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EVALUATION OF POWER CONTROL IN UTRA-TDD

Paper submitted to the 6th CDMA International Conference

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Keywords:	UMTS, Power Control, CIR-based, UTRA-TDD
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EVALUATION OF POWER CONTROL IN UTRA-TDD

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Abstract **–** This paper investigates the *Carrier-to-Interference-Ratio* (CIR) based *Power Control* (PC) algorithm in *UMTS Terrestrial Radio Access in Time Division Duplex* (UTRA-TDD), as standardized in the 3G Technical Specification 25.224. Simulations of a system with this PC enabled have been carried out in Manhattan-like dense urban scenario. The paper focuses on the power control's ability to satisfy various CIR targets, and the implication of dynamic range on the performance.

I. Introduction

Power Control (PC) is a well known method for reducing interference within a CDMA system [1]. In *Universal Mobile Telecommunication System* (UMTS), PC becomes even more important for multimedia traffic services because they usually requires lower *Bit Error Ratio* (BER), and therefore it requires higher CIR than its speech counterpart.

The UTRA-TDD system uses a *Time-Division / Code-Division Multiple Access Scheme* (TD-CDMA). In this scheme, time is divided into frames. *Base Stations* (BS) coordinate *User Equipments* (UE) so that each has chance to transmit its message on certain timeslots by means of certain codes within frames. Theoretically, these codes are supposed to be orthogonal to one another, that is, a user with specific spreading code can only detect the signal being sent to him, and all signals sent to other users in the system disappear into noise. However in real systems with an increasing number of users, it is not possible to ensure perfect orthogonality among all the codes because of multipath propagation, imperfect synchronization, and receiver restrictions. As a result, interference situation deteriorates as more and more users are added to a timeslot. In addition, there are other sources of interferences such as imperfect synchronizations among BS and UE.

In a CDMA system, whose capacity is limited by interference, it is important to reduce interference as much as possible to increase spectrum efficiency. One such way to do so is through the usage of PC, which limits the transmitting power of both BS and UE to certain values. These values should be set such that the signal is strong enough to carry information with minimal error, while reducing interference to other users. Some PC scheme use the received signal level to control transmitting power. In UTRA-TDD, [5] specifies that PC uses CIR-level values in particular.

In the next section, the power control algorithm is described in details. In section III, the scenario and important parameters involved are given. The results of simulations and analysis are presented in section IV, and the paper ends with conclusion.

II. Power Control Algorithm

PC specified in [2] is a CIR-based algorithm, which adjusts the power to a pre-defined CIR target at the receiver side. There are two parts to PC: *outer loop* and *inner loop*. CIR targets (set by network radio resource controller) are parameters belonging to the outer loop PC. The inner loop PC is the ability of the transmitter to adjust power in response to the received signal measurement or command. PC scheme in *Uplink* (UL) and *Downlink* (DL) are different. Figure 1 depicts the power control mechanism in UL [2].

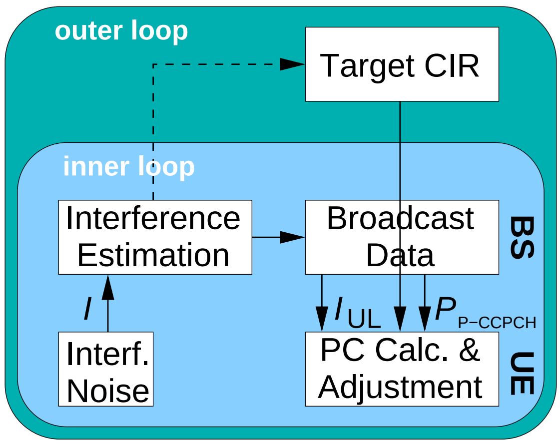

FIGURE 1 – Open loop PC in uplink.

In the UL, power is controlled by an *open loop* PC, in which new power is set following the formula:

$$P_{new} = \alpha L_{P\text{-}CCPCH} + (1-\alpha) L_0 + I_{UL} + CIR_{target} + c \quad (1)$$

Interference power at BS (I_{UL}) and BS's reference transmitting power ($P_{P-CCPCH}$) are periodically broadcasted on broadcast channel. Combining BS's reference power with the received signal strength measured at UE, UE can estimate the path loss $L_{P-CCPCH}$. The L_o value is long term average path loss. Both $L_{P-CCPCH}$ and L_o are weighted by a parameter α. This α represents the quality of path loss measurement, which is function of time delay between the UL timeslot and the most recent DL timeslot containing physical channel that provides the beacon function. This α is calculated at UE by:

$$\alpha = 1 - \frac{(D-1)}{6} \qquad (2)$$

Where D is the number of slots between the UL timeslot and the most recent DL timeslot. Note that $\alpha = 1$ is the minimum delay of one slot and $\alpha = 0$ is the maximum delay of 7 timeslots (up to 14). Finally the new UL power P_{new} is calculated taking into account the CIR_{target}. To offset some fading margin, a constant c may be added.

For DL, *closed loop* PC is used as seen in Figure 2.

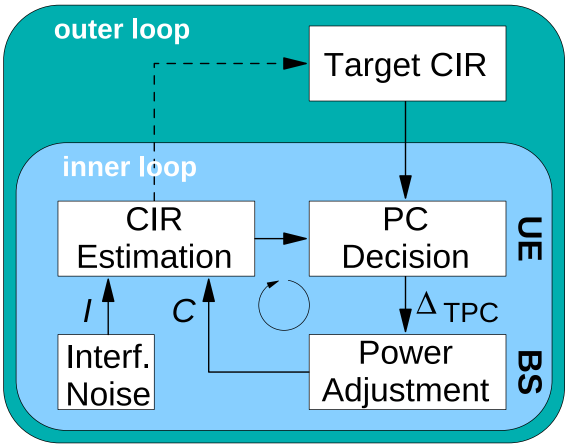

FIGURE 2 – Closed loop PC in downlink.

The UE measures the interference and the received signal power at its side and then it generates power control commands to tell BS either to increase or decrease the power. This can be expressed by the following formula:

$$P_{\text{new}} = P_{\text{current}} \begin{cases} +\Delta_{pc}, \text{if } CIR_{\text{est}} < CIR_{\text{target}} \\ -\Delta_{pc}, \text{if } CIR_{\text{est}} > CIR_{\text{target}} \end{cases} \qquad (3)$$

The basic idea is that if the estimated CIR is less than the specified CIR target, the transmitting power will be increased by a pre-defined constant Δ_{PC}. On the other hand, if the estimated CIR is more than the specified CIR target, the transmitted power will be decreased. Unlike UL, where power can be adjusted to the exact level, the DL adjustment can be done by only integer step size of 1, 2, or 3 dB .

Another difference between PC in UL and DL is that in DL there is a dynamic range limitation. Within a TD-CDMA frame, up to 16 coded signals can be transmitted simultaneously in each timeslot. Channel estimation is performed by cyclic correlation using midamble training sequence. *Joint Detection* (JD) can be used during signal detection to detect all signals and therefore reduce intra-cell interference [3]. However, JD requires that the difference between the strongest signal and the weakest signal must stay within a dynamic range 20 or 30 dB. ([5] also suggests both numbers.)

III. Simulation

The simulations are carried out using [4] as our guideline with one exception. Instead of having 72 BS as specified in [5], our smaller Manhattan scenario consists of 60 BS as depicted in Figure 3. The only difference between the two scenarios is the absence of BS around the scenario border. This is done to reduce calculation overhead. These outer BS do not contribute significant interference to the inner six BS (marked with X in figure 3), where all measurements are taken. At these inner BS the interference situation is expected to be the worst.

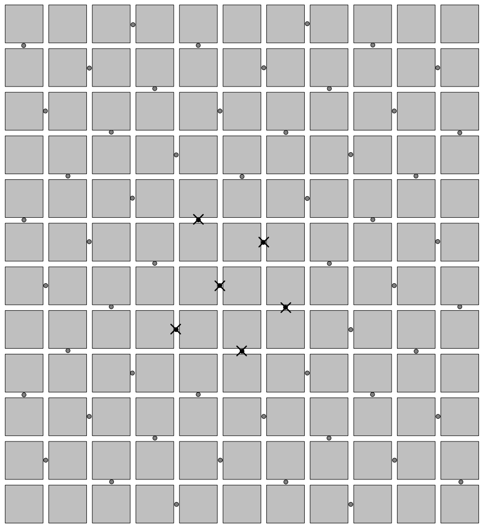

FIGURE 3 - Manhattan scenario with 60 BSs

Only speech service in the system with *Discontinuous Transmission* (DTX) is enabled. The resulting call activity is 50%. The system runs with a simple fixed channel allocation algorithm which allocates channel resources within the frame randomly and assigns them fixed to the connection. It does not take interference into account when making an allocation decision. In addition, Table 1 presents important simulation parameters.

TABLE 1 – Scenario Parameters

Parameters	
Number of BSs	60
Cell Radius	460 m
UL Frequency	2010-2015 MHz
DL Frequency	2010-2015 MHz
Background Noise	-102 dBm
Shadowing (Log normal)	Mean 0 dB, Std 10 dB
Timeslot	8 DL / 7 UL
Spreading Factor	16
Modulation	QPSK
Max. BS Power	33 dBm
Max. UE Power	24 dBm
Min. UE Power	-56 dBm
PC Step Size Δ_{PC}	1 dB

IV. Results

There are two sets of simulations. The first set of simulations investigates the dynamic power range limitation. The second set of simulations focuses on the ability of PC to hold specified CIR targets.

Dynamic Range Simulations

Since PC has to make sure that the maximum transmitting power and the minimum transmitting power of BS stay within a dynamic range, this could have an impact on how effectively PC can regulate DL power. Simulations are performed with PC enabled with the parameters shown in Table 2. Max DL Dynamic Range parameter tells PC, what is the maximum power difference between the strongest signal (sent to the UE that experiences the worst interference situation) and the weakest signal (sent to the UE that experiences the best interference situation).

TABLE 2 – Dynamic Range Simulations

Series Name	Max. DL Dynamic Range	CIR Target in UL & DL	Traffic Load
R20	20 dB	-10.5 dB	60 Erlang
R30	30 dB		
R50	50 dB		
R100	100 dB		

We emphasize on the DL results only since dynamic range does not affect the UL. Figure 4 presents the DL CIR distribution. The result clearly shows that dynamic range has an impact on PC's performance. Higher dynamic range allows PC to further reduce power and hold targeted CIR, since PC has more room to maneuver. At lower dynamic ranges, a lot of UE experience better than the specified target. This is because UE come too close to a BS. Even though BS should decrease power further to reach the target, but it is not possible so due to the dynamic range limitation. At R20, for example, these BS cannot decrease power further than 20 dB below the DL power for the worst UE. (The worst UE receives the highest DL power.)

In the DL transmission power graph, Figure 5, we can see that the DL graph has steps. This is because PC can adjust power in integer step Δ_{PC}. If wider dynamic range is allowed, transmitting power can be as low as -60 dBm.

Figure 6 shows the dynamic range distribution. When dynamic range is limited to 20 dB, about 30% of the UE transmit with the same power (dynamic range equal to 0). When the dynamic range is relaxed up to 100 dB, all UE stay within 60 dB range, although up to 100 dB is allowed. This suggests that dynamic range of 60 dB is sufficient.

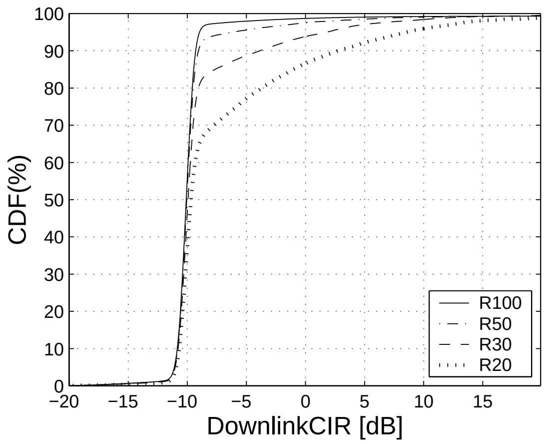

FIGURE 4 - Downlink CIR distribution

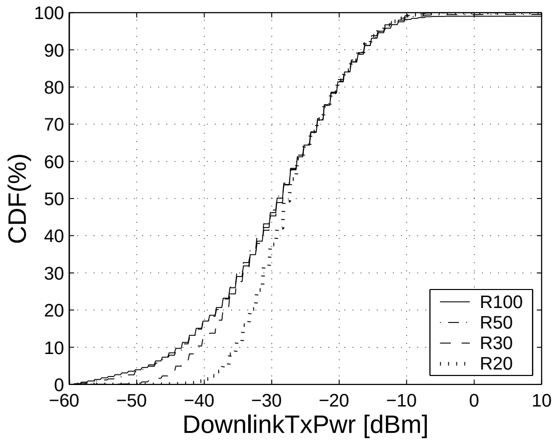

FIGURE 5 - Downlink Tx Power distribution

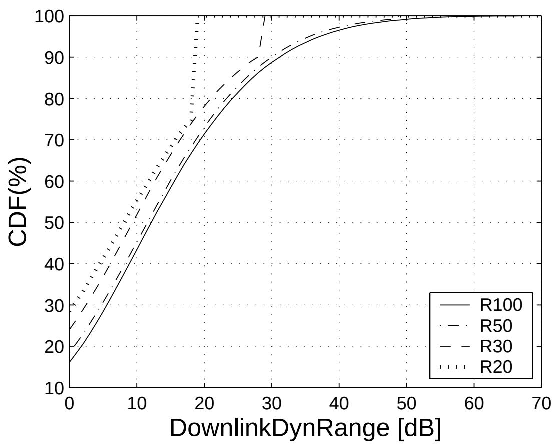

FIGURE 6 – Downlink dynamic range

CIR-Target Simulations

These simulations are aimed to determine if PC can hold specified CIR targets, or if any constant offset value has to be added to (1) and (3) to compensate differences. We also evaluate signal quality at various UE-BS separating distances. The simulations are configured as follows:

TABLE 3 – CIR-target simulations

Target CIR in UL & DL	Max. DL Dynamic Range	Traffic Load
-9.5 dB -10.0 dB -10.5 dB -11.0 dB -11.5 dB	30 dB	60 Erlang

Figure 7 shows the CIR distribution in DL. The curve "without PC" means the transmission power is set at the maximum. When PC is enabled, around 20% of users experience lower than each specified CIR target. This is due to the fact that only integer step size power adjustment can be done. So it is recommend that network operator adds Δ_{PC} (1 dB in our case) as a constant to (1). Also, since maximum dynamic range is only 30 dB, many users receive better CIR than specified. Similarly in Figure 8, it is recommended that a constant value of 1.5 dB is added to make sure that PC can hold the UL targets more precisely. Unlike DL, there is no dynamic range restriction in the UL. Therefore most users experience CIR close to the targets.

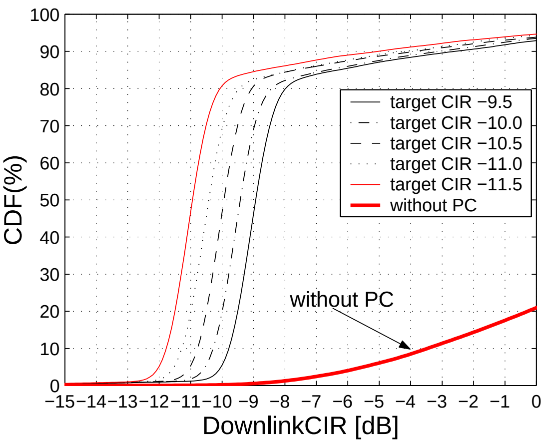

FIGURE 7 – Downlink CIR distribution

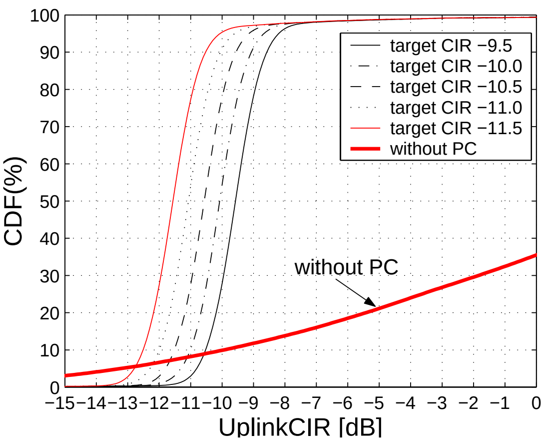

FIGURE 8 – Uplink CIR distribution

Figures 9 and 10 show the DL and UL transmission power. Again, the DL graph contains step due to power in the DL is adjusted with constant step size only. However the UL graph is smooth because of the exact power adjustment. The power range in DL is between –50 and –10 dBm, and between –57 and –10 dBm in UL. Though simulations show the power range is quite low, manufacturing such low-power BS and UE may not be possible currently.

Figure 11 shows CIR versus UE-BS distances in DL. Most UE have similar CIR over long distance. UE close to BS have better CIR because PC has already reduced power to the lowest limit. The UL result in Figure 12 looks similar, except there is no spiking effect around 0 km distance. Due to no dynamic range limitation in UL, UE can decrease power further. Figure 13 and 14 show DL and UL transmission power over distance. As expected, longer distances between UE and BS require more power to hold PC target. Note that UL and DL graphs differ slightly. The UL graph shows a sharp drop of the power as UE moves closer to BS, e.g.0 km distance (again, due to no dynamic range restriction.)

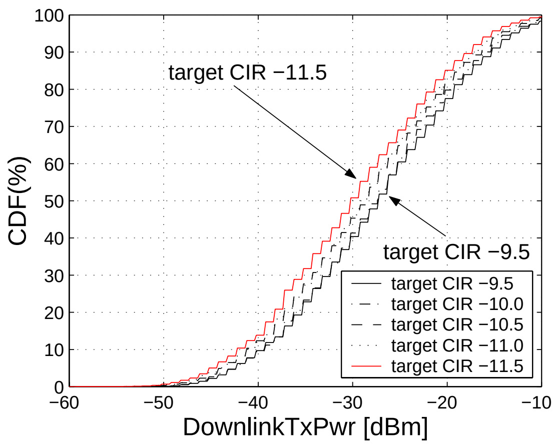

FIGURE 9 – Downlink Tx power distribution

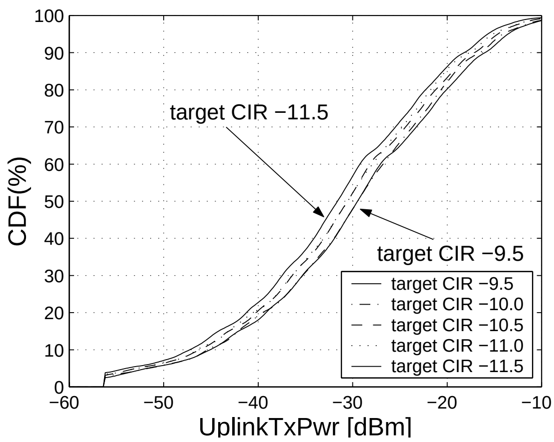

FIGURE 10 – Uplink Tx power distribution.

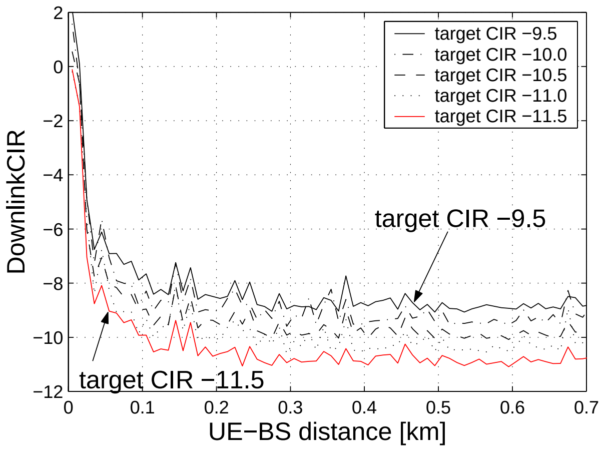

FIGURE 11 – Downlink CIR over distance.

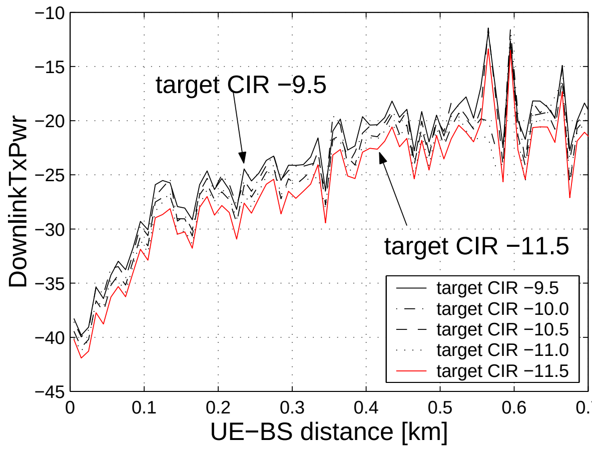

FIGURE 13 – Downlink Tx power over distance.

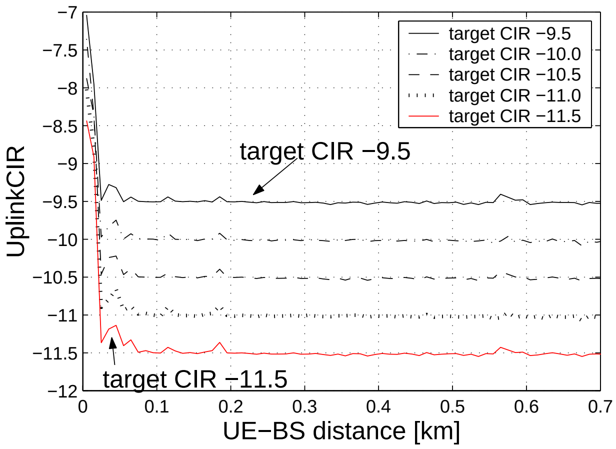

FIGURE 12 – Uplink CIR over distance.

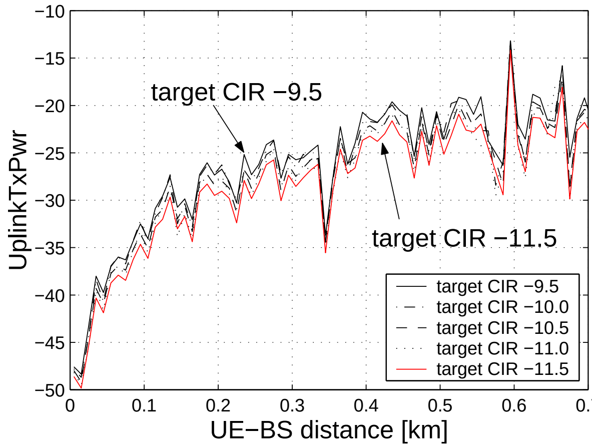

FIGURE 14 – Uplink Tx power over distance.

V. Conclusion

PC in UTRA-TDD system is evaluated and parameters which affect its performance. In order to really provide the CIR according to the target, constant values, which depends on scenario and service classes, should be added to uplink and downlink power. Maximum dynamic range parameter plays also a role. Higher dynamic range up to 60 dB would allow more room for PC to maneuver, if hardware limitation can be overcome. Currently, dynamic range of only up to 30 dB is foreseeable. In the future it would be interesting to see how this PC would perform in conjunction with adaptive switching point allocation algorithm in multiple services environment.

VI. Acknowledgement

Authors would like to thank Professor Walke, Peter Seidenberg, and Stefan Mangold (RWTH-Aachen, Germany) for their advice.

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