IST VIRTUOUS Project – Integration of GPRS, T-UMTS and S-UMTS

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Abstract: *The VIRTUOUS project is an IST project. It primarily investigates integration of the three segments of future mobile communications: GPRS, terrestrial UMTS and satellite UMTS. Main VIRTUOUS project objective is to design, develop and implement a test-bed where specific functionality of GPRS, T-UMTS and S-UMTS are integrated. On such a test-bed, two types of experiments are foreseen: Inter-segment roaming and Quality of Service experiments.*

I – Introduction

The VIRTUOUS project belongs to the IST project group funded by European Commission. The project has started on 1/1/2000 and will end on 1/7/2002. The project primarily addresses the following topics of the IST framework:

- **Network integration, interoperability and internetworking:** VIRTUOUS is expected to provide contributions to this action, since one of the key objectives of the VIRTUOUS project is to develop interworking procedures among 2nd generation (GPRS) and 3rd generation (Terrestrial-Satellite-(T-S)-UMTS) Access and Core Networks and interworking among T-UMTS and S-UMTS networks. The developed and experimented procedures will carry into effect the VHE (Virtual Home Environment) concept.
- **Engineering of intelligent services:** VIRTUOUS will address the problem of providing services across heterogeneous networks (i.e. 2nd and 3rd generation terrestrial and satellite networks). In this respect, service negotiation, quality assurance and management in an heterogeneous network will be key issues.
- **Terrestrial wireless system and networks:** VIRTUOUS is expected to provide major contributions to this key action, since it is expected to develop and experiment (i) meaningful functions of the RTI (Radio Terminal Independent) and RTD (Radio Terminal Dependent) parts of the URAN (UMTS Radio Access Networks), (ii) appropriate Inter Working Units (IWUs). The equipment to be used will deal with fundamental wireless system procedures such as resource management, flow control, signalling, QoS adaptation, intelligent mobility (roaming), etc…
- **Integrated satellite systems and services:** VIRTUOUS will contribute to the development and experimentation of the S-UMTS standard proposed by the European Space Agency (ESA). Moreover, VIRTUOUS will integrate the S-UMTS in the URAN; this means that a common RTI part between S-UMTS and T-UMTS will be developed. Finally, VIRTUOUS will cope with the problem of interworking a satellite system with the terrestrial networks (inter-segment mobility procedures, inter-segment QoS adaptation, etc.).

Moreover VIRTUOUS will facilitate the introduction of Terrestrial/Satellite - UMTS by:

- drawing and demonstrating a viable migration path from second to third generation systems,

- introducing UMTS functions in a modular, flexible and scalable way,
- sponsoring and demonstrating the S-UMTS standard sponsored by ESA,
- designing and demonstrating interworking procedures among second-third, terrestrial-satellite, Access-Core Networks,
- experimenting attractive UMTS services.

The team is composed of the different type of companies (manufacturers, operators, research bodies, engineering companies, universities) :

Italy	Telespazio
Italy	Space Engineering
Austria	Siemens Austria
France	Thomson
Italy	University of Rome
Germany	Aachen University of Technology
Switzerland	Ascom
Italy	European Business Associates
Spain	Telefonica
Italy	CSELT

II – Project Objectives

Main VIRTUOUS project objective is to design, develop and implement a test-bed where specific functionality of GPRS, T-UMTS and S-UMTS are integrated. On such a test-bed, trials of meaningful UMTS service can be performed.

As components of this test-bed, a RTI and a separated RTD parts of a URAN, are to be designed, developed and implemented, having as result a hardware emulator representative of satellite and terrestrial UMTS protocol layers. This separation is made in terms of decoupling control and transport functions. As part of the test-bed, GPRS segment elements are provided. Additionally, IWUs necessary to complete the architecture will be designed and developed.

The integration of the test-bed will be done in terms of identifying, designing and demonstrating a feasible, pragmatic and smooth migration path towards T-S-UMTS. The migration path is being identified taking into account current standardisation activities and other UMTS related projects.

In a fist migration step, an URAN is being gradually introduced providing real UMTS access. The RTI and RTD URAN functionality and features are still limited. Under these restrictions, the URAN is used to enhance second generation capacity and to provide 3rd generation mobile users higher bit rate access and a limited set of services. In order to guarantee the interworking between UMTS and GPRS, an IWU is placed on the terminal side. The VIRTUOUS project test-bed is built from the conclusions reached during this fist step and consequently will serve to trial a limited set of UMTS features.

In a second migration step, the URAN RTI and RTD parts as well as the Core Network (CN) will be upgraded in order to encompass the whole set of UMTS functions and features. This will allow the deployment of the full set of UMTS services.

Each study or activity carried out under VIRTUOUS project is being done following standardisation bodies publications, in such a way that the test-bed and trials will support standards activity results. Also, VIRTUOUS project will contribute to the S-UMTS standardisation process by an evaluation of the S-UMTS standard proposed by ESA. Within the project lifetime neither a satellite constellation offering wideband support capabilities nor a real terrestrial UMTS network, would be available. The emulation was proposed as an available recourse to provide both satellite and terrestrial RTD access parts. An adaptation of a physical layer emulator based upon Satellite W-CDMA proposed by ESA as S-UMTS standard and the development of an unit able to support Terrestrial W-CDMA was proposed as VIRTUOUS RTD access part. With the trials to be performed within the project, conclusions to evaluate the feasibility of ESA proposal will be laid out.

III – Technical Approach and Demonstrator Description

Fig. 1 shows the VIRTUOUS demonstrator architecture. The VIRTUOUS demonstrator consists of:

- a second generation Access network, namely the *GPRS network*, which is, definitely, the most advanced of the 2nd generation systems since it supports packet oriented techniques and higher bit rates than basic GSM;
- two next generation access networks, namely the *W-CDMA based T-UMTS* ETSI standard and the *W-CDMA based S-UMTS* supported by ESA for standardization. In other words, the VIRTUOUS URAN consists of two RTD parts, i.e. of two segments (the former is W-CDMA T-UMTS based and the latter is W-CDMA S-UMTS based), and a common RTI part. In the figure the RTD parts are split in two sub-parts, i.e. the *Physical RTD* sub-part (including the physical layer Emulators) and the *Access RTD* sub-part (including MAC, segment-specific LLC and segment-specific resource management layers).
- an IP based LAN. This LAN is linked through 2G and 3G GGSNs to the UMTS CN (consisting, as for the VIRTUOUS demonstrator, of SGSNs, of GGSNs and of an HLR). The LAN includes one or more PCs which are expected to handle simultaneous connections with the Terminal Equipment (TE) in the multi-mode mobile.
- A multi-segment TE.

As for the two third generation Access Networks which form the VIRTUOUS URAN, they use the concept, already developed in the framework of the RAINBOW demonstrator system, of the splitting between RTD and RTI functions. The separation between RTD and RTI parts will be carried out following the indications provided by standardization bodies. In particular, the MAC layer functions, as well as the segment-specific Logical Link Control (LLC) and Radio Resource Control (RRC) functions are included in the *Access RTD part*. The RTI parts (both on the terminal and on the network side) will be common to both the W-CDMA satellite and the W-CDMA terrestrial links, while the RTD parts will be customized on the considered segment. In addition, the RTI parts will be designed so that additional possible RTD parts can be easily added.

As far as the terrestrial and the satellite *Physical RTD parts* are concerned, an hardware physical layer Emulator will be used. In this respect, two equipment are being developed for the terrestrial and satellite segments, respectively. Each equipment will include a Base Station, a wireless channel simulation (also including a mobility simulator), and a Mobile Terminal (MT). It is important stressing the fact that the two equipment reuse similar technology and are customized on the terrestrial and on the satellite links, respectively (so, for instance, two very different wireless channels will be considered).

Note that a real GPRS Base Station System (BSS) and MT will make part of the VIRTUOUS demonstrator. The GPRS BS and MT are linked via a *Fading Emulator* which takes into account the fading effects (attenuation, multipath, etc.).

As a matter of fact, it should be noted that the VIRTUOUS UE will be a steady equipment, since the GPRS, T-UMTS and S-UMTS terminals are physically connected to the relevant BSs. This fact, thanks to the appropriate channel and mobility emulators does not affect the result significance.
As far as the *RTI functions* are concerned, the lessons learned from the RAINBOW project will be reused. Nevertheless, the VIRTUOUS platform will be built according to a modular, easily scalable approach in which a rigid separation among control and transport functions will be performed.
The above-mentioned modular approach will permit to implement, in the first migration step, just some basic functions. The following step will just build over these functions, i.e. add further modules without redesigning the functions already implemented in the first step.

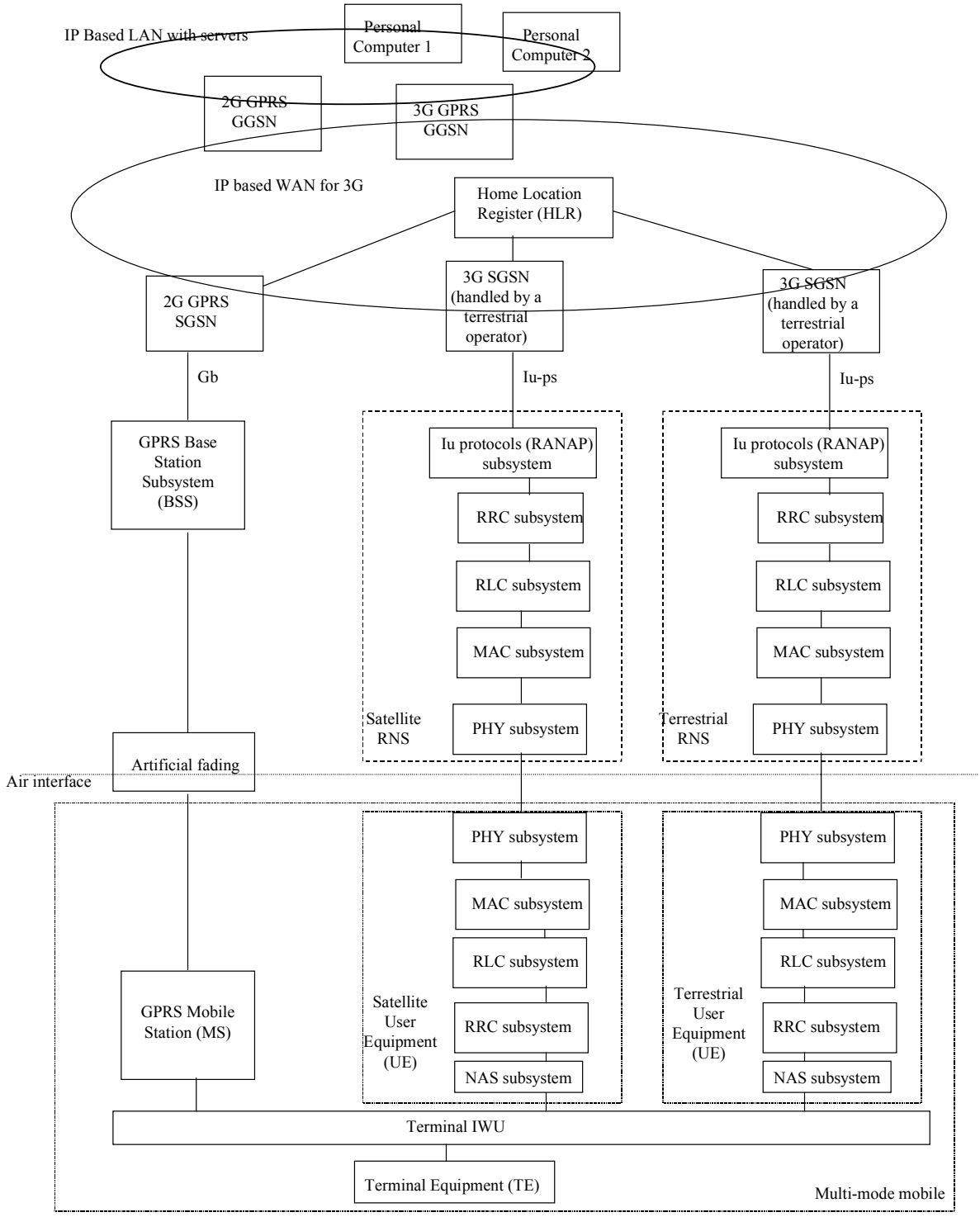

Fig. 1 - Reference Demonstrator Architecture

In general, in UMTS a one-to-one correspondence is expected between SGSNs and RNSs (in spite of the fact that specifications allow more than one RNSs to be linked to a single SGSN); in addition, terrestrial and satellite UMTS are expected to be handled by different operators, hence availing of different RNS equipment. For these reasons, two different RNSs and two different, separate SGSNs are considered for the satellite and the terrestrial segments, respectively. The two SGSNs are assumed to be both handled by a same operator (a terrestrial one). This assumption makes possible the sharing of a same HLR between the two SGSNs, as shown in Fig. 1. It is also assumed that the same operator

also handles the GPRS segment. Furthermore, in spite of the physical separation between satellite RNS and terrestrial RNS and between satellite UE and terrestrial UE in the Reference Demonstrator Architecture, the concept of the presence of common RTI functions still holds.

As a matter of fact, it is expected that, mainly due to the similarities of the satellite W-CDMA ESA proposal with the terrestrial W-CDMA UMTS standard, many functions will likely be the same both in the satellite and in the terrestrial segment. This fact should permit to reuse common software routines (possibly, with some parameter reconfigurations) both in the satellite and in the terrestrial RNSs, as well as both in the satellite and in the terrestrial UEs.

IV – VIRTUOUS experiments

In the scope of the VIRTUOUS project two types of experiments are foreseen:

- Inter-segment roaming and
- Quality of Service experiments.

These two experiments have been chosen because they cover a wide area of interesting questions to be investigated in future generation systems and in the same time they are achievable within VIRTUOUS time plan and equipment.

Inter-segment roaming experiment

The aim of the future systems and also of the VIRTUOUS demonstrator is that user can use all segments that are on disposal. One of the first steps is to be able to roam in all of the segments. This ability is known as Inter-segment roaming. It means that a user could be registered in his 'home segment', defined in Terminal IWU, but if necessary, in some circumstances, user could be registered in one of the other segments. It is to be stressed that all procedures dealing with Inter-segment roaming are 'off-line' i.e. there is no active connection with some other parties (user is in idle mode). For terminology clarification it should be mentioned that roaming means registration into the network which is not home network. In that sense Inter-segment roaming represents registration into one of the 'non-home-segments'.

This experiment could evolve as follows:

- The Multi-mode mobile is in the stand-by mode, being served by a certain segment, say the GPRS segment.
- The Terminal IWU of the stand-by Multi-mode mobile on the basis of the measurements received from the GPRS MS and from the terrestrial and satellite UE, decides, according to before defined criteria, that an other segment, say the S-UMTS segment, is more appropriate to serve the Multi-mode mobile.
- The Terminal IWU pushes the Satellite UE to trigger a location update procedure which updates the HLR. The new HLR entry corresponding to the Multi-mode mobile will include the address of the SGSN linked to the satellite RNS. This means that new possible connections will be set-up via the S-UMTS segment (the experiment is limited to the demonstration that the HLR is actually updated). In addition, the Terminal IWU has to push the GPRS MS to close its Mobility Management context.

QoS experiment

The QoS contract is a fundamental issue for the VHE concept in the future networks. VIRTUOUS will demonstrate some of the QoS guaranteeing provisions. In this respect, even the Inter-segment roaming experiment considered in the previous issue can be considered as a QoS guaranteeing provision. Nevertheless, the main goal of this experiment is demonstration of the Congestion Control.

The QoS experiment is limited and determined by the S-T-physical layer emulator. As this emulator supports only one user connection at the same time in each of the segments it is not possible to demonstrate QoS issues related to the larger number of users. On the other side the emulator emulates some kind of Dummy Traffic. The Dummy Traffic amount changes randomly in the time.

In this context it is to deal with Congestion Control on the user and/or base station (BS/RNC) level. The Congestion Control on the user level means that the user itself regulates the QoS control of its applications. Congestion Control on the base station level means that the base station overtakes the control of the QoS.

Assume that the real terrestrial user is simultaneously involved in N1 speech connections, N2 web browsing connections and N3 file transfer connections; the peak rates of these three kinds of connections are assumed to be P_1, P_2, P_3, while the average rates of these three kinds of connections are assumed to be A_1, A_2, A_3. All the PDUs (Protocol Data Units) relevant to all these connections are multiplexed on the above-mentioned real terrestrial CDMA chain. So, assuming that the real user is availing of the only real terrestrial CDMA chain, the QoS experiment could be as follows:

- The Dummy Traffic Generator is regulated so that the interfering traffic consumes, on the average, a capacity Cx (where C is the total capacity offered by the VIRTUOUS equipment, and x is included in the range [0,1]); this means that, on the average, the real user can avail of the capacity $C(1-x)$.
- The sum of the peak rates of the connections the real user is involved in is greater than the capacity left available by the dummy traffic, while the sum of the average rates of the connections the real user is involved in is lower than the capacity left available by the dummy traffic i.e.

$$N1\ P_1 + N2\ P_2 + N3\ P_3 > C(1-x) > N1\ A_1 + N2\ A_2 + N3\ A_3.$$

- An appropriate congestion control mechanism implemented in the RRC subsystems (both on the UE and on the RNS sides) takes care that on the one hand, the QoS contracts established with the connections are respected (as far as the QoS constraints relevant to the run within the UMTS access network are concerned), and that, on the other hand, the capacity the real user can avail of is efficiently exploited.
- The same experiment is repeated several times by varying the parameters Ni, P_i, Ai, x with and without the congestion control mechanism.

It is important noting that this QoS experiment does not limit itself to demonstrate the Access Network QoS, but since the connection holds between the UE in the Multi-mode mobile and the computers in the fixed LAN, it also demonstrate for the considered services (i.e. Voice over IP, web browsing, file transfer) the end-to-end QoS.

V – Conclusions

The VIRTUOUS project is expected to provide valuable contributions in the direction of T- and S-UMTS introduction and development which is one of the key EC objectives in the framework of mobile communications.
In particular, VIRTUOUS will facilitate the introduction of T/S-UMTS by drawing and demonstrating a smooth, pragmatic and viable migration path from second to third generation systems and by introducing UMTS functions in a modular, flexible and scalable way.
The main results will be presented by two experiments: Inter-segment roaming and QoS control.

References

[1] IST VIRTUOUS Project Technical Annex, 2000
[2] 3GPP TS 23.121 V 3.3.0 Architectural Requirements for Release 1999
[3] 3GPP TS 23.122 V 3.2.0 NAS Functions related to Mobile Station (MS) in idle mode