GPRS link adaptation switching thresholds and intervals

J. Gozalvez and J. Dunlop

A complementary approach is presented for obtaining the link adaptation (LA) switching thresholds defining the regions (CIR ranges) where each coding scheme is most suitable. The approach is based on multiple replications providing an indication of the accuracy of the threshold. GPRS and different operating environments are studied.

Introduction: Link adaptation [1] has been identified as a key technology for evolved GSM systems such as adaptive multi-rate codec (AMR), general packet radio services (GPRS) and enhanced data rates for GSM evolution (EDGE). Link adaptation is based on assessing the channel conditions and then using a channel coding scheme (CS), from a set of predefined options, that is optimised for these conditions.

Previous work [2, 3] defined the switching thresholds as single points, each corresponding to a particular carrier-to-interference ratio (CIR). These points were defined through simulation based on a single replication. There is therefore no indication of the accuracy of the switching threshold. This Letter presents a complementary approach, a 'multiple replication procedure', which provides these thresholds and an estimate of their accuracy through intervals termed LA switching intervals.

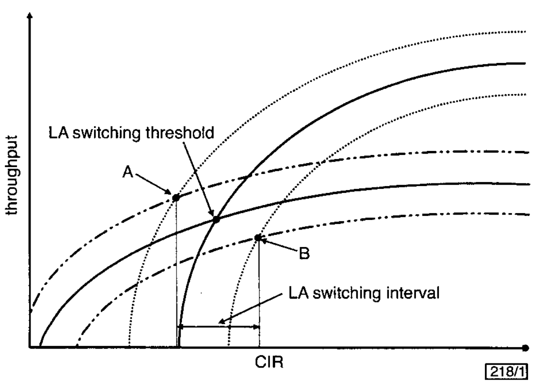

Fig. 1 *Illustration of definition of LA switching intervals*

LA switching intervals: For the purpose of this work, LA considers a coding scheme to be optimal if it provides the highest throughput. The user throughput depends on the quality of the link and the CS data rate (R_n). The link quality can be expressed by means of the block error rate (BLER), which is the ratio of erred blocks to the total number of blocks received. The BLER is a function of the CIR. The user throughput (S_n) can then be expressed as follows:

$$S_n = R_n * (1 - BLER_n(CIR)) \qquad (1)$$

Previous work [2, 3] used a mean BLER estimate (obtained by a single replication) to define the LA switching thresholds. In this Letter, the mean BLER estimate based on multiple replications is used to obtain the LA switching thresholds. Moreover, an estimation of the accuracy of the BLER value is introduced through 95% confidence intervals. The confidence intervals are then used in eqn. 1 to define an interval, termed the LA switching interval, in which the 'ideal' LA switching threshold may be found, as illustrated in Fig. 1. In this Figure, the solid lines represent the throughput of a CS using the estimated mean BLER. The crossing point of two solid lines will then define the LA switching thresholds. The dashed and dotted lines represent the throughput obtained considering the BLER 95% confidence interval limits. The lower limit corresponds to the more pessimistic estimation of the radio link quality while the upper corresponds to an optimistic estimation. Assuming each CS treats errors in a similar manner, the LA switching interval is defined by the crossing points A and B. The LA switching intervals will then provide an indication of the accuracy of the LA switching thresholds.

LA will select the most suitable CS using the LA switching thresholds. To reduce the probability of ping-pong effects, which might produce a signalling overhead, a hysteresis window can be used. As shown in [1], the use of a hysteresis window reduces considerably the number of CS changes while only decreasing slightly the perceived quality. As the LA switching intervals represent the region where a change of CS is needed, they could also be used as hysteresis windows in the LA process.

The work presented in this Letter concentrates on GPRS. The effect introduced on the LA switching thresholds and intervals by varying the number of replications considered is studied.

Table 1: GPRS channel coding scheme parameters

Scheme	Code rate	Radio block (including tail and parity bits)	Coded bits	Punctured bits	Data rate (kbit/s)
CS1	1/2	228	456	0	9.05
CS2	≃2/3	294	588	132	13.4
CS3	≃3/4	338	676	220	15.6
CS4	1	456	456	—	21.4

GPRS channel coding: The GPRS standard specifies four channel coding schemes, CS1 to CS4 [4]. Each scheme has different error correcting capabilities and data rates (Table 1). CS1 uses a half rate convolutional coding and is the more robust scheme. CS2 and CS3 use the same convolutional coding as CS1 but require the application of puncturing schemes. CS4 is the less robust scheme as it does not apply any convolutional encoding.

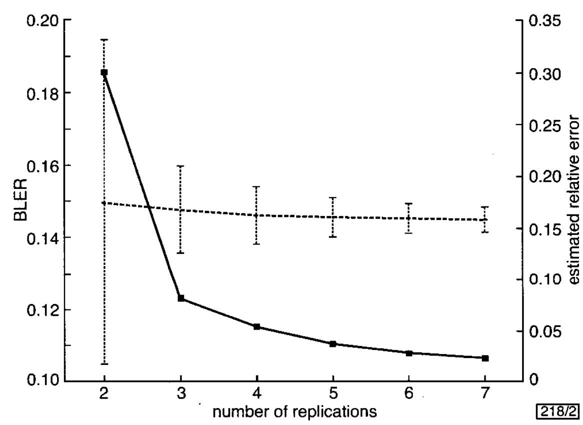

Fig. 2 *Estimate variation of CS4 BLER*

5km/h, no FH and CIR = 16dB
------ mean BLER
|--|--| 95% confidence interval
—■— estimated relative error

Table 2: GPRS LA switching thresholds and intervals

Switching between schemes	GPRS LA switching thresholds and intervals											
	5 km/h and no FH			5 km/h and FH			50 km/h and no FH			50 km/h and FH		
	2 rep.	4 rep.	6 rep.	2 rep.	4 rep.	6 rep.	2 rep.	4 rep.	6 rep.	2 rep.	4 rep.	6 rep.
CS1/CS2	–	–	–	5.69–*6.05*–6.6	5.57–*5.93*–6.34	5.8–*5.98*–6.2	3.84–*5*–6.96	4.73–*5*–5.3	4.82–*5*–5.08	5.53–*5.88*–6.34	5.71–*5.89*–6.13	5.84–*5.89*–6.03
CS2/CS3	2.16–*3.21*–4.68	2.85–*3.17*–3.71	3.21–*3.34*–3.42	9.28–*9.95*–10.5	9.55–*10*–10.21	9.82–*10*–10.05	8–*9.5*–10.4	9.16–*9.46*–9.67	9.28–*9.46*–9.57	9.37–*9.91*–10.98	9.66–*9.91*–10.19	9.75–*10*–10.08
CS3/CS4	6.33–*9.23*–10.5	8.72–*9.1*–9.45	9.06–*9.19*–9.32	16–*16.7*–17.55	16.4–*16.6*–16.85	16.55–*16.69*–16.8	15.7–*16.46*–17.5	16.25–*16.44*–16.6	16.34–*16.43*–16.5	16.28–*16.96*–17.5	16.7–*16.98*–17.1	16.77–*16.94*–17

Simulation environment: The BLER was obtained through link level simulations performed with an evolved software version of the emulator presented in [5]. An independent replication method was used to estimate the BLER. Each replication simulated the transmission of 15000 radio link control blocks (each block was interleaved over four GPRS bursts). Speeds of 5 and 50km/h were considered in a typical urban environment (as specified in the

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GSM standards). The use of slow frequency hopping (FH), over four frequencies, was also simulated. Slow FH introduces frequency and interference diversity, which help to mitigate the effects of deep fades.

Results: Simulations demonstrated that the 95% confidence interval of the BLER is highly dependent on the number of replications simulated, as shown in Fig. 2. This dependence affects the user throughput and therefore the width of the LA switching intervals.

The GPRS LA switching thresholds and intervals for all the operating environments are reported in Table 2 (the thresholds appear in italic while the two other values represent the limits of the intervals). Their variation for different number of replications is also depicted. For a speed of 5km/h and without considering FH, no switching threshold and interval were obtained between CS1 and CS2, indicating that CS2 outperforms CS1 in this operating environment. According to Table 2, the simulation length has little effect on the LA switching thresholds. However, its effect is quite important for the LA switching intervals as short simulation lengths produce wide LA switching intervals. This influence is particularly important for the case of 5km/h and no FH. This is due to the fact that for low speeds without the use of frequency hopping, the BLER is higher and therefore the accuracy of BLER estimation is more sensitive to the number of replications considered. A practical implementation of LA will base its decision on the LA switching thresholds. These thresholds have to be estimated accurately for proper design of the LA algorithm. The results presented here indicate that 6 replications are needed in order to have an LA interval of 0.4dB or less. In the particular scenarios considered, the mean BLER did not vary considerably with the simulation length. However, it cannot be concluded that this will be the case for other scenarios and therefore confidence in fixing LA thresholds can only be established by use of replications as shown in this Letter. Also, when using the LA switching intervals as hysteresis windows, longer simulations are required. In [1], it is shown that wide hysteresis intervals can produce an important decrease in perceived quality. As depicted in Table 2, the width of the LA switching interval is reduced by increasing the simulation length, suggesting that longer simulations are required to define LA switching intervals that could be used as appropriate hysteresis windows.

Conclusions: This Letter has presented a complementary approach to defining GPRS LA switching thresholds by introducing an indication of their accuracy through the LA switching intervals. It also suggests the possibility of using the LA switching intervals as hysteresis windows in the LA algorithm.

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Hourly statistical analysis of fade occurrence and duration

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An approach to evaluating and specifying the availability and quality of performance of radiocommunication services is presented. The number and total duration of fade events, within independently processed clock hours, were observed by carrying out a two-year statistical analysis of Olympus 12.5GHz beacon data. The hourly probability of given fade levels being exceeded was obtained by varying both the number of events and total excess time over the course of one hour. The possibility of modelling these parameters is explored, with satisfactory results.

Introduction: A typical second-order analysis of radio-propagation studies establishes the statistical distribution of the excess duration after a specific rain attenuation threshold is exceeded [1]. According to a design-oriented approach [2], attention can be focused on clock hours by calculating, for a predetermined attenuation level, both the number n of the events exceeding fade levels and the total fading duration t, and total time of the n events, thereby establishing the probability of the hour being 'disturbed' by different numbers of 'degraded time intervals' and for various 'total disturbed time' values.

The first step is to calculate the fraction of hours affected by at least one event and hence the hourly probability of fading occurring. This figure indicates the probability of exceeding fade levels at a given attenuation. This will be higher because the disturbed hours are added to the total time regardless of the fraction of time the threshold is actually exceeded. This criterion is more conservative and can be applied whenever the contract terms allow the customer to claim reimbursement for reduced availability and/or quality of service.

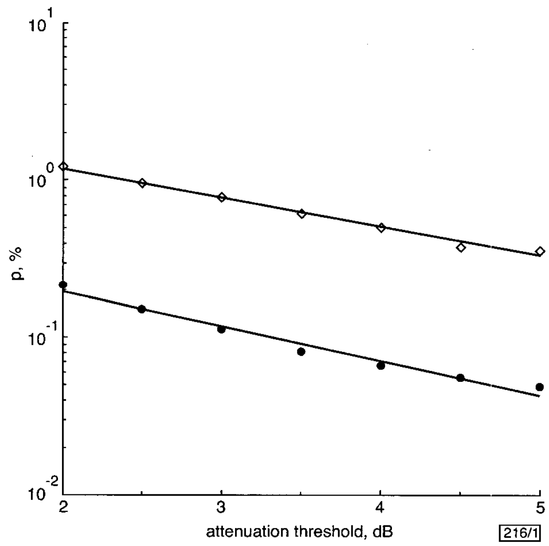

Fig. 1 *Cumulative distribution of attenuation A intended as percentage of hours with at least one excess event and percentage of actual total excess time*

◇ percentage of hours with at least one excess event
$p = 2.7\exp(-0.42\,A)$, $R^2 = 0.989$, $rss = 0.014$ (best fit)
● percentage of actual total excess time
$p = 0.52\exp(-0.50\,A)$, $R^2 = 0.974$, $rss = 0.045$ (best fit)

Statistical analysis of the events observed at 60min intervals is provided in this Letter, in terms of the number and the total duration of events over one hour. Useful design parameters and fitting models are also extracted.

Experimental setup and data processing: The beacon level data were measured using an Olympus receiving station at 12.5GHz, with 3m antenna diameter, 49dB gain and 0.6° –3dB beamwidth. The LNA had a 46dB gain, a 2.8dB noise figure and a fade dynamic of 23dB. Data from the two year period from March 1990 to August 1992 were processed, with 90% acquisition availa-

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