Table 1: Maximum degradation by Doppler frequency error against coherent integration interval N

N [symbols]	1	2	4	8	10
Degradation [dB]	−0.0150	−0.0599	−0.2407	−0.9793	−1.5510

Conclusions: Performances of multi-path searcher were presented when transmit diversity is employed. Knowing how to find the optimum parameters will aid engineers to implement the most efficient multi-path searcher of a mobile station.

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Performance of link adaptation in GPRS

J. Dunlop and J. Gozalvez

The impact of random and sequential slot allocation on the performance of link adaptation in a GPRS system is considered. Of particular interest is the impact on throughput.

Introduction: The general packet radio service (GPRS) and its derivative EGPRS are seen as an evolutionary step towards the provision of 3G services. Both GPRS and EGPRS and are able to operate with a choice of coding scheme appropriate to the prevailing signal to interference ratio (SIR). The basis of link adaptation (LA) is to make such a process dynamic by continuous assessment of SIR and the subsequent use of a channel coding that is optimised for these conditions.

Previous work [1] has shown that slot allocation strategies within a packet radio system can influence the interference distribution experienced by mobile stations. The channel coding schemes specified for GPRS are CS1 to CS4, the properties of which are shown in Table 1.

Table 1: GPRS channel coding parameters

Scheme	Code rate	Payload [bits]	Data rate [kbit/s]
CS1	1/2	181	9.05
CS2	≃2/3	268	13.4
CS3	≃2/3	312	15.6
CS4	1	428	21.4

This Letter examines the impact of shaping the interference distribution on the throughput of a GPRS system employing dynamic link adaptation, and considers the slot allocation mechanisms shown in Fig. 1. The sequential slot allocation mechanism increases the probability of a slot being occupied at the start of a frame and therefore increases the probability of co-channel interference for these slots. In principle the SIR for sequential allocation would be higher, but also less variable than for random allocation and thus produce fewer mode changes per unit time, hence allowing a potential trade off in terms of signalling.

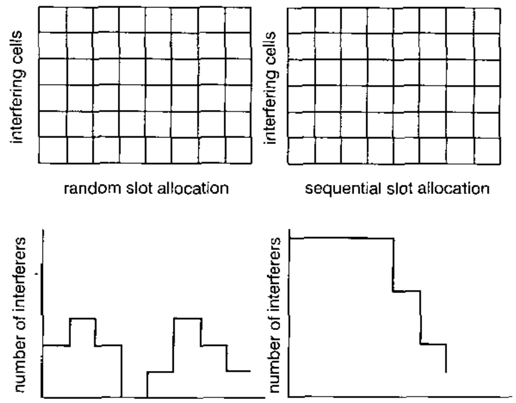

Fig. 1 *Random and sequential slot allocation mechanisms*

System modelling: A cellular network with a cluster size of 4 with 3 sector/cell is considered, each cell having a radius of 1 km and each sector being assigned two carriers. Results are derived from simulation in which the system load is varied by changing the number of users in the system, with each user operating for the complete duration of the simulation and being allocated only a single slot (multi-slot operation is supported by GPRS). Users are assigned channels on a first-come-first-served basis and the channel is kept by a user until all its data has been correctly transmitted. An ARQ protocol, following the GPRS specifications, has been implemented to request the retransmission of erroneous blocks. A perfect feedback of the ARQ report with no RLC block loses has been assumed. The ARQ window size is equal to 64 RLC blocks. An ARQ report is sent after transmitting 16 RLC blocks, following the recommendations from [2]. Although the current GPRS standard does not contemplate CS changes for retransmissions, such changes have been considered in this work so that results are not conditioned by GPRS limitations.

An Okumura-Hata pathloss model has been used with shadow fading (log normal distribution, standard deviation of 6 dB and a decorrelation distance of 20 m). Fast fading has been included in the system level simulations but power control and slow frequency hopping have not been implemented.

Traffic modelling: The models considered in this Letter are web browsing and email, evenly distributed amongst active users. Both traffic sources have been implemented as an ON/OFF model [3]. The Web model considered uses a separate TCP connection to transfer each file, or object, in a web page. The email size distribution is bimodal as emails are also used to transfer files. For both traffic models, the transmission of a new packet cannot start until the previous transmission has finished, i.e. all the data has been correctly received. The active transmission time will hence depend on the channel quality conditions.

LA algorithm: In the case of LA a coding scheme is considered 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_{CS}). The link quality can be expressed in terms of the block error rate (BLER), which is the ratio of erred blocks to the total number of blocks received and is a function of SIR. The user throughput (S_{CS}) is given by

$$S_{CS} = R_{CS} \times (1 - BLER_{CS}) \quad (1)$$

with R_{CS} and $BLER_{CS}$ being the data rate and BLER for a given CS. The LA switching thresholds define the boundaries between the regions where each CS is optimum. These boundaries are defined as a collection of points, each representing a combination of mean and standard deviation of BER values.

The LA algorithm uses the quality measurements over the previous updating period to decide on the optimum CS. The mean BER and the standard deviation of the BER over a block for each transmitted block during the last updating period are filtered to obtain the channel quality estimation necessary for the LA algorithm. A filter with a rectangular shape has been applied throughout and a fixed initial coding scheme, CS4, has been selected at the start of each new data transmission value.

Simulated performance: The performance is represented by means of the cumulative distribution function (cdf) of the throughput, which allows the assessment of the performance of an LA algorithm for the whole range of bit rates. The throughput is collected for all users in the centre cell and the cdf generated is used to provide an indication of the system performance. The study has been conducted for loads of 8, 16, 24 and 36 users per sector, representing a mean bandwidth occupancy of 20%, 45%, 67% and 93% respectively. To ensure results with good statistical accuracy, each simulation scenario (i.e. considering a different load) simulates the transmission of $>30 \times 10^6$ RLC blocks in the centre cell.

Results for different loads are shown in Figs 2 to 5 which show that as the load increases the performance under both slot allocation mechanisms converge. The channel occupancy increases under high loads and therefore when a user requests a channel to transmit there is a small number of available channels to choose from. As a result both slot allocation mechanisms operate in an almost identical way, which explains their close performance under high loads. However, the effect of the load on the performance of each slot allocation mechanism differs. While the performance under a random slot allocation mechanism is clearly affected by the load in each sector this is not the case for the sequential slot allocation mechanism. As this allocation mechanism assigns slots sequentially from the start of a frame, the first slots of a frame experience the conditions of a highly loaded system. The load has therefore a much smaller effect on the performance of the sequential slot allocation mechanism.

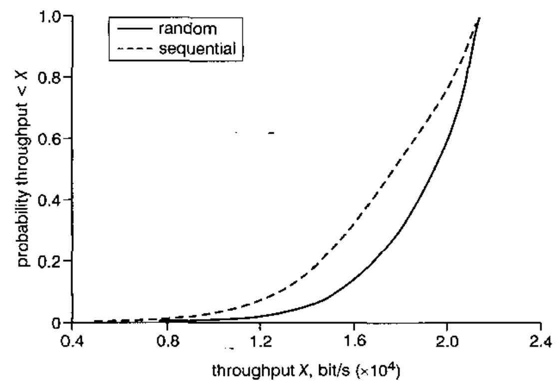

Fig. 2 *Cdf of throughput (8 user/sector)*

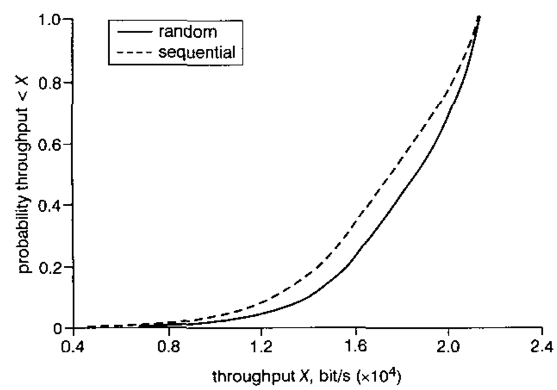

Fig. 3 *Cdf of throughput (16 user/sector)*

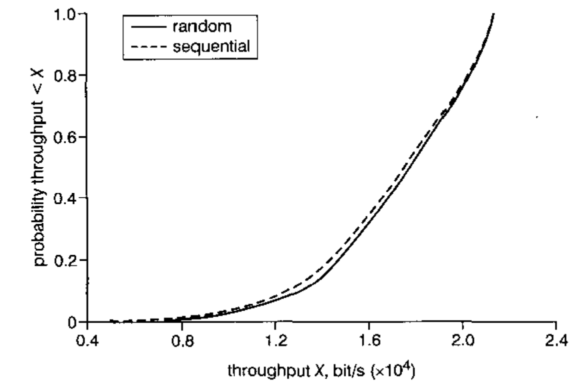

Fig. 4 *Cdf of throughput (24 user/sector)*

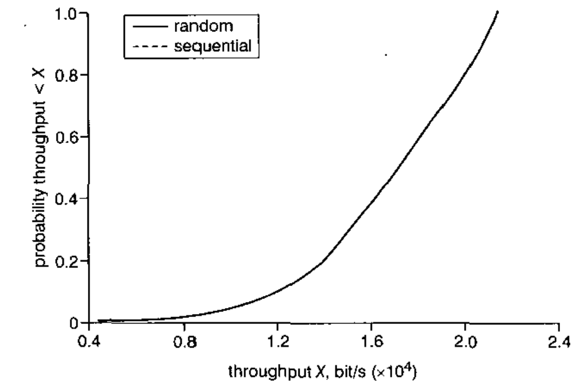

Fig. 5 *Cdf of throughput (36 user/sector)*

Conclusion: It has been shown in previous work on TDMA packet cellular radio that slot allocation policies have a marked impact on shaping the interference distribution. This Letter has shown that such strategies also affect the performance of link adaptation. In particular results have been presented which suggest that for GPRS, under low and medium loads, the operation of LA is improved with a random slot allocation mechanism. The increased interference level resulting from a sequential slot allocation mechanism is the origin of this difference in performance.

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