POWER CONTROL FOR SOFTWARE DOWNLOAD USING COMMON CHANNELS IN WCDMA

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ABSTRACT

The issue of software downloads is currently a hot topic in 3rd and beyond 3rd generation mobile systems. Some of the benefits are: application of the push type services, Multimedia Broadcast and Multicast Services (MBMS) and terminal reconfigurability. Those applications will not only enhance the validity of business profitability of UMTS by introducing the push service, but will also dramatically increase the chances of co-operation between co-existing sub-networks due to the terminal reconfiguration, which will also result in higher spectrum efficiency.

In scenarios where a number of terminals are downloading the same content, common channel in interference limited system is of highest priority to be selected. However, additional broadcast channels will increase the interference, and techniques that enhance spectrum efficiency are needed.

In this paper, power control for software download is introduced. The power control algorithms, system integration and performance evaluation are given. It is investigated that by applying power control algorithms, significant gain can be obtained by reducing considerable interference level. In order to avoid the masking effect brought by near far problem, strategy of grouping users in download classes is also discussed.

1. INTRODUCTION

In the third wireless systems generations and beyond, interworking of co-existing heterogeneous networks in the same operating area is of primary importance, e.g., the co-existence of WCDMA and WLAN. It is expected that Software Defined Radio (SDR) will play an important role in the development of those future wireless communication systems [1][2]. The compatibility between the terminals and the different Radio Access Technologies (RAT) can be realized through terminal reconfiguration. This will involve the download of core software and applications that are not already on the terminal. Software download (SD) can range from simple parameters to actual executable program code [3].

On the other hand, the push services provide users with updates of any information change that is stored in network caches, e.g. Proxy Reconfiguration Manager (PRM). Push services can be daily (or more frequent) newspaper, weather forecast, and stocks news. Since the information within this service is the same for a large number of subscribers, establishing a common channel is of great sense to be considered.

Thanks to the establishment of broadcasting channels, system capacity is highly enhanced due to considerable reduction of interference [4][5][6][7]. Indeed, if we think of establishing a broadcast channel, the current standard is to transmit at a constant power throughout the whole download session [8][9][10]. And how about applying a suitable power control (PC) algorithm in common channel case? The fact is that by assigning too low power level broadcast channel, less successful software download will take place, however, when too high power level is assigned for SD usage, improper interference will be generated to pollute the regular users in the same cell and the adjacent cells. This will bring instable load situations for interference-limited system. Therefore, the question of how much benefit of PC applied in SD, what parameter need to be considered, what is the optimal configuration should be answered by this paper.

This paper is organized as follows: in the first part, we will introduce the threshold for using common channels instead of dedicated channels, as well as the broadcast channels necessary for this operation. Then we will show the necessity and benefits of power control, the sub-groups selection and focus on the key parameters of this technique. The system integration and protocol realization, especially the paging and reporting mechanism will be explained in the end.

2. CHANNEL SELECTION

If a certain number of users should download the same traffic stream from the network, common channels are of great interest to be used. Due to the nature of broadcast channels, a closed loop fast power control is not possible in the conventional UMTS specification [8][9]. The interference from the broadcast channel will highly influence the regular traffic. In the following, the selection of channel types is discussed.

2.1. Dedicated versus Common Channels

The interference from the uncontrolled broadcast channel will unavoidably influence the regular voice traffic. Therefore in case when only small number users are downloading a session, it might not be necessary to transmit over the broadcast channel, instead dedicated channels can be used. But in the case where a large number of users have applied for the same context-based information it is advisable that common channel to be used for software download.

The load created by an uncontrolled broadcast channel is constant. The intersection point between the load curve generated by dedicated channel and the one generated by common channel is the threshold of choosing a broadcast channel or to carry out downloads with dedicated channels. [4][5]. Nevertheless, if the use of a broadcast channel is justified as the above, more gain in interference reduction and system capacity increase can be achieved when broadcast channel is power controlled. This issue will be addressed later.

2.2. Common Channels

We introduce the following channels needed for downloading software on common channels, as well as for power control purposes.

SDC *(Software download Data Channel):* a common channel used to transmit broadcasted data, in contrast to establishing dedicated channels for individual serving.

SCC *(Software download Control Channel):* this channel will be used to carry the format of the transmitted data, as well as other parameters relevant to Download Management like session repetition number, and handover conditions [2]. It can also be used in sub-group paging as is explained in the last section of this paper.

SUC (*Software download Uplink Channel*): It will be used to return the control information necessary for the power control of broadcast users to the base station.

3. POWER CONTROL FOR COMMON CHANNELS

In general broadcast channels (e.g. BCCH) transmit with a constant transmitting power between 1 and 6W [9][10], depending on the cell size and deployment environment. Additional common channel will bring a lot of undesirable interference to the normal voice users, and the remedy to it is by mastering the power control of this channel. We verified and proved the latter postulate by means of an extensive system level simulations campaign.

3.1 Simulation Scenario

While investigating software download, we have considered UMTS system as a test bed for experimenting. Two classes of users are defined: the normal users using the speech service labeled as G_{ss}, and the users of the software download class labeled as G_{sd}.

It is necessary to introduce a software download mode due to extraordinary actions required in the software download procedures. In addition to the idle mode and connected mode, a terminal enters the SD (Software Download) mode once it is paged for downloading software and accepts to download. An incoming voice call while in the SD mode should be handled according to the priority configuration chosen by the user at the beginning of the download session. That is to say, either to automatically drop the call, or to drop the SD mode and accept the call.

The G_{sd} and G_{ss} are both moving elements within the network with constant speed of 120 km/h and with an angle α, which is a random variable uniformly distributed within the interval $[0, 2\pi]$. G_{sd} user group uses hard handover strategy. The general simulations parameters are summarized in the following table:

Table 1. Simulation parameters

Simulation Parameters	Values
Channel profile	UMTS 30.03
Number of Cells	27 hexagonal cells
Cell size	2 km radius
Orthogonality Factor	0.4
Mobile Speed	120 km/h
Thermal Noise Power	- 103 dBm
Number of users in G_{ss}	10 users per sector cell
Number of users in G_{sd}	20 users per sector cell
Fading type	Fast Fading
Spreading Factor for G_{ss}	128
Spreading Factor for G_{sd}	128
Active Set size for both	1 cell
Candidate Set size for both	3 cells
SIR target	0.8 dB

The modeling of intra-cell and inter-cell interference are as follows:

Interference for G_{ss}: $INT_{ss = j, BS = i} =$

$$\sum_{i \in BS} (P_i + P_{broadcast,i}) * \partial(S_{ji}) - (1 - OF) * P_i * \partial(S_{ji}) - OF * P_{ji} * \partial(S_{ji}) + T_{noise} \quad (1)$$

Interference for G_{sd}: $INT_{ss = j, BS = i} =$

$$\sum_{i \in BS} P_i * \partial(S_{ji}) + \sum_{\substack{i \in BS \\ i \neq BS(j)}} P_{broadcast,i} * \partial(S_{ji}) - (1 - OF) * P_i * \partial(S_{ji}) + T_{noise} \quad (2)$$

With:

BS: set of all base stations.

P_i: total power in cell i.

$P_{broadcast, i}$: power of the broadcast channel in cell i.

OF: Orthogonality Factor in DL.

$\partial(S_{ji})$: signal attenuation caused by user's position, fading, and antenna gain.

T_{noise}: Power of the thermal noise.

3.2 Benefits of Power Control

Utilizing common channels in a wireless network increases the interference and reduces capacity. This interference increase from the side of G_{ss} leads to a consequent increase in the transmitted power of the BS, and inter-cell interference increases in neighboring cells, and this eventually leads to an uncontrolled increase of power in the whole system.

In Figure 1, the CDF of the interference caused on the group G_{ss} is plotted, and by applying power control, interference is reduced by 13 dB with 80% confidence when compared to the 4 W broadcast, and 6.5 dB when compared to the 1 W case.

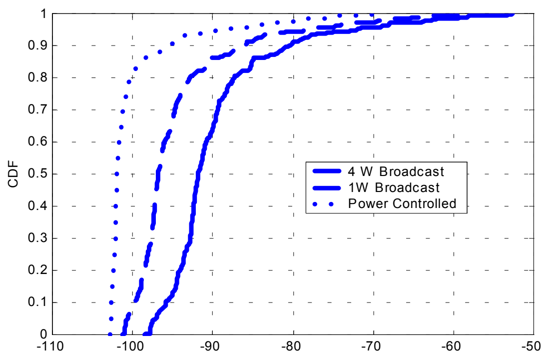

Figure 1, CDF of interference of group G_{ss}

Controlling the SDC reduces also interference experienced by the G_{sd}, and which is due in part to the broadcast channel increasing power of neighboring cells. The decrease brought is of about 8.5 dB with the 4W case, and 5.5 dB with the 1 W case, as shown in Figure 2.

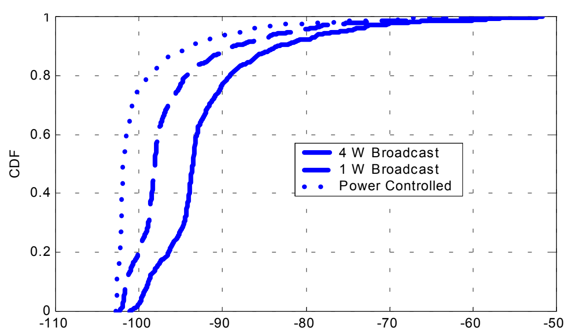

Figure 2, CDF of interference of group G_{sd}

Therefore, it can be deduced that power control for the broadcast channel is of primary interest especially in interference-limited systems.

3.3 Sub-groups Selection

Power control strategy is based on mobile equipment in the network reporting their SIR each time interval T_r. After each T_r, the base station receives all SIR of interest, and based on the mean value, makes the decision of whether to increase or decrease the transmitted power on the common channel. The decision is a discrete variable ψ that can take the values -1 or +1 to respectively decrease or increase the power.

$$\psi = \frac{\gamma_E - \gamma_e}{|\gamma_E - \gamma_T|} \cdot 1\text{dB} \qquad (3)$$

Where:

ψ is the power control step.

γ_E and γ_T are estimated and target SIR value respectively.

Depending on the value of ψ, the base station changes the power value in discrete steps. However, the problem encountered in such a strategy is that users closer to the base station will mask the far users. Those users will be complaining about the low QoS. In addition to the near-far problem, the uplink resources will also be heavily used if we assume that all users are reporting their SIR to the base station.

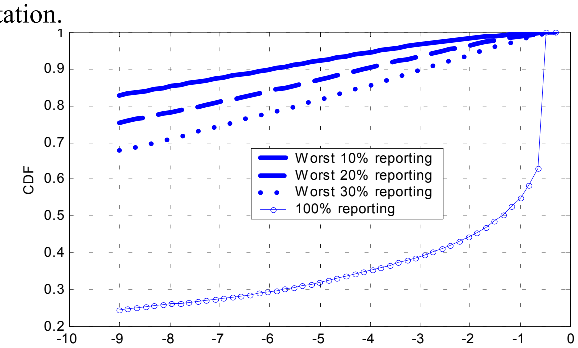

Figure 3, CDF of BER for worst reporting percentages

As shown in Figure 3, the BER is unacceptably high in case all users are taken into account for reporting back to the base station, and the solution is to select a certain percentage (sub-group selection) of the users to report. In this case, we chose the worst 10, 20 and 30 % to report to the base station and to take decision according to equation (3), i.e. according to their SIR values.

Using this sub-group selection procedure, the quality of service is acceptable for all users in the networks (i.e. if the SIR target is met). But what is the best sub-group size?

Investigations on the interference increase on other users when the sub-group selection strategy is adopted are shown in Figure 4.

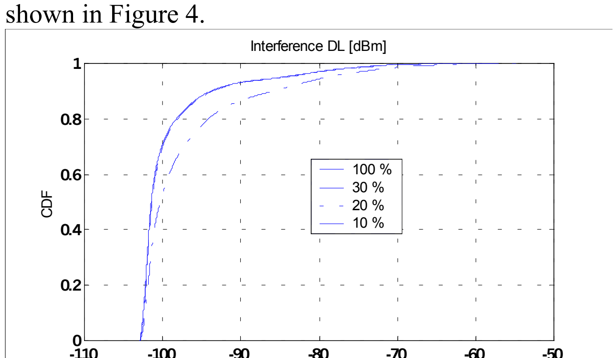

Figure 4, CDF of interference in Gss

From this figure, it is clear that the interference level on class G_{ss} did not increase when we apply sub-grouping reporting, as long as the size of the sub-group does not go below the worst 10 %. For sub-groups of sizes 20, 30 and 100%, interference remains the same. For a sub-group composed of the worst 10 %, an increase in interference is experienced. The explanation to this phenomenon is that the fast power control of class G_{ss} is able to keep up with the increasing transmission power level to insure an acceptable QoS for class G_{sd}.

In order to save resources in uplink, we propose to use a sub-group class of the worst 20 % of the users in the network to report.

3.4 Power Control Update Rate

A key parameter for power control is the update rate at which mobile equipment have to report their SIR. We define this parameter as:

$$R_{update} = \frac{1}{T_r} \tag{4}$$

Where T_r is the period of time after which mobiles has to report. It can be slot-based, frame-based, or multiple frame-based. Figure 5 shows the CDF of the BER for the G_{sd}, in case of 20 % sub-group size. The slot-based power control brings out a BER of less than 10^{-6} for 90% of the SD connections; whereas frame-based power control increases this quantity up to 10^{-4}. Two-frame-based power control degrades a little compared to the frame-based one.

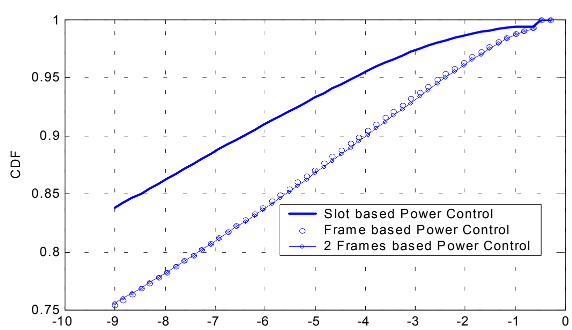

Figure 5, CDF of BER in Gsd

The decision on whether to use slot or frame based power control is a compromise between the quality of service that has to be assumed for G_{sd} users and the matter of saving spectrum by means of less signaling in the uplink.

3.5 Power Control Step Size

The step size discussed here is a scaling of the decision variable ψ defined in equation (3). We remind the reader that all parameters discussed are related to the power control of common channels and not for dedicated channels used by normal speech users of class G_{ss}. Therefore, we investigate step sizes of ψ, 2ψ, and soft continuous value of ψ which is given by the following formula:

$$\psi = (\gamma_E - \gamma_e) \cdot 1\text{dB} \tag{5}$$

From the simulations results; higher step sizes lead to slightly lower QoS for G_{sd}, that is to say higher BER as can be seen from Figure 6 (shift from $10^{-5.7}$ to $10^{-5.3}$ for 85% of connections).

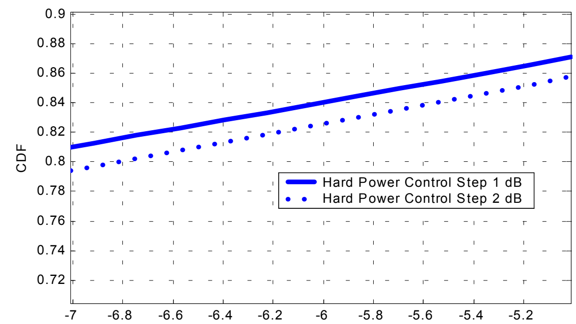

Figure 6, CDF of BER in Gsd

On the other hand, the interference in G_{ss} group slightly decreases as we increase the step size. Soft values of ψ did not give any improvement over hard-type power control (BER=10^{-1} at 85% point). Pre-processing of the data and equation more complex than equation (5) has to be used in order to achieve similar or better performance than equation (3).

3. UPLINK REPORTING MECHANISM

Due to the fact that uplink radio resources are mainly blocked by inference due to their asynchronous nature, saving capacity in the reporting mechanism is important. In the following three strategies for reporting mechanism are derived.

3.1 Dedicated Uplink Channels

With this straightforward strategy, dedicated channels can be established to carry the QoS indicator back to the base station. It can either be the transmission power command (TPC), or the soft value of the SIR of each G_{sd} user. The base station should then calculate the transmission power value for the next period T_r.

A frame structure for the channel *SUC* (Software download Uplink Channel), which will carry the power control command, is depicted in Figure 7. Slot based power control can be realized in this case without additional losses in uplink due to the fact that the power control command can be carried in each slot.

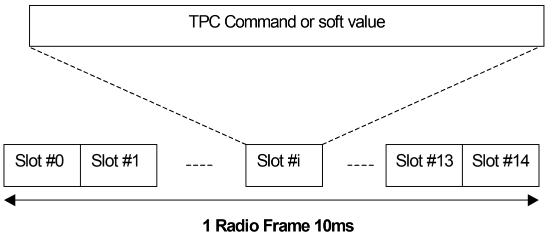

Figure 7, SUC radio frame structure for slot-based power control

3.2 On-Demand Power Control Adjustment

In this approach, users who are suffering from bad QoS can send a request to increase the transmission power via RACH or CPCH. Although RACH carries less information than CPCH, it offers faster access to network than dedicated channels.

Nevertheless, the actual scenario could tend towards an ever-increasing level of transmitted power at each cycle if weak power complaints are not well handled. The solution is to set a timer in the base station, based on which the transmitted power can be adjusted. If after a certain period of time (timer value expired), the base station does not receive any complaint from the users, it should reduce its transmitted power. The timer value can be designed as adaptive function of the number of complaints previously received. If the arrival rate of mobile complaints is relatively low, the timer value should be smaller, and this will result in lower transmitted power in the next cycles. The following MSC chart, Figure 8, illustrates the reporting mechanism proposed:

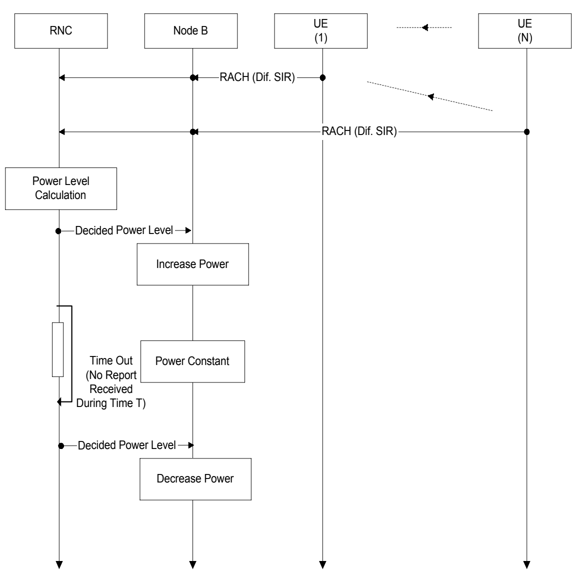

Figure 8, MSC Chart of on-demand timer based power control

3.3 User Grouping Algorithm

In this approach, the base station pages a group of users to ask them to report their QoS for the coming period of time. Those users will be categorized as the reporting sub-group, and can send in the uplink the signal to interference ratio (SIR). The base station is involved with the coordination, the timing scheme, and the paging process, i.e. the base station can coordinate the schedule of uplink report based on a time division manner.

However, since users are expected to be moving in the network, this sub-group needs to be refreshed after a certain time denoted as paging campaign. The mobile terminals keep on reporting the power control command or measurement report in each radio frame to the base station till the base station triggers a new paging campaign. The rate of the paging campaign is highly related with the mobility nature and handover characteristics. In addition, after a new paging campaign, ex-members of the sub-group who do not have to report anymore are automatically excluded by not being paged again, or through a stop-reporting command embedded in the Software download Data Channel (*SDC*) in case the paging rate is not known by the mobiles (only in the Base Station). The paging procedure has a much lower rate than the power control rate, the former one being based on multiple frames, and the latter on slot or frame rate. An illustration of user grouping refreshing and the comparison between the paging rate and power control rate are shown in Figure 10.

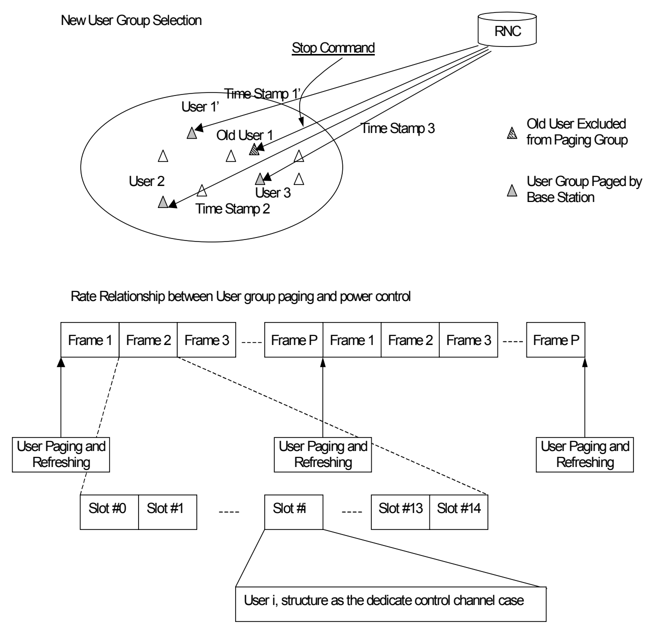

Figure 9, Sub-Group Refreshing and Comparison between Paging Rate and Power control rate

The adherence to the reporting sub-group for the up-coming period until the next paging campaign is made in the mobiles according to the following formula:

$$\frac{\sum t_i}{T_{polling}} \geq \beta \qquad (6)$$

Where t_i is the cumulative amount of time when SIR_{actual} is successively greater than SIR_{target}, $T_{polling}$ is the length of the polling campaign period, and β is a threshold defined according to the quality of service required by the download group, as is also a key parameter to choose the reporting sub-group. If the condition given by the above formula is not met, users should/must report their complains to the Base Station. The three variables t_i, $T_{polling}$ and β should be known by all users at the start of a download session, and could be downloaded to users on the first frames of the downloaded data on the SDC channel.

An example is shown in Figure 10 where SIR varies over time dimension. The mobile equipment decides to join the reporting sub-group based on equation (6).

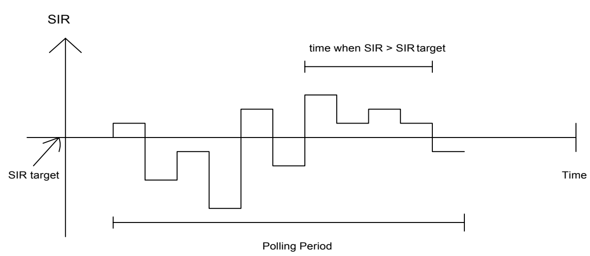

Figure 10, Discrete SIR variations over a polling period

4. CONCLUSION

In this paper, we introduced the new concept of software download via power controlled common broadcast channels. New channel types were introduced, and power control efficiency is proved. Interference reduction up to 13 dB can be gained through power control, and sub-grouping technique is the key solution for the near-far sub-group power control of those channels.

Moreover some key parameters and their effects for power control, such as the update rate and the step size have been investigated.

Uplink reports were also tackled and three strategies for minimizing necessary uplink resources through sub-grouping and paging algorithms were proposed. Power control for common channels in interference-limited systems is still new chapter for research work, more optimization work, e.g., optimization of power control parameters in unbalanced user density situation, is still in a great need to be studied.

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