

Uplink Admission Control in WCDMA

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Abstract — The 3G cellular mobile systems which are based on WCDMA technology are expected to be interference limited. Soft capacity is one of the main characteristics of 3G (i.e, UMTS) and it requires new radio resource management strategies to serve diverse quality of service requirements. In this paper we formulate the soft uplink capacity of a 3G WCDMA cell as a function of bandwidth and interference and the capacity utilization of an individual user as a function of the user's traffic class and activity factor.

A WCDMA prioritized uplink call admission control (CAC) algorithm for UMTS, which combines QoS negotiation and service differentiation by priority, is studied. This CAC scheme gives preferential treatment to high priority calls, such as soft handoff calls, by reserving some bandwidth margin (soft guard channel) to reduce handoff failures. In addition, queuing is also used to enhance the handoff success probability. The algorithm uses the effective load as an admission criterion and applies different thresholds for new and handoff calls. Finally, the study considers two types of services: voice and data calls. Simulation results indicate the scheme reduces the drop and increases the GoS and hence the system performance can be significantly improved.

Index Terms — Connection Admission Control , Load Estimation ,Queuing, SIR, Soft Handoff , WCDMA.

I. INTRODUCTION

Third generation radio communication systems are designed to offer multimedia services, including voice and video telephony and high-speed Internet access. In Universal Mobile Telecommunication System (UMTS), the radio interface is based on the Wideband Code-Division Multiple Access (W-CDMA) technology. UMTS WCDMA is a Direct Sequence CDMA system (DS-CDMA). WCDMA has two basic modes of operation: Frequency Division Duplex (FDD) and Time Division Duplex (TDD). In the FDD mode, uplink and downlink transmissions use different frequency bands while for the TDD mode, uplink and downlink transmissions can be implemented on unpaired bands but separated by a guard period. In this paper DS-CDMA (FDD) is considered [1]-[3].

The measurement of the resource capacity in a spread spectrum system is distinct from that for conventional

TDMA/FDMA systems. In conventional TDMA and FDMA systems such as IS-54 (TDMA) and GSM (hybrid TDMA/FDMA), the number of traffic channels is fixed. It is determined by the number of time slots in the TDMA system or by the number of non-overlapping frequencies in the FDMA system. The spread spectrum system, such as W-CDMA, does not have a fixed number of channels. Instead, the capacity of a CDMA system is limited by the total interference the system can tolerate. Such a system is referred to as an interference-limited system. Each additional active mobile user will increase the overall level of interference. Normally, the interference level increases rapidly when the system load reaches a certain level. Users with different traffic profiles and attributes such as the service rate, the signal-to-Interference ratio (SIR) requirement, media activity, etc. introduce different amounts of interference to the system. These factors are especially important in 3G wireless networks that support multimedia services [1]-[3].

The coverage of WCDMA is assumed uplink limited in high-load scenarios. Referring to [6] and [13], the capacity of DS-CDMA networks depends on the reverse link (uplink) rather than the forward link (downlink). Uplink call admission control strategies play a very important role in the performance of CDMA systems as it directly controls the number of users in a cell and thus limit the interference in the system. In this paper only the uplink direction is considered.

The rest of this paper is organized as follows. In section II the admission control strategy in the uplink direction with the general problem formulation is presented. In section III, the formula for calculating the Uplink capacity and estimating the increase in the interference level caused by incoming user are shown. Section IV describes the system model and explains our considered admission control in WCDMA systems while section V presents the simulation model, the obtained results, as well as the discussion. Finally, the paper is concluded in section VII.

II. UPLINK ADMISSION CONTROL AND RELATED WORK

A call admission control algorithm is needed to limit the interference by controlling the number of accepted flows. The CAC is performed for the uplink and downlink transmissions separately because the traffic load can be asymmetric. The new user is admitted into the system only if the both uplink and downlink admission control requirements are fulfilled. In this paper only the uplink admission control is considered.

Several uplink CAC algorithms have been developed in UMTS. Some of them are based on a predetermined maximum number of users in the system [9]. For the number-based call admission control schemes (NCAC), the QoS requirement, in terms of bit-error-to-interference ratio, is mapped into a maximum number simultaneous users that can be accommodate in the system. Other algorithms are more CDMA-oriented and consider the SIR as the determinant parameter in accepting or not accepting a new call. Those algorithms are commonly called Interference-CAC (ICAC) [10]-[16]. Based on previous studies [10]-[16], the interference-based schemes can be further classified into:

- *Wideband Power-based CAC*: This method computes the increase in the interference (power) caused by the establishment of a new user in the cell in uplink and accepts the call only if the total interference does not exceed a predefined threshold.
- *Throughput-based CAC*: A throughput-based CAC algorithm computes the increase in the load caused by the establishment of a new user in the cell in uplink and accept the call only if the total load does not exceed a predefined threshold.
- *Signal to noise interference ratio-based CAC*: This algorithm computes the minimum required power for the new user and accepts it if it is not below a predefined minimum link quality level.

A. Research Contributions of this Paper

In this paper a variant of the throughput-based CAC is considered. This scheme differentiates between two types of services and gives the higher priority to soft handoff calls by using a soft load factor margin and by implementing queuing techniques. Rejection of soft handoff requests causes forced termination of an ongoing real-time call, which is a severer problem than blocking of new call attempts. This admission control scheme can guarantee a higher QoS for the soft handoff requests of real-time services in 3G DS-CDMA systems by introducing the idea of soft guard channel to prioritized soft handoff calls. Unlike FDMA or TDMA systems, which use frequency bands or time slot as resources for

'hard' guard channels, the resources in CDMA cellular systems are interference limited. To prioritize the soft handoff calls, a certain amount of cell load is reserved exclusively soft handoff calls. In addition, queuing is also used to enhance the handoff success probability.

B. Relation to Previous Work

In [17] A CAC algorithm using total received power as thresholds when there exist multiple types of services is proposed. By setting the higher threshold to voice traffic, the voice traffic is given the higher priority than data traffic. Multiple threshold schemes are investigated and its performance is compared with that of a single threshold scheme. Also In [18], received power based algorithm is proposed, and when higher priority is desired for handoff calls, it allows different thresholds for new calls and handoff calls. In [15] an interference-based admission control strategy with multi level threshold is analyzed. Two classes of traffic are considered and the higher priority class is given higher threshold.[16] Provides a study of threshold-based call admission control in CDMA systems Whereas in [14], an adaptive interference threshold-based call admission control in multi-service CDMA systems is proposed. Different interference thresholds are employed for new and handoff calls. The interference threshold for handoff calls is higher than that for new calls.

Our algorithm differs from those algorithms in terms of using the cell load as an admission criteria and also using queuing as an additional priority techniques for handoff calls. In addition, the capacity estimate of W-CDMA systems is formulated. So, before presenting the description of this uplink admission control studied in this paper, next section will present the uplink capacity calculation and load estimation (in term of interference) for the WCDMA system. This estimation provides the key criterion in designing the admission control.

III. CAPACITY AND LOAD ESTIMATION IN W-CDMA SYSTEMS

To implement the admission control for WCDMA systems, first an estimate of the total interference should be computed to be employed in the decision process of acceptance or rejection of new connections. In this section the uplink capacity and load estimation of a homogenous, uniformly loaded network will be presented. The analysis carried out will focus on the UTRA-FDD mode. Furthermore, the analysis assumes perfect power control operation. Hence, a mobile station (MS) and its home base station (BS) use only the minimum needed power in order to achieve the required performance. The CDMA capacity

has been subject to extensive research work,[1]-[3]and [4]-[8], hence only a short description is given here.

The value of the bit-energy-to-noise-density ratio E_b/N_o corresponds to the signal quality, since it determines the bit error rate, BER. Let \mathbf{r} be the target bit-energy-to-noise-density ratio required to achieve a particular BER, or equivalently a particular frame error rate ($E_b/N_o \geq \mathbf{r}$). That means the maximum bit (BER) or blocks (BLER) error rates, can be mapped into an equivalent E_b/N_o constraint denoted by \mathbf{r} . If we assume perfect power control, then $E_b/N_o = \mathbf{r}$. The resulting BER can be approximated using:

$$Q\left[\sqrt{\frac{2E_b}{N_o}}\right] \approx \frac{e^{-E_b/N_o}}{2\sqrt{P(E_b/N_o)}} \quad (1)$$

In the uplink, the criteria for the received power for i^{th} MS can be written as:

$$(E_b/N_o)_i = \frac{G_i * P_i}{I_{own}(1+f) - P_i + I_o} \geq \mathbf{r}_i \quad ; i=1, \dots, N \quad (2)$$

$\frac{W}{R_i} = G_i$: is the processing gain for the i^{th} MS,

R_i : The bit rate associated with the i^{th} MS,

W : The chip rate of the WCDMA (3.84 Mcps),

P_i : received power of the desired signal,

I_o : Thermal noise (background noise power in the case of an empty cell received at base station),

I_{own} : intra-cell interference, i.e. the power received from other MSs connected to the same BS,

I_{oth} : the inter-cell interference, i.e. the total power received from MSs connected to other BSs in neighboring cells, and

v_i : the average voice activity factor indicating the portion of time when the user is actively transmitting.

Using the above definitions, the total interference on the uplink, I_{total} , is the sum of I_{own} , I_{oth} in addition to the thermal noise, I_o . Finally, the ratio of I_{oth} to I_{own} is denoted by f , i.e.

$$f = \frac{I_{oth}}{I_{own}} \quad (3)$$

Form (2), it is easy to derive the minimum required power (sensitivity), P_i :

$$P_i = \frac{1}{1 + \frac{G_i}{\mathbf{r}_i}} * I_{total} = \Delta \mathbf{h}_i * I_{total} \quad (4)$$

Where $\Delta \mathbf{h}_i$ is called load factor increment for the new user i (load factor of one connection). therefore,

$$\Delta \mathbf{h}_i = \frac{1}{1 + \frac{G_i}{\mathbf{r}_i}} \quad (5)$$

The total load factor \mathbf{h} of such an interference system is the sum of the load factor increments brought by N active mobile users. Therefore,

$$\mathbf{h} = \sum_{i=1}^N \Delta \mathbf{h}_i = (1+f) \sum_{i=1}^N \frac{1}{1 + \frac{G_i}{\mathbf{r}_i}} v_i \quad (6)$$

Assuming perfect power control on the reverse link, and that every user has the same service rate (constant R , v , and \mathbf{r}). (1) Can be rewritten as

$$\mathbf{r} = \frac{G P}{I_{own}(1+f) - P + I_o} = \frac{G P}{(N-1) P v(1+f) + I_o} \quad (7)$$

Using (7) one can calculate the maximum number of simultaneously active users which can be permitted as:

$$N = 1 + \frac{\mathbf{h} G}{\mathbf{r} v(1+f)} \quad (8)$$

When the system is 100% loaded, it has reached pole capacity or the maximum theoretical capacity of WCDMA system. Letting the $\mathbf{h} \rightarrow 1$ in (8) yields:

$$N_{pole} = 1 + \frac{G}{\mathbf{r} v(1+f)} \quad (9)$$

IV. SYSTEM MODEL AND ASSUMPTIONS

This section provides a brief description of the system under study. The throughput-based CAC algorithm computes the increase in the load caused by the uplink admission of a new user in the cell $\Delta \mathbf{h}_i$ and accepts the new connection only if the following inequality is satisfied,

$$\mathbf{h}_{UL} + \Delta \mathbf{h}_i \leq \mathbf{h}_{UL-thr} \quad (10)$$

Where \mathbf{h}_{UL} is the current uplink load of the cell and \mathbf{h}_{UL-thr} is the uplink load threshold.

We consider a single cell with perfect power control in a homogenous and uniformly loaded network. Since the network is assumed to be homogeneous, the performance of the system can be deduced from the performance of a single cell analyzed in isolation. Only uplink direction is considered and it is assumed that whenever the uplink channel is assigned the downlink is established. Two types of services are considered, voice and data. Each type has two classes, newly originating calls and soft handoff calls. The soft handoff calls have higher priority than new calls. The system contains a separate queue for each handoff calls type and a predetermined load threshold. The system model is depicted in Fig. 1.

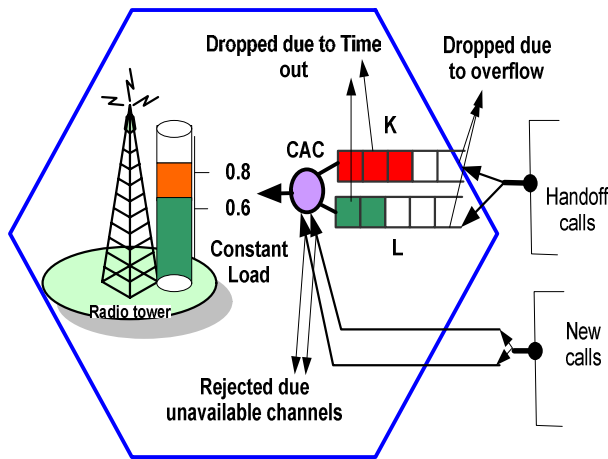


Fig. 1: Detailed Cell Model

The arrival process of new and handoff calls is Poisson with rates, I_{h1} , I_{h2} , I_{n1} , I_{n2} for voice handoff call, data handoff calls, voice new calls and data new calls, respectively. The channel holding time for each type of calls is exponentially distributed with mean m^1 while the queuing time of each handoff calls class is exponentially distributed with mean g^{-1} . This algorithm has the following steps:

When a call arrives, load factor threshold for new and handoff calls h_{thr_i} and QoS requirements are determined firstly. Then the load increase of the arrived call and the current cell load factor before accepting the arrived call are calculated, h_{new} . After calculating the current load of the target cell $h_{current}$, it is compared with the load factor threshold of the arrived call of type i h_{thr_i} . If the current cell load factor plus the load increase is less than or equal the required load factor threshold for the arrived call, then

the arrived call can be admitted to enter the target cell. Other wise, the arrived call is queued or rejected based on queue availability. Queued soft handoff calls can be accepted if sufficient bandwidth gets available, or can be terminated due to timeout.

V. SIMULATION RESULTS

A. Simulation Parameters

In this paper, two services are simulated, voice and data. Characteristics of them are listed in table 1.

Table 1: Simulation Parameters

Parameter	Value
Radio Access Mode	WCDMA (FDD)
Service classes	Voice ,data
Bit rates	Voice:12.2Kbps; Data: 144Kbps
Required Eb/No	Voice :5.6dB; Data : 3.2dB
activity	Voice :0.4; Data : 1
Fractional load	62.5% - 65%
Interference factor (f)	0.5
Chip-rate	3.84Mbps
Thermal noise	1.0 e-15 W
Channel holding time	3 min
Arrival rate	Poisson (0.2-2 calls/sec)
Channel holding time	Exponential (3 min)
Queue limit	0,5
Queuing time	Exponential (15 s)

The system bandwidth is 5MHz, and power control is assumed perfect.

B. System Performance

Algorithms are evaluated based on two Quality of Service (QoS) metrics: the new call blocking probability, which is the probability that a new call is denied access to the system, and the forced-termination probability, which is the probability that a call that has been admitted will be terminated prior to the call's completion. The Grade of service is considered here to evaluate the system performance and defined as:

$$GoS = a * P_{hb} + P_{nb} \quad (11)$$

Where P_{hb} is the handoff blocking probability, and P_{nb} is the new call blocking probability. $a = 10$, which indicates priority level for handoff call to new call. Smaller GoS means better system performance.

C. Result Discussions

New calls and handoff calls are treated differently. Handoff calls are given higher priority to new calls, and load factor threshold for handoff calls and new calls are different. Handoff calls share residual capacity exclusively besides sharing available capacity with new calls. In simulation we consider the following three scenarios:

Scenario1: All call services classes (new calls and soft handoff calls) are treated equally where they have the same load threshold and no queuing is used.

Scenario2: Same as 1, and in addition to that, the handoff calls are allowed to be queued till the resource is available or the time out is reached.

Scenario3: Same as 2, and in addition to that, the handoff calls have higher load threshold than new calls

Average service time for all services is 180 s. Arriving rates of all services are changed. Fig. 2 gives voice (GoS) vs. arrival rates. Fig. 3 gives data (GoS) vs. arrival rates. From these figures, it is clear that the performance improves as we use the queue and the soft guard channel. In general as shown in these figures, the system has a better performance under this algorithm.

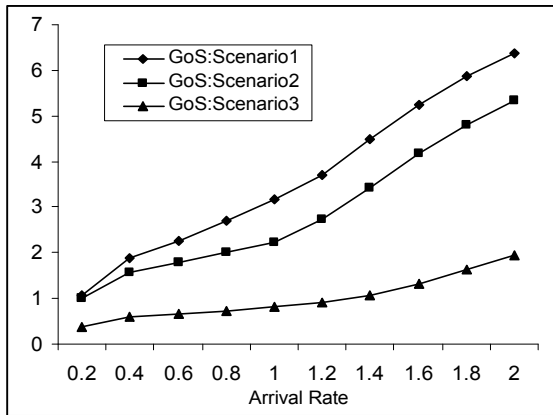


Fig. 2: GoS the voice calls

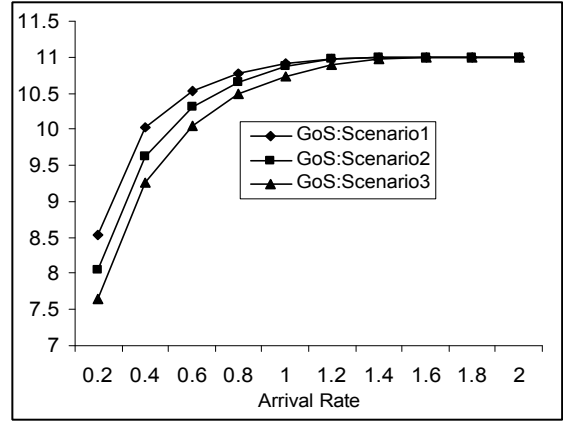


Fig. 3: GoS the data calls

VII. CONCLUSION

Call admission control is a very important measure in CDMA system to guarantee the quality of the communicating links. In future wireless networks multimedia traffic will have different QoS requirements. In this paper, the uplink capacity and load estimation formulas is formulated. Then, a prioritized throughput-based uplink call admission control algorithms, for a WCDMA cellular system with perfect power control is presented. To give priority to soft handoff calls, we introduce queuing techniques and the idea of 'soft guard channels', which is represented by reserving a small fraction of the cell load for the higher priority calls. The performance of this admission control with different scenarios is studied. Based on the simulation results we can conclude that this algorithm can reduce the dropped soft handoff calls and improves the over all system performance.

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REFERENCES

- [1] Gautam T., and Bijan J., "Performance analysis of a CDMA network with mixed traffic using unequal power control," *Vehicular Technology Conference Proceedings*, 2000. VTC 2000-Spring Tokyo. 2000 IEEE 51st , Vol. 3 , pp.1683 - 1687 ,15-18 May 2000.
- [2] E. Dahlman, P. Beming, J. Knutsson, F. Ovesjo, M. Persson and C. Roobol, "WCDMA-the radio interface for future mobile multimedia communications", *IEEE Transactions on Vehicular Technology*, Vol. 47, No. 4, pp. 1105-1118, November 1998.

- [3] H. Holma and A. Toskala (Editors), "WCDMA for UMTS: Radio Access for Third Generation Mobile Communications," John Wiley & Sons, Ltd, England, 2000.
- [4] A. M. Viterbi and A. J. Viterbi, "Erlang capacity of a power controlled cdma system," *IEEE Journal on Selected Areas in Communication*, vol. 11, no. 6, pp. 892–900, 1993.
- [5] Dongwoo K. and Jeong D.G., "Capacity unbalance between uplink and downlink in spectrally overlaid narrowband and wideband CDMA mobile systems," *IEEE Transactions on Vehicular Technology*, Vol. 49, No. 4, , pp. 1086-1093, July 2000.
- [6] K S Gilhousen, I M Jacobs, 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.
- [7] A. Sampath et al., "Erlang Capacity of a Power Controlled Integrated Voice and Data CDMA System," *IEEE VTS Proceedings of Vehicular Technology Conference*, pp. 1557-1561, May 1997.
- [8] Jamie S. Evans and David Everint, "On the Teletraffic Capacity of CDMA Cellular Networks," *IEEE Trans. Vehicular Technology*, vol. 48, no. 1, Jan 1999.
- [9] Y. Ishikawa and N. Umeda, "Capacity Design and Performance of call admission control in cellular CDMA systems", *IEEE Journal on selected area in communications*, Vol. 15. No. 8., pp. 1627- 635 Oct. 1997.
- [10] Z. Liu and M. E. Zarki, "SIR-based call admission control for DS-CDMA cellular systems," *IEEE J. Select. Areas Commun.*, vol. 12, no. 4, pp. 638–644, Apr. 1994.
- [11] S. M. Shin, C. Cho and D. K. Sung, "Interference-based channel assignment for DS-CDMA cellular systems", *IEEE Trans. Veh. Technol.*, pp. 233 – 239, January 1999.
- [12] F. Gunnarson, E. Geijer-Lundin, G. Bark, and N. Winberg, "Uplink admission control in WCDMA based on relative load estimates," in *Proc. of ICC 02*, vol. 5, New York, NY, USA, pp. 3091–3095, Apr. 2002.
- [13] K. S. Gilhousen, I. M. Jacobs, R. Padovani, and L. A. Weaver Jr., "Increased capacity using CDMA for mobile satellite communication," *IEEE J. Select. Areas Commun.*, vol. 8, pp. 503–514, May 1990.
- [14] Lidong Zhu; Xiang Ling; Shiqi Wu, "Call admission control in multiservices CDMA systems," *Communications, Circuits and Systems and West Sino Expositions, IEEE International Conference*, pp. 177 - 181 vol. 1, 29 June-1 July 2002.
- [15] Wang Ying; Wang Weidong; Zhang Jingmei; Zhang Ping, " Admission control for multimedia traffic in CDMA wireless networks" *Communication Technology Proceedings*, International Conference , pp. 799 - 802 vol. 2, 9-11 April 2003.
- [16] Badia, L.; Zorzi, M., "A framework for call admission control with threshold setup and evaluation of the performance in WCDMA systems," *Vehicular Technology Conference*, vol. 2 , pp. 1213 – 1217, 22-25 April 2003.
- [17] Kuenyoung Kim; Youngnam Han, "A call admission control with thresholds for multi-rate traffic in CDMA systems," *Vehicular Technology Conference Proceedings*, 2000. VTC 2000-Spring Tokyo. 2000 IEEE 51st , Volume: 2 , pp. 830 - 834 May 2000 .
- [18] Derong Liu; Yi Zhang, " Call admission control algorithms for DS-CDMA cellular networks supporting multimedia services," *Multimedia and Expo, 2002. ICME '02*.