UL coverage problems
	Low UE transmitted power	High *RSCP*	**CASE 3:** Problem no related with RF
		Low *RSCP*	**CASE 4:** DL coverage problems
Low CPICH E_c/N_o	High UE transmitted power	High *RSCP*	**CASE 5:** UL and DL interference
		Low *RSCP*	**CASE 6:** UL and DL coverage problems
	Low UE transmitted power	High *RSCP*	**CASE 7:** DL interference problems
		Low *RSCP*	**CASE 8:** DL coverage problems

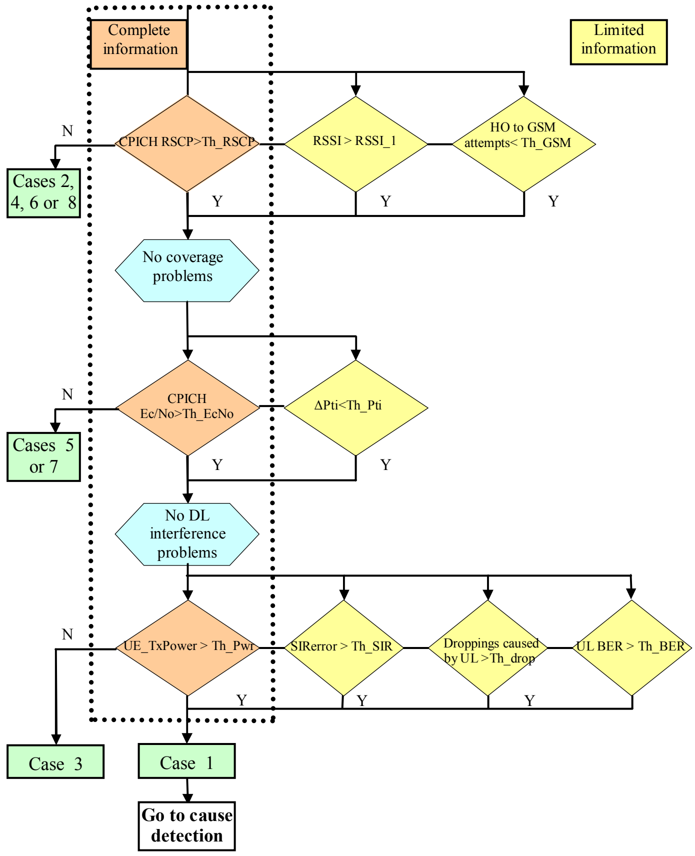

Figure 1.- Diagram for RF problem detection

A.1.- Detection of coverage problems

In the complete information case, a CPICH *RSCP* below a certain threshold *Th_RSCP* may indicate coverage problems. In this case, it is possible that some users will try to handover to GSM in order to maintain the required user QoS requirements. Then, the number of attempts of handover to GSM divided by the cell load can be computed and may substitute the CPICH *RSCP* condition. A possible setting of the *Th_GSM* threshold is done according to the 80 percentile of this statistic in all the cells of the RNC, which leads to *Th_GSM=0.15* in the considered case. Coverage problems can also be detected by studying the uplink *RSSI* (Received Signal

Strength Indicator) which is available at the Node-B/RNC and represents the total received power at the Node-B. The *RSSI* can be written as:

$$RSSI = \frac{P_N}{1-(1+f)\sum_{i=1}^{n}\frac{1}{\frac{W}{R_{bi}\left(\frac{E_b}{N_0}\right)_i}+1}} \quad (1)$$

Where W is the bandwidth, $R_{b,i}$ is the i-th user bit rate, n is the number of connected users in the cell, $(E_b/N_0)_i$ represents the i-th user requirement, f is the relation between intercellular and intracellular interference and P_N denotes the thermal noise power. Let us define $RSSI_1$ as the *RSSI* when there is not intercellular interference ($f=0$). Measuring a *RSSI* lower than $RSSI_1$ may indicate uplink coverage problems meaning that the connected users cannot obtain the required E_b/N_o.

A.2.- Detection of downlink interference problems

In the complete information case, a CPICH E_c/N_o lower than a certain threshold *Th_EcNo* may indicate DL interference problems. However, this is a measurement collected by the terminal and, if periodic reporting is not enabled, it is not always available at the management system. Consequently, in the following an alternative estimation based on the DL transmitted power is provided. Specifically, CPICH E_c/N_o can be estimated as:

$$(E_c/N_0)^{-1} = \frac{P_T}{P_p}\left(\frac{\rho P_{Ti}}{P_{Ti,\min}} + (1-\rho)\right) \quad (2)$$

According to equation (2), for a given value of the orthogonality factor ρ, an estimation of the user CPICH E_c/N_o can be obtained as a function of the total base station transmitted power P_T, the pilot power P_p and the transmitted power per connection P_{Ti}. From the transmission power measurements and equation (2), the relationship between the variability ΔP_{Ti} (defined as the difference between the 90 and 10 percentiles of P_{Ti}) and the variability $\Delta E_c/N_0$ (defined as the difference between 90 and 10 percentiles of E_c/N_0) has been obtained empirically and by means of simulation and is plot in Figure 2 for the case of $\rho=0.4$.

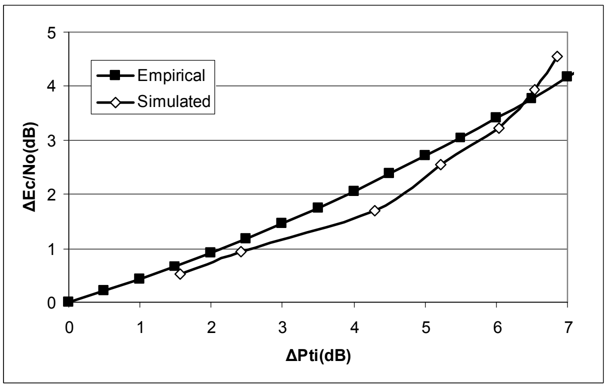

Figure 2.- Correspondence between $\Delta E_c/N_0$ and ΔP_{Ti}

As a result, the condition $E_c/N_0>Th\_E_cN_0$ in Figure 1 could be expressed as $\Delta P_{Ti}<Th\_Pti$. A threshold to detect cells with DL interference can be obtained by evaluating e.g. the 80 percentile of ΔP_{Ti} in all the cells of the RNC (*Th_Pti=3dB*).

A.3.- Detection of uplink interference problems

In the complete information case, uplink problems can be detected by measuring an UE transmitted power higher than a certain established threshold *Th_Pwr*. Nevertheless, if this measurement is not available, some other conditions can be used. On one hand, uplink problems can be detected by observing the uplink $SIR_{error}=SIR_{target}-SIR$, being *SIR* the measured Signal to Interference Ratio and SIR_{target} the *SIR* user requirement). In general, uplink problems occur when the user power control is not able to keep the *SIR* equal to the SIR_{target} and consequently, the user QoS requirement is not achieved. Similarly, droppings will occur in instants of time with high uplink BER. A relationship between the SIR_{error}, the dropping probability and the uplink BER has been found. Although it is not presented in this paper, in the considered measurements when the 90 percentile of the SIR_{error} is higher than *Th_SIR=6dB* the dropping probability caused by uplink problems is higher than *Th_drop=0.37%* and the 90 percentile of the UL BER is also higher than *Th_BER=20%.* These three conditions may be used to detect uplink problems in the limited information case.

B.- Detection of the problem cause

Following the RF problem detection of case 1 in Figure 1, this subsection presents a flow diagram to identify the causes of the problem, see Figure 3. First, the methodology makes use of the *RSSI* in order to determine if the uplink interference problem is caused by intracellular or by intercellular interference. For that purpose, a new threshold $RSSI_2$ is defined. It corresponds to the RSSI that would be measured if the relation between intercellular and intracellular interference was f=0.6 (in equation 1), which is a typical value [13]. Note that *RSSI* higher than $RSSI_2$ may indicate an excessive level of either uplink intercellular interference or external interference caused by other communication systems. Once the problem has been identified as a high intercellular or external interference the specific causes can be distinguished according to handover statistics. Specifically, if the number of handovers divided by the cell load is higher than a threshold *Th_A*, it may indicate that the interference is in fact caused by neighbouring cells. This is because a high number of handovers may be related with many users located at the cell edge of neighbouring cells and in this case, a high level of uplink intercellular interference would be observed. The corresponding threshold can be determined according to e.g. the 20 percentile of this measurement in all the cells of the RNC (*Th_A=13.26).* The rest of causes are identified by analysing the average number of simultaneous Node-Bs per connection (*AvgNodeBs*) and the average number of simultaneous cells (sectors) per connection (*AvgCells*). Similarly, considering the 50 percentile of *AvgCells* and

AvgCells-AvgNodeBs, the thresholds for these statistics would be *Th_B=1.36* and *Th_C=0.2* respectively.

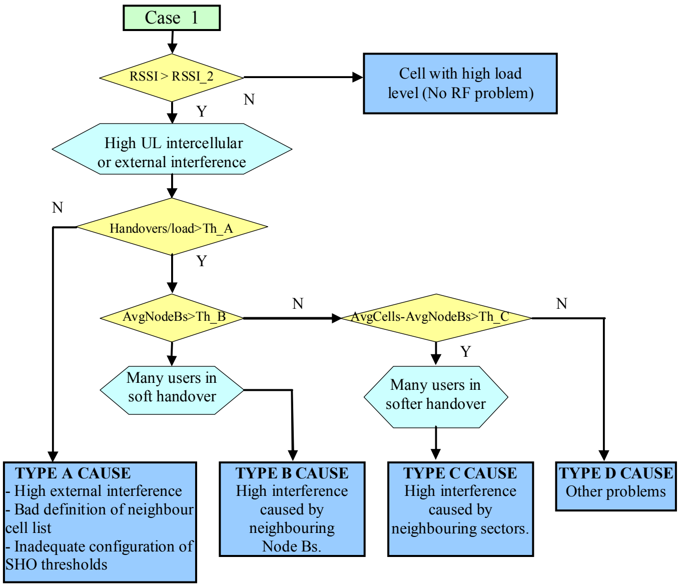

Figure 3.- Diagram for detection of causes of problems

IV. Problem Cause Classification

The proposed methodology has been applied in a real scenario with 75 trisectorial Node-Bs each of them identified by the pair *Cell_x_y* where *x* corresponds to the Node-B identifier and *y* is the sector of this Node-B. Table 2 shows all the cells for which a case 1 RF problem was detected. They are classified according to the specific type of problem. For each cell, the number of handovers divided by the cell load, the term (*AvgNodeBs)* and the difference *AvgCells-AvgNodeBs* is presented. The percentile of these parameters in each cell with respect to all the considered cells is presented in brackets. Note that two sectors of Cell 65 have a type C problem. It is possible that an excessive overlap between sectors Cell_65_1 and Cell_65_2 may exist. On the other hand, although it is not shown in this paper, an extremely high value of the RSSI observed in certain periods of time in Cell_71 indicated the existence of an external interference. This is detected for Cell_71_2 and Cell_71_3 with the proposed methodology (see Table 2). The presented results were validated by expert radio engineers with detailed knowledge on the real network deployment.

V. Conclusions

This paper has proposed a new methodology to detect RF failures in UMTS networks based on several KPIs. In particular, the methodology has been firstly developed based on CPICH E_c/N_o, UE transmitted power and *RSCP*. Nevertheless, since these parameters may not be always available at the network management entity, some alternative KPIs have also been defined. A flow diagram based on threshold comparisons has been proposed for the detection of uplink problems and the possible causes of these problems. The thresholds of the flow diagram have been adjusted according to certain percentiles of the different KPIs in all the cells obtained from real measurements. Finally, the methodology has been applied to a real scenario and the results have been validated by expert radio engineers with detailed knowledge on the real network deployment.

Table 2.- Cell classification with the proposed methodology

Type of problem	Cell	HOs per cell load	AvgNodeBs	AvgCells-AvgNodeBs
A	Cell_71_2	12.60 (17)	1.20 (11)	0.2 (50)
	Cell_71_3	6.10 (3)	1.04 (1)	0.14 (26)
	Cell_73_3	12.94 (18)	1.11 (4)	0.42 (89)
B	Cell_52_1	22.23 (44)	1.42 (63)	0.3 (73)
	Cell_01_3	17.27 (32)	1.52 (81)	0.21 (53)
	Cell_66_2	20.32 (41)	1.43 (63)	0.1 (10)
	Cell_15_3	38.79 (75)	1.47 (69)	0.1 (10)
	Cell_32_2	39.16 (76)	1.53 (82)	0.1 (10)
	Cell_66_1	30.68 (63)	1.46 (67)	0.2 (50)
	Cell_74_1	42.57 (78)	1.57 (87)	0.06 (3)
C	Cell_30_1	37.33 (73)	1.33 (43)	0.41 (88)
	Cell_65_1	13.81 (21)	1.26 (27)	0.59 (98)
	Cell_65_2	37.66 (74)	1.26 (27)	0.2 (48)
	Cell_71_1	22.82 (45)	1.04 (1)	0.39 (86)
D	Cell_30_2	16.50 (27)	1.22 (16)	0.12 (18)

Acknowledgments

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