# A functional S-/T- UMTS Testbed for QoS-enabled IP Multimedia Services

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**ABSTRACT**

The IST FUTURE project aims at adopting recent advances in the Internet arena by exploring applicability of native internet protocols (in accordance with IETF multimedia data and control architecture) in a terrestrial and satellite UMTS integrated system. This achievement will be demonstrated with two kinds of experiments; SIP based IP multimedia services and QoS provision in S-UMTS.

This paper describes the FUTURE demonstrator architecture, drawing particular attention to the foreseen experiments. For each one of them, a general description of its architecture is presented, which is followed by the progression of the experiment.

## I. INTRODUCTION

In order to find out key functions of the full IP based target UMTS, the FUTURE project is investigating the applicability of real-time UMTS multi-media services and applications in an integrated UMTS environment among terrestrial and satellite systems. As a result of this investigation, two types of demonstration will be performed; Demonstration of optimized multi-media communication and information services based on the *Session Initiation Protocol* (SIP) and the appropriate and efficient adaptation of *Quality of Service* (QoS) parameters of IP based multi-media UMTS services. Thereby the demonstrator consists of several HW devices for emulating the real network elements such as the physical emulator, the TE (Terminal Equipment), the MT (Mobile Termination), the GW (Gateway), the CN (Core Network) which partly implement UMTS functionalities and are adapted to FUTURE specific functionalities required for demonstrating the desired experiments.

The main objectives of this paper are to introduce the implementation details of the FUTURE demonstrator, i.e., how the physical demonstrators have been built up for showing the highlighted performance of each experiment, and to illustrate the progression of the experiments, i.e., in which way the demonstration will be performed. In the next clause, the description of the overall demonstrator architecture is introduced, among which components the physical emulator is further detailed for a better understanding of the reality-near environment that has been set up. The explicit progressions of each experiment follow in clause IV while our conclusions are presented in clause V.

## II. FUTURE Demonstrator Architecture

The Future Demonstrator physical architecture is illustrated in Figure 1. As it can be seen, it is composed of the *Bearer Level Demonstrator*, which incorporates both Access and Non Access Stratum (NAS) functionality, and the *Application Level Demonstrator* that is comprised of the PCs running the applications and the Future IP Multimedia Subsystem. As for the Bearer Level Demonstrator, it consists of the two user PCs (MT User #0 and #1), the Satellite and Terrestrial PLSEs and the network PC (incorporating Gateway and Core Network functionality). While the Satellite QoS experiment only requires the satellite part of the Bearer Level Demonstrator, the terrestrial modules (T-RLC, T-MAC, T-PLSE) and the Application Level Demonstrator serve the 'IP Multimedia Services' experiment as it will described in a following section. The MT User PCs and the T-PLSE are connected to an Ethernet HUB on the user side whereas the network PC and the T-PLSE communicate via an Ethernet HUB on the network side. The satellite communication paths between the two users and the gateway pc are achieved through RS232 data interfaces.

At the user side, the MT User PCs contain NAS functionality (e.g. Session Management), radio resource control (RRC) functionality, as well as modules carrying out RLC and MAC functionality (segmentation and multiplexing of packets). Likewise, at the network side, the radio functionality (RRC, RLC and MAC) as well as the NAS functionality resides at the network PC. The physical layer simulator elements (PLSE) act as the link between the user side and the network side and implement the physical layers of both user and gateway parts.

The FUTURE Bearer Level Demonstrator allows for the establishment of 14 bi-directional, QoS enabled, logical channels per user enabling as well their modification and release. Moreover, it provides for the establishment of one downlink multicast logical channel (to one or both testbed users), which is carried over the FACH or DSCH transport channels.

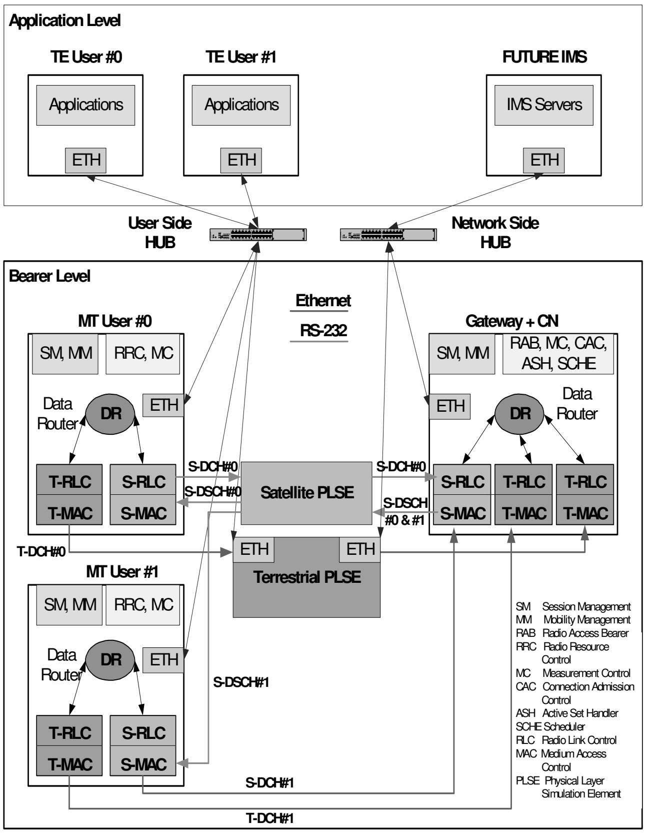


**Figure 1: FUTURE demonstrator architecture**

## III. Physical emulator architecture

The FUTURE UMTS physical emulator test bed is formed by two different units, one for the satellite (S-UMTS) and one for the terrestrial segment (T-UMTS). The test bed has been realized using several personal computers and specialized hardware, hosted in three racks.
The S-UMTS physical layer unit allows a real time emulation of two complete links between a Gateway Emulator and two Mobile Terminals which comply with the SW-CDMA. The transport channels that are emulated by the S-PLSE are:

- FACH (3.8 Kbits) and DSCH (64 or 128 Kbits) on the downlink for both users, and
- DCH (128 Kbits) on the uplink for user #0,

while the return link of user #1 is virtual.
The T-UMTS physical layer unit allows a real time emulation of one user at 384 kbps in downlink and 128 kbps in uplink. Both segments have interference signal generators and dynamically controlled channel simulators.
In Figure 2, the emulator's general architecture is illustrated. In what follows, a description of the main emulator subunits is given.

## Satellite segment emulator

***Gateway Modem Assembly*** (GWA) comprises the following units.
-*Gateway Modulator Generating Signal Unit* (GWGSU) is in charge of generating the primary channel and two traffic channels of forward link (FL) for two Mobile Terminals. This unit also supports FL power control, by varying the transmit power in accordance with incoming setting commands.
-*Gateway Interference Simulation Unit* (GWISU) is in charge of generating interference signals (IS) for the 2 satellites.
-*Gateway Modulator Combining Signal Unit* (GWCSU) produces for each satellite the replicas of the ISs required by the beam configuration. This unit also implements the variable attenuation to reproduce the current path loss for each down-link beam, and finally combines useful signal and ISs into a single flow per satellite.
-*Gateway Demodulator Unit* (GWDU) is in charge of multi-finger demodulation and combining of return link (RL) signals for one user.
-*Mobile Terminal Interference Simulation* Unit (MTISU) is in charge of generating an IS allowing to realistically simulate the presence of other system users in the RL.

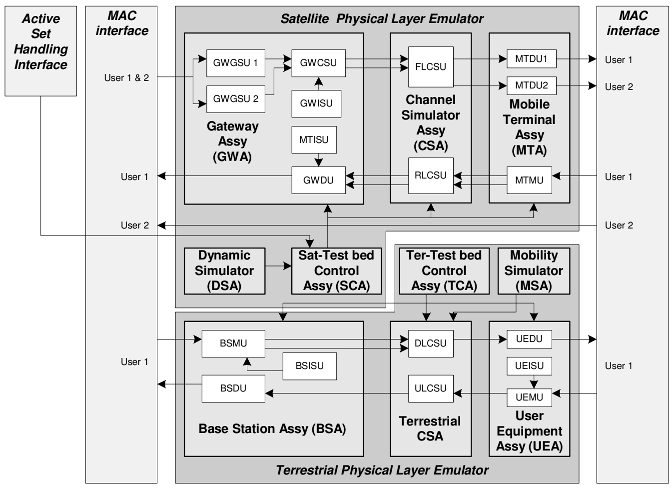


**Figure 2: FUTURE Physical emulator architecture**

***Channel Simulator Assembly*** (CSA) comprises the following units.
-*Forward-link Channel Simulator Unit* (FLCSU) is in charge of reproducing for the two satellites, the effects occurring in a real transmission channel: path loss variations, path delay, doppler frequency shift, fading, shadowing and thermal noise.
-*Return-link Channel Simulator Unit* (RLCSU) is performing, for the return link, similar functions to those of the FLCSU.
***Mobile Terminal Assembly*** (MTA) comprises the following units:

-*Mobile Terminal Demodulation Units 1 & 2* (MTDU1/2) are in charge of multi-finger demodulation & combining the FL signals for two collocated users.
-*Mobile Terminal Modulator Unit* (MTMU) is in charge of generating the RL signals. The MTMU supports RL power control. The RL of the second user is virtual (i.e. directly connected with the GW via Ethernet).
***Satellite Controller Assembly*** (SCA) configures and monitors all the satellite subunits. In particular, it dynamically updates the channel simulator (CSA) parameters on the basis of the Dynamic Simulator (DSA) and of the Active Set Handling module inputs.
***Dynamic Simulator Assembly*** (DSA), once a satellite constellation and a system configuration has been selected by the operator, generates and delivers in real-time to the SCA the information needed for varying the test-bed configuration and parameters, such as to reflect the status of the links of the time-evolving constellation.

**Terrestrial segment emulator**

***Base Station Assembly*** (BSA) comprises a *Base Station Modulator Unit* (BSMU), a *Base Station Demodulator Unit* (BSDU) and a *Base Station Interference Simulator Unit* (BSISU), with the same functions of the corresponding satellite sub-units, where the two satellites links are replaced with two base stations.
***Terrestrial Channel Simulator*** (T-CSA), formed by two sub-units for the down link (DLCSU) and the up link (UPCSU), simulates two base stations direct paths and six reflected paths. The paths and their parameters are dynamically selected and updated by the MSA. Shadowing and thermal noise are also simulated.
***User Equipment Assembly*** (UEA) includes an *User Equipment Demodulator Unit* (UEDU), an *User Equipment Modulator Unit* (UEMU) and an *User Equipment Interference Simulator Unit* (UEISU), with similar functions of the correspondent satellite sub-units.
***Terrestrial Controller Assembly*** (TCA) configures and monitors all the terrestrial subunits.
***Mobility Simulator Assembly*** (MSA), once a configuration of base stations and reflectors is selected, it simulates a random user terminal trajectory with a programmable speed. The best direct and reflected path is dynamically selected and the T-CSA parameters are updated.

## *IV. Progression of FUTURE experiment*

### *A. QoS in S-UMTS*

Prior to the execution of the QoS experiment, a number of relevant system parameters and configuration data for the different modules need to be setup. Among others, this includes: thresholds for the CAC algorithms, maximum transmit power at the gateway and mobile terminals, orthogonality factors or average interference power.
The first action to be executed in the experiment is the setting up of a connection; this is a PDP context, destined to carry the data of a certain application. This is done by means of a graphical interface called Application Launcher (see Figure 3) which enables the user to define the QoS parameters (Traffic Class, Guaranteed Bit Error Rate (Uplink and Downlink), Error Rate, Delay and Priority) and the intended segment (Satellite for QoS trials), to trigger the PDP Activation procedure and, upon success, to initiate the desired application to be supported by the established channel. The PDP Activation procedure involves the Session Management (SM) modules at user and network sides and the RRC layer (RRC user module and RAB gateway module): the PDP activation request message is transferred by the RRC layer from the terminal towards the Core Network, which asks the RAB for the establishment of a radio bearer with the required quality parameters. The RAB, in turn inquires the Connection Admission Controller (CAC) about the feasibility to support the connection in the current state of the radio interface.

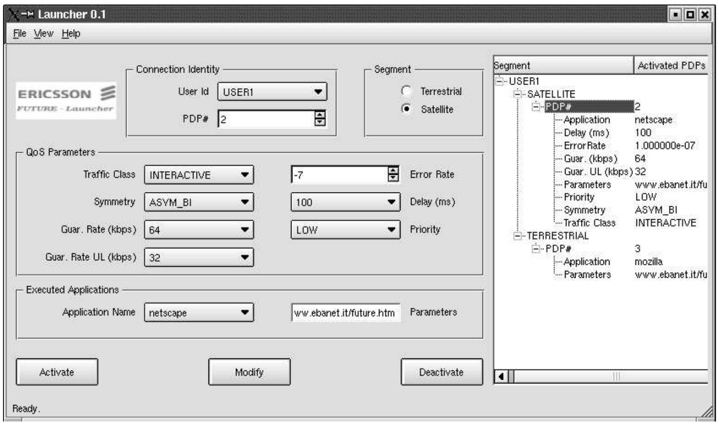


**Figure 3: FUTURE Application Launcher**

The CAC bases its decision on radio measurements (power levels, interference etc.) stored in a database managed by a so called Measurement Controller (MC), as well as on a capacity planning function provided by the DSCH Scheduler (SCHE), performing a mid-term simulation of the averaged traffic presently served in order to estimate the resources left for the new connection. Assuming a positive result of the admission procedure, the RAB proceeds to configure the appropriate modules at both user –through its RRC connection– and gateway sides to support the connection: it assigns logical queues to carry application data, it informs the Scheduler of the QoS treatment for the new queue, it updates if needed the power control modules with a new bit-energy-to-noise-plus-interference (Eb/No) target, it instructs Data Router (DR) modules to process correctly the established QoS flow and finally stores the connection parameters in the database. The response is given to the SM at the Core Network that in turn informs its peer module at user side of the PDP activation result.

Once a data path provided with proper QoS guarantees has been established, the application can send/receive data to/from the UMTS network. Thus, the packets originated at user side (either at the "MT User X" PC or at an external

PC) are captured by the Data Router, identified as belonging to an established QoS flow by checking the IP header (ports, addresses and level-4 protocol) and injected into the proper queue towards the user scheduler.

A brief description of the downlink scheduling operation follows (see Figure 4). Asynchronously, the DR fills the terminal logical channels with IP packets (each channel corresponds to a specific user application); at the same time, via the MR synchronization signal, every TTI the physical layer asks GWDIU a message in the format reported in Figure 5.

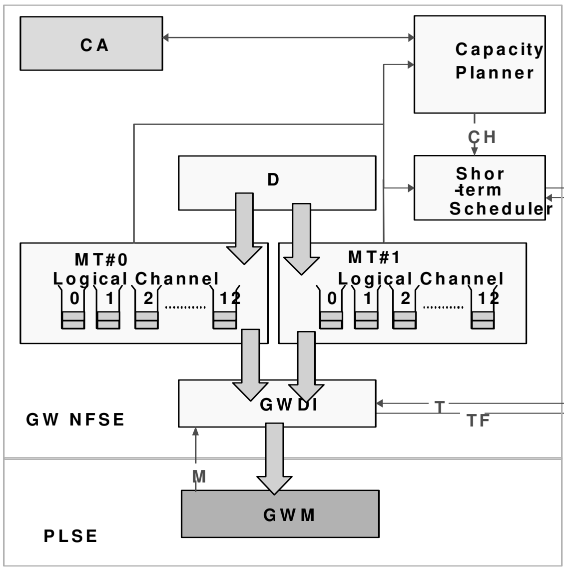


**Figure 4: Interaction between FUTURE Scheduler and MAC (downlink).**

To elaborate this message, the GWDIU asks the Scheduler to select both the channels from which data packets are to be picked for transmission and the best TF to be used to form PDUs. In FUTURE the downlink channel (DSCH section) can be used in two basic modes: either dedicated to one user only (full-rate mode, 5120 bits per TTI), or shared between the two users (half-rate mode, 2560 bits per user/TTI).

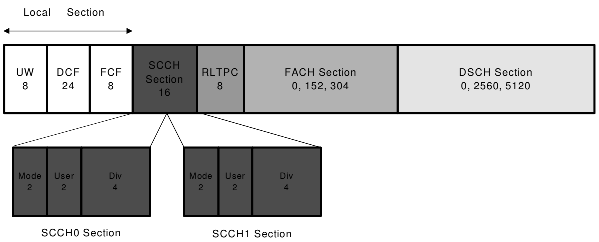


**Figure 5: Message format in the interface I-14D**

Deciding the mode is the task of the Capacity Assignment, which communicates it to the Scheduler via the CHS signal and fills both mode/user parts of the SCCH section. Based on this information and on the main characteristics of each active connection in terms of guaranteed bit rate, priority and delay (obtained from CAC) the scheduler computes the TF. (In downlink, the TF assignment is subject to limitations since there is no standard mechanism to enable the usage of distinct TFs within a TTI). Subsequently, proper segmentation, concatenation and padding procedures are carried out by the GWDIU to fill up the DSCH section with the PDUs.

Based on scheduler provisions, proper segmentation and multiplexing is carried out at RLC and MAC layers.

As for the maintenance of the ongoing connections at radio level, physical channels are power controlled: open-loop power control for the PDSCH on the downlink and closed-loop power control for the DPCH on the uplink. In addition, an Active Set Handler (ASH) module manages the downlink satellite diversity, attempting to enhance the downlink reception conditions of the mobile terminal.

In order to support the operation of several modules (CAC, ASH, SCHE, power control), radio measurements are continuously executed by the PLSE, passed to the Measurement Controllers –at user and gateway sides–, properly processed, stored in the Gateway database and distributed to the interested modules according to their particular needs such as timing or delivery-style (periodic, on demand or event triggered). In addition to radio measurements, the real time QoS parameters of the active connections are continuously acquired by the MCs, so that whenever the system fails to meet the requirements of a given connection, the RAB is informed so as to take corrective actions.

Each of the testbed users can activate up to 12 bi-directional connections to carry their application data plus one multicast downlink connection that can be associated to one or to both users. Obviously, they are also able to deactivate (PDP Deactivation) and even modify the QoS (PDP Modification) of ongoing connections through the Application Launcher. Two signaling connections are permanently configured for each user: one to carry RRC PDUs and another one to carry measurement reports and requests between user and network.

*B. SIP based IP multimedia service*

For evaluating the FUTUTRE IMS (IP Multimedia Subsystem), the following services are foreseen [1].

- 3$^{rd}$ Party Call Control
- User Initiated Session Modification
- Location Based Service
- Context Awareness of Application Service
- Presence Service
- Telelearning Service

In this paper, only the progression of the implemented telelearning service is presented due to the limited paper volume.

*B.1 Telelearning Service*

The Telelearning Service comprises a Multicast service with which a group of users has the possibility, to follow a

lesson (video + audio) and to interact with the teacher (i.e. to pose questions).
In order to efficiently use radio resources, the communication path from the teacher to the students is performed via multicast operation and therefore the S-UMTS segment is used (broadcast mode of the USRAN test bed). Each of the students must be a member of the multicast group used for the Telelearning service.
In addition, separate individual connections from each of the students back to the teacher are employed. This service is based on the usage of SIP signaling.
The telelearning service design foresees the following steps:

1. Session announcement
2. Session registration
3. Session initiation
4. During session
5. Session closing

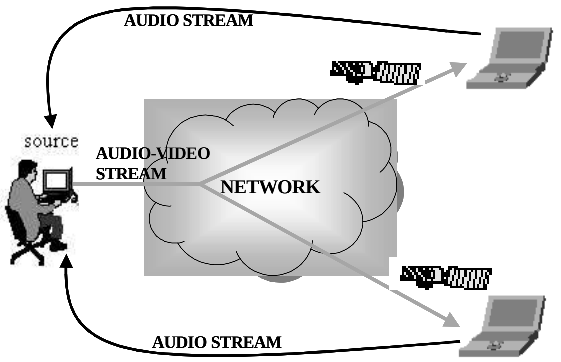


**Figure 6: Telelearning scenario - FUTURE**

***Session Announcement***
An Advertisement is sent to all users who have subscribed at the FUTURE IMS, independently if they are registered or offline. The technical approach is the following: the teacher sends a single e-mail (Info of Lesson, URL) to the IMS FS (Feature Server); this e-mail is sent to all the subscribed users of the IMS. The message contains an URL to a certain web page for registration.
***Session Registration***
Concerning the session registration, a short premise has to be done: users use a Laptop as a Terminal and a proper web page for registration has been implemented. Keeping into account this scenario, each user connects to the web page (on the FUTURE Web-Server as part of the FS) using a WEB-Browser. He or she has to enter his user information (name, SIP address, etc.) at the lesson(s) he/she will participate. The registration may also be done independently of the session announcement.
***Session Initiation***
For the session set-up three different solutions have been analysed:
1.The teacher sends an INVITE SIP message to all registered students. The disadvantage of this solution is that the teacher has to know the SIP addresses of all users in advance (e.g. by interrogating the data base using a web-page) and he has to set-up multiple sessions on his own.
2. A web page is available for the teacher who is able to activate the 3PCC [2] service by a simple click. In other words, the teacher activates the 3PCC service (all of the details of the registered students are already available) and the sessions are set-up by the 3PCC service.
3.The FS set-up session on a specific time automatically (i.e. the teacher has to be ready to accept the session)

After a deep analysis it has been decided that in the FUTURE demonstrator the second proposed option will be implemented. As a precondition for the session initiation, the Teacher as well as the users have to be registered at the IMS to be able to accept the INVITE message.
***During Session***
After the session set-up students will join the ongoing lesson. In principle, the possibility that the teacher invites additional students during the lesson may be considered, but it will not be implemented within FUTURE. The lesson is performed through the Distribution of Audio-Video via multicast. The questions from students to teacher are sent via unicast using messaging and the questions may be answered by the teacher via the multicast (reading the questions and providing soon the answer) or by the teacher via unicast (also in this case messaging will be used).
***Closing Session***
Concerning the session closing, there are two actions that maytake place: the teacher closes the whole session or each student may leave the session individually.

## V. CONCLUSIONS

In this paper, we have represented the implementation details and the experiment progression, which will be performed under the T-/S-UMTS integrated environment in the scope of the FUTURE project.
We are currently at the final stages of implementation of the FUTURE test bed for demonstrating QoS in S-UMTS and SIP based multimedia service experiments. Its evaluation and validation through demonstration results in several trial cases (configuration scenarios), i.e., with several kinds of applications, LEO/GEO satellite constellation etc., will follow.

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