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Simulation model for performance evaluation of Internet applications using GPRS radio interface

J. Rendón, F. Casadevall, L. García and R. Jimenez

Since Internet applications such as WWW, FTP and e-mail will work over the GPRS mobile system, it is important to establish how they perform using the GPRS radio interface. Results are presented that show the usefulness of the GPRS radio interface for Internet applications.

Introduction: The general packet radio service (GPRS) system is a wireless packet switching system designed to work over GSM (global system for mobile communications). Whereas GSM is basically a wireless circuit switching network, capable of transmitting voice, GPRS offers easy access to data services. This feature enables easy adaptation to the bursty traffic generated by Internet applications such as e-mail, WWW and FTP. GPRS uses the GSM infrastructure, but adapts the radio interface and adds two new nodes: the serving GPRS support node (SGSN) and the gateway GPRS support node (GGSN).

To analyse the GPRS performance, we can simulate the behaviour of the SGSN and GGSN. The problem arises when we try to simulate the radio interface, because this type of simulation is slow and, as a result, it is difficult to simulate an end-to-end Internet connection through GPRS with the radio interface simulation running. In this Letter, we propose a simple GPRS radio interface model that considers all the different parameters relevant to the characterisation of the physical and link layers, for instance the number of users, the channel coding, the C/I ratio, the number of PDCHs, the type of service offered and the transmission direction. Unlike the results obtained in previous GPRS simulations [1, 2], in which the GPRS radio interface is analysed mainly in terms of the throughput, the radio link results obtained in this Letter, PER and the cumulative distribution function of the packet delay, allow accurate and rapid simulation of an FTP Internet connection over a GPRS network.

Simulator structure: The GPRS radio link simulation model was created with the event-driven Cadence Bones Designer simulator. The LLC layer was simulated operating in unacknowledged mode. The RLC/MAC layer was implemented in detail following the ETSI technical specifications [3]. The MAC layer used the slotted Aloha access mechanism. A round robin scheduling method without priorities was assumed. The RLC layer used a selective-repeat ARQ mechanism. The physical layer was implemented using results that appear in related pre-simulations [4].

Three types of bursty traffic were considered: e-mail, WWW and FTP. We distributed the type of users in the following form: 50% e-mail, 30% WWW and 20% FTP. The traffic generated for e-mail was similar to the Funet traffic model, whereas the traffic generated for the WWW and FTP services was modelled using the ETSI model [5].

Using the aforementioned simulator, a statistical model of the GPRS radio interface was obtained by varying the following parameters: number of PDCHs (1, 2 or 4), C/I relation (2 per coding scheme, one appropriate and the other inappropriate), coding scheme (4) and number of mobile stations (10 or 15). Although three types of traffic were generated, we considered the results corresponding to the FTP traffic. For each combination of input parameters, we obtained two output values: the PER and the cumulative distribution function of the LLC frames delays. In particular, we assumed for the analysis of the results that an LLC frame was equivalent to a packet.

Simulation results: The following results show the GPRS radio layer behaviour for an FTP connection. We believe that these types of result are useful for easy simulation of the GPRS radio layer. Fig. 1 shows a downlink simulation with 2 PDCHs, a C/I relation of 12dB, CS-2 and (10-15) mobile hosts. The x-axis of the graph uses the block period as a time metric. Each block period is equivalent to 18.46ms. As it is foreseeable, the PER and delay increase as the number of MHs increases. The delay values for this simulation are notable. For 10 MHs the maximum delay is around 750 block periods, which is around 13.84s. The high delay value that appears in this result is due to the low number of PDCHs present in the system (2) and the inappropriate C/I relation for this coding scheme. As can also be seen in Fig. 1, the PER value for the transmission with 15 MHs is much larger than the PER with 10 MHs.

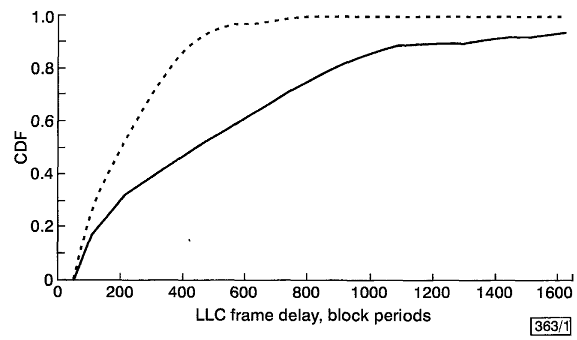

Fig. 1 *2 PDCHs, 12dB, CS2 and (10-15) MHs*
- - - - 10 MHs, PER = 3.52%
——— 15 MHs, PER = 9.76%

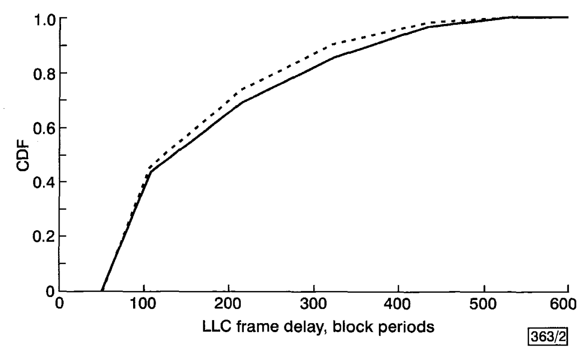

Fig. 2 *2 PDCHs, 16dB, CS2 and (10-15) MHs*
- - - - 10 MHs, PER = 1.41%
——— 15 MHs, PER = 2.36%

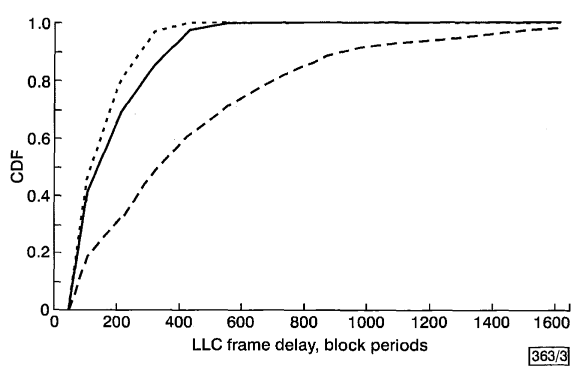

Fig. 3 *(1, 2, 4) PDCHs, 8dB, CS1 and 10 MHs*
- - - - - 1 PDCH, PER = 2.51%
——— 2 PDCHs, PER = 2.03%
– – – – 4 PDCHs, PER = 1.82%

Fig. 2 shows the results for the same simulation when we use a C/I relation of 16dB. The importance of the C/I value for each coding scheme was mentioned in previous studies [2]. Unlike the results in Fig. 1, in which there is a big difference in the system when it has 10 or 15 MHs, there is not so much variation when the system uses an appropriate value of C/I for CS-2. Every code has its own C/I values with which it reaches its maximum throughput. It can be seen in Fig. 2 that both delays and PERs are similar. This means that the system, in this case, is capable of supporting more MHs without so much performance variation.

Fig. 3 shows the influence of the number of PDCHs in the GPRS system. In all cases, the PER values are small (< 3%). There is no great difference between the delay with 2 and 4 PDCHs. This means that, for this simulation, it is not necessary to add more PDCHs in order to obtain a significant performance advantage.

The results presented in this Letter can be used for simulating the impact of GPRS performance on Internet applications packets sent through the air interface. Given the statistical results shown in the previous Figures, the following procedure is used for simulating the effects of the radio channel in a particular IP packet: first, using the PER value, it is determined whether the LLC frame is correctly received or discarded. Then, if the LLC frame is selected as correctly received, its block delay, evaluated according to the CDF statistic, is determined.

Conclusions: We have presented a simulation model for the GPRS radio interface which gives useful types of results in order to simulate the transmission over a GPRS network of LLC packets for FTP. Using these types of results, it is possible to understand the importance of the parameters which have more influence on the PER and packet delay in the GPRS radio interface and model it properly.

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Comparison of Si and SiC diodes during operation in three-phase inverter driving ac induction motor

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4H-SiC JBS diodes have been used in an inverter circuit, driving an actual three-phase ac induction motor at power levels up to 2.2 HP. Switching waveforms were measured and compared between inverters based on Si PiN diodes and 4H-SiC MPS diodes. The results clearly show a significant reduction in power dissipation, in both the diode and the IGBT switch, when SiC diodes replace the Si diodes. The reduction is most evident at the higher temperatures.

Introduction: Recent comparative studies of Si and 4H-SiC diodes based on a Schottky barrier have clearly demonstrated the advantages of SiC with respect to recovery and high temperature operation. Most such measurements, however, were conducted using test circuits specifically designed to characterise diode recovery (at various temperatures), or in inverter circuits without an actual motor load [1, 2]. In contrast, this Letter presents data on the comparison of the two diodes while operating in a full bridge inverter, driving an actual three-phase ac induction motor. The full bridge inverter, which may be considered a superposition of three single-phase half-bridge configurations, was operated under microprocessor control using square wave modulation. Although operating efficiency is lower with square wave modulation, compared to pulsewidth modulation, the inverter circuit, as well as the data acquisition, are greatly simplified due to the elementary nature of the square wave modulation.

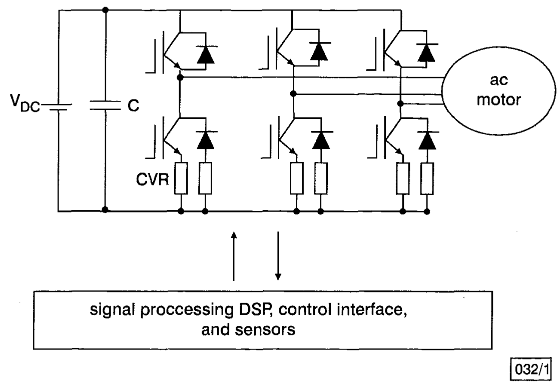

Fig. 1 *Schematic circuit diagram of full-bridge inverter and sensing circuitry for three phase ac induction motor*

Current viewing resistors (CVRs) are present in upper legs as well

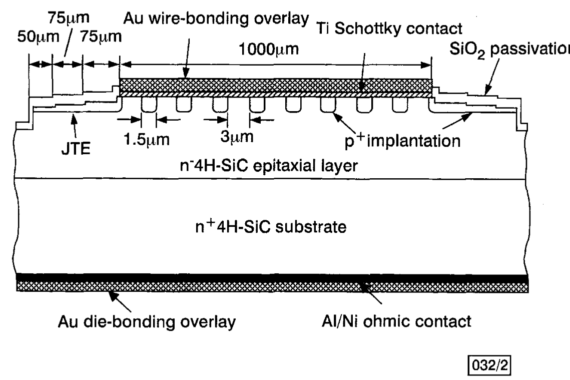

Fig. 2 *Cross-sectional view of SiC JBS diode*

Approach and experimental results: The inverter layout was designed with separate Si IGBTs and freewheeling Si or SiC diodes, each with an individual heatsink for individual temperature control. Provision was made for inserting current viewing resistors (CVRs) for measuring individual component current waveforms. Voltage waveforms were measured with differential probes. Fig. 1 shows a schematic circuit diagram of the full-bridge inverter circuit used to drive the three-phase motor. Gate drive signals were optically isolated from the power components. The inverter load was a 1750 RPM induction motor loaded with a centrifugal blower and variable ratio pulley-belt coupling. Measuring the blower speed and approximating shaft horsepower from the blower curves confirmed the operating conditions. The inverter was operated up to 2.2 HP, using either all silicon components or hybrid Si IGBTs plus SiC diodes (the presented waveforms were taken at 0.8 HP to reduce the noise level).

For comparative measurements, one of the Si TO-247 diodes was replaced by a 4H-SiC diode with cross-sectional view shown in Fig. 2. The SiC diode was a JBS (junction barrier Schottky) type. The diode exhibits the usual low forward drop characteristic of the Schottky, while in the reverse direction the diode resembles a reverse biased *p-n* junction. Owing to the relatively large band-