A SCTP – Layer 2 Cross Layer Mechanism for Data Handover in Wireless Networks (application to EGPRS)

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***Abstract – This* paper proposes a new extension for the SCTP protocol which aims at improving the transport performance in wireless environments. This extension is named QoS-_Measurement_chunk. It relies a) on a cross-layer mechanism taking place between SCTP and the link layer and b) on a new SCTP control chunk. Network can be informed of variations of link layer transmission conditions via control QoS_Measurement_chunks and SCTP congestion control parameters are modified to take into account new radio conditions. The present study illustrates the use of this extension in a EGPRS context. It compares its performances with standard SCTP when downlink transmission is considered in handoff situation.**

Keywords – QoS_Measurement_Chunk, SCTP, cross-layer mechanism, QoS variation, Wireless

I. Introduction

Some well known wireless link characteristics (high error rates, limited bandwidth, handovers ...) degrade the performance of transport protocols in wireless networks. Many studies have been designed to improve performances of these protocols and to overcome the impairments inherent to wireless channels. These solutions include wireless TCP extensions or more recently the use of SCTP to transport application data over the air interface to take benefit from the multistreaming.

This paper introduces a general cross layer mechanism between SCTP and wireless link layers. Its use is illustrated on a EGPRS network. The proposal relies on a modification on the SCTP congestion control mechanisms and on a new control chunk, named QoS_Measurement_Chunk. It makes it possible to inform transport layer about any modification of transmission conditions on the wireless link. In a EGPRS context, QoS_Measurement_Chunk informs SCTP about the coding scheme used on the air interface. This information is then taken by SCTP to compute new cwnd and ssthresh values. This work investigates the performance evaluation of the proposed extension when dynamic changes in the radio transmission conditions (in our case it will be coding schemes used at the RLC/MAC level) occur. This study is focused on EGPRS network. We assume that an SCTP association is setup between the mobile and the GGSN. The SCTP association is setup at the PDP context activation and is maintained by the network even when handover occurs. Only downlink transmission is considered here and the work focuses on SCTP behavior during handover process. Unlike, Mobile IP approaches, the mobile is not multihomed (it has a single IP address). The GGSN can be multihomed if required (for example for handover support).

The paper is structured as follows. Section 2 provides a short description of SCTP's multihoming feature and of its congestion control mechanisms. Section 3 details simulation scenario. Section 4 provides simulation results and their interpretations. Finally, some conclusions and perspectives are drawn.

II. SCTP Multihoming Feature and Congestion Control Mechanism

A. Multihoming

SCTP multihoming provides a redundancy functionality between two distant nodes. SCTP associates several IP addresses to a single SCTP port. To carry out a transmission towards a multihomed node, the transmitter chooses at the association establishment one of the possible IP addresses which will correspond to the "primary path". The transmitter should then send data only on this primary path (it is then qualified as active) till it becomes unavailable. To prepare for primary link unavailability, SCTP probes alternate paths that were setup at association establishment [1]. The availability of the secondary addresses is controlled by the regular sending of HEARTBEAT chunks, which must be acknowledged by a HEARTBEAT ACK chunk. The Primary path is supposed to be inactive, if the transmitter cannot reach it after several expired RTO. In this case, SCTP packets will be transmitted towards another active address. The choice of the alternate IP destination address is insured by sending a Heartbeat Request chunk to its peer. SCTP peer's node must answer with a Heartbeat Ack chunk by indicating the backup IP address which will be active in the current association. A heartbeat chunk is sent periodically to the destination transport addresses in order to update their accessibility states. The heartbeat period is given by Hi (see equation 1). The emission period of heartbeat chunk is controlled by the HB.Interval parameter (30 second) [1].

$$Hi = RTOi + HB.Interval(1+\delta) \qquad (1)$$

RTOi is the last value of the RTO of the destination relating to the transport address (i) and δ is a random value in [-0.5,0.5] chosen at the association setup.

The SCTP association should with this feature recover faster and provide better throughput as long as the alternate path is not affected by important error rates or congestion losses. SCTP's multihoming feature can be exploited to allow a mobile node to choose which wireless path is more suitable for communicating and then, to perform a data handover in the downlink.

B. SCTP Congestion Control Mechanism

Congestion control in standard SCTP consists of two modes [1] : slow start and congestion avoidance, it is similar to the congestion control in TCP [2].

Slow Start

Initially, the cwnd is set to 2*MTU. If an entering SACK increments the Cumulative TSN Ack Point, cwnd must be incremented by the minimum of the total size of the buffered blocks previously acknowledged and of the path MTU of the destination.

Congestion avoidance

If cwnd > ssthresh, cwnd is updated by doing cwnd=cwnd +1*MTU by RTT (2) if the transmitter has cwnd or more bytes of suspended data for the corresponding transport address.

In practice an implementation can carry out this in the following way [1] : **(1)** partial-bytes-acked = 0

(2) each time that cwnd > ssthresh, when a SACK that increments Cumulative TSN Ack Point is received, partial-bytes-ack inceases by the total number of acked bytes ; **(3)** if partial-bytes-ack ≥ cwnd, and that before the reception of a SACK the transmitter has cwnd or more suspended data bytes, cwnd increases by MTU and

partial-bytes-acked = partial_bytes_acked – cwnd

(4) As in Slow start, when the transmitter has no data to transmit to a given destination transport address, cwnd of that address must be adjusted to max(cwnd/2, 2*MTU) by RTO. **(5)** When all the transmitted data are acked by the receiver, partial-bytes-acked = 0.

Congestion Control

Upon the detection of packet losses indicated by SACK, an SCTP node must :

$$ssthresh = max(cwnd/2, 2*MTU) \quad (2)$$

$$cwnd = ssthresh \quad (3)$$

Primarily a packet loss causes the reduction by half of the cwnd. When T3-rtx expires for an address, SCTP must execute Slow Start by:

$$ssthresh = max(cwnd/2, 2*MTU) \quad (4)$$

$$cwnd = 1*MTU \quad (5)$$

and ensures that there is no more than one SCTP packet that will be transmitted for this address until SCTP node receives the acknowledgment for a successful delivery of the data towards this address.

III. Simulation Scenario and Extension Description

A. Simulation parameters

The simulated scenario is given by figure 1. We consider two EGPRS cells and we suppose that we have one mobile that makes a handover between these two cells. An SCTP association is setup between the mobile and its IP server (the fixed Host, directly connected to the GGSN).

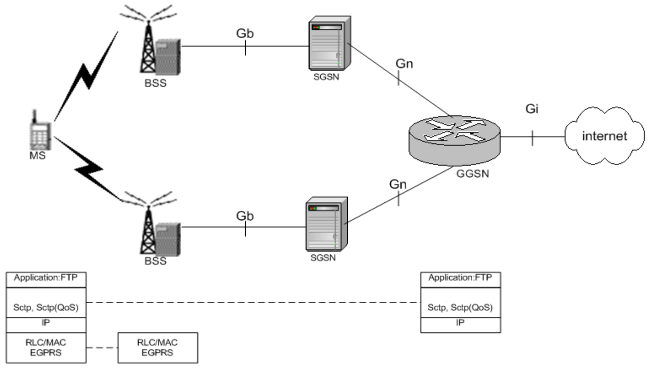

Figure 1.. Simulated Architecture

It is established during the establishment of a PDP context between the mobile and the GGSN. SCTP association is multi-homed on server IP side and transmission are made on streamId 0. On the other hand, the mobile has only one IP address (it does not change during the lifetime of the PDP context). The primary address of the SCTP association corresponds to the IP address located on the same subnetwork as the SGSN with which the mobile established the PDP context. This address can be changed if the mobile changes of SGSN. The primary link corresponds to server's primary address that is defined by the path : Server-GGSN-SGSN1-BSS1-MS. The alternate link is the one defined by the path : Server-GGSN-SGSN2-BSS2-MS. On the radio interface we use a degradation process at level 2 (RLC/MAC) that simulates the decrease of link quality by changing the coding scheme used to transmit RLC blocks. We consider a deterministic variation of the coding scheme and the corresponding block error rate (BLER). The change of the coding scheme is designed to degrade the transmission condition quality and to activate the radio handover towards the second cell. The table1 describes the change of the transmission parameters during a communication.

Instant	Coding scheme	BLER
0sec	CS4	0.01
200sec	CS3	0.015
400sec	CS2	0.1
600sec	CS1	0.15
700sec	HO	
CS3 over second cell		0.015

Table 1. Transmission parameters change.

The window size can vary at the RLC/MAC level from 64 to 384 blocks. A TBF can use up to 3 PDCH in downlink and 1 PDCH in uplink. Gb Interface is modeled with a duplex link of 64kbps transmission rate and 100ms propagation delay. Gi interface is modeled with a duplex link of 5Mbps transmission rate and 100ms propagation delay. The link between GGSN and the fixed host is a duplex link of 5Mbps transmission rate and 100ms propagation delay. The error model on the wired part, Gi interface, is uniformly distributed with a mean packet error rate of 1%. Simulations are developed using NS2 by exploiting SCTP simulator developed by [3] and the RLC/MAC simulator developed by [4]. We use this SCTP simulator to which we have added the functionality of Qos_Measurement_Chunk.

B. Extension description

The proposed extension is a modification of congestion control algorithms of standard SCTP that applies when a significant change of radio conditions occurs on the air interface. Indeed, the problem addressed here is the change of radio conditions and its impact on the flow transmission control at the transport layer. The losses on the radio interface are generally interpreted by transport protocol as congestion problems on the fixed part of the network. QoS_Measurement_Chunk is an approach that makes the possibility to inform the transport protocol about the transmission parameters on the radio interface. This makes it possible to adapt the flow of data transmission by an update of the parameters of congestion control mainly the size of the congestion window (cwnd) and the slow start threshold (ssthresh) (vs. Figure 3).

At the establishment of the association, the mobile transmits to the GGSN (via the PDP context activation procedure) the capabilities of the radio bearer used by the mobile terminal (multi-slot class, list of available coding schemes, ...). The GGSN is kept informed about any modification on the coding scheme used for transmission on the air interface (typically due to the link adaptation procedure or to a handover). All this information are sent in Qos_Measurement_chun format is given by figure 2 .

Chunk type	Chunk length
TLV : QoS_parameter	

Figure 2.. Qos_Measurement_chunk

The reception of a Qos_Measurement_chunk containing the information about the coding scheme used in the downlink just after the handover, will cause a recalculation of the cwnd in the new cell. The cwnd is performed as follows.

*cwnd(new)=cwnd(old)-C(Cs_old)*RTT+C(Cs-new)*RTT*, where

C(Cs_old) is the throughput provided by the coding scheme used in the change of coding scheme and *C(Cs-new)* is the throughput provided by the new activated coding scheme just after the change of the transmission conditions.

Another modification is in the calculation of the ssthresh after the transmission conditions change. The old value of the previous conditions is kept. That means that if the mobile is in congestion avoidance phase before coding scheme changes, it will stay in this phase in the new cell with an updated value of cwnd. For handover if the mobile is in slow start phase in the old cell, it will stay in the slow start phase in the new cell but with a value equal to the *cwnd(new)* instead of one or two MTUs. As a result, slow start is not systematically triggered when a handover occurs such as it is done in classical SCTP.

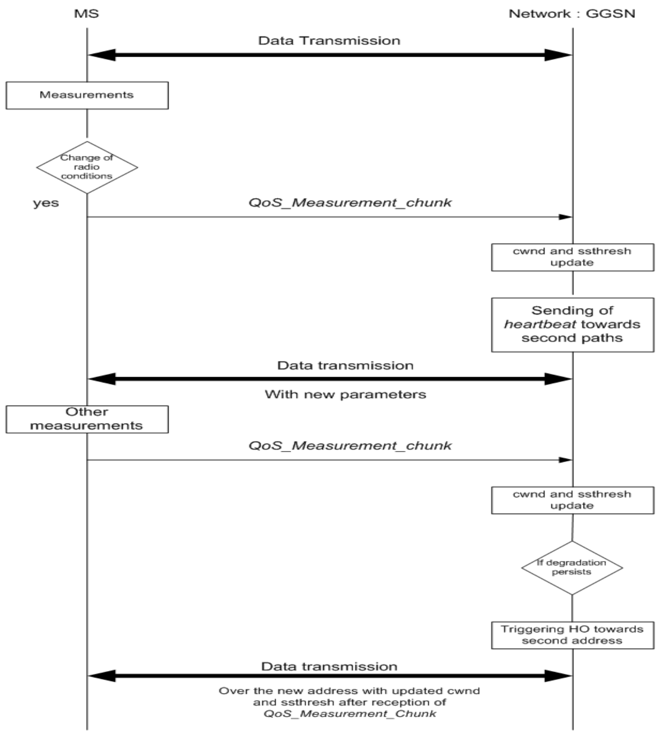

Figure 3. Qos_Measurement_chunk approach

IV. Simulation results and performance evaluation

Here we present some simulation results that compare the performance of SCTP standard with SCTP QoS_Measurement_Chunk extension.

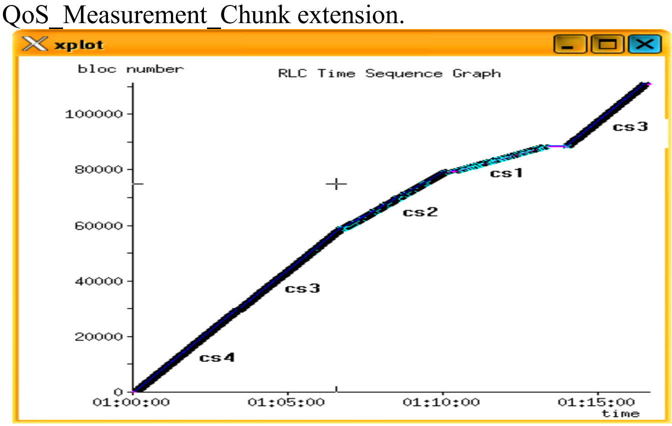

Figure 4. Variation of the RLC/MAC sequence number in the case of SCTP standard.

The figures 4 and 5 present the evolution of the sequence number on RLC/MAC blocks for standard SCTP and the proposed extension. Figures 4 and 5 illustrate the losses due to the degradation of the link quality, followed by a cut of the connection with the first cell due to handover and the connection to the new cell. For the standard SCTP with the multihoming we notice that when changing from CS3 to CS2 we have a little transmission cut which corresponds to a retransmission timeout, whereas with the proposed extension no timeout occurs. This is due to the fact that cwnd in the proposed extension remains unchanged and keeps growing after the radio transmission conditions change. This trend confirmed by the evolution of TSN given by figure 7 and figure 8 for standard SCTP compared to SCTP with QoS_Measurement_Chunk. That explains that the evolution of cwnd (vs. figure 6) is better for the proposed extension and that the throughput increases also more rapidly for the proposed extension.

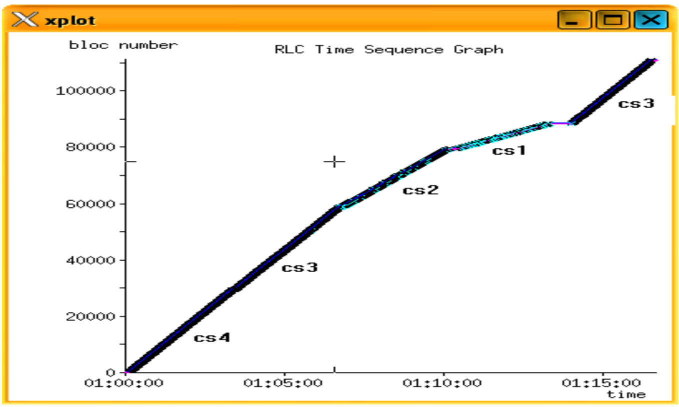

Figure 5. Variation of the RLC/MAC sequence number in the case of SCTP with QoS_Measurement_Chunk.

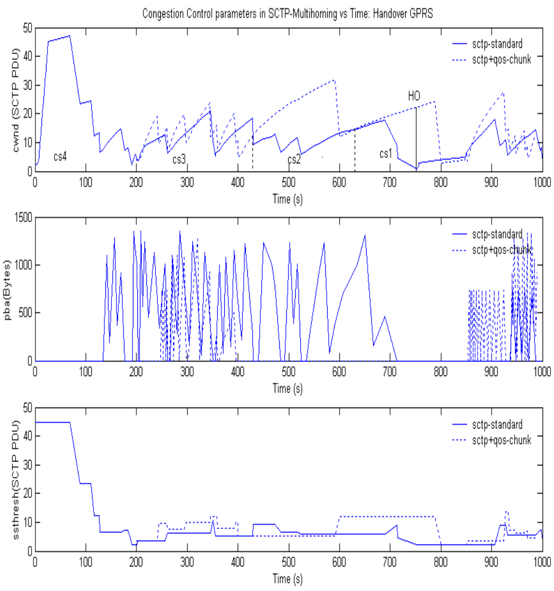

Figure 6. Congestion Control parameters with Standard SCTP compared to SCTP with QoS_Measurement_Chunk.

V. Conclusion

This paper addresses the performance issues raised by transmission data conditions variation on the radio interface at the SCTP level. This work proposes a modification of standard SCTP that consists in creating a new control chunk: QoS_Measurement_Chunk and new way of updating cwnd and ssthresh whenever a new QoS_Measurement_Chunk is received by the network. This chunk serves to inform the network about the state the radio link. In this study we consider a deterministic change of the peer (coding scheme, BLER) with an aim of testing the behavior of the suggested extension by varying the transmission parameters. This extension used conjointly with the multihoming has shown better performances, especially when used in handover situation. Future works will investigate the performance of the proposed extension in a inter-system handover context.

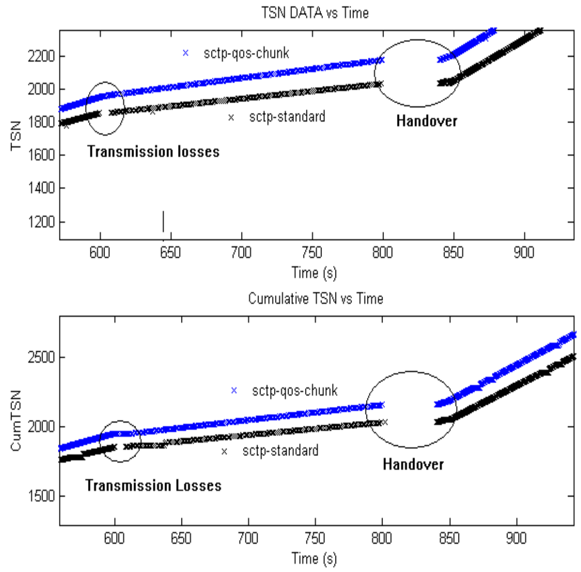

Figure 7. Variation of TSN and CumTSN with Standard SCTP compared to SCTP with QoS_Measurement_Chunk.

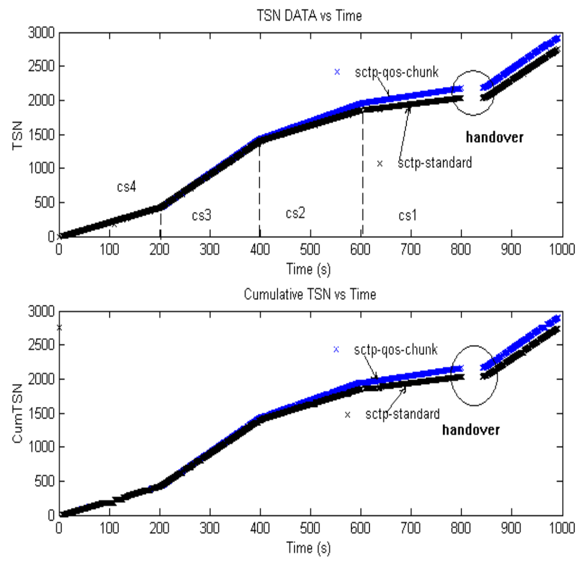

Figure 8. Variation of TSN and CumTSN with Standard SCTP compared to SCTP with QoS_Measurement_Chunk (zoom of figure 7).

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