Channel allocation mechanisms for improving QoS in packet mobile radio networks

J. Gozalvez and J.J. González-Delicado

New quality-based channel allocation mechanisms are evaluated. The mechanisms assign incoming calls the available channel that previously experienced the best link quality. For that purpose, three metrics have been considered: BER, BLER and CIR. The proposed techniques improve the QoS compared to the traditional random allocation mechanism while also offering its benefits in terms of uniform long-term channel use.

Introduction: User demands and expectations for high Quality of Service (QoS) increase the importance of Radio Resource Management techniques aiming to efficiently manage the available radio resources. One of these techniques is channel allocation.

At present, most of the work that has been conducted regarding channel allocation for packet data services in a GSM framework has focused on how to distribute and manage the available channels between GSM and GPRS [1]. On the other hand, this Letter considers the case where a number of channels are exclusively reserved for GPRS and focuses on mechanisms used to decide which available channel is assigned to an incoming call.

One of the most commonly used allocation mechanisms is random channel allocation. This technique decides, randomly, which one of the unoccupied channels is assigned to an incoming call. Apart from its simplicity, this technique offers the advantage of a uniform use of all channels assigned to a given base station. This characteristic is quite interesting from an engineering point of view, since it avoids surcharging particular channels and, therefore, RF equipments. In [2], the authors suggested the idea of basing the allocation process on the quality previously experienced in each one of the available channels. Following this suggestion, this Letter proposes and evaluates three 'intelligent' channel allocation mechanisms to improve the system performance. The techniques assign an incoming call the available channel that previously experienced the best link quality conditions. The difference between each mechanism is the channel quality metric considered. In particular, three metrics are proposed: mean carrier-to-interference ratio (CIR), mean block error rate (BLER) and mean bit error rate (BER).

Proposed allocation schemes: The maxCIR algorithm assigns incoming calls the available channel that experienced the highest mean CIR during the previous transmissions. This metric has been considered since it is commonly used to represent the channel quality variations. A second proposal bases its channel allocation decision on BER estimates. In this case, the minBER algorithm assigns the available channel that previously experienced the lower BER. The BER was chosen as quality metric since it has a considerable relation with the QoS perceived by a user. While obtaining BER and CIR estimates could have an important implementation cost in current systems, this is not the case of the BLER. In fact, BLER estimates are already available in GPRS-like systems since acknowledgment reports are regularly sent to the transmitter. As a result, a third proposal, the minBLER algorithm, considers the BLER as its channel quality metric. The potential disadvantage of the BLER is that it might need a considerable number of samples (a BLER sample is a 1 or 0 depending on whether a transmitted block has been received in error or not) to provide an accurate and meaningful average value.

The operation of the proposed algorithms is as follows. Each channel is being provided with an array used to store the metric estimates measured during the previous transmissions. While BER and CIR values are stored for each transmission burst, BLER estimates are only stored at a block level (in GPRS, each RLC block is transmitted over four bursts). Once the array has been filled, the oldest estimates are discarded in order to store the new ones. When an incoming call requests a new channel, the proposed algorithms produce a channel quality estimate for each one of the available channels. Each estimate is obtained by filtering all the measurements stored on each channel's array (a filter with a rectangular shape has been considered). The algorithm decides which channel is allocated to the incoming call by comparing the obtained estimates for each one of the available channels.

Evaluation environment: This research has been conducted using a system level event-driven simulator based on the GPRS standard. The simulator works at the burst level and concentrates on the downlink performance. Users are assigned channels on a first-come-first-served basis and the channel is kept until all its data has been correctly transmitted (an ARQ protocol following the GPRS specifications is used). Although mobility has been implemented, handover between sectors has not been considered.

The effects at the physical layer are included by means of look-up tables (LUTs). In particular, this research uses a set of advanced LUTs working at the burst level and introducing the fast fading at the system level [3]. The main simulation parameters are summarised in Table 1. To ensure results with good statistical accuracy, each simulation scenario simulates the transmission of more than 30×10^6 RLC blocks in the central cell.

Table 1: System parameters

Parameter	Value
Cluster size/cell radius	4/1 km
Sectorisation/channels per sector	120°/16
Traffic load	WWW (4 users/sector) and email (4 users/sector)
Vehicular speed	50 km/h
Pathloss/shadowing	Okumura-Hata/log-normal distribution (6 dB standard deviation and a 20 m decorrelation distance)

This work has been conducted in an adaptive radio environment employing link adaptation (LA). The use of LA for the GPRS standard is possible since it defines four coding schemes (CS) that offer a trade-off between throughput and coding protection. The basis of the implemented LA algorithm is to assess the channel conditions and then use the CS that maximises the throughput. The algorithm decides which is the optimum CS each 100 ms.

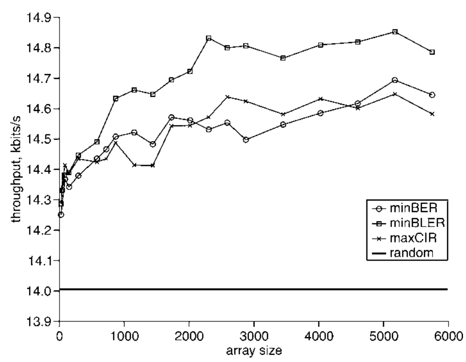

Fig. 1 *Minimum throughput for 95% of samples against array size*

Results: A key parameter affecting the performance of the proposed schemes is the array size. Fig. 1 illustrates the minimum throughput experienced by 95% of the samples against array size. This Figure shows that the performance of the proposed schemes strongly depends on the considered array size, and in particular, it increases with the array size. This is due to the fact that with larger number of measurements it is possible to obtain a more reliable and representative estimate of the previously experienced channel quality conditions. The minBLER algorithm improves its performance with the array size but only up to an array size of 2304 measurements. Increasing further the array size does not have a significant effect on the performance but it increases the implementation cost since larger memory sizes are needed. For the maxCIR and minBER algorithms, the higher performance has been obtained for array sizes of 2592 and 5184, respectively. Similar conclusions, regarding the effect of the array size on the algorithm's performance, have been obtained for the average throughput and the minimum throughput experienced by 99% of the samples.

Fig. 1 also demonstrates that the proposed techniques outperform the random scheme and that the algorithm that achieves the highest throughput performance is minBLER. The improved channel assignment process observed with the minBLER proposal is due to the fact that while BLER estimates provide a clear indication of the user perceived QoS, the effect of BER and CIR estimates depends on the employed CS.

Table 2 shows the system performance considering the previously mentioned best array sizes for each one of the proposed schemes. The Table also indicates the gain (in %) achieved with the proposed techniques compared to the random allocation mechanism. Table 2 outlines that, while the gains are not too important for the mean throughput, the minimum guaranteed QoS is greatly improved with the proposed mechanisms. Such improvements are due to an important decrease of the experienced average BLER (see Table 2). These results highlight that the proposed schemes mainly benefit the QoS of the users that experience the worst performance. The proposed schemes also affect positively the operation of LA since the proportion of blocks received with the optimum CS is increased and the signalling load associated with the use of LA is importantly decreased. Such signalling load is represented by means of the average number of CS changes per second.

Table 2: System performance

	Random	MinBLER	MinBER	MaxCIR
Mean throughput (kbits/s)	18.76	19.14/2.03%	19.08/1.7%	19.06/1.6%
Minimum throughput for 95% of samples (kbits/s)	14	14.83/5.9%	14.69/4.9%	14.64/4.6%
Minimum throughput for 99% of samples (kbits/s)	10.88	12.09/11.14%	11.85/8.9%	11.75/8%
Average BLER (%)	4.97	4.32/13.1%	4.42/11.1%	4.45/10.5%
Optimal CS (%)	75.86	78.56/3.6%	78.14/3%	78/2.82%
Number of CS changes per second	2.227	2.062/7.41%	2.089/6.2%	2.093/6.01%

Fig. 2 plots the average time occupancy of each channel for the array sizes considered in Table 2. This Figure shows that the proposed mechanisms exhibit the same long-term uniform use of all channels, and therefore RF equipment, as the random allocation scheme. However, the proposed schemes exhibit a different short-term pattern compared to the random scheme. In particular, it has been observed during our simulations that, with the proposed schemes, interfering cells avoid using the same channels at the same moment. As a result, our proposals guarantee a lower instantaneous interference level, compared to the random allocation mechanism, and therefore a higher performance.

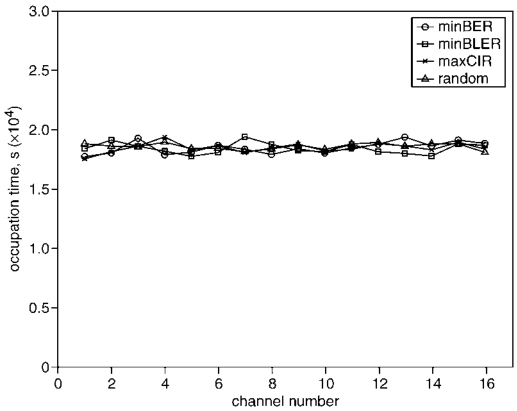

Fig. 2 *Measured average channel occupancy*

Conclusions: We have proposed and evaluated three quality-based channel allocation mechanisms designed to improve the system performance. The obtained results demonstrate that the three proposals outperform the widely used random channel allocation mechanism, while also exhibiting a long-term uniform use of all channels. The mechanism based on BLER estimates is the one offering the strongest performance and the lowest implementation cost, since BLER measurements are already available in packet-based systems.

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