INTERFERENCE CONTROL TECHNICS IN MIXED NETWORKS: DOWNLINK POWER CONTROL FOR GPRS

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ABSTRACT

Packet Switched (PS) services are being introduced gradually in already existing GSM networks. This GSM evolution is known as GPRS (General Packet Radio Service) and it allows cellular wireless data services. Since circuit and packet switched services share the same physical resources, a notably increase in the interference level is appreciated in the whole system. In order to smooth this negative effect, Downlink Power Control (DLPC) for GPRS is considered.

DLPC for GPRS reduces considerably the interference introduced by the PS services and therefore increases the system capacity. In this paper a basic DLPC algorithm is presented together with results obtained from dynamic simulations in mixed scenarios (voice and data). Next results show important capacity improvements in mixed environments with PS traffic (FTP, WWW and Mail); i.e. around 50% capacity gain, maintaining the same quality in speech communications. Finally, it is demonstrated that DLPC allows the operator to control the impact of PS over CS by tuning a DLPC parameter, which is an offset of the transmitted power, increasing notably the number of satisfied voice users.

KEY WORDS

Downlink Power Control (DLPC), General Packet Radio System (GPRS), Packet Switched (PS), Circuit Switched (CS)

1. INTRODUCTION

GPRS emerges from combining the cellular mobile technology with the access to packet data networks, that is the case of Internet, whose number of users has grown impressively in a few years. GPRS is a new bearer service added to GSM that allows cellular wireless data services. GPRS offers more benefits than existing CS data and Short Message Service since GPRS is based on PS instead of CS radio transmission [1].

GPRS users benefit from a shorter access time and higher data rates. In addition, GPRS offers a fairer billing than conventional GSM, since the first one is based on amount of transmitted data whereas the second one is based on the call duration. Thus, GPRS users can be connected to the Network (to be "online") for a long time without charge if no data is transmitted.

Mainly, GPRS advantages come from the utilization of PS radio transmission. Due to the bursty nature of the data traffic (e.g. internet traffic), PS radio transmission allows a more efficient resource utilization than CS. CS allocates an entire traffic channel while the user is connecting even when he or she is not transmitting anything during the whole call period. PS only reserves a traffic channel when there is data to be transmitted and releases the resources immediately after the transmission has finished. This is how multiple GPRS users can share the same physical channel (statistical multiplexing).

However, the fact of having several users sharing the same traffic channels increases the interference level generated by them. Simulation studies show that interference generated by PS services is always higher than the one generated by CS for a certain load. The interference increase affects the rest of GPRS connections, and more important, it also affects voice communications. Therefore, one of the main concerns for the operators nowadays is to know how the progressive inclusion of PS services is going to affect the quality of existing voice services. There are several techniques that reduce the interference. One of the most interesting is Downlink Power Control that optimizes the base station transmitted power depending on the radio link conditions of the addressed mobile.

In this paper, Downlink Power Control for GPRS is deeply analyzed. In the section 2, an introduction to the Downlink Power Control for GPRS can be found. Main improvements achieved by this functionality are commented as well as the parameters of the Downlink Power Control algorithm used in this study. Next, in section 3 decisive results about the Downlink Power Control performance are presented. Results show how tuning one Downlink Power Control parameter (P0) that is an offset of the transmitted power, the operator can control the interference generated by PS over CS increasing the system capacity. Finally, in section 4 the main conclusions extracted from this study are indicated.

2. DOWNLINK POWER CONTROL ALGORITHM

Downlink Power Control is important for spectrum efficiency as well as for power consumption in GPRS. This functionality has as main goals to decrease cochannel interference and to increase the system capacity. Using downlink power control, BTS output power is adapted to the radio link conditions. The idea is to minimize the output power maintaining a good quality in the communications. As figure 2.1 shows, the process is composed of two steps mainly,

- The MS performs quality measurements in downlink
- Depending on these measurements, Downlink Power Control algorithm updates base station output powers.

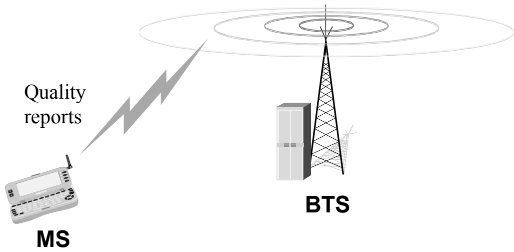

Fig 2.1: Downlink Power Control process

Depending on the kind of the measurements and the used criteria in order to change the output power, several downlink power control algorithms can be defined. In this paper, a basic downlink power control algorithm based on Carrier Interference Ratio (CIR) values is used to perform the simulations.

In this case Downlink Power Control Algorithm compares the CIR values reported by the MS with two thresholds: CIRmin and CIRmax. If the CIR value is higher than the CIRmax then the base station output power is decreased in 2dB. Otherwise if the CIR value is lower then the CIRmin then the base station output power is increased in 2dB.

CIR thresholds for the algorithm are chosen outside of the Link Adaptation work window in order to avoid possible changes in the coding schemes used by GPRS due to low power levels. Thus, Link Adaptation and Downlink power Control work independently.

In this case the step used to update the BTS output power is equal to 2dB, however, a different step may be used to increase or decrease the power always using 2dB multiples.

The main parameter of Downlink Power Control is P0. According to the spec [2], P0 is defined as a power reduction relative to BCCH output power. This parameter determines the maximum and minimum transmitted power for the base stations. Hence, since Downlink Power Control window is only 10dB for Downlink Power Control working in mode A [2], the maximum and the minimum transmitted power will be,

Pmax_GPRS = Power_BCCH – P0 (1)

Pmin_GPRS dB = Pmax_GPRS – 10dB (2)

By means of P0, the operator can control how much interference is generated by GPRS connections over the speech connections. The reduction in interference achieved by Downlink Power Control, as the results show in next sections, is translated into an important increase in the system capacity.

In addition, P0 determines the maximum throughput that a GPRS mobile station receives. Therefore P0 values should be chosen carefully in order to not penalize so much the GPRS connections in favor of speech services. The final decision is taken by the operator who has the possibility to decide between increasing the system capacity or reaching a balance that guarantees good quality for GPRS and speech services.

GPRS connections are allocated dynamically in uplink and downlink (dynamic allocation). Every time that a data block is sent to a mobile station an uplink state flag (USF) is also sent. The value of this flag is unique for each mobile that has an uplink established in the same time slot. USF informs the mobile station in question that it has to transmit in the next frame. Therefore, Downlink Power Control should limit the base station output power decrease in order to assure that, the output power must be sufficient for the mobile station that receives the data block, and for the mobile that receives the USF. This limitation has not been taken into account in the simulations and only downlink has been simulated.

3. SIMULATION RESULTS

In this section Downlink Power Control performance for GPRS is analyzed carefully in mixed scenarios with speech and packet switched traffic. This algorithm reduces the impact of PS services over speech services by means of decreasing the whole interference in the system. Consequently, a better performance in speech services is obtained.

In order to measure the capacity increase of this algorithm in terms of Effective Frequency Load (EFL), one parameter is defined: Downlink Power Control Gain,

$$Downlink\ Power\ Control\ Gain\,(\%) = \frac{EFL_{PC} - EFL_{NOPC}}{EFL_{NOPC}} * 100 \quad [1]$$

where EFL is defined as,

$$EFL = \frac{Erlangs\_CS + Erlangs\_PS}{number\ of\ TS * number\ of\ frequencies(TCH)} \quad [2]$$

It is assumed that no connection is allocated in the BCCH transceiver, therefore BCCH load is not taken into account in the EFL estimate. Therefore Downlink Power Control gain is relative exclusively to traffic channel layer.

DLPC gain parameter informs about the increase of the total capacity in the whole system keeping certain quality for speech connections, when Downlink Power Control is used. Maintaining the percentage of speech users for example, this parameter can inform the operator about how much extra percentage of GPRS traffic can be supported by the system without degrading the performance of speech services.

All simulations have been performed in a system level dynamic simulator. Only the downlink has been simulated, the uplink has not been taken into account.

Simulation environment

Simulations have been performed for several EFL values with the same proportion of speech and packet switched traffic. The percentage of GPRS users is 55% and 45% for Enhanced Full Rate (EFR) speech users. GPRS traffic is distributed between 60% for WWW, 30% for FTP and 10% for Mail traffic. Frequency Hopping with reuse 1/1, 10 frequencies with MAIO management has been considered in the traffic layer. BCCH reuse is 5/15.

For speech, Downlink Power Control based on RXQUAL and RXLEV and Dual Transmission (DTX) functions are active.

For GPRS, Coding Schemes CS1 and CS2 are used depending on Link Adaptation function. Downlink Power Control parameters: CIRmin=20, CIRmax=26 and P0=3dB. Thresholds are outside of the Link Adaptation window and correspond to the zone where the maximum throughput for CS2 is reached.

Simulation results

The following figures show the percentage of speech samples taken every 2 seconds with a FER>1% and FER>4% vs EFL. (Note: FER, Frame Erasure Rate).

In both figures 3.1 and 3.2, the percentage of speech samples whose FER values are higher than 1% and 4% respectively are depicted. The two lines traced correspond to both cases, i.e. without Downlink Power Control active for GPRS (continuous line), and with Downlink Power Control active for GPRS (dashed line).

Downlink Power Control Gain is calculated for two intermediate points. In figure 3.1 the 8% of speech samples are considered with FER>1% and in figure 3.2 the 3% of samples with FER>4%. In table 3.1 both Downlink Power Control gain values are gathered.

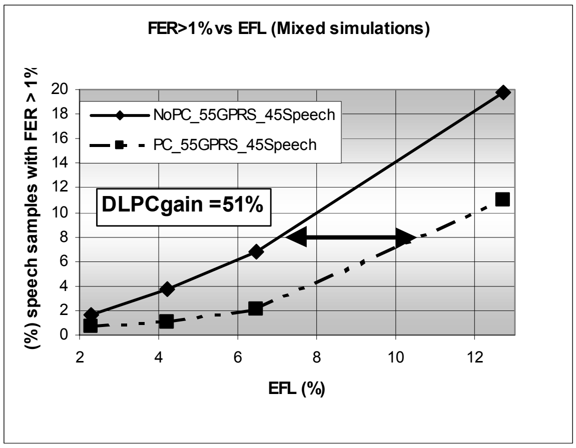

Figure 3.1: % speech samples with FER >1% vs EFL

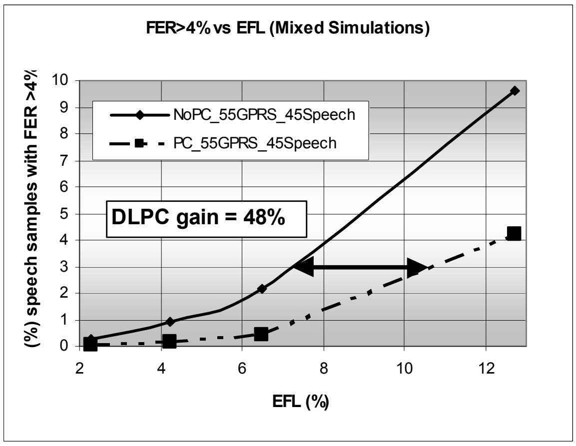

Figure 3.2: % speech samples with FER >1% vs EFL

As it is shown in the table below, Downlink Power Control achieves a capacity increase around 50% maintaining the quality in speech connections.

% speech samples	Downlink Power Control Gain(%)
8% for a FER>1%	$DLPC\ Gain = \frac{10.6-7}{7} * 100 = 51.4\%$
3% for a FER>4%	$DLPC\ Gain = \frac{10.8-7.3}{7.3} * 100 = 47.9\%$

Table 3.1: Downlink Power Control Gain for a 55% GPRS traffic and 45% Speech traffic

Such Downlink Power Control gains are achieved thanks to the power reduction applied to GPRS connections. The following figures 3.3. and 3.4 show how the average gross throughput is affected separately per FTP, WWW and Mail connections. Continuous lines in both figures correspond to the case without Downlink Power Control active for GPRS whereas the dashed lines correspond to the case with Downlink Power Control active for GPRS.

As figures 3.3 and 3.4 show, when Downlink Power Control is applied to GPRS connections, the average gross throughput achieved for these connections is reduced. However all throughput connections are not affected evenly. The FTP connections suffer a throughput reduction around 2kbps, WWW connection throughput is reduced less than 1Kbps and for Mail connections the throughput reduction is negligible.

The reason why FTP connections are a little more penalized by the power reduction than the others is their call duration that is longer than other cases. Thus, the Downlink Power Control algorithm has more time to optimize the base station output power and lower power levels are reached more often with FTP connections. In some cases lower base station power levels involve bad receptions and therefore retransmissions that generally are performed with a slower coding scheme (CS1), which reduces the average throughput experienced by the FTP connections.

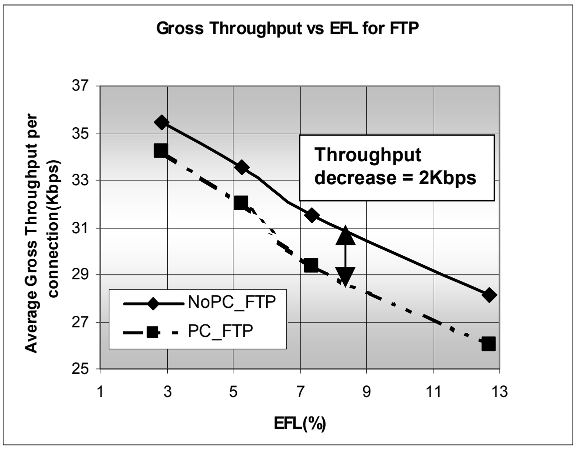

Figure 3.3: Average gross throughput for FPT connection vs EFL

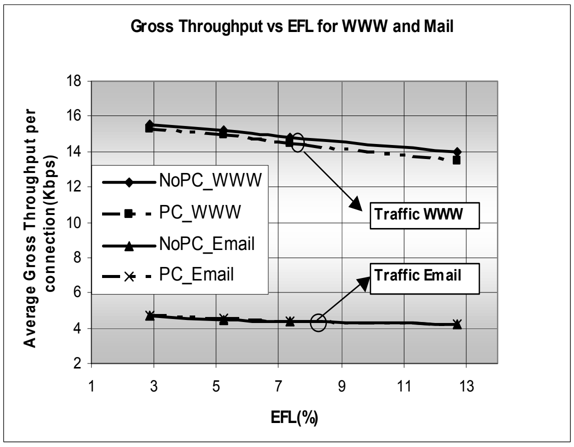

Figure 3.4: Average gross throughput for WWW and Email connections vs EFL

All these results are obtained with a P0 value equal 3 dB since it allows an acceptable balance between speech and GPRS quality. However, more aggressive P0 values could have been used allowing higher capacity gains but also higher throughput reduction in GPRS connections. Anyway that is an operator decision.

4. CONCLUSION

In this paper the performance of a Downlink Power Control algorithm for GPRS has been analyzed. Results here presented show that Downlink Power Control algorithm for GPRS is a useful functionality in mixed scenarios with speech and packet switched services. By applying Downlink Power Control the whole energy radiated is lower, so cochannel and channel adjacent interferences are reduced considerately. A less impact of PS over speech service is achieved due to interference decreasing.

EFL analysis has shown that using DLPC algorithm, a large increase in the total capacity of the whole system is achieved keeping certain quality for the speech traffic. A parameter, DLPC Gain, has been defined in order to measure this increase. For GPRS with LA and CS1 and CS2, the improvement in the capacity is around 50% for combined traffic (FTP, WWW and Mail). However, throughput for GPRS connections decreases in mixed scenarios when DLPC is used, due to GPRS connections being penalized in favor of speech connections.

Downlink Power Control allows the operator to control the impact of PS over CS by means of the P0 parameter. Tuning P0 value, the operator will reach a trade off between Speech and Packet Switched services, which assures a good performance for both.

5. ACKNOWLEDGEMENT

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REFERENCES

[1] T. Halonen, J. Romero, J. Melero, GSM, GPRS and EDGE Performance, Evolution Towards 3G/UMTS (Wiley, 2002)

[2] 3GPP TS 05.08, V8.13.0, (2002-02) 3rd Generation Partnership Project; Technical Specification Group GSM/EDGE Radio Access Network; Radio subsystem link control (Release 1999)