WIRELESS TCP PROPOSALS WITH PROXY SERVERS IN THE GPRS NETWORK

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Abstract: The General Packet Radio Service (GPRS) system will offer to the users an easy access to Internet applications which work with the TCP protocol. We analyse by means of simulations the performance in the GPRS network of the following wireless TCP proposals that use a proxy server: the Snoop protocol and the Split mechanism. We also describe the impact of the GPRS LLC layer in Acknowledged mode in the TCP end-to-end throughput. Unlike previous research we consider two scenarios for the GPRS radio interface: one with several users present in the system, and the other with only one user in it.

Index Terms: GPRS, TCP, Split, Snoop, LLC ACK .

I. INTRODUCTION

GPRS is the packet switching system defined to work over the GSM system. GPRS is intended to offer the mobile users an easy access to applications running in the Internet. Three of the main Internet applications, WEB browsing, FTP and e-mail, use Transmission Control Protocol (TCP) as transport protocol. TCP is a protocol initially designed for working in fixed networks such as the Internet, where the main problem is the 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 [1]-[3].

The performance of TCP over GPRS was analysed in [4] considering different GPRS radio channel parameters with all the mobile users working only with the WEB browsing application. The way the TCP packets delays in the GPRS radio interface affect the end-to-end TCP performance is described in [5].

One of the ways to improve the TCP performance in wireless systems consists of the use in the mobile network of a proxy server which enhances the TCP end-to-end throughput. In this paper, we analyse by means of simulations the performance of the following TCP wireless proposals which use a proxy server in a GPRS system: the Split mechanism [1] and the Snoop protocol [2]. It is well known that the Snoop protocol and the Split mechanism enhance the TCP performance in wireless LAN environments. Therefore, we consider necessary the study of the performance these mechanisms could have in a cellular system like GPRS, which behaves in a very different way. We also study the TCP performance when the LLC Acknowledged mode in the GPRS radio interface is activated.

The Snoop TCP performance over GPRS was described in [6], but only for the case of a busy GPRS radio channel. In this study we consider two scenarios for the GPRS radio interface: a busy GPRS radio interface with several users working with different applications, and a radio interface with only one mobile user present in the system. One of the objectives of this paper is to determine if the Snoop protocol can enhance the TCP performance when the GPRS radio channel conditions are good.

The rest of this paper is organized as follows: Section II presents a brief description of the TCP proposals for wireless networks. Section III describes the simulator structure used for the study presented in the paper. In Section IV simulation results for a busy GPRS radio channel are given, whereas in Section V results for a GPRS radio channel with one user are presented. Finally, conclusions are derived in section VI.

II. TCP IN WIRELESS NETWORKS

During the last years several authors have made proposals which enhance the TCP performance in wireless environments. According to the analysis presented in [3], 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 Fixed Host (FH) [7] and sometimes also in the Mobile Host (MH). Some of the TCP RFCs like SACK and Timestamps are in this group. With the SACK option the TCP receiver informs the TCP sender about all the segments that arrived correctly. The Timestamps option allows the TCP sender to collect more RTT samples, so the RTO value would be more accurate.

Split protocol: It makes two different TCP connections, one from the FH to the Base Station, and the other from the Base Station to the MH [1]. 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 [2]. 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.

Cross Layer Signalling: The link or network layers at intermediate nodes or at the MH inform the TCP sender at the FH about the state of the wireless link (loss packets, handovers, etc.), e.g. in [8] the TCP sender gets information about the handovers.

Link layer proposals: With these types of proposals the Base Station makes retransmissions at the radio link layer [9]. They depend on the type of radio link protocols used for each wireless network.

III. SIMULATOR STRUCTURE

The GPRS simulation model has been created with the event driven simulator Cadence Bones Designer. 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.

We have simulated the behaviour of all the main nodes that exist in the GPRS architecture (see Figure 1). A FTP server, with the corresponding TCP and IP layers, models the Fixed Host. TCP-Reno version is assumed. The TCP Maximum Segment Size (MSS) is 430 bytes. The Internet is modelled by means of the loss packet probability (less than 1%) and a delay which is statistically characterized as a gaussian random variable with mean 100 ms. The Gateway GPRS Support Node (GGSN) is represented by means of a router, whereas the Serving GPRS Support Node (SGSN) is modelled as a fixed delay that represents the node process delay. 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. 2Mbps and 64 Kbps, respectively. These capacities are always in our simulator much higher than the capacity of the GPRS radio channel, which is the bottleneck of the transmission throughout the GPRS network. The Mobile Host is modelled by means of a TCP/IP host like the FH.

The radio link is statistically modelled by means of the packet loss probability as well as by the LLC frame delay histogram [10]. For this study we have assumed two types of radio interfaces: an empty one with only one mobile user present in the system, and a busy radio interface with 15 users present in it. In both cases we consider a GPRS radio link with 4 PDCHs, Coding Scheme CS2 and a C/I relation of 24 dB. Three types of bursty traffic have been considered in the busy GPRS radio link, 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 modelled using the ETSI model [11]. The statistics of the FTP traffic in the busy GPRS radio interface are used later for the end-to-end FTP downlink transmission.

A proxy server containing the split function or the Snoop agent is located between the SGSN and the GGSN [12]. Taking into account that the mobility management is a service offered by the SGSN node, the mobility inside the service area covered by the SGSN node is transparent to the proxy server attached to the SGSN node. When there is a cell reselection between cells pertaining to different SGSN nodes with different proxy servers, all the user's information is passed from the old proxy server to the new one.

We do not consider the split function delay in the proxy server, because this delay is very low in comparison with the delay found in the GPRS radio interface. On the other hand, the Snoop agent installed in the proxy server contains two processes: snoop_data( ) and snoop_ack( ) [13]. Snoop_data( ) saves the data packets coming from the FH, whereas snoop_ack( ) analyzes the type and number of the acknowledgments it receives from the MH. Snoop_ack( ) does local retransmissions from the Snoop agent to the FH if it deduces from the acknowledgments received that a packet is lost, or if a timer at the Snoop agent triggers. The snoop_ack( ) timer is similar to the TCP timer: the Round Trip Time (RTT) of the TCP segments in the radio link is calculated, and the timer is triggered after reaching a Retransmission TimeOut (RTO) value.

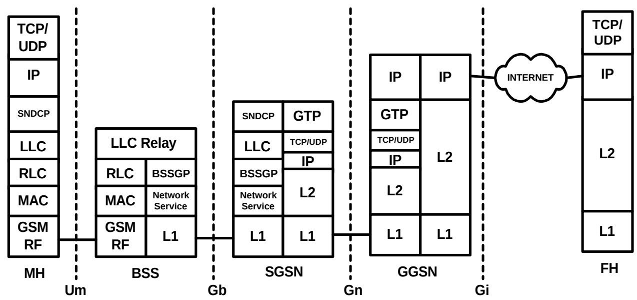

Figure 1: The GPRS network with connection to the Internet.

Table 1 summarizes the most important simulation parameters.

Table 1: Simulation Parameters.

Parameter	Value
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
TCP MSS	430 bytes
Mean Internet Delay	100 ms.

IV. TCP IN A BUSY GPRS RADIO CHANNEL

The busy GPRS radio channel has a packet error rate (PER) of 2.3% and it has long and variable IP packets delays ranging from 800 to 2000 ms. Figure 2 shows the evolution of the Round Trip Time in the FH when the TCP Reno protocol is considered. The figure shows that RTT values of tens of milliseconds can be reached, imposing severe limitations on the TCP behaviour. In that sense, Table 2 shows a comparison of the throughputs and retransmissions types for the analysed options. The data-driven retransmissions correspond to retransmissions done when the TCP sender receives a certain number of Duplicate ACKs (DUPACKs). Timer-driven retransmissions occur when a timer at the TCP sender triggers after reaching a Retransmission TimeOut value, which is function of the RTT value.

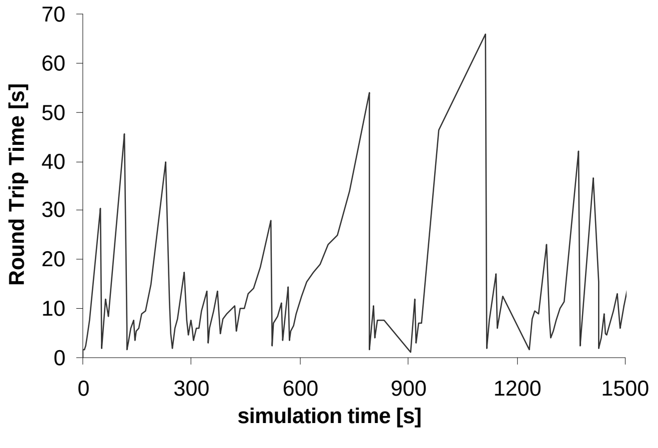

Figure 2: RTT (TCP Reno) in a busy GPRS radio channel.

Table 2: Comparison of Throughput and Retransmissions – A busy GPRS radio channel.

	Throughput (Kbits/s)	Retransmissions (%)			
		Place	Data-driven	Timer-driven	Total
TCP Reno	2.73	FH	2.53	0.23	2.76
Snoop	2.29	FH	0.55	0.60	1.15
		Proxy	6.85	0.08	6.93
Split	2.75	FH	2.14	0.03	2.17
		Proxy	1.56	0.24	1.80
TCP + LLC ACK	2.95	FH	0.90	0.08	0.98
Split + LLC ACK	2.99	FH	2.14	0.03	2.17
		Proxy	0.00	0.01	0.01

IV.1 TCP Reno

The throughput is directly limited by the GPRS radio channel, the 2.76% retransmissions correspond basically to the lost packets in the radio interface (PER = 2.3%).

IV.2 Snoop Protocol

The throughput with the Snoop protocol, 2.29 Kbits/s, is less than the one without it, i.e., 2.73 Kbits/s. Therefore, there is no advantage in using the Snoop protocol for this case.

To work well, enough time is required for the Snoop agent, located at the proxy, to realize that a packet is lost, retransmit it and obtain the corresponding ACK. In the analysed case the packet transmission through the GPRS radio interface takes several hundreds of milliseconds, whereas the transmission through the Internet takes around 100 ms. We observe that high delay values of the GPRS radio interface do not give 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.

Another problem with the Snoop protocol is the arrival of out-of-order packets from the Internet. The Snoop agent sends them to the MH, which generates one DUPACK per each out-of-order TCP segment that it receives. With the arrival of the first DUPACK, the Snoop agent retransmits the corresponding TCP segment. This data-driven retransmission is useless in this case, because the segment has arrived most of the times correctly at the MH, ant it also can generate a second useless retransmission by the Snoop agent. Note the high number of data-driven retransmissions in the Snoop agent derived from this behaviour: 6.85%

IV.3 The Split mechanism

With the Split mechanism the end-to-end TCP performance is only slightly enhanced (from 2.73 to 2.75 Kbits/s). The Split mechanism isolates the wireless part from the two problems found in the Internet: packet reordering and packet losses.

IV.4 LLC in Acknowledged mode

The LLC Acknowledged mode allows until 2 retransmissions of a lost LLC frame in the GPRS radio interface. With this mode, the PER is decreased from 2.3% to $5x10^{-4}$%. When the retransmission is done, the delay for a lost packet increases, but this additional delay does not have an overall negative impact.

When the Split mechanism uses the LLC Acknowledged mode, there are practically no retransmissions in the wireless part.

V. TCP IN A GPRS RADIO CHANNEL WITH ONE USER

A GPRS radio channel with only one user has a PER value of 0.5% and IP packets delays that range from 80 to 120 ms. Figure 3 shows the evolution of the Round Trip Time (RTT) in the FH when the TCP Reno protocol is considered. Table 3 shows a comparison of the throughputs and retransmissions types for this scenario.

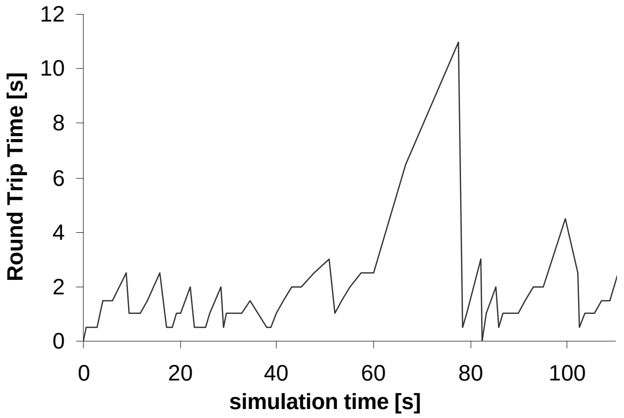

Figure 3: RTT (TCP Reno) in a GPRS radio channel with one user.

V.1 TCP Reno

For this case the TCP Reno end-to-end throughput is 36.47 Kbits/s. Theoretically, the LLC throughput is 48 Kbits/s (12 Kbits/s x 4 PDCHs) [4], but this theoretical throughput includes the LLC and IP headers. Moreover, due to losses at the GPRS link layer level, there are retransmissions of RLC data blocks, which increases the delay. On the other hand, there are also losses of IP packets in the GPRS radio channel and in the Internet, which affects negatively the end-to-end TCP throughput.

Table 3: Comparison of Throughput and Retransmissions – A GPRS radio channel with one user.

	Throughput (Kbits/s)	Retransmissions (%)			
		Place	Data-driven	Timer-driven	Total
TCP Reno	36.47	FH	1.22	0.19	1.41
Snoop	36.79	FH	0.90	0.08	0.98
		Proxy	5.93	0.08	6.01
Split	41.94	FH	2.14	0.03	2.17
		Proxy	0.41	0.00	0.41
TCP + LLC ACK	40.72	FH	1.07	0.00	1.07
Split + LLC ACK	42.37	FH	2.14	0.03	2.17
		Proxy	0.00	0.00	0.00

V.2 Snoop Protocol

The packets delays in the GPRS radio channel are more or less equal than the delays found in the Internet (around 100 ms). Therefore, also in this scenario the Snoop protocol does not recover quickly the packets lost in the radio interface. The throughputs of the Snoop protocol and of the TCP Reno are quite similar: 36.79 and 36.47 Kbits/s, respectively.

V.3 The Split mechanism

There is a throughput enhancement when the Split mechanism is used (from 36.47 to 41.94 Kbits/s). The data-driven retransmissions at the proxy (0.41%) depend directly on the GPRS radio channel PER (0.5%).

V.4 LLC in Acknowledged mode

Using this mode the PER is decreased from 0.5% to $4x10^{-6}$ %. There are practically no lost packets in the radio interface. The retransmissions correspond to the losses in the Internet. This behaviour is clearly manifested when the Split mechanism is used: in practice, there are no losses in the GPRS radio channel.

VI. CONCLUSIONS

The Snoop protocol does not work well in the GPRS system channel because the high delays in the GPRS radio channel, even when it works with only one user, do not give the Snoop Agent enough time to recover properly from losses. The Split mechanism separates the wired and wireless connections and its problems, but it only provides a slightly throughput enhancement. Moreover, the IPsec security protocol could not work appropriately in the presence of a proxy containing the Snoop or Split functionalities [14]. On the other hand, the use of the LLC layer in Acknowledged mode reduces the PER values in the GPRS radio channel to very low values, eliminating thus the negative effect that lost packets in this path have in the TCP throughput.

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REFERENCES

[1] A.B. Bakre and B.R. Badrinath, "Implementation and performance evaluation of indirect TCP", *IEEE Trans. on Computers*, vol. 46, No. 3, Mar. 1997.

[2] H. Balakrishnan, V. Padmanabhan, S. Seshan, and R.H. Katz, "A comparison of mechanisms for improving TCP performance over wireless links", *IEEE/ACM Trans. on Networking*, vol. 5, No. 6, Dec 1997.

[3] R. Ludwig, "Eliminating inefficient cross-layer interactions in wireless networking", Ph.D. dissertation, Technische Hochschule Aachen, Germany, April 2000.

[4] R. Kalden, I. Meirick. M. Meyer, "Wireless internet access based on GPRS", *IEEE Personal Communications*, April 2000.

[5] A. Gurtov, "Effect of delays on TCP performance" in *Proceedings of IFIP Personal Wireless Conference*, 2001.

[6] J. Rendón, F. Casadevall, D. Serarols, "Snoop TCP Performance over GPRS", in *Proceedings of IEEE Vehicular Technology Conference 2001 Spring*, Greece, May 2001.

[7] D. Bansal, A. Chandra, R. Shorey, "An Extension of the TCP Flow Control Algorithm for Wireless Networks", in *Proceedings of IEEE ICPWC 1999.*

[8] R. Caceres and L. Iftode, "Improving the Performance of Reliable Transport Protocols in Mobile Computing Environment", *IEEE JSAC*, June 1995.

[9] C. Parsa and J.J. Garcia-Luna-Aceves, "Improving TCP performance over wireless networks at the link layer", *Mobile Networks and Applications 5 (2000)*, P. 57-71, Baltzer Science Publishers.

[10] J. Rendón, F. Casadevall, L. García, and R. Jiménez, "Simulation model for performance evaluation of Internet applications using GPRS radio interface", *IEE Electron. Lett.*, vol. 37 No. 12, pp. 786-787, Jun 7th 2001.

[11] ETSI, "Universal mobile telecommunication system (UMTS); Selection procedures for the choice of radio transmission technologies of the UMTS", UMTS 30.03, v. 3.2.0, 1998.

[12] Z. Jiang, L.F. Chang, B. J.J. Kim, K.K. Leung, "Incorporating proxy services into wide area cellular IP networks", *Wireless Communications and Mobile Computing*, 2001, Vol 1, No. 3.

[13] H. Balakrishnan, S. Seshan, E. Amir, R. H. Katz, "Improving TCP/IP Performance over Wireless Networks", in *Proceedings of. 1st. ACM Conf. on Mobile Computing and Networking*, Berkeley, CA, November 1995.

[14] J. Border, M. Kojo, J. Griner, G. Montenegro, Z. Shelby, "Performance enhancing proxies intended to mitigate link-related degradations", IETF RFC 3135, Jun 2001.