SNOOP TCP PERFORMANCE OVER GPRS

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Abstract: The General Packet Radio Service (GPRS) system developed to work with the existing GSM infrastructure is basically a packet switching system via radio that will provide an easy adaptation to bursty traffic generated by Internet applications like e-mail, WWW and FTP. These applications use as Transport Protocol TCP and therefore a good interaction is necessary between TCP and the GPRS protocols. TCP is a protocol initially designed to work in fixed networks, and in order to solve its problems in wireless networks, some proposals have been made in the last years. One of the most importants proposals is the Snoop TCP protocol, which was initially designed to work in a wireless LAN environment. In this paper we analyze the performance of the Snoop TCP protocol in a GPRS network.

I. INTRODUCTION

General Packet Radio Service is the packet switched data service for GSM. GPRS was standardized by the European Telecommunications Standards Institute (ETSI) and uses the GSM infrastructure. GPRS provides an easy adaptation to the bursty traffic generated by Internet applications like e-mail, WWW and FTP. All three of these applications use as Transport Protocol TCP (Transmission Control Protocol). TCP is a protocol that was developed for fixed networks like Internet. Then it is important to understand the behaviour of TCP in GPRS. There has been only one study which describes the performance of TCP in GPRS [1], but it takes only a single user into consideration.

For some years the behaviour of TCP in wireless networks has been analyzed and there are some proposals which improve the TCP performance in these types of networks. One of the most well-known proposals is the Snoop TCP protocol [2], which was initially developed for a wireless LAN environment. The Snoop TCP protocol has still not been analized in a GPRS network. In order to analyze the behaviour of the Snoop TCP protocol under realistic conditions in GPRS we have built a simulator. This simulator allows us to change the main GPRS system parameters and observe their influence in the Snoop TCP protocol.

The rest of this paper is organized as follows: Section II presents a brief description of the GPRS system. In Section III the main TCP proposals for wireless networks are described. Section IV describes the simulator structure used for the study presented in the paper. In Section V simulation results are given and finally, conclusions are derived in section VI.

II. GENERAL PACKET RADIO SERVICE

In order to work with the existing GSM infrastructure GPRS adds two new nodes: the Serving GPRS Support Node (SGSN) and the Gateway GPRS Support Node (GGSN). The SGSN is connected to the Base Station Subsystem (BSS) through the Gb interface. The Gn interface connects the SGSN and the GGSN, which in turn is connected to a Packet Data Network (PDN) (e.g. Internet) through the Gi interface. The Mobile Station (MS), or Mobile Host (MH), is connected to the BSS through the radio interface Um. Figure 1 shows the protocols stack of the basic nodes that take part in a packet transmission in the GPRS network [3].

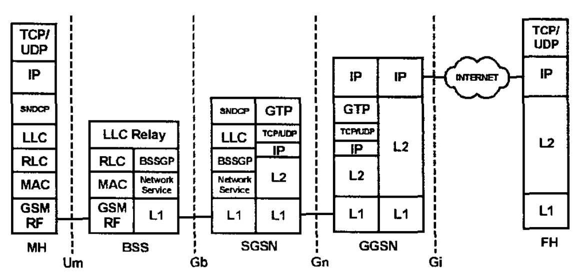

Figure 1: The GPRS network with access to Internet.

Depending on the application the TCP or the UDP protocol is used as Transport Protocol for the end-to-end connection from a Mobile Host in the GPRS network to a Fixed Host (FH) in Internet. The GPRS MH uses IP for its connection to Internet. The GPRS Tunnel Protocol (GTP) uses a tunneling mechanism for sending the upper IP datagrams between the SGSN and the GGSN nodes in the GPRS backbone. The IP and TCP/UDP protocols are also used in the GPRS backbone.

The Subnetwork Dependent Convergence Protocol (SNDCP) is used between the SGSN and the MH. It maps network-level characteristics onto the characteristics of the LLC layer. The Logical Link Control (LLC) protocol provides a highly reliable ciphered logical link between the MH and the SGSN. It provides flow control, in-order delivery, sequence control, detection of transmission errors and retransmissions. The Base Station System GPRS Protocol (BSSGP) conveys routing and QoS-related information between the BSS and the SGSN. The Network Service Protocol is based on the Frame Relay Protocol. The Radio Link Control (RLC) protocol establishes a reliable link between the MH and the BSS. Its functionality includes the segmentation and reassembly of LLC frames into Radio Link Control (RLC) data blocks and retransmission of corrupted and lost blocks using an Automatic-Repeat-reQuest (ARQ) mechanism. The Medium Access Control (MAC) protocol controls the access signalling procedures for the radio channel (request and grant). The GSM RF layer is similar to the physical layer used in GSM.

III. TCP IN WIRELESS NETWORKS

TCP is a protocol initially designed for working in fixed networks, where the main problem is the congestion. Therefore it has mechanisms to avoid sending useless TCP segments into the network when a congestion situation is detected. 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. They can be divided into the following categories:

End to end mechanisms: These proposals don't make changes to intermediate nodes and can modify the TCP protocol in the FH [4] and sometimes also in the MH. The Explicit Loss Notification mechanism for example [5] differentiates the congestion problem in the fixed network from other types of packet losses.

The following three categories make changes in intermediate nodes:

Link layer proposals [6]: With these types of proposals the Base Station makes retransmissions at the radio link layer. They depend on the type of radio link protocols used for each wireless network.

Split protocol [7]: It makes two different TCP connections, one from the FH to the Base Station, and the other from the Base Station to the MH. It breaks the end-to-end TCP semantic.

Snoop TCP protocol: It consists in 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 MH and on local timers. Snoop hides the TCP sender in the 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 realizes there has been a packet loss.

Snoop TCP is a protocol which has been proven to work well in a wireless LAN environment [5]. In comparison with the Split protocol, it doesn't change the end-to-end TCP semantic; it also makes intelligent retransmissions at the link layer because it is TCP aware, and that is the main difference with Link Layer proposals. Snoop doesn't modify the TCP version at the FH nor at the MH. For all these reasons we consider an analysis necessary of the Snoop Protocol in a GPRS network, which has different characteristics than a wireless LAN network.

IV. SIMULATOR STRUCTURE

The GPRS radio link simulation model has been created with the event driven simulator Cadence Bones Designer. This software supports three programming modes: a block oriented hierarchical system modeling approach, a Finite State Machine (FSM) model and the C++ programming language.

We simulate the FTP transmission of a 512 Kbytes data file from a FTP server attached to the Internet to a Mobile Host connected to the GPRS network.

Figure 2 shows the top-level of the simulator. We have simulated the behaviour of all the main nodes that exist in the GPRS architecture. A FTP server, with the corresponding TCP and IP layers, models the Fixed Host. TCP-Reno version is assumed. The Internet cloud is modeled by means of a loss packet probability and a delay. The delay is statistically characterized as a gaussian random variable. The GGSN is represented with a router, whereas the SGSN is modeled as a fixed delay that represents the node process delay. The SGSN node contains the Snoop agent. The GGSN-SGSN and SGSN-BSS links are also modeled with fixed delays, which take into account the limited link capacities, i.e. 2Mbps and 64 Kbps respectively.

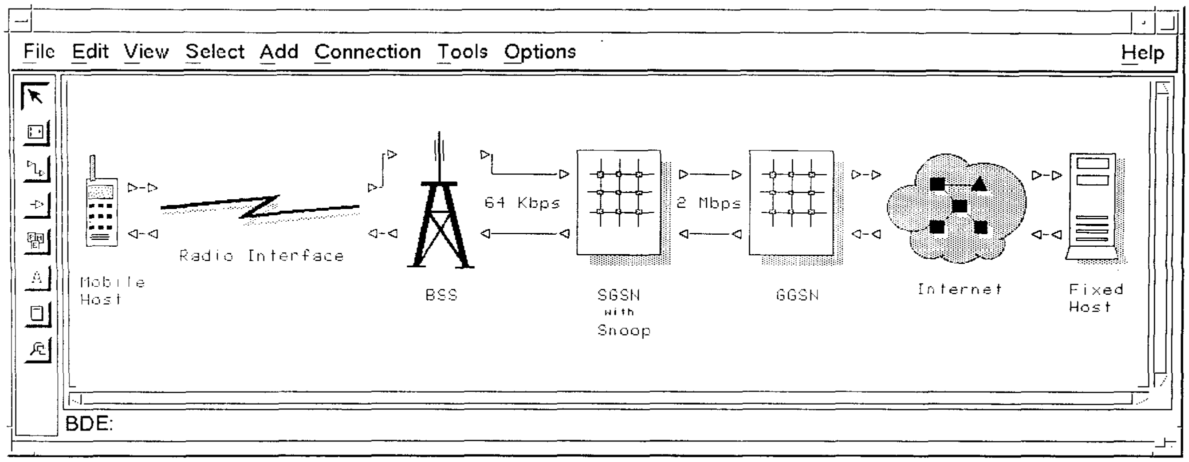

Figure 2: The GPRS Simulation Tool.

In the radio link a transmission at the Logical Link Control (LLC) layer has been simulated. The SNDCP protocol is not implemented. 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 simulator 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). Then for each assumed set of parameters the LLC Packet Error Rate (PER) and the cumulative distribution function of the LLC frame delays are obtained. In particular, we consider for the analysis of the GPRS radio channel results that a LLC frame is equivalent to a packet. A more detailed description of the GPRS Radio Channel Simulator can be found in [8].

Three types of bursty traffic have been considered in the paper, namely: e-mail, WWW and FTP. We have distributed the type of users in the following form: 50% e-mail, 30% WWW and 20% FTP. The traffic generated for e-mail is similar to the Funet traffic model, whereas the traffic generated for WWW and FTP services has been modeled using the ETSI model [9].

Table 1 summarizes the most important simulation parameters.

Parameter	Value
Max. number of retransmissions per frame	10
Max. time waiting for an AGN (access grant notification)	0.1 sec
Max. time waiting for random access attempts per frame	0.3 sec
Max. Time waiting for an acknowledgment	0.1 sec
E-Mail generation frequency	5 messag./hour
WWW pages generation frequency	3 bursts/hour
Number of WWW pages per burst	5 pages/burst
Time between WWW pages	412 sec
Number of frames per WWW page	25 frames/page
Time between WWW frames	0.125 sec
FTP burst generation frequency	6 bursts/hour
PRACH blocks	0; 6
Number of Mobile Stations	10-15
Number of PDCHs	1, 2 or 4
TCP MSS	431 bytes
Mean Internet Delay	100 ms.
Simulation time	100 - 120 min

Table 1: Simulation Parameters.

V. SIMULATION RESULTS

In this section we will explain how the Snoop TCP protocol works in GPRS. We have taken for this analysis the following radio channel parameters: 4 PDCH, a C/I relation of 24, CS-4 and 15 MHs. Even though we are working with 4 PDCHs and a good C/I value for CS4, the high number of MHs present in the system generates a very busy channel with high and very variable delay values for a FTP packet transmission.

Figures 3 and 4 show the sequence number evolution of a TCP transmission with and without Snoop.

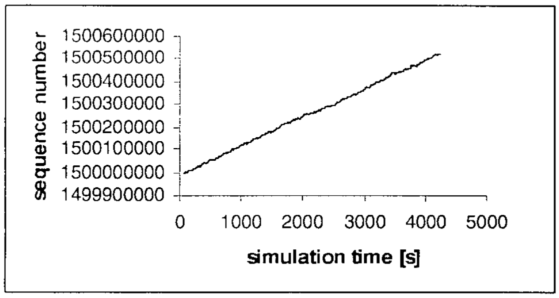

Figure 3: Sequence Number (FH), TCP without Snoop

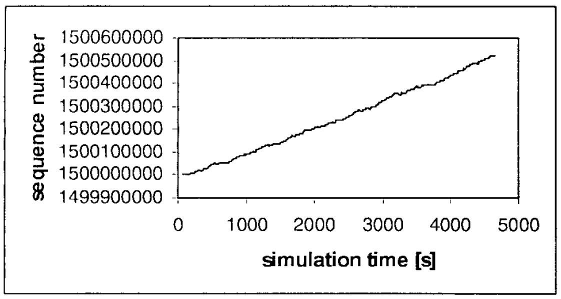

Figure 4: Sequence Number (FH), TCP with Snoop.

Comparing both figures, we can see that the sequence number evolution of the transmission with and without Snoop is very similar. That is, there is not a significant advantage for using the Snoop agent. Then, to identify the reasons for this behaviour, the figures 5 and 6 show the evolution of the Round Trip Time (RTT) in the FH and in the Snoop agent calculated for the simulation with Snoop. First of all we observe that the RTT value can vary significantly. Second, both RTT values are similar in magnitude. Then , taking into account that the Retransmission TimeOut (RTO) value depends directly from the last RTT value obtained and that it indicates the TCP module and the Snoop agent when to do a retransmission, we come to the conclusion that the RTO values in the FH and in the Snoop agent vary permanently and that both timers trigger more or less at the same time.

In order to work well the Snoop agent needs time to realize that a packet is lost, retransmit it and get the corresponding ACK. In this case the packet transmission through the GPRS radio interface takes several seconds, whereas the transmission through Internet takes approximately 100ms. We observe that high delay values of the GPRS radio interface don't give the Snoop agent the chance to retransmit the lost packet and get its ACK, and, as a result, the RTO FH triggers at the same time, reducing then the congestion window at the FH TCP sender.

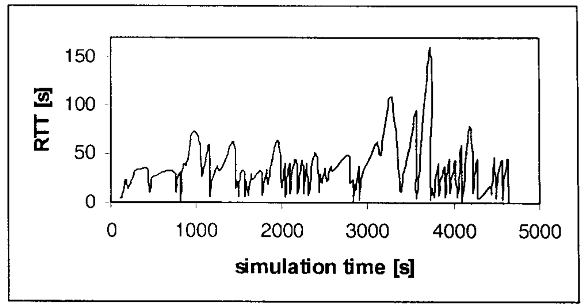

Figure 5: RTT (FH), TCP with Snoop.

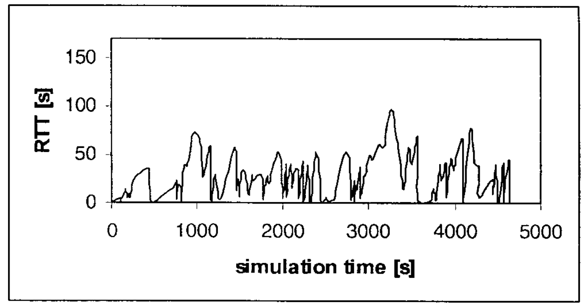

Figure 6: RTT (Snoop agent), TCP with Snoop.

Table 2 shows a comparison of the throughput and of the retransmissions type in both cases. Data-driven retransmissions originate when the TCP sender or the Snoop agent gets duplicate acknowledgments (DUPACKs) and depending on the number of DUPACKs received it decides to retransmit a packet, whereas time-driven retransmissions are done when a timer triggers.

	Without Snoop	With Snoop	
Retransmissions	FH (%)	FH (%)	Snoop (%)
Data-driven	3,4	1,1	13
Timer-driven	13,1	8,9	4,2
Total retx	16,5	10	17,2
Throughput	1,012 Kbps	0,925 Kbps	

Table 2: Comparison of throughput and retransmissions with and without Snoop.

In the case of the transmission without Snoop we appreciate a high value of timer-driven retransmissions (13,1%), motivated by the inaccurate calculation of the RTO value. We observe with the Snoop agent a high percentage of timer-driven retransmissions in the FH (8.9%). The number of data-driven retransmissions in the FH is low (1,1%), because the Snoop agent doesn't send the duplicate ACKs to the FH.

If we consider that the PER of the radio channel for this case is only 2,3%, we come to the conclusion that 17,2% of retransmissions at the Snoop agent is a very high percentage. In particular, 13% are data-driven retransmissions and 4,2% correspond to timer-driven retransmissions. Certainly, in the ideal case, without considering out of order and lost packets in the Internet path, only 2,3% of the packets should be retransmitted by the Snoop agent.

The throughput with the Snoop protocol, 0,925 Kbps, is a little bit less than the one without it, 1,012 Kbps. Next, using Figure 7 as an example, we will explain what happens usually with the Snoop protocol in the GPRS system.

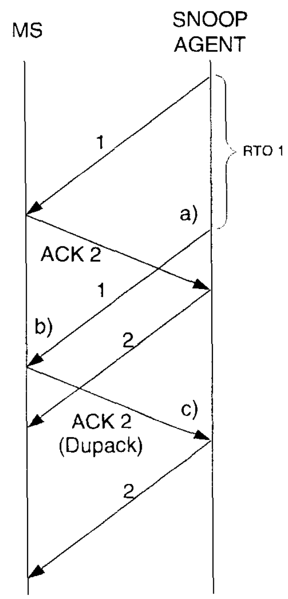

Figure 7: Example of Snoop behaviour.

a) The Snoop Agent sends the segment 1 and sets its RTO value to a value that depends on the RTT in the wireless part. Due 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.

b) This retransmitted segment (1) arrives at the MS and the TCP receiver sends a ACK2 again (a Dupack)

c) This Dupack 2 arrives at the Snoop agent, which interprets that the segment 2 was lost and that it needs to be retransmitted. The original segment 2 had been previously transmitted.

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

VI. CONCLUSIONS

In summary, we have demonstrated that the Snoop agent doesn't 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. Second, the highly variable delays in the GPRS radio link don't allow a fair calculation of the RTO value in the Snoop agent.

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