

NOVEL GPRS SIMULATOR FOR TESTING MAC PROTOCOLS

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ABSTRACT

A simple, effective model of a GPRS/GSM cell is developed that can give a clear insight into the behaviour of MAC layer scheduling algorithms for a definable cohort of users. Users are defined in terms of their QoS class, their mobility characteristics and their traffic characteristics. The channel model is a C/I statistical model that has a variable mean value that is generated from a two state Markov model for each user.

As an example, a weighted round robin scheduling algorithm is analysed within this simulated environment to predict its effect on traffic flow and user perceived network performance. Results presented show that the scheduling algorithm can simply and effectively implement QoS differentiation and reduce the perceived delay for real time streaming users, thereby improving the user perceived performance of the network.

INTRODUCTION

With an increasing demand for multimedia services, the design of high-speed data networks that can give Quality of Service (QoS) differentials is an important task in the wireless mobile environment. GPRS (General Packet Radio System) is the next step in the evolution of the Global System for Mobile (GSM) offering a packet data bearer within a GSM network.

The user's perception of throughput and delay are central to the concept of QoS differentiation in this mobile multimedia scenario. The network operator, however, needs to try to maximise utilisation of their network infrastructure. The trade off between these seemingly opposing goals has been the subject of considerable research [1 – 12]. Much of this work does not deal with streaming traffic or uses a static channel model or includes levels of complexity that can mask the performance of the scheduling algorithms.

The focus in this work is the ability to develop a simulation environment that can be used to test the effect of Medium Access Control (MAC) layer scheduling algorithms for GPRS. To that end, several prudent design maxims have been employed:-

1. The channel model needs only to be a reasonable depiction of a credible propagation scenario. It is not a goal here to produce a highly accurate propagation model. The channel model must also have some features that reflect the mobility of users within a cell.
2. The Radio Link Control (RLC) layer is modelled as an implementation of the Link Adaptation (LA) technique.
3. Higher layers add only overhead, with no mismatch of packet sizes between layers, so that their effect can be neglected. Most importantly, the congestion control aspect of the Transmission Control Protocol (TCP) and the Logical Link Control (LLC) layer is not included.
4. Signalling delays to establish Temporary Block Flows (TBFs) or to acknowledge packet deliveries are not included.

With these assumptions in place it is clear that any effects observed in such a simulator can only be caused by normal traffic engineering effects or by the MAC protocols used.

SIMULATOR ARCHITECTURE

A flexible GPRS system model has been constructed in a discrete event simulator as shown in fig.1. It can enable a single cell to be loaded with different types of users and analysed under a range of different scenarios to evaluate performance. To demonstrate the efficacy of the simulator, QoS differentiation is implemented with a Weighted Round Robin (WRR) scheduling algorithm.

The set of input data is :-

Cell definition:-

- Cell Radius (r) (km)
- Cell type (urban, sub-urban, rural, user defined)
- User Density (u/km²)

User definition:-

- Proportion of high-speed users (%)
- Proportion of medium-speed users (%)
- Proportion of low-speed users (%)
- Proportion of background traffic users (%)
- Proportion of interactive traffic users (%)
- Proportion of streaming users (%)

Network definition:-

- Number of traffic channels available in the cell
- Average number of traffic channels available to GPRS
- Average number of traffic channels used for voice
- Weight for the background traffic (W_b)
- Weight for the interactive traffic (W_i)
- Weight for the streaming traffic (W_s)

Users are categorised by their mobility, fast users having a maximum speed of 100km/h, medium users 20km/h and slow users at 5km/h. The user population will also have a distribution of traffic types: background, interactive and streaming, with each traffic class requiring different QoS guarantees. Since there are three types of user mobility and three traffic classes, there are a total of nine user classifications. The

simulator uses input data to establish the number of users in each of these classifications.

The cell type will determine the shape of the probability distribution function (pdf) of the Carrier to Interference ratio (C/I) that is typically experienced by users in that type of cell. For example, users in urban cells will experience broad distributions while users in rural cells will experience a lower variance from the expected mean value at any given time. The simulator user may also define their own shape of pdf if the defaults are not representative of the types of cells being analysed. Further cell definition data includes the cell radius and the user density so that the total number of users in the cell can be calculated.

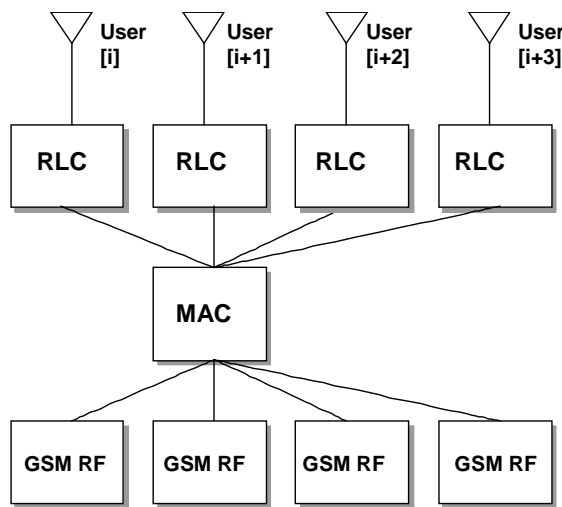


Figure 1. System architecture

CHANNEL MODEL

A separate pdf of C/I is generated for each user and a simple two state Markov model varies the median value of the pdf for each individual user. That is, although the shape of each user's pdf remains the same, the median is varied in steps of 1dB within a range from 6dB to 50 dB. These values correspond to the extreme edge (C/I_{\min}) and centre (C/I_{\max}) of the cell under investigation.

The Markov model for fast users is triggered by a clock that has a period (Δt) equal to the minimum time possible for a user to move from the centre of the cell to its edge divided by the range of mean values.

$$\Delta t = \frac{r}{v} \cdot \frac{1}{(C/I_{\max} - C/I_{\min})} \quad (1)$$

In this case the user speed, v , is 100km/h, while the clock period for the medium speed users is twice this value and that of the slow moving users is twenty times the period of the fast users.

This assumes that the fastest change in a user's mean C/I is caused by moving radially towards or away from

the base station, so that behaviour including going indoors or into a tunnel is not modelled here. Modelling the mobility in this way enables the cell characteristics to be captured in a very flexible and simple way. Moreover, the shape of the pdfs and the way in which the median is varied can be linked directly to measured data to improve the accuracy of this model.

RLC MODEL

The pdf of the C/I is converted to a cumulative distribution function (cdf), which, in turn, is used to estimate the best Coding Scheme (CS) to use in an implementation of LA. Since the pdf that will be used for the simulation of the channel is also used in the LA section, this is equivalent to having a perfect channel predictor for LA. The efficacy of LA as a link quality control technique is, therefore, removed from this investigation. The Block Erasure Rate (BLER) expected for each user is then calculated from the cdf for the selected CS. This BLER is then passed to the MAC model where the Automatic Repeat reQuest (ARQ) mechanism is implemented.

MAC MODEL

The radio resource allocation algorithm used here is a WRR algorithm where the weight assigned to a user is dependent on their QoS class. User's queue's are serviced in a round robin manner and are allocated a number of channels proportional to their assigned weight. Other weighting allocations can be used [12] and other algorithms have also been implemented [11]. The ARQ system is integrated with the scheduling algorithm to yield a priority based scheme where blocks that are to be retransmitted are serviced before other blocks.

This environment can be used to demonstrate the effect of the MAC protocols on their own, with all other aspects of the system being modelled so as to have no dynamic effect. This means that results obtained are due to changes in the MAC layer and uncertainties about the effect of TCP or LLC flow control are removed from the results.

RESULTS

As a first demonstration of the use of this simulator model, a rural cell with radius 25km is considered with the cohort of 25users as follows:-

- 6 users streaming
- 6 users browsing Internet
- 13 users background traffic

These users are simulated with different traffic and behaviour characteristics. The file sizes are:-

- streaming – 1kbit
- interactive – 10kbits
- background traffic – 100kbits

	Streaming			Interactive			Background		
	Delay (ms)	ND	UPBR (kbps)	Delay (ms)	ND	UPBR (kbps)	Delay (ms)	ND	UPBR (kbps)
a	63.6	1	15.7	1046	16.4	9.6	19044	299	5.3
b	44.2	1	22.6	633	14.3	15.8	21927	496	4.6
c	40.2	1	24.9	1032	25.7	9.7	19172	477	5.2

Table 2: Average user delays, normalised delay (ND) and average user-perceived bit-rate (UPBR) for “Case 1” with three different configurations of weighting factors (a, b and c)

	Streaming			Interactive			Background		
	Delay (ms)	ND	UPBR (kbps)	Delay (ms)	ND	UPBR (kbps)	Delay (ms)	ND	UPBR (kbps)
a	98.7	1	10.1	1758	17.8	5.7	33136	336	3.0
b	70.3	1	14.2	1146	16.3	8.7	29609	421	3.4
c	62.8	1	15.9	1742	27.7	5.7	33140	528	3.0

Table 3: Average user delays, normalised delay (ND) and average user-perceived bit-rate (UPBR) for “Case 2” with three different configurations of weighting factors (a, b and c)

The streaming users’ traffic is assumed to be a continuous generation of these packets while the other users are assumed to not commence downloading a file until the previous one has been fully received. The performance metric under investigation here is the time taken to receive each packet as it is assumed that the user will perceive the system delay as the delay incurred in the delivery of each packet.

Two test cases are used:-

1. No voice traffic, Mean number of GPRS timeslots=8
2. Poisson distributed voice traffic, Mean number of GPRS timeslots=3.5

Three sets of WRR weights are considered:-

	a	b	c
Ws	8	8	4
Wi	4	4	2
Wb	2	1	1

Table 1: WRR weights for each user-type group

As a final dimension to the simulations, several mobility cases are considered and the results averaged across all mobility groups within each user-type group.

These results indicate that a smaller delay can be achieved in delivering a small real-time packet, such as might be used for Voice over IP (VoIP) applications, compared to other applications. To enable comparison between user types, the delay is normalised to the delay figure for the streaming users within the same group of tests. The user perceived bit rate is also calculated as shown in Equation (1).

$$Perceived_bit_rate = \frac{packet_length}{delay} \quad (1)$$

To compare these results to a theoretical prediction, the Weighted Fair Queuing (WFQ) seems appropriate. This would predict that the delay experienced by a particular user should be proportional to the ratio of the sum of all the weights divided by the weight for that user. Since the users in this case use fixed length packets or files, then the delay can be simply considered as shown in Equation (2):-

$$Delay \propto packet_length \cdot \frac{\sum Weights}{user_weight} \quad (2)$$

Inserting the values used here yields:-

	Streaming	Interactive	Background
a	1	20	400
b	1	20	800
c	1	20	400

Table 4: Predicted user delays normalised to the streaming case

Thus, the expected delays for configuration a and c are the same as they are effectively the same. The results in tables 2 and 3, however, show that the small packet size used in the streaming case has an effect. In these cases, the shorter cycle time of configuration c can yield a substantial decrease in the delay and hence increases in the user-perceived bit rate.

When compared to the theoretical predictions, it is clear that, although the results are of the correct order of magnitude, the simple WFQ model is not sufficient in this case. The main cause of discrepancy is thought to be the influence of the LA mechanism that will change the coding scheme used depending on the user’s C/I. The maximum throughput at any given time is therefore variable and the average throughput will be dependent on the type of cell in which the user is located.

These results clearly show that the WRR algorithm used is effective in delivering QoS differentiation amongst a range of user cohorts in a range of cells.

CONCLUSIONS

The simulation environment discussed here has been used to demonstrate the effects of MAC/RLC protocols in GPRS. User cohort definition and cell definition are very flexible and can yield a wide range of usage scenarios.

Results have been presented that demonstrate that QoS differentiation can be provided in a range of different cell types, yielding an acceptable difference in the user experience for those with the most stringent QoS requirements. It was also shown that the background traffic users would bear the brunt of service degradations that are required in cases of heavy load or unfavourable propagation scenarios.

Another interesting result is that, although the user's mobility will affect the changes in the link quality and therefore the instantaneous throughput, it seems to have no effect on the ability to differentiate between users.

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