Hämäläinen A., Valkealahti K., Höglund A. and Laakso J., 2002, Auto-tuning of Service-specific Requirement of Received EbNo in WCDMA, Proceedings of the 56th IEEE Vehicular Technology Conference (VTC 2002 Fall), vol. 4, pp. 2253-2257.

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# Auto-tuning of Service-specific Requirement of Received EbNo in WCDMA

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*Abstract-* **The paper validates the feasibility of auto-tuning of service- and bit rate-specific EbNo requirements. The planned EbNo values can be used e.g., to scale the powers when service is varying. The proposed methods, one for uplink and one for downlink, are tested using dynamic WCDMA system simulator with a deployment of macro cells on a city region whose measured propagation characteristics were incorporated into the model. The results show that the proposed methods tune the initially incorrect planned EbNo values so that the throughput in the system increases.**

## I. INTRODUCTION

### A. Background

The WCDMA radio interface for third generation mobile networks carry voice and data services with various data rates, traffic requirements, and quality-of-service targets [2]. Moreover, the operating environments vary greatly from indoor cells to large macro cells. An efficient usage of the limited frequency band in the diverse conditions requires careful setting of numerous vital network and cell parameters such as maximum load levels and allocated channel powers. The parameter setting is referred to as radio network planning and optimization. Once a WCDMA network is built and launched, an important part of its operation and maintenance is monitoring of performance or quality characteristics and changing parameter values in order to improve performance. The operability of the network would greatly benefit from automated monitoring and parameter changing. The automated parameter control mechanism can be simple but it requires an objectively defined performance indicator that unambiguously tells whether performance is improving or deteriorating. Conceiving of such indicators is a major task. WCDMA network auto-tuning and advanced monitoring are discussed in [6], for instance.

### B. Parameter control

This paper addresses adaptive estimation of service- and bit-rate-specific EbNo requirements. The EbNo requirement is the level of the received bit energy to the interference and noise density that the receiver equipment requires for proper decoding of the signal. The EbNo requirement depends on diverse factors. Receivers in base stations can be made more sensitive than those in mobile terminals. Thus, the EbNo requirements are normally lower in uplink (UL) than in downlink (DL). The packet service is normally used for non-real time services that apply a retransmission protocol. Frame errors are thus less critical to the packet service performance and sufficient quality is obtained with a lower EbNo requirement in comparison with the real-time services. The purpose of coding is to reduce the EbNo requirement [8]. The coding gain improves with increasing bit rate and decreasing requirement of bit error rate. Thus, different coding schemes, error rates, and bit rates produce different EbNo requirements. Moreover, the speed, multi-path diversity, and burstiness of interference have an effect on the temporal distribution of bit errors that may deviate from the optimum of the coding scheme, which produces a higher EbNo requirement.

Knowledge of the average levels of EbNo requirements facilitates the radio resource management unit of the radio network controller in the optimum resource allocation. The admission control and the packet scheduler estimate changes in the cell air interface load owing to a resource allocation decision. In the following, the anticipated or estimated EbNo requirements are referred to as planned EbNos.

The DL EbNo planned tables can be applied, e.g, to:

- DL power increase estimation [2, 9]
- Static Rate Matching
- For scaling powers when service is varying in general

$$P_X = \frac{R_X(EbNo_X)}{R_Y(EbNo_Y)} P_Y \qquad (1)$$

- When calculating the power ratio between the PDSCH and the controlling DPCH.

Moreover, a conceivable application of the planned DL EbNos is to use them as the initial EbNo targets of the outer-loop power control of the User Equipment (UE). However, currently this is not possible according to the 3rd Generation Partnership Program specifications. The Radio Resource Control specification states that, at the physical establishment of the Dedicated Channel, the UE sets the initial EbNo target of the outer-loop power control based on the block error rate target that the Radio Network Controller (RNC) gives for the Dedicated Channel.

The UL EbNo can be applied, e.g., to.:

- UL power increase estimation [2, 9]
- Static Rate Matching

- Initial EbNo targets of uplink outer-loop power control

In this paper, we propose methods to estimate the DL and UL planned EbNos of services. In downlink, the method applies information about the ratio of the link power of the service to the total power, the code orthogonality factor, and the average own-cell-to-other-cell interference ratio. In uplink, the planned EbNos are obtained as the averages of the EbNo targets of the UL outer-loop power control. The benefit of the methods to the performance of the packet service is studied with a dynamic WCDMA system simulator.

## II. Methods

### *A. Estimation of DL EbNo*

The RNC goes through all active transmitting terminals of a cell. If the cell has the highest pilot strength to the terminal and the DSCH is not transmitting to the terminal, then the current EbNo level of the link is estimated with the following formula:

$$ebno = \frac{processingGain \cdot ptx}{pathloss \cdot interference} \tag{2}$$

in which the processing gain and the link power (*ptx*) are known by the RNC. The product of path loss and interference is estimated with the following method:

$$\begin{aligned} &pathloss \cdot interference = pathloss \cdot (I_{own} + I_{oth}) = \\ &pathloss \cdot \left(\frac{PtxTotal}{pathloss} \cdot (1-\alpha) + \frac{PtxTotal}{pathloss} \cdot i\right) = \\ &pathloss \cdot \frac{PtxTotal \cdot (1-\alpha+i)}{pathloss} = \\ &PtxTotal \cdot (1-\alpha+i) \end{aligned} \tag{3}$$

in which the downlink code orthogonality, $\alpha$, and the other-to-own-cell interference ratio, $i$, are fixed parameters, the $pathloss>1$, and *PtxTotal* is the total cell transmission power.

Thus, the EbNo level estimate obtains the form:

$$\begin{aligned} ebno &= \frac{processingGain \cdot ptx}{pathloss \cdot interference} = \\ &\frac{processingGain \cdot ptx}{PtxTotal \cdot (1-\alpha+i)} \end{aligned} \tag{4}$$

In this study, we assume that the orthogonality factor and the other-to-own-cell interference ratios are equal, which removes factor $1-\alpha+i$ from the formulas. In general, this results in a bias in the DL planned EbNo estimation, but, especially with a macro cell, the bias can be small. Anyhow, the values of $\alpha$ and $i$ are not critical to the method because the DL planned EbNo values are mostly used in operations in which one planned EbNo is divided with another, which is shown by eq. (1), for instance. Factor $1-\alpha+i$ is thus cancelled in such operations.

If the ratios of link powers to the total transmission power change a lot with changing total transmission power, the EbNo values determined in this way may be applicable to the situations of average load only. The problem can be solved by limiting the tuning and application of the planned EbNo values to high-load situations only when the accuracy of EbNo values is most critical.

### *B. Estimation of UL EbNo*

The UL EbNo, *ebno*, is obtained directly as the EbNo target of a connection in the UL outer-loop power control of the cell.

### *C. Auto-tuning of planned EbNo*

The service, bit rate, block error rate target, etcetera of the connection, from which *ebno* was obtained, are mapped to an appropriate entry of the planned EbNo table. The planned EbNo in the entry is updated with formula:

$$\begin{aligned} &PlannedEbNo = (1 - forgetFactor) \cdot \\ &PlannedEbNo + forgetFactor \cdot ebno \end{aligned} \tag{5}$$

Coefficient *forgetFactor* is a small positive scalar. The convergence rate depends on this scalar. In this paper we used the value 0.01.

Different users have different EbNo targets owing to diverse factors (different bit rates, services, mobile speeds, channel profiles, transmission burstiness etc) and, thus, the optimum EbNo values for individual users vary. The proposed method with update rule (5) estimates the mean value of *ebno* in the cell for the services mapped to the same entry of the planned EbNo table. The effects of other factors are averaged out. In our simulator, the speeds and channel profiles were identical for all mobile terminals. Thus, the variation in measured EbNo values was smaller than would be in a real network. Moreover, the simulator did not model measurements errors that can be significant in a real network. However, if the measurements are unbiased in the real network, the errors are averaged out with a sufficiently long-term filtering.

## III. Simulation Parameters

The automated control method is verified with an advanced WCDMA radio network simulator developed at Nokia Research Center in Helsinki [3]. The simulator models 17 macro cells deployed over an area of Helsinki center. A set of mobile terminals move in the area with constant speed and, with random intervals, make calls of the packet-switched data service and a small amount of calls of the voice service. The voice data rate is fixed but packet data rates can vary. The simulation step is one frame or 10 ms, at which the transmission powers, received interferences, and signal-to-interference ratios are recalculated for each connection in uplink and downlink. The method of [4] is used to obtain correctness of received frames from signal-to-interference ratios. The simulator implements many advanced features such as admission control, closed-loop and outer-loop power controls, soft and hard handover controls, packet scheduler, load control, and quality manager. Previous studies with the simulator are described in [1,7], for instance.

To get the *ebno* value, the total transmission power was averaged over two frames. The link powers were sampled from single users. The link powers were those computed internally with the simulator, which are not necessarily available in the real system. The *PlannedEbNo* was updated once in 10 frames. In practice the update period would be longer, e.g., once every 15 minutes.

Fig. 1 shows the general view of the simulated network. Green bars indicate cells by pointing to the principal direction of antenna pattern. The antenna of the one-cell sites was omni directional, however. The channel multi-path profile was that of ITU Vehicular A [5] with 5-path propagation. The path gains are shown in Table I. One half of the signal power came along the line of sight and the other half was a sum of powers from four reflected signals. The propagation loss was calculated using the Okumura-Hata model with average correction factor of –6.2 dB. The shadow fading process conformed to the buildings, streets, and water areas, Fig. 1. Short-term fading with 7-dB deviation was added to the process. The fast fading process was that of Jakes [2].

The mobile stations were uniformly distributed along the streets of simulated area and they made new calls according to a Poisson inter-arrival distribution. The packet size of packet calls was generated according to a Pareto distribution. The service of new calls was generated according to the probabilities shown in Table I. The number of users was 4000 of which 1% in DL were speech users. The UL and DL were simulated separately. The packet scheduler allocates new bit rates for each active user every 100 ms. The initial powers for the user were taken from the statistics and the tuned EbNo values were used, when the bit rates were changed. The forgetFactor was set to 0.01.


Fig. 1. Deployment of five three-cell and two one-cell macro cell sites in Helsinki center area. Water areas are shown in blue. Average site distance roughly 910 m. Subset of 32-cell scenario in [3] p. 119.

TABLE I
NETWORK PARAMETERS

| Parameter | Value |
|---|---|
| Chip rate | 3.84 MHz |
| Frequency | 2.0 GHz |
| Bandwidth | 5.0 MHz |
| Base station maximum transmission power | 20 W |
| Mobile station maximum transmission power | 125 mW |
| CPICH transmission power | 1 W |
| Power control dynamic range | 65 dB in UL, 20 dB in DL |
| Maximum link power in downlink | 1 W |
| Base station antenna cell and gain | 65°, 17.5 dBi Omni, 11.0 dBi |
| Mobile station antenna cell and gain | Omni, 0.0 dBi |
| Uplink system noise | –102.9 dBm |
| Downlink system noise | –99.9 dBm |
| Minimum coupling loss with O-H model | –50 dB |
| Propagation loss model | Okumura-Hata |
| Shadow fading deviation | 7 dB |
| Average antenna height | 18 m |
| Multipath propagation gains | 50, 30, 11, 6, 3 % |
| Mobile station speed | 3 km/h |
| Number of mobile stations | 4000 |
| Call arrival rate for a mobile station | 5 $h^{-1}$ |
| Probability of packet service | UL 100 %, DL 99% |
| Probability of speech service | UL 0 %, DL 1% |
| Average discontinuous transmission period | 3.0 s |
| Average voice call length | 120 s |
| Voice data rate | 8 kb/s |
| Packet data rates | 8, 12, 64, 144, 512 kb/s |
| Packet-switched data outer loop FER target | 20 % |
| Admission control noise rise target | 6 dB |
| Admission control transmission power target | 16 W |
| Handover control add window | 1 dB |
| Handover control drop window | 3 dB |

## IV. RESULTS AND DISCUSSION

The EbNo values were tuned globally, i.e., we tuned all the EbNo values in the cells at the same time using the same data. We could tune also locally in each cell separately, but this would require enough data from each cell. Unfortunately, the simulation times in our dynamic simulator are so short that we may not have enough data from each cell to do local tuning.

In the first simulation we tested how the throughput behaves when load increases. The used bit rates were 8, 12.2, 64, 144 and 512 Kbps and the corresponding initial incorrect EbNo values were 12, 11, 9.5, 8.5, 8.0 dB for DL and 5.0, 4.0, 2.5, 2.0, 1.5 dB for UL.

The Fig.2 show that some gain can be achieved, especially in UL, when EbNo values are tuned. The reason for that in DL not much gain was achieved is that even the initial EbNo values are incorrect, the ratios of the values are in the correct level and then the packet scheduler allocates the bit rates correctly.

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Now let us set the initial planned EbNo for speech to incorrect (12 dB) value and the planned packet EbNos to 3 dB, which is close to correct value. Now the ratio of reference service (speech) and packet service is incorrect. The Figure 4 shows that in this case, if no tuning is used, the packet link powers are low. The maximum link powers are low because of the low ratio between planned packet EbNo (3 dB) and reference EbNo (12 dB). The frame error rate (FER) starts increasing and is close to 50% in the end of the simulation. The average FER over the time is 27%. The bad quality (BQ) and blocking (BL) probabilities for speech are 1.2% and 0.0% and the total throughput 185.7 Kbs/cell/MHz. Because the packet link powers are low the speech quality is good. The packet users use higher bitrates and more retransmissions (higher FER), but still the system end up to a high throughput when compared to Fig.1 simulation.

If we now tune the planned EbNos using global tuning (forget factor 0.01) the planned EbNos converge to the correct level (Fig.3) and the FER is 17.9%, which is below 20% target. The BQ and BL for speech are 0.3% and 15% and the total throughput is 170.3 Kbps/cell/MHz, which is less than previous case. This change in the throughput may be a general behavior showing that FER target setting can have a significant effect to the network throughput, but in practice 50% retransmission rate may cause long delays to packet data service.

The packet link powers are nicely distributed between the absolute minimum and maximum link powers (Fig.5). The results with tuning are close to those results that would have been obtained, if correct initial planned Eb/Nos were used. This simulation shows that tuning can find the correct planned Eb/Nos even if the initial values are incorrect and cause too low link powers for, e.g., packet data service.

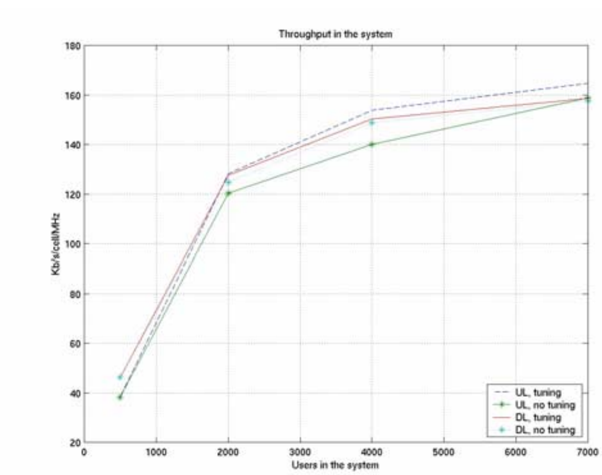


Fig.2. The UL and DL throughput vs. number of users in the system. In UL the Eb/Nos were tuned locally and only packet users were in the system. In DL 1 % of the users were speech users and Eb/Nos were tuned globally.

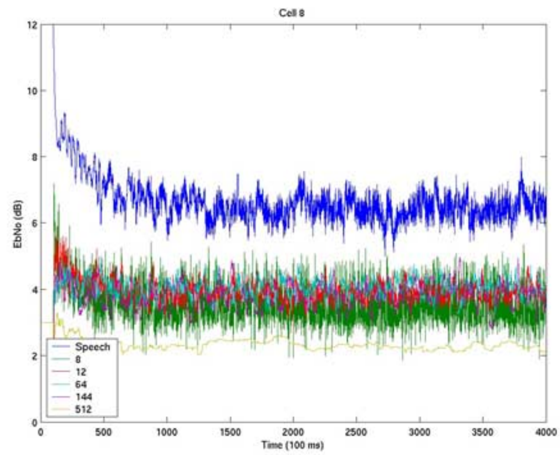


Fig.3. The convergence of DL planned EbNo values (dB) during the simulation. The maximum number of users was set to 4000.

## V. Conclusion

The methods to tune the DL and UL EbNo values for packet data were proposed. The results show that the proposed methods work well and improvement in performance of the system can be achieved if the initial incorrect EbNo values are tuned. Note here, that neither the tuned EbNo values are correct on an absolute level. When they are used in bit rate allocations, only the ratio of these values is important, not the actual values, and thus the improvement can be achieved.

The proposed method may not give very big gains for circuit switched services, because those users do not change the bit rates as often and even if the initial EbNo values are incorrect, the outer loop power control quickly tunes the EbNo target to the right level. Further, in admission control, the planned EbNo values should be as close to the true value as possible.

The tuning must be based on a data set that is large enough. Further, each of the EbNos for different services should be tuned at the same time to avoid cases where some of the Eb/Nos are changed radically and others not. This may lead to situation where the ratios of the Eb/Nos are incorrect and cause problems in link power limit allocation.

At the beginning the forget factor may be large, but fine tuning should be slow. The large forget factor value helps the system tune the planned EbNos quickly to the correct level. When the initial EbNos are close to the correct values, the slow local fine-tuning improves the situation.

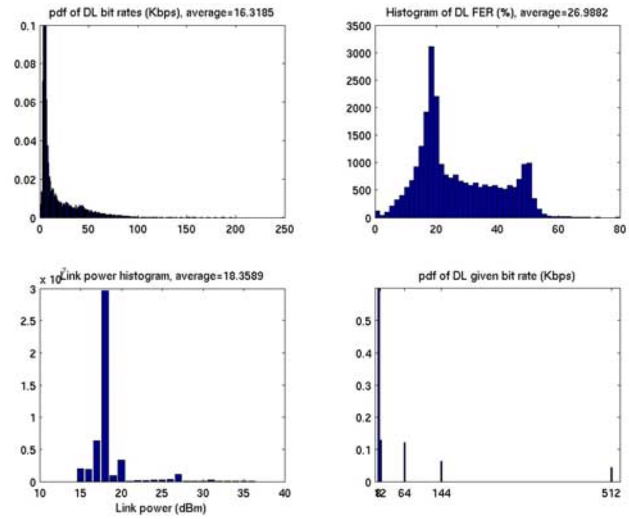


Fig.4. From left to right and up to down: The density function of DL average bitrates, FER histogram, packet data link power histogram and the distribution of given bit rates. No tuning is used. Because the Eb/No of reference service is too high is causes low maximum link powers for packet service and thus higher FER than target, 20%.

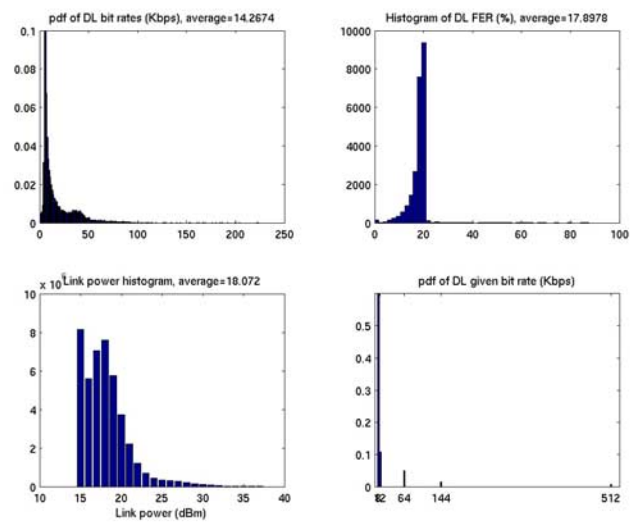


Fig.5. From left to right and up to down: The density function of DL average bitrates, FER histogram, packet data link power histogram and the distribution of given bit rates. The Eb/Nos are tuned globally. The result show that the FER target is met when tuning is used.

## ACKNOWLEDGMENT

Authors thank Mika Kolehmainen for his support in the use and development of the simulator. Nokia Networks is acknowledged with gratitude for financing the study.

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