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*Technical Report*

## Satellite Earth Stations and Systems (SES); Satellite component of UMTS/IMT-2000; General aspects and principles

Reference

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# Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Satellite Earth Stations and Systems (SES).

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# Introduction

S-UMTS stands for the Satellite component of the Universal Mobile Telecommunication System. S-UMTS systems will complement the terrestrial UMTS (T-UMTS) and inter-work with other IMT-2000 family members through the UMTS core network. S-UMTS will be used to deliver $3^{rd}$ Generation mobile satellite services (MSS) utilizing either low (LEO) or medium (MEO) earth orbiting, or geostationary (GEO) satellite(s). For the purpose of the present document it is assumed that S-UMTS systems will be based on terrestrial 3GPP specifications and will support direct access to UMTS core networks.

NOTE 1: The term T-UMTS will be used in the present document to further differentiate the Terrestrial UMTS component.

Due to the differences between terrestrial and satellite channel characteristics, some modifications to the terrestrial UMTS (T-UMTS) standards are necessary. Some specifications are directly applicable, whereas others are applicable with modifications. Similarly, some T-UMTS specifications do not apply, whilst some S-UMTS specifications have no corresponding T-UMTS specification.

Since S-UMTS is derived from T-UMTS, the organization of the S-UMTS specifications closely follows the original $3^{rd}$ Generation Partnership Project (3GPP) structure. The S-UMTS numbers have been chosen to correspond to the 3GPP terrestrial UMTS numbering system but are prefixed with S-UMTS.

An S-UMTS system is defined by the combination of a family of S-UMTS specifications and T-UMTS specifications.

NOTE 2: If an S-UMTS specification exists it takes precedence over the corresponding T-UMTS specification (if any). This precedence rule applies to any references in the corresponding T-UMTS specifications.

# 1 Scope

The present document describes the general aspects and principles that apply to satellite systems intended to be an integral part of the Universal Mobile Telecommunications System (UMTS)/IMT-2000. The S-UMTS systems considered in the present document are expected to provide a comprehensive range of satellite services, mainly derived from the terrestrial UMTS network, to a range of mobile terminals including, handheld, car mounted and portable/nomadic terminals.

The ETSI TC-SES S-UMTS Working Group provides a forum to develop voluntary S-UMTS/IMT-2000 specifications.

# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication and/or edition number or version number) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.

[1] ETSI TS 121 111 (V3.0.1) "Universal Mobile Telecommunications System (UMTS); USIM and IC Card Requirements (3G TS 21.111 version 3.0.1 Release 1999)".

[2] ETSI TS 121 905 (V3.0.0) "Universal Mobile Telecommunications System (UMTS); Vocabulary for 3GPP Specifications (3G TR 21.905 version 3.0.0 Release 1999)".

[3] ETSI TS 123 101 (V3.0.1): "Universal Mobile Telecommunications System (UMTS); General UMTS Architecture (3G TS 23.101 version 3.0.1 Release 1999)".

[4] ETSI TS 122 001 (V3.1.1): "Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); Principals of circuit telecommunications services supported by a Public Land Mobile Network (PLMN) (3G TS 22.001 version 3.1.1 Release 1999)".

[5] ETSI TS 131 102 (V3.0.0): "Universal Mobile Telecommunications System (UMTS); Characteristics of the USIM Application (3G TS 31.102 version 3.0.0 Release 1999)".

[6] UMTS Forum report number 2: "The Path towards UMTS - Technologies for the Information Society".

[7] ETSI TS 125 401 (V3.1.0): "Universal Mobile Telecommunications System (UMTS); UTRAN Overall Description (3G TS 25.401 version 3.1.0 Release 1999)".

[8] UMTS Forum report number 8: "The Future Mobile Market: Global trends and developments with a focus on Western Europe".

[9] E. Lutz, D. Cygan, M. Diepold, F. Dolainsky, and W. Papke: "The land mobile satellite communication channel" IEEE Trans. Vehic. Technol., vol. VT-40, pp. 375-386, May 1991.

[10] Y. Karasawa, K. Kimura, and K. Minamisono (1997): "Analysis of Availability Improvement in LMSS by Means of Satellite Diversity Based on Three-State Propagation Channel Model," IEEE Trans. Veh. technol., vol. 46, 4, pp. 1047-1057 {Janan, review, mobile propagation, satellite propagation, channel model, LMSS}.

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[12] ETSI TS 125 212 (V3.1.1): "Universal Mobile Telecommunications System (UMTS); Multiplexing and channel coding (FDD) (3G TS 25.212 version 3.1.1 Release 1999)".

[13] ETSI TS 125 214 (V3.1.1): "Universal Mobile Telecommunications System (UMTS); Physical layer procedures (FDD) (3G TS 25.214 version 3.1.1 Release 1999)".

[14] ITU-R Recommendation M.1457: "Detailed specifications of the radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)".

[15] ETSI TS 122 105 (V3.9.0): "Universal Mobile Telecommunications System (UMTS); Service aspects; Services and Service Capabilities (3G TS 22.105 version 3.9.0 Release 1999)".

[16] ETSI TS 122 071 (V3.3.0): "Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); Location Services (LCS); Service description, Stage 1 (3GPP TS 22.071 version 3.3.0 Release 1999)".

[17] ETSI TS 123 110 (V3.3.0): "Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); UMTS Access Stratum Services and Functions (3G TS 23.110 version 3.3.0 Release 1999)".

[18] ETSI TS 125 413 (V.3.0.0): "Universal Mobile Telecommunications System (UMTS); UTRAN Iu Interface RANAP Signalling (3G TS 25.413 version 3.0.0 Release 1999)".

[19] ETSI TR 125 931 (V.3.0.0):"Universal Mobile Telecommunications System (UMTS); UTRAN Functions, Examples on Signalling Procedures (3G TR 25.931 version 3.0.0 Release 1999)".

[20] ETSI TS 123 107 (V.3.1.0):"Universal Mobile Telecommunications System (UMTS); QoS Concept and Architecture (3G TS 23.107 version 3.1.0 Release 1999)".

# 3 Definitions, symbols and abbreviations

## 3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

**domain:** highest-level group of physical entities

NOTE 1: Reference points are defined between domains.

**stratum:** grouping of protocols related to one aspect of the services provided by one or several domains

**Radio Network Controller:** equipment in the RNS which is in charge of controlling the use and the integrity of the radio resources

**Controlling RNC:** role an RNC can take with respect to a specific set of Node Bs

NOTE 2: There is only one Controlling RNC for any Node B. The Controlling RNC has the overall control of the logical resources of its node Bs.

**Node B:** logical node responsible for radio transmission/reception in one or more cells to/from the UE

NOTE 3: Terminates the Iub interface towards the RNC.

**Radio Network Subsystem:** either a full network or only the access part of a UMTS network offering the allocation and the release of specific radio resources to establish means of connection in between an UE and the UTRAN

NOTE 4: A Radio Network Subsystem contains one RNC and is responsible for the resources and transmission/reception in a set of cells.

**Serving RNS:** role an RNS can take with respect to a specific connection between an UE and UTRAN

NOTE 5: There is one Serving RNS for each UE that has a connection to UTRAN. The Serving RNS is in charge of the radio connection between a UE and the UTRAN. The Serving RNS terminates the Iu for this UE.

**Drift RNS:** role an RNS can take with respect to a specific connection between an UE and UTRAN

NOTE 6: An RNS that supports the Serving RNS with radio resources when the connection between the UTRAN and the UE need to use cell(s) controlled by this RNS is referred to as Drift RNS.

Other terms relating to the Universal Mobile Telecommunications System (UMTS) may be found in TS 121 905 [2].

## 3.2 Symbols

For the purposes of the present document, the following symbols apply:

| | |
|---|---|
| Cu | reference point between USIM and UE |
| Iu | interconnection point between an RNC and a Core Network. It is also considered as a reference point |
| Iu* | modified interconnection point between a RNC and a Core Network. It is also considered as a reference point |
| Iub | interface between an RNC and a Node B |
| Iur | A logical interface between two RNC. Whilst logically representing a point to point link between RNC, the physical realization may not be a point to point link |
| Uu | reference point between User Equipment and Infrastructure domains, UMTS radio interface |
| Uu* | modified reference point between User Equipment and Infrastructure domains, UMTS radio interface |
| [Yu] | reference point between Serving and Transit Network domains |
| [Zu] | reference point between Serving and Home Network domains |

## 3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

| | |
|---|---|
| 2G | 2$^{nd}$ Generation |
| 3GPP | 3$^{rd}$ Generation Partnership Project |
| CDMA | Code Division Multiple Access |
| DARS | Digital Audio Radio Services |
| EF | Elementary File |
| ESA | European Space Agency |
| FDD | Frequency Division Duplex |
| FEC | Forward Error Correction |
| GNSS | Global Navigation Satellite System |
| GPS | Global Positioning System |
| GPRS | General Packet Radio Service |
| GSO | GeoStationary Orbit |
| GSM | Global System for Mobile communications |
| GW | Gateway |
| HE | Home Environment |
| HEO | Highly Elliptical Orbit |
| IF | Intermediate Frequency |
| IMT-2000 | International Mobile Telecommunication system 2000 |
| ISDN | Integrated Services Digital Network |
| ISL | Inter Satellite Link |
| ITU | International Telecommunications Union |
| IST | Information Society Technology |
| LCS | LoCation Services |
| LEO | Low Earth Orbit |
| LOS | Line Of Sight |
| MAC | Medium Access Control |
| MEO | Medium Earth Orbit |
| MP3 | Moving Picture expert group 1 layer 3 standard |
| MMI | Man Machine Interface |
| NCC | Network Control Centre |
| NGSO | Non-Geostationary Satellite Orbit |
| PDN | Packet Data Network |

| | |
|---|---|
| PLMN | Public Land Mobile Network |
| QoS | Quality of Service |
| RAN | Radio Access Network |
| RF | Radio Frequency |
| RLC | Radio Link Control |
| RNC | Radio Network Controller |
| RNS | Radio Network Sub-system |
| RTT | Radio Transmission Technologies |
| SAR | Specific Absorption Rate |
| SDO | Standards Development Organizations |
| SN | Serving Network |
| S-PCS | Satellite Personal Communication System |
| SRI | Satellite Radio Interfaces |
| S-UMTS | Satellite component of the Universal Mobile Telecommunications System |
| TDD | Time Division Duplex |
| TDMA | Time Division Multiple Access |
| TRI | Terrestrial Radio Interfaces |
| T-UMTS | Terrestrial component of the Universal Mobile Telecommunications System |
| UE | User Equipment |
| UIM | User Identity Module |
| UMTS | Universal Mobile Telecommunications System |
| USIM | Universal Subscriber Identity Module |
| USRAN | UMTS Satellite Radio Access Network |
| UTRAN | UMTS Terrestrial Radio Access Network |
| VHE | Virtual Home Environment |

# 4 Background to IMT-2000 and Satellite-UMTS

The Universal Telecommunications System is a member of the IMT-2000 family of global systems. Satellite-UMTS is an integral part of UMTS and provides direct access to the UMTS core network via the Iu interface. Figure 4-1 shows the overall structure of the S-UMTS concept.

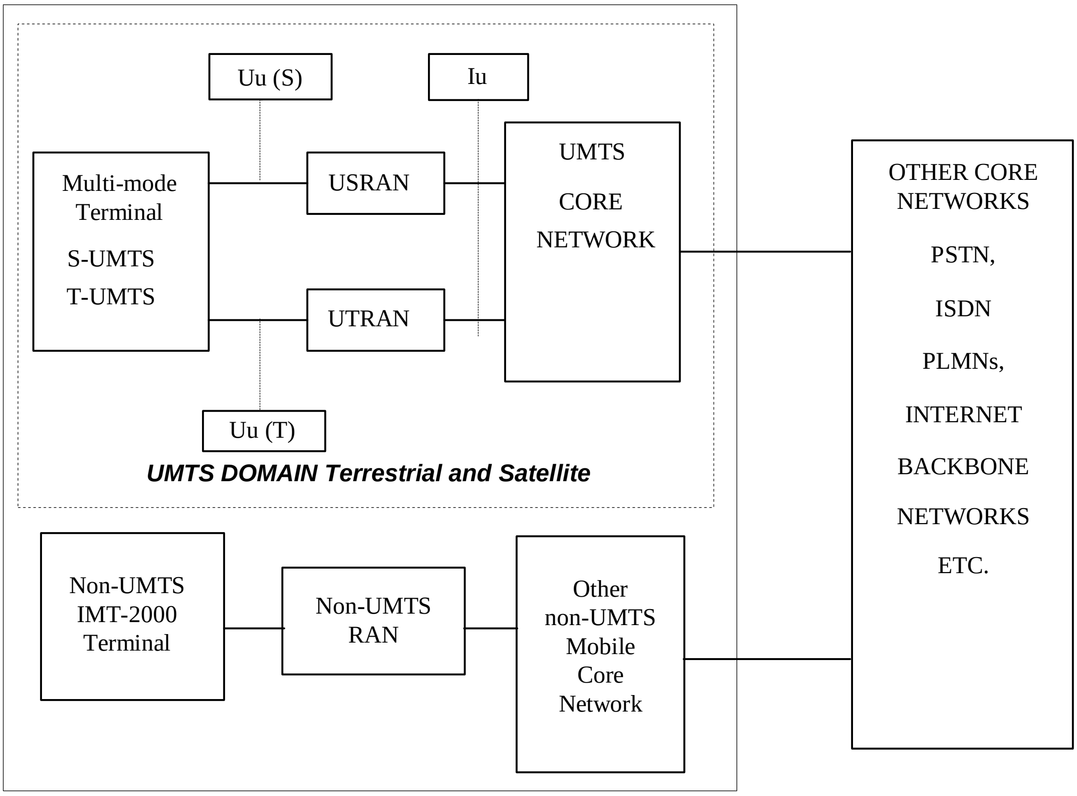



**Figure 4-1: Satellite-UMTS concept**

The International Telecommunications Union (ITU) has approved five technical options for 3rd Generation (3G) terrestrial networks and six different options for the satellite component of IMT 2000 (ITU-R Recommendation M.1457 [14]). These RTTs (Radio Transmission Technologies) are further described in Clause 8. The Universal Mobile Telecommunications System (UMTS), being developed by the 3rd Generation Partnership Project (3GPP), uses Wideband Code Division Multiple Access (W-CDMA) for Frequency Division Duplex (FDD) and TD-CDMA for Time Division Duplex (TDD). Although UMTS has been evolved from the highly successful GSM standard, it is expected that the UMTS core network will become Internet Protocol (IP) based when 3GPP Release 5 specifications are introduced. Some current 2G networks will employ GPRS and EDGE to deliver limited 3G services during and after the initial phase of UMTS deployment.

## 4.1 S-UMTS as in integral part of the UMTS network

Satellite-UMTS systems may use one of the previously mentioned six radio air interfaces endorsed by the ITU and described in more detail in clause 8.1.1 of the present document. Future RTTs, subject to the ITU evaluation process, may also be used. Some of the benefits to be gained from a fully integrated S-UMTS/T-UMTS system are:

- Seamless service provision;
- Re-use of the terrestrial infrastructure;
- Highly integrated multi-mode user terminals.

The satellite component of UMTS may provide services in areas covered by cellular systems, complementary services, e.g. broadcasting, multicasting, and in those areas not planned to be served by terrestrial systems. This is illustrated in the following figure reproduced from UMTS Forum report number 2 [6].

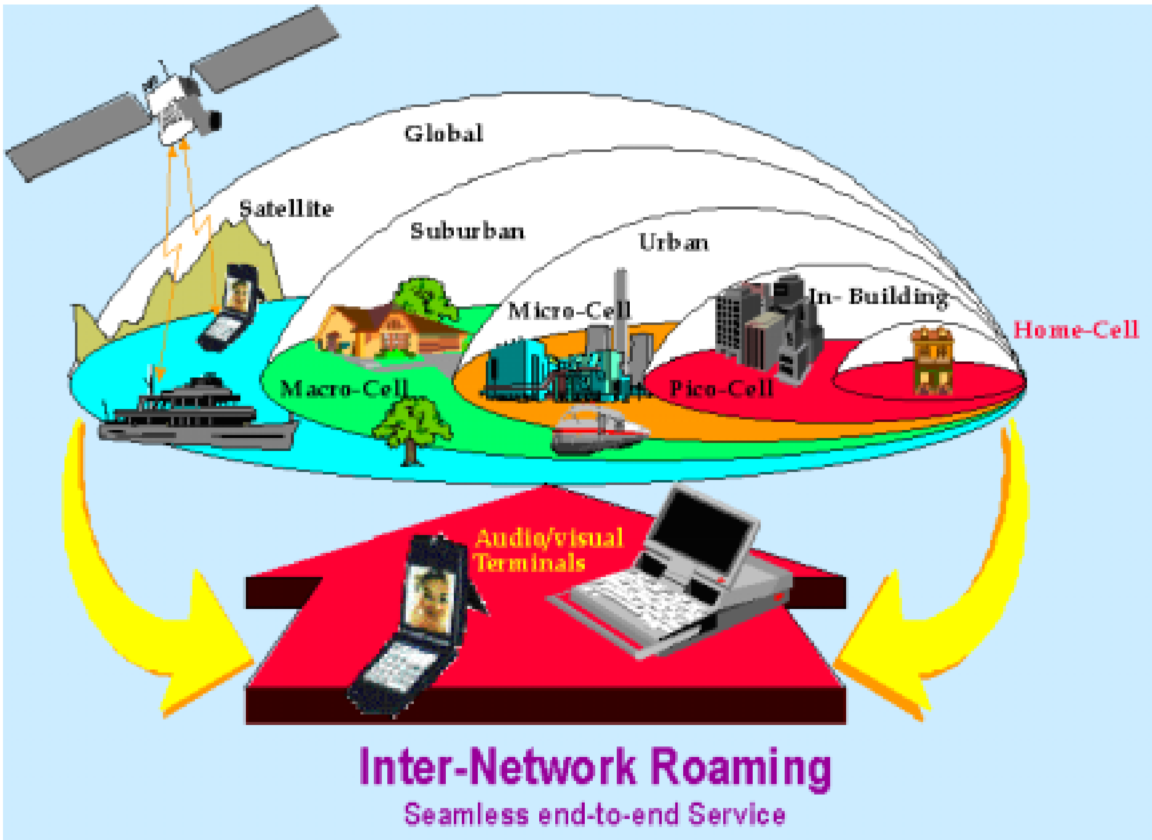



**Figure 4-2: The role of S-UMTS as an integral part of the UMTS network (UMTS Forum)**

## 4.2 Evolution of current satellite systems to deliver enhanced services

In the same way that some terrestrial 2nd Generation networks are upgrading via GPRS and EDGE to offer 3rd Generation services, it is expected that some of the current TDMA and narrow band CDMA Mobile Satellite Services (MSS) will do the same. For example Thuraya and ACeS, which use the ETSI specified GMR-1 and GMR-2 air interfaces respectively, and Inmarsat and Globalstar, may be upgraded to enable higher data rates. Examples of satellite air interface evolutionary paths for both TDMA and CDMA are shown in figure 4-3.

In the future, new systems designed specifically to inter-work with IMT-2000 compliant core networks and, in particular, those forming an integral part of the terrestrial UMTS core network, are likely to be the most effective in delivering 3rd Generation services.

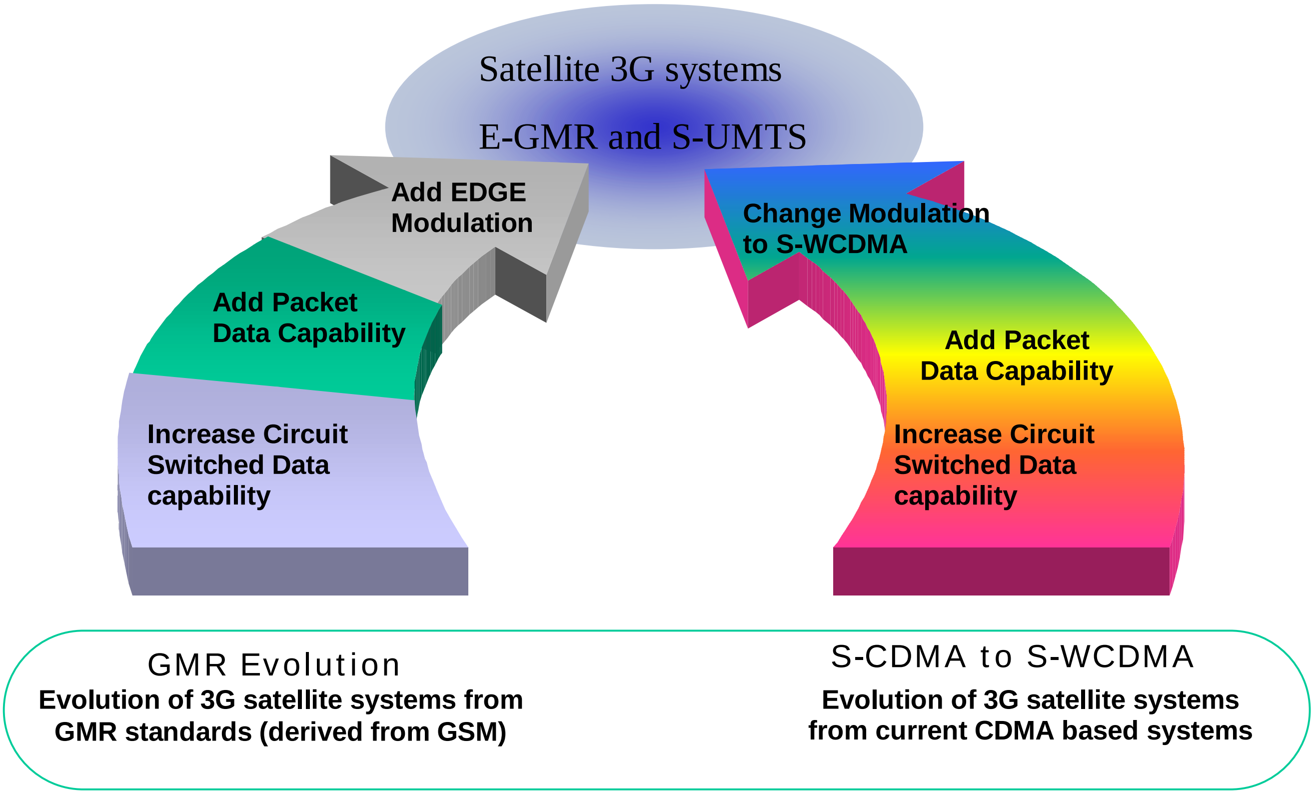



**Figure 4-3: Evolution of current TDMA and CDMA based satellite systems**

# 5 S-UMTS Service Aspects

## 5.1 Service principles

3rd Generation systems will provide integrated personal communications services. They will support different applications, ranging from narrow-band to wide-band communications capabilities, with integrated personal and terminal mobility in order to meet the user and service requirements for the 21st century.

One key aspect of these systems is that they will be based on defined "service capabilities", rather than on defined services. These standardized capabilities will provide a defined platform enabling the support of speech, video, multi-media, messaging, data, user applications and supplementary services, while enabling the market for services to be determined by users and home environments. This approach will ensure that operators will be capable of rapid development and deployment of competitive service offerings.

Global roaming will be achieved by means of the Virtual Home Environment (VHE). The VHE concept enables users to obtain services in a consistent way, regardless of their location or the particular terminal used, provided that the necessary service capabilities are available in the serving network.

## 5.2 Service capabilities

### 5.2.1 Multimedia

3rd Generation systems will support both single-media e.g. telephony, and multimedia services which combine two or more media components e.g. voice, audio, data or video, within one call.

Multimedia services are typically classified as interactive or distribution services.

Interactive services are, in turn, typically subdivided into conversational, messaging and retrieval services:

- **Conversational services:** are real time (no store and forward), usually bi-directional where low end to end delays and a high degree of synchronization between media components (implying low delay variation) are required. Video telephony and video conferencing are typical conversational services.
- **Messaging services:** offer user to user communication via store and forward units (mailbox or message handling devices). Messaging services might typically provide combined voice and text, audio and high resolution images.
- **Retrieval services:** enable a user to retrieve information stored in one or many information centres. The start at which an information sequence is sent by an information centre to the user is under control of the user. Each information centre accessed may provide a different media component, e.g. high resolution images, audio and general archival information.

Distribution services are typically subdivided into those providing user presentation control and those without user presentation control.

- **Distribution services without user control:** are broadcast services where information is supplied by a central source and where the user can access the flow of information without any ability to control the start or order of presentation e.g. television or audio broadcast services.
- **Distribution services with user control:** are broadcast services where information is broadcast as a repetitive sequence and the ability to access sequence numbering allocated to frames of information enables the user (or the user's terminal) to control the start and order of presentation of information.

3GPP specifications support single media services and all calls have the potential to become multimedia calls. It will be possible to reserve resources in advance to enable all required media components to be available. In a similar way to the inter-operation of a multimedia PC with the Internet, once a call has been established, via the S-UMTS multi-mode terminal, any number of multimedia components can be added.

## 5.2.2 Service architecture

As multimedia services may involve several parties and connections, flexibility is required in order to add and delete both resource and parties, without compromising the quality of service targets. Services will be integrated in an architecture frame as shown in figure 5-1.

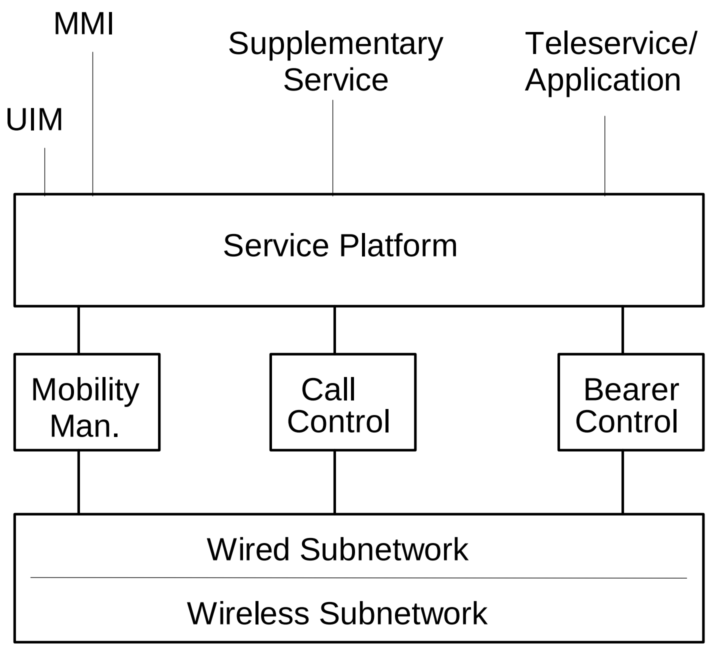



**Figure 5-1: Service architecture**

A number of bearers will be provided, which may differ in flexibility and offer different capabilities. Bearers can be characterized by parameters such as "throughput", "delay tolerance", "maximum bit error rate", "symmetry", etc. These bearers transfer the information necessary for the provision of teleservices, and generally for end user applications, via subnetworks which typically provide different specified qualities of service.

The assignment and release of bearers is provided by the bearer control function. Provision should be made for several bearers to be associated with a call and for bearers to be added to a call and/or to be released from a call following call establishment. The bearers should be independent of radio environments, radio interface technology and fixed wire transmission systems.

Adaptation/Interworking functions are required in order to take account of the differences between the bearers used for the provision of a teleservice/application in the fixed network and the bearers. Adaptation/Interworking functions are required which take account of the discontinuous and/or asymmetrical nature of most teleservices/applications.

The service platform shall provide interfaces (to serving networks and home environments) for the creation, support and control of supplementary services, teleservices and user applications. The service platform will also provide interfaces enabling subscribers to control supplementary services, teleservices and user applications. As far as possible, the service platform is required to enable new supplementary services, teleservices and/or end user applications to be supported at minimum cost, with minimum disruption of service and within the shortest possible time.

Supplementary service provision and control will be independent of radio operating environment, radio interface technology and fixed wire transmission systems.

# 5.3 Telecommunication services and applications

## 5.3.1 General

Telecommunication services defined by 3GPP specifications are the communication capabilities made available to users by home environment and serving network. A PLMN provides, in co-operation with other networks, a set of network capabilities which are defined by standardized protocols and functions and enable telecommunication services to be offered to users.

A service provision by a home environment and serving network to a user may cover the whole or only part of the means required to fully support the service.

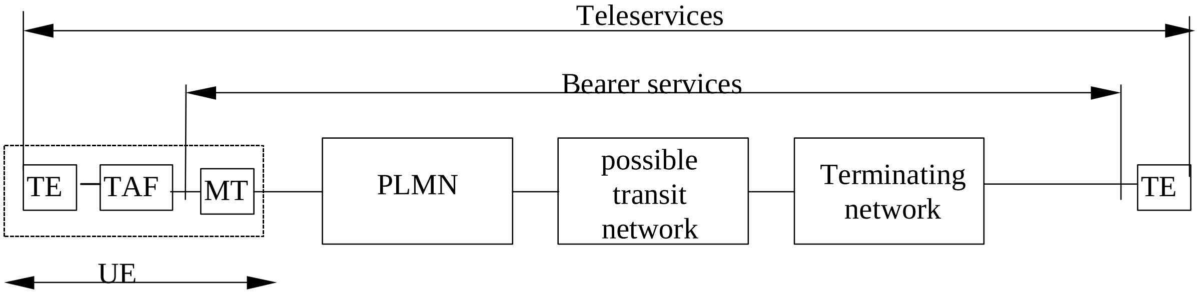
The service classification and description that follows are independent of different possible arrangements for the ownership and provision to the user of the means required to support a service.

## 5.3.2 Basic telecommunication services

Basic telecommunication services are divided in two broad categories:

- bearer services, which are telecommunication services providing the capability of transmission of signals between access points;
- teleservices, which are telecommunication services providing the complete capability, including terminal equipment functions, for communication between users according to protocols established by agreement between network operators.

The communication link between the access points may consist of PLMN, one or more transit networks and a terminating network. The networks between the two access points typically use different means for bearer control. Figure 5-2 illustrates these definitions.




UE: User Equipment
MT: Mobile Termination
TE: Terminal Equipment
TAF: Teminal Adaption Function

NOTE 1: In order to limit the complexity of the figure, only one transit network is shown.
NOTE 2: The terminating network type may include a PLMN, either the originating one or another one.
NOTE 3: The bearer service terminates in the user equipment.
NOTE 4: The terminating network may be another network such as: PSTN, ISDN, IP networks/LANs and X.25.

**Figure 5-2: Basic telecommunication services supported by a PLMN**

#### 5.3.2.1 Bearer services

Bearer services are distinguished by their individual characteristics that apply at the reference point where the user accesses the bearer service.

In general, different networks, connecting two access points, use different control mechanisms. Because of these differences, in order to realize an end to end bearer service, the bearer services of each network throughout the communication link have to be translated at the network interfaces. The bearer services are negotiable and can be used flexibly by applications.

#### 5.3.2.2 Teleservices

Because some teleservices are standardized and others are not, a decoupling between the lower layer i.e. bearer attributes and the higher layer capabilities, will be necessary for the development of teleservices.

### 5.3.3 Supplementary services

A supplementary service modifies or supplements a basic telecommunication service. Consequently, it cannot be offered to a user as a stand alone service. It shall be offered together or in association with a basic telecommunication service. The same supplementary service may be applicable to a number of basic telecommunication services.

Two methods are used for the characterization of supplementary services:

- The first method is used for the description of existing standardized supplementary services. These services are specified through the detailing of each of the operations involved in service provision and service usage (the provision/withdrawal, registration/erasure, activation/deactivation, invocation and interrogation operations).

- The second method enables the provision of HE/SN specific supplementary services. To make this possible, services can be built using service capability features which are accessed via the standardized application interface.

A PLMN shall be able to handle multiple supplementary services within a call. Interactions shall be handled when several supplementary services are activated in the same call. When multiple supplementary services can be activated concurrently, some prioritization of the services will be necessary. Certain services may override or deactivate other services.

Interactions between operator specific supplementary services are not defined.

The following issues need consideration when interactions between services occur:

- Different phases of a call.
- A service spanning on more than one network.
- Service interactions that may occur between services offered to a single user, as well as between services offered to different interacting users.

NOTE: The methods defined for characterization of services are description methods. They do not imply or restrict different implementations.

### 5.3.4 Quality of Service requirements

TS 122 105 [15] presents a detailed description of telecommunication services, including requirements on quality and several examples of possible services built upon these capabilities. In particular, both for connection and connectionless traffic, in a satellite environment, the network shall efficiently guarantee these requirements for bearer services:

- **Real time (constant delay):** Maximum transfer delay of 400 ms; Bit Error Rate in the range $10^{-3}$ to $10^{-7}$.
- **Non real time (variable delay):** Maximum transfer delay (for 95 % of the data) of 1 200 ms, or more; Bit Error Rate in the range $10^{-5}$ to $10^{-8}$.

As specified in TS 122 105 [15], a bit rate of at least 144 kbit/s should be supported in a satellite radio environment in a nomadic operating mode.

## 5.4 Location based services

Location Services may be considered as a network provided enabling technology, consisting of standardized service capabilities, which enable the provision of location applications. The application may be service provider specific.

LCS can be offered without subscription to basic telecommunication services. LCS is available to the following categories of LCS clients:

- Value Added Services LCS Clients - use LCS to support various value-added services;
- PLMN Operator LCS Clients - use LCS to enhance or support certain Operation & Maintenance related tasks, supplementary services, IN related services and bearer services and teleservices;
- Emergency Services LCS Clients - use LCS to enhance support for emergency calls from subscribers;
- Lawful Intercept LCS Clients - use LCS to support various legally required or sanctioned services.

LCS is applicable to any target UE whether or not the UE supports LCS, but with restrictions on choice of positioning method or notification of a location request to the UE user when LCS or individual positioning methods, respectively, are not supported by the UE.

## 5.5 S-UMTS services as a complement to T-UMTS services

S-UMTS services can complement T-UMTS services in two ways:

- **Geographic extension services**; where the USRAN is used to provide extended geographic coverage for UMTS services. This includes telephony for maritime and aeronautical users, remote surveillance of high value objects e.g. pipelines and industrial plant in hard to access regions, news gathering and database access for journalists operating in remote parts of the world, tele-diagnostic in emergency cases, and many other telemetry applications.
- **Functional extension services**; where the USRAN is used to provide services that extend the functionality of UMTS services. These services may be used to complement other services provided by either a USRAN or a UTRAN. This category includes multicast and broadcast services which cannot be efficiently provided by T-UMTS.

In both cases the S-UMTS component can complement T-UMTS in an economic and efficient way.

# 6 Terminals for S-UMTS

Studies recently completed for the European Space Agency have identified a range of potential terminal designs based on S-UMTS market studies. Terminal design and cost have been identified as major factors in the success or failure of any satellite system. Current satellite phones (e.g. Globalstar, ACeS and Thuraya) offer dual mode GSM/Satellite functionality and they are voice centric with limited data rates. As data rates increase, a variety of terminals will be needed to deliver new faster services. In this clause of the present document we look at several possible handheld, nomadic, vehicle mounted and fixed satellite-UMTS terminal designs.

## 6.1 Handheld S-UMTS Terminals

A range of handheld terminals offering high quality voice and data rates of up to 64 kbit/s on the forward link and 16 kbit/s on the return link are envisaged. These handheld single S-UMTS or multi-mode terminals will have large display screens and may include the following options:

- S-UMTS only
- S-UMTS/GSM/GPRS
- S-UMTS/T-UMTS/GSM/GPRS

Where GSM is included, this is likely to be a multi-band GSM 900 Mhz, 1 800 MHz and 1 900 MHz. It is also assumed, for the purpose of this discussion, that the S-UMTS air interface will be derived from the 3 GPP T-UMTS air interface and signalling protocols.

S-UMTS handsets are likely to have the following characteristics:

- Multi-mode terminals
- Large display area

Typical performance characteristics:

- Antenna gain ~ -1,2 dBi (This figure assumes that the antenna will be of similar size to T-UMTS handsets)
- EIRP ~ -3 dBW
- G/T ~ -26,6 dB/K
- Data rates in the region of 64 kbit/s of the forward link and 16 kbit/s for the return link.
- Bluetooth Interface

As with today's S-PCS handsets, the S-UMTS terminals will look like their terrestrial UMTS counterparts, perhaps as shown in figure 6-1.

**Figure 6-1: S-UMTS/T-UMTS handheld concept terminals**

If based on a conventional handset design, the target dimensions would be about 130 mm by 50 mm by 15 mm including battery, but excluding antenna. The volume would be approximately 100 cc excluding the antenna and the weight approximately 100 g including a standard Li-ion battery and antenna.

## 6.2 Nomadic S-UMTS Terminals

Nomadic products for mobile communications are not new, they have been available on other satellite systems e.g. Inmarsat Mini M for some time. Nomadic terminals have evolved from the need for personal and workplace mobility, where higher data rate telecommunications will be required from fixed, semi-permanent locations. Possible uses for this type of product are:

- Mobile computing applications;
- Data logging;
- Video conferencing/video assistance i.e. remote technical or medical assistance with guidance provided by and expert at the non-remote end of the video link;
- Mapping.

These applications could be served by either by small laptop computer with an external communications device providing S-UMTS communications or a dedicated terminal with an S-UMTS function. The reality is that both types may exist to serve the market demand, which may be driven both by telecommunication companies and computer companies.

### 6.2.1 Nomadic terminal concepts

Two type of terminal will be described:

- Nomadic User Terminal with integrated antenna;
- Nomadic User Terminal with external antenna.

#### 6.2.1.1 Nomadic User Terminal with Integrated Antenna

The nomadic terminal with integrated antenna would take the form of a traditional laptop PC with a built in RF subsystem or PCMCIA satellite card. The only obvious addition would be the integral antenna shown deployed in figure 6-2, or a directional patch antenna.

**Figure 6-2: Nomadic User Terminal with Integrated Antenna**

Characteristics:

- Integrated Quadrifilar Helix antenna
- Limited Tx power levels

Typical performance characteristics:

- Antenna gain ~ 4 dBi
- EIRP ~ 2,2 dBW
- G/T ~ -20,8 dB/K
- Data rates: 384 kbit/s Forward Link and 64 kbit/s Return link
- Laptop style user interface

With the integrated antenna option shown above, it is clear there are a number technical problems to be overcome, one of which being the maximum transmit power with the RF system being so close to the users body.

### 6.2.1.2 Nomadic User Terminal with External Antenna

One solution proposed to overcome the RF power limitations associated with a nomadic terminal with an integral antenna, is a user terminal with a remote satellite air interface module which would incorporate an RF system, including antenna, capable of transmitting at much higher power levels. These power levels being dependent upon battery/power supply availability, rather than Specific Absorption Rate (SAR) rules.

Connectivity between the terminal and user interface would be provided in much the same way as the satellite repeater terminal mentioned later in the present document i.e. Cable or Bluetooth link.

**Figure 6-3: Nomadic User Terminal with External Antenna**

Characteristics:

- No dedicated User Interface

- Connected to PDA, laptop or other data/voice device via wireless interface or cable
- Higher Tx power levels

Typical performance characteristics:

- Antenna gain ~ 4 dBi
- EIRP ~ 15 dBW
- G/T ~ -20,8 dB/K
- Size ~ 180 × 120 × 45 mm (palmtop size)

# 6.3 Vehicle S-UMTS Terminals

The car industry is currently very interested in providing Internet and other wireless communications in their cars and an S-UMTS system could become very important in making this possible. Cars are inherently well suited for satellite communications for a number reasons:

- The traditional limitation of satellite communications regarding lack of in-building penetration is not an issue for cars.
- When people are moving in rural and remote areas, they are usually using their car. Those areas will be the last to have T-UMTS.
- Size of the terminal is not so important.
- Cost of the terminal is not critical, especially if it is offered as an option similar to a sunroof, hands-free phone, navigation system, etc.

There are already a number of systems offering emergency and convenience services to cars. The potential in-car S-UMTS terminal may provide a number of these plus additions including:

- Emergency services, including air bag deployment notification, remote door unlock, theft protection, etc.
- Convenience services, including listing of hotels, restaurants, etc. with online reservation possibilities.
- Route support providing customers with directions to find shortest route, closest gas station or Automatic Teller Machine (ATM), avoiding jams, etc.
- Radio and possibly TV broadcasting and multicast
- Other Internet or Intranet services, including e-mail and web browsing

Low to medium quality TV broadcasting may be possible in S-band if the necessary data rate is available, especially for small screens which may reduce the needed bandwidth.

A typical vehicle terminal scenario is shown in figure 6-4.

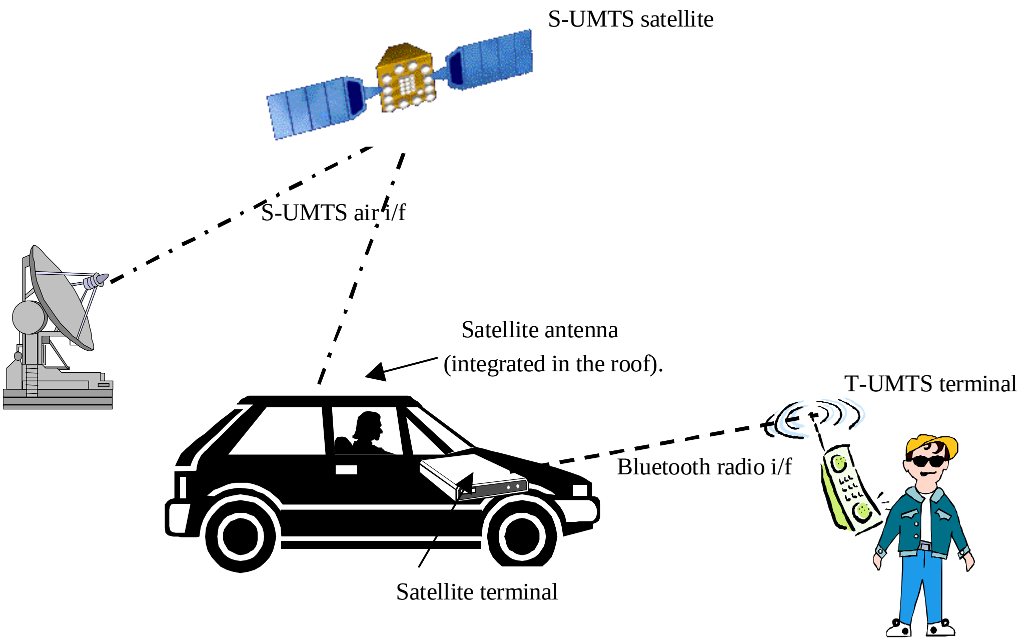



**Figure 6-4: A typical vehicle terminal scenario**

Characteristics:

- Functionality similar to that of the nomadic terminal with external antenna. In this case a patch antenna could be integrated in the roof of the car.
- Higher Tx power, higher antenna gain and unlimited standby time.
- Multi-mode terminal.
- Advanced car "infotainment" type user interface.
- Wireless interface (Bluetooth) connects to other internal and external devices e.g. mobile phones, traffic control equipment or perhaps home computing devices when the vehicle is stationary.

## 6.4 The S-UMTS Repeater/Exciter Product Concept

In this product concept, an additional external repeater unit extends the capability of ordinary terrestrial phones or computing devices and provides access to S-UMTS services. Although the obvious interconnection between the repeater unit and phones or other devices may be Bluetooth, interconnection methods could also include re-transmission in the same frequency band, subject to regulatory approval.

**Figure 6-5: S-UMTS Repeater/Exciter concepts**

Functionality is similar to that offered by the nomadic terminal but it is envisaged that this unit is a fixed device providing access to multiple users.

## 6.5 S-UMTS multi-mode terminal architecture

Compared to the current generation of terrestrial and satellite mobile phones, UMTS is characterized by an increased complexity, both from the air interface and the applications point of view. For this reason, a UMTS system on chip for the baseband functions includes much more functionality than today's 2G baseband ASICs. Moreover, power consumption must be kept as low as possible. As a consequence, the DSP-centric based architectures in use for most GSM baseband ICs are no longer the best option for UMTS.

An example of a UMTS multi-mode terminal architecture combines both DSP and reconfigurable hardware technology to satisfy the higher complexity and power saving requirements mentioned above. The following subsystems can be distinguished:

Re-configurable hardware for the UMTS inner and outer modem functionality, interfacing the front end with a versatile radio interface. This hardware is re-configurable between terrestrial and satellite UMTS modes. For navigation purposes, the inner modem part can be reconfigured for GPS reception.

A GSM baseband subsystem based on a DSP core, with some limited hardware accelerators. When the terminal is operating in UMTS mode, this DSP core is not involved in Layer 1 (L1) execution, as L1 is completely covered by the re-configurable hardware subsystem supported by software for configuration and low speed loops. The use of a DSP core is hence avoided for UMTS L1 allows to save power by using a slower master clock for the digital hardware.

A first power efficient micro-controller unit, running the L1 software and reconfiguration control. This subsystem interfaces to a second Layer 2 (L2)/Layer 3 (L3) micro-controller via a dual port RAM based mailbox. The second micro-controller unit can switch between GSM and UMTS protocol stacks and communicates with the L1 micro-controller via predefined primitives and function calls. It also transfers data blocks to and from the outer modem.

A multi-mode IF/RF unit which is usually the most difficult part to realize the reuse of hardware for the different modes. Today's most realistic solution still involves the use of separate IF/RF units and filters for each mode. At the antenna side a compromise can be made by using a two-antenna approach, one for GSM /UMTS and a second one for GPS reception.

The same software reconfigurable hardware can be used for terrestrial and satellite modes of operation. The only exception is possibly represented by the RF front-end, in particular the antenna is likely to be satellite specific.

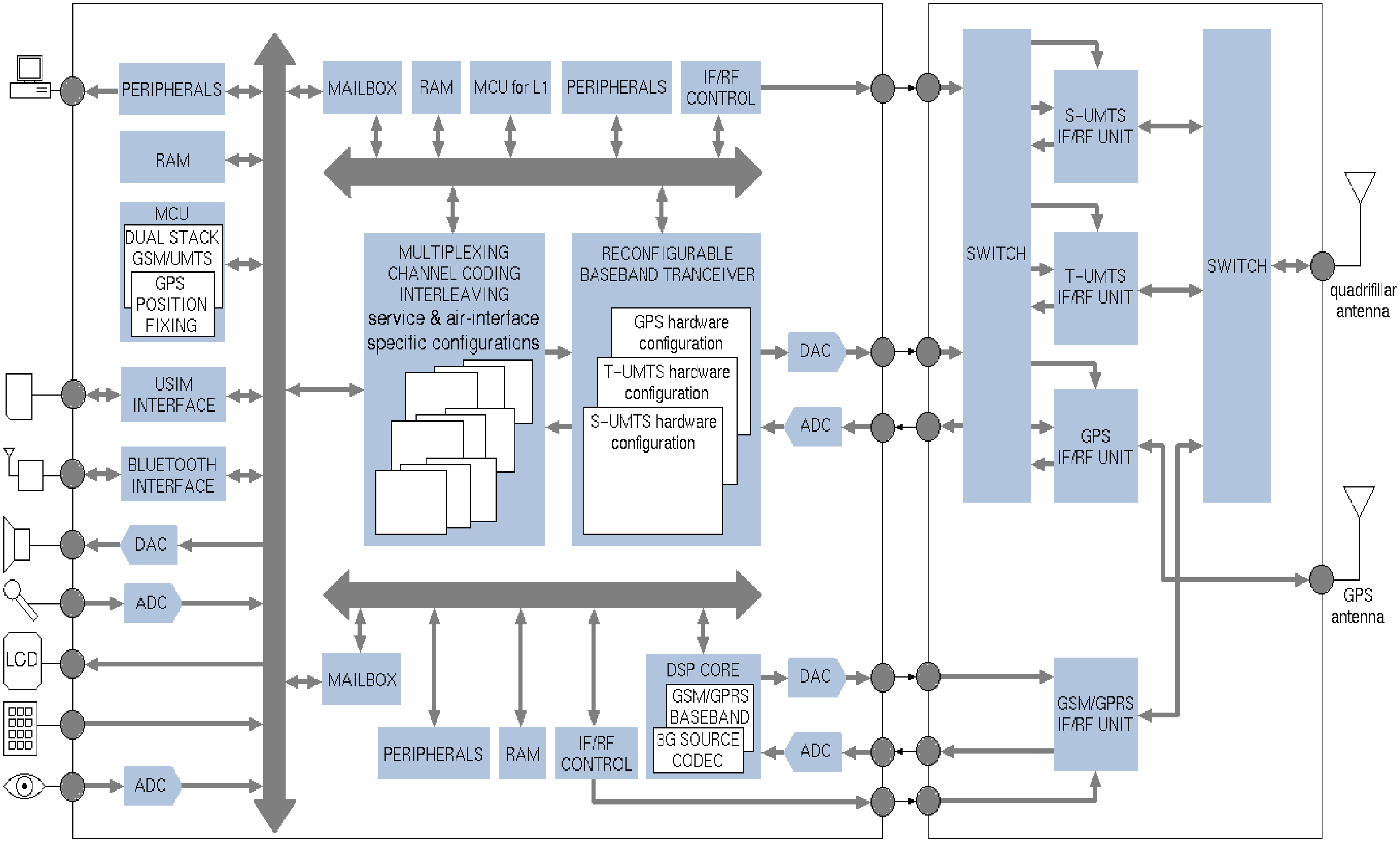



**Figure 6-6: Example of a S-UMTS multi-mode terminal architecture**

Finally a summary of the key RF characteristics for each of the terminal types is shown in table 6.5-1.

**Table 6.5-1: Summary of typical terminal RF performance**

| Typical RF Performance | Handheld | Nomadic (1) Integral Antenna | Nomadic (2)/Vehicular Repeater |
|---|---|---|---|
| Antenna Gain (dBi) | -1,2 | 4 | 4 |
| Tx Power (dBW) | -1,8 | -1,8 | 11 |
| EIRP (dBW) | -3 | 2,2 | 15 |
| System Temperature (K) | 350 | 300 | 300 |
| Noise Figure (dB/K) | -26,6 | -20,77 | -20,77 |

NOTE: EIRP and Tx power values for Nomadic (2) are given as peak.

# 7 High level reference architectures

## 7.1 T-UMTS architecture

### 7.1.1 T-UMTS reference architecture

Figure 7-1 shows the basic domains in UMTS as described in TS 123 101 [3].

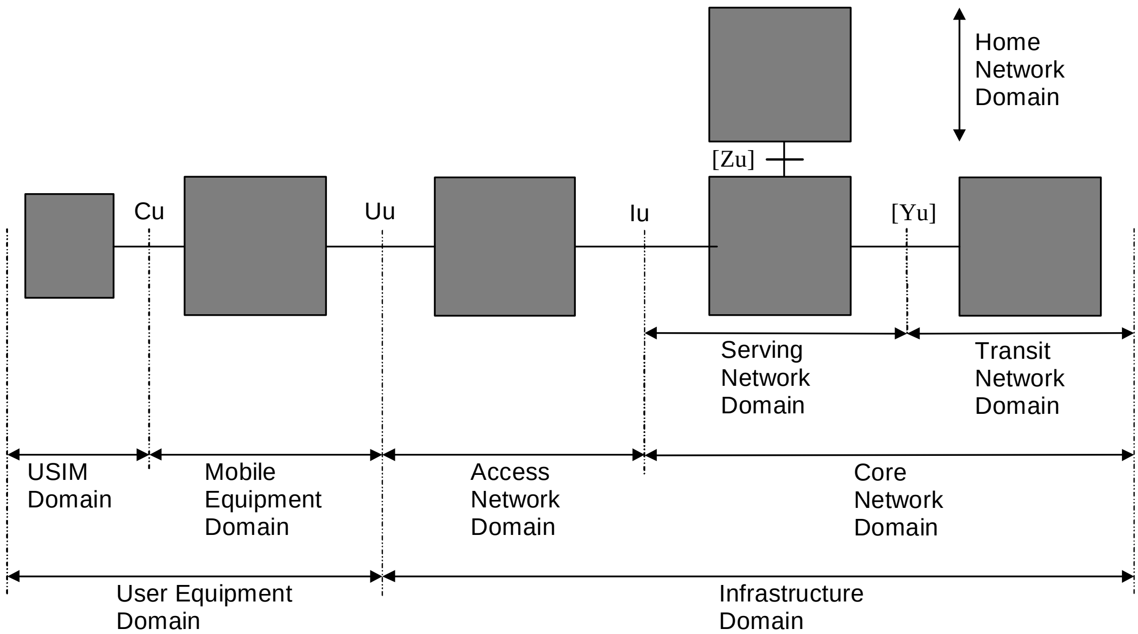



**Figure 7-1: UMTS domains and reference points**

NOTE: The domains identified in the figure will generally result from an evolution of existing network infrastructures. The core network domain may result from evolutions of existing network infrastructures, e.g. a GSM infrastructure, a N-ISDN infrastructure, a B-ISDN infrastructure or a PDN infrastructure. The evolution of these infrastructures may be performed via the use of Inter-working Units (IWU), hidden within the domains shown in the figure.

Cu = Reference point between USIM and ME
Iu = Reference point between Access and Serving Network domains
Uu = Reference point between User Equipment and Infrastructure domains, UMTS radio interface
[Yu] = Reference point between Serving and Transit Network domains
[Zu] = Reference point between Serving and Home Network domains

The satellite component of UMTS will be compatible with this architecture.

### 7.1.2 UTRAN architecture

The UTRAN consists of a set of Radio Network Subsystems (RNS) connected to the Core Network through the Iu.

A RNS consists of a Radio Network Controller (RNC) and one or more abstract entities currently called Node B. Node B are connected to the RNC through the Iub interface.

A Node B can support FDD mode, TDD mode or dual-mode operation.

The RNC is responsible for the Handover decisions that require signalling to the UE.

The RNC comprises a combining/splitting function to support macro diversity between different Node B.

The Node B can comprise an optional combining/splitting function to support macro diversity inside a Node B.

Inside the UTRAN, the RNCs of the Radio Network Subsystems can be interconnected together through the Iur. Iu(s) and Iur are logical interfaces. Iur can be conveyed over physical direct connection between RNCs or via any suitable transport network.

The UTRAN architecture is shown in figure 7-2.

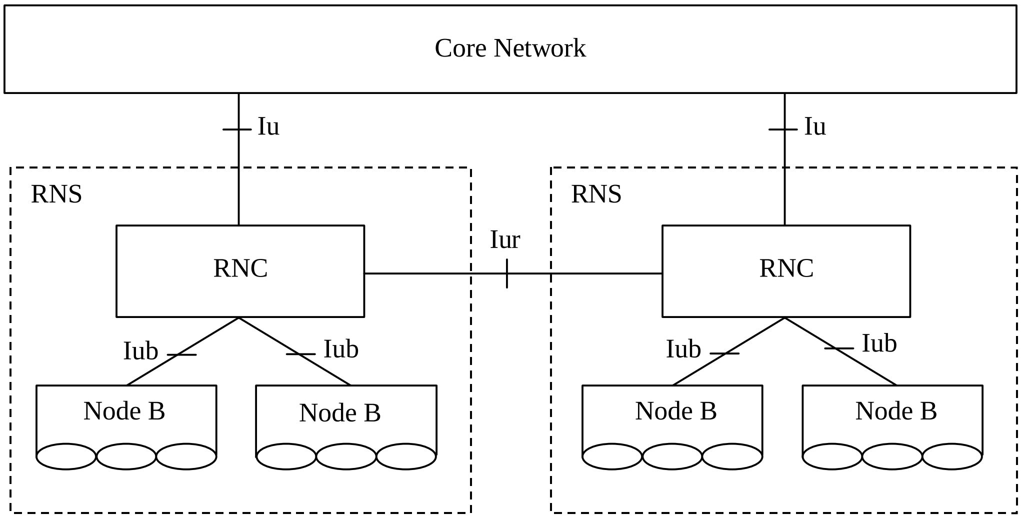



**Figure 7-2: UTRAN Architecture**

Each Radio Network Subsystems is responsible for the resources of its set of cells.

For each connection between a User Equipment and the UTRAN, One RNS is the Serving RNS. When required, Drift RNSs support the Serving RNS by providing radio resources as shown in figure 7-3. The role of an RNS (Serving or Drift) is on a per connection basis between a UE and the UTRAN.

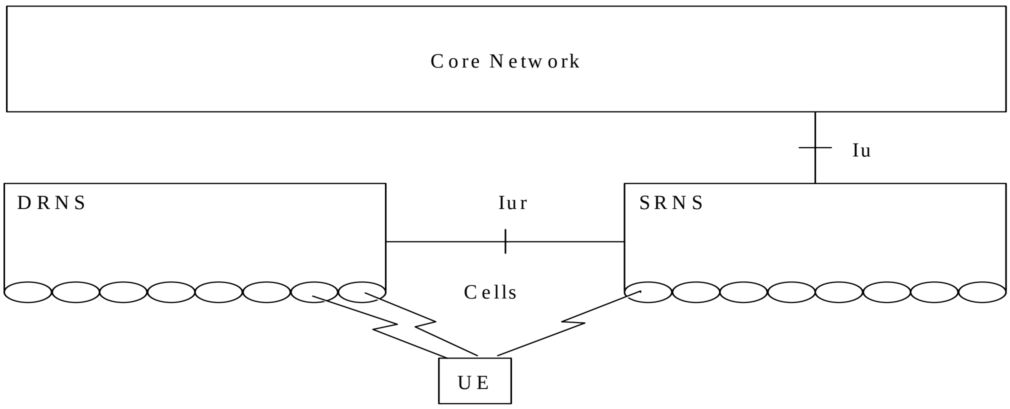



**Figure 7-3: Serving and Drift RNS**

## 7.2 S-UMTS architecture

### 7.2.1 Segments

A S-UMTS can be divided into three segments: a space segment, a user segment and a ground segment.

The space segment is composed of one or several GSO satellites and/or by a constellation of non-GSO satellites, with or without Inter Satellite Links, its associated Tracking Control and Ranging (TCR) stations and Satellite Control Centre (SCC).

The user segment is made of the User Equipment (UE): these are also referred to as Mobile Earth Stations (MES).

The ground segment comprises Network Control Centre(s), gateway(s) and inter-sites communication facilities. The NCC provides the fault, anomaly, configuration, performance, and security functions for management of the network and the gateways interface with other telecommunication networks

### 7.2.2 Satellite systems classification

Satellite systems can be classified as follows:

a) Satellite constellation: GSO or NGSO

b) Single-hop or double-hop architecture

c) Bent-pipe or regenerative satellite

d) Inter-Satellite Links: ISL or non-ISL

A number of systems can be designed by combining the above parameters. However, the major impact on the UMTS and UTRAN architectures is found in the first two parameters: the constellation and the single/double hop architecture. We illustrate this with some examples.

## 7.2.3 GSO systems

### 7.2.3.1 GSO double-hop system

A double-hop satellite system based on a GSO constellation is shown in figure 7-4.

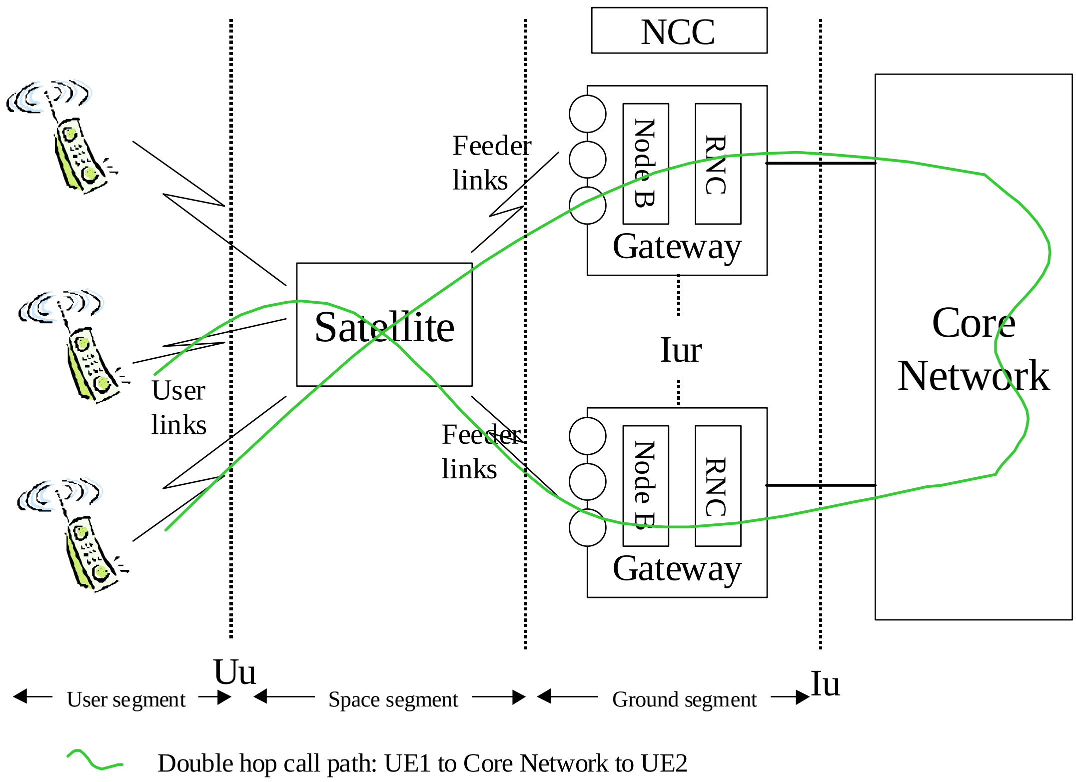



**Figure 7-4: Double-hop, GSO model for S-UMTS**

The following elements are used in this model:

- RNC (radio network controller)
- Node B entities
- NCC (network control centre)

The RNC is responsible for the control of the mobile communication. It is located in the gateway.

The Node B entities provide mainly RF functions and these are located in the gateway in the case of a transparent satellite payload as illustrated in figure 7-4. The Node B functions may be located in the satellite in the case of regenerative payload.

The NCC provides resource management functions for the whole UMTS satellite network. A single NCC is assumed and this will typically be co-located at one of the gateways.

The space segment may be composed of one or several GSO satellites depending on the assumed coverage (global or regional).

In this double-hop case the satellite system is only performing radio access network (USRAN) functions, whereby the satellite system is only used to route traffic between the UE and the core network. The interfaces are based on interfaces defined in 3GPP/T-UMTS as follows:

- The Iu interface is the interface between the RNC and the core network. This interface should preferable use the same Iu interface as defined for T-UMTS in order to allow the USRAN to connect to a standard T-UMTS core network.
- The Uu interface is the interface between the Node B and the user equipment. This interface is based on the Uu interface as defined for T-UMTS with minimum adaptation for the satellite radio path. Minimum adaptation is desirable to optimize the terminal design for a dual mode (S-UMTS and T-UMTS) terminal.
- An optional Iur interface may also be added to provide a direct interface between the gateways for S-UMTS. This interface should be based on the Iur interface as defined for T-UMTS.

### 7.2.3.2 GSO single-hop system

A single-hop satellite system based on a GSO constellation is shown in figure 7-5.

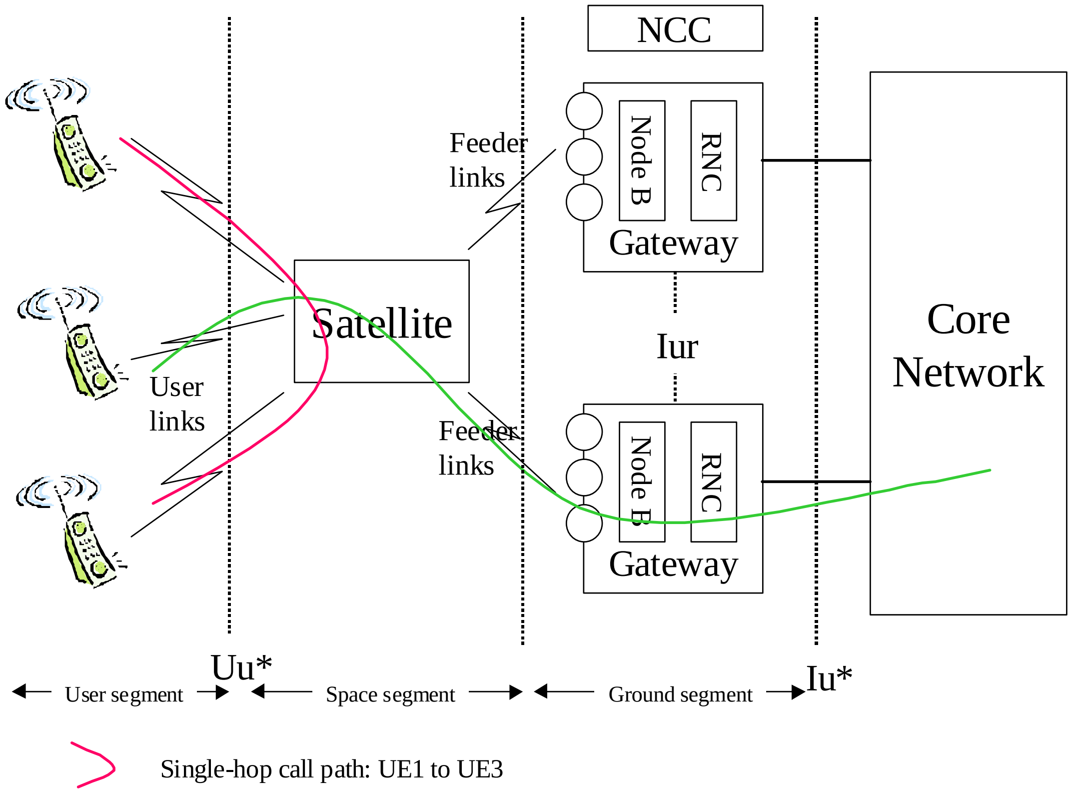



**Figure 7-5: Single-hop, GSO model for S-UMTS**

In this case the satellite segment is performing limited routing functions (in addition to the access functions) that are used to route traffic between two UEs in a single hop without going through the core network. This ability means that the satellite access network contains some of the functions that are normally provided by the core network and this additional functionality may require modifications to the both the Uu and Iu interfaces as follows:

- The Iu* interface is a modified version of the Iu interface between the RNC and the core network. This modified interface enables the USRAN to perform the single hop traffic routing in addition to the functions provided in the double-hop model. The Iu* interface should be closely based on the Iu interface defined for T-UMTS in order to allow the USRAN to connect to a standard T-UMTS core network with minimal changes to the core network.

- The Uu* is a modified version of the Uu interface between the Node B and the user equipment with the additional functions to support single hop traffic. As for the double-hop case, this interface is based on the Uu interface as defined for T-UMTS with minimum adaptation for the satellite radio path. Minimum additions and modifications to support the single-hop case is desirable to optimize the terminal design for a dual mode (S-UMTS and T-UMTS) terminal.

### 7.2.3.3 GSO S-UMTS system

Figure 7-6 illustrates an example of a GSO S-UMTS system. It consists of a geo-stationary transparent satellite payload, a number of gateways, network and satellite control centres, and the user terminals.

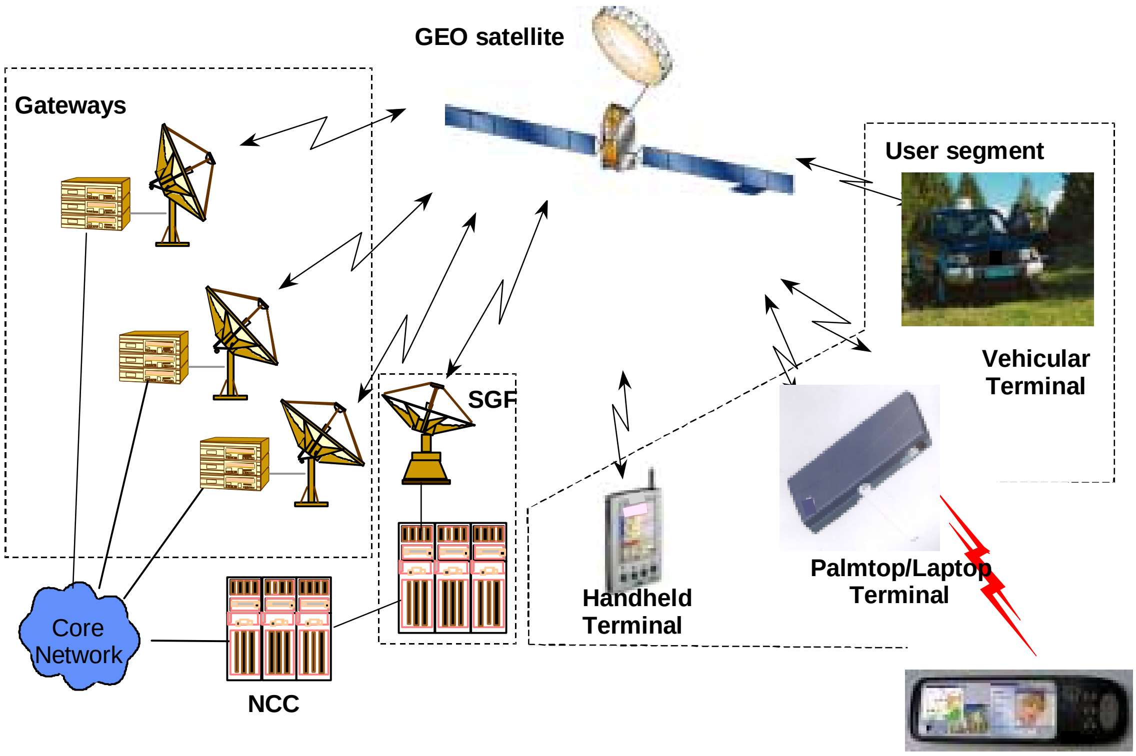



**Figure 7-6: GSO system example for S-UMTS**

The space segment consists of the satellite (or satellites) and the SGF (Satellite Ground Facilities).

The system has a large number (>100) of separate spot beams to provide the user links. These high-gain spot beams enable the system to operate with hand-held terminals. The system has a small number of separate feeder beams which provide the feeder links to one or more gateways.

The ability to support single hop UE-UE connections is optional and this service may not be supported in some cases (eg a GSO bent pipe S-UMTS system).

The satellite gateway provides similar functionality to the RNC+Node B in T-UMTS and this group of gateway functions interfaces to the core network through the standard Iu interface.

## 7.2.4 NGSO systems

### 7.2.4.1 NGSO single-hop system

A single-hop satellite system based on a LEO constellation with inter-satellite links is shown in figure 7-7.

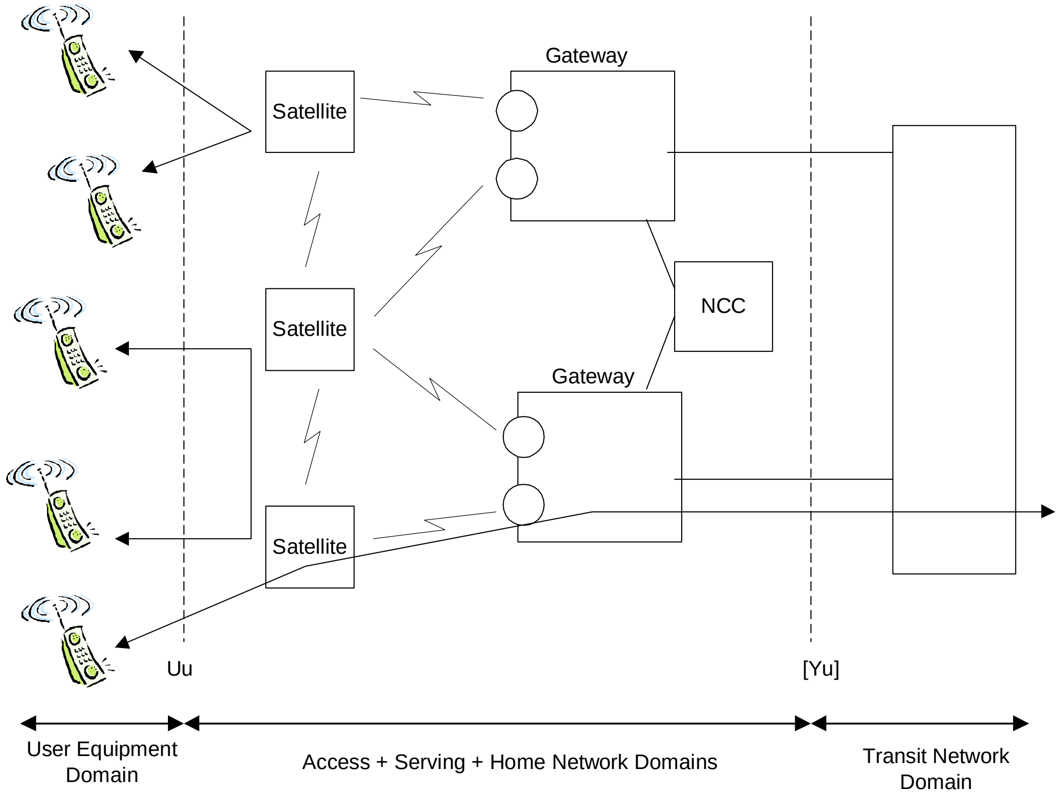



**Figure 7-7: Single-hop, regenerative, ISL, LEO model for S-UMTS**

In this model we can see that the satellite segment is performing both access and routing functions. Because of that, users can communicate directly without going through the gateway. In this model only the Uu interface can be standardized. There is no clear separation between the access and the serving network. Due to this, the overall system will act as an independent network that connects to other transit networks via the [Yu] interface.

### 7.2.4.2 NGSO double-hop system

The architecture that may be adopted for double-hop, bent-pipe, LEO system is shown in figure 7-8

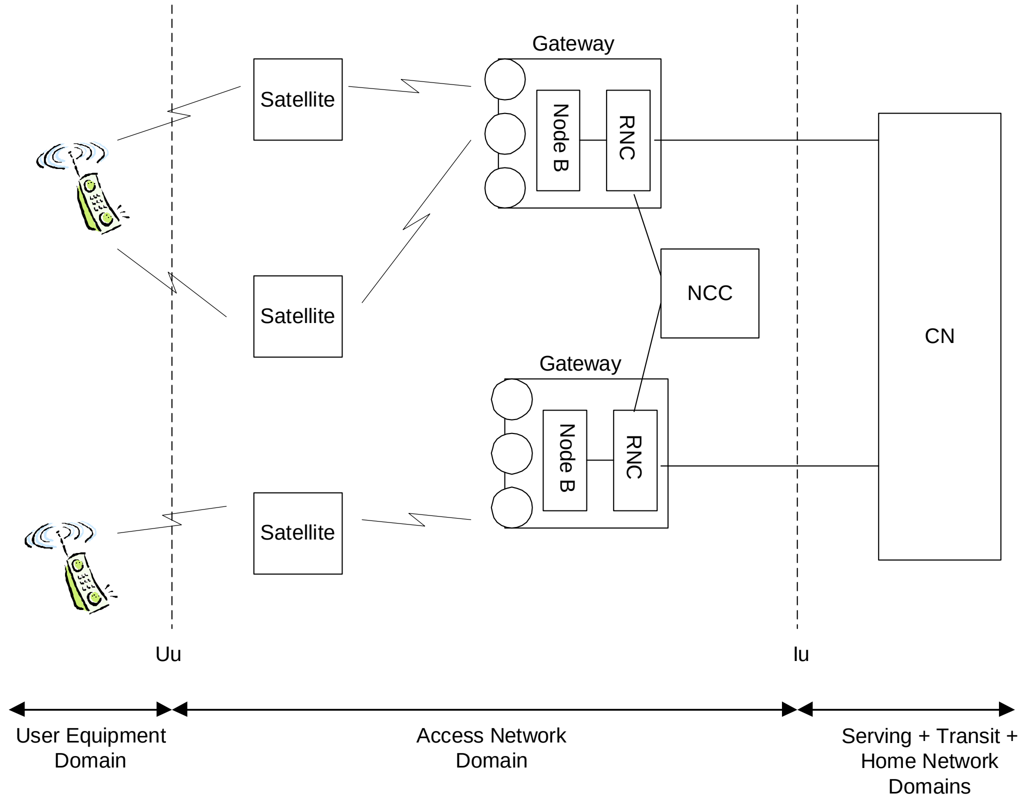



**Figure 7-8: Double-hop, bent-pipe, LEO model for S-UMTS**

The following elements taken from 3GPP specifications are used in this model:

- **the Radio Network Controller (RNC)**. Controls the radio resources. It may be co-located with the gateway and is equivalent to the BSC-Base Station Controller of GSM;
- **the Node B**. This is a base station or a set of base stations. It is usually co-located with the gateway but in the regenerative case it may be located elsewhere in the system. The 3GPP specification for the base station (Node B) may need to be adapted to cope with the movement of satellites and in particular for LEO satellites. The dynamic allocation of satellite spot beams make the interface between the Nodes B and the user terminal more complex than in the terrestrial case. This is also true for Geostationary satellites which are not truly stationary in relation to the earth's surface due to the earth's diurnal movement. Node B is equivalent to the BTS-Base Transceiver Station of GSM;
- **the RNS-Radio Network Subsystem**. This is made up of one RNC and one Node B. It is equivalent to the BSS-Base station Subsystem of GSM and is co-located with the gateway.

In addition to the previous elements, a **Network Control Centre (NCC)** has been introduced in order to co-ordinate the use of satellite resources among all gateways.

Interfaces are described as follows:

- **the Iu** interface is the interface between the RNS and the core network. It is equivalent to the A interface of GSM. The Iu interface, which is already defined for the terrestrial component of UMTS, may be shared with the satellite component with a minimum of adaptations with respect to the current specifications;
- **the Uu** interface is the air interface located between the user terminal and the satellite.

# 8 UMTS/IMT 2000 Interface adaptation to S-UMTS

## 8.1 Radio Interface (Uu) specifications for S-UMTS

The ETSI TC-SES S-UMTS/IMT-2000 working group will create air interface specifications for which there is enough interest from ETSI members. A natural set of candidates are the Radio Transmission Technologies (RTT) approved by ITU TG8/1 and ITU Radio Assembly (May 2000), but any other air interface compliant with the satellite UMTS/IMT-2000 requirements will be considered even if not part of current ITU RTTs. It is expected that the different air interfaces will be specified according to a common tree of documents whose content is specific to each air interface. Possible harmonization effort among air interfaces showing large commonalities is also encouraged.

### 8.1.1 Review of ITU-R IMT-2000 Radio Transmission Technologies

According to ITU-R Recommendation M.1457 [14] and to the associated M.1455, five Terrestrial Radio Interfaces (TRI) have been considered for the terrestrial component of IMT-2000 and six Satellite Radio Interfaces (SRI).

The Terrestrial Radio Interfaces (TRI) are:

1) UTRA WCDMA, alias CDMA Direct Sequence;

2) CDMA 2000, alias CDMA Multi-carrier;

3) UTRA TDD, alias TD-SCDMA, alias CDMA TDD;

4) UWC-136, alias TDMA single carrier;

5) DECT, alias FDMA/TDMA.

The Satellite Radio Interfaces (SRI) and their alphabetical designations are:

1) A: SW-CDMA, Satellite Wide-Band CDMA (ESA RTT);

2) B: W-C/TDMA, Wide-Band Code/Time Division Multiple Access (ESA RTT);

3) C: SAT-CDMA, formerly TTA-SAT;

4) D: formerly ICO;

5) E: formerly Horizons;

6) F: formerly INX, by Motorola.

An important point is that the approved documents mentioned above contain the main specifications and characteristics of the RTTs. However, as detailed RTT specifications are very thick and in continuous evolution, it was agreed that for detailed specifications each approved ITU TRI will point to the corresponding Standards Development Organizations (SDO) web sites. A similar approach has been followed for SRI A and B that are pointing to the ETSI TC-SES web site.

### 8.1.2 Design considerations for S-UMTS air interfaces

Propagation conditions for satellite communication differ greatly from those commonly associated with terrestrial wireless systems. The much greater distances between the transmitter and receiver, Doppler effects, atmospheric attenuation, blocking, fading and multipath diversity, are just some of the characteristics of the propagation channel. These factors, together with the operating characteristics and limitation of the satellite(s), gateway(s) and user terminals, are used to calculate the link budget, or margin of power, needed to achieve the required quality of service under adverse conditions.

A summary of orbital characteristics is given in table 8.1.2-1 and some of the more significant propagation channel design considerations, as listed below, are discussed in the following clauses:

- Propagation Channel Characteristics
- Doppler Effect
- Satellite Diversity
- Power Control

**Table 8.1.2-1: Orbit characteristics overview**

| Characteristics | GSO | HEO | MEO | LEO | Remarks |
|---|---|---|---|---|---|
| Propagation delay [ms] | 280 | 200 - 310 | 80 - 120 | 20 - 60 | maximum |
| Satellite handover during call | unlikely | every 4 - 8 hours | every 2 hours | every 10 minutes | typical values |
| Delay jump on handover [ms] | none | 12 | 24 | 4 | approx. |
| Doppler shift [kHz] | ±1 | ±50 | ±100 | ±200 | |
| Doppler jump on handover [kHz] | none | 100 | 200 | 400 | |
| Multipath delay/delay spread in-building (echo) [ns] | 200 | < 100 | 200 | 200 | much higher for aircraft and ships |
| In-call multipath fading margin [dB] | 5 to 10 | 2 | 5 to 10 | 10 - 15 | |
| Signal/data buffer needed | no | yes | yes | yes | |
| Protocol response timing | fixed | variable | variable | variable | |
| Orbit period [hours] | 24 | 8 to 24 | 6 to 12 | 1,5 | |
| Approx. number of gateways for global coverage | 10 | 10 | 10 | 50 | |
| Range of elevation angles [degrees] | > 10 | > 40 | > 10 | > 10 | |
| Number of satellites for near global coverage | 3 | 5 - 12 | 10 - 15 | > 48 | |

### 8.1.2.1 Propagation channel characteristics

As for any wireless system, channel characteristics play a key role in the definition of an S-UMTS RTT. Note that propagation conditions are quite different for LEO/MEO/GSO S-UMTS with respect to T-UMTS. In fact, the T-UMTS channel is typically affected by lognormal long-term shadowing and by Rayleigh short-term multipath fading, with generally no line-of-sight (LOS) component, except possibly in pico-cellular environments. In these conditions the adoption of a rake receiver is certainly advisable, to detect and combine the strongest multipath components and to allow for soft hand-off. Multipath diversity provides increased quality of service through fading mitigation. Conversely, due to the larger free space loss and on-board RF power scarcity, mobile satellite systems are forced to operate under LOS propagation conditions, at least for medium-to-high data rates. This results in a milder Rice (or at most Rice-lognormal) fading channel [9], with a Rice factor (the power ratio between LOS component and diffuse component) typically ranging between 7 to 15 dB. Multipath diversity in a single satellite link cannot be exploited due to the fact that paths with differential delays exceeding 200 ns most often result to have insufficient power to be usefully combined by the rake receiver. Thus fading is effectively non-selective, preserving the multiplex orthogonality and minimizing intra-beam interference. Another major difference is that the useful dynamic range for the received signal power is much smaller than for terrestrial systems (for which it goes up to 80 dB). This is due to the different system geometry (reduced path loss variation within each satellite beam, in the order of 3-5 dB), and again to the limited on-board RF power which is insufficient to counteract path blockage. Path blockage can be induced by heavy shadowing from hills, trees, bridges and buildings; the car's body, and the head of the user can also have a non-negligible impact. Tree shadowing can lead to 10-20 dB of excess attenuation and is often the cause for link outage. In essence, S-UMTS must operate in an on/off propagation channel, with Rice fading in the on condition [9]. Countermeasures to blockage-induced outage are essential to achieve satisfactory quality of service.

### 8.1.2.2 Doppler effect

Doppler effects are of relevance to S-UMTS because of the possible satellite rapid movement with respect to the gateway stations and user terminals. For LEO and most of MEO constellations satellite-induced Doppler is dominating over possible user terminal speed effects. User speed has still a major impact in determining the Ricean fading bandwidth. In fact, the Doppler and delay variations due to the satellite movement relative to the gateway station can almost be perfectly compensated by means of feed-forward pre-compensation techniques based on precise satellite orbital position knowledge. This approach allows to remove the largest Doppler (and Doppler rate) contribution being the feeder link frequency typically operating at C/Ku/Ka frequency band whereby the carrier frequency is much higher than the S-band user link. Satellite to user downlink Doppler can also be removed with feed-forward techniques for the centre of each antenna beam, thus leaving the demodulator to deal with the differential Doppler between the centre of the beam and its current location. Depending on the beam size the downlink residual differential Doppler offset amounts to a few kHz, i.e. typically less than frequency offset caused by terminal clock instabilities. The user terminal demodulator can estimate the downlink satellite carrier frequency differential Doppler, allowing for accurate uplink Doppler pre-correction. The latter, jointly with feeder link Gateway pre-correction, minimize the amount of return link frequency uncertainty at the gateway demodulator input.

GSO systems also experience Doppler effects but these are limited to about 1 kHz. Software in the user terminal compensates for this effect particularly when the user terminal is located at the edge of adjacent spot beams.

### 8.1.2.3 Satellite diversity

Satellite diversity can provide benefits in terms of reduced blockage probability, soft and softer-handoff capability, slow fading counteraction, and under certain conditions even increased system capacity. First of all, the intuition that the probability of complete blockage greatly reduces with the number of satellites in simultaneous view recently found confirmation in experimental campaigns [10]. Figure 8-1 from [11] shows how in a typical suburban environment the probability of blockage varies with the minimum elevation angle and the number of satellites in view. Reduced blockage translates immediately into improved quality of service. Note that the multiple satellites can be exploited very efficiently in a CDMA system adopting rake receivers to realize soft satellite-handoff and softer spot beam-handoff. CDMA also allows flexible allocation of diversity to different classes of terminals supported by IMT-2000. In fact, fixed or transportable terminals enjoying low blockage probability can be operated without satellite diversity in the forward link thus optimizing network resources exploitation. It should be noted that for packet services directed to nomadic users a selection diversity scheme may be preferable. Some form of satellite diversity exploitation with TDMA is also possible in principle but is not elaborated in the following discussion.

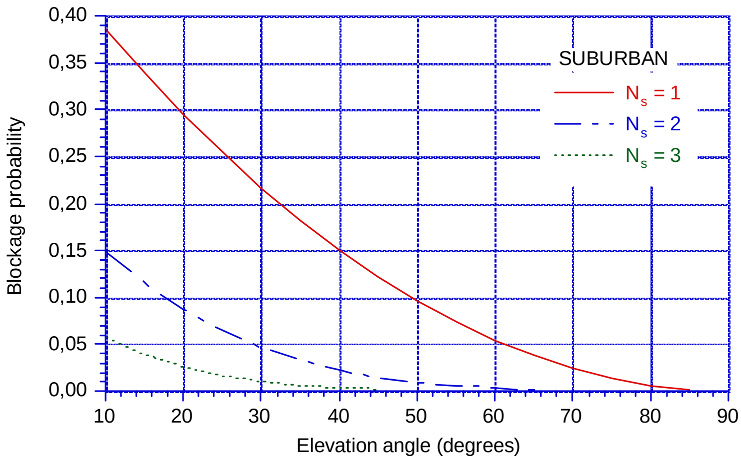



**Figure 8-1: Path blockage probability in a suburban area, with the number of satellites ($N_S$) above the minimum elevation angle as a parameter [11]**

Satellite diversity exploitation in the forward link has a few differences with respect to the return link that are worth recalling. In the forward link satellite diversity must be forced by the system operator by sending the same signal to different satellites through highly directive antennas. Note that the forward link transmitted multiplex can adopt synchronous CDMA with orthogonal spreading sequences. Differently from the terrestrial case, the non-selective satellite fading channel preserves the multiplex orthogonality, thus minimizing intra-beam interference. It should be noted that forwarding the signal through different non co-located satellites somewhat increases the amount of inter-beam interference, thus causing an apparent capacity loss. The amount of forward link capacity loss due to satellite diversity exploitation depends on many system parameters. In general we can say that by proper system design the loss can be kept within acceptable boundaries.

Assuming transparent transponders, exploitation of satellite diversity in the return link is practically unavoidable due to the MT quasi omni-directional antenna. Universal frequency reuse allows for satellite antenna arraying (similar to Deep Space probes ground reception techniques) whereby the different replicas of the same user terminal signal transponded by the different satellites are independently demodulated, time aligned and coherently combined at the gateway station. This detection technique, requiring a rake receiver, results in a drastic reduction in the user terminal EIRP even under LOS conditions.

As noted in clause 8.1.2.1, multipath diversity cannot be exploited in S-UMTS, and this fact can seriously affect the link budget especially for slow moving User Equipment (UE). Once more, satellite diversity comes in to yield very significant gains even in the presence of slow fading. This is extremely important as slow fading is neither counteracted by power control (characterized by very slow dynamic capabilities) nor by the finite size interleaver. For mobile satellite systems slow fading represents the most power demanding link condition. With satellite diversity it is possible to largely counteract these adverse slow fading effects with very modest power margins.

#### 8.1.2.4 Power control

In general we can say that power control is important for any mobile satellite network to maximize system efficiency and to maximize User Equipment (UE) battery lifetime. Although it is sometimes felt that the power control for TDMA is less important than for CDMA this opinion is debatable in view of the 3G networks need to maximize efficiency and UE data rate capabilities. Aggressive frequency reuse for TDMA will enhance the power control relevance for this multiple access too. The following discussion is mainly centred on the issue of power control for CDMA satellite networks that is generally deemed the most critical case.

Considerable attention has been devoted to a fundamental issue for any CDMA system: power control. In fact, although the near-far effect in S-UMTS is not as bad as for T-UMTS, power control must necessarily be implemented in order not to waste precious power and system capacity. Slow (traceable) power level variations are due to different causes such as satellite motion (path loss changes), satellite and user antenna gain variations, shadowing, user MT speed changes, time varying co-channel interference. As in T-UMTS, a combination of open-loop for random access channels and closed-loop power control for connection-oriented channels is required. Due to the longer satellite propagation delay, closed-loop power control is slower and less responsive to fast dynamics as compared to T-UMTS, and as such its design is critical.

NOTE: Power level variation resulting from satellite motion tends to be compensated by the so-called iso-flux antenna design that attempts to equalize the geometry dependent path loss with antenna gain shaping.

Simulation results confirm that in S-UMTS power control is unable to track fading fast power variations, and as such there are limited gains in average requested power with respect to non-power controlled system. However, if power control is not implemented the requested power must be achieved through the use of static link margins, which must therefore be sized for the worst case attenuation. Instead, adaptive power control is capable to detect unacceptable link quality of service and promptly correct for it with an adequate average power increase only when it is required. In essence, power control is essential in S-UMTS systems to avoid capacity degradations induced by the use of static link margins.

## 8.2 Universal Subscriber Identification Module (USIM) and USIM Mobile Terminal Interface (Cu)

It is envisaged that the USIM will be used in the same way as the current 2G SIM in existing dual mode satellite handsets. Assuming that S-UMTS terminals, the ground segment architecture and network signalling will in most cases be the same as that specified for terrestrial UMTS, no changes to the USIM to terminal (Cu) interface, as specified by 3GPP, are envisaged in the immediate future. With regard to the USIM, some additional parameters may need to be added to the USIM as currently specified by the 3GPP and this is discussed in clause 8.2.1.

The Universal Subscriber Identification Module (USIM) functionality, whilst retaining backward compatibility with GSM, differs from the current 2G SIM in several ways. One of the most significant design enhancements enables higher data rates and thus faster access to the USIM. This has been achieved by changing from the current serial data transfer to block data transfer across the Cu interface.

Extra USIM capacity should allow some S-UMTS system information, for example spot beam pre-selection details, and S-UMTS specific service information, to be held on the USIM rather than in the terminals own memory.

### 8.2.1 Analysis of USIM and S-UMTS requirements

At the time of writing the present document some 3rd Generation USIM details were yet to be specified. However, an initial analysis of TS 131 102 [5] has revealed that certain S-UMTS parameters should be added to the proposed USIM. The results from this analysis are shown in tables 8.2.1-1 and 8.2.1-2. The comments indicate which Elementary Files (EF) should be added to TS 131 102 [5], and which still need more investigation.

In the information tables 8.2.1-1 and 8.2.1-2 below, a letter after the EF name has the following meaning:

**n)** Indicates a new EF for S-UMTS Mobile Terminal.
**m)** Indicates an EF for S-UMTS Mobile Terminal whose contents or size are different than that corresponding for GSM.

**Table 8.2.1-1: New and Modified Elementary Files in the "S-UMTS directory" for a multi-mode USIM**

| SIM EF | S-UMTS Directory Contents and Usage | Size (bytes) | Comments |
|---|---|---|---|
| LOCI **m)** | LAI+, TMSI, LU Status; LAI+ consists of PLMN (MCC/MNC), PSMN (SSC/SNC), LAC. | 14 | 3G $EF_{LOCI}$ (Location information) is only 11. Further S-UMTS details are needed to motivate increase in size. |
| PSMN Selector **m)** | Preferred PSMN list. List of preferred PSMNs to select service in (4 PSMNs). | 12 | 3G $EF_{PLMNsel}$ (PLMN selector) contains Mobile Country Code (MCC) followed by the Mobile Network Code (MNC). Some details of the S-UMTS PSMN would be needed. May need an extra byte per selector which identifies the type: terrestrial, satellite, etc. |
| Forbidden PSMNs | Forbidden PSMNs. List of PSMNs NOT to select for service (4 PSMNs). | 12 | Same as above |
| S-BCCH Table **m)** | Neighbour spotbeam descriptor. | 18 | Similar to GSM 11.11 clause 10.3.14 $EF_{BCCH}$ (Broadcast control channels). The 3G spec has nothing comparable! |
| SIM Service Table | S-UMTS features available on the SIM. | 5 | 3G 4.2.7 $EF_{UST}$ (USIM service table) is just a single table. There is no provision for an alternate service table, which is what S-UMTS will use. This should be incorporated. |
| HPSMN Search Period | Used during search for HPSMN. | 1 | 3G 4.2.5 $EF_{HPLMN}$ (HPLMN search period) is similar. Really just a re-naming and allocation of a new storage location, since the value may be different for satellite vs. terrestrial network. |
| Phase ID | S-UMTS phase ID. | 1 | Corresponds to the GSM Efphase id. This is currently not used, since there has never been a 2nd phase of UMTS specifications. There is no EF with this name in 3G. |
| Home PSMN **n)** | SCC and SNC for the home PSMN. | 3 | Nothing with a comparable name (Home PLMN) in GSM or 3G. This is used to determine if satellite access is granted or barred. There MUST be something like that in terrestrial network operation. |
| Beam Pair LAI List **n)** | Valid beam pair LACs for current LA. | 12 | New for satellites. This feature is used to reduce the number of location updates caused by the earth's motion with respect to the satellite. Inclined Orbit Beam Pairs are broadcast as System Information, and the S-UMTS SIM stores the information. There is nothing comparable in a terrestrial system. |

**Table 8.2.1-2: New Elementary Files in the Telecom directory for S-UMTS/UMTS/GSM multi-mode USIM**

| Item name | Values | Comments |
|---|---|---|
| HPMN Indicator **n)** | HPMN is Satellite or Terrestrial.<br>1 byte. | Needs to be added to 3GPP specification. |
| Operational Mode **n)** | Mode: TO=Terrestrial Only,<br>TP=Terr. Preferred,<br>SO=Satellite Only,<br>SP=Satellite Preferred.<br>1 byte. | Needs to be added to 3GPP specification. |
| CCP-S-UMTS **n)** | Same as CCP for GSM, but used in S-UMTS mode. 14 bytes. | Similar to 3GPP USIM TS clause 4.4.3.11 $EF_{CCP}$ (Capability Configuration Parameters), but for the satellite mode. Needs to be added to 3GPP specification. |

## 8.3 Core Networks interfaces

### 8.3.1 Interface with the UMTS core network (Iu)

Depending on the architecture of the satellite system (e.g. GSO, non-GSO, single-hop, double hop, ISL, non-ISL, etc.) different solutions shall be implemented when interfacing the satellite system with the core network (CN) (see clause 7). For example, in the double-hop scenario (for both GSO and non-GSO) this interface shall preferably use the same Iu interface as defined for T-UMTS in order to allow the USRAN to connect to a standard T-UMTS core network. In other scenarios, e.g. single-hop GSO or single-hop non-GSO the satellite system shall interface respectively to the core network with a modified version of the Iu interface (i.e. Iu*) or as a serving network domain within the core network (Yu). This is due to the fact that in the double-hop scenario the satellite system is mainly performing radio access network (USRAN) functions whereas in the single-hop case the satellite system also performs routing functions.

### 8.3.2 Recommendations for interfacing a satellite system with the core network at the Iu level

As already mentioned, it is not expected that the interface of a satellite radio access network (i.e. providing radio access bearers) to the core network presents any major difference in comparison to terrestrial radio access networks. However, the following recommendations are given in order to technically assess the compatibility of a specific satellite system at the Iu interface level:

- **Access stratum functions resolved with support from CN**. In order to assess the suitability of the Iu interface to specific satellite architecture, it is recommended to perform a functional analysis of the USRAN (e.g. radio resources control, mobility aspects, etc.). After performing the functional model, those functions that need to be resolved with the support of the CN shall be identified (e.g. hand-over between two access networks, macro-diversity, etc), and differences with respect to the T-UMTS case shall be assessed (e.g. new functions, different information elements, etc). A list of functions and services provided by the access stratum for T-UMTS is given in TS 123 110 [17]. It is interesting to note that the RNSs belonging to the same satellite system can be interconnected via the NCC, as shown in clause 7. This may allow co-ordination at the RNS level of satellite specific functions without relying on CN support (e.g. satellite resource management), thus easing the interfacing of the satellite access stratum to the core network by means of the Iu interface.

- **Extension of signalling protocols at the Iu interface [**18**] to perform new access stratum functions with support from CN**. Current signalling protocols at the Iu interface define a set of elementary procedures (e.g. messages, timers and information elements). In case needed, it is not expected to be a problem to add a new elementary procedure based on current definitions.

- **Performance assessment of the functions performed and services offered by the satellite access stratum**. The same model of the USRAN shall be used to assess the performance of the different signalling procedures performed by the satellite access stratum. This shall demonstrate the Iu protocols execution and performance (e.g. delays, overheads, etc.) for a specific satellite scenario. A similar analysis of the signalling procedures for the terrestrial access network can be found in TR 125 931 [19]. This exercise shall also assess the quality of the services offered by the satellite access stratum and seek to integrate the satellite QoS. with the terrestrial QoS. (see TS 123 107 [20] for T-UMTS radio access bearer QoS attributes and range values.)

# 9 Standards and Regulatory Aspects

The ongoing ITU IMT-2000 regulatory work is discussed below. It should be noted that ITU-R created a special task group TG8/1 to select and evaluate candidate RTTs for both the terrestrial and satellite segments of IMT-2000. On completion of their work, TG8/1 was dissolved and future work relating to these, and any new RTTs, will be carried out by ITU-R Study Group 8 (Working parties 8F and 8D).

## 9.1 ITU-R Recommendations for IMT-2000

Mobile systems are under responsibility of the Study Group 8 in the Radio-communication sector of the International Telecommunication Union (ITU-R). The Recommendations developed so far on IMT-2000 are (the complete list of recommendations on mobile can be found at: http://www.itu.int/itudoc/itu-r/rec/m/index.html.

**Table 9.1-1: ITU-R (Radio Communication Sector) IMT-2000 Recommendations**

| | |
|---|---|
| ITU-R M.687 | International Mobile Telecommunications-2000 (IMT-2000) |
| ITU-R M.816 | Framework for services supported on International Mobile Telecommunications-2000 (IMT-2000) |
| ITU-R M.817 | International Mobile Telecommunications-2000 (IMT-2000) - Network architectures |
| ITU-R M.818 | Satellite operation within International Mobile Telecommunications-2000 (IMT-2000) |
| ITU-R M.819 | International Mobile Telecommunications-2000 (IMT-2000) for developing countries |
| ITU-R M.1034 | Requirements for the radio interface(s) for International Mobile Telecommunications-2000 (IMT-2000) |
| ITU-R M.1035 | Framework for the radio interface(s) and radio sub-system functionality for International Mobile Telecommunications-2000 (IMT-2000) |
| ITU-R M.1036 | Spectrum considerations for implementation of International Mobile Telecommunications-2000 (IMT-2000) in the bands 1 885-2 025 MHz and 2 110-2 200 MHz |
| ITU-R M.1167 | Framework for the satellite component of International Mobile Telecommunications-2000 (IMT-2000) |
| ITU-R M.1224 | Vocabulary of terms for International Mobile Telecommunications-2000 (IMT-2000) |
| ITU-R M.1225 | Guidelines for evaluation of radio transmission technologies for International Mobile Telecommunications-2000 (IMT-2000) |
| ITU-R M.1308 | Evolution of land mobile systems towards IMT-2000 |
| ITU-R M.1311 | Framework for modularity and radio commonality within IMT-2000 |
| ITU-R M.1343 | Essential technical requirements of mobile earth stations for global non-geostationary mobile-satellite service systems in the bands 1-3 GHz |
| ITU-R M.1455 | Key characteristics for the IMT-2000 radio interfaces |
| ITU-R M.1457 | Detailed specifications of the radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)* |
| ITU-R M.1480 | Essential technical requirements of mobile earth stations of geostationary mobile-satellite systems that are implementing the GMPCS-MoU arrangements in parts of the band 1-3 GHz |
| ITU-R SM.329 | Spurious emissions |

## 9.2 ITU-T Recommendations for IMT-2000

A Special Study Group on « IMT-2000 and beyond » has been created during the World Telecommunication Standardization Assembly (WTSA-2000) held in Montreal, Quebec, Canada, from 27 September to 6 October 2000. This group has the primary responsibility within ITU-T for overall network aspects of IMT-2000 and beyond. This group is responsible for (http://www.itu.int/ITU-T/ssg/area_resp.html):

- Developing a work plan for ITU-T activities on IMT-2000 systems and beyond, to ensure that this work is progressed effectively and efficiently with organizations external to ITU and internally with ITU-R and ITU-D, as appropriate.
- Providing a migration path regarding network aspects and mobility from existing IMT-2000 systems towards systems beyond IMT-2000.
- Enhancing an overview road map (Supplement to Recommendation Q.1701) on network aspects and mobility of existing IMT-2000 systems specified by ITU-T and external organizations (e.g. Standards Development Organizations (SDOs), Partnership Projects (PPs), IETF, and relevant external forums, etc.)
- Providing interworking functions as needed and if not provided by other organizations, to allow for global mobility between existing IMT-2000 systems specified by external organizations.

The second point above includes the development of a long-term common IP-based network architecture as applicable to IMT-2000. The fourth point above, considering the ongoing evolutionary directions of network infrastructure, includes near term IP-based internetworking.

In addition, this Special Study Group will study:

- Harmonization of different IMT-2000 Family member standards as they evolve beyond IMT-2000 as much as possible in co-operation with relevant bodies.
- Evolution of network aspects of IMT-2000 from the existing fixed network by utilizing the IMT-2000 radio transmission technologies as fixed wireless access.
- Network aspects of the convergence of fixed and wireless networks and ultimately migration to interoperable and harmonized network architectures to provide services transparently to users across different access arrangements.
- Assessment of the need for, and standardization of, IMT-2000 interfaces to provide multi-vendor advantages for operators, if not provided by external organizations.

In order to assist developing countries in the application of IMT-2000 and related wireless technologies, consultations should be held with representatives of ITU-D with a view to identifying how this might best be done through an appropriate activity conducted in conjunction with ITU-D.

The existing IMT-2000 Recommendations are as shown in table 9.2-1. The complete list of Q Recommendations can be found at: http://www.itu.int/itudoc/itu-t/rec/q/q1000up/index.html.

**Table 9.2-1: ITU-T (Telecommunications Sector) IMT-2000 Recommendations**

| | |
|---|---|
| ITU-T Q.1701 | Framework of IMT-2000 networks |
| ITU-T Q.1711 | Network functional model for IMT-2000 |
| ITU-T Q.1721 | Information flows for IMT-2000 |
| ITU-T Q.1731 | Functional specifications and requirements for IMT-2000 radio interface |

# 10 Survey of current R&D projects related to the satellite component of UMTS

A brief summary of some current Research and Development (R&D) project related to the satellite component of UMTS is provided in the following clauses.

## 10.1 IST Project: VIRTUOUS

VIRTUOUS project aims at investigating the UMTS system in order to contribute to the standardization process for the satellite part while reducing the impact in introducing this new radio access segment. At the same time this project aims at defining a migration path from the second generation toward the third generation cellular system for the terrestrial segment to facilitate the development and the introduction of this new system. VIRTUOUS project has the main scope to integrate the terrestrial segment with the satellite one while guaranteeing the integration and the interaction with the second generation terrestrial cellular system (i.e. the GPRS).

As main result of this integration process of the different radio access networks, the prototype of a multi-mode terminal will be developed and designed in order to obtain service from both the second generation and the third generation radio access networks and, for the last one, utilizing both the terrestrial and the satellite segments.

The integration of the S-UMTS part with the terrestrial one of the UMTS network is key objective of VIRTUOUS. Within this project this aim is reached by introducing a satellite part which is as similar as possible to terrestrial one, following the 3GPP principles, in order to share the most part of the architecture and functionalities.

The method utilized to obtain the integration of the different radio access segments is based on the commonalities between the two segments and the sharing of the common functions to reduce the impact on the previously implemented part and the complexity of the overall radio access network.

As regards the integration of these two different segments the main concept is the reuse of the terrestrial radio access part also for the satellite segment identifying the Radio Technology Independent (RTI) part shared between the two segments. The remaining part of the functional architecture, referred as Radio Technology Dependent (RTD) part, has been specifically designed to match the specific requests of the terrestrial and satellite segments.

The integration of the T/S-UMTS radio access network with the second generation system, needed to facilitate the introduction process of the UMTS, is done by connecting the UMTS access network to the GPRS core network via a 3rd Generation-Serving GPRS Support Node (3G-SGSN) at the network side, and introducing a Terminal Inter-Working Unit (T-IWU) inside the terminal to manage the different radio access networks providing service.

The overall VIRTUOUS demonstrator architecture is shown in figure 10-1:

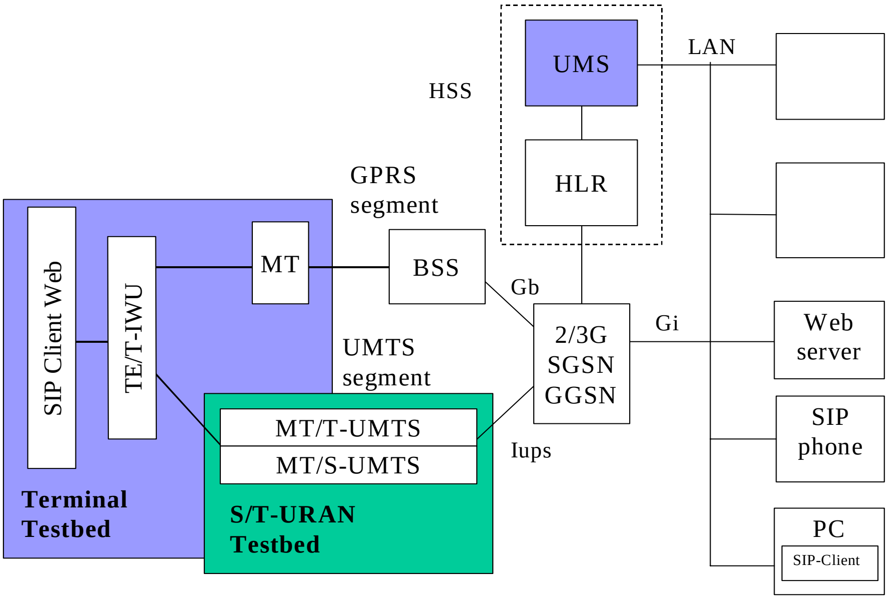



**Figure 10-1: VIRTUOUS demonstrator architecture**

The basic device of the overall demonstrator is the S/T-URAN Testbed which is the emulator of the physical layer both for the terrestrial and the satellite segment.

For the terrestrial segment it is able to emulate the coverage provided by more than one Node_B and the movement of the mobile user on a real environment. For the satellite one the same device can emulate different satellite constellations, (e.g. LEO, MEO or GSO) by setting some control parameters and emulate the coverage provided by the overall constellation simulating also the movement of the satellites.

As depicted in the previous figure, the radio access network is divided in two different parts that are relevant to the 2nd and 3rd Generation systems.

For the 2nd Generation system the GPRS system has been utilized and the overall protocol architecture for the radio access network has been implemented. The connection of the 2nd and the 3rd Generation radio access networks has been performed utilizing the same 2G/3G-SGSN which provides the access to the GPRS/UMTS core network. The 2G/3G-SGSN has been obtained by enhancing a 2nd Generation SGSN while introducing some further functionality to support the UMTS radio access network.

At the terminal side the utilization of all the foreseen radio access networks is obtained by including in the terminal a T-IWU which decides the more suitable segment and network from which to receive service. This device is responsible for the monitoring of the quality of service that different radio segments can provide and of the decision about the segment selection.

To manage the mobility of the terminal over an multi-coverage environment an enhanced Home Location Register (HLR) has been foreseen with some additional functionalities more suitable for a 3G system. A further device is in charge of the mobility management, this is the User Mobility Server (UMS) which is responsible for the mobility management from the application point of view introducing the functionalities according to the Session Initiation Protocol (SIP) specifications.

At the network side the above-mentioned demonstrator has a Local Area Network (LAN) with some users connected to the fixed network which represents the called/calling party to permit the communication with the mobile user.

These users are represented by a Web Server, a PC with SIP client features and a SIP based phone.

The overall demonstrator is utilized to show the ability of the designed system to:

- Provide a SIP based service for telephony, web browsing and multimedia communications;
- Ensure the wanted Quality of Service to all the active connections;
- Permit the user to roam in a multi-segment environment.

The above-mentioned key-points are relevant for the three experiments that are foreseen in VIRTUOUS project.

The first experiment is referred as "End-user service experiment" and it aims at investigating and demonstrating the application of a SIP based service provision for real-time, non-real-time and multimedia communications.

The goal of the "Quality of Service experiment" is to demonstrate the ability of the designed architecture to ensure a service specifically tailored for the needs of the active connection.

The ability of the designed terminal to utilize different radio access segments is demonstrated with the "Inter-Segment Roaming Experiment"; the foreseen trial has the main scope to show how the designed terminal can decide the most suitable segment and the functionalities needed to ensure the inter-working among all the available segments.

To perform the choice among the segments and to execute the registration on the selected one, the terminal is provided with all the segment-specific terminals that are monitored and controlled by a Terminal Inter-Working Unit, as depicted in figure 10-2.

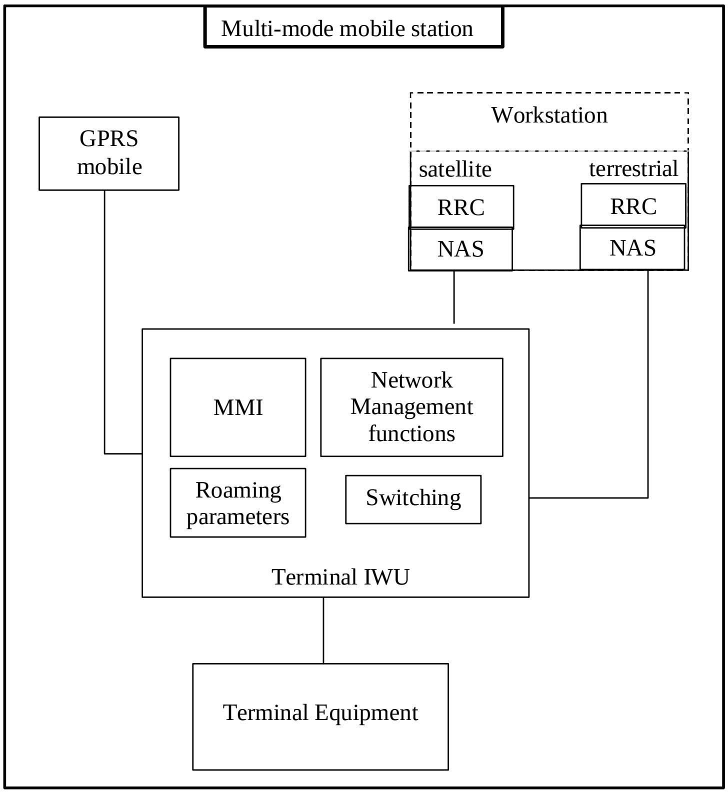



**Figure 10-2 : Multi-mode mobile terminal**

The main device of the multi-mode terminal is represented by the above-mentioned T-IWU which manages the segment-specific terminals and triggers the attachment and registration procedure in the more suitable segment translating the messages accordingly to the specific format of the required terminal (i.e. GPRS or S/T-UMTS).

Actually VIRTUOUS consortium is defining the functional architecture of all the needed functionalities for the foreseen experiments and starting the implementation of the different parts of the presented demonstrator. In the next months all the functionalities will be implemented and tested in order to perform the integration of the overall demonstrator.

The results of this project will be as input for the FUTURE project aiming at introducing some additional capabilities, functionalities and services toward the real implementation of the UMTS network and at developing this system in order to obtain the complete integration with an IP core network.

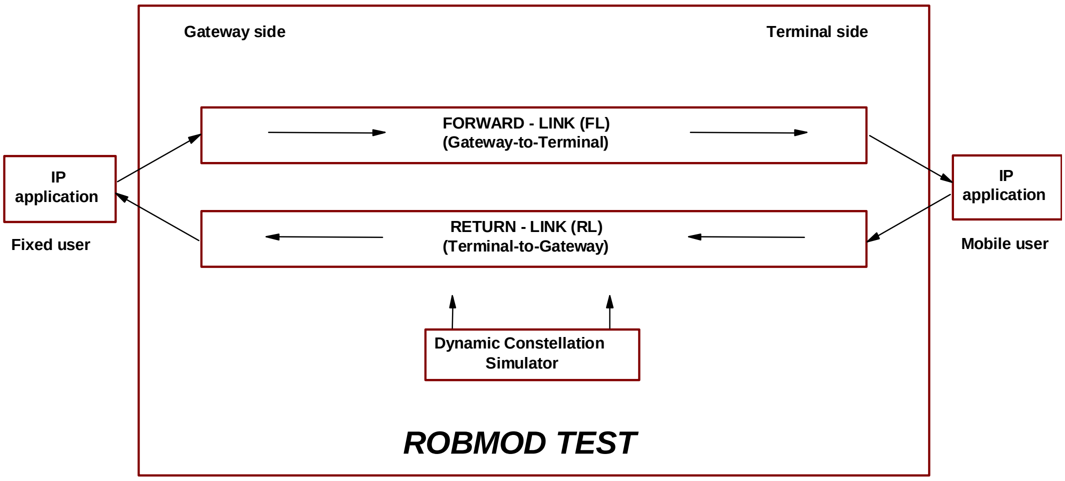
## 10.2 ESA: ROBMOD

The ESA ROBMOD project (Robust Modulation and Coding for Personal Communications Systems ) aims at defining and validating a candidate physical-layer approach for the satellite component of UMTS. ROBMOD saw the participation, under Space Engineering (I) prime-contractorship, of Ascom (CH), CoRiTel (I), IMST (D), Politecnico di Torino (I) and SquarePeg (C).

Contract Phase 1, completed by 1999, mainly consisted of extensive trade-off and simulation activities, covering important issues such as frame structures, diversity advantage assessment in realistic conditions, acquisition and synchronization, chip-synchronous reverse-link feasibility, power control performance, multi-user interference mitigation techniques, impact of non-linearity, BER/FER performance assessment in a real channel, ad-hoc coding techniques for speech and video transmission, embedded user-location functions. On the basis of ROBMOD Phase-1 results, ESA submitted ITU a standardization proposal for two CDMA-based Radio Transmission Technologies, i.e. a SW-CDMA solution exploiting pure CDMA and suitable for FDD operation, and a S-CTDMA solution exploiting CDMA/TDMA and suitable for TDD operation.

Phase 2, scheduled to complete by mid-2001, covers the implementation and testing of a very comprehensive hardware facility (the Test Bed) which had been specified by the end of Phase-1. Such facility consists of physical devices generating and modifying signals, as required to faithfully reproduce the effects experienced in a real via-satellite SW-CDMA operational environment. It also includes some basic upper-layer functions, such as to permit realistically demonstrating, in real-time, an IP-based application though the Test Bed. The ESA choice to concentrate mainly on physical-layer issues followed the consideration that, especially for the satellite case, this layer will constitute one of the hardest challenges with regard to successful UMTS deployment; on the other hand most of the upper-layers will likely be common to those of the terrestrial component.

The ROBMOD Test Bed models a complete bi-directional Gateway Terminal satellite link, interfaced, for demonstration purposes, to two external PCs respectively running the client function (at the mobile user side) and the server function (at the fixed user side) of an IP-based application, as synthetically shown below.




- CDMA chip-rate: 3,84 Mchip/s
- Information rate: 64 kbit/s (being upgraded to 128 Kbit/s in the frame of VIRTUOUS)

**Figure 10-3**

The Test Bed provides an hardware-based emulation of virtually all effects occurring in a real SW-CDMA environment. The following main features are offered:

- multi-satellite diversity and beam-handover with coherent combining. For these purposes, hardware emulation of three independent and fully-programmable "satellite paths" is provided, each including seven "beam paths", also programmable. On the forward-link, the Gateway transmit-side incorporates three data-channel modulators, while the Terminal demodulator has three fingers. On the reverse-link, the Gateway demodulator has four fingers;
- realistic channel representation, by means of hardware providing independent emulation of free space losses, delay, Doppler, user-defined propagation channel, etc.;
- Multiple-user Access Interference, simulated by hardware CDMA codes generators. not just by thermal noise;
- power control implemented via real signalling channels; frequency control loops;
- adaptive interference suppression for the Gateway demodulator (Blind-Minimum Output Energy algorithm);
- selection of FEC codes (convolutional, 3GPP turbo code);
- support of most physical and logical channels specified for SW-CDMA.

The physical layer is basically managed on circuit-basis; furthermore some upper-layer functions were included (e.g. call control and satellite- & beam-handoff management via ad-hoc signalling channels).

A Dynamic Simulator makes the Test Bed parameters evolve, for having it to reproduce, in real-time, the link parameters and the geometric characteristics of any user-defined constellation, including the LEO ones.

The Test Bed incorporates interfaces at IF level, for connection to Gateway and Terminal radio front-ends, in view of future tests via a real satellite.

A software-intensive implementation strategy has been adopted, to allow varying, to a good extent, the air-interface parameters and the test conditions, in the perspective of tracking specification changes being progressively introduced by 3GPP. A top-level block diagram is presented in figure 10-4.

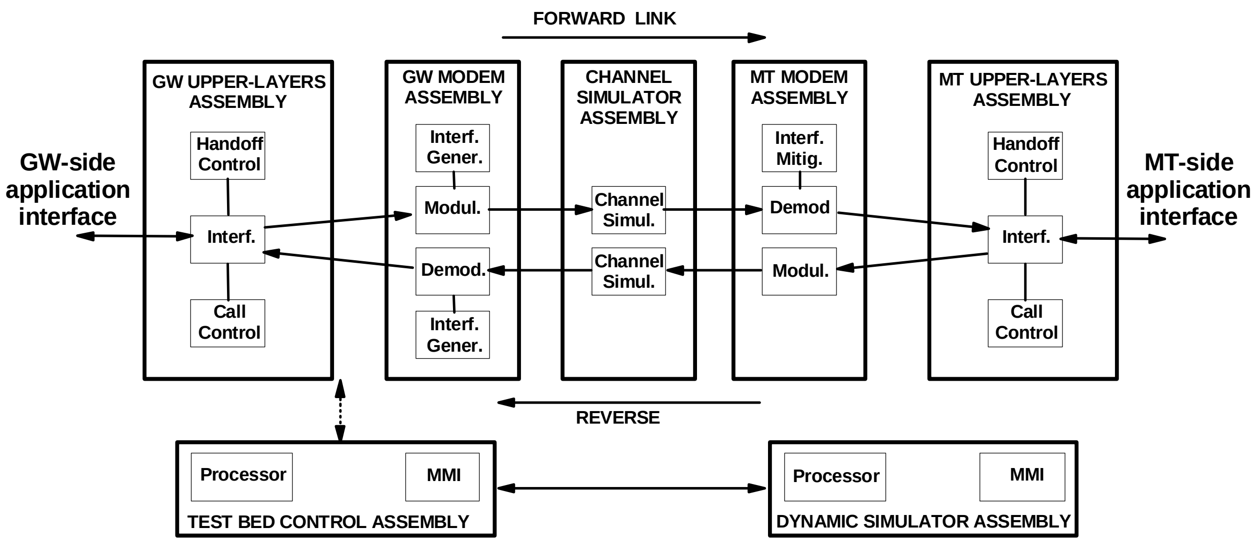



**Figure 10-4**

The ROBMOD Test Bed will constitute an important facility for SW-CDMA physical-layer validation and tune-up, even in conjunction with real satellites. Its ability to reproduce different constellations and system configurations, as well as the possibility to adapt it to different physical-layer parameters, make the Test Bed a tool of quite general use.

IST: SATIN

Project SATIN (Satellite over IP Network) is an in-depth research and technology project that will define and evaluate efficient S-UMTS access schemes based on packet-based protocols whilst allowing multicast service optimization. These access schemes will be based as much as possible on the UTRA access scheme to allow maximum commonality of terminals. Approaches for LEO, MEO and GSO constellations will be included. The type of satellite constellation is a major consideration in the overall S-UMTS design. S-UMTS services might in fact be best delivered through a hybrid system with regional and global components. For instance different service types are associated with different levels of mobility: high data rate services will best suit multimedia-type terminals with low mobility and larger directional active or passive antennas, making a GSO-based solution more attractive. On the other hand, lower bit rate services are associated with mobile hand-held type terminals requiring high satellite elevation angle statistics making N-GSO more attractive. These objectives target the whole of the "Access Stratum" of the UMTS, aimed at definition of a set of satellite-specific radio-technology dependent functions for the UMTS Access network. The higher layer "Non-Access Stratum" UMTS protocols will be adopted in order to ensure easy integration of S-UMTS with the UMTS core network, and with the T-UMTS. The definition of satellite packet data mode will lead to functional specification of the OSI physical layer (layer 1) and RLC/MAC layer (layer 2) protocols within the Access Stratum.

Layer-1: Various aspects of the packet mode W-CDMA access scheme will be optimized in realistic satellite communication environments. Amongst these, fast acquisition, synchronization, adaptive and predictive power control, and advanced receivers specifically designed for packet based communications would be investigated.

Layer-2: Definition and optimization of the MAC layer and resource management for the packet mode of S-UMTS will be considered within the framework of this activity. Maximizing the overall system capacity whilst achieving the required end-to-end QoS.

SATIN will introduce a novel concept for the satellite component of UMTS. The main innovative aspects of the SATIN project are to propose and evaluate:

- New satellite UMTS access network architectures with emphasis on point-to-multipoint service provision.
- Efficient IP access for multimode (T/S-UMTS) mobile terminals.
- Novel transport and access mechanism for guaranteed IP QoS.
- Bandwidth on Demand (BoD) for optimizing radio resources.

Based on the access schemes defined, a range of S-UMTS architectural issues will be extensively simulated resulting in performance analysis and evaluation under a wide range of operational conditions, and finally in specification of recommended solutions. Performance of the satellite "packet mode" will be evaluated using a combination of simulation and analysis at both system and link levels. The performance of the proposed techniques will be evaluated against a series of criteria, such as, Packet Error Rate, effective service delivery rates in different environments, spectrum efficiency, power control error, acquisition time and synchronization accuracy, etc. The performance simulation will be used to show whether the proposed solutions meets the satellite system requirements set out. Furthermore, SATIN aims to act as the driving force for standardization of S-UMTS by making several major contributions to ETSI and 3GPP.

# 10.3 IST: GAUSS

## 10.3.1 Objectives

GAUSS (Galileo And Umts Synergetic System) is an RTD (Research and Technological Development) project founded by the European Community IST (Information Society Technologies) Programme.

The GAUSS purpose is to analyse and demonstrate the potential integration ("Synergy") between navigation and communication services, by providing Galileo Navigation services through an S-UMTS communication infrastructure. Such integration represents an innovation with respect to the current vision of the Galileo System which, as a complement to the main navigation mission could also incorporate communications facilities.

In order to achieve this objective, the project work will be focused on the following main activities:

1) Definition and identification of the services (Galileo oriented) to be provided

2) Definition and specification of a navigation/S-UMTS integrated model, named "Target System", aimed to provide the GALILEO navigation services through the S-UMTS.
   In this framework, the specification of the various protocol layers and the identification of the provided services and applications will be performed.

3) Design and development of a "Demonstrator System", with the purpose to build up a realistic scenario for the "Target System".
   The GAUSS Demonstrator will be realized based on existing ground and space infrastructures, and on new advanced hardware and software developments. More specifically a real GSO Satellite will be used for the communication component, and available standard navigation systems (GPS and EGNOS) for the navigation facilities. An ad-hoc S-UMTS Mobile Terminal will be developed and specific application will be realized, addressed to Info-Mobility and Inter-Modal Transport Management services.

4) A trial campaign will be carried on, aimed at validating and proving the built up system and the developed applications. Test collected data and results will be assessed to prove the provided services and verify the benefits achieved from the integrated navigation and S-UMTS communication system architecture.
   The assessment is expected to generate also refinements or corrections on the Target System specifications and on the design of the GAUSS Demonstrator equipment and applications.

### 10.3.2 Contribution to Standardization

Supporting the S-UMTS Standardization process and concertation with other relevant projects and researches is one of the main issues of the GAUSS project. As matter of fact, GAUSS is expected to give significantly contribution to some S-UMTS Standardization activities, in particular making recommendations and developing common specifications/standards as far as services and protocols are concerned.

The project aims at developing applications, based on the integrated positioning/communication satellite systems, for the provisioning of location-based services basically oriented to the mobility management, more specifically for Info-Mobility and Inter-Modality Transport chains.

Inter-Modality Services will include the development of on-board systems for intelligent vehicles involved in two different transport modes, road and river:

- localization;
- tracing & tracking of professional users;
- remote monitoring & control of the vehicles;
- emergency ship operations support;
- assisted navigation.

Info-Mobility Services will consist of the development of advanced tele-medicine application supporting health-service management and independent living:

- personal health status monitoring;
- emergency management;
- route guidance.

As a consequence of the above considerations, the GAUSS project will be capable to strongly contribute to the S-UMTS Standardization, for the Services and Terminal specifications.

- More specifically, as far as the Service aspects are concerned, GAUSS will be involved in:
- Messaging services (narrow band - no voice);
- Location based Value added Services and Emergency services;
- Satellite specific services, such as Positioning systems, Vehicle Localization and Emergency/Distress services.

Additionally, as far as the Terminal is concerned, within the GAUSS project framework, an innovative multi-mode user equipment is going to be developed, with an unique front-end supporting both the S-UMTS communications (narrow band) and the navigation band segments (GPS, EGNOS and GALILEO). Such front-end utilizes a single A/D (Analogue-to-Digital) converter and advanced digital processing techniques to efficiently filter various band segments, namely the GPS segment, the S-UMTS segment and the segments that will be specified for the Galileo navigation signal(s). The front-end will be re-programmable, so that it will be capable to handle different band segments. The access to the network will be W-CDMA based, according to the standards.

# 11 Summary and Recommendations

## 11.1 S-UMTS opportunities

Third-generation wireless networks will allow users to browse and download information from the Internet, receive pre-defined news and information bulletins containing full-motion video and even real-time broadcast, view and respond to video and audio e-mail, and access any of the information stored on their desktop PC at work or home. This new set of services will complement conventional voice and short messaging capabilities common to second-generation networks. The UMTS terminal will constitute the ultimate personal mobile accessory combining in a small piece of equipment the features of a phone, a computer, a personal diary, a navigation device and a shopping and credit tool.

Considering their micro and pico-cellular network structure suiting best point-to-point links, there is a clear need to complement the terrestrial UMTS systems with another system providing broadcasting/multi-casting services. Satellite here can play an important role in particular for the vehicular market if able to timely provide integrated solutions.

There are two main domains in which satellites can be a good solution:

1) Geographical extension: There are geographical areas in which satellites can be the only service available: such as in areas with low population density, less developed regions, unpredicted traffic hot-spots, aeronautical and maritime services. This is the more traditional domain for Mobile Satellite Systems.

Complementary services e.g. multicast and broadcast applications: Those applications which are based on point to multi-point communication topology such as "push technology" (e.g. pointcast), or "pervasive computing" (e.g. data distribution to vehicles, palmtops), and more in general data, software distribution (MP3-audio, Video).

An interesting perspective is also represented by concept derived from the evolution of current DARS systems. This vision assumes the development of a satellite overlay for the provision of sub-set of services fully integrated and compatible with the terrestrial service provision. For such a "horizontal" market the S-UMTS seems to be well suited to complement T-UMTS in terms of services i.e. providing interactive broadcasting/multi-casting of digital data for multi-media services for the vehicular market. From this point of view the satellite "large" antenna beam footprint size is a plus compared to T-UMTS micro/pico-cells that are unsuitable for this one-to-many services. As an example for news or navigation maps update multi-casting a few Km radius cell is not suitable as it will saturate T-UMTS networks capacity as the same information shall be repeated at the same time over many T-UMTS cells. Interactivity is anyway required and can be achieved by terrestrial or satellite networks when terrestrial networks are missing. In any case the inbound link does not represent a big deal of traffic compared to the outbound. In a first step return via GSM is acceptable.

The vehicular market represents one of the best candidates to host S-UMTS terminals since:

- Terminal & antenna size and power consumption is not an issue
- A vehicle typically operates outdoor
- A vehicle typically travels over large areas
- Pre-installed terminals [as for GPS and later Galileo] can push the sales volume and solve the satellite terminal distribution and sales problem
- Satellite antennas for GPS[/DARS] is becoming standard option for new vehicles and is opening up the possibility to integrate new satellite digital services on top of navigation and radio broadcasting

## 11.2 Standardization objectives

Two parallel objectives have been identified:

1) An alignment of mobile satellite systems with terrestrial standards, especially with GSM second-generation plus/GPRS. This would apply to all areas of design but especially to mobile users and ground networks. A key area is in development of interfaces between the satellite and the terrestrial networks, as an interim solution before full alignment becomes possible with subsequent generations.

2) To continue the S-UMTS activities, reflecting evolution to 3G. Ground networks and space segment should be made as transparent as possible, minimizing the satellite-unique elements and optimized for Internet Protocol based services. The opportunity for additional operators and the development of a dedicated S-UMTS system will be determined by the extent to which success is achieved in these areas.

## 11.3 Recommendations for further work

With respect to S-UMTS standardization activities it is recommended to:

Start the standardization of packet, broadcasting/multi-casting modes for S-UMTS.

Study the T-UMTS Iu interface compatibility with S-UMTS and define possible extension.

Maintain and extend the S-UMTS specifications accounting for T-UMTS evolutions and including the specification of higher layer protocols.

Adapt the GSM/GPRS specifications for use in the satellite environment. This work shall be done in co-operation with the ETSI SES GMR working group.

Ensure the maximum commonality with terrestrial terminal technologies to allow the timely availability of low-cost dual-mode terminals.

Specific attention has to be given to the following items:

1) Definition of QoS for satellite-UMTS (as defined in TS 122 105 [15]).

2) Definition of new Elementary Files for the USIM which would enhance S-UMTS operation.

3) If required, definition of modification of the T-UMTS Iu interface to support S-UMTS.

When appropriate, change requests will be forwarded to 3GPP for consideration.

# History

| Document history | | |
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| V1.1.1 | July 2001 | Publication |
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