Correlation between Uplink Noise, Uplink Load and Call Drop Rate in a WCDMA Network

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ABSTRACT
The 3G wireless network system based on the WCDMA technology is a self-interference system. A self-interference system is one in which interference is internally generated by the components that make up the system. Controlling the level of interference on the system is pivotal for stability of WCDMA cells. In this paper a study of the correlation between the uplink noise generated on a WCDMA based cell and the rate of voice and data call drops experienced by User Equipment (UEs) connected to that cell is performed. Network data from a live WCDMA cell in a network is collected and analyzed. This paper is intended to illustrate to engineers one of the many causes of a high call drop rate and ways of mitigating them.

General Terms
UMTS NetworkOptimization, Call Drop Optimization, Network Quality Improvement.

Keywords
Call Drop, Call Disconnections, Uplink Load, UMTS, WCDMA and Noise Rise.

1. INTRODUCTION
The evolution of the Third Generation (3G) system marked the introduction of new services such as video telephony, multimedia, video-on-demand, audio streaming, email and internet browsing to the burgeoning telecommunications ecosystem. The radio interface of the Universal Mobile Telecommunication System (UMTS) system is based on the Wideband Code Division Multiple Access (WCDMA) technology. The modes of operation of the WCDMA system include Frequency Division Duplex (FDD) and Time Division Duplex (TDD)[2]. Uplink is the radio connection in the direction from the user equipment to the cells of a NodeB and downlink is the radio connection in the direction from the cells of a NodeB to the UE's. Refer to figure 1.In the TDD mode, transmissions are separated by time and FDDby frequency. The UMTS technology employs FDD as compared to the GSM technology which employs TDD[2]. In this paper, FDD is modeled.

WCDMA systems are self-interference systems. This is because every UE transmitting on the system serves as a source of interference to other UEs on the system [3]. Moreover, a rise in the noise level resulting from the transmissions of UEs in the same cell, other cells and other sources of external interferences reduces the overall capacity of a WCDMA system[3].

Furthermore, the level of interference on a cell is time-varying with no regular pattern and as such the capacity of a WCDMA system cannot be predetermined. For this reason, WCDMA systems are said to have a soft capacity. However, in the conventional TDMA and FDMA systems, the capacity can bepredetermined as the numbers of channels available for traffic can be planned and is not limited by the noise level in the system[1].

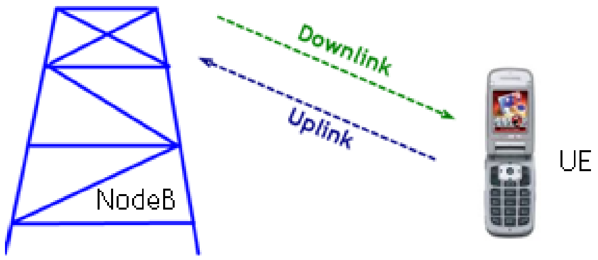


Figure 1: Uplink and Downlink Convention

Various key performance indicators (KPIs) checked concomitantly tell the quality of a WCDMA network. These KPIs usually identify issues pertaining to retainability, accessibility and mobility in the WCDMA network. In this paper focus is ona very important KPI, the call drop rate (CDR) which is under the retainability group of indicators. The call drop rate accounts for all the call disconnections that occur on the network. The call drop rate is defined as the ratio of dropped calls for both voice and data services to successfully established calls.

Another KPI closely linked to CDR which will be shown in this paper is the uplink load. The uplink load represents the level of noise rise, a soft resource [3], caused by interference from UE's transmitting on a celland other external interference sources such as a radio station transmitting on the same frequency band as the uplink frequency. Furthermore, according to [4], the capacity of a WCDMA system is limited on the uplink in high load situations. Thus, the capacity on the uplink is to be closely monitored.

2. RELATIONSHIP BETWEEN CALL DROP RATE, NOISE RISE AND UPLINK LOAD
To demonstrate the correlation between uplink noise and call drop rate, first it is pertinent to define the relationship between noise rise and uplink load. Second, define a relationship between uplink load and call drop rate.

2.1 UplinkNoise Rise and Uplink Load
From the study of[1],the following is derived:

Let, I^{tot} be defined as the total uplink interference power.

N is defined as the background noise power.

Ci is defined as the received power per user transmitting on the UL of a cell.

L be defined as the uplink load.

$\wedge$ be defined as the noise rise.

The uplink load, L, is represented as:

$$\frac{\text{Useful Received Interference Power}}{\text{Total Received Interference Power}} \quad (1)$$

In the uplink, the useful total interference power is the sum of all the individual users transmit power received on acell. Also, the total received interference power is the sum of all the individual users transmit power received on acell and the background noise. This is represented as:

$$L = \frac{\sum_{I=1}^{M} C_i}{\sum_{I=1}^{M} C_i + N} \quad (2)$$

(2) can be rewritten as

$$L = \frac{I^{tot} - N}{I^{tot}} \quad (3)$$

According to [1], noise rise, ʌ, is defined as (4)

$$\frac{\sum_{I=1}^{M} C_i}{I^{tot}} = \frac{L/\wedge}{1 - L} \quad (8)$$

$$\wedge \triangleq \frac{I^{tot}}{N} \quad (4)$$

(3) and (4) can be merged as

$$L = 1 - \frac{1}{\wedge} \quad (5)$$

From (5), the pole capacity equation can be written as

$$\wedge = \frac{1}{1 - L} \quad (6)$$

$$\frac{\sum_{I=1}^{M} C_i}{\sum_{I=1}^{M} C_i + N} = \frac{LN/(\sum_{I=1}^{M} C_i + N)}{1 - L} \quad (9)$$

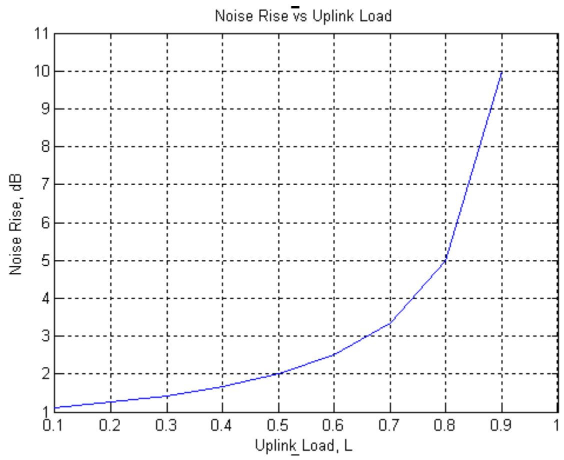
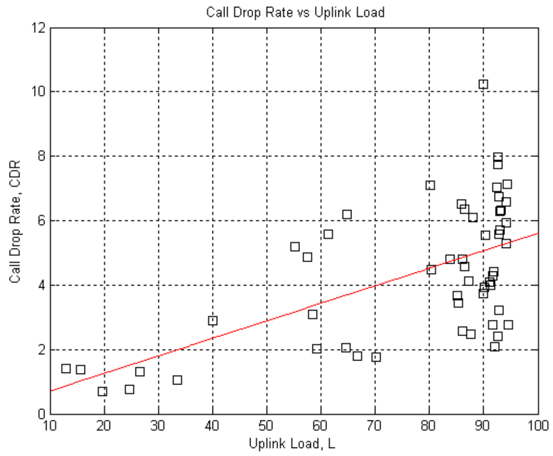


Figure 2: Noise rise and uplink load trend

Figure 2 shows the trend for uplink load at different levels of noise rise using (6). From the diagram it can be seen that as the uplink load increases beyond 90%, the noise rise increases to infinity.

2.2 Uplink Load and Call Drop Rate

A trial site was configured to aggregate the uplink loadand call drop rate – ratioof dropped calls to the ratio of successfully established calls– for different voice and data services at intervals of 168 hours,for a duration of 2,160 hours. The result is represented using Matlab as shown in Figure 3 below, which shows a direct proportionalityrelationship between CDR and the UL load. The data shows conclusively that as the UL load increases, so does the CDR on a cell.



$$\sum_{I=1}^{M} C_i = \frac{LN}{1 - L} \quad (7)$$

Figure 3: Call drop rate and uplink load trend

3. MITIGATION TECHNIQUES FOR UPLINK NOISE RISE, UPLINK LOAD AND CALL DROP RATE

In this section, the relationship between the total carrier to interferencepower and the uplink loadis shown.

3.1 Total Carrier to Interference Power and Uplink Load

To illustrate the relationship between the useful transmit power to total interference power and the uplink load, (2) is rewritten as

From (7),

$$\frac{\sum_{I=1}^{M} C_i}{I^{tot}} = \frac{L/\wedge}{1 - L} \quad (8)$$

Rewriting (8)

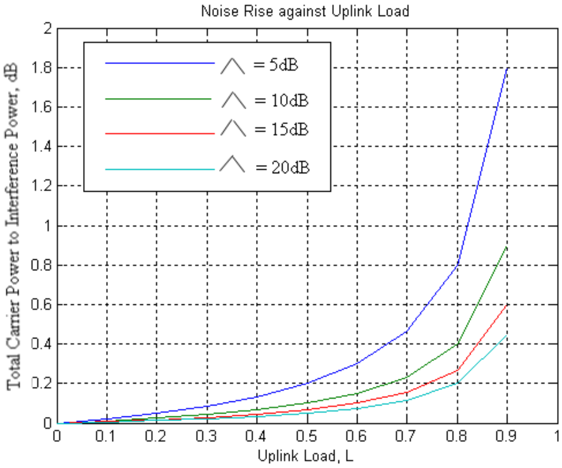


Figure 4: Background noise and uplink load trend

The chart in figure 4 shows that at different levels of noise rise, as the total carrier to interference power reduces so does the uplink load.

From (9) it can be seen that reducing the carrier power orbackground noiseleads to a reduction in the uplink load.In practice, a reduction of the total carrier power can be achievedinvarious ways, which include:

- The addition of a second frequency on NodeB’s whose cells have a high uplink load.
- Reduction in the coverage of the cell with a high uplink load, allowing for surrounding cells with a lower uplink load to serve UE’s previously covered by the cell with a high uplink load.
- Eliminating sources of external interference such as the transmission from nearby radio stations on the same frequency as that of the cell.

4. CONCLUSION

A rise in the noise caused by an increase in the number of UEs or presence of external interference in a cell leads to an increase in the uplink load and consequently, an increase in the call drop rate as illustrated in this paper. Thus, the UL load is a pertinent KPI that identifies the level of noise rise on the network and should be monitored to controlthe call drops rate on the network. Reducing the noise rise by limiting M, reduces the total carrier power on the uplink of a cell. There are however other causes of call drops which engineers should also be aware of. Some of these cases include, but are not limited to, wrong parameter setting, wrong neighbor cell configuration and poor radio coverage amongst others.

5. REFERENCES

[1] Erik GeijerLundin, “Uplink Load in CDMA Cellular Radio Systems”,pp. 9-13, 43,pp 27-28, 2005.

[2] Salman Al-Qahtani and Ashraf Mahmoud “Uplink Admission Control in WCDMA”, 2005.

[3] Christophe Chevallier, Christopher Brunner, Andrea Garavaglia, Kevin P. Murray, Kenneth R. Baker “WCDMA Deployment Handbook Planning and Optimization Aspects”, 2006.

[4] K S Gilhousen, I MJacobs, R Padovani, A J Viterbi, L. A. Weaver, Jr., and C. E. Wheatly III, “On the capacity of a cellular CDMA system,” IEEE Transactions on Vehicular Technology, vol. 40, no. 2, pp. 303–312, May 1991.