areas containing only noise, and that it almost completely preserves most of the original resolution.

Conclusions: A new technique for SAR interferometric noise reduction, based on the wavelet transform, has been presented. The technique is highly robust in the presence of noise, avoiding the loss of resolution, while preserving the original fringes. The proposed technique provides better results than those obtained using a multilook filter.

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Analysis of Snoop TCP protocol in GPRS system

J. Rendón, F. Casadevall, D. Serarols and J.L. Faner

The General Packet Radio Service system provides an easy adaptation to bursty traffic generated by Internet applications, e.g. e-mail, WWW and FTP. These applications use TCP as the transport protocol and therefore good interaction is necessary between the TCP and GPRS protocols. The performance of the Snoop TCP protocol in a GPRS network is analysed.

Introduction: The General Packet Radio Service (GPRS) is the packet switching data service for GSM. It provides an easy adaptation to the bursty traffic generated by Internet applications, e.g. e-mail, WWW and FTP. All three of these applications use transmission control protocol (TCP) as the transport protocol. TCP is a protocol initially designed for working in fixed networks such as the Internet, where the main problem is congestion. The problems in wireless networks vary: bursty packet losses, high packet delays depending on the wireless network, variable throughput, etc. There have been some proposals which enhance the TCP performance in wireless networks. One of the most well known is the Snoop TCP protocol.

The Snoop TCP protocol [1] consists of having an agent installed at the base station which makes local retransmissions on the wireless paths depending on the type of acknowledgments (ACKs) received from the mobile host (MH) and on local timers. Snoop hides the TCP sender in the fixed host (FH) from losses in the wireless link. When the Snoop agent detects a loss, it retransmits the lost TCP segment to the MH, waits for the corresponding ACK and sends it to the FH before the FH realises there has been a packet loss. Snoop TCP is a protocol which has been proven to work well in a wireless LAN environment [2], but its performance in a mobile cellular network such as GPRS has not been analysed. In this Letter we analyse, with the use of a simulator, the behaviour of the Snoop TCP protocol under realistic conditions in GPRS.

Simulator structure: The GPRS radio link simulation model has been created with the event driven simulator Cadence Bones Designer. We simulate the FTP transmission of a 512Kbytes data file from an FTP server attached to the Internet to a mobile host connected to the GPRS network.

We have simulated the behaviour of all the main nodes that exist in the GPRS architecture. An FTP server, with the corresponding TCP and IP layers, models the fixed host. TCP-Reno version is assumed. The Internet cloud is modelled by means of a loss packet probability and a delay. The delay is statistically characterised as a Gaussian random variable. The GPRS backbone is characterised as follows: the gateway GPRS support node (GGSN) is represented with a router, whereas the serving GPRS support node (SGSN) is modelled as a fixed delay that represents the node process delay. The SGSN node contains the Snoop agent. The GGSN-SGSN and SGSN-BSS (base station subsystem) links are also modelled with fixed delays, which take into account the limited link capacities, i.e. 2Mbit/s and 64Kbit/s, respectively.

In the radio link, a transmission at the logical link control (LLC) layer has been simulated. The LLC layer has been simulated operating in unacknowledged mode. The RLC/MAC layer has been implemented in detail. The MAC layer uses the slotted Aloha access mechanism. A round robin scheduling method without priorities is assumed. The RLC layer uses a selective-repeat ARQ mechanism. In the GPRS radio interface we can vary the number of users, the coding scheme, the channel conditions (C/I), the number of PDCHs, the type of service offered (WWW, FTP or e-mail), and the transmission direction (uplink/downlink). Three types of bursty traffic have been considered in the radio interface, i.e. e-mail, WWW and FTP. We have distributed the type of users in the following form: 50% e-mail, 30% WWW and 20% FTP.

Table 1: Comparison of throughput and retransmissions

	Without Snoop	With Snoop	
Retransmissions	FH	FH	Snoop
	%	%	%
Data-driven	3.0	1.3	12.5
Timer-driven	10.5	21.4	13.1
Total retransmissions	13.5	22.7	25.6
Throughput	1.373Kbit/s	1.053Kbit/s	

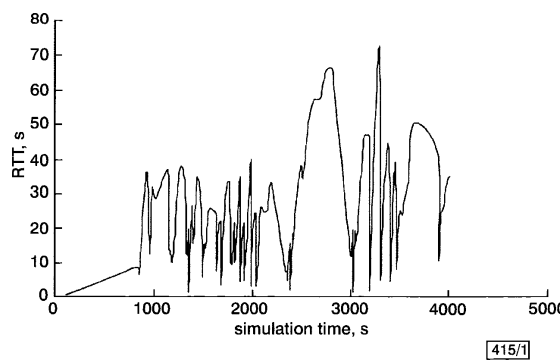

Fig. 1 *RTT (FH), TCP with Snoop*

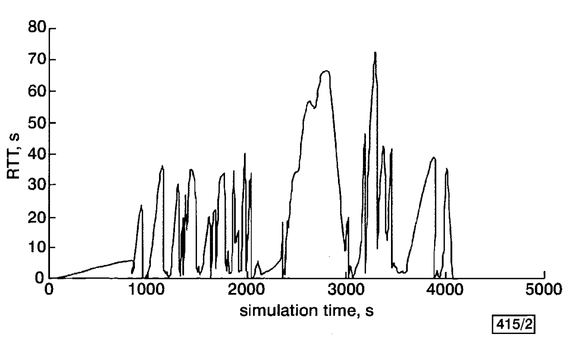

Fig. 2 *RTT (Snoop agent), TCP with Snoop*

Simulation results: We have considered for this analysis the following radio channel parameters: 2 PDCHs, a C/I relation of 20dB, CS-3 and 10 MHs. The high number of MHs present in the system generates a very busy channel with high and very variable delay values for an FTP packet transmission. Table 1 shows a comparison of the throughputs and retransmissions types in two transmissions, with and without the Snoop agent. The throughput with the Snoop protocol, 1.053Kbit/s, is a little less than the one without it, i.e. 1.373Kbit/s. Therefore there is no advantage in using the Snoop agent. To identify the reasons for this behaviour, Figs. 1 and 2 show the evolution of the round trip time (RTT) in the FH and in the Snoop agent calculated for this simulation. First, we observe that the RTT value, and consequently the retransmission timeout (RTO) value, can vary significantly. Secondly, both RTT values are similar in magnitude.

To work well, time is required for the Snoop agent to realise that a packet is lost, retransmit it and obtain the corresponding ACK. In this case the packet transmission through the GPRS radio interface takes several seconds, whereas the transmission through the Internet takes ~100ms. We observe that high delay values of the GPRS radio interface do not permit the Snoop agent opportunity to retransmit the lost packet and obtain its ACK, thus both the FH RTO and the Snoop RTO trigger more or less at the same time, thereby reducing the congestion window at the FH TCP sender.

For transmission without Snoop, Table 1 shows a high value for timer-driven retransmissions (10.5%), which arises due to inaccurate calculation of the RTO value. Table 1 also shows, for with Snoop, a high percentage of timer-driven retransmissions in the FH (21.4%). The number of data-driven retransmissions in the FH is low (1.3%). This is because the Snoop agent does not send the duplicate ACKs to the FH. If we consider that the PER of the radio channel for this case is only 0.7%, we can conclude that 25.6% of retransmissions with the Snoop agent is a very high percentage. In particular, 12.5% are data-driven retransmissions and 13.1% correspond to timer-driven retransmissions. Certainly, in the ideal case, without considering out of order and lost packets in the Internet path, only 0.7% of the packets should be retransmitted by the Snoop agent.

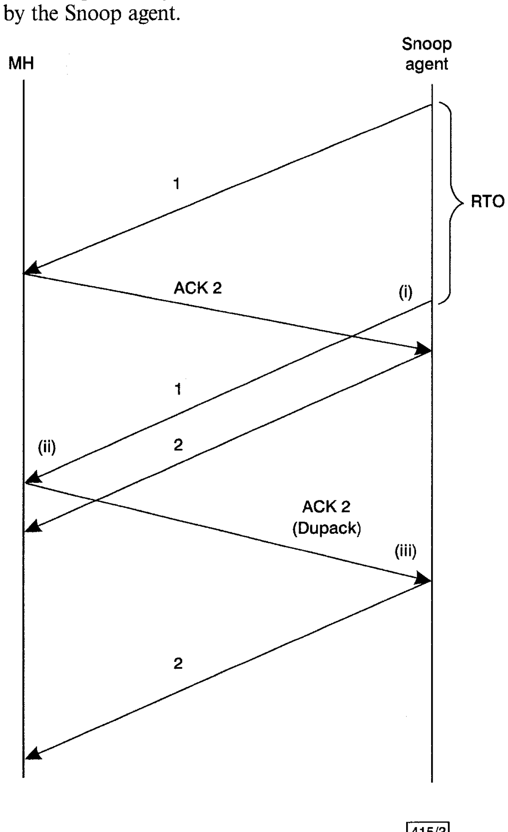

Fig. 3 *Example of Snoop behaviour*

We now explain what usually happens with the Snoop protocol in the GPRS system, using Fig. 3 as an example. (i) The Snoop agent sends segment 1 and sets its RTO to a value that depends on the RTT in the wireless part. Owing to the highly variable delays that exist in the GPRS radio channel, this RTO value is inaccurate. The RTO triggers before the corresponding ACK2 arrives at the Snoop agent. In this case we are retransmitting a packet that is not lost. (ii) This retransmitted segment (i) arrives at the MH and the TCP receiver sends an ACK2 again (a Dupack). (iii) This Dupack 2 arrives at the Snoop agent, which interprets that segment 2 was lost and that it needs to be retransmitted. The original segment 2 had been transmitted previously.

We can observe that in this case an unnecessary retransmission per timeout (i) causes an unnecessary retransmission per Dupack (iii). The timer-driven retransmissions are one of the main causes of the high data-driven retransmission percentage (13%) in the Snoop agent.

Conclusions: We have demonstrated that the Snoop agent does not work well in a busy GPRS network for two reasons. First, the high delay values of the GPRS radio link in comparison with the delays in the fixed network make the Snoop agent and the FH timers trigger at the same time. Secondly, the highly variable delays in the GPRS radio link do not allow a fair calculation of the RTO value in the Snoop agent.

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Generalised Fourier transform-domain technique for narrowband interference suppression in CDMA communication systems

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A generalisation of Fourier transform-domain technique for narrowband interference suppression in CDMA communication systems is introduced. In this technique, first the sum of a number of sinusoids each modulated by a polynomial is chosen as a model for the narrowband interference. Then, by fitting the received signal on the proposed model, an estimate of the narrowband interference signal is obtained, and its effect is subtracted from the received signal.

Introduction: Direct-sequence CDMA (DS-CDMA) is one of the most promising multiplexing techniques for cellular communication systems [1]. This technique enables the bandwidth to be shared with narrowband communication systems without undue degradation of either system's performance. The inherent ability of the DS-CDMA system can be further improved by using a narrowband interference suppressor prior to correlation [2, 3]. In this Letter, we propose to use a generalisation of the well known Fourier transform-domain technique [3] for narrowband interference rejection.

Owing to the resistance of DS-CDMA systems to narrowband interference, an extra processing step to reject narrowband interference is necessary only when there is very strong narrowband