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Full Length Research Paper

SCTP-multihoming for intra and inter-RAT data handover management

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SCTP (Stream Control Transmission Protocol) provides interesting features, as multihoming and multistreaming, to enhance information transport performances over air interfaces. Additional extensions have been proposed to adapt SCTP to wireless context (mSCTP: mobile SCTP). However, published approaches do not take into account channel state information during handover processes. The present work proposes a new extension for SCTP which aims at improving transport protocol performance in wireless environments: 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. It allows the emission of radio information from the mobile to its SCTP peer. These information can be used by SCTP layer to adapt transmission rate to the current radio transmission conditions. So, SCTP congestion control parameters are modified to take into account new radio conditions. The combined using of QoS_Measurement_Chunk and multihoming feature provide a data handover with a performance improvement. This new mechanism is useful to perform intra or inter RAT (Radio Access Technology) data handover. The obtained simulation results are compared with the standard SCTP when downlink transmission is considered in handover situation and present better performance in terms of data throughput over the access network.

Key words: Inter-RAT handover, SCTP, Qos_measurement_chunk, cwnd adaptation, flow control.

INTRODUCTION

The multihoming is an SCTP feature that refers to a situation where an endpoint can use multiple paths for data transmission (Gundu (2004). In SCTP, multihoming mechanism provides redundancy between two remote nodes. Each node can be accessed by multiple IP (Internet Protocol) addresses negotiated at the establishment of SCTP association. With this feature data transmission performance over radio networks, has been improved (Sukwoo and Matthew 2003).

Several SCTP extensions have been defined for adapting SCTP to radio environment such as mobile SCTP (mSCTP) and cellular SCTP (cSCTP). However, proposed approaches and extensions for transport protocols, do not take into account radio measurements for handover and cell reselection processes. Based on previous studies developed for intra and inter-RAT data handover management and taking advantage of SCTP multihoming coupled with mobility, an SCTP extension is proposed in this work. The proposed extension aims to improve performance of transport layer in a wireless environment, by introducing a new SCTP control chunk control: the Qos_Measurement_Chunk. With this chunk mobile client can inform its associated SCTP endpoint about radio transmission conditions. This information would be used by SCTP layer to adapt transport transmission throughput to radio interface transmission conditions (particularly useful in a handover or cell reselection situation).

The proposed SCTP extension QoS_Measurement_ Chunk is based firstly on a cross-layer mechanism between SCTP and data link layer, and secondly on the creation of a new SCTP control chunk. The combined use of QoS_Measurement_Chunk and multihoming mechanism provides improved performance for data handover management.

This paper is organized as follows. In section 2 we situate our contribution by presenting related works. We present a short description of SCTP's multihoming feature and of the proposed solution of SCTP for ensuring mobi-

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lity, mSCTP are detailed on the third section. QoS_Measurement_Chunk extension is described and detailed on the fourth section. We describe simulation parameters and the simulated scenarios in section 5. Section 6 provides some simulation results and their interpretations related to the different simulated scenarios. Finally, some conclusions and perspectives are drawn.

RELATED WORKS AND OUR PROPOSED CONTRIBUTION

Within current networks, mobility from one network to another is a research topic on which several studies have focused. Ensure the communication continuity when switching the link from a certain type of access network technology to another, is not always obvious. Mobile SCTP provides a means to ensure such continuity. However, mSCTP, to manage mobility must be combined with Mobile IP. Indeed, the mobility management consists of two phases. The first step is provided by Mobile IP which consists of localization management to identify the MN (Mobile Node) location. After that, mSCTP manages the connection change in connection with multihoming and dynamic addressing mechanisms.

Despite its shortcomings, mSCTP coupled with MIP (Mobile Internet Protocol) introduces the basic solution as adopted for managing inter-RAT data handover. Studies like (Luo et al. 2003; Peddemors et al. 2004; Ylitalo et al. 2003; Mihailovic et al. 2002; Aahlund et al. 2003a; Aahlund et al. 2003b) propose mechanisms to cooperate with the mobility protocols at different levels of the layered model : mSCTP as transport protocol and MIP for network layer. A mobility manager is introduced to dynamically configure interfaces for different RAT in MN. Other works [Aydin et al. (2003)] are based on mSCTP. The cellular SCTP, for example, introduces an improvement to overcome mSCTP shortcomings, but still restrictive because it allows the transmission of duplicate data packets over two simultaneously activated primary addresses, resulting in a redundancy at SCTP receiver and thus bandwidth wasting. Also the idea to decide the IP address change based on radio signal level can improve mSCTP performance but does not consider transport layer congestion control mechanism.

Others seek the solution for achieving an optimal and lossless inter-RAT data handover from lower layers. One approach has been proposed by J. Sachs (Sachs et al. 2003a), it is to design a GLL (Generic Link Layer). The integration of this concept in future radio access networks, allows reliable and lossless inter-system handovers. One reason for GLL integration [Beming et al. 2004; Sachs et al. 2004b)] is to promote a generic data processing for different radio access technologies. In fact, GLL concept allows the integration of rats with differrent characteristics and heterogeneous requirements (Sachs et al. 2004c). Indeed, Generic Link Layer is a layer that provides data link operating in different radio access technologies and can be identified as a block of link layer functions that can be easily adapted to the characteristics of new radio access technologies. GLL layer is a unified interface to upper layers (Figure 1) acting as a layer of convergence of several rats, and hiding heterogeneous environments of several fundamental RAT. It monitors and improves the functionality of RLC / MAC (Radio Link Control / Medium Access Control) layer for different supported RAT, in order to increase the application layer performance. GLL provides a modular architecture that easily covers the integration and co-operation of different types of rats [Magnusson et al (2004)].

GLL entity in its appearance ensures a reliable and lossless inter-RAT data handover. This concept is incomplete, to accomplish its function, a GLL requires a radio resource management module in a multi radio-access context. Indeed, a GLL entity, located between the control plan and the user plan must provide a dynamic path changes between different RATs for upper layer's data streams. In addition, as it is conceived, a GLL does not affect upper layer congestion control. In fact, events in layers RLC / MAC and physical remain ambiguous to the upper layers. In this case the errors on radio interface for any radio access technology, are always interpreted as congestion problems of wired side. Therefore designing a mechanism that ensures the interaction between transport and link layers is essential to ensure reliability of inter-RAT handover. In summary, a proposal an inter-RAT data handover management must provide two main functions:

- Dynamic interfaces for different RATS,
- Generic data procession for different radio access technologies.

We present in the flowing our solution to manage inter-RAT data handover, based on SCTP protocol. Our approach is to introduce changes to the SCTP congestion control mechanism in order to separate real congestion problems from transmission QoS degradations at RLC / MAC. To do this we will communicate quality of service measures, recorded at radio interface, to SCTP layer using the basic features of SCTP: multihoming and control chunks. We formulate our proposition from alternatives proposed with mSCTP, cSCTP or GLL, a reliable inter-RAT data handover management approach must guarantee the convergence of mobility management mechanisms, congestion control and different RAT QoS criteria (Figure 2).

SCTP MULTIHOMING FEATURE AND MSCTP EXTENSION FOR RADIO HANDOVER

Multihoming

SCTP multihoming mechanism provides redundancy between two distant endpoints. Each SCTP endpoint can be accessible via several IP addresses (and one single SCTP port) fixed at the setup of the association. The Upper Layer Protocol (ULP) determines all IP addresses associated with SCTP association and they choose the primary path (one single path active at time). When the pri-

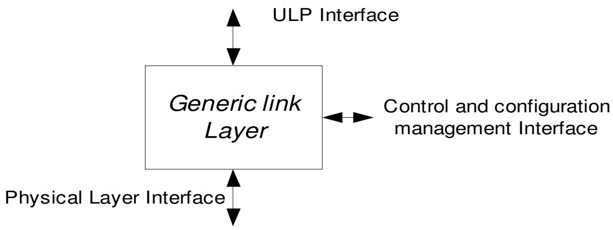

Figure 1. GLL functions and interfaces (Sachs et al. 2003a)

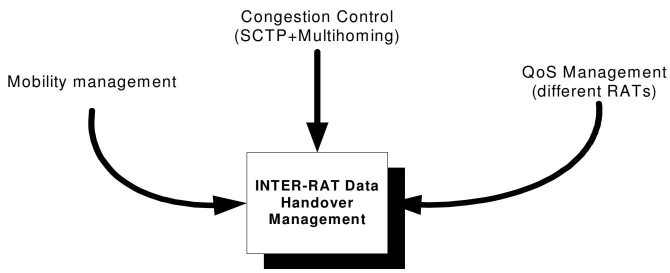

Figure 2. Inter-RAT Data Handover management proposed solution

mary path becomes unavailable (following a congestion, or a significant data loss), SCTP sends all the traffic to one of the alternate addresses of the considered association. The reachability (or active state) of one destination address is probed with a heartbeat mechanism (Stewart et al. 2000).

The Primary path is supposed to be inactive, if the transmitter cannot reach it after several expired RTO (Retransmission Time Out). In this case, SCTP packets will be transmitted towards another active address. The scan of an alternate IP destination address is insured by sending a Heartbeat Request chunk to its peer. SCTP peer's endpoint must answer with a Heartbeat (HB) 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 (Equation 1). The emission period of heartbeat chunk is controlled by the HB.Interval parameter (30 s) (Stewart et al. 2000).

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

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.

SCTP association with this feature recovers faster and provides better throughput as long as the alternate path is not affected by transmission errors. 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.

SCTP congestion control mechanism

SCTP uses the same algorithms of congestion control as TCP (Transmission Control Protocol) (Allman et al., 1999). The congestion control in SCTP is always applied to the whole association and not to individual streams. Congestion control in standard SCTP consists of Stewart et al. (2000): slow start, congestion avoidance and congestion control.

Slow Start: Initially, the cwnd (congestion window) is set to 2*MTU (Maximum Transmission Unit) If an entering SACK (Selective Acknowlegment) increments the Cumulative TSN (Transmission Sequence Number) 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(Round Trip Time), 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. Partial-bytes-acked = 0
2. Each time that cwnd > ssthresh Slow Start Threshold), when a SACK that increments. Cumulative TSN Ack Point is received, partial-bytes-ack increased by the total number of acked bytes.
3. If partial-bytes-ack ≥ cwnd, and that before the recaption of a SACK the transmitter has cwnd or more suspended data bytes, cwnd increased 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 do the following:

$$Ssthresh = max(cwnd/2, 2*MTU) \quad (1)$$

$$Cwnd=ssthresh \quad (2)$$

Primarily a packet loss causes the reduction by half of the cwnd. When T3-rtx (retransmission time out) expires for an address, SCTP must execute Slow Start by: and ensures that there is no more than one SCTP packet and that will be transmitted for this address until SCTP node receives the acknowledgment for a successful delivery of the data towards this address.

$$Ssthresh = max\ (cwnd/2, 2xMTU) \quad (3)$$

$$Cwnd = 1xMTU \quad (4)$$

Chunk type	Chunk length
TLV : QoS_parameter	

Figure 3.. Qos_Measurement_chunk.

Chunk type : 16 bits (unsigned integer)
Chunk length : 16 bits (unsigned integer)
QoS_Parameter : this field should include information about the current values of QoS transmission parameters over radio interface measured by the sender (Mobile Station) (it can be BLER (Block Error Rate) , maximum rate...).

mSCTP

Mobile SCTP is based on the SCTP's multihoming feature and uses the possibility to add or delete dynamically new IP addresses to an existing association and to change the primary path. Mobile SCTP (mSCTP) uses ADDIP extension for that purpose. This extension consists in introducing two new chunk types [Riegel et al. (2005)]: Address Configuration Changes Chunk ASCON F and Address Configuration Acknowledgment ASCONF-Ack.

Mobile SCTP such as it is presented in [Riegel et al. (2005)] has some limitations in managing radio links during handover. Indeed, in mSCTP data packets are sent towards old IP address before the MN (Mobile Node) considers new IP address as the primary path for the association. This generates packet losses in the server side while the primary path change is not effective at the client and server level. Moreover, mSCTP does not manage mobility, it only takes care of describing how to change the primary path in the SCTP association. Additional mechanisms have to be provided to take care of user mobility (carried out by mobile IP in WLAN networks or by mobility management procedures in case of cellular networks).

QOS_MEASUREMENT PROCEDURE PERFORMANCE

Qos_Measurement_chunk

Our solution is based on the fact that datagrams transmission error does not trigger congestion control mechanisms on the transmitter side. At the receiver side, the idea is conceived to hide the transmission process to the transport protocol and rescuing it at link layer through a reliable ARQ (Automatic Repeat Request) mechanism (which is not always possible because of retransmissions delays). Existing solutions such as TCP-Eifel algorithm (Ludwing and Meyer 2003) requires to both endpoints (transmitter and receiver) to support TCP timestamp option. In our approach we consider SCTP protocol for its reliability and innovative transmission features. In this work, we propose an SCTP modification in order to transmit to the network any type of information from link layer or even physical layer. It consists to create a Cross-Layer aspect based on SCTP control chunks. We create a new chunk that we called QoS_Measurement_chunk control. This chunk is used to inform transport layer about radio transmission conditions which help to adjust congestion control parameters in relation with radio interface variations. This information will determine when trigger the change of address at SCTP level.

QoS_Measurement_chunk allows the possibility to mobile node to give to GGSN (Gateway GPRS Support Node) information on radio link quality (example, error rate PDCP,Packet Data Convergence Protocol, frames, max throughput supported by radio interface,...). This chunk can also be used to inform GGSN about any change of the available throughput on radio transmission conditions (example, radio degradation conditions, change of coding scheme, ...). This information can be used by the GGSN to update congestion control window on the downlink depending on radio interface transmission conditions.

The extension consists in the following : at the association establishment, the mobile node transmits to the GGSN (via the PDP,Packet Data Protocol, context activation procedure) the capabilities of the radio bearer as well as the current coding schemes used for transmission on the air interfaces (uplink and downlink). The GGSN is kept informed about any change in the coding scheme used by opened TBF (Temproray Block Flow) (typically due to the link adaptation procedure or to a handover). This information is sent in the Qos_Measurement_chunk which formats are given by Figure 3.

Congestion control modifications

The proposed extension is a change 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. QoS_Measurement_ Chunk approach makes it possible to notify the transport layer about the radio link transmission parameters. Consequently the transport layer may adapt the transmission data flow by updating size of the congestion window (cwnd) and the slow start threshold (ssthresh) (vs. Figure 4). The receiver side does not send an ACK after processing of a QoS_Measurement_Chunk, it is a measurement report. For example, in case of handover, the reception of a Qos_Measurement_chunk after cell switching will trigger the computation of the new cwnd in the target cell. The cwnd value is determined as follows;

$$cwnd(new)=cwnd(old)-C(Cs\_old)*RTT+C(Cs\text{-}new)*RTT,$$

where;
C(Cs_old) is the throughput provided with the old coding scheme and *C(Cs-new)* is the throughput provided with the new coding scheme.

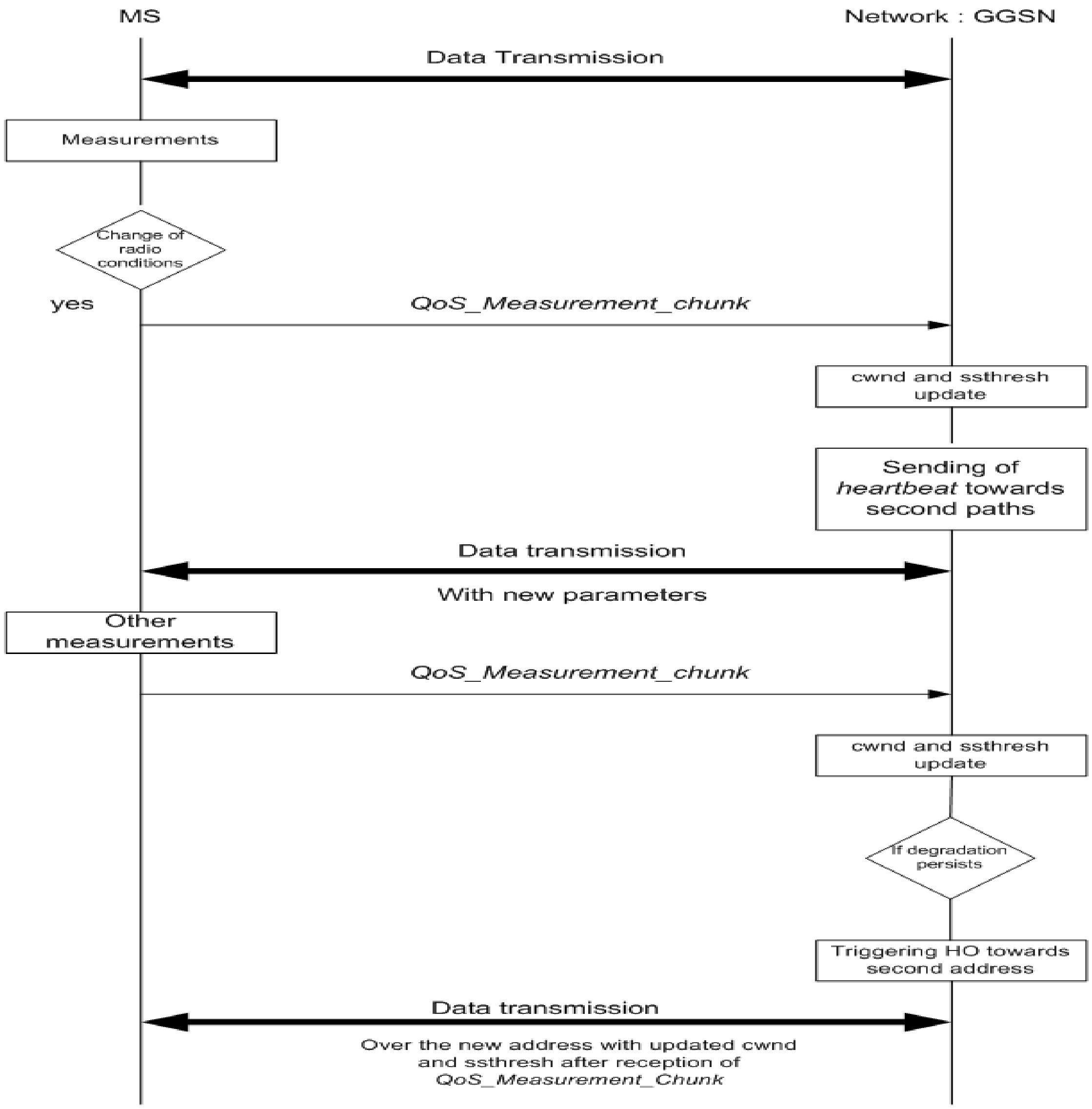

Figure 4. Qos_Measurement_chunk proposed approach

Another change concerns the determination of ssthresh parameter after transmission conditions change. The old value of the previous conditions is kept, meaning that if the mobile is in congestion avoidance phase before coding scheme change, it will remain in this phase in the target cell with an updated value of cwnd. These two modifications of standard SCTP congestion control can more generally be applied when the coding scheme used for transmission changes. Furthermore, in case of handover, a mobile in the slow start mode in the old cell, will stay in this mode in the target cell but with a value equal to the *cwnd(new)* instead of one or two MTUs. Another important point is the face that slow start is not systematically triggered when a handover occurs such as it is achieved in classical SCTP as it is specified in (Stewart et al. 2000).

SIMULATION SCENARIOS

We simulate three scenarios to study the improvement of our modification to the SCTP protocol. Two possible cases for intra-RAT data handover and one for inter-RAT data handover.

First scenario: intra-RAT (EGPRS technology) data handover without variation of coding scheme

We have evaluated the performance of this scheme by simulating a scenario shown in Figure 5. We consider two EGPRS (Enhanced General Packet Radio Service) cells and one mobile reached by one IP address that it is conserved for the lifetime of the PDP context. The handover is triggered by the BSS (Base Station Subsystem).

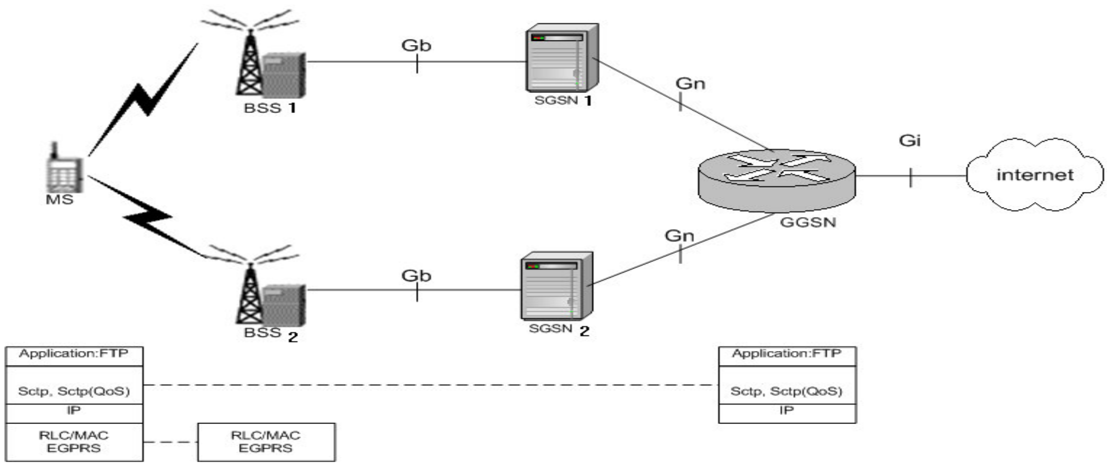

Figure 5.. Simulated Architecture

We consider an SCTP association between the mobile and its IP server (the fixed Host, directly connected to the GGSN).

SCTP association is multihomed on IP server side, and we activate one single stream that transports a simple FTP (File Transfert Protocol) flow. The problem of head of line blocking is not discussed here. 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 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 to another SGSN.

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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 (Errors uniformly distributed at RLC/MAC level with a 10^{-2} loss probability). Coding scheme (Cs) can change from cs3 to cs1 in the performed simulations. The coding scheme used in the new cell is cs3 just after the handover). The window size can vary at the RLC/MAC level from 64 to 384 blocks. This degradation of throughput on the rate interface triggers the handover towards the new cell and then new radio conditions are taken into account for the alternate SCTP path. A TBF can use up to 3 PDCH (Packet Data Channel) in downlink and 1 PDCH in uplink. Gb Interface is modeled with a duplex link of 64 kbps transmission rate and 100 ms propagation delay. Gi interface is modeled with a duplex link of 5 Mbps transmission rate and 100ms propagation delay. The link between GGSN and the fixed host is a duplex link of 5 Mbps 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 Network Simulator NS2 by exploiting SCTP module. We use this SCTP simulator to which we added the functionality of Qos_Measurement_Chunk.

Second scenario: Intra-RAT(EGPRS technology) data handover with variation of coding scheme

We consider the same simulated topology given by Figure 5. SCTP association is established during the establishment of a PDP context between the mobile and the GGSN. SCTP association is multihomed on server IP side and transmission are made on streamed 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 (Serving GPRS Support Node) 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. Table 1 describes transmission parameters change during an SCTP association.

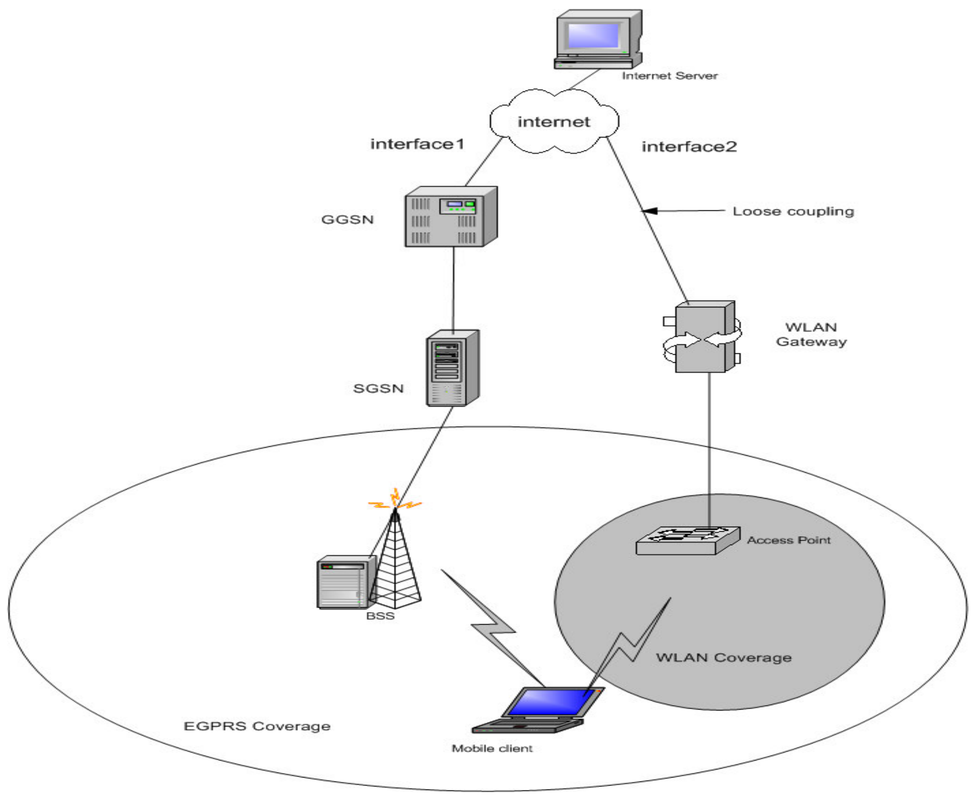

Figure 6.. Simulated scenario for EGPRS/WLAN handover.

Table 1. Transmission parameters change.

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

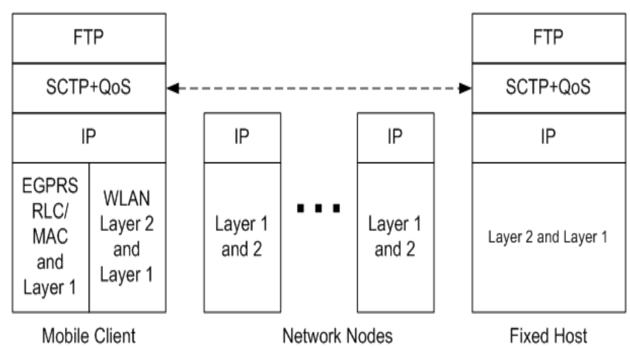

Figure 7.. Protocol Architecture.

Third scenario: EGPRS/WLAN data handover

Here we consider an inter RAT handover: data handover from EGPRS cell to WLAN (Figure 6). Protocol architectture for different simulated nodes is given by Figure 7. Parameters for EGPRS cell are the same as the previous studied scenario, we consider that the quality is decreased over the EGPRS cell, controlled by the BLER.

Over WLAN (Wireless Local Area Network) radio interface we consider a two ray ground propagation model that considers both the direct path and a ground reflection path. For the EGPRS/WLAN handover we consider a loose coupling approach that the WLAN gateway does not have any direct connection to EGPRS network elements. WLAN traffic would not go through EGPRS core network. We suppose that the fixed host is multihomed where each interface corresponds to different radio access technology. The Mobile host isn't multihomed.

SIMULATION RESULTS AND PERFORMANCE EVALUATION

First scenario: intra-RAT (EGPRS technology) data handover without variation of coding scheme

Performance evaluation of Qos_Measurement_chunk mechanism is studied in the following, at the SCTP level and at the RLC/MAC level. In the following we present only SCTP level parameter variations.

By comparison with the standard SCTP with multihoming feature, we notice that the throughput of the proposed extension is higher which is illustrated by the evolution

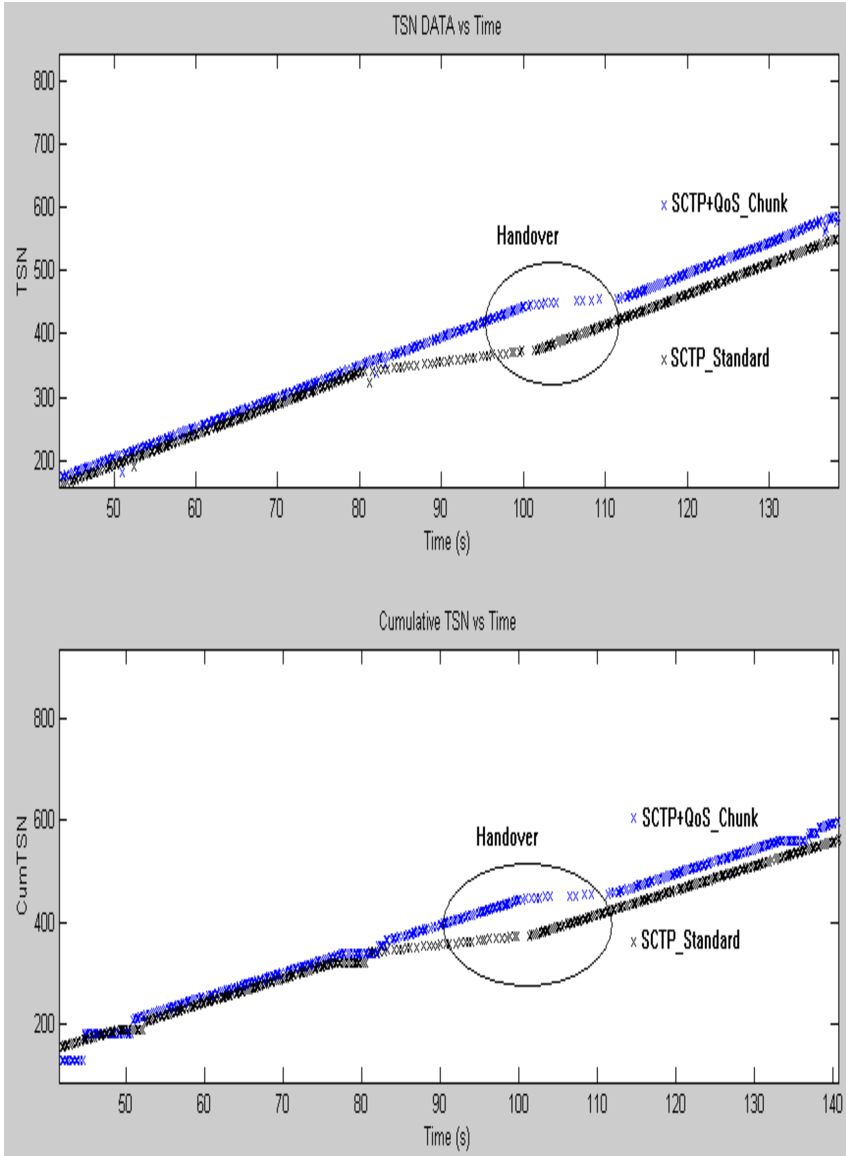

Figure 8 SCTP TSN variations

of the TSN given in Figure 8 . This result is confirmed by the cwnd variation given by Figure 9. The modification introduced to SCTP protocol, suggested by this work, is useful for a better adaptation of the transport protocol to radio environment. SCTP with its multihoming feature ensures better performance for data handover. The addition of a new chunk type (QoS_Measurement_chunk) makes the possibility to adapt the variation of cwnd according to the radio conditions. With QoS_Measurement_chunk procedure, we adapt cwnd and thus transmission flow to the radio environment conditions. The association does not execute slow start as the case of standard SCTP which slowed down the transmission rate. With QoS_Measurement_chunk a data radio handover is performed better than the case of ordinary transport protocols, which is proved in this scenario and in a homogeneous radio access technology. This feature will be particularly interesting in heterogeneous radio access technologies where we will have different radio quality parameters and which is explained in the third scenario.

Second scenario: Intra-RAT(EGPRS Technology) Data Handover with variation of coding scheme

Now we present some simulation results that compare the performance of SCTP standard with SCTP QoS_Measurement_Chunk extension. Figures 10 and 11 present the evolution of the sequence number on RLC/MAC blocks for standard SCTP and the proposed extension. Figures 10 and 11 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

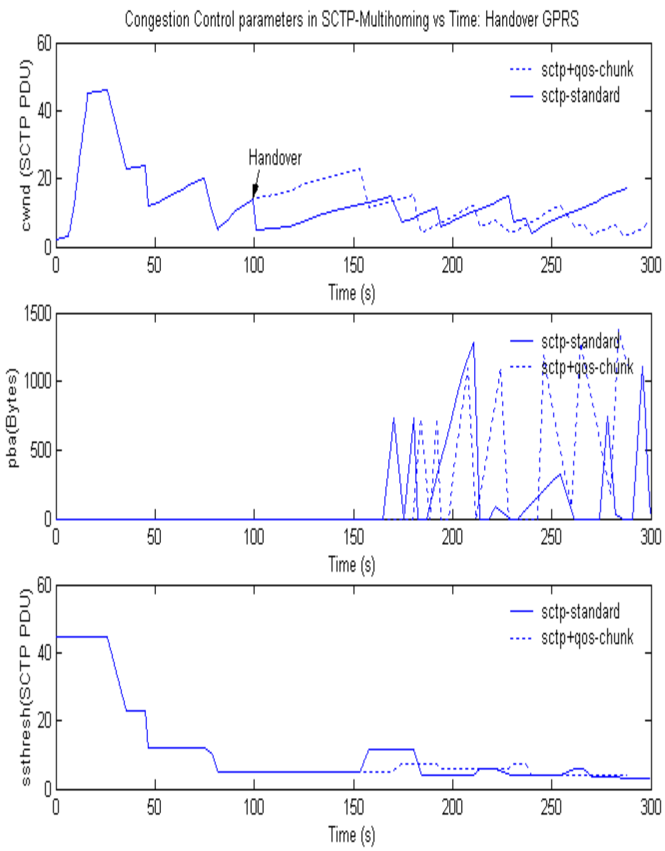

Figure 9. Congestion control parameters.

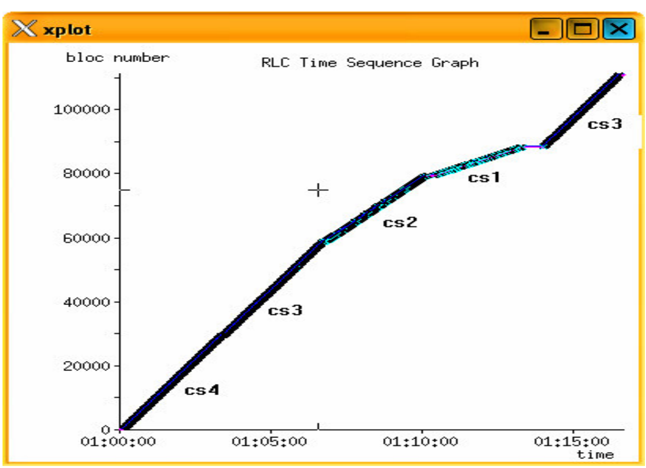

Figure 8. RLC/MAC sequence number variation for standard SCTP

connection to the new cell. For the standard SCTP with the multihoming we notice that when changing from CS3to CS2 we have a little transmission cut 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 which transmission conditions change.

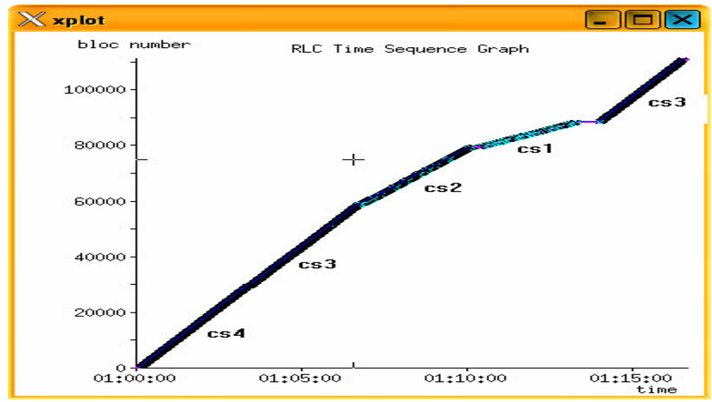

Figure 9. RLC/MAC sequence number variation for SCTP with QoS_Measurement_Chunk.

This trend confirmed by the evolution of TSN given by Figure 12 and 13 for standard SCTP compared to SCTP with QoS_Measurement_Chunk. That explains that the evolution of cwnd (vs. Figure 12) is better for the proposed extension and that the throughput increases also more rapidly for the proposed extension. The present simulation scenario addresses the performance issues raised by transmission data conditions variation on the radio interface at the SCTP level. We note that QoS_Measurement_Chunk serves to inform the network about the state of the radio link. Here 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.

Third scenario: EGPRS/WLAN data handover

The IEEE 802.11 WLAN can offer high bandwidth user access, and is envisioned to interwork with EGPRS cellular network to provide better data services to mobile clients. Here we present the simulated results of data handover between EGPRS and WLAN with the proposed scheme compared to the standard SCTP. We consider that both the mobile client and the fixed host are assumeed to implement SCTP with QoS_Measurement_Chunk. The mobile client supports both EGPRS and WLAN at the physical and data link layers. The fixed host is implementing SCTP multihoming feature that each interface corresponds to a type of radio access technology. The mobile is single homed during the overall communication, it provides only one IP address to support handover. The handover is initiated and controlled by the network. Figure 14 represents the evolution over time of the congestion control mechanism for the SCTP proposed extension compared to the standard SCTP. The results show that the proposed extension performs better at transport layer that after handover the cwnd increase continuously without restart with slow start as the case for standard

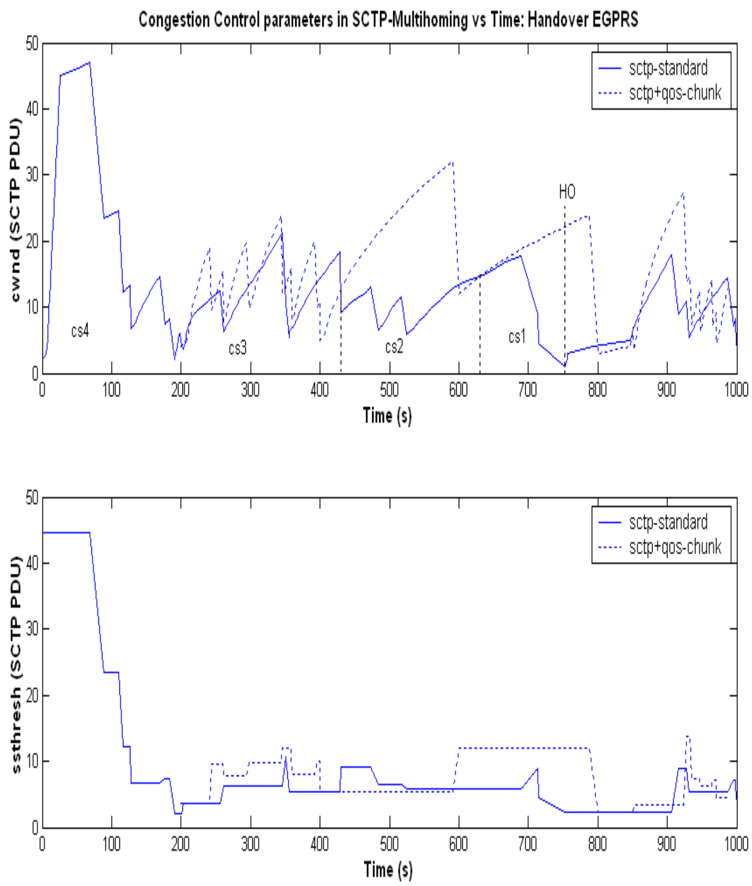

Figure 10. Congestion Control parameters for Standard SCTP compared to SCTP with QoS_Measurement_Chunk.

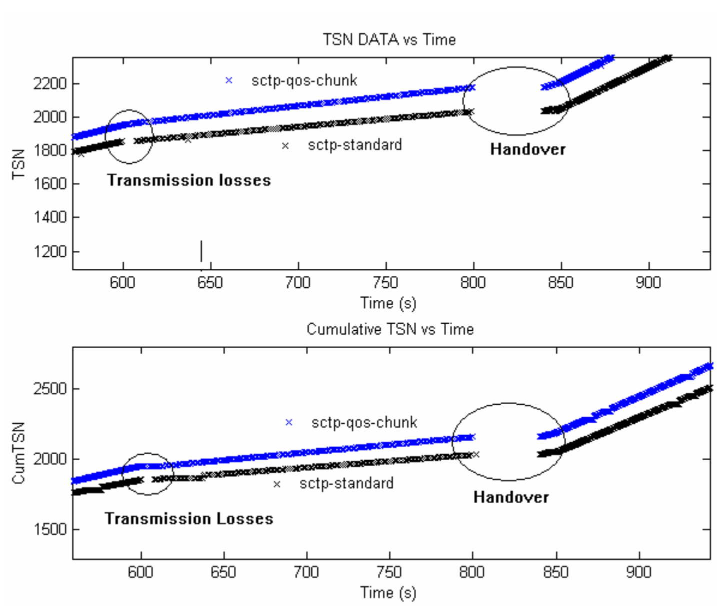

Figure 11. Variation of TSN and CumTSN with Standard SCTP compared to SCTP with QoS_Measurement_Chunk.

for standard SCTP witch supports the normal evolution of the communication and the improvement of the reception quality. For the proposed extension the throughput increases more rapidly than the standard SCTP.

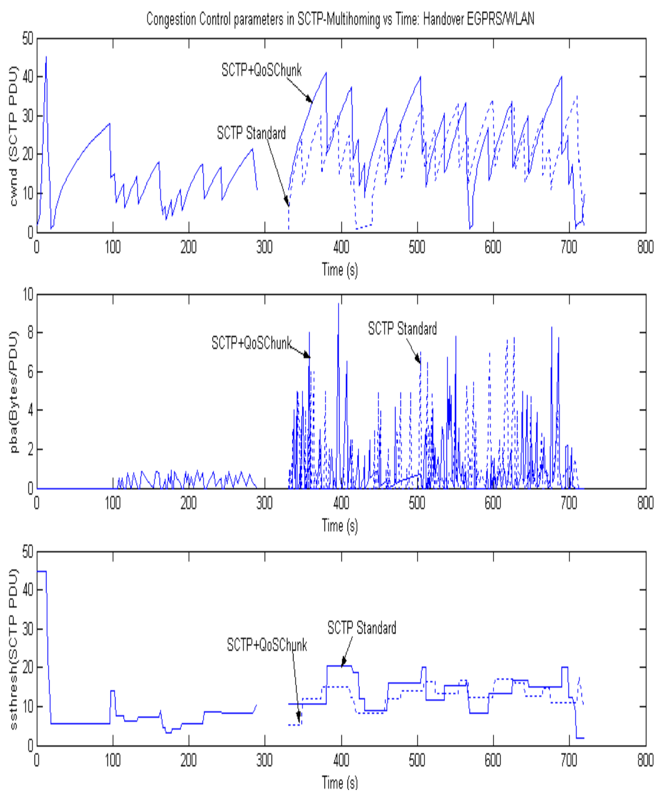

Figure 12. Congestion control parameters in the case of EGPRS/WLAN handover.

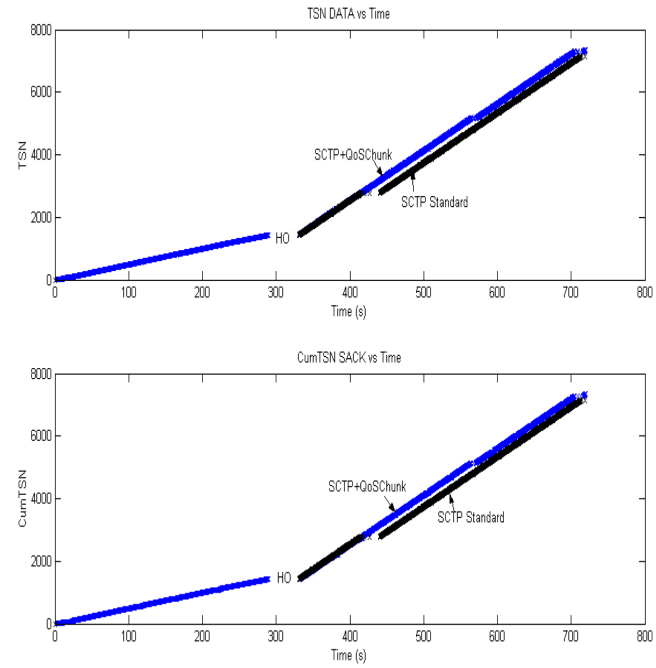

Figure 13. SCTP TSN variations.

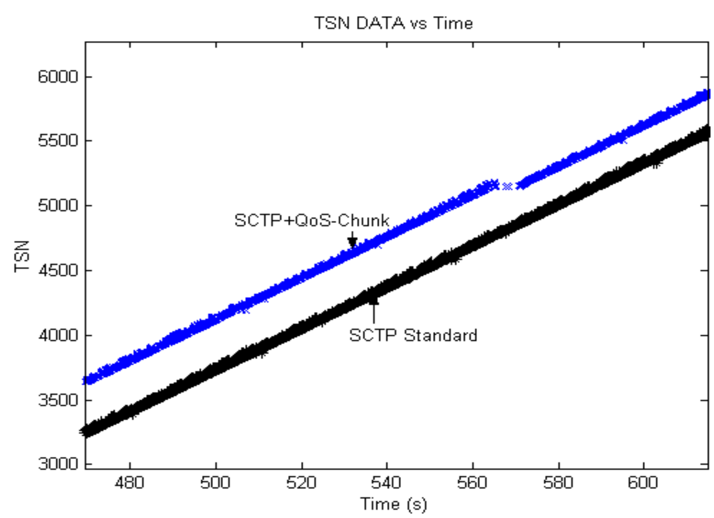

Figure 14. SCTP TSN data variations after Handover.

Figure 15 shows the evolution of the transmission sequence number of the transmitted data chunks. We can see that SCTP with QoS_Measurement_Chunk performs better than the standard SCTP, it provides a higher throughput. Just after the link switching the standard SCTP trigger more retransmissions than the proposed extension in order to rebuild the gaps caused by the quality degradation over the EGPRS link and the setup of a slow start phase (Figure 16), the cumulative TSN curve shows the reception of duplicate TSNs which triggers a Timer expiration and so a setup of slow start phase (Figure 14 at 415 s). In the case of SCTP with QoS_Measurement_Chunk, we have no timer expiration because the sender transmits continuously without losses and so the losses over wireless link are independent of congestion over the wired link.

Simulation results show that SCTP with QoS_Measurement_Chunk performs better than standard SCTP. The proposed modification proposed, is useful for an adaptation of the transport protocol to the radio environment. SCTP with its multihoming feature ensures data handover, with the addition of a new chunk type (QoS_Measurement_chunk control). This allows adapting the variation of cwnd according to the radio conditions. The association does not execute slow start as the case of standard SCTP which slows down the transmission rate. QoS_Measurement_Chunk procedure allows data handover to be performed better than with ordinary transport protocols within a homogeneous radio access technology. This will be even more interesting in heterogeneous radio access technologies with different quality parameters as we have seen the results above. The introduced SCTP modification allows to perform data handover inter RAT in B3G networks.

Conclusion

In this paper a new extension is proposed to SCTP based on multihoming feature and mobility aspect coupling. QoS_Measurement_Chunk is an approach that aims to improve transport layer performance in radio environments. This solution is based on the proposed alternatives with mSCTP, cSCTP or with the idea of GLL. The proposed changes in SCTP congestion control algorithms are based on radio measurements given by the mobile to the core network through QoS_Measurement_Chunk control chunk. This new feature is useful to carry out inter-RAT handover. Simulation results show that SCTP with QoS_Measurement_Chunk is more efficient than the standard SCTP. SCTP with its multihoming feature plus QoS_Measurement_Chunk ensures either the intra or inter RAT data handover with minimal losses. In fact, changes in cwnd conditions are suitable for transmission on radio interface. SCTP association does not begin with slow start after executing a handover as in the case of standard SCTP, which slows transmission speed. Our approach allows better management of data handover with usual transport protocols, both in the case of a homogeneous radio access technology, as in the case of heterogeneous radio access technologies involving different quality of service parameters.

In the modification outlined in this paper, we considered a simple relationship of changes in congestion control settings due to radio interface transmission conditions change (either on the primary link with the serving cell or following a handover). In future work we propose to establish relationships that offer the possibility to elaborate analytical functions which express transport layer throughput depending on link layer throughput. This allows us to express congestion control window size depending on RLC / MAC throughput and so developing a cross-layer, transport/link layers, in order to provide real interacttions between independent layers in wireless/mobile networks.

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