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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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Keywords

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Contents

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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 3rd 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 3rd 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 pocket phones, PDA types, car mounted plug-in and nomadic terminals. Also the use of intermediate module repeaters (IMR) to improve coverage is highlighted. Evaluating the implication on the IP level completes the document.

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

2 References

For the purposes of this Technical Report (TR), the following references apply:

[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 TR 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 No. 2: "The Path towards UMTS - Technologies for the Information Society".

[7] ETSI TS 125 401: "Universal Mobile Telecommunications System (UMTS); UTRAN Overall Description (3GPP TS 25.401 version 5.3.0 Release 5)".

[8] UMTS Forum Report No. 8 (March 99): "The Future of Mobile Services".

[9] IEEE Transactions on Vehicular Technology Vol. VT 40 (May 1991): "The Land Mobile Satellite Channel - Recording, Statistics and Channel Model", E. Lutz, D. Cygan, M. Dippold, F. Dolainsky, W. Papke.

[10] IEEE Transactions on Vehicular Technology (Nov. 1997): "Analysis of Availability Improvement in LMSS by Means of Satellite Diversity Based on Three-State Propagation Channel Model", Y. Karasawa et al.

[11] IEEE Wireless Communication and Networking Conf., WCNC '99, pp. 1203-1207 , New Orleans, (Sept. 21-24, 1999): "Satellite Diversity Exploitation in Mobile Satellite CDMA Systems", G.E. Corazza, C. Caini.

[12] ETSI TS 125 212: "Universal Mobile Telecommunications System (UMTS); Multiplexing and channel coding (FDD) (3GPP TS 25.212 version 5.1.0 Release 5)".

[13] ETSI TS 125 214: "Universal Mobile Telecommunications System (UMTS); Physical layer procedures (FDD) (3GPP TS 25.214 version 5.1.0 Release 5)".

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

[15] ETSI TS 122 105 (V4.3.0): "Universal Mobile Telecommunications System (UMTS); Services and service capabilities (3GPP TS 22.105 version 4.3.0 Release 4)".

[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: "Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); UMTS Access Stratum Services and Functions (3GPP TS 23.110 version 4.0.0 Release 4)".

[18] ETSI TS 125 413: "Universal Mobile Telecommunications System (UMTS); UTRAN Iu interface RANAP signalling (3GPP TS 25.413 version 5.0.0 Release 5)".

[19] ETSI TR 125 931: "Universal Mobile Telecommunications System (UMTS); UTRAN Functions, examples on signalling procedures (3GPP TR 25.931 version 5.1.0 Release 5)".

[20] ETSI TS 123 107: "Universal Mobile Telecommunications System (UMTS); Quality of Service (QoS) concept and architecture (3GPP TS 23.107 version 5.5.0 Release 5)".

[21] 3G-generation.com; Web site for 3G issues: http://www.3g-generation.com.

[22] Report N° 9 from the UMTS Forum (September 2000): "Structuring the Service Revenues Opportunities".

[23] IEEE Personal Communications Magazine (October 2000): "Standardization of the Satellite component of the UMTS", P. Dondl.

[24] ITU-R Recommendation M.1391: "Methodology for the calculation of IMT-2000 satellite spectrum requirements".

[25] IETF RFC 3135 (June 2001): "Performance Enhancing Proxies Intended to Mitigate Link-Related Degradations" J. Border et al.

[26] 19th AIAA Conference, Toulouse (April 2001): "TCP performance on split connection GEO satellite links", M. Karaliopoulos et al.

[27] Internet Draft: "IGMP-based Multicast Forwarding ("IGMP Proxying")" W. Fenner.

[28] ETSI TS 101 376-1-2: "GEO-Mobile Radio Interface Specifications; Part 1: General specifications; Sub-part 2: Introduction to the GMR-1 Family ; GMR-1 01.201".

[29] ETSI TS 101 377-1-2: "GEO-Mobile Radio Interface Specifications; Part 1: General specifications; Sub-part 2: Introduction to the GMR-2 family of specifications; GMR-2 01.201".

[30] ETSI TS 101 851-1: "Satellite Component of UMTS/IMT2000; A-family; Part 1: Physical channels and mapping of transport channels into physical channels (S-UMTS-A 25.211)".

[31] ETSI TS 101 851-2: "Satellite Component of UMTS/IMT2000; A-family; Part 2: Multiplexing and channel coding (S-UMTS-A 25.212)".

[32] ETSI TS 101 851-3: "Satellite Component of UMTS/IMT2000; A-family; Part 3: Spreading and modulation (S-UMTS-A 25.213)".

[33] ETSI TS 101 851-4: "Satellite Component of UMTS/IMT2000; A-family; Part 4: Physical layer procedures (S-UMTS-A 25.214)".

[34] ITU-T Recommendation H.323: "Packet-based multimedia communications systems".

[35] ITU-T Recommendation H.324: "Terminal for low bit-rate multimedia communication".

[36] IETF RFC 3077 (March 2001): "A Link-Layer Tunneling Mechanism for Unidirectional Links".

[37] UMTS Forum Report No. 15: "Key Component for 3G Devices".

[38] ETSI TR 125 956 (V4.0.0): "UTRA Repeater; Planning Guidelines and System Analysis".

[39] ETSI EN 301 489 (all parts): "Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services".

[40] ETSI TS 125 101 (V5.3.0): "Universal Mobile Telecommunications System (UMTS); UE Radio transmission and reception (FDD) (3GPP TS 25.101 version 5.3.0 Release 5)".

[41] ITU-R Recommendation M.1455: "Key characteristics for the International Mobile Telecommunications-2000 (IMT-2000) radio interfaces".

[42] ETSI TR 123 486: "Multimedia Broadcast/Multicast Service (MBMS); Stage 2".

[43] ETSI TS 122 146: "Universal Mobile Telecommunications System (UMTS); Multimedia Broadcast/Multicast Service (MBMS); Stage 1 (3GPP TS 22.146 version 5.2.0 Release 5)".

[44] IETF RFC 2760 (February 2000): "Ongoing TCP Research Related to Satellites".

[45] IEEE INFOCOM: "Understanding the Performance of TCP pacing", A. Aggarwal et al. Tel Aviv, Israel, March 200, pp 1157-1165.

[46] IETF RFC 3095: "RObust Header Compression (ROHC): Framework and four profiles: RTP, UDP, ESP and uncompressed".

[47] ETSI TS 101 329-2 (V2.1.3): "Telecommunications and Internet Protocol Harmonization Over Networks (TIPHON) Release 3; End-to-end Quality of Service in TIPHON systems; Part 2: Definition of speech Quality of Service (QoS) classes".

[48] IEEE Trans. On Vehicular Technology, March 2002 paper: "Wide-Band CDMA for the UMTS/IMT-2000 Satellite Component".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

donor antenna: repeater antenna which receives from and transmits towards the satellite

service antenna: repeater antenna which receives from and transmits towards the mobile stations

domain: highest-level group of physical entities

NOTE: Reference points are defined between domains.

inner modem: baseband part of a transceiver which processes physical channel processing. It contains all the functions performed at (oversampled) chipping rate and symbol rate like: spreading/de-spreading, scrambling/de-scrambling, low IF up-/down-conversion, Rake or PLL/DLL based reception and the runtime control of all these functions.

outer modem: baseband part of a transceiver which performs transport channel processing. It contains the following functionality: interleaving/de-interleaving, channel encoding like Turbo and Viterbi coding, rate matching, transport channel multiplexing and physical channel mapping.

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

NOTE: Terminates the Iub interface towards the RNC.

Radio Network Controller: equipment in the RNS 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: 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.

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

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

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

NOTE: 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.

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

Unidirectional link: 1-way connection between the UE and the S-UMTS network

Bi-directional link: 2-way connection between the UE and the S-UMTS network

Other terms relating to the Universal Mobile Telecommunications System (UMTS) may be found in TR 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	2nd Generation
3G	3rd Generation
3GPP	3rd Generation Partnership Project
ACG	Adjacent Channel Gain
ACK	ACKnowledgement
ACLR	Adjacent Channel Leakage Ratio
ADC	Analog Digital Converter
A/D	Analog Digital
AGC	Auto Gain Control
ALC	Auto Limit Control
ASIC	Application Specific Integrated Circuit
ASMS-TF	Advanced Satellite Mobile Systems Task Force
ASYM	bi-directional ASYMmetric
ATB	Advanced satellite UMTS Test Bed
ATM	Asynchronous Transfer Mode
BCCH	Broadcast Control CHannel (GSM)

BER	Bit Error Ratio
BFN	Beam-Forming Networks
B-ISDN	Broadband-Integrated Services Digital Network
BoD	Bandwidth on Demand
BOM	Bill Of Material
BSS	Base Station Subsystem
BTS	Base Transceiver Station
CBR	Constant Bit Rate
CCP	Capability Configuration Parameters
CDMA	Code Division Multiple Access
CDN	Content Delivery Network
CN	Core Network
CoS	Class of Service
CPCH	Common Packet CHannel
CPE	Customer Premises Equipment
DAB	Digital Audio Broadcasing
DARS	Digital Audio Radio Services
D/A	Digital Analog
DBP	Delay Bandwidth Product
DECT	Digital Enhanced Cordless Telecommunications
DI	Downstream Interfaces
DLL	Delay Locked Loop
dRoD	dataRate on Demand
DSCH	Downlink Shared CHannel
DSP	Digital Signal Processor
DTH	Direct To Home
DVB	Digital Video Broadcasting
DVB-S	Digital Video Broadcasting Satellite
EDGE	Enhanced Data-rate for GSM Evolution
EF	Elementary File
EIRP	Equivalent Isotropically Radiated Power
EMC	ElectroMagnetic Compatibility
EN	European Standard (CEN/CENELEC/ETSI)
ESA	European Space Agency
ESTEC	European Space TEchnology Centre (ESA)
ETSI	European Telecommunications Standards Institute
EVM	Error Vector Magnitude
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction
FER	Frame Error Rate
FES	Fixed Earth Station
FTP	File Transfer Protocol (Internet)
FUTURE	Functional UMTS Real Emulator
GAUSS	GALILEO and UMTS Synergetic System
GGSN	Gateway GPRS Support Node
GMQ	General Membership Query
GMR-2	GEO-Mobile Radio Interface
GNSS	Global Navigation Satellite System
GPRS	General Packet Radio Service
GPS	Global Positioning System
GRE	Generic Routing Encapsulaiton
GSM	Global System for Mobile
GSO	Geo-Synchronous Orbit
G/T	Gain to noise-Temperature ratio
GW	GateWay
HE	Home Environment
HE/SN	Home Environment/Serving Network
HEO	Highly Elliptical Orbit
HI	High Interactive
HIMM	High Interactive MM
HLR	Home Location Register

HMM	High MM
HPA	High Power Amplifier
HPSMN	Home Public Satellite Mobile Network
HSS	Home Subscriber Server
HTTP	HyperText Transfer Protocol
HW	HardWare
ICO	Intermediate Circular Orbit
ID	IDentifier
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IF	Intermediate Frequency
IGMP	Internet Group Management Protocol
IMR	Intermediate Module Repeater
IMS	IP Multimedia Subsystem
IMT-2000	International Mobile Telecommunication system 2000
INX	Iridium NeXt generation
IP	Internet Protocol
IrDA	Infrared Data Association
ISDN	Integrated Services Digital Network
ISL	Inter Satellite Link
IST	Information Society Technology
ITU	International Telecommunications Union
IWU	Inter-Working Units
L1	Layer 1
LA	Location Area
LAC	Location Area Code
LAI	Location Area TD
LAN	Local Area Network
LBS	Location Based Service
LCS	LoCation Services
LEO	Low Earth Orbit
LI	Low Interactive
LOCI	LOCation Information
LOS	Line Of Sight
LU	Location Update
M	Messaging
MAC	Medium Access Control
MBMS	Multimedia Broadcast and Multicast Services
MCC	Mobile Country Code
MCU	Micro Controller Unit
MEO	Medium Earth Orbit
MES	Mobile Earth Stations
MF	Multiple Frequency
MH	Mobile Host
MM	MultiMedia
MMI	Man Machine Interface
MMS	Multimedia Messaging Service
MNC	Mobile Network Code
MP-MP	MultiPoint-to-MultiPoint
MP3	Moving Picture expert group 1 layer 3 standard
MS	Mobile Station
MSS	Mobile Satellite Service
MT	Mobile Termination
NAS	Non-Access Stratum
NCC	Network Control Centre
NGSO	Non Geo-Synchronous Orbit
NI	Not Interactive
N-ISDN	Narrowband - Integrated Services Digital Network
NRT	Non-Real-Time
OEM	Original Equipment Manufacturer
PC	Personal Computer
PCC	Power Control Commands

PCI	Peripheral Computer Interface
PCMCIA	Personal Computer Memory Card International Association
PDA	Personal Digital Assistant
PDN	Packet Data Network
PDP	Packet Data Protocol
PLL	Phase Locked Loop
PLMN	Public Land Mobile Network
P-MP	Point-to-MultiPoint
P-P	Point-to-Point
PPP	Point-to-Point Protocol
PSMN	Public Switched Mobile Network
QoS	Quality of Service
QRT	Quasi Real Time
RACH	Random Access CHannel
RAM	Random Access Memory
RAN	Radio Access Network
RESV	RESerVation message of RSVP protocol
RF	Radio Frequency
RNC	Radio Network Controller
RNS	Radio Network Sub-system
ROBMOD	ROBust MODulation and coding for satellite personal communications systems
RRM	Radio Resource Management
RSVP	Reservation Protocol
RT	Real Time
RTB	ROBMOD Test Bed
RTD	Research and Technological Development
RT/NRT	Real Time/Non Real Time
RTT	Radio Transmission Technologies
SAT-CDMA	SATellite Code Division Multiple Access
SATIN	SATellite-UMTS IP-based Network (IST project)
SAW	Surface Acoustic Waves
S-BCCH	Satellite Broadcast Control CHannel
SC	Satellite Component
S-CTDMA	Satellite Code Time Division Multiple Access
SCC	Satellite Control Centre
SD	Switched Data
SDO	Standardization Development Organizations
SDP	Session Description Protocol
SDR	Software Defined Radio
SGF	Satellite Ground Facilities
SGSN	Serving GPRS Support Node
SIM	Subscriber Identity Module
SIP	Session Initiation Protocol
SLA	Service Level Agreement
SLS	Service Level Specification
SMS	Short Messaging Services
SN	Serving Network
SNC	Satellite Network Controller
SNIR	Signal to Noise plus Interference Ratio
SO	Satellite Only
SP	Satellite Preferred
SRI	Satellite Radio Interfaces
SS-TDMA	Satellite Switched - Time Division Multiple Access
S-UMTS	Satellite component of the Universal Mobile Telecommunications System
SW-CDMA	Satellite Wideband - Code Division Multiple Access
SW-C/TDMA	Satellite Wideband.- Code/Time Division Multiple Access
SYM	bi-directional SYMmetric traffic
TAF	Terminal Adaptation Function
TC	Terrestrial Component
TCPSAT	Transport Control Protocol over SATellite
TC-SES	Technical Committee/Satellite Earth stations and Systems
TCR	Tracking Control and Ranging

TD-CDMA	Time Division Code Division Multiple Access
TD-SCDMA	Time Division Synchronous Code Division Multiple Access
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TFT	Thin-Film Transistor (Matrix) (LCD Flat Displays)
TE	Terminal Equipment
TG8/1	Task Group 8/1 (in ITU-R)
T-IWU	Terminal Inter-Working Unit
TO	Terrestrial Only
TP	Terrestrial Preferred
TR	Technical Report
TRI	Terrestrial Radio Interfaces
TTA-SAT	Telecommunications Technology Association (Korea)
T-UMTS	Terrestrial component of the Universal Mobile Telecommunications System
TV	TeleVision
Tx	Transmitter
UDLR	UniDirectional Link Routing (IETF)
UDP	User Datagram Protocol (TCP/IP-IETF)
UE	User Equipment
UI	Upstream Interface
UIM	User Identification Module
UMTS	Universal Mobile Telecommunications System
UNI	UNIdirectional
USB 2.0	Universal Serial Bus version 2
USIM	Universal Subscriber Identity Module
USRAN	UMTS Satellite Radio Access Network
UTRA	Universal Terrestrial Radio Access
UTRAN	UMTS Terrestrial Radio Access Network
UWC-136	Universal Wireless Communication 136 (Now is IMT-2000 TDMA Single Carrier)
V	Voice
VBR	Variable Bit Rate
VHE	Virtual Home Environment
VIRTUOUS	VIRTUal hOme UMTS on Satellite
VoIP	Voice over IP
VPN	Virtual Private Networks
W-CDMA	Wideband Code Division Multiple Access
W-C/TDMA	Wideband Code/Time Division Multiple Access
WTSA-2000	World Telecommunications Standardization Assembly 2000
WWW	World Wide Web

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.

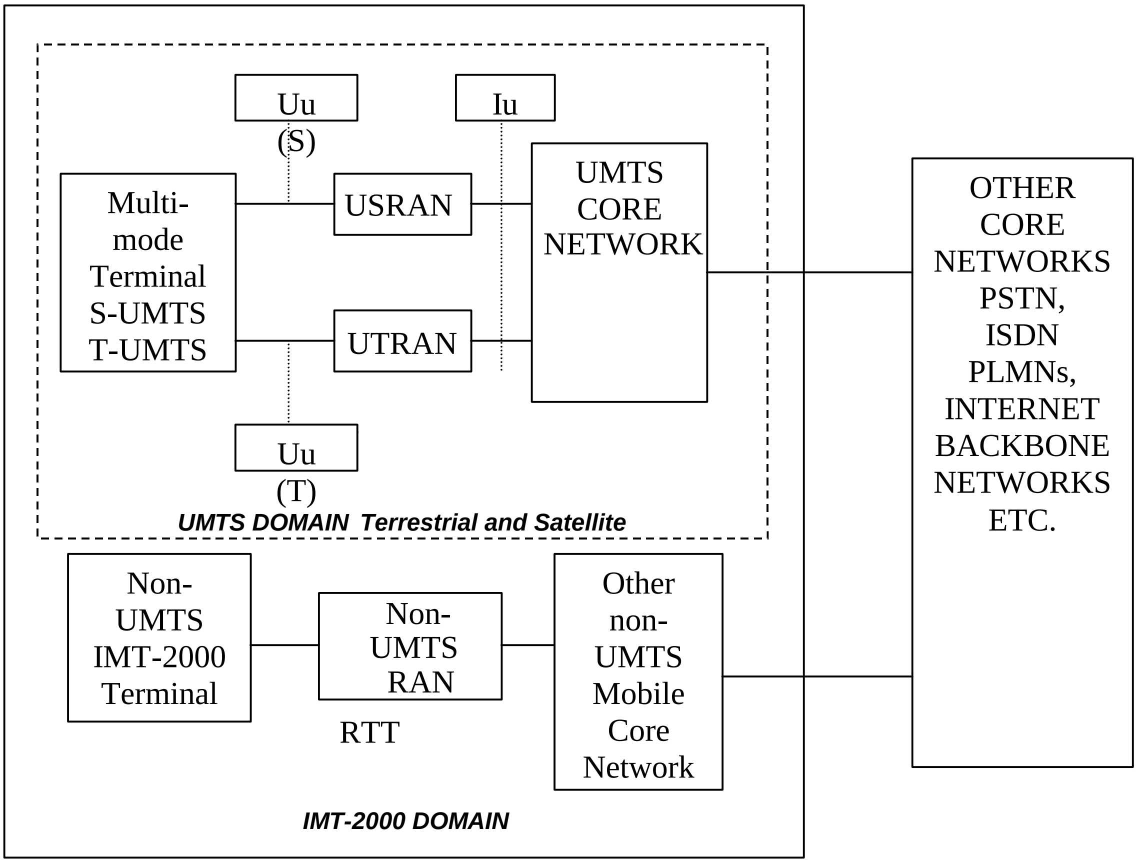


Figure 4.1: Satellite-UMTS concept

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 figure 4.2 reproduced from a UMTS Forum Report No. 2 [6].

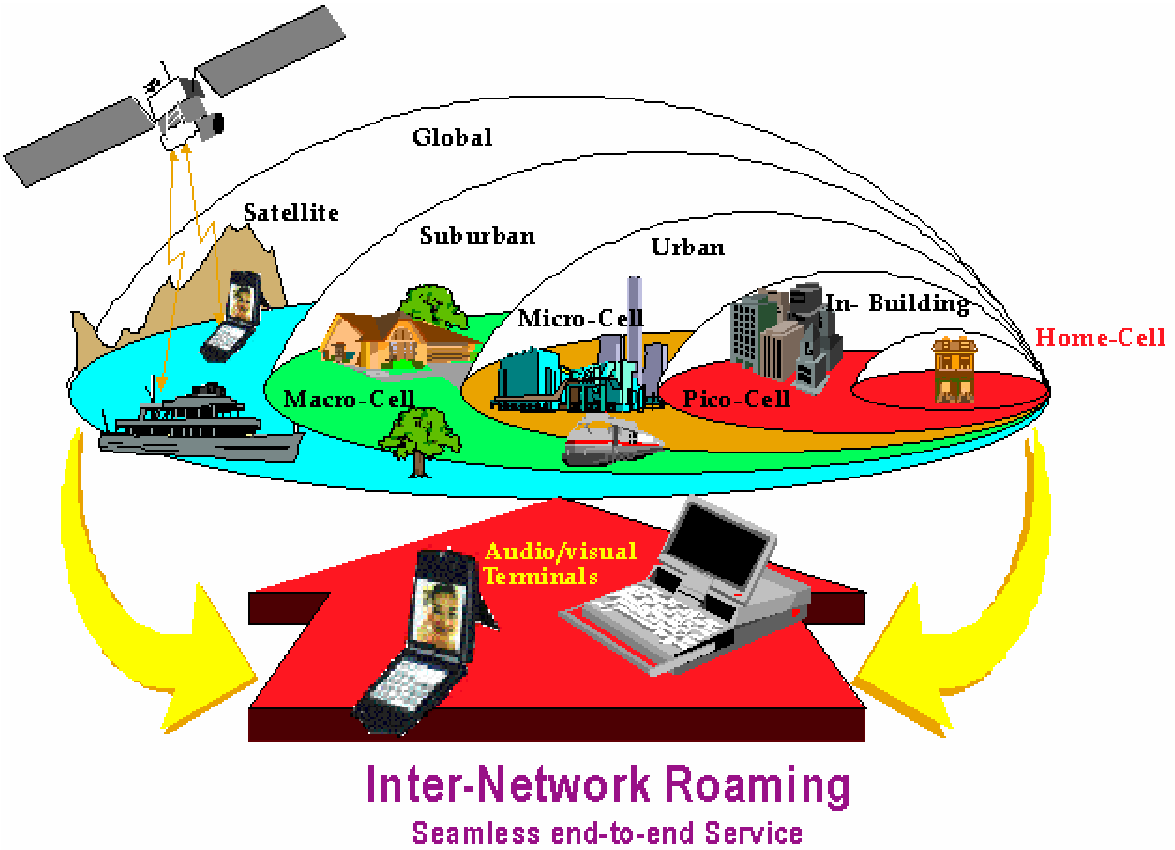


Figure 4.2: The role of S-UMTS as an integral part of the UMTS network (UMTS Forum)

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, some satellite systems use the TS 101 376-1-2 [28] and TS 101 377-1-2 [29] air interfaces. 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.

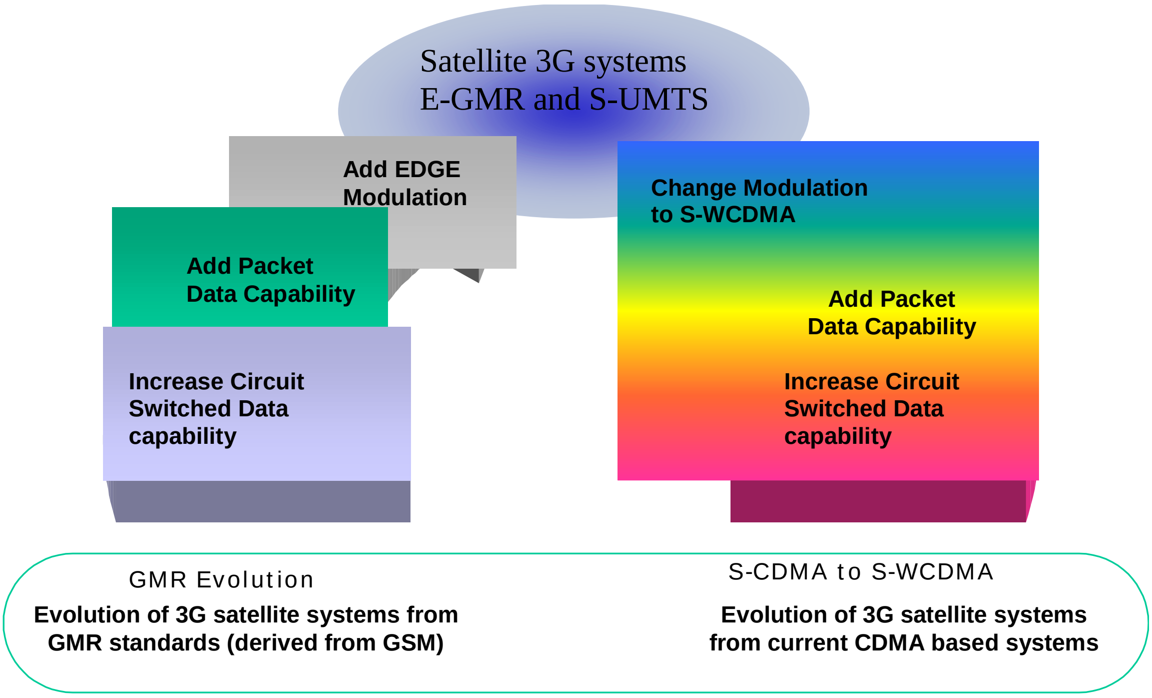


Figure 4.3: Evolution of current TDMA and CDMA based satellite systems

5 Service Aspects

5.1 General 3G service aspects

5.1.1 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.

5.1.2 Service capabilities

5.1.2.1 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.

5.1.2.2 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.

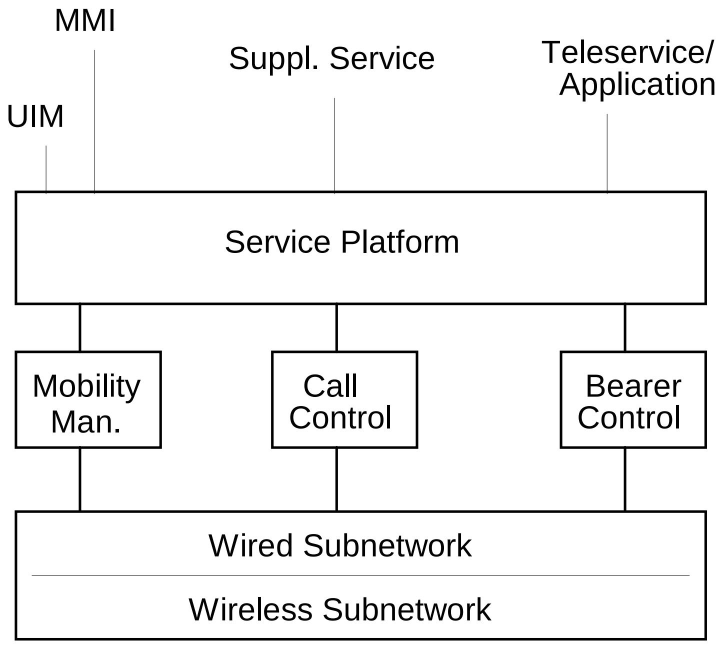


Figure 5.1: Service architecture

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.

5.1.3 Telecommunication services and applications

5.1.3.1 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.

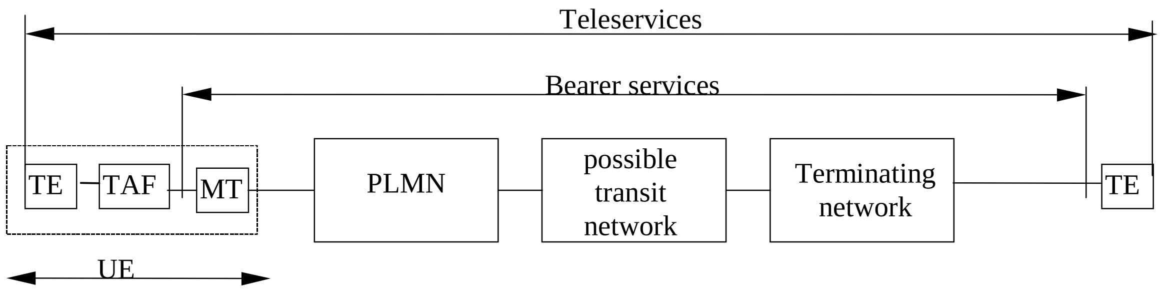
The service classification and description that follows are independent of different possible arrangements for the ownership and provision to the user of the means required to support a service.

5.1.3.2 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

5.1.3.2.1 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.

5.1.3.2.2 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.

5.1.3.3 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.

5.1.3.4 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.

5.1.4 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 and 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.

5.2 Satellite service characteristics

The satellite component aims to complement/enhance the UMTS/IMT-2000 terrestrial component (UTRAN networks) so as to offer a true global mobile multimedia system. In this respect, the satellite community has many attractive systems to match the IMT-2000 vision.

5.2.1 Satellite main characteristics

It is generally accepted that satellite based-systems provide:

- Immediate global and seamless coverage: this enables them to cover remote areas and sparse populations. It also provides a rapid deployment tool when terrestrial infrastructure has collapsed in case of conflicts or natural disaster. For instance a truly global coverage requires a complex LEO/MEO constellation. A regional/world-wide coverage within the -70° to +70° latitude range can be achieved with a simple GEO satellite/GEO constellation, although for urban and indoor and eventually sub-urban environment, satellite systems require additional devices such as "gap-fillers" / "boosters" to achieve coverage.

- Broadcast/multicast capability, as a direct consequence of their coverage properties, satellite systems provide increased efficiency when addressing multiple users.

- Transmission delay is generally constant (see note) and independent of the user location.

NOTE: Round-trip delay ranging from 250 ms to 280 ms for GEO, 110 ms to 130 ms for MEO and 20 ms to 25 ms for LEO.

On the other hand, satellite-based systems introduce the following constraints:

- Higher one-way propagation delay as compared to terrestrial systems.

- Lower capacity with respect to frequency band consumption/area

5.2.1.1 Implications upon the service attributes

The implications of the satellite component of UMTS upon the services envisaged for T-UMTS can be identified with regard to the service attributes introduced in annex A. More specifically:

Mobility

Depending on the integration scenario of the satellite system within terrestrial UMTS, the terminal is mobile with respect to the satellite, or a base station is mobile with respect to the satellite. The mobility condition depends on the usage environment. Satellite based systems can address all three levels of mobility - low, medium and high - facilitating the provision of services to both maritime and aeronautical market segments.

Data rate

Current terrestrial radio transmission technologies for UMTS, propose data rates up to 2 Mbit/s in both directions. Actually, the data rate depends on the mobility condition. This figure corresponds to a static or low mobility condition of the terminal with respect to the base station. It refers also to a condition of short distance to the base station. This corresponds typically to indoor and low range outdoor environment. Data rates as high as 384 kbit/s will be supported in outdoor environments. UMTS further distinguishes between urban/suburban outdoor and rural outdoor environments with achievable data rates of 384 kbit/s and 144 kbit/s respectively. For satellite, the need for high data rate depends firstly on the services to be offered and also on the user mobility condition regarding the base station. The lower the mobility, the higher the data rate is desirable.

Uni-directional transmission or Broadcast

Satellite systems are best suited for broadcast applications since the number of terminals do not affect the capacity dimensioning. Indeed, radio resources can be shared amongst all terminals. The implementation of broadcasting transmission is obviously easier with geo-stationary satellites than with LEO or MEO constellations, because there is no need for a handover scheme if one wants to broadcast over a defined coverage.

Bi-directional/Symmetry

Satellite systems can support either symmetrical or asymmetrical services.

Interactivity

In the case that real time conversational services have to be offered, the round trip delay requirements could influence the orbit choice. However most data applications do not introduce strict requirements of interactivity, allowing satellite-based systems to offer most of the UMTS services panel without significant impairments.

5.2.1.2 Satellite transport and IP-based services

The main problems are related to the performance of the Transmission Control Protocol (TCP) over satellite links. Given that Internet traffic is by far the most dominant type of traffic in current data networks and TCP is the transport protocol for its main portion , it becomes obvious why significant research efforts have been devoted to this field in recent years.

Large propagation delay

Due to the propagation delay of some satellite channels (e.g. approximately 250 ms over a geosynchronous satellite), it may take a long time for a TCP sender to determine whether or not a packet has been successfully received at the final destination. This delay seriously impacts end-to-end performance of short or interactive transfers delivering applications such as telnet, as well as some of the TCP congestion control algorithms.

Large delay ·bandwidth product

The delay bandwidth product (DBP) defines the amount of data a protocol should have "in flight" (data that has been transmitted, but not yet acknowledged) at any one time to fully utilize the available channel capacity. The delay used in this equation is the round-trip time (RTT) of the connection and the bandwidth is the capacity of the "bottleneck" link in the network path. Full utilization of the satellite link capacity in case of bulk transfers necessitates modifications to the "normal" configuration of the TCP module in comparison to what is practised in terrestrial networks (larger buffers, window value etc). However sharing of the link by multiple users - as is the case in a multiple access medium - can restrict the actual dimensions of this problem.

Transmission errors

TCP experiences problems whenever it has to cross a wireless, non error-free link. The TCP flow/congestion algorithms were designed assuming fixed, error-free links, so that any concluded packet loss is assumed to be due to congestion in the network (buffer overflow). This creates problems in paths including a wireless (in our case) link, since in this case packets may be lost due to air-link errors. TCP interprets every packet loss as a signal of network congestion and reduces its sending rate, even when this is not necessary. So far there is no widely accepted solution, although a number of proposals - each one with its own advantages and weak points - have been made in recent bibliography.

Asymmetric use

Due to the cost of the equipment used to send data to satellites, asymmetric satellite networks are often constructed. For example, a host connected to a satellite network will send all outgoing traffic over a slow terrestrial link (such as a dialup modem channel) and receive incoming traffic via the satellite channel. Another common situation arises when both the incoming and outgoing traffic are sent using a satellite link, but the uplink has less available capacity than the downlink due to the cost of the transmitter required to provide a high bandwidth return channel. This asymmetry may have an impact on TCP performance.

Variable Round Trip Times

In some satellite environments, such as low-Earth orbit (LEO) constellations, the propagation delay to and from the satellite varies over time.

Intermittent connectivity

In non-GSO satellite orbit configurations, TCP connections must be transferred from one satellite to another or from one ground station to another from time to time. This handoff may cause packet loss, if not properly performed, trigger the TCP congestion control mechanisms and eventually lead to throughput degradation.

5.2.2 Potential service areas for S-UMTS

Multimedia services deployed for mobile terminals will be a subset of all fixed network multimedia services. This is mainly due to limitations that are intrinsic to mobile networks with respect to fixed networks (available bandwidth, quality of service, etc.).

5.2.2.1 S-UMTS service categories

The main drivers for multimedia communication arise from packet switched and circuit switched terminals, respectively described in ITU-T Recommendation H.323 [34] and ITU-T Recommendation H.324 [35]. The future UMTS network should then support services generated by these terminals. In principle it is possible to identify five main service categories (see note) for S-UMTS:

NOTE: Actually, this classification is the same one identified by UMTS Forum Report No.8 [8]. See also annex A.

- Not interactive Audio-visual services.
- Not interactive audio services.
- Educational/Informational/Entertainment services.
- Interactive Audio-visual services.
- Corporate communication services.

Table 5.1 shows a summary of applications with the principal characteristics for each one:

Table 5.1: S-UMTS potential service requirements based on TS 122 105 [15]

Service media	Type	Applications	BER	Max End-to-End Delay [ms]	User Data Rate [kbit/s]	Terminal Type
Speech	Real Time	Telephony	10^{-3}	400	Up to 8	Hand-held, Portable, Transportable, Vehicular
Data	Non Real Time	Internet Access, News Distribution, Electronic mail with attachments, Facsimile, Broadcast applications (see note), tele-banking, e-commerce	10^{-5} to 10^{-6}	500	Up to 64 on Forward Link, Up to 16 on Return Link	Hand-held
					Up to 64	Portable, Transportable, Vehicular
Text	Non Real Time	Short Message	10^{-6}	500	9,6	Hand-held, Portable, Transportable, Vehicular
Video	Real Time	Video Telephony Video Conference	10^{-6}	400	64	Hand-held, Portable, Transportable, Vehicular

NOTE: Broadcast Applications including Data and Video Services (Sport, News, etc.) are specified with data rates up to 400 kbit/s.

5.2.2.2 Multicast/Broadcast services aspects

There is a strong feeling in the industry that the future satellite systems can play a key role in UMTS due to their efficient broadcast/multicast capability. This clause provides a further insight in this discussion.

5.2.2.2.1 Benefits of multi/broad-cast based services delivered over satellite

IP Multicast is an Internet protocol that enables transmission of data packets to a group of receivers. IP Multicast makes efficient use of bandwidth by setting up a mid-point between uni-cast traffic (one-to-one) and broadcast IP traffic (one-to-many). IP Multicast transmits a single copy of a message to a group of interested receivers. This mode of transmission scales well with increasing number of receivers and it is also more efficient than IP Broadcasting (one-to-many), since in broadcasting, a copy of a message is sent to all receivers, including receivers who may not want to receive the message.

With the pace of Internet evolution and the increasing demand for multimedia services there is a growing belief among network experts that the IP Multicast transport technique will inevitably be a core part of the next generation Internet/Internet2. On the other hand UMTS is expected to make the difference with respect to existing cellular networks on the basis of its high mobile data transfer capabilities, that will provide user with new experiences of information or entertainment services, including various range of multimedia content.

However fixed Internet multimedia services and business have been heavily impacted by the lack of cheap and efficient transfer mechanisms on current best-effort IP network, mainly due to the restricted deployment of IP multicast protocols, traffic congestion and multiple hop through the network that often result in unbearable transit delay. Similarly in case of UMTS, traffic costs on pure point-to-point mode might restrict the range of multimedia services that could potentially be provided.

Satellite systems may offer a complementary solution, with a possible long-term impact to the way in which multicast data is delivered over the Internet. Satellite's broadcast nature and ubiquitous coverage offer a natural way to multicast data over a large cell. Their wide footprint coverage enables mobility and flexibility. In fact satellites may constitute a Content Delivery Network (CDN); that is a multicast layer over the internet, which is in charge of distributing any kind of large content to the edge of the IP network, as close as possible to the user. In this way mobile satellite broadcast systems may become a very efficient complement to terrestrial mobile networks, removing their asymmetric load and providing them with far more point to point equivalent capacity for far less investment cost.

By combining satellite and terrestrial repeater deployment, infrastructure cost could be drastically reduced, providing the system with a global and complete coverage, and allowing distribution cost to really fit price constraints of multimedia business.

The main advantages coming from the implementation of a multicasting approach over satellite can be summarized as follows:

a) Several services with medium - high bit rates can be provided without requiring for unfeasible on board power and bandwidth;

b) the network load (that is the load both for the radio links and for the on ground infrastructure) does not increase in proportion with the users to be served;

c) further if a store and forward approach can be adopted, a best effort based usage of the network can be exploited; it is important to consider that data store can be implemented even on ground, hence there is no problem of memory size;

d) a great number of users can get data in almost the same time: in principle there is no limit for the number of users receiving the same information without additional costs, if they are in the same coverage area;

e) multi-casting functionality can be provided in absence of terrestrial networks;

f) it could be also envisaged to save feeder link bandwidth and, in the same time, on ground Tx Power considering that the same stream to be delivered to many beams belonging to the same satellite could be transmitted only once in the up-link. In particular we could reserve one or more frequency slots in the forward uplink for multicasting services and then provide more versions of these streams in the mobile link. Obviously such an approach prevents from a mixed usage - in the same frequency slots - of multicasting and uni-casting if bent pipes satellites are considered.

It should be noticed that both multicasting as above described and a so called narrowcasting, i.e. a selective multicasting in which only authorized users can receive data, can be implemented over S-UMTS in an effective way.

5.2.2.2.2 Multicast Applications

Multicast applications can be classified into three main categories:

- One-to-many (single host sending to one or more receivers).
- Many-to-one (any number of receivers sending back to sender via unicast or multicast).
- Many-to-many (any number of hosts sending and receiving to a group address).

Multicast applications have varying network and protocols requirements in terms of delay, bandwidth and loss. They deliver both RT and NRT content, and guarantee either best effort or reliable data delivery. In the following tables, these applications are grouped, based on delivery mode (RT/NRT), topology and relative bandwidth required.

Real-time and non Real-time services are defined in TS 122 105 [15].

Table 5.2: Classification based on delivery mode

	Real-time	Non-Real-time
Data only	Auctions Data collection/Monitoring News feeds Stock quotes Interactive gaming/simulation White-boarding Session directory	File/Data distribution Databases replication Software updates Web caching Polling
MultiMedia	Audio/Video broadcast Multimedia conferencing Internet audio Video-on-Demand Distance learning	Content distribution Audio/Video replication

Table 5.3: Classification based on topology

Topology	Applications
One-to-many	Audio/Video broadcast Caching Data distribution Software updates Data monitoring Stock quotes
Many-to-one	Resource discovery Data collection (survey) Auctions Polling (voting)
Many-to-many	Multimedia conferencing Concurrent processing Shared distributed databases Distance learning Distributed Interactive Simulations Multiplayer games

Table 5.4: Classification based on bandwidth requirements

Bandwidth	Applications
Low	Caching Data/Content distribution Data monitoring Stock quotes
Medium	Resource discovery Software updates Data collection (survey) Auctions Polling
High	Multimedia conferencing Concurrent processing Shared distributed databases Distance learning Distributed interactive simulations Multi player games Audio/video broadcast

5.2.3 The potential role of S-UMTS: S-UMTS vs T-UMTS services

As already discussed, growing demand for access to MM services anytime/anywhere will be the key driver of 3G services roll-out. However, it seems clear that without satellites, this "*anywhere*" characteristic is impossible to achieve. This clause discusses possible scenarios for the integration of S-UMTS into the overall 3G concept, i.e. its relationship with T-UMTS from a service viewpoint.

5.2.3.1 S-UMTS complementing T-UMTS

The terminology describing the relation of the satellite component of UMTS to its terrestrial analogue is extensive though sometimes confusing. The degree of integration between the two systems can vary significantly and for instance three different levels of interoperability have been identified: terminal level, network level and service level interoperability.

At the service level - and irrespective of the network level integration - there seems to be a general agreement within the European satellite community upon the **complementary** role that S-UMTS should play with reference to T-UMTS. Even in the case of [21], where the word "competitive" is adopted to denote one of the potential roles of S-UMTS with reference to T-UMTS, the term refers to the broadcast and point-to-multipoint services that S-UMTS can more efficiently accommodate, rather than implying a thoroughly competitive role.

Interpreting the word "competitive" as "service complementary" we may say that S-UMTS can - with reference to the T-UMTS point-to-point services - constitute:

- A **geographical complement** in territories where the demand is increasing in isolated regions (*coverage extension*), in areas placed in gaps of T-UMTS network (*coverage completion*) or when the other telecommunication systems definitely or temporarily collapse because of a disaster or a conflict (*disaster-proof availability*). Hence dimensioning terrestrial infrastructure could be optimized, peak traffic in excess being absorbed by satellites (*called dynamic traffic management*).

- A **service complement** such as aeronautical or maritime services, information broadcast and multicast and various supplementary services could be developed based on satellite ground-location ability such as fleet management, route guidance, etc and also generate new markets. Future UMTS broadcast and multicast services may benefit from in-sky implementation.

- An **early service proposition** in territories where there is no infrastructure yet in order to test the potential of an emerging market. During transitory phase from 2nd to 3rd generation, satellites may offer day-one global roaming solutions whereas terrestrial UMTS is more likely to be deployed firstly over limited "islands" of coverage. Hence there would be an opportunity for an early development of worldwide multimedia services (*rapid deployment*).

While satellite systems take advantage of certain capabilities terrestrial systems cannot offer, as already discussed, they have particularities (e.g. propagation delays, attenuation [23], Doppler shift and channel bandwidth). These capabilities and limitations which vary according to type of orbit/constellation, are important aspects of on-going research.

A discussion, in this direction, relating to the different roles that may be undertaken by S-UMTS with respect to the terrestrial component, is included in ITU-R Recommendation M.1391 [24]. The following clauses elaborate on these scenarios from a service perspective.

5.2.3.2 Geographical Complement/Early Service Proposition scenarios

5.2.3.2.1 Direct access to the satellite

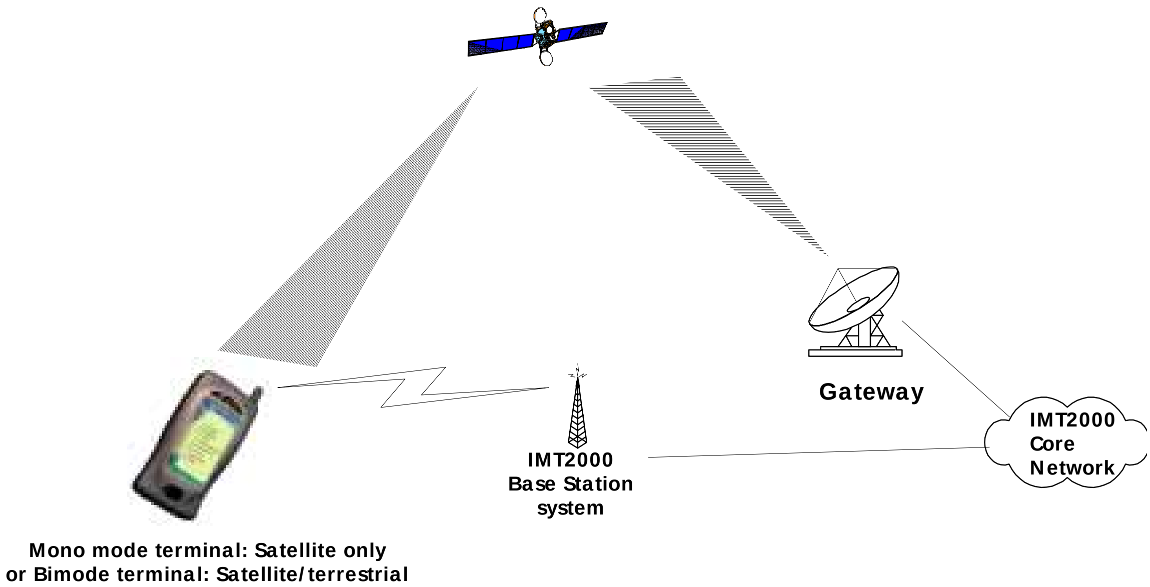


Figure 5.3: Direct access to satellite configuration - Source [24]

In this scenario the system uses mono (S-UMTS only) or dual mode (S-UMTS/T-UMTS) terminals. The terminal receives directly from the satellite (downlink) and the return link goes through the terrestrial network, via appropriate gateway functionality. When out of coverage of the terrestrial network, the S-UMTS satellites are used for both the forward and return link to the terminal.

Service portfolio:	Able to support conversational, interactive and distribution services.
Advantages:	Global coverage.
Disadvantages:	Limited operation in indoors environments. Dedicated techniques must be used to support paging while indoors.

5.2.3.2.2 Indirect access to the satellite - individual configuration

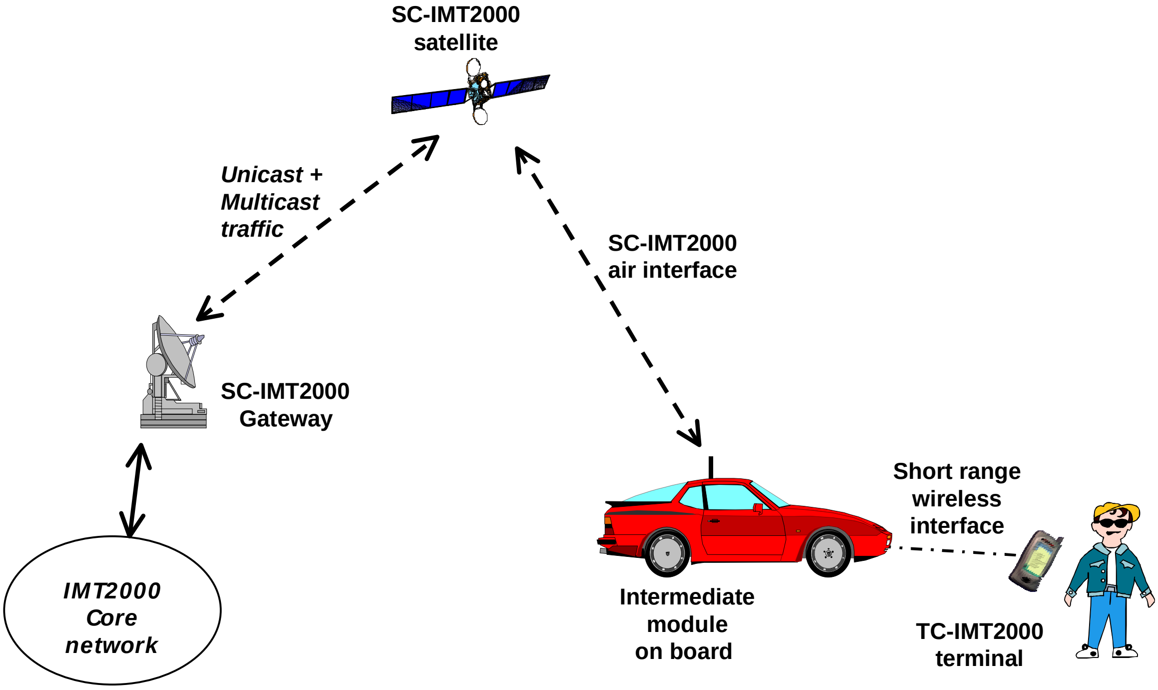


Figure 5.4: Indirect access to satellite - individual configuration - Source [24]

In this scenario the system requires «distributed» terminals, i.e. a T-UMTS standard terminal equipped with a short-range wireless interface (e.g. Bluetooth) and an "exciter/booster" allowing the communication with the T-UMTS satellites. When out of coverage of the terrestrial network the S-UMTS satellites are used for both the forward and return link to the terminal.

Service portfolio:	Able to support conversational, interactive and distribution services.
Advantages:	Well suited for vehicle use. Could be used outdoors and - depending on the specification of the wireless interface and the « booster » - in indoor environments
Disadvantages:	Less practical for a pedestrian user - full mobility in areas out of coverage of the terrestrial component

5.2.3.2.3 Indirect access to the satellite - collective configuration

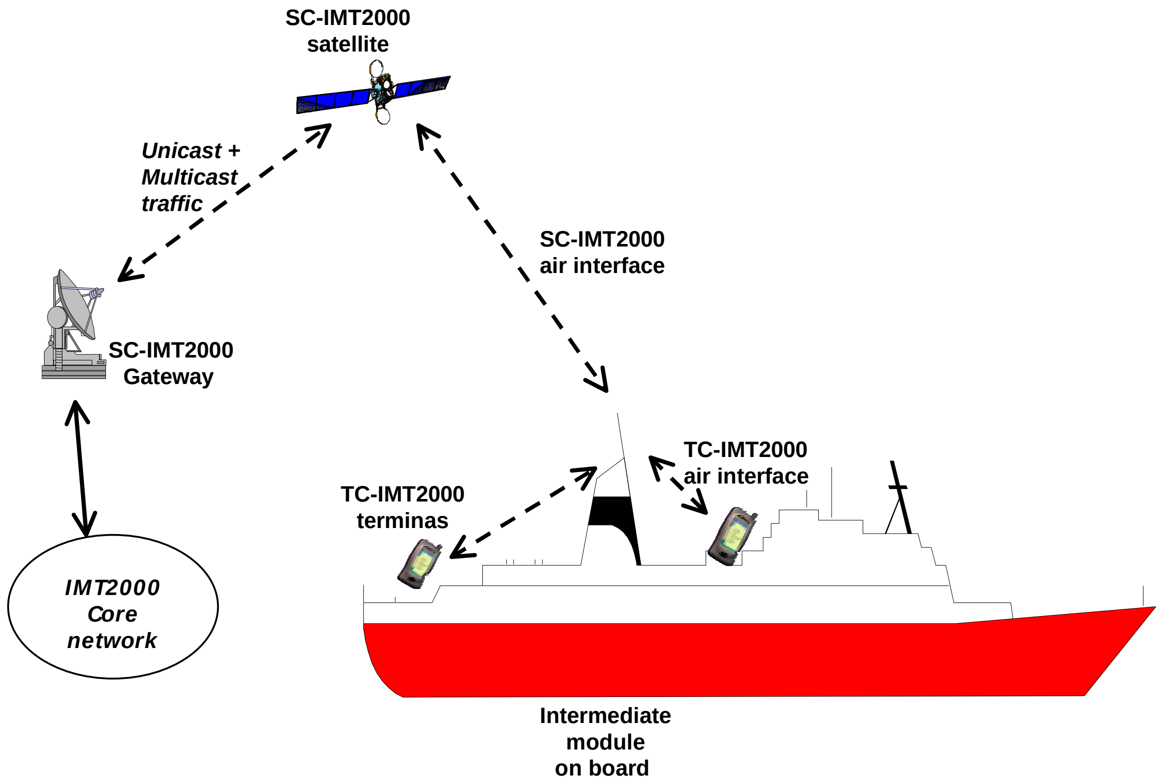


Figure 5.5: Indirect access to satellite - collective configuration - Source [24]

In this scenario the system uses standard T-UMTS terminals communicating to the satellite via a wireless interface and an IMR ("gap filler"). Satellite serves both forward and return link to the gap filler, which - in this case - comprises the functions of a remote T-UMTS access node. The terminal may use a simple "gap filler"-optimized protocol, i.e. implying moderate cost and increased efficiency.

Service portfolio:	Able to support conversational, interactive and distribution services
Advantages:	Well suited for creating «remote» islands (such as on board ferries, trains, isolated villages) attached to a T-UMTS core network. Fast deployment. Depending on gap filler specification could be used indoors and outdoors.
Disadvantages:	Terminals cannot be used in areas out of coverage of the designated gap fillers.

5.2.3.3 Service complement scenarios

5.2.3.3.1 Indirect access to the satellite

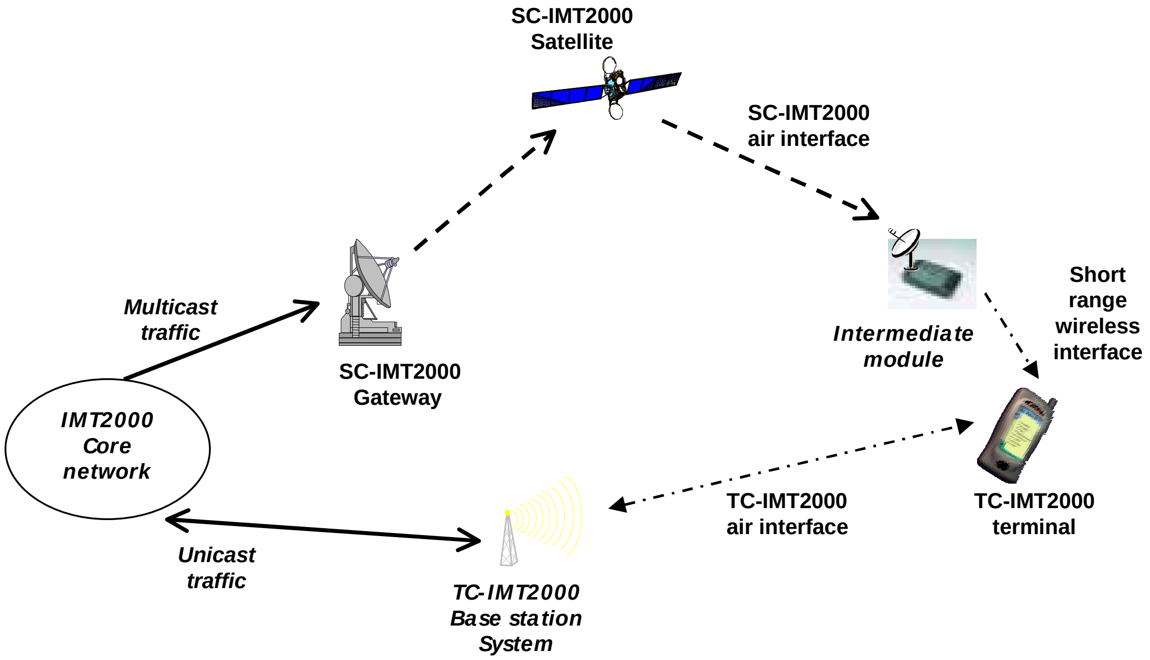


Figure 5.6: Broadcast oriented - Indirect access to satellite - Source [24]

In this scenario the system uses standard T-UMTS terminals communicating to the satellite (downlink) via a wireless interface and an IMR ("exciter/booster/gap filler"). The return link is realized via terrestrial UMTS.

Service portfolio:	Well adapted to broadcast/multicast applications (distribution services)
Advantages:	Could be used outdoors and indoors, depending on the appropriate IMRs. Broadcast/multicast services can be delivered more efficiently as compared to using valuable resources of the T-UMTS network.
Disadvantages:	Cannot be used in areas out of coverage of the gap fillers/IMRs.

5.2.3.3.2 Direct access to satellite

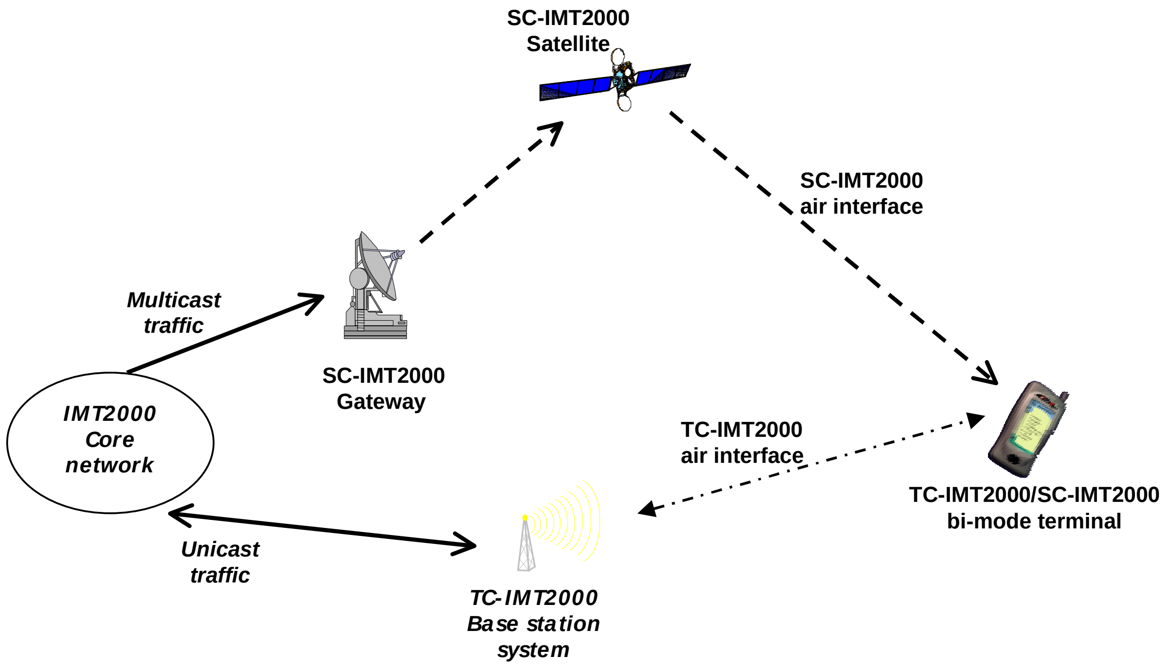


Figure 5.7: Direct access to satellite (Broadcast oriented) - Source [24]

In this scenario, the system uses an integrated dual-mode terminal (T-UMTS/S-UMTS) with embedded functions to benefit from the satellite broadcast capability (downlink). The return link is realized via terrestrial UMTS.

Service portfolio:	Well adapted to broadcast/multicast applications (distribution services)
Advantages:	Well suited for fully mobility in areas of coverage of T-UMTS.
Disadvantages:	Limited use in indoor and obscure environments. Requires advanced terminals.

6 Terminals and intermediate modules repeaters for S-UMTS

Studies recently completed for the European Space Agency and IST Satin 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, Iridium and Thuraya) offer dual mode GSM/Satellite functionality and they are voice centric with limited circuit switched data rates. As data rates increase, a variety of terminals will be needed to deliver new faster services.

6.1 General aspects

6.1.1 Terminal characteristics

Terminals for wireless communication networks are characterized by different aspects. Perhaps the most obvious one is the supported radio transmission technology. Other main aspects are transportability, mobility and communication capability. In the following clauses, the impact of each aspect on terminal complexity, cost and business opportunities is evaluated in more detail.

This clause describes a general overview of terminal aspects for wireless networks and additionally, each clause contains some relevant satellite specific terminal characteristics.

6.1.1.1 Terminal cost

From the future UMTS-user point of view, when UMTS is becoming a commercial success, the price of the services and equipment (terminal) will be equivalent to the actual GSM terminal price. The economical aspects (cost) of a terminal are defined by 2 aspects. The first is related to the production cost of such a terminal. The BOM (Bill Of Material) including all the requested hardware, the plastic and production cost must be kept as low as possible. In other words, the increase of the BOM due to the additional satellite capabilities of a terminal must be limited.

The second aspect related to the cost of the terminal is the development effort. Knowing that the development of a T-UMTS terminal is already a big effort, implementing the S-UMTS capability in a terminal should not have a major impact on the development effort and development time. Assuming the S-UMTS standard will be designed to have a maximum resemblance to the T-UMTS standard.

As third generation terminals will be devices with highly advanced functionality, product differentiation will be a successful method to attract the mass market with low-cost implementations on one hand and high-end professional equipment for smaller user groups on the other hand. One way to obtain product differentiation is by offering terminals with different capabilities like supported radio transmission technologies, data rates and satellite reception and/or transmission capability.

6.1.1.2 Radio transmission technology

The supported radio transmission technology has mainly an influence on terminal complexity and even more on business opportunities. Both complexity and business opportunities will drive production costs. Most radio transmission technologies adopted for personal communication networks can be subdivided into first, second and third generation systems and into terrestrial and satellite systems.

Terminals for first generation networks were mainly built with analogue technology resulting in expensive, heavy and power hungry devices.

Second generation networks paved the way for true handheld terminals thanks to the immense progress of digital technology. Today, terminals for second-generation networks are relatively inexpensive and have created a worldwide business. GSM is the best example one can give to prove this.

Third generation networks are entering the stage of commercial introduction and target on enhanced multimedia services and worldwide coverage and roaming. Due to these high level capabilities new efficient radio transmission technologies are developed. Terminals will become much more complex and will interact in a different way with the user.

Satellite networks for personal communication are far less evolved than their terrestrial counterparts. Although digital technology enabled the deployment of handheld satellite terminals providing similar services as second-generation terrestrial networks, terminal complexity and cost prohibited the deployment of a mass market. As a result, today, the only successful networks are situated in the niche markets of high-end business users, fleet management and maritime and aerospace markets. This evolution is nevertheless not surprising as radio transmission technologies adopted for these satellite networks where not at all optimized for co-operation with the existing terrestrial networks. As a result, a user of both networks needs to buy two separate terminals. For the mentioned niche markets this is not a constraint but for the consumer market it is a serious drawback. Third generation networks can create new mass-market opportunities in the satellite domain if the selected radio transmission technology demonstrates a high convergence with the terrestrial counterpart.

Despite the initial wish among several standardization organizations to create one worldwide standard for third generation wireless networks, political as well as technical reasons prohibited a global convergence. As the situation is today, terrestrial third generation networks will be based mainly on four different standards known as UTRA-FDD, UTRA-TDD, TD-SCDMA and CDMA2000. For the satellite component, six radio transmission technologies have been submitted to ITU by organizations from all around the world see 8.1.1.1. In order to enable mass production of low-cost terminals and to guarantee global roaming, terminals will need the capability to support multiple modes including combined terrestrial-satellite capability.

Multi-standard terminals are already used for second generation networks like combined GSM/DECT, GSM/GPS and second-generation satellite terminals with additional GSM functionality. In most of the cases, these multi-standard terminals are not more than multiple terminals under one and the same cover, resulting in expensive devices, unattractive for a mass-market approach. For future terminals supporting operation in multiple third generation networks together with existing or enhanced second generation systems, operating in the terrestrial and/or satellite domain, new terminal architecture concepts are necessary. So-called "software defined radios" will show very high flexibility enabling the support of different radio transmission technologies. It is obvious that the complexity of such multi-standard terminals is largely influenced by the convergence between the supported standards.

Flexible reconfigurable multi-standard terminals will bring new opportunities in several different ways. First of all, they enable real global roaming. Secondly, although multi-standard terminals will be high complex devices they could reduce production costs by offering a more differentiated product range based on one and the same hardware platform. Another less obvious advantage is the smoother evolution towards third generation by providing backwards compatibility with second-generation networks. And last but not least, bi-mode terrestrial/satellite terminals will create a critical mass for personal communication satellite networks by reusing the existing mass-market already created by the terrestrial component. Although, to succeed, the satellite component has to provide more than just enhanced coverage but a real complementary set of services. Existing satellite networks are purely coverage focussed thereby missing most of the mass-market consumers who will rather spend their money on new services than on a coverage extension. The best example that proves this is the enormous spread internet has made in the last couple of years using the existing telephone network infrastructure.

6.1.1.3 Terminal transportability

Terminal size will always be a trade-off between user-friendliness, battery autonomy and transportability. It says more about the way the user interacts with the terminal than how the user interacts with the environment. Wireless terminals for personal communication networks can roughly be divided into five different classes dependent on the required transportability:

- Pocket phone terminal type
- PDA terminal type
- Nomadic terminal type
- Modular built-in terminal type
- Plug-in terminal type

Each type has an impact on terminal cost, potential capability and business opportunities.

6.1.1.3.1 Pocket phone terminal type

This is the classical type of low-cost terminal that is used today in second-generation networks. It offers a maximum of transportability at the expense of screen size and battery autonomy. Although third generation terminals will contain much more complexity at the hardware level, the ever-growing miniaturization of digital hardware will limit its impact of increasing complexity on the terminal size. On the other hand, the higher data rates, intense source and channel encoding together with power demanding multimedia applications raises energy consumption. Unfortunately, battery technology does not show the same technological evolution, as is the case for digital hardware. Therefore, if conventional pocket phones would be used for third generation networks, they will be characterized by short operation times that make them less attractive. Moreover, screen size will be insufficient for the new multimedia services. From a real pocket phone, users will expect a very low weight (between 100 g. and 200 g.), and small (e.g. 12 cm by 5 cm) terminal with a stand-by battery autonomy of around 3 days. Technically, it will be a big challenge to achieve the mentioned specs while supporting the high demanding UMTS services.

For a dual-standard terrestrial/satellite terminal, size reduction will be even more a difficult task. Although a reconfigurable baseband architecture can solve part of the problem, the RF-part is less suited for reconfiguration. For instance, additional filters for the satellite bands are necessary and cannot be reused. In case the terminal has been designed for direct transmission to satellite, the more powerful amplifier is responsible for a bigger energy consumption, which fortify the need for a bigger and heavier battery.

Figure 6.1: Pocket phone type

6.1.1.3.2 PDA terminal type

The new wireless multimedia applications demand bigger screen sizes and more efficient interaction utilities on third generation terminals. The future handheld terminal will no longer have the same aspects as today's GSM phone but will rather be a merging between a cellular phone and a PDA (Personal Digital Assistant). Today, PDA systems already offer applications that can very well use the availability of a wireless link (e.g. agenda, email, web browsing, etc.). Most likely, the combination of third generation services and PDA systems will probably be very successful on the consumer market and the PDA terminal will certainly be the most produced terminal for UMTS.

Thanks to the bigger size of a PDA terminal, bigger batteries can be mounted without bothering the user to much. On the other hand, due to the additional mounted utilities like speaker, camera and the bigger screen, power consumption will remain a critical design aspect.

Terminal ergonomic design is very important for this type of consumer products and consequently manufacturers will do everything to keep the antenna small. This limits antenna gain and has an influence on the overall performance.

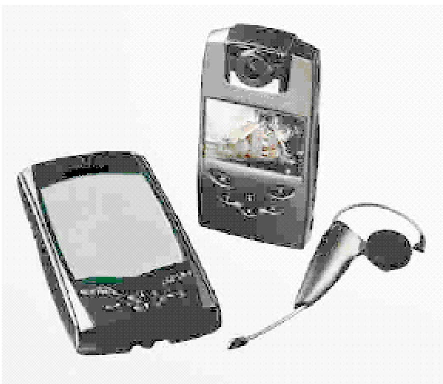


Figure 6.2: PDA terminal type

A PDA terminal type offers more space to implement dual-standard terminals although for power consumption reasons, direct transmission to satellite will be only achievable for low data rates, comparable with those supported by handheld terminals for second-generation satellite networks. Higher data rates could be expected when using a terminal extension with improved antenna gain and a higher transmission power (see clause 6.1.1.5 for more details).

6.1.1.3.3 Nomadic terminal type

The typical nomadic terminal is known by the image of a person with a small suitcase having a phone call in the middle of the Sahara desert. A nomadic terminal is the best solution to provide a robust and high data rate satellite link with a device that is still portable by a human being. Furthermore, nomadic terminals have evolved from the need for personal and workplace portability, where higher data rate telecommunications are required. Nomadic terminals can therefore be situated in the medium and high-end range, typically used by business users. These types of users do not want to compromise too much on communication capabilities and battery autonomy.

The nomadic terminal would take the form of a traditional laptop PC with a built in RF subsystem. Its design enables the implementation of a bigger antenna integrated in the cover, thereby having an important impact on the antenna gain that is reported on the link budget. Patch antenna designs are very well suited for this type of integration. In this way, it is an ideal candidate for implementation of direct satellite communication capability.

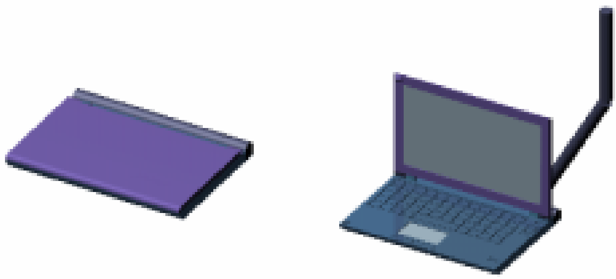


Figure 6.3: Nomadic terminal type

Even if the size of the nomadic terminal is less problematic than in the case of a pocket or PDA terminal, the weight and the power consumption remains an important challenge.

With the integrated antenna option, it is clear there are a number of technical problems to overcome, one of which being the maximum transmit power with the RF system being so close to the users body. A solution is the use of an external antenna (see clause 6.1.1.5).

A laptop without communication facilities can be completed with a terminal integrated in a PCMCIA-card (see clause 6.1.1.3.5). However, this solution will not give the same possibilities as a laptop with integrated modem and antenna.

6.1.1.3.4 Modular built-in terminal type

Built-in terminal types are specially adapted to be mounted into cars, small planes and boats and even as fixed stations. Although they cover a wide range of equipment, they all have the following characteristics in common:

- External power supply.
- Modular concept of different components that can be mounted separately e.g. antenna, user interface, speaker etc.
- In most cases sold as OEM (Original Equipment Manufacturer) equipment to e.g. car manufactures.

This type of terminals will be available with a broad range of capabilities from low-cost up to professional high-end versions. Thanks to an external power supply, transmit power is less limited which makes direct transmission to satellite possible, even when high bit rates are necessary. Furthermore, less trade-offs have to be made when designing antennas and other terminal components as size and weight are no longer critical issues.

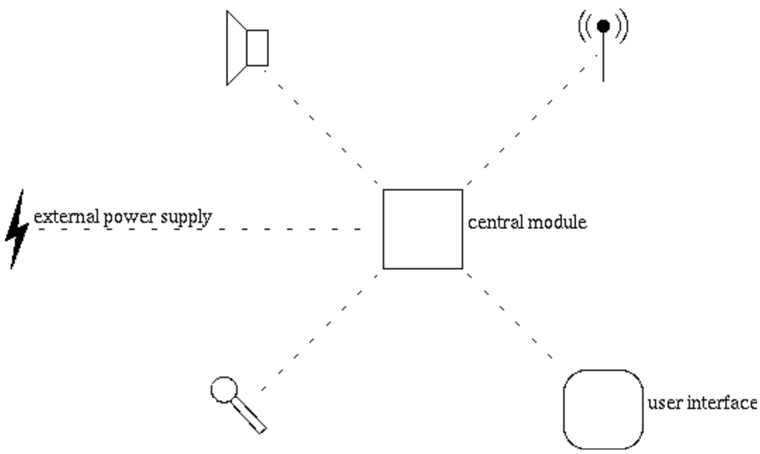


Figure 6.4: Built-in terminal type

Main application of modular type of terminal will be used in the automotive industry.

6.1.1.3.5 Plug-in terminal type

Plug-in terminals are very high-integrated communication devices without user interface and battery. They can be used to add communication functionality to standard laptop computers in the form of a PCMCIA card.

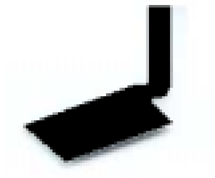


Figure 6.5:Plug-in type

6.1.1.4 Terminal capabilities and performance

6.1.1.4.1 Terminal capabilities

From a terminal manufacturer point of view, it makes sense to optimize his product range in a way that a maximum number of users can be satisfied. Roughly speaking, this approach will lead to a product differentiation into two groups of terminal types as far as communication capabilities are considered. A first group will be designed to find a balance between cost and the necessary complexity to support as much as possible different types of services. In this way, retail prices will be kept low enough to reach most part of the interested users in the consumer market. A second product range will be formed by terminals using the latest technology and offering best performance. Targeted users are part of the professional users who are able to pay for a state of the art product and expect full functionality of their terminal under all circumstances.

From the market analyses, you can derive that there is only a niche market related to "satellite only" terminals. Development cost related to such "satellite only" specific terminals cannot be spread on the mass production like the industry can do with GSM or T-UMTS. Therefore a combination of a T-UMTS terminal (with GSM backwards compatibility) and a S-UMTS terminal will be required for a successful introduction of S-UMTS.

When we take the above-mentioned aspects into consideration, two-product differentiation can be proposed:

1) For the mass market or consumer market a T-UMTS terminal with additional S-UMTS reception capability should be able to provide the following services:

    - Full duplex voice and multimedia services in urban area covered by the T-UMTS network.

    - Full duplex voice and low rate data services in suburban area covered by GSM and GPRS networks.

    - Full duplex voice and multimedia services in isolated highly populated places like ferries, small islands and remote cities by locally deployed T-UMTS network which is connected to the core network through a dedicated satellite feeder link.

    - Broadcast and multicast services in isolated highly populated places, using S-UMTS for the downlink and the locally deployed T-UMTS network for the uplink.

    - Broadcast and multicast services in urban area, using S-UMTS for the downlink and T-UMTS for the uplink.

    - Broadcast and multicast services in suburban area, using S-UMTS for the downlink and GSM/GPRS for the uplink.

    - A subset of broadcast and multicast services in rural area, using S-UMTS for the downlink. Pseudo interactivity can be created by filtering the huge amount of broadcasted information when no terrestrial network is available.

Most users of the satellite component will be satisfied by the offered broadcast services, a typical service which can be delivered more efficient by the satellite component. Most of those users will also be located near or inside urban area, where the terrestrial component can serve the uplink if necessary. Outside the coverage of T-UMTS, broadcasted information can still have a big value, even without the availability of an uplink.

2) A selected number of users will need and pay for T-UMTS terminals with additional full duplex S-UMTS capabilities. These terminals will be independent from terrestrial networks for their uplink.

As an example, the vehicular mounted terminal can be seen as one of the short future applications that will be based on a built-in terminal concept. Actually with the increasing problematic of traffic jams, having the possibility to access a wide band network containing travel, tourism and entertainment information will become a very helpful option. The expected sales of such terminals are much lower than the sales volume of a handheld type. This implies that the development and production costs (BOM) will have a higher impact on the sale price of such terminals.

The car industry is currently very interested in providing Internet and other wireless services 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 of reasons:

- The traditional limitation of satellite communications regarding lack of in-building penetration is not an issue for cars.
- Transmit power is not determined by battery live (although for safety and EMC reasons, Tx power will always be subject of regulatory limitations).
- Antenna and RF-module can be situated at a suitable distance from the user, loosening restrictions on Tx power levels.
- When people are moving in rural and remote areas, they are usually using their car.
- Those areas will be the last to be covered by T-UMTS.
- Size and weight of the terminal are less critical.
- An UMTS terminal can be offered as an option similar to a sunroof, hands-free phone, navigation system, etc. Moreover, people tend to spend more money on luxury devices when they are integrated in a car.

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, 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 6.6.

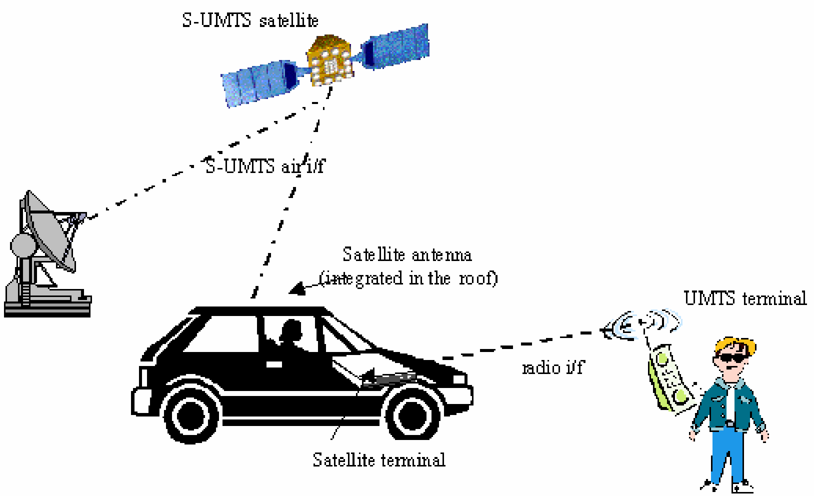


Figure 6.6: A typical vehicle terminal scenario

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.

6.1.1.4.2 Terminal performance

Terminal performance characteristics are mainly driven by the available resources inside the terminal like space and energy and in some way also from the level usage of state-of-the-art technology. In general, the following differentiation can be made for terminals having S-UMTS capability:

For low-cost terminals with small integrated antenna and limited energy provision typical values are:

- 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.

For nomadic terminals with integrated antenna typical values are:

- Antenna gain ~ 4 dBi.
- EIRP ~ 2,2 dBW.
- G/T ~ -20,8 dB/K.
- Data rates: 144 kbit/s Forward Link and 64 kbit/s Return link.
- Laptop style user interface.
- Integrated Quadrifilar Helix antenna or patch antenna.
- Limited Tx power levels.

For built-in terminals and terminals with external RF-module and antenna typical values are:

- Antenna gain ~ 4 dBi.
- EIRP ~ 15 dBW.
- G/T ~ -20,8 dB/K.

6.1.1.5 Terminal extensions

In some cases an expansion with one or more extensions can be necessary or helpful. Terminal extensions can be situated at the network side to improve radio link characteristics or at the user side to improve user interaction with the terminal. For the connection between the terminal and the external device several wired and wireless options are possible. Table 6.1 gives an overview of potential candidate interfaces and their characteristics.

Table 6.1: Terminal extensions

	Cables		**RF interfaces**			**Infrared**
	IEEE 1349 b	**USB 2.0**	**DECT**	**Bluetooth**	**HomeRF**	**IrDA**
Range	4,5 m	5 m	in: 20 m to 50 m out: 300 m	< 10 m	in: 50 m	1 m
LOS necessary	No	No	No	Yes	No	Yes
Max. data rate	800 Mbit/s	480 Mbit/s	Speech: 32 kbit/s Data: 512 kbit/s	Asym: 732,2 kbit/s Sym: 432,6 kbit/s	1,6 Mbit/s	16 Mbit/s
Max. no. of Users	N/A	N/A	120	Active: 8 Inactive: > 200	127	N/A
Frequency band	N/A	N/A	1 880 MHz to 1 900 MHz	2 400 MHz to 2 483 MHz	2 400 MHz to 2 483 MHz	N/A

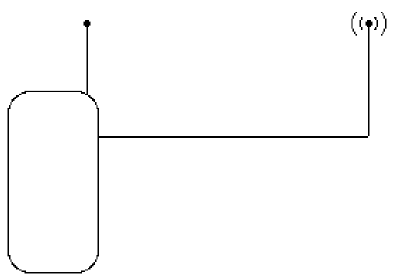
6.1.1.5.1 Network side terminal extensions

In places with high signal blocking, an external-RF module can improve both reception and transmission quality. Especially when direct transmission or reception to satellite is considered, an external antenna and high-power amplifier is advised to support higher data rates, unless the terminal already covers such capabilities (e.g. in the case of high-end nomadic and built-in terminal types).

Apart from avoiding signal blocking, external RF-modules also help to decrease electromagnetic radiation in the proximity of the user, lowering the level of specific absorption rate.

Different architectures are possible:

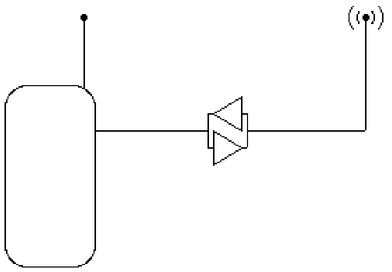
- External antenna with analogue wired interconnection:



  - only suited for short interconnection distances;
  - transmit power still limited by terminal;
  - low-cost solution;
  - enables the use of antennas with higher gain;

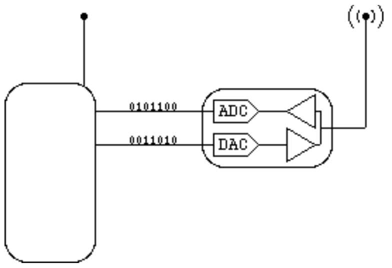
- enables better antenna location.

▪ External antenna with booster module and analogue wired interconnection:



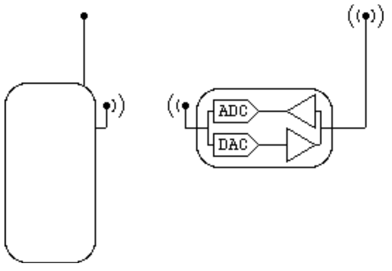
- higher cost;
- higher transmit power possible;
- enables the use of antennas with higher gain;
- enables better antenna location;
- suited for medium interconnection distances.

▪ External antenna with booster module and digital wired interconnection:



- higher cost;
- higher transmit power possible;
- enables the use of antennas with higher gain;
- enables better antenna location;
- suited for long interconnection distances;
- enables transmission and reception in other bands.

▪ External antenna with booster module and wireless interconnection:



- highest cost;
- higher transmit power possible;

- enables the use of antennas with higher gain;
- enables better antenna location;
- very flexible interconnection;
- enables transmission and reception in other bands.

Potential applications are:

- Usage of PDA-type and nomadic terminals inside a car.
- Usage of PDA-type and nomadic terminals inside buildings.
- For direct transmission to satellites.

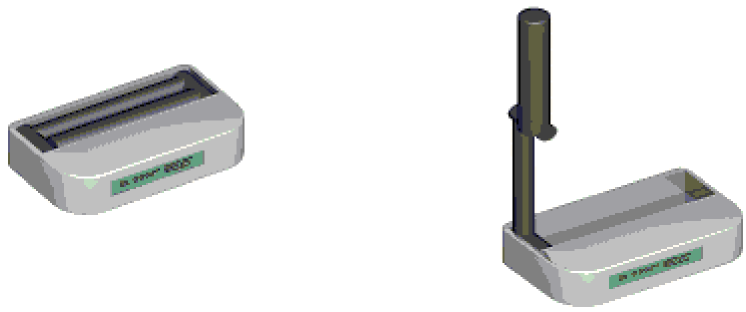


Figure 6.7: Example of external RF module design

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.

6.1.1.5.2 User side terminal extensions

A variety of external devices can be helpful to increase user comfort. The following list gives an impression of the possibilities:

- Additional batteries or external power supply.
- External and bigger screen.
- External and more ergonomic keyboard.
- Connection to PC.
- Etc.

6.1.2 Considered intermediate module repeater types (IMR)

Intermediate modules are network components placed and maintained by the network operator. In a S-UMTS network, their function is to significantly increase the coverage in areas where due to shadowing or blocking direct reception of the satellite signal is impossible.

In general, 5 different Intermediate Module Repeater (IMR) types can be identified:

1) Simple bi-directional IMR.

2) Simple unidirectional IMR.

3) Simple IMR with a subset of Node B functionalities.

4) IMR with Node B functionality.

5) IMR with Node B and RNC functionalities.

6.1.2.1 Simple bi-directional IMR

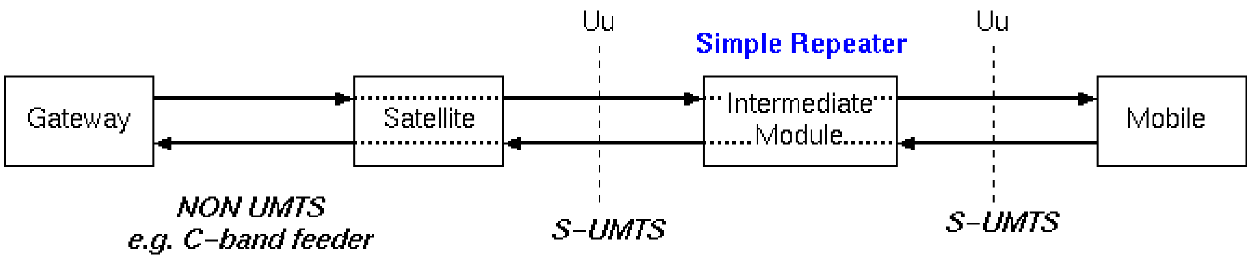


Figure 6.8: Simple bi-directional IMR

Utilization of fixed terrestrial IMR transmitting in the MSS band allocated to Space-to-Earth needs further clarification from a regulatory point of view.

This IMR has a repeater function in both directions, meaning both downlink and up-link will be S-UMTS.

The direct access architecture scenario implies a direct link between the satellite and the mobile terminal. Link budget calculations point out that the downlink is feasible in rural environments. In urban environments however, satellite reception is poor, especially indoors. A possible solution to this drawback of the considered scenario is to install, at strategic locations, IMRs that simply receive, amplify and retransmit the S-UMTS signal.

Positive aspects of this approach include:

- Creation of a multipath environment, a Rake receiver in the terminal can exploit this and enhance the SNIR of the signal. Note that this is limited to urban areas, in rural environments the channel still has a Rice/LOS character (in some cases, especially in geographical areas with very small elevation angles, the channel could have Rayleigh characteristics).

- Effectively "everywhere/anytime", because the terminal can communicate pseudo-directly to a satellite in an urban environment *and* directly in an open environment.

- The cost of the IMRs is relatively low in this scenario.

Negative aspects include:

- Only slow inner loop power control is possible due to large propagation delay between the IMR and the satellite. PCC instructions will be given on a frame-to-frame basis (100 Hz instead of 1 500 Hz as in T-UMTS). This will result in a serious decrease in the ability to compensate for fading channels. (Up link power control).

- No possibility to implement any form of power control to regulate the transmit level of the IMRs to mitigate intra-spotbeam interference.

- Terminals will have to be bi-mode (multi-standard), and hence more expensive.

Comments:

It seems difficult to design low-cost *power effective handheld* terminals that can handle the full rate up-link straight to the satellite, as is the case in rural areas not covered by the IMRs. This does not necessarily mean that a receive-only scenario is the only option left. For low data rates the processing gain can be high enough to uplift the up-link signal sufficiently at the satellite receiver. Hence an asymmetrical link scenario (Multicast/Broadcast) seems feasible for handheld terminals.

When aiming at the geographical complement goal of S-UMTS (offer T-UMTS services in non-covered areas), hand-held terminals will only be able to provide *low up-link bit rates*. A possible way to alter the up-link bit rate is to use an extension module with enough transmit power, connected to the terminal (or laptop/PDA/etc.) with a short range wireless link or a cable (see nomadic terminal type 2) or to use the nomadic terminal type 1. The highest performance will probably be reached when using a vehicular IMR that can either be a simple repeater, or a short-range wireless interface/S-UMTS converter comparable to the nomadic type 2, because in this case available Tx power will be highest. When applying S-UMTS/short-range converters we are talking about the indirect access scenario, individual configuration.

6.1.2.2 Simple unidirectional IMR

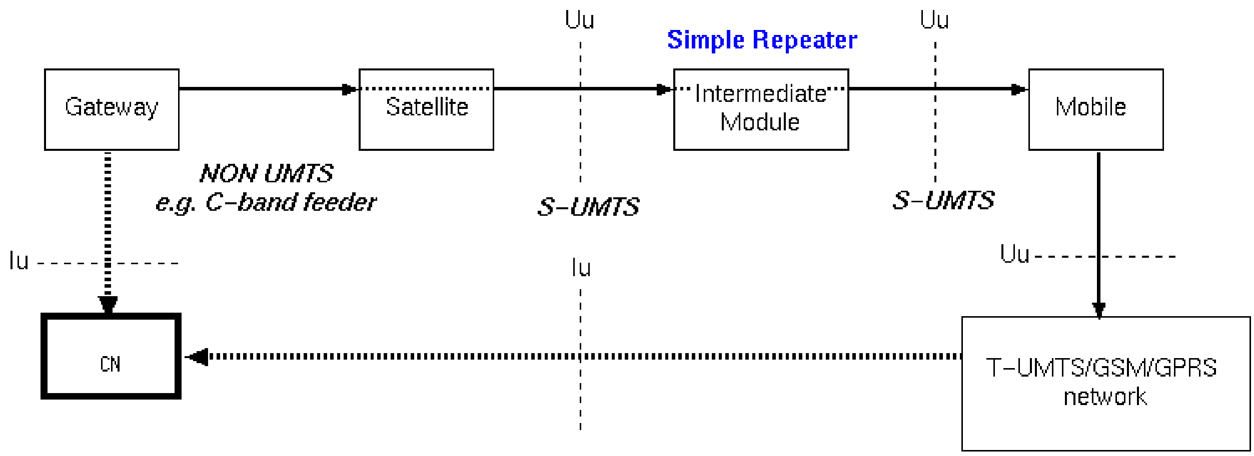


Figure 6.9: Simple unidirectional repeater

The simple unidirectional IMR is a repeater only for the downlink. The up-link will be T-UMTS.

This scenario has some advantages with respect to the simple repeater type 1:

- The IMR complexity (and cost) will be greatly reduced, because the RF must only be capable of receiving from satellite and transmitting to the mobiles, whereas the type 2 had to do Rx from/Tx to satellite and Tx to/Rx from the mobiles. The IMRs are cheapest in this scenario.
- The terminal complexity (and cost) will be considerably lower because it must only be able to *receive* S-UMTS. The most cost-saving factor is the considerably less complex RF/IF part. Additional advantages include: extra protocol-stack to support S-UMTS is considerably less, power consumption will be considerably less, no extra S-UMTS Tx hardware (this would be limited anyway).
- Benefit of the terrestrial up-link infrastructure features, like (fast) up-link power control (T-UMTS), Rake combining (T-UMTS), etc., it is all there.

Negative aspects are:

- If T-UMTS is selected for the up-link, geographical complement is non-existing.
- If the up-link is GSM/GPRS the geographical complement goal is in a way achieved, since not many areas are outside GSM/GPRS coverage, but the up-link capabilities will of course be insufficient to support *full* T-UMTS services.

- T-UMTS/GSM/GPRS up-link gets some additional loading. This should however be very limited, since broadcast/multicast applications are aimed at.

This scenario seems to be the most interesting when geographical complement is not the main objective. Different types of terminals (in terms of T-UMTS/S-UMTS capabilities) will probably be available in the market. For people wanting to pay for it, terminals with up-link S-UMTS capabilities (low rate) could be available (= optional terminal type architecture).

6.1.2.3 Simple IMR with a subset of node B functionalities

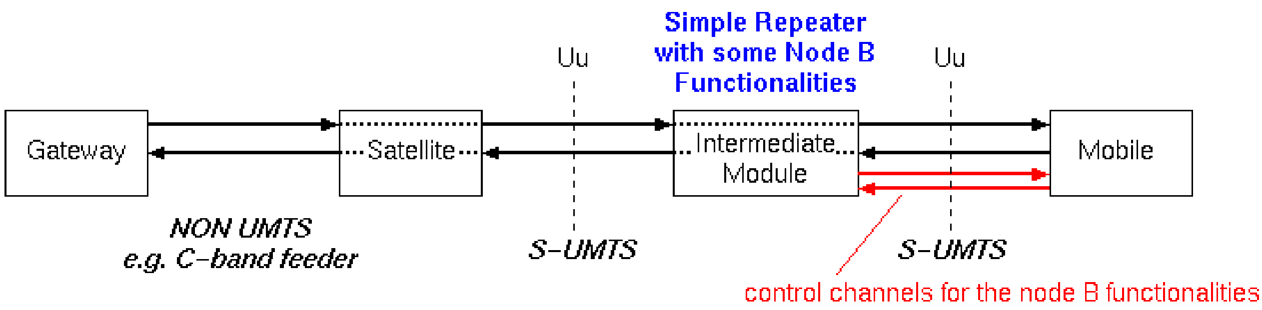


Figure 6.10: Simple IMR with a subset of node B functionalities

This set-up also relates to the direct access scenario. Depending on the extra cost some node B functionalities could be implemented into the IMRs. Functionalities that could be interesting:

- Power control
- Multipath reception (Rake Rx)

As indicated in figure 6.10, the IMR will have to be able to communicate with the mobile in a direct and independent manner. One or more control channels per mobile user will have to be present to manage the envisaged functionalities. Inherently the IMR must be capable of doing demodulation and re-modulation of the control signal(s). This will demand for a digital part, its complexity depending on the functionalities to be included. The analogue part (RF) will also be more complex because some additional filtering, frequency conversion, amplification, and A/D - D/A conversion will be necessary.

Important to note is that the IMR is still a repeater, so the interface with the gateway is the same S-UMTS interface as between IMR and mobile. For most of the signals the IMR will be transparent.

6.1.2.3.1 Power control

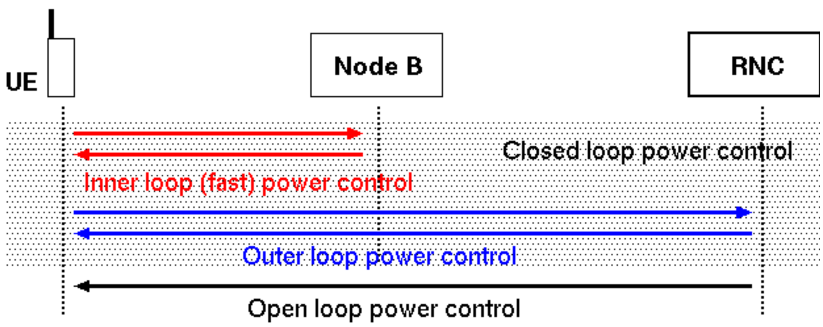


Figure 6.11: W-CDMA power control mechanisms

Power control is an essential feature of any CDMA based cellular system. The mechanism to be considered in this scenario is the inner loop power control (both up-link and down-link). It continuously adjusts the UE transmit levels in order to meet a specified SNR (depending on needed QoS) set by the outer loop power control. Open loop power control involves the RNC and is certainly not to be implemented in the IMR.

The main reasons for implementing power control are the near-far problem, interference dependent capacity of the WCDMA system, the limited power source of the UE and the presence of fading channels. An effective PC mechanism is of key importance in combating all of these problems, but only the latter would really require *fast* inner loop PC (1 500 Hz). A frame-based PC (100 Hz) should be sufficient to effectively handle the other drawbacks. If the power control signal would only have to travel the distance between mobile and IMR, a T-UMTS like power control mechanism can be implemented and fading would be more effectively mitigated.

6.1.2.3.2 Multipath reception

The channel between mobile and satellite does not have Rayleigh multipath characteristics. But if an IMR is included this module sees a multipath environment, exactly in the same way as in T-UMTS. These multipath characteristics can be exploited by incorporating a Rake receiver into the module. An advantage of putting a Rake already into the IMR as opposed to only having a Rake receiver in the gateway is that the IMR would need less transmit power. Putting a Rake in the gateway makes it possible to exploit macro diversity (from different IMRs). If the IMR up-link transmit power is not really an issue, there is probably no considerable benefit since the path between IMR and gateway should not really distort the signal (only path loss) so the multipath characteristics of the signal are prevailed and can be exploited by a Rake in the gateway.

6.1.2.3.3 Comments

The strong increase in complexity and hence cost outweigh the gain in implementing power control in the IMR. Implementing power control implies (de)modulating capabilities and some decision-making software. Also the analogue part (RF/IF) will become more complex and thus expensive. The only actual gain is better fading mitigation.

Implementing a Rake receiver in the IMRs seems only beneficial if the IMRs up-link transmit power is a critical factor.

6.1.2.4 IMR with full Node B functionalities

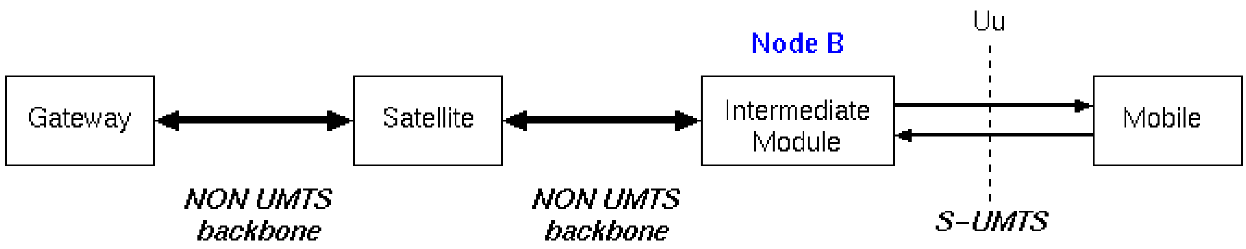


Figure 6.12: IMR with full Node B functionality

The difference with the architecture in 6.1.2.3 is that in this case the IMR has full Node B functionality and the interface between gateway and IMR is a whole different story. The question "which interface to use", is of course determining for the complexity of the module. This set-up relates to the indirect access scenario (collective configuration).

6.1.2.5 IMR with full Node B and RNC functionalities

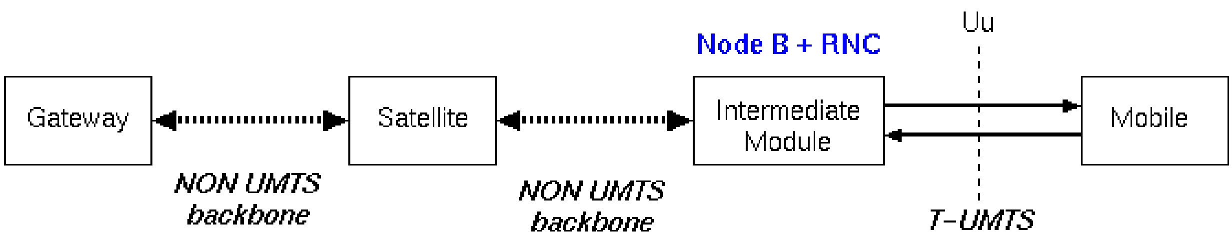


Figure 6.13: IMR with full Node B and RNC functionality

This configuration could be interesting for the "UMTS island" scenario in the sense that the satellite link is responsible for the interface between the "island" and the UMTS core network. In some cases this could be much cheaper than connecting the "island" to the Core Network with cables. An "island" can be a remote, though relatively dense populated area, it can be a ship, etc.

6.1.2.6 Conclusion

Table 6.2: Overview of different IMR scenarios

IMR type	Advantages	Disadvantages
Simple bi-directional IMR	• Creation of a multipath environment • No extra load for the UTRAN • Good coverage	• Terminals need an expensive satellite transceiver • No fast power control possible
Simple unidirectional IMR	• Reduced IMR cost • Reduced terminal complexity and cost • Fast uplink power control possible • Gain from uplink multipath diversity	• Extra load for the UTRAN • No geographical extension due to limited uplink coverage
Simple IMR with some node B functionality	• Fast uplink and downlink power control possible • Multipath combining in both uplink and downlink possible	• Higher complexity and cost of the IMRs
IMR with full Node B functionality	• Fast uplink and downlink power control possible • Multipath combining in both uplink and downlink possible	• Higher complexity and cost of the IMRs
IMR with full Node B and RNC functionality (no real S-UMTS application)	• Full UMTS provision • Single mode T-UMTS terminal is sufficient	• High cost and complexity at the network side

The simple unidirectional IMR seems to be the most attractive one in many ways. The service complement goal, to provide broadcast and multicast services in addition to T-UMTS services, seems feasible in this scenario since down-link traffic is dominant. An open issue may be the suitability of the terrestrial up-link for *multicast* traffic in terms of the extra load this will cause.

Up-link through a IMR as in the simple bi-directional IMR option is less cost-effective for both the terminals and the IMRs. An advantage could be in the geographical complement, but that is unlikely because IMRs will most probably be located in areas where there is already a terrestrial coverage.

Two different types of terminals can be envisaged (only the air interfaces specific to the satellite services are considered):

1) S-UMTS Rx/Terrestrial Tx (Baseline terminal architecture).

2) S-UMTS Rx and Tx (Optional terminal architecture).

The baseline terminal type will be significantly cheaper than the optional type. The geographical complement objective will not be fully achieved with the baseline type terminal. However, if the up link is through GSM/GPRS, many areas not covered by T-UMTS will still be covered by GSM/GPRS. Most users will not have the need to be able to communicate outside of the widespread GSM/GPRS covered areas.

The two main possibilities to reach the geographical complement aim are the T-UMTS island scenario and using the optional type terminals. T-UMTS island is the most efficient option when aiming to provide remote, though relatively dense areas with *full* UMTS services. In case of total coverage need, independent of any terrestrial network, direct communication (both down-link and up-link) with the satellite is necessary and an optional type terminal is the only possible solution. Up-link straight to satellite will be difficult for less powerful terminals, so an extension module of some kind can help enhance the up-link capabilities and hence the amount of feasible UMTS services. Note that a geographical complement, in the sense of offering *full T-UMTS services*, will probably not be achievable through using the S-UMTS up-link. Different degrees in offering T-UMTS services will exist according to terminal characteristics.

From a terminal marketing point of view the baseline type will be the most successful in the early stages of S-UMTS. As technology evolves and S-UMTS matures, the optional type terminals will become cheaper and probably comparable to baseline type terminals in price. In this stage users will be able to *fully* benefit from both the geographical and the service complement capabilities of S-UMTS. From this point of view, the down-link-only IMRs do not prevent any future developments in terminal technology according to marketing prospects. It seems to be the most cost-effective option for early (deployment) stages of S-UMTS *and* an adequate solution for the future.

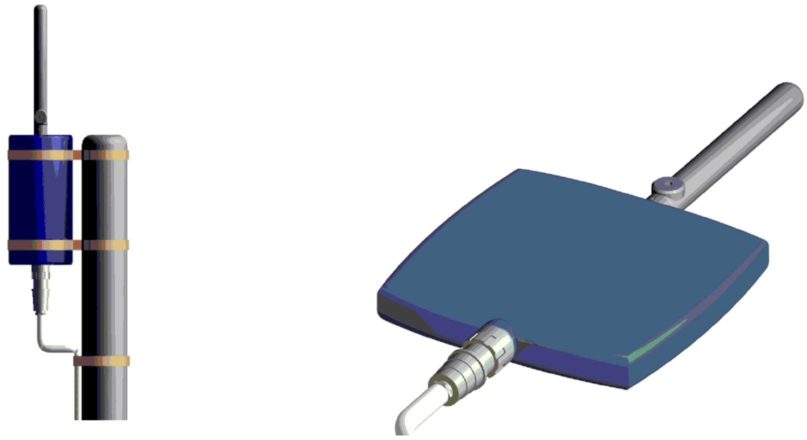


Figure 6.14: Examples of S-UMTS IMR

6.2 Architecture and design aspects

Duplexing mode implementation consideration can be found in clause 8.1.2.8.

6.2.1 Terminal functional modules

This clause will define and give a short overview on the different terminal modules that are implemented in the T/S-UMTS and FDD/TDD mode. The hardware and software necessary to support the applications will not be discussed.

The (S-)UMTS services will require a certain flexibility in the terminal hardware. Changing parameters like transport channel characteristics and adding/removing additional channels are inherent to the standard and will happen on the fly.

6.2.1.1 RF front-end and antenna

The RF and antenna clause is defined as the analogue clause of the terminal starting from the low IF interface at the output of the inner modem till the antenna.

It is quite a challenge to design an RF section for a multi-standard (satellite and terrestrial) phone, because of the differences like Doppler conditions, HPA requirements and gain control.

6.2.1.2 Inner modem hard - and software

We define the inner modem as all the functions performed at (oversampled) chipping rate and symbol rate like: spreading/de-spreading, scrambling/de-scrambling, low IF up-/down-conversion, Rake or PLL/DLL based reception and the runtime control of all these functions. To keep the requested degree of flexibility (T/S UMTS reconfigurability), different design approaches can be followed:

- DSP based design.
- Hardware design.
- Reconfigurable hardware design.

These 3 different approaches are independent from the selected access network (S-UMTS or TDD/FDD T-UMTS).

6.2.1.2.1 DSP based design

The DSP core offers the largest flexibility. It is clear that reprogramming loops and decisions on the fly can be implemented in software. In case you would like to pass from TDD to FDD duplexing or from S-UMTS to T-UMTS, the only thing you will need to do is to download the appropriate inner modem software. The biggest disadvantage of such an inner modem architecture is the power consumption. Actually the market is developing "low power" DSP cores with an average power consumption of less than 4 W for a technology of 0,18 µ clocked at 266 MHz (Source: Apex Technology). This design solution will not be evaluated further due to the problem of power consumption. Moreover, even with such a powerful DSP, you still need accelerator hardware for Rake, Turbo decoder, etc.

6.2.1.2.2 Hardware design

To avoid the problem of a power hungry DSP based architecture, the second solution is to develop bigger hardware blocks that are clocked at lower speed. The power consumption of such hardware block will be reduced, but the requested flexibility to support the UMTS standard will not be present. The reconfiguration between FDD/TDD or S/T-UMTS will be impossible without having each demodulator already implemented in the hardware. This design solution is rejected due to the excessive gate count and hence the too high silicon (component) cost.

6.2.1.2.3 Reconfigurable hardware design

Both design techniques (DSP based and hardware based) have their own advantages and disadvantages. The aim of the reconfigurable hardware design technique is to combine the flexibility of a processor-based system and the low power aspect of a hardware based system.

The hardware/software split is in this architecture less clear comparing to the other types of design. In this case, the hardware will process the data and chip related activities such as spreading, scrambling, etc. and the software will take decisions based on measurements performed by the hardware such as acquisition or finger management (Rake-receiver). The reconfigurability is done by the processor by writing values to registers which control the hardware. Because the processor in this case is mainly involved in control tasks, and not in DSP type of operations, a power optimized microcontroller is sufficient. The power estimated for such reconfigurable inner modem developed on a 0,18 µ clocked at 40 MHz is less than 0,7 W.

This reconfigurability allows also the design of inner modem architecture supporting different standards with sharing of hardware when it is possible. So you can imagine a T-UMTS terminal where some specific block related to the S-UMTS have been added or reconfigured. This reconfigurability between T-UMTS and S-UMTS can decrease dramatically the cost of a S-UMTS compliant terminal.

6.2.1.3 Outer modem hardware and software

We define the outer modem as the architecture containing the following functionality: interleaving/de-interleaving, channel encoding like Turbo and Viterbi coding, rate matching, transport channel multiplexing and physical channel mapping.

Like in the inner modem, the S-UMTS services will require certain flexibility from the outer modem. Rate matching and other parameters can change on-the-fly when the data rate is changed or channels are added or removed.

Because of the high power consumption of a DSP approach, only the hardware-based designs are considered.

6.2.1.3.1 Hardware design

When the data of different transport and physical channels is handled in a serial way, no duplication of the data path is needed and power consumption will be lower then with a DSP solution. On the other hand, the data path will have an overhead of hardware due to the necessary flexibility for different data rates. This will increase the power consumption and the size of the chip.

6.2.1.3.2 Reconfigurable hardware design

In this approach, the split between hardware and software must be chosen very carefully to keep the microcontroller clock speed low instead of using a high speed DSP core to process the data flow. The control information communicated by higher layers will be processed by the software that will set the appropriate registers to reconfigure the hardware.

In this case, the data path can be implemented efficiently in hardware with a maximum of flexibility. And together with the proper low power design techniques, this architecture provides a flexible low power baseband solution for 3G terminals.

With this reconfigurability, the outer modem can be easily adapted from T-UMTS to S-UMTS with addition of some hardware blocks (currently this is only the scrambling module in down-link).

6.2.2 Multi-standard and SDR

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 based architectures in use for most GSM baseband integrated circuits are no longer the best option for UMTS.

An example of a UMTS multi-standard 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:

Reconfigurable 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 that allows saving 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.

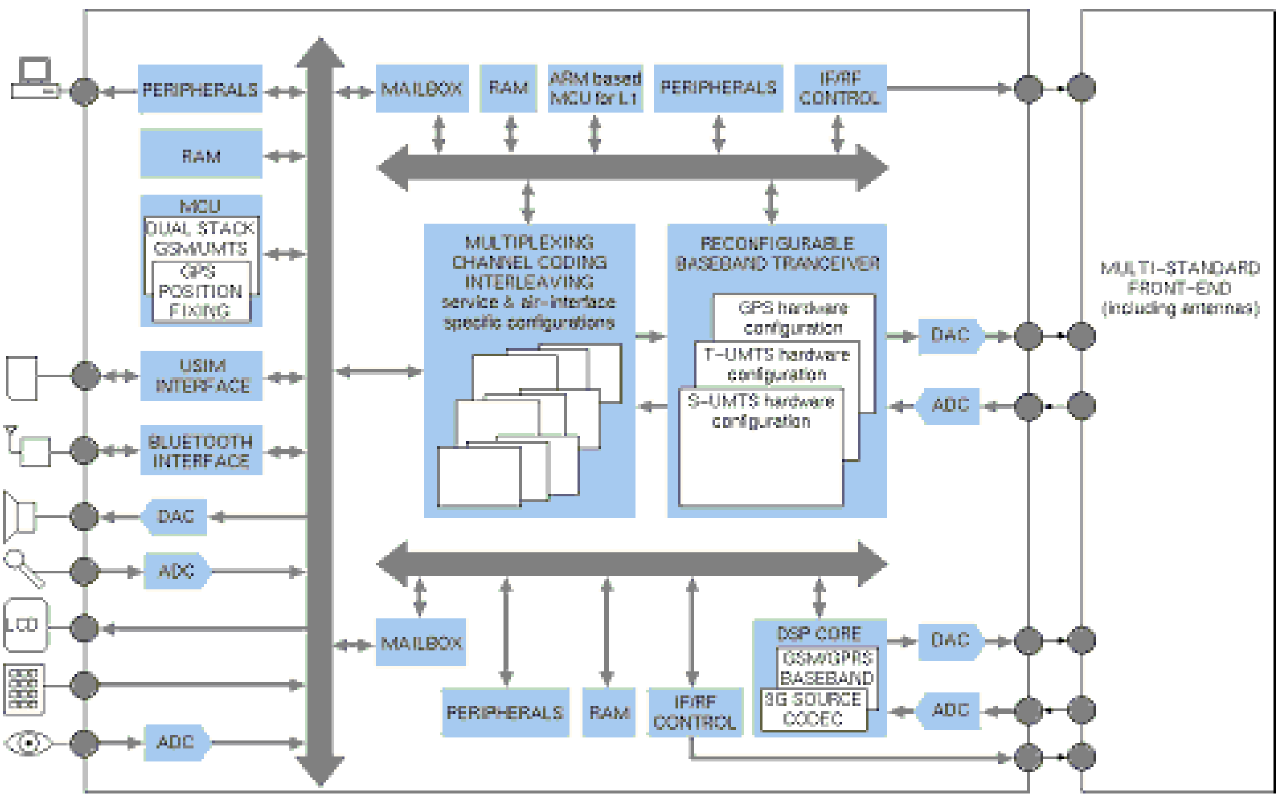


Figure 6.15: Multi-standard terminal architecture

A multi-standard IF/RF unit that 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 GNSS reception (such as GPS, Gallileo or Glonass).

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.

6.2.3 Power consumption and low power aspects

Power consumption is one of the biggest challenges in 3G terminal design. Power hungry UMTS applications such as video-conferencing, always-on connections, games and m-commerce all put more pressure on battery life, as do hardware elements like graphically better screens and more powerful RF chips. The consumer wants all of this using a handheld terminal with a similar size as GSM terminals, and demanding a comparable battery autonomy and battery life. Because there is a disparity between the evolution of semiconductor chip performance and battery performance, power consumption is a very important aspect in terminal design

The main consumers of power in a mobile terminal and therefore the main targets for improvement, are the display, the RF power amplifier and the baseband ASIC or DSP.

6.2.3.1 Baseband

ASICs use less power than DSPs for equivalent performance because they employ fewer transistors and operate at slower speeds. Therefore power-hungry functions should be implemented in an ASIC. The key of low power design is to evaluate each component individually *and* how all the components work together as a system.

Three basic principles should be kept in mind: turn it off (put to sleep/low-power state) if you are not using it, lower the voltage, and reduce clock frequency. Clever idle and sleep mode algorithms should be designed to take maximum advantage of the discontinuous reception features built into the radio standard and thoughtful attention should be given to how the customer will use the product.

Voltage scaling is another innovative way of reducing power consumption in terminals. The idea is to vary the core voltage based on the demand. On a similar tip, the internal core clocking frequency can be reduced during periods of low demand. Using this method you can decide to perform a given task in a longer time and that way save power. If you can afford to trade time for performance, you can increase battery life using voltage scaling and clock frequency scaling.

Below is a more concrete example of a baseband chip design with attention for power consumption issues:

At the architecture level, power savings can be obtained by having almost all inner modem (Layer 1) functionality implemented on reconfigurable hardware (ASIC). This hardware/software trade-off allows avoiding a power-inefficient DSP core for L1 software execution. The maximum clock speed in the transceiver part can be reduced to a multiple of the chipping rate specified by the T-UMTS specifications (e.g. 4 times oversampled chip clock = 15,36 MHz) and for commonality reasons best reused for the satellite extension. A low power micro-controller subsystem, clocked at 40 MHz to 60 MHz, performs parameter downloading at boot time, control of acquisition and tracking, programming of the transmit power control hardware, run-time control of slow loops (e.g. for parameterization of different channel estimation and multipath searching algorithms), and L1 software such as rate matching. The micro-controller peripherals are used among others for radio control and communication with various source codecs.

Further information on terminal power and system information can be found in [37].

Low power design techniques can also be applied on the circuit level. As WCDMA architectures are by nature multi-rate, different clock frequencies are required in different regions of the transceiver. Moreover, multiple services imply multiple data rates depending on the activation of the service in the terminal. Also, when a terminal is just roaming, a considerable part of the digital functions can be switched off completely. For all these reasons, an innovative inter-module communication protocol in which clock speeds are self-adaptable as a function of the runtime parameters can save a considerable amount of energy. The technique results also in a significant reduction of the load on the high frequency clock nets, while the hardware overhead is negligible. Idle blocks are switched off automatically, which results in an ultra-low power consumption in idle (roaming) mode.

6.2.3.2 Analogue part

When the terminal is transmitting, the power amplifier dominates power consumption. Third generation use a different modulation scheme than GSM, although this improves bandwidth efficiency, it makes the amplifier less efficient. In this view, the up-link through GSM/GPRS seems more power-effective, but since the up-link traffic load for S-UMTS services will probably be very small with respect to the T-UMTS services up-link traffic loads, this effect will be negligible. Most proposed schemes to increase power amp efficiency revolve around *predistorting the baseband signals* to compensate for non-linearities.

A move to *direct conversion* of RF-to-baseband signals could also contribute to lower power consumption. The general idea is to shift as much as possible analogue functions, like filtering, into the digital domain. A consequence is that this method puts higher demands on the A/D converters.

6.2.3.3 Display

Another big power consumer is the display of a terminal. Three main areas of large power consumption are: lighting the display, data transfer to the controller and running higher colour depth. Innovations in these areas are reflective displays, low-temperature polysilicon TFT displays together with lower driving voltage, liquid crystal and colour-depth enhancement systems.

6.2.4 IMR basic architecture and characteristics

6.2.4.1 Architecture

This clause gives an overview of the basic architecture for the simple unidirectional IMR.

The IMRs function is simply to receive, amplify and re-transmit the signal coming from the satellite towards the mobile. Therefore, the entire module can be kept analogue, since only RF-related functions have to be implemented.

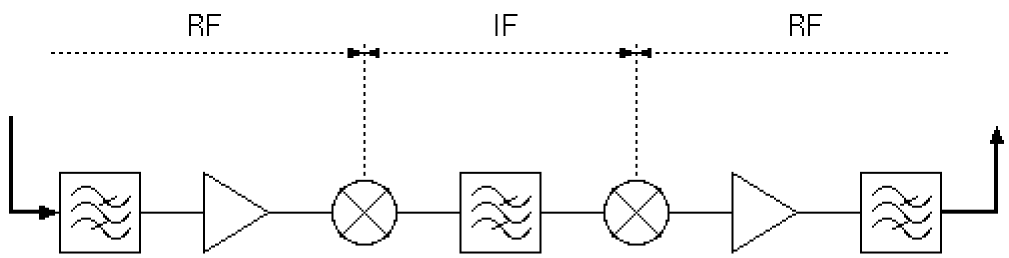


Figure 6.16: Basic architecture for simple unidirectional IMR

Figure 6.16 displays a simple model of a possible architecture. The number of components of this IMR type are limited:

- *Donor antenna:* the IMR antenna directed towards the satellite, picking up the downlink signal. This antenna should be highly directional.
- *Service antenna:* the IMR antenna covering the service area.
- *RF band pass filters:* determine the frequency range for operational configuration.
- *IF band pass filter:* defines the actual pass band and is a determining factor in important issues like out-of-band-gain, delay, EVM, etc. for which a compromise will have to be made.
- *Mixers.*
- *Local oscillators.*
- *Low noise amplifier (input).*
- *Power amplifier (output).*

6.2.4.2 Typical characteristics:

- *Gain:* 65 dB to 95 dB.
- *Output power:* ±30 dBm.
- *Rx antenna gain:* 24 dBi to 31 dBi.
- *Noise figure:* 5 dB.
- Most IMR feature *Auto Limit Control (ALC)* or *Automatic Gain Control (AGC)*, an adjustable limit for the output power to be able to inhibit out of band gain and emissions, and to prevent self-oscillation.
- *Mechanical characteristics:*
  - *size in cm:* 40H x 35W x 30D.
  - *weight:* < 20 kg.

Further information can be found in TR 125 956 [38].

6.2.4.3 Issues to be addressed when implementing a IMR (specifying requirements)

In terms of co-existence:

- **Out of band gain (or Adjacent Channel Gain, ACG):** The frequency band in which the IMR amplifies has to be well controlled and shall cover the assigned band of the operator. The bandwidth and slope of the IF filter determine the degree of suppression of the unwanted channel outside the operating band.
- **Out of band emissions (accounting for ACLR):** Unwanted emissions immediately outside the operating band resulting from the modulation process and non-linearity in the transmitter.
- **Spurious emissions:** Unwanted emissions that are caused by unwanted filter effects such as harmonics emission, parasitic emission, intermodulation products and frequency conversion products.

Applicability of EN 301 489 [39] concerning EMC issues has to be investigated.
It is expected that the specific harmonized standard would have to be developed according to the RTTE Directive.

In terms of the sole system:

- **Modulation accuracy (accounting for EVM):** Is a direct result of the IF filter bandwidth (and slope), a smaller bandwidth yields a worse EVM value. Note that a compromise will have to be found for the demands of out of band gain and emissions, and modulation accuracy.
- **Antenna isolation**: As a repeater only amplifies a received signal, it can act as an oscillator under certain circumstances. The feedback path in this amplifier system are the two antennas. In order to prevent self-oscillation of the system, the feedback must be significantly lower than the amplifier gain. The loss factor in the feedback path is called the *Antenna Isolation*. Several factors have an influence on this: antenna pattern, vertical separation, environment of both antennas (shielding, reflections, etc.). Note that a GEO constellation is the most beneficial option with respect to the antenna isolation because very highly directive donor antennas can be used.
- **Delay:** Using common narrow band filter technologies (SAW) the IF-filtering process introduces a time delay of about 5-6 μs to the signal. This puts a requirement on the length of the receiver's search window. It is however not expected to be a problem, as the 3GPP standard requires a search window of 20 μs (TS 125 101 [40]).

Utilization of fixed terrestrial IMR transmitting in the MSS band allocated to Space-to-Earth needs further clarification from a regulatory point of view.

6.2.4.4 Remarks on frequency separation of donor link and service link

High power IMR used for large coverage areas might imply a frequency separation of both links, because the antenna isolation demand can become too strict. As we see it, for high power IMR a trade-off exists between extra effort in antenna isolation (shielding, highly directional Rx antenna pattern, etc.) and the need for extra spectrum. The increase in IMR complexity as a consequence of the need for frequency conversion will be negligible.

Using a GEO constellation, highly directional antennas are possible and because the majority of IMR will probably not be large coverage area oriented, the most favourable option seems a single-frequency repeater.

6.2.4.5 Special cases

Indoor IMR:

Indoor reception will already be greatly improved by the outdoor IMR. Still, coverage dead zones might exist (e.g. in tunnels, underground parking lots, etc.). The IMR will take the outside-received signal and retransmits it inside a building. These IMR will be similar to the outdoor ones but will need less gain and less output power.

Moving IMR:

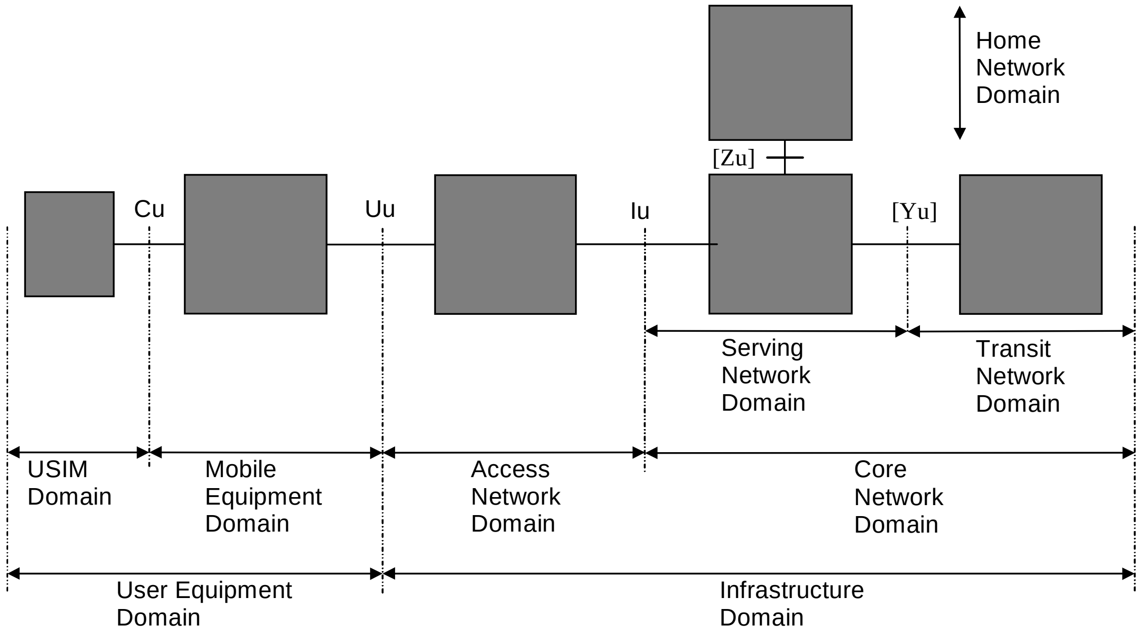
Another remark is to be made concerning moving IMRs (on a ship, train, etc.). The presence of Doppler frequency shifts due to the relative motion with respect to the satellite will most likely not demand for a different type of IMR, since the shifts will be very small in respect of the signal bandwidth (for ships, trains, etc.). Some extra attention could be given to the IF filter characteristics. In case of moving IMRs it can be better to use a wider although steeper filter characteristic to tolerate a slightly frequency shifted signal with a minimum amount of distortion. The Doppler frequency shift will be removed in the UE.

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].



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.

Figure 7.1: UMTS domains and reference points

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.

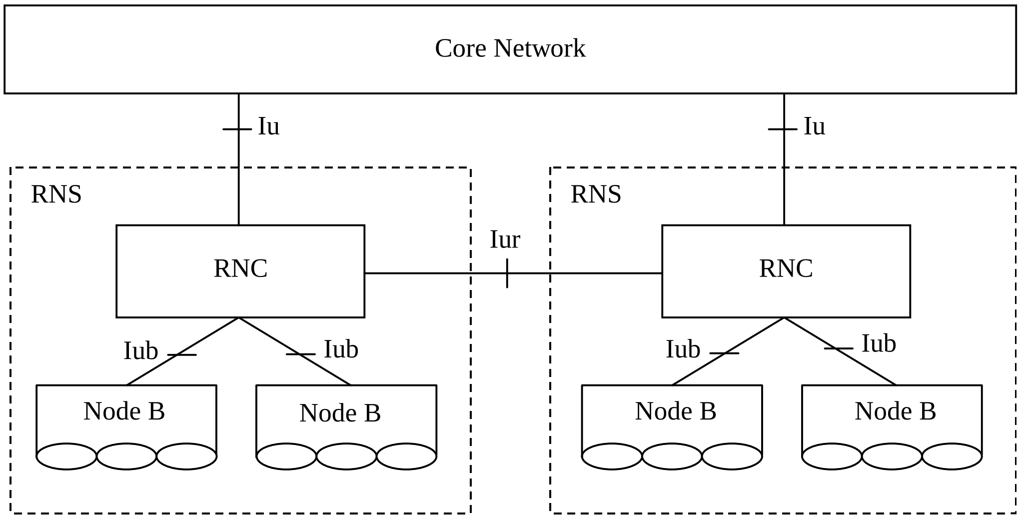


Figure 7.2: UTRAN Architecture

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.

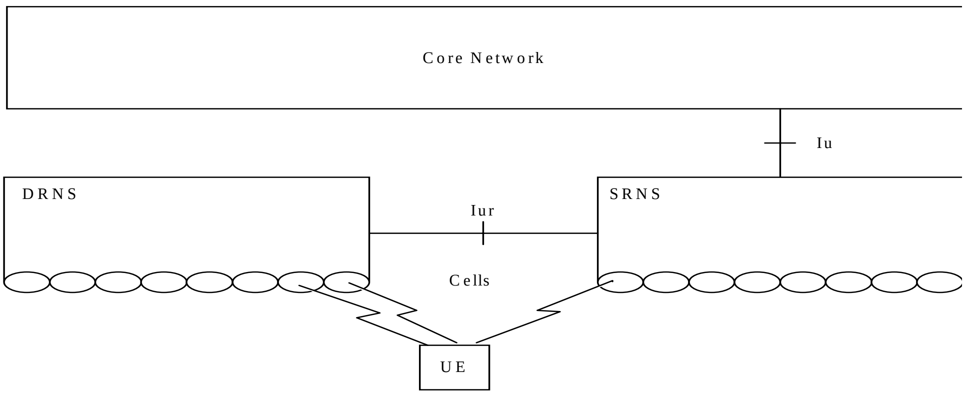


Figure 7.3: Serving and Drift RNS

7.2 S-UMTS architecture

Service interoperability is only one of the different levels of interoperability that characterize the positioning of S-UMTS with respect to T-UMTS. The service interoperability between the terrestrial and the satellite component can result from different architectures exhibiting different degrees of integration between the two components with a direct impact on the system cost. Ideally this interoperability would expand down to the terminal level, in order to make the S-UMTS system more "attractive" to the end-user.

7.2.1 System impact

The architectures that will be analysed in this clause can be classified under two main categories:

- Coverage oriented:
    - Direct access to satellite.
    - Indirect access to satellite.

- Broadcast oriented:
  - Direct satellite reception.
  - Indirect satellite reception.

For each satellite-based system type, the basic principles are described and a system configuration is presented. An attempt to identify the advantages and disadvantages of each of them with regard to the requirements summarized in the previous clause is also made. In any case, coupling of satellite positioning system with the satellite component of UMTS realized at terminal level through a dedicated chipset is the only configuration envisaged here.

7.2.1.1 Coverage oriented

Due to the large coverage offered by satellites, the S-UMTS can complement the terrestrial component in the following roles:

- **Coverage completion**: the terrestrial mobile systems deployment is long and largely controlled by the economics and demographics of the region concerned. The satellite component can be used to complete the coverage of the terrestrial component. Furthermore, aeronautical and maritime users may be solely dependent on the satellite component for the provision of services.
- **Coverage extension**: the satellite component can be used to extend coverage boundaries of the terrestrial component.
- **Disaster Proof Availability**: satellite systems can provide a back-up service if some form of natural or man-made disaster reduces the effectiveness of the terrestrial component.
- **Rapid deployment**: the satellite component can be used to rapidly extend the coverage of the terrestrial component.
- **Global roaming**: the satellite component can provide users with global roaming capability

To sum-up, the satellite component can complement the terrestrial component in providing coverage in areas that:

- Are not yet covered by the terrestrial component taking advantage of the rapid deployment feature of the satellite system.
- Cannot be covered by the terrestrial component for instance to address the maritime and the aeronautical markets.
- Will not be covered by terrestrial component for whatever reasons.

There are two ways to provide coverage, either through a direct link between the terminal and the satellite or indirectly using intermediate equipment. The interest for a satellite component to fulfil the coverage role depends largely on the degree of coverage offered by the terrestrial component. This degree of coverage relies on two main factors:

- The relative growth of multimedia traffic with reference to non-multimedia traffic already supported in existing 2G networks.
- The possible congestion of 2G systems that may drive the need of an accelerated roll-out of UMTS system.

7.2.1.1.1 Direct access to satellite configuration

The services supported are basically the same as the one provided by the terrestrial component. Due to link budget characteristics, operation in indoor conditions is limited. Therefore dedicated techniques must be used to support paging while indoor.

Nevertheless, the cost for the usage of the satellite component will remain higher than for the terrestrial component. Consequently, all satellite terminals will support as well the feature to operate directly with the terrestrial component. Whenever the terrestrial component becomes available, the bi-mode terminal will turn back to terrestrial mode.

The size of the addressable market within that segment highly depends on the matching of the terminal cost and performance as well as the service offer to the market expectation. Such system enables to provide wide area coverage (eventually a world-wide) for hand-portable terminal. It effectively matches the "anywhere, anytime" goal.

The S-UMTS reference architecture for transparent payload (GEO; Non-GSO) is shown below.

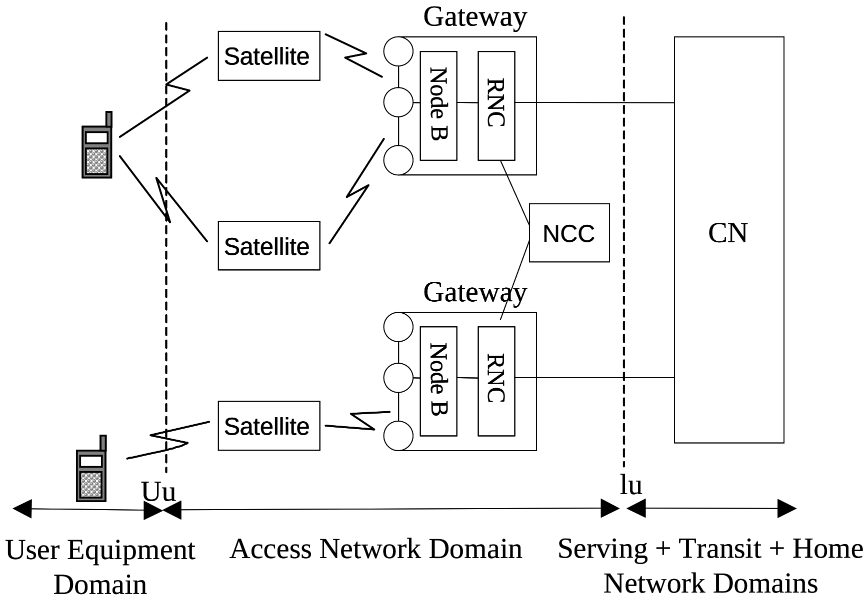


Figure 7.4: GEO and/or Non-GSO reference architecture for S-UMTS

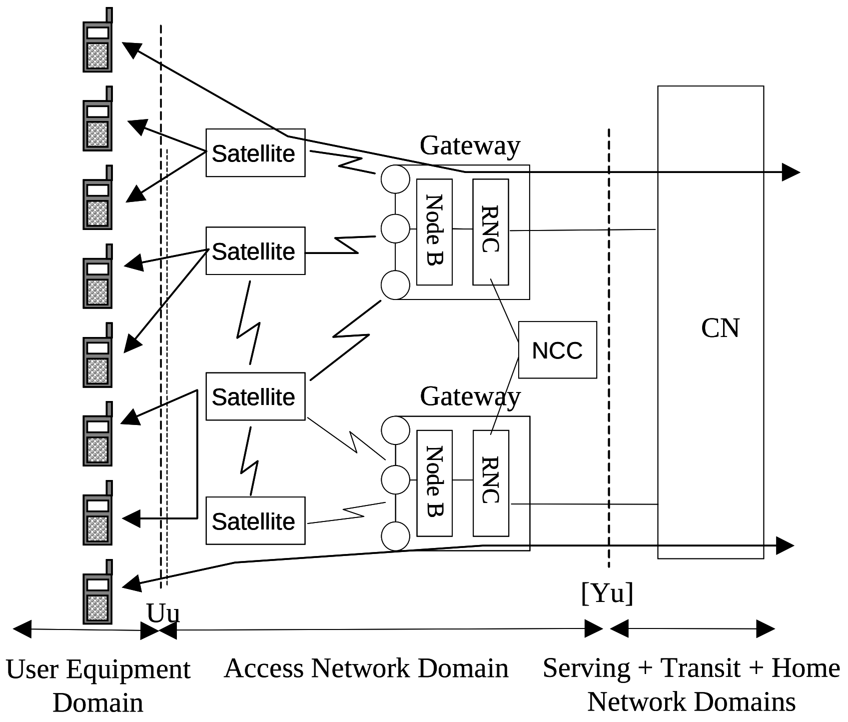


Figure 7.5: GEO and/or Non-GSO reference architecture using regenerative satellites

The S-UMTS reference architecture for regenerative satellite (GEO; Non-GSO, with or without ISL) is shown in figure 7.5.

In this model we can see that the satellite segment is performing both access and routing functions. Because of this, 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, [Yu] interface.

7.2.1.1.2 Indirect access to satellite configuration

Another way to consider the coverage problem is to design satellite systems that support any terminal compatible to the terrestrial component without modification. This requires inserting between the terminal and the satellite, an IMR. This module adapts the satellite signals to the terminal interfaces and vice-versa.

Such a system enables full independence from the terminal segment. The satellite component ensures traffic transportation between local networks and the public network. This has several advantages:

- Reduced investment and delay in the development due to a possible reduction in complexity/constraints on the terminal design.
- Possible evolution of the satellite segment in a transparent way to end-user terminals.
- Compatibility with existing terminals, which enable satellite communication systems to reduce the introductory phase of the service.

Such compatibility with terrestrial component terminal enables a technological independence with the satellite component and the terminal, which offers the following advantages:

- The terrestrial component terminals benefit naturally from the technology trends which enable marketing parameter improvements, such as cost and size reduction, extended autonomy, man machine interface improvements, features extension (Personal Digital Assistant, credit card payment etc.) as well as market segmentation declination.
- The satellite component may be improved and optimized in capacity as well as bandwidth performance consumption provided that the IMR is equipped with new features or advanced satellite components.
- To benefit from satellite services, the user does not have to learn the usage of another terminal with a different man machine interface. His environment is not affected. This will become increasingly of importance since the number of features in a terminal will grow.
- Subsequently, this configuration enables us to potentially capture a share of the terrestrial component market since the subscriber can access the satellite component service with an additional fee rather than a specific hardware upgrade.

Two system configurations may then be envisaged, collective and individual. A system supporting both can also be envisaged.

7.2.1.1.2.1 Collective configuration

The satellite-based system is inserted within a radio access network of the terrestrial component. The system is used in a trunking mode and transports the traffic exchanged between the terrestrial network and the served local network. The IMR constitutes an entry point for a local network. It constitutes part of the radio access network or a single base station. It provides UMTS services to all terminals within the coverage area.

Rapid installation of the IMR could be an advantageous feature. Installation on a building roof or terrestrial mast for earth fixed coverage, on board a vehicle transporting passengers as well as maritime and aeronautical applications can be foreseen.

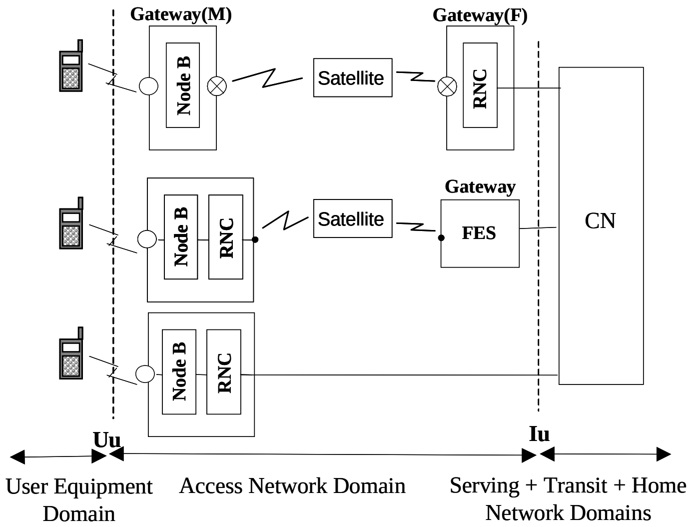


Figure 7.6: Indirect access to satellite - Collective configuration

7.2.1.1.2.2 Individual configuration

The approach is similar to the Direct Access to satellite system except that it is based on a distributed terminal concept (MS: Mobile Station). It consists of a booster-equipment and a standard terrestrial terminal. The booster converts the satellite signals into a format compatible to the short-range wireless interface of the terrestrial terminal. It relies on the assumption, that mobile stations will support such short-range wireless interface to connect phone accessories as well as computing devices.

To reach the largest market, different kinds of booster may be envisaged according to:

- Mobility capability criteria.
- The transportable or nomadic types, bigger in size but can be installed in a vehicle or easily carried out in a suitcase.
- Service capability criteria.
- Voice and low rate data only.
- Video, voice and high data rate.
- Traffic asymmetry for video, voice, high data rate on downlink and voice, low data rate on uplink.

Basically such a system can address nearly the same market as the "Direct access to satellite" configuration since most of the market segment identified can be targeted with a terminal in a distributed configuration (several parts). In most cases, a nomadic terminal is able to satisfy the needs of the users. It can either be a transportable terminal or a terminal installed on-board a vehicle.

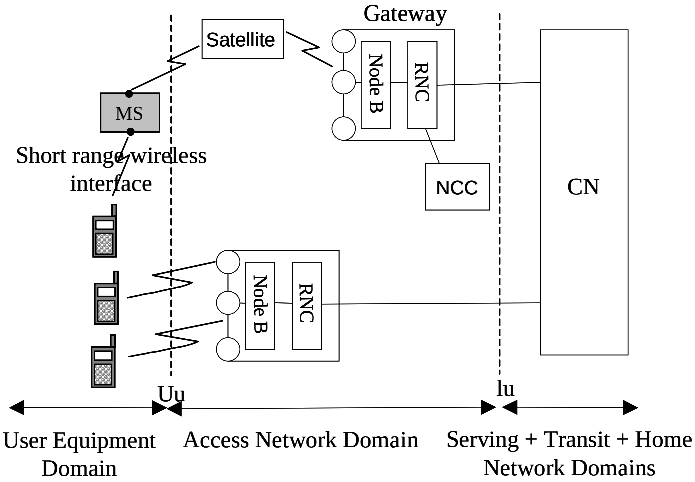


Figure 7.7: Indirect access to satellite - Individual configuration

7.2.1.2 Broadcast oriented

The satellite component is based on similar transport capabilities provided by the S-UMTS, DAB and/or DVB technology. The end user benefits from the terrestrial component services and can simultaneously access the services offered by the satellite component using two possible terminal configurations:

- Indirect access to satellite or Distributed terminal configuration: an external module enables a terrestrial terminal to benefit from broadcast services offered by the satellite component. The inter-connection between the terminal and the external module can be realized using short-range wireless technology.

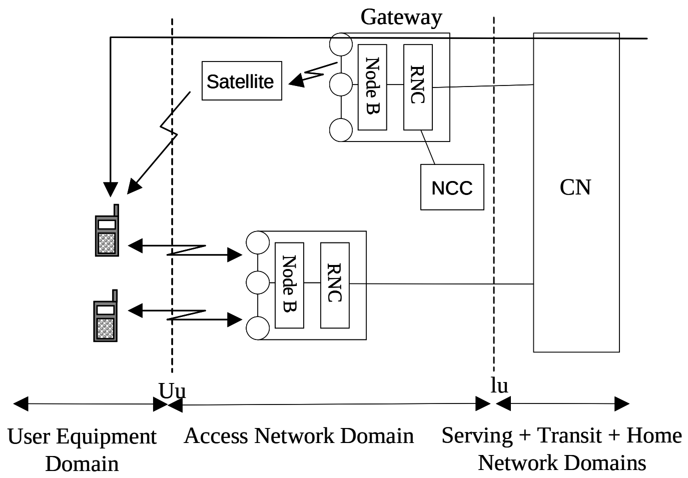


Figure 7.8: Direct reception from the satellite

- Direct access to satellite or Integrated terminal configuration: the terrestrial terminal contains embedded functions to benefit from the broadcast services.

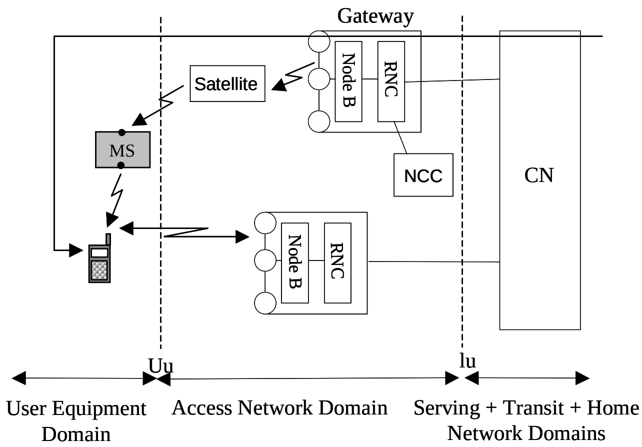


Figure 7.9: Indirect reception from the satellite

The two figures above show that the user benefits from broadcast/multicast services either with an integrated or a distributed terminal. Another configuration could be envisaged which would provide transport for broadcast/multicast traffic towards base stations typically the High Rate Packet Node. This would enable lower congestion within the radio access network of the terrestrial component.

The system aims at supporting all **unidirectional** services:

- Passive audio-visual services such as Pay-TV, narrowcast business TV.
- Passive audio services such as Radio programs, Music Entertainment, Public information.
- Passive data services for general purpose information such as stock exchange, weather forecast, News, Government announcement etc.

Broadcast will be supported for public information and multicast for value added services. Terminals equipped with positioning devices can filter useful broadcast/multicast information according to their geographical location, their subscriber profile or other criteria. This requires that relevant in-band signalling characterize the information transmitted.

7.2.2 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.

The following elements taken from 3GPP specifications TS 125 401 [7] are used for the architecture definitions in this clause:

- **The Radio Network Controller (RNC)**. Controls the radio resources. It may be co-located with the FES 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 FES. The 3GPP specification for the base station (Node B) may need to be adapted to cope with the movement of LEO satellites. The dynamic allocation of satellite spot beams makes the interface between the Nodes B and the user terminal more complex than in the terrestrial case. 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 FES.

  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 minimum adaptations with respect to the current specifications.

- The **Uu** interface is the Air Interface located between the user terminal and the satellite.

7.2.3 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.

7.2.4 GSO systems

7.2.4.1 GSO double-hop system

A double-hop satellite system based on a GSO constellation is shown in figure 7.10.

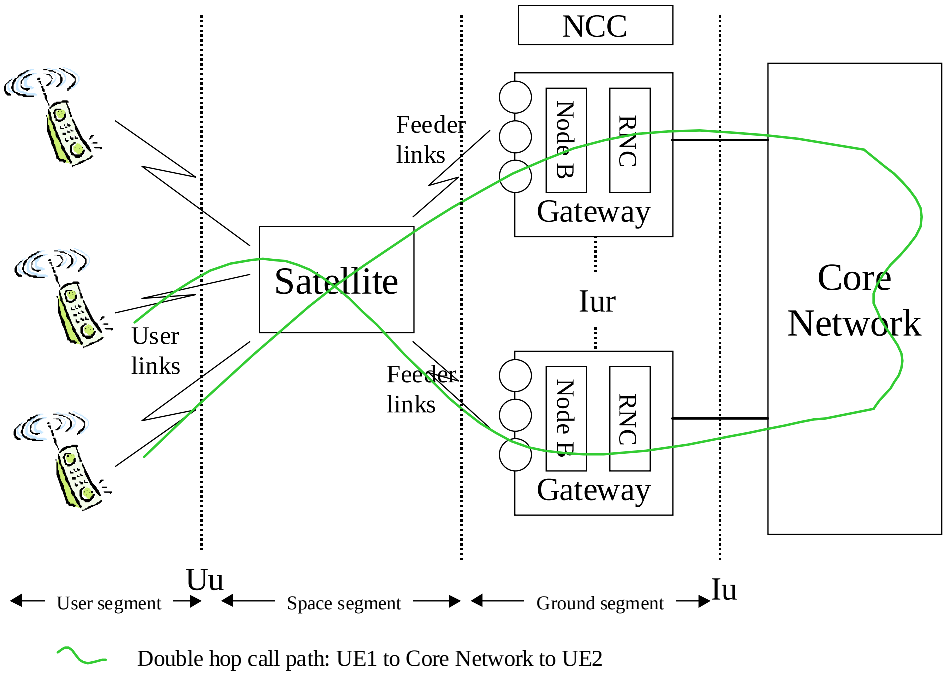


Figure 7.10: Double-hop, GSO model for S-UMTS

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 7.10. 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.

7.2.4.2 GSO single-hop system

A single-hop satellite system based on a GSO constellation is shown in figure 7.11.

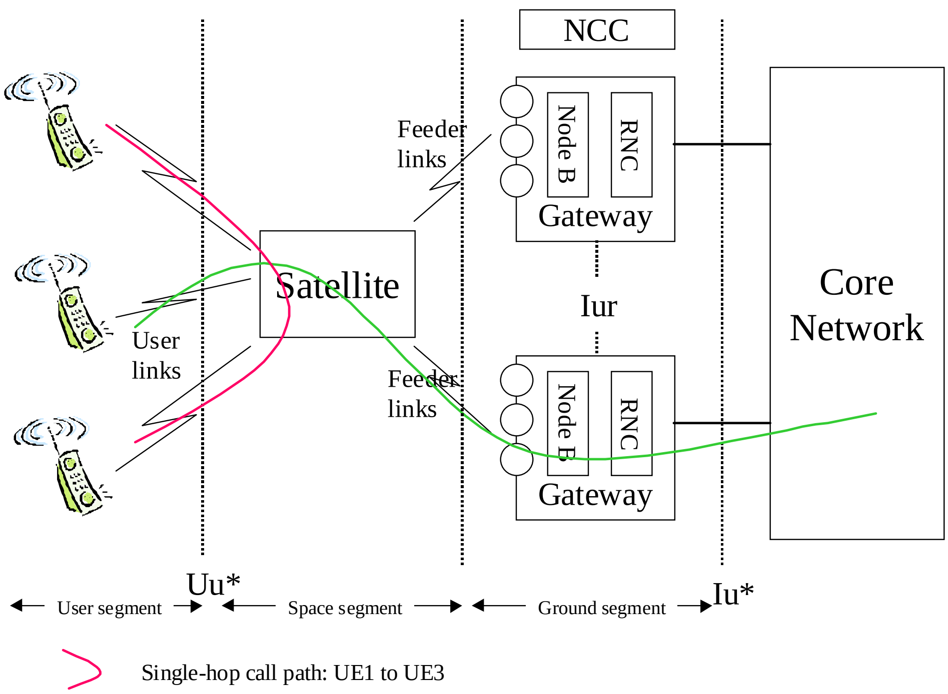


Figure 7.11: Single-hop, GSO model for S-UMTS

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.

7.2.4.3 GSO S-UMTS system

Figure 7.12 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.

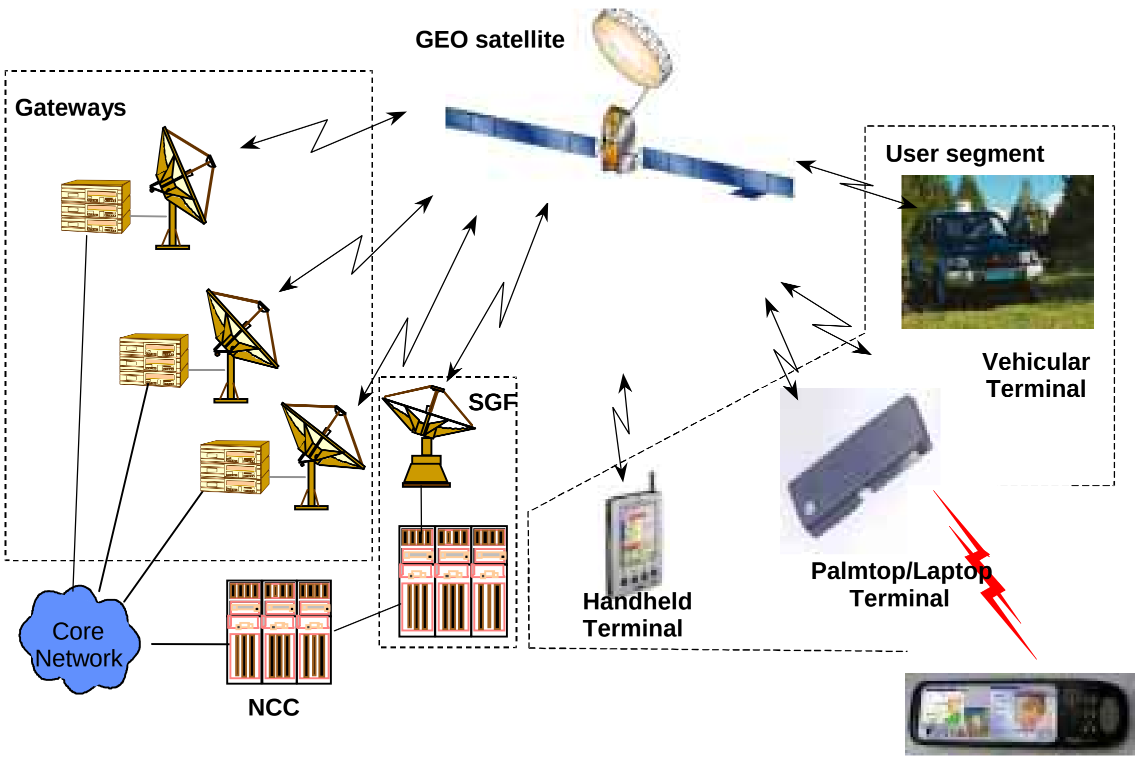


Figure 7.12: GSO system example for S-UMTS

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 that 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 (e.g. 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.

7.2.5 NGSO systems

7.2.6 NGSO single-hop system

A single-hop satellite system based on a LEO constellation with inter-satellite links is shown in figure 7.13.

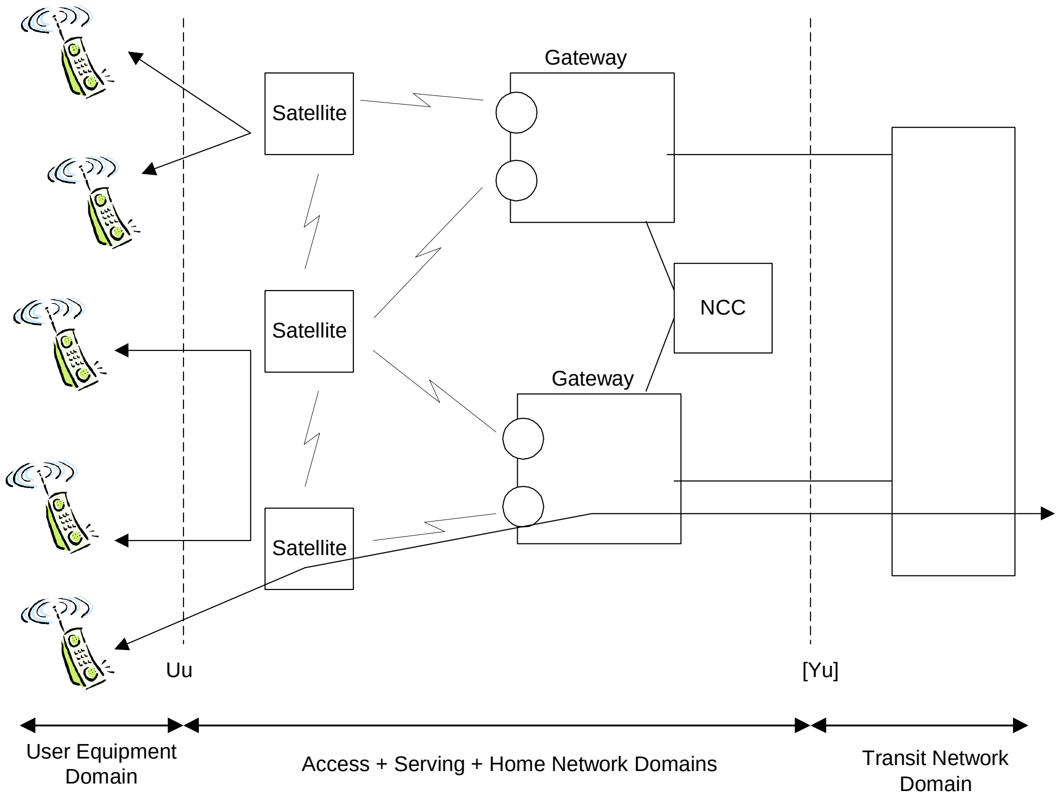


Figure 7.13: Single-hop, regenerative, ISL, LEO model for S-UMTS

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.

7.2.6.1 NGSO double-hop system

The architecture that may be adopted for double-hop, bent-pipe, LEO system is shown in figure 7.14.

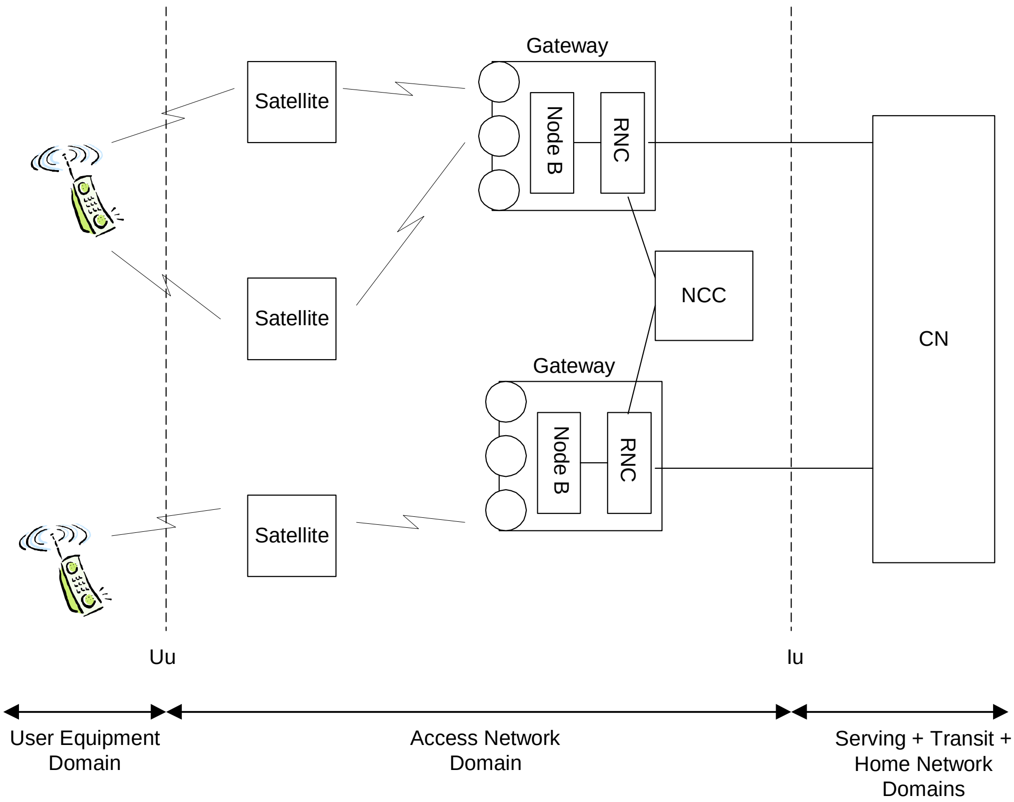


Figure 7.14: Double-hop, bent-pipe, LEO model for S-UMTS

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.

7.2.7 Payload aspects

This clause presents the different levels of functionality that the space segment, and in particular the communication payload characteristics on-board the satellite, could offer and relate them to different system configuration and topology.

The main functional added-values that the space segment can bring, additionally to its traditional signal amplifying function, can be summarized by:

- *Connectivity*: transparent analog or digital processors can offer a layer 1 connectivity between spot-beam and/or frequency channels, thus allowing either regional (among a few spot-beams) or global (through the whole satellite coverage) connectivity in a single satellite hop; this is of particular interest in case of a multi-beam coverage. Regenerative payloads can further improve the granularity of the connectivity by implementing layer 2 circuit or packet switched functions, or multiplexing functions.

- *Link performance enhancement*: on-board signals demodulation/re-modulation and possible decoding/re-encoding functions allow to alleviate the constraints put on transmission performance and, as a consequence, on their cost; indeed, low cost satellite terminals are usually characterized by low level transmitting power and poor local oscillator stability that could prevent to meet link budget through a transparent payload.

- *Flexible use of the satellite resource*: this aspect is closely related to the level of granularity that the satellite payload processes (i.e. on-board access to, for example, layer 2 packet), and also to resource management techniques (which allows to allocate a given resource - channel, carrier, slot - to a specific demand more or less dynamically and care for minimizing congestion occurrence); digital regenerative on-board processor, for this purpose, enables on-board buffering and statistical multiplexing of layer 2 resource, two functions which contribute to the improvement of the resource management.

The kind of functions implemented on-board a mobile multimedia satellite really depend on many parameters, and there is not a single ideal solution as designing is a trade-off management process. Though the payload issue is usually addressed as bent-pipe versus regenerative different steps/options can be foreseen ranging from a purely transparent payload (targeted at wide coverage, broadcast configuration or point to point through a star topology because the services offered support double hop links) to a fully regenerative payload with fast packet switching (multi-beam coverage, mixed of connectivity requirements, highly dynamic resource management, variety of traffic types).

7.2.7.1 Transparent payloads

Transparent communication payloads can be split into two major families:

- The bent-pipe type payload, which plays the role of an amplifier of RF signals that go through the satellite.

- The processed type payload, also referred to as payload with transparent on-board processing, which provides, in addition to amplifying the signals, a connectivity at L1.

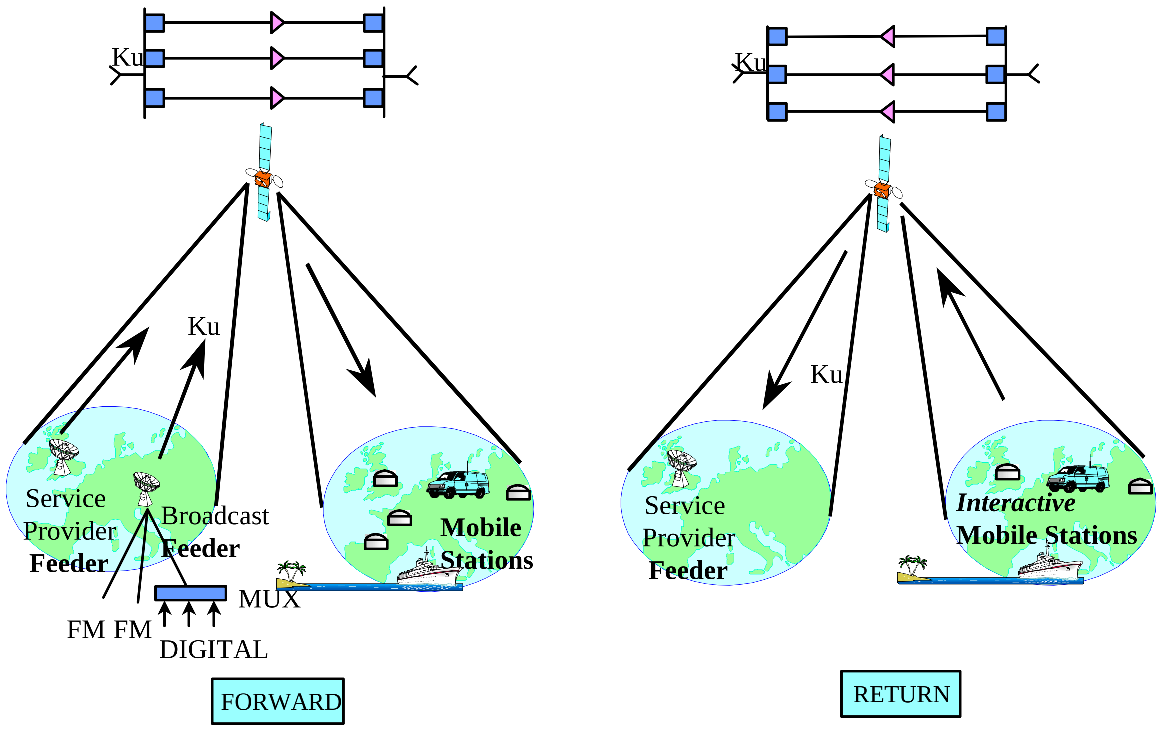


Figure 7.15: Bent-pipe satellite with wide coverage

Bent-pipe payloads family can itself be divided into two sets of payloads. The first set is the traditional type payload associated with global coverage satellite as shown in figure 7.15. The broadcasting satellite systems, or point-to-multipoint networks, are mostly based on that type of payload. Services such as IP multicast towards scattered users or big multicast groups, or Internet access with terrestrial return link are also well provided through such a satellite.

The second set of bent-pipe payloads (shown in figure 7.16) is associated with multi-beam coverage: this suits the market of smaller satellite terminals (thanks to the higher gain reached by narrow spot-beam) that can be used for Internet access and VPN services, but the connectivity between spot-beams over the whole satellite coverage is rather limited (further connectivity needs between spot-beams areas may then be fulfilled by terrestrial network).

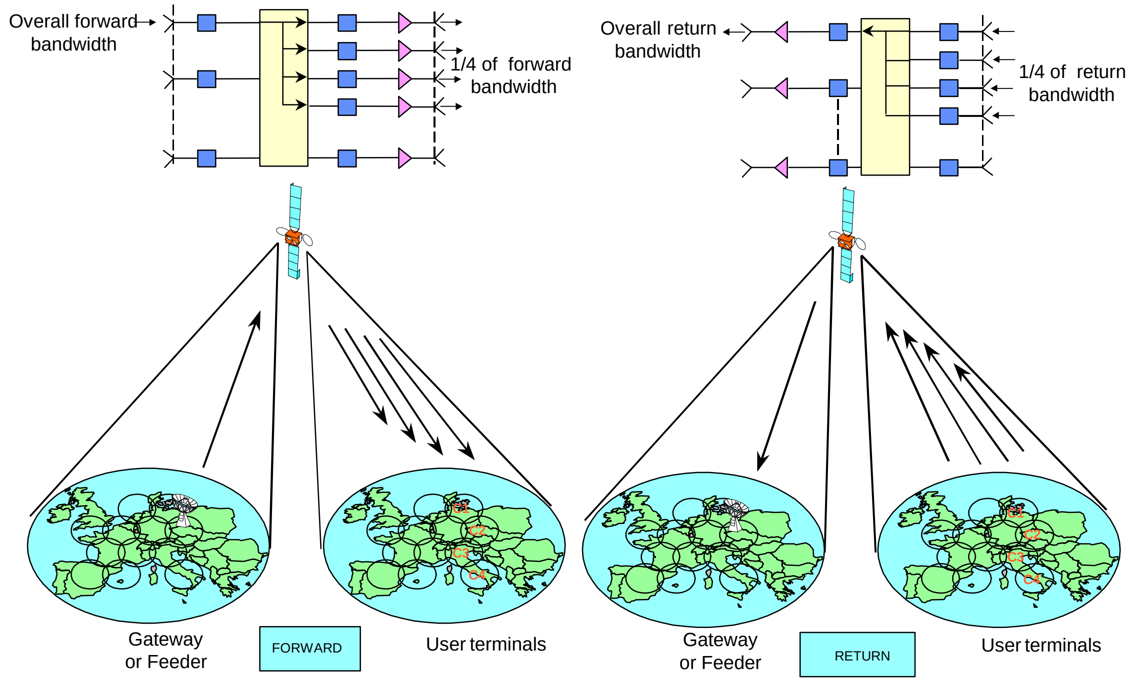


Figure 7.16: Bent-pipe multi-beam satellite

The payloads with transparent on-board processing are characterized by the connectivity they provide between satellite physical resources, i.e. at layer 1. As illustrated in figure 7.17 the first level of connectivity is achieved by means of spot-beams, which can take advantage of flexible Beam-Forming Networks (BFN). Depending on the system requirements, that connectivity can be refined and provided between satellite channels (e.g. between several MHz channels) or between individual frequency carriers occupying those channels. The smaller degree of granularity that those payloads are capable of processing is the TDMA time-slot, referred as the "Satellite Switched-TDMA" (SS-TDMA) type payload.

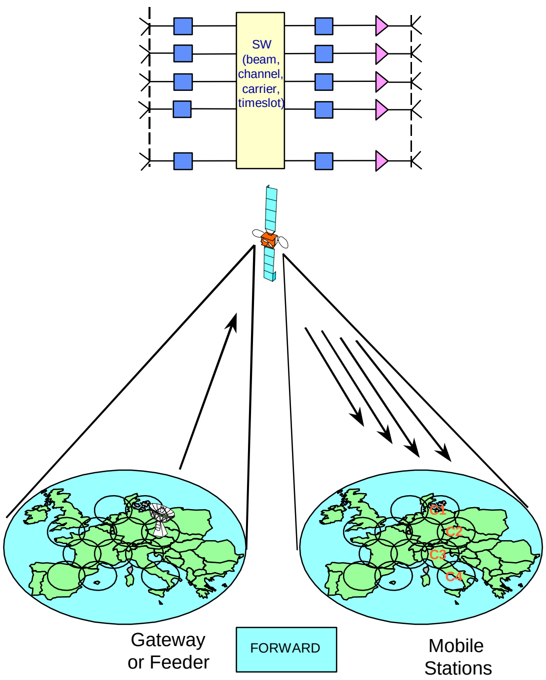


Figure 7.17: Transparent On-Board Processing satellite with multi-beam

From a technology point of view those payloads can be implemented using either analog devices, operating at Intermediate Frequency, or digital devices (hence requiring on-board A/D and D/A conversion); in the latter case, a higher degree of flexibility in the connectivity and re-configurability can be achieved: the frequency pattern (number of carriers, carrier bandwidth, organization of the carriers in the different channels) can evolve and carriers of different bandwidth can be switched through the same processor (this characteristics can be desirable in systems for which services are supposed to evolve along the satellite life time). However, the current performances of radiation hardened technology used to develop such digital processors still restrict their use to systems with connectivity requirements for low/medium data rate carriers (i.e. hundreds of kbit/s). Analog type processor, although less flexible, have, up to now, been preferred when carriers wide part of the spectrum need to be switched. Evolution of technology performances and of digital frequency de-multiplexing techniques will surely enable an increase of the capability of digital transparent processing in the mid-term.

7.2.7.2 Hybrid payloads

A hybrid communication payload consists of a small capacity on-board regenerative processor aside a transparent payload (see figure 7.18). Hybrid payloads are originally used in broadcast-based satellite systems with or without satellite return channel, possibly evolving towards the provision of a mixed of DVB and Internet services. The regenerative processor performs frequency de-multiplexing, demodulation, decoding of low/medium data rate carriers (from hundreds of kbit/s up to around 12 Mbit/s) so as to multiplex the information they carry (content of transport stream possibly be video or data - IP datagrams for example) coming from different sources/forward up-links (micro broadcasters or Internet service providers), prior to broadcast onto a higher bit rate downlink channel.

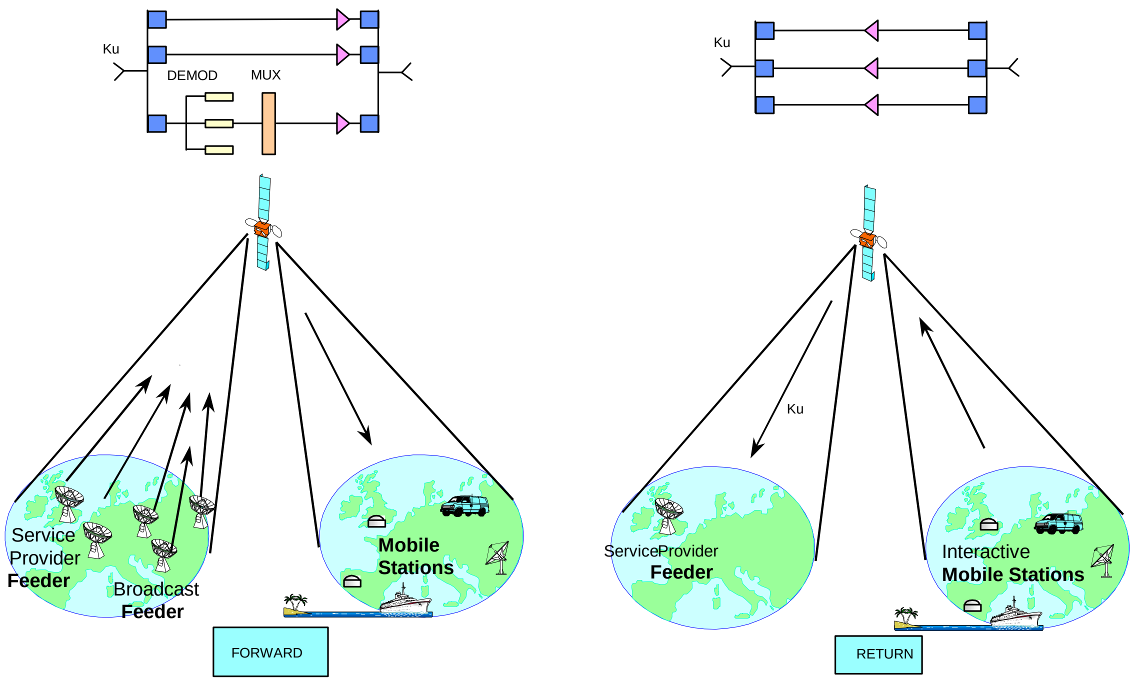


Figure 7.18: Regenerative/bent-pipe Forward Links and Bent-pipe Return Links

One shall note that the above hybrid payload, as well as the traditional bent-pipe first mentioned, can feature a transparent part (i.e. no process with respect to the protocol stack), which multiplexes return link channels (see figure 7.19).

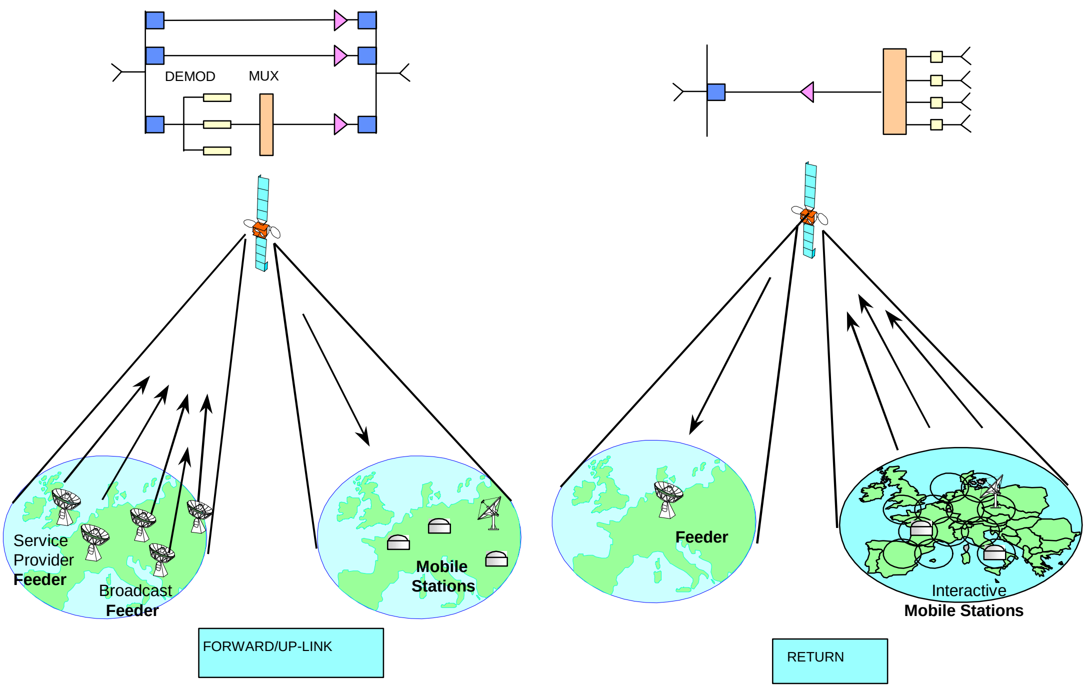


Figure 7.19: Regenerative/bent-pipe Forward Links and Transparent multiplexed Return Links

7.2.7.3 Regenerative payloads

Regenerative payloads (illustrated in figure 7.20) are primarily characterized by the demodulation of telecommunication signals on board. Additionally, and according to the access scheme of the up-link (such as FDMA, MF-TDMA or CDMA), frequency de-multiplexing functions are required to separate different carriers; and, depending on the type of terminals addressed, and the applications that are transported, decoding can also be required on-board to meet the BER requirements.

But the major subsequent capability of those payloads is that once signals are de-spread, demodulated and decoded, ones have access to the layer 2 information, i.e. layer 2 packets, and can proceed to smart enhanced processing: this means switching the packets through a static or quasi-static switching configuration, equivalent to cross-connecting/circuit switching, or through a fully dynamic and real time configuration, usually referred to as *packet switching*. Other functions can also be implemented on-board such as QoS management, by means of buffering and prioritizing packets before transmitting them on the down-link, congestion management through statistical multiplexing, once again by means of buffering and applying specific method for filling and emptying the buffers, packet discards, etc.).

Those kinds of payload offer a high degree of connectivity (since granularity of the information processed is layer 2 packet), contribute to a significant improvement of the satellite resource management, and ease the development of low cost terminals, at the expense of a strong dependence of the actual on-board processing on the layer 2 packet format and on the air interface definition.

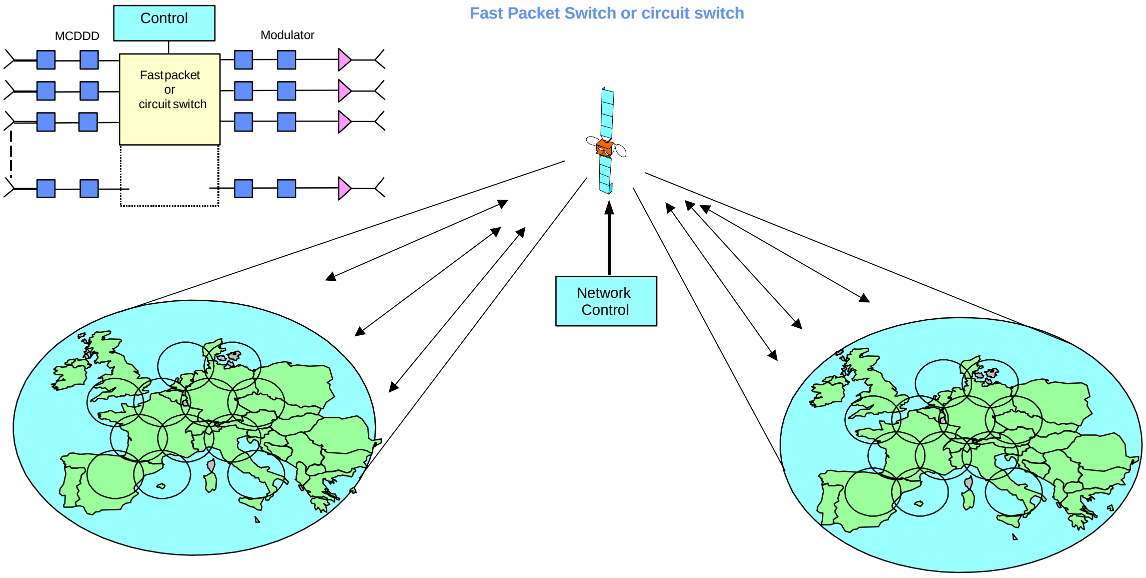


Figure 7.20: Multi-beam full Regenerative satellite

7.2.7.4 Main advantages and drawbacks

Table 7.1 briefly summarizes the advantages and drawbacks of the main types of payload.

Table 7.1: Main types of payloads - advantages and drawbacks

Payload Type	Advantages	Drawbacks
Bent-pipe with wide coverage	High connectivity Robust and reliable technology Friendly to system evolution (i.e. no impact of protocol stack and transmission schemes evolution)	No "routing" capability Link budget restriction
Bent-pipe with multibeam	Downlink improvement (allow very small terminal) Robust and reliable technology Friendly to system evolution (i.e. no impact of protocol stack and transmission schemes evolution)	Low "routing" resolution (beam is the first degree of granularity in connectivity) Few beams interconnected
Transparent OBP with multibeam	Refined connectivity (from several inter-beam till physical channels switching) allowing increase in capacity Friendly to system evolution (i.e. no impact of protocol stack but possibly affected by waveform upgrade)	Possible complexity No data multiplexing on-board
Hybrid Regenerative/Transparent	in the regenerated link Relax link budget Data multiplexing on-board Improved satellite capacity (Data link MUX and spot-beams)	Increased complexity/cost Dependent on transmission schemes
Full regenerative with multibeam	Optimum link budget High degree of connectivity and high "routing" resolution (L2 packet switching associated with multibeam) Enables efficient use of the satellite resource (enhanced bandwidth due to QoS and congestion management)	Increased complexity/cost sensitive technology, not commonly used for commercial missions Dependent on waveform and packet format (until eventual cost-effective Software Radio)

Furthermore mass and power consumption are major issues, which shall be taken into account in selecting a payload solution. However such criteria require in-depth design of the payload based on detailed requirements, which is out of the scope of the present study.

7.2.8 Gateway

In a typical S-UMTS system architecture the Gateway (GW) is interconnected to the Core Network (CN) through the Iu interface. No proprietary network is envisaged in between Radio Access Network (RAN) and CN.

The Node B and RNC are the main UMTS entities gathered in the GW. One shall note that Node Bs - RNC interfacing (i.e. at Iub) requires real-time exchange of information.

The RNC primarily controls the radio resources and the mobile connections (including management of security procedures, e.g. ciphering). It is also involved in the IP flows handling, performing the following functions:

- mapping between IP QoS and UMTS QoS class of service (or CoS);
- support of IP multicast and UDLR mechanisms;
- adaptations to counter-measure satellite environment impact (e.g. IGMP Proxying and TCP Performance Enhancements);
- setting of specific system information parameters.

The Node B converts the data flow between the Iub and Uu interfaces. It manages the power control and Hand-Over together with its RNC.

The GW functional architecture comprises the functions shown in figure 7.21.

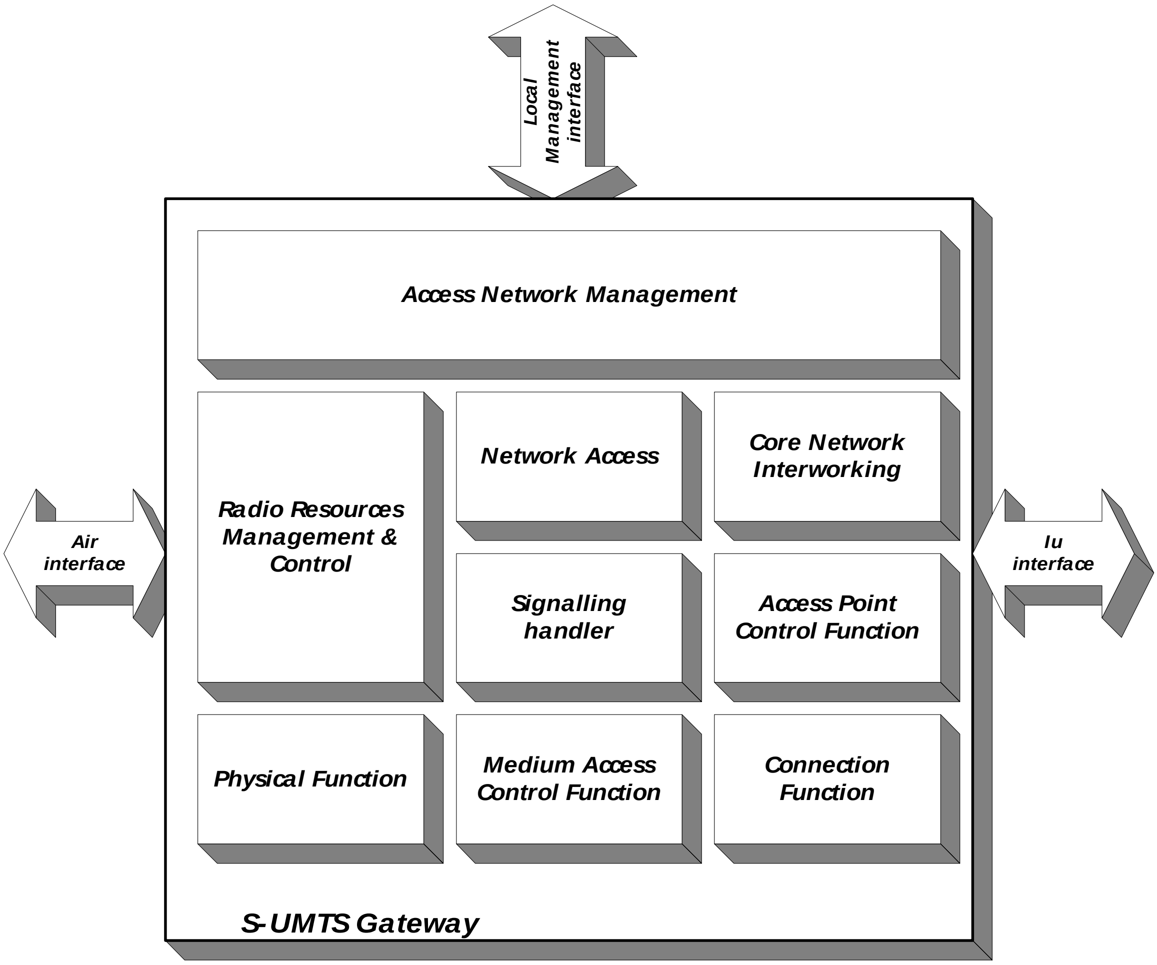


Figure 7.21: gateway functionality

- The physical function, which is responsible for the transmission and the reception of transport channels information flows over the air interface.

- Medium access control, which is responsible for the multiplexing/de-multiplexing of transport channels and mapping to the physical radio resources for both traffic and signalling information flows. It also performs monitoring of the radio resource.

- Radio resource management and control, which establishes, maintains and release radio link connections consisting of transport channels/physical channels.

Access point control function that controls the end-to-end radio connection between the Iu interface (GW/CN) and the corresponding internal interface in the User Equipment. It interacts with the connection function and the radio resource management and control for the configuration, set-up and release of the radio connections.

Network access which controls the access of Mobile Stations to the S-UMTS system with registration and authentication as well as de-registration procedures.

- Core network inter-working function which controls the required data and protocol adaptation between the S-UMTS access domain and the CN domain (e.g. inter-working of specific S-UMTS positioning update procedure and CN location update procedure).

- Access network management, which manages the S-UMTS system components of the GW, the S-UMTS radio resources and the end user's connections.

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 commonalties 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 ITU-T Recommendation H.1455 [41], 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); [30], [31], [32],[33];
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 Standardization 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 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.
- Duplexing mode.

Table 8.1: Orbit characteristics overview

Characteristics	GSO	HEO	MEO	LEO	Remarks
Propagation delay [ms]	280	200 to 310	80 to 120	20 to 60	maximum
Satellite handover during call	Unlikely	every 4 to 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 to 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 to 12	10 to 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 dB 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 dB to 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 dB to 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 removing 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 might be preferable. Some form of satellite diversity exploitation with TDMA is also possible in principle but is not elaborated in the following discussion.

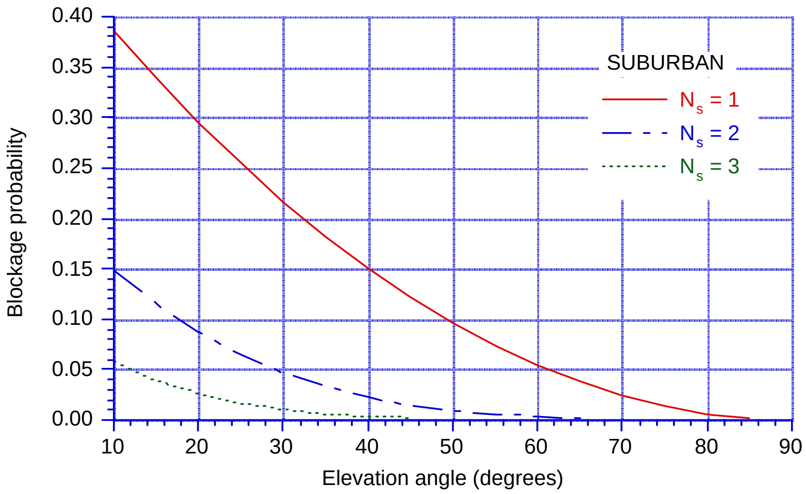


Figure 8.1: Path blockage probability in a suburban area, with the number of satellites (Ns) above the minimum elevation angle as a parameter [11]

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 the previous clause, 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 (trackable) 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.

8.1.2.5 Duplexing mode impact

In the following, we consider the impact of FDD, TDD and F/TDD duplexing modes in a third generation mobile satellite scenario.

8.1.2.5.1 Spectrum allocation

In Europe the spectrum allocation for MSSs including S-UMTS is (prior to WRC 2000):

- 1 980 MHz/2 010 MHz (uplink); and
- 2 170 MHz/2 200 MHz (downlink).

This symmetric frequency allocation strongly impacts on the choice of the duplexing mode. The envisaged possibilities are hereafter reported.

- **FDD:** standard approach, which motivated the above spectrum allocation.
- **TDD:** use of the paired bands in TDD mode would be in conflict with the hard allocation of frequencies to downlink in 2 170 MHz to 2 200 MHz and uplink in 1 980 MHz to 2 010 MHz. Studies on the compatibility of an uplink allocation in 2 170 MHz to 2 200 MHz and of a downlink allocation in 1 980 MHz to 2 010 MHz would be required, and, provided they are successful, an action in a WRC conference would be necessary to introduce TDD. Today, the only part of MSS spectrum allocated both in the space-to-Earth and Earth-to-space directions is 1 613,8 MHz/1 626,5 MHz (primary allocation in the uplink, secondary allocation in the downlink). Part of the band is used by Iridium which uses the TDD mode.
- **F/TDD:** same requirements as for TDD.

In the case whereby the spectrum once allocated to Iridium is re-farmed, then a portion of unpaired spectrum would become immediately available for MSSs.

8.1.2.5.2 Asymmetric traffic handling

Asymmetric traffic occurs when the traffic volume sent in one direction (normally the downlink) is much larger than the volume sent in the other (normally the uplink) direction. Handling such asymmetry is a crucial point for S-UMTS to avoid spectrum usage inefficiencies. Examples of asymmetric traffic sources are file download services, web browsing services, multicasting and broadcasting services, etc. However note that in the case of multicasting that represent one of the main targets of S-UMTS systems, the degree of the aggregate traffic asymmetry is significantly reduced with respect to that of a single browsing session. This mitigates the necessity for strongly unbalanced resource allocation between forward and return links.

- **FDD** spectrum allocation is normally designed for symmetric traffic. In principle, asymmetric traffic can be accommodated with FDD if more bandwidth is allocated to, e.g. the downlink. However, this asymmetric spectrum allocation is rigid and may again become inefficient if it does not match the aggregate traffic asymmetry. Note also that the required frequency separation between forward and return links inhibits the possibility to use part of the up link spectrum to enhance the down link capacity.
- **TDD** is generally claimed to be very well suited for asymmetric traffic handling. However, this statement needs to be qualified. In a single user scenario, TDD can easily accommodate different levels of traffic asymmetry by appropriately changing the ratio between the number of downlink and uplink time slots within a frame. Note that even in this case, this ratio is limited by the number of time slots in a frame minus one. More importantly, in multi-user multi-beam scenario this flexibility is dramatically reduced, if not even eliminated, by the following constraints.
- The switching point for all the traffic flows through a given transponder, frequency and beam must be unique. Unfortunately, different users generally need different asymmetry ratios.
- Due to imperfect inter-beam isolation, to avoid system damage the switching point pertaining to different beams is forced to be the same for a given carrier frequency. It is worthwhile noting that in a terrestrial environment this constraint, referring to adjacent cells, is only slightly relaxed. As a matter of fact, to avoid severe capacity reduction due to MT->MT and BS->BS interference, the switching point in adjacent cells must be synchronized. Unfortunately, this requirement propagates from cell to adjacent cell and in turn constrains all the TDD isle to operate with the same level of asymmetry between forward and return links.
- Due to adjacent channel interference, the use of different switching points in systems operating in adjacent frequency bands should be carefully avoided to prevent capacity reduction.
- **F/TDD:** same as for FDD.

8.1.2.5.3 Asynchronous traffic management

In the return link, asynchronous traffic occurs whenever a MT tries to access the BS without being time aligned to the return link frame structure. Initial access at start-up, connection restoring procedures, transmission of data packets in connectionless mode are all examples of asynchronous traffic generation.

- **FDD:** due to the asynchronous characteristic of the RL, no special care should be taken to handle asynchronous traffic. Special codes are reserved for initial access.
- **TDD:** due to the frame-synchronous characteristics of the return link, asynchronous traffic should be appropriately handled. To this end, special slots may be reserved within each frame for asynchronous access. This hard reservation reduces the system capacity. Moreover, note that the asynchronous traffic management for a TDD satellite system is more complex than for a terrestrial system. In fact, due to the generally larger coverage area in a satellite environment, a MT accessing the time frame without radio connection may reach the satellite with large time misalignment.
- **F/TDD mode:** same as for TDD.

8.1.2.5.4 On Board Processing

- **FDD:** both regenerative and transparent payload solutions are possible.
- **TDD:** a purely transparent payload is not feasible, since the satellite must know at least the switching point of the incoming traffic.
- **F/TDD:** as for FDD.

8.1.2.5.5 Channel Reciprocity

- **FDD**: channel reciprocity is weak, open loop power control is scarcely efficient.
- **TDD:** one of the major claims for systems operating in TDD mode is that they can exploit channel reciprocity to implement signal pre-distortion, antenna pre-selection and efficient open loop power control. However it has to be underlined that:
  - The application of these techniques is possible only if the channel coherence time is large with respect to the time elapsing between transmission and reception. Figure 8.1 reports the channel coherence time as a function of the MT speed for the forward and return links operating at 2,0 GHz and 2,2 GHz, respectively. Now three cases are possible.
  - Channel estimation is performed at the MT. In this case, the time that elapses between the two-way passage across the distorting effects is small (comparable to that for a terrestrial system), and open-loop power control is effective.
  - Channel estimation is performed on-board. Then the elapsed time is half the round-trip delay, which is a large quantity with respect to the coherence time except for low mobile speeds.
  - Channel estimation is performed at the FES. Then the elapsed time is the round-trip delay, which is a very large quantity with respect to the coherence time except for very low mobile speeds.

Antenna pre-selection is not feasible in satellite systems.

- **F/TDD mode:** same as for FDD.

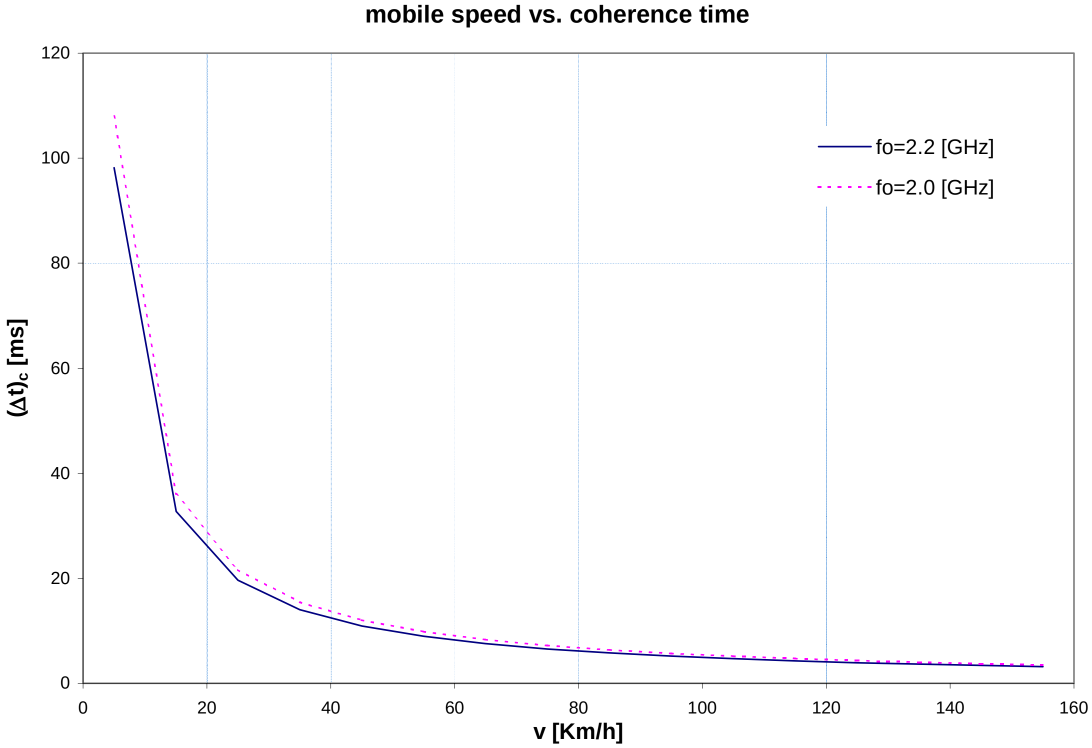


Figure 8.2: Channel coherence time as a function of the MT speed in Km/h

8.1.2.5.6 Delay variation

The end-to-end delay t_d is not fixed for satellite systems employing satellites in LEO and MEO orbits. The satellite motion with respect to the ground results in the time variation of the slant range (the distance between the mobile terminal and the satellite).

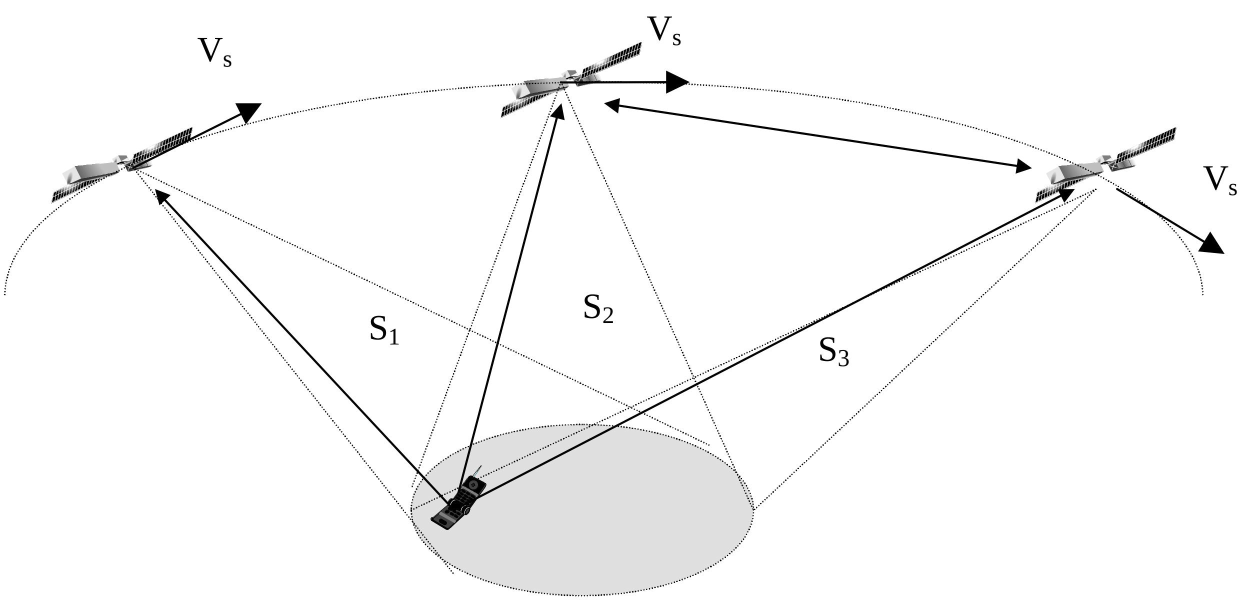


Figure 8.3: Slant Range/Delay Variation

The propagation time delay drift is:

$$t_{dr} = \frac{dt_d}{dt} = \frac{dS}{dt}\frac{1}{c}$$

The following values of delay drift correspond to the different types of constellations:

Table 8.2: Delay drift

Constellation	Delay Drift
LEO	18,3 μs/s
MEO	5,2 μs/s
GEO	0

- **FDD**: the delay drift does not involve any special attention.
- **TDD**: The delay drift causes a displacement of the position of a burst in the frame. Therefore it contributes to the amount of guard time needed between successive timeslots.
- **F/TDD**: same as for TDD.

8.1.2.5.7 End to End delay

The end-to-end delay is not affected by the duplexing scheme if we assume that in TDD higher bit rates (and power) are used to transmit all the information over the half of the frame that is used for a FDD transmission and that the total amount of spectrum is the same in both cases.

8.1.2.5.8 Interference Aspects in different duplex modes

The comparison and evaluation of the duplexing methods reveals some interference problems to be handled when TDD schemes are used.

8.1.2.5.8.1 Interference From TDD Power Pulsing

If fast power control frequency with open loop is desired to support higher Doppler shifts, then short TDD frames must be used. The short transmission time in each direction results in the problems listed below:

Audible interference from pulsed transmission both internally in the terminal and to the other equipment. Generated pulsing frequency in the middle of voice band will cause problems to small size speech terminal design where audio and transmission circuits are relatively close to each other and achieving the needed isolation is costly and requires design considerations. At high power levels this may not be achievable at all.

Base station synchronization requirements are tight and more overhead must be allocated for guard times and also for power ramps as EMC requirements limit the ramping speed.

Fast ramping times set tighter requirements to the components (e.g. to the power amplifier).

Lower pulsing frequency, say, 100 Hz (i.e. a TDD frame of l0 ms), results in less audible pulsing but limits the maximum tolerable Doppler shifts. In the TDD-WCDMA of T-UMTS the uplink slot and the downlink slot are both 0,666 ms, resulting in an audible interference at 750 Hz.

8.1.2.5.8.2 Intracell Interference Between Uplink and Downlink

In CDMA systems, the SIR may be quite low (e.g. below -15 dB) at carrier bandwidth. After despreading, the SIR is improved by the processing gain. In TDD systems, a transmitter located close to a receiver may block the front end of the receiver, since no RF filter can be used to separate uplink and downlink transmission as in FDD operation. This blocking may happen even if the transmitter and receiver are not operating in the same frequency channel but if they are operating in the same TDD band. In that case, the processing gain at baseband does not help since the signal is already blocked before baseband processing. Within one TDD-CDMA cell, all users must be synchronized and have the same time division between uplink and downlink in order to avoid interference between uplink and downlink. This time division is based on the average uplink and downlink capacity need in that particular cell. Each user then applies multirate techniques to adapt its uplink and downlink capacity needs to the average need in that cell. The same time division must be applied to all carriers within one base station. If the base station transmits and receives at the same time at adjacent carriers, it would block its own reception.

8.1.2.5.8.3 Intercell interference due to asymmetry in Uplink/Dowlink

Intercell interference problems occur in asymmetric TDD-CDMA if the asymmetry is different in adjacent cells even if the base stations are synchronized. MS2 is transmitting at full power at the cell border. Since MS 1 has different asymmetric slot allocation than MS2, its downlink slots received at the sensitivity limit are interfered by MS1, causing blocking. On the other hand, since BS 1 can have much higher effective isotropically radiated power (EIRP) than MS2, it will interfere with BS2 receiving from MS2. It is difficult to adjust the asymmetry of an individual cell in a network due to interference between adjacent cells. If TDD-CDMA cells are located adjacent to each other, offering a continuous coverage, then synchronization and asymmetry coordination between these cells is required. This ensures that the near-far problems of interference between mobiles in adjacent cells can be controlled.

This type of interference is typical for T-UMTS networks. For S-UMTS networks the problem is less difficult since the near-far effect is not as severe due to the limited link margin and line-of-sight operational conditions. Moreover the problem of accurate synchronization of Node Bs is easily solved in a S-UMTS system.

8.1.2.5.9 Implementation Issues

From an implementation point of view, FDD systems require two synthesizers on transmitter and receiver side due to simultaneous operation. In addition a tight duplex filter must be used to prevent transmitter signal leaking to receiver side. In contrast to TDD systems a single synthesizer and no expensive duplex filter is needed since the terminal equipment is not transmitting/receiving simultaneously. Furthermore on the baseband processing side there are few physical resources that could be shared between the transmitter and receiver. A good example is the DS-CDMA code generators for which polynomials and states are reloaded upon Tx/Rx switching. In addition the multipath channel estimation could be made easier due to channel reciprocity. If Pre-RAKE is utilized in uplink, simple TDD Node Bs could be built. This will be the case of dual FDD/TDD terminals, since UE will already have RAKE receiver due to FDD operation. Therefore simple TDD Node Bs with no RAKE receivers are needed. Moreover multiuser detections algorithms at Node Bs would be simpler if there is only one multipath component per user to be treeked.

8.1.2.5.10 Modem configuration

8.1.2.5.10.1 Duplexer

- **FDD:** duplexers are needed to achieve the required tx and rx frequency separation. In a satellite receiver, high quality (low loss => large size) duplexers are desirable to achieve a large G/T ratio for the given required frequency separation. However, in a MT the duplexer size is heavily constrained so that one may have to live with a low G/T. Thus, provided that the satellite e.i.r.p. is large enough to allow link budget closure, a smaller duplexer can be adopted at the MT side. Note that for some experimental SW-CDMA implementation, it is envisaged to use a duplexer of the same size of those used in terrestrial terminals yielding a G/T ratio in the order of -26 dB/K.

- **TDD:** no duplexer is needed. A switch that is smaller than the duplexer and has less insertion loss can be used. However, an input/output selective RF filter must obviously be implemented anyhow, with its own insertion loss. It is worthwhile noting that it is highly probable that W-CDMA will be the most diffuse T-UMTS interface. In this case, dual mode terminals (terrestrial/satellite) will encompass in any case a duplexer for the terrestrial component, which can in principle also be used for S-UMTS, being the bands adjacent. Thus this particular benefit of the TDD approach is reduced.

- **F/TDD:** same as for FDD at the satellite side. At the MT side, due to the time orthogonality of transmitting and receiving periods, lower quality duplexers can be used. In this case the duplexer size is traded-off against frequency separation and not G/T.

8.1.2.5.10.2 Guard Time

- **FDD:** no guard times are needed for downlink channels and dedicated uplink channels For uplink common channels, which are time shared, guard times are needed to separate users. Evaluation of guard time is as for TDD.

- **TDD:** guard times are needed to separate the uplink and downlink time slots and to prevent the generation of MT->MT and BS->BS interference. Evaluation of guard time is as follows.

- Let us assume User #1 is at a distance D1 from the satellite and user #2 is at a distance D2 from the satellite. The distance between them is D. They both use the same carrier frequency (different spreading codes) and the aim is to have their uplink signals aligned at the satellite receiver. Since user #1 is further away from the satellite, he will start transmitting the uplink slots with a timing advance with respect to user #2.

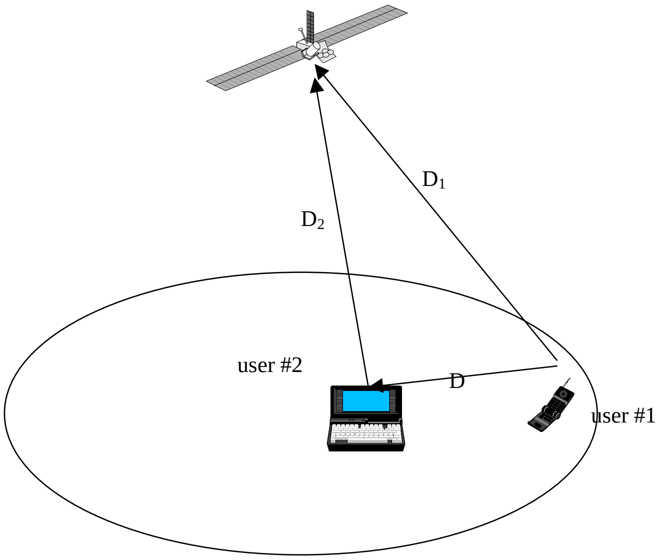


Figure 8.4: multi-user transmission/reception

In figure 8.4, the frame transmission of each user is illustrated. The total duration of the uplink slots is T_u and of the downlink slots is T_d. The guard period between the uplink and downlink slots is t_{gp}. User #1 starts transmission with a timing advance t_a with respect to user #2.

The transmitted signal of user #1 is received at the correct time by the satellite. This can also be received by user #2, if the antennas used for the user equipment are omnidirectional and do not have an antenna pattern directive towards the satellite. However, due to transmitting time difference, user #2 will be also in the transmit mode when the signal from user #1 reaches his location.

On the other hand, it is possible that the transmitted signal by user #2 will reach (after time t) user #1 when he is in the receive mode. That will cause MT->MT interference.

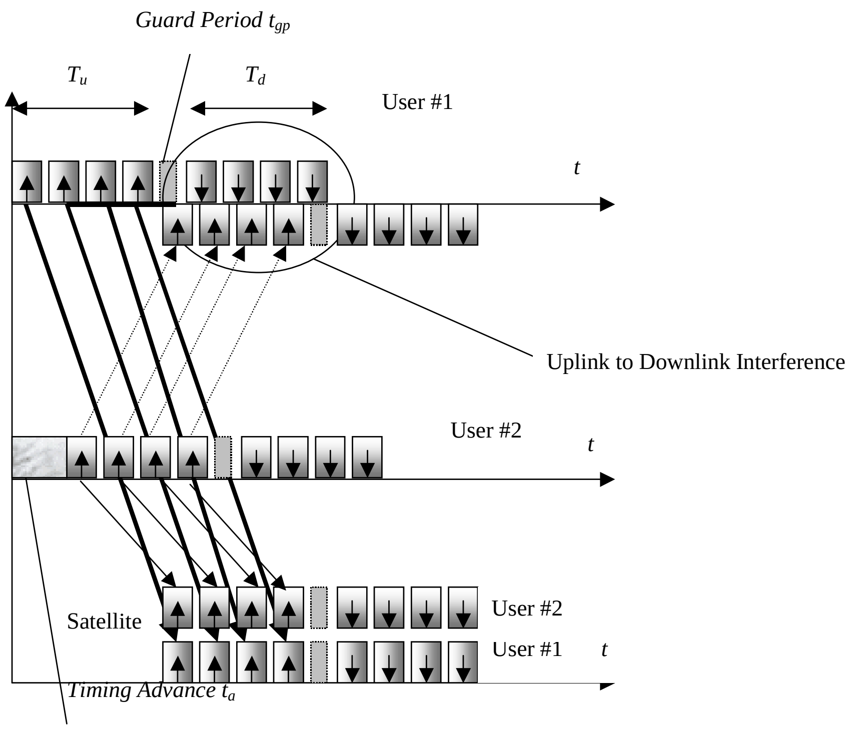


Figure 8.5: Uplink/Downlink Other user interference scenario

To avoid the interference from user #2 uplink to user #1 downlink, the following condition should apply:

$$t_a + t \leq t_{gp}$$

where t represents the propagation time between user #1 and user #2 locations, i.e. D/c. Since the timing advance is equal to the propagation delay difference between the two users and the satellite, the previous expression can be modified.

$$t_{gp} \geq \frac{D_1 - D_2 + D}{c}$$

where c is the velocity of light.

The optimum guard period should correspond to the case where user #1 is on the edge of the spot beam and user #2 is on the sub-satellite point.

Therefore, we have:

$$t_{gp.opt} = \frac{D_{\max} - D_{\min} + R}{c}$$

where R is the spot beam radius.

Table 8.3: Spot-beam and guard period comparison

Constellation	Height (km)	Spot beam radius (km)	Guard period (TDD) (ms)
LEO	1 410	628	1,93
MEO	10 355	668	2,29
GEO	35 786	496	2,11

Table 8.2 lists some examples spot beam characteristics and the required guard period for the different constellations.

Based on the aforementioned points, an efficiency calculation will be done for TDD over satellite. The main criterion will be the frame efficiency, meaning the amount of required overhead per frame that is dictated by the use of TDD.

All three different constellation types will be evaluated. For each constellation two cases will be considered: transparent (bent-pipe) and regenerative (with on board processing, including Doppler pre-compensation).

Table 8.4: Frame Efficiency comparison

	Doppler Shift (kHz)	Delay Drift (µs/s)	Required timeslot separation (µs)	Required Guard Period (ms)	% Frame Overhead (omnidir. antenna terminals)	% Frame Overhead (directive antenna terminals)
TDD GEO (bent pipe)	0	0	25	2,11	25 %	3,75 %
TDD GEO (OBP)	0	0	25	2,11	25 %	3,75 %
TDD MEO (bent pipe)	20	10	50	2,29	30 %	7,5 %
TDD MEO (OBP)	10	5	25	2,29	26 %	3,75 %
TDD LEO (bent pipe)	72	36	180	1,93	46 %	27 %
TDD LEO (OBP)	36	18	90	1,93	33 %	13,5 %

The frame overhead is the total frame duration required to separate 15 time slots taking into consideration the delay drift. If the mobile terminals use omni antennas, then there is also the need for a guard time separation between the uplink and downlink parts, which should be added to the total overhead. The percentage of overhead is calculated based on the assumption that the frame duration will be 10 ms.

The required timeslot separation was calculated based on the assumption that the burst position in the frame should be corrected at intervals of 5 sec (synchronization interval).

From the above table it is evident that the relative motion of MEO and LEO satellites leads to the requirement of a significant portion of the frame for synchronization and guard time separation. This overhead requirement can be decreased if on board processing is used (with Doppler precompensation) and if the required synchronization interval is further reduced.

Clearly GEO systems seem to waste less resource for synchronization, and as such are more amenable to the use of TDD.

- **F/TDD:** much less stringent requirements than for TDD.

8.1.2.5.10.3 Peak to average power ratio

- **FDD:** for a given received energy target, low peak to average power ratios are possible.
- **TDD:** for a given received energy target, a slotted transmission requires a larger peak to average power ratio than for FDD.
- **F/TDD**: same as for TDD.

8.1.2.5.10.4 Channel estimation

- **FDD:** the continuous transmission of dedicated channels eases channel estimation.
- **TDD:** due to the slotted structure of the transmission, channel estimation is not an easy task. Channel estimates must be interpolated between the transmission slots.
- **F/TDD:** same as for TDD.

8.1.2.5.10.5 Multi-user detection

- **FDD:** due to the large number of used codes, multiuser detection is a complex task; however continuous transmission eases the channel estimation procedure needed by adaptive interference cancellation.
- **TDD:** due to the small number of used codes, multiuser detection is a simpler task; however burst transmission complicates the channel estimation procedure needed for adaptive interference cancellation.
- **F/TDD:** same as for TDD.

8.1.2.5.10.6 Modem chain reuse

- **FDD:** since transmission and reception are simultaneous no circuit reuse can be adopted.
- **TDD:** since the radio frequency and modem parts of both the transmit and receive chains are operating on the same frequency but at different times, certain elements for both chains such as filters, mixers, frequency sources, and synthesizers may be possibly reused.
- **F/TDD**: same as for FDD at BS side; at the MT side, only some base band transceiver circuits can be reused thanks to the time orthogonality.

8.1.2.6 Synchronization issues

8.1.2.6.1 Inter-beam synchronization

- **FDD:** forward link frame synchronization among beams is not necessary. It can be introduced to reduce interference and/or simplify interference cancellation.
- **TDD:** due to imperfect inter-beam isolation, the forward and reverse traffic flows through different beams using the same frequency must be frame synchronous and have to use the same switching point to avoid system damage.
- **F/TDD:** as for FDD. However inter-beam synchronization has been proposed to simplify inter-beam handover of MTs.

8.1.2.6.2 Intra-beam reverse link frame synchronization

- **FDD:** no reverse link frame synchronization reference needed for dedicated channels. For common channels, which are time shared, time synchronization reference is required. See TDD.
- **TDD:** a time synchronization reference is needed to realize a frame-synchronous return link. In satellite environments, time/frequency references are given with respect to the beam centre. BSs broadcast satellite positions and velocities to MTs. In order to compensate for the time/frequency residual, due to MTs displacement with respect to the beam centre, dedicated time/frequency controls must be sent to the MTs.
- **F/TDD:** same as for TDD.

8.1.2.6.3 Code synchronization: tracking

- **FDD**: the pilot signal can be used for efficiently tracking the code epoch.
- **TDD:** due to the burst nature of transmission, tracking can become a difficult task. In particular tracking loops may lose lock during transmitting periods.
- **F/TDD:** same as for TDD.

8.1.2.7 Interworking

Future S-UMTS satellite systems will be required to interwork with their terrestrial-based counterparts (i.e. mobile stations, mobile terminals, gateways). This implies interworking at the level of supported services, network protocols, and clearly the mode of operation (i.e. TDD/FDD). This clause mainly concentrates on the mode of operation.

8.1.2.7.1 Interworking between Terrestrial and Satellite systems

It should be expected that a good part of the success or failure of S-UMTS will depend on its capacity to efficiently integrate with the T-UMTS system. This consideration strongly impacts on the selection between the FDD or TDD approaches in that, from a physical layer point of view, full integration with T-UMTS translates in the necessity of strong commonality between satellite and terrestrial radio interfaces. In particular, it is a widespread opinion that T-UMTS will be mainly based, at least for the first few years after its roll-out, on the W-CDMA (FDD) radio interface. Therefore, future multi-mode (terrestrial/satellite) terminals will encompass, in any way, the FDD interface. Note that dual mode terminals are mandatory when connection to the core network (MT->BS) occurs through the terrestrial RAN in the baseline system configuration.

- **FDD:** high level of commonality with terrestrial systems.
- **TDD:** reduced level of commonality with terrestrial system at least in the first phase after deployment. In the above framework, choosing the TDD mode for the UMTS satellite component will not only have a small advantage in terms of duplexer simplification, but it may even produce an increase in the complexity of dual mode terminals.
- **F/TDD:** reduced level of commonality.

8.1.2.7.2 Inter-Operator Interference Considerations

If there are several operators offering the service in the same geographical area in the TDD band, base station synchronization for the different operators is required and asymmetry flexibility between uplink and downlink becomes considerably more difficult. Asymmetric TDD-CDMA systems are therefore not well suited if several operators share the spectrum and the same area. In those cases, TDD-TDMA systems are better off since the signal is concentrated in the time domain. In TDD-TDMA, interference can be averaged with time hopping or avoided with dynamic channel allocation techniques not applicable in CDMA systems. A difficult problem for operation in an unlicensed band is the case where different operators use different multiple access techniques in the same TDD band.

Adjacent channel interference between operators may also cause problems. As the terminals have limited dynamic range and neighbouring channel filtering capability, adjacent channel interference in this kind of uncoordinated operation may prove to be *very* severe. The power differences between the transmission of the desired base station and the interfering mobile transmitting at the same time as adjacent carriers can block the receiver terminal's A/D converters and can also cause problems in the RF components.

8.1.2.8 Terminal implementation considerations

Eventually add this clause in the terminal clause or put a reference to this clause.

At this moment, a limited set of physical layer specifications are produced by the ETSI SES S-UMTS WG. Unfortunately, they only deal with an FDD mode for S-UMTS, which follows closely the terrestrial UMTS/FDD. Therefore, initial comparison of TDD and FDD mode for the satellite component will be based on the existing specifications of both modes of T-UMTS and an evaluation of the differences and similarities between the physical layers of satellite and terrestrial FDD.

TDD and FDD modes of T-UMTS are harmonized which each other as much as possible to facilitate the reuse of physical layer hardware and software.

Because higher layers will be implemented completely in software, related complexity issues results in different processing power demands for the on-board micro-controller system together with different power consumption rates. Their characteristics are more closely related to the UMTS network aspects and will not be further investigated in the present document.

8.1.2.8.1 RF front-end and antenna

Some issues related to RF front end are:

- In TDD mode, no duplexer is needed to separate uplink and downlink as it is the case in FDD.
- Due to the bursty nature of TDD transmissions, a higher amount of electromagnetic interference has to be expected.

- The RF module of a terminal, existing for almost 100 % of analogue technology, is the most difficult part to introduce the reuse of hardware.
- A rather new technology called direct conversion or zero-IF enables the elimination of the intermediate frequency stage and the related filtering. This technology eases the implementation of multi-standard terminals by means of a significant reduction of the required hardware in the RF frontend.

8.1.2.8.2 Inner modem

The following parameters are identical for both TDD and FDD modes:

- Channel spacing: 5 MHz.
- Chipping rate: 3,84 Mcps.
- Frame length: 10 ms.
- Frame structure: 15 timeslots/frame.
- Downlink modulation: QPSK.
- Pulse shaping filter: rooted raised cosine (RRC) with roll-off equal to 0,22.
- Channelization codes: real orthogonal variable spreading codes (OVSF).

The following parameters are fundamentally different in TDD mode:

- Duplexing method: time division duplex

  Due to the time-multiplexing of transmitter and receiver activities some hardware blocks could be reused (e.g. pulse shaping filter, code generators, NCO). However, if the TDD mode is implemented together with FDD in a multi-standard terminal, these hardware blocks have still to be implemented for both the transmitter and receiver.

- Multiple access scheme: CDMA, TDMA and FDMA

  Compared to the FDD mode, TDD uses a supplementary dimension to map transport channels onto physical channels, namely time division multiple access (TDMA). This adds additional complexity to the mapping hardware and software.

- Multirate scheme: OVSF, multicode and multislot

  The additional TDMA component requires more flexibility from both the hardware and the software.

- Uplink modulation: QPSK

  Besides the additional flexibility, this implies no complexity increase.

- Channel estimation: based on midamble training sequences

  Instead of a pilot channel or pilot symbols, a training sequence is used to estimation channel distortion. Although the training sequence generator can be time-multiplexed by the transmitter and receiver, the related hardware implies a considerable amount of complexity increase especially when TDD is implemented together with FDD.

- Power control: 100 Hz open loop in uplink; 100 Hz to max. 750 Hz closed loop in downlink

  The slower power control mechanism will need a higher link margin to combat fading, resulting in higher power consumption rates at the terminal.

- Spreading factor: 1, 2, 4, 8, 16 for uplink and 1 or 16 for downlink

  Extra low spreading factors (1 and 2) are typical for TDD mode operation and have to be supported by the hardware. However, no significant complexity increase must be expected.

- Scrambling codes: source specific 16 chips long complex PN-sequences

  These codes are much shorter than the scrambling codes used for FDD. Although base-stations are frame-synchronized in TDD mode, intercell or interbeam interference must be taken into account when choosing an appropriate data detection algorithm. Knowing the fact that the conventional RAKE receiver is highly interference limited, possibly more sophisticated detection algorithms like multi-user detection or antenna arrays will be necessary to assure sufficient network capacity. However, these advanced receiver algorithms will cause a severe increase of terminal complexity. Fortunately, the use of short scrambling codes makes such an implementation still feasible. Thorough simulation should prove the necessity of such advanced receivers for TDD.

8.1.2.8.3 Outer modem

This clause will give an overview of the differences in implementation between FDD and TDD mode for the outer modem.

For both uplink and downlink, the second interleaving must be expanded from frame interleaving to frame and timeslot related interleaving. The physical channel mapping and demapping will be put in additional hardware blocks because of the large differences with FDD.

Accept these additional hardware, the uplink data flow does not change. Rate matching can be adapted to TDD by reconfiguring the set of data with the software.

At downlink side, the modules rate matching, first de-interleaving and radio frame recombination are handled in a different sequence and radio frame de-equalization must be added. For rate matching, the same algorithm as in uplink rate matching is used. The sequence of the data flow can be changed by reconfiguration of the data path. The impact of the T-UMTS air interface

UMTS terminals supporting the satellite component will only be a commercial success when the terrestrial component is also available by the same phone. Knowing this, the terrestrial air-interface will have a big impact on the appropriate choice for the satellite component. We can now already say that UMTS/FDD, perhaps better known as WCDMA, is worldwide the most accepted standard for the first 3G terrestrial networks. Main reasons for this are the worldwide availability of the same spectrum for WCDMA (except USA) and the higher bandwidth available compared to the TDD spectrum (2x60 MHz for FDD, 35 MHz for TDD)

This clause summarizes the influence of the terrestrial air interface on the terminal characteristics. The following assumptions have been taken into account:

- To ensure the availability of the allocated spectrum for mobile satellite systems (MSS), a quick deployment of S-UMTS is necessary. This means that the initial situation of the T-UMTS market will have a big impact on the S-UMTS deployment.

- In the initial phase of T-UMTS, WCDMA alias T-UMTS/FDD will be the most accepted air-interface.

- Unless for indoor and private applications, T-UMTS/TDD will probably be used to extend the capacity of the existing T-UMTS/FDD network. Therefore, access to the TDD network will most likely be offered by multi-mode terminals together with WCDMA.

- Abstraction was made of the fact that in the first introduction of UMTS, 3G-terminals will still offer access to 2G networks like GSM and GPRS. For the present document, only the coexistence of satellite and terrestrial modes of UMTS are investigated.

- Assumption was made that only one air-interface (TDD or FDD) will offer satellite services for UMTS.

The first two columns of the following tables indicate the possible duplexing mode combinations. The third column gives an indication of the reusability of the terminal hardware based upon the chosen duplexing modes. The fourth column gives a idea on the expected market opportunities during initial deployment of the UMTS. These are mainly based on the T-UMTS duplexing mode and/or on the capability of the terminal to support multiple access networks. In the last column a comparative indication of expected retail price is given based on both the reusability and the addressable market size.

Single mode terminal:

Table 8.5: Single-mode terminal complexity

Terrestrial mode	Satellite mode	Reusability	Initial market opportunities	Retail price
not applicable	FDD	not applicable	Niche market	very high
not applicable	TDD	not applicable	Niche market	very high

On the consumer market, access to the S-UMTS network will be seen as an optional feature extending the capabilities of your mobile phone and it will be difficult to convince people that they need to carry a secondary terminal for this. Therefore, single-mode S-UMTS terminals are banned to niche-markets like maritime and aeronautical applications.

2-mode terminals:

Table 8.6: Dual-mode terminal complexity

Terrestrial mode	Satellite mode	Reusability	Initial market opportunities	Retail price
FDD	FDD	High	Mass market	Low
TDD	FDD	Low	Small	High
FDD	TDD	Low	Mass market	Medium
TDD	TDD	High	Small	High

An efficient multi-standard terminal supporting both terrestrial and satellite components will only be achievable when there are as much as possible similarities between both specifications. In other words, both air interfaces should preferably be based on the same duplexing method.

Besides the complexity of the terminal, the market size will dictate the production costs. Therefore, the FDD option has the best chance to allow the production of low-cost satellite-mode supporting terminals that can be sold to the users of WCDMA networks around the world.

Note that the T-UMTS/TDD specification will probably demand more modifications to be suited for the satellite component due to the high impact of the longer propagation delay on a TDD link (e.g. longer guard periods will be necessary).

3-mode terminals:

Table 8.7: Triple-mode terminal complexity

Terrestrial mode	Satellite mode	Reusability	Initial market opportunities	Retail price
FDD + TDD	FDD	High	Mass market	Medium
FDD + TDD	TDD	High	Mass market	Medium

T-UMTS/TDD will possibly be largely exploited in a later phase to enhance the capacity of the UMTS network. TDD can also offer more flexibility when new spectra has to be allocated due to the unpaired nature of the required band. Therefore, once the UMTS network has reached its mature phase, terminals will offer both modes as it is the case with today's dual-band GSMs at slightly higher prices. Although, the late introduction of TDD could temper the success of a TDD-based S-UMTS network.

8.1.2.9 Recommendations

From the previous discussion, it appears that the selection of the duplexing technique constitutes a rather difficult decision. There are a number of aspects to be taken into consideration, and for each aspect there are advantages and disadvantages for any technique. However, it may be appropriate to critically review some of the claims usually put forth to sustain the TDD cause, with reference to the satellite application at hand.

- *Claim: TDD allows significant terminal size reduction*

  It is obviously true that for TDD a frequency duplexer is not needed; however to limit adjacent band interference, a high quality RF filter (with its insertion loss) is still a necessity. Furthermore, for FDD duplexers of the same size of the ones used in T-UMTS terminals may be used in S-UMTS terminals provided that the satellite e.i.r.p. is sufficiently large to compensate for the low G/T figure yielded by these duplexers. For the sake of fairness, it should be added that some circuit reuse is possible for TDD and that the CPU never operates simultaneously over forward and reverse link bursts, thus saving battery power.

- *Claim: TDD handles efficiently asymmetric traffic*

  First of all, it is not possible to accommodate the asymmetric traffic requirements of every single user, but only those of the aggregate traffic, which in general is less unbalanced (in particular for multicast services). Secondly, even considering the aggregate traffic, it should be clear that in a multibeam scenario the necessary degree of intra and inter beam switching point synchronization will largely reduce the flexibility of TDD.

- *Claim: TDD efficiently exploits channel reciprocity*

  Unfortunately, at the FES and on-board the satellite, channel reciprocity is spoiled by the fact that the propagation delay is large with respect to the channel coherence time. Channel reciprocity may be exploited at the MT.

These facts certainly do not rule out the TDD option, but somewhat reduce its appeal at least for the satellite scenario.

In the end, we strongly believe that the most relevant issues in selecting the duplexing mode are the following:

- Spectrum allocation.
- Opportunity of exploiting commonalities with T-UMTS.
- Flexibility in adapting to ever-changing market and traffic scenarios.

Given that - at least in the first years of UMTS operation, FDD will be the standard mode, the second point, in addition to the first point on spectrum allocation, strongly privileges the latter over TDD.

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 8.2.2.

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. Some future uses of the USIM to enhance S-UMTS terminal performance are summarized, with comments, in tables 8.8 and 8.9.

8.2.1 Analysis of USIM and S-UMTS requirements

At the time of writing this report some 3rd Generation USIM details were yet to be specified. However, an initial analysis of the TS 131.102 [5] entitled "Characteristics of the USIM Application" has revealed that certain S-UMTS parameters should be added to the proposed USIM. The results from this analysis are shown in tables 8.8 and 8.9. 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 8.8 and 8.9, a letter after the EF name has the following meaning:

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 8.8: 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 8.9: 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. 1 Byte.	Needs to be added to 3GPP specification.
Operational Mode **n)**	Mode: TO = Terrestrial Only, TP = Terr. Preferred, SO = Satellite Only, SP = Satellite Preferred. 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 in the present document). 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 §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 Q.o.S. with the terrestrial Q.o.S. (see TS 123 107 [20] for T-UMTS radio access bearer QoS attributes and range values).

8.4 IMS and MBMS

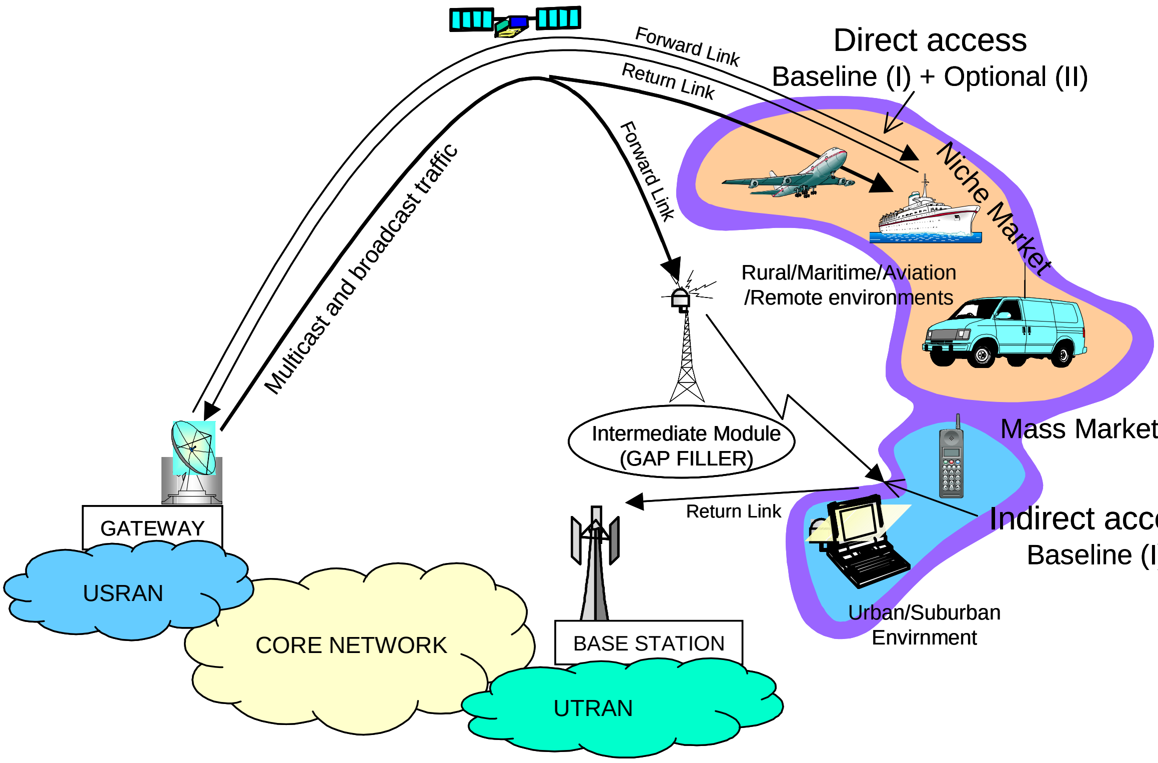


Figure 8.6: possible MBMS architecture

Maybe the first thing, which is worth clarifying before proceeding with the IP implications, is the relation of S/T-UMTS mode to the IP. IP is a connectionless, network layer protocol featuring packet (datagram) switching at the network nodes. In the traditional best effort manner, these nodes do not maintain any state about packets that come from a specific source and/or belong to the same information stream. Every packet is treated in an independent manner and there is no sense of connection on the network layer. However, this does not necessarily mean that IP is carried always in this "pure" packet mode. Depending on the underlying transmission technology, which supports IP in a specific domain, the IP datagrams. The IP transport over PPP connections in the case of dial-up links is maybe the most straightforward example of circuit-mode transport of IP datagrams. In this case the connectionless service of IP layer is emulated over a strictly connection - oriented technology.

In UMTS the concept of packet mode encompasses specific transport methods that differentiate this mode from the traditional circuit-mode of the 2G networks. The major components of this method are the shared channels and the lack of explicit connection set-up procedures for the initiation of a so-called "packet call".

Therefore an IP-based packet-mode S-UMTS has to face two kinds of implications:

- the ones stemming from the adoption of packet-mode. These are not irrelevant to the IP suite, but are mainly a consequence of the transport protocols and the applications (e.g. TCP and HTTP induced traffic burstiness in case of the WWW) rather than a direct consequence of the Internet Protocol as such.

- the ones originating from the necessity or wish to achieve a closer integration with the Internet and the fulfilment of some functions in an end-to-end manner. To a great extent these implications are a consequence of the way these functions are performed in the terrestrial Internet (e.g. protocols, architectures).

Note that in some cases it may be difficult to discriminate between the two categories. While these issues also arise in the T-UMTS, the specific characteristics of the satellite environment may magnify, alleviate or add new dimensions to them.

Further information on MBMS can be found in TR 123 486 [42] and TS 122 146 [43].

8.5 Packet-mode and S-UMTS

The satellite environments impose extra difficulties in the packet mode support, at least the way it is implemented in T-UMTS, arising mainly from the higher propagation delays and the larger cell sizes related to satellite systems. The interaction of the satellite environments and the UMTS packet-mode can be summarized into the following points:

- The high propagation delay over satellite links puts a hard limit to the responsiveness of the resource allocation mechanisms. Whether dedicated channels are used or common/shared channels without connection set-up and release are used, efficient utilization of the resources (channels) is dependent on the flexibility of the resource allocation/release procedures. In fact, the advantages of the latter method regarding the respective delay become less apparent in the satellite case.
- The delay spread among users is higher, introducing an uncertainty in the time of packet arrivals, when packet transmission is discontinuous. The problem becomes more significant in the LEO case.
- Given the burstiness of packet data traffic and when this type of traffic is the dominant one, the interference is expected to be changing more quickly. The large round-trip delay however reduces the potential of power control procedures to respond to such scenarios, with negative impact on the system capacity.
- The MAC mechanisms for supporting packet data on RACH and CPCH (access preambles, collision detection preamble, power control preamble) in terrestrial networks are not efficient in the satellite case, again due to the high round-trip delay
- The applicability of diversity - mainly envisaged for LEO satellites - becomes a more complicated case if packet-mode does not make use of dedicated traffic channels.

In case of satellite links, the channels are power limited. Particularly in the case of a handheld terminal, the range of services supported is limited to the ones requiring modest rates.

8.6 Multicast

The broadcast/multicast case in media with inherent broadcast capabilities is a significantly different case from the conventional implementation of broadcast/multicast over networks consisting of point-to-point links. A great deal of the complexity and difficulty arising in multicast support in the wireline networks has to do exactly with the non-broadcast nature of the media. The routing of packets to the end hosts in an efficient manner is a problem to solve. In broadcast media - and particularly in the case of satellites - this problem is solved a priori, since all hosts within the satellite coverage can be reached in a single-hop. The problem in the satellite case - and this mainly but not exclusively corresponds to the multicast case - is rather the engineering of a scheme (subscription registration, activation and respective security associations, group management) that will allow the reception of information only from those that have subscribed to it while avoiding inefficient use of network resources.

The IP multicast handling is mainly foreseen in:

Taking benefit of the advantages of the connectionless datagram service provided by UDP for broadcast/multicast transport of applications characterized by a simple request/reply traffic pattern (i.e. within one datagram), and leaving acknowledgement processing at the application level (reliable multicast transport techniques).

Targeting minimum acknowledgement of multicast transmission and retransmission needs.

Optimizing the content distribution by means of Broadcast/Multicast Data Servers and techniques such as Web caching and mirroring, that are not necessarily located in the GW and perform:

Routing to build multicast/broadcast IP streams of multimedia content (use of different multicast address each corresponding to a service offer to the users in terms of content type and associated quality of service and security requirements) associated with content element segmentation, possibly QoS based routing (terrestrial versus satellite segment), scheduling as well as security features and reliable multicast transport techniques (FEC, retransmission).

Content serving to assign service descriptor to each multimedia content; this descriptor being used all along the distribution chain to perform optimum routing, scheduling, and subsequently filtering, cache management as well as presentation to the user.

The implementation of both these functions will be based on open standards such as those devised within IETF or other fora. However the way multicast will be supported in any S-UMTS configuration will heavily dependent on the level of IP penetration in the UMTS CN.

8.6.1 Multicast in an all-IP CN

The adoption of Mobile IPv6 in the CN makes more straightforward (or even mandatory) the application of IP-derived solutions for multicast support:

Multicast capable routers can be deployed at the CN for more efficient multicast transport.

IGMP can/must be used for group management purposes.

For the unidirectional link, where the return link is provided by the T-UMTS, a solution for overcoming the unidirectional nature of the satellite link is provided by the Link Layer Tunnelling Mechanism (LLTM), standardized in the IETF UDLR WG. The respective functions and their potential are commented in clause 8.7.

Support of IP multicast has to address mainly the *scaling* problem; that is the standard IP multicast architecture implies a significant overhead of signalling/control messages, given the number of potential hosts per spot beam. These messages can be either multicast routing messages exchanged between the multicast-routing capable entities of the network or IGMP (Internet Group Management Protocol) messages. IGMP capable routers detect the presence of group members by sending IGMP queries, to which hosts answer with IGMP report messages. The messages are timer-driven and may constitute a significant portion of the network load, effectively reducing its available capacity for data traffic.

Nevertheless, there are two features of satellite networks that have to be noted and can be exploited for a more efficient support of multicast services.

8.6.1.1 The tree-like topology of the network and the IGMP proxying principle

The aforementioned signalling load and the respective resource consumption can be avoided in certain topologies. This is the main reason why the "IGMP proxying" (IGMP-based Multicast Forwarding) technique was conceived.

With respect to its position in the multicast spanning tree, the router interfaces can be divided into two classes: downstream interfaces (DI) and upstream interfaces (UI). There can only be one UI for an IGMP proxying device. DIs are in the direction of hosts while UI is in the direction of another router. This differentiation is introduced since, depending on its type, a different role in the protocol is played by the interface.

In the proxying technique, DIs run the so called *router portion* of the IGMP protocol, in other word, on each interface, the normal IGMP operations are performed, maintaining in a separate way, a membership database. These databases are then merged to obtain a *global membership database* that accounts the memberships on each interface.

UI runs the *host portion* of the IGMP protocol, so it has to send IGMP membership reports when it receives a query message, and has to send unsolicited reports or leaves when database changes.

As far as the forwarding technique is concerned, when a router (or proxying device) receives a multicast packet, it builds a record in a *forwarding database* consisting of a list of the interfaces (UI and DIs) where there is a subscription to the group except for the interface from which the packet arrived. Then it forwards the packet to those interfaces. This operation can be made simpler if the forwarding database is used as a cache, so that the creation of a record in the database is made once for all the packets belonging to the same group. This simplification comes however at the cost of updating the cache every time the situation in the membership changes.

It is possible that the S-RNC (Gateway) and potentially the UTRAN-IP gateway (physically they might be the same) that has to play the role of the proxying device(s).

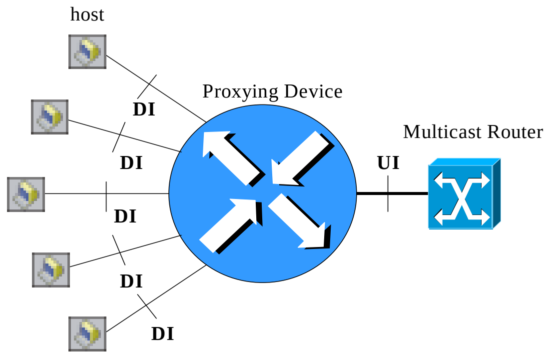


Figure 8.7: Standard IGMP proxying interfaces classification

8.6.1.2 The LAN-like nature of the network

Rather than implying a strict resemblance the similarity refers to the capability of all the hosts within a beam to receive all transmissions destined for this beam. This capability can be exploited in reducing the number of exchanged IGMP messages over the air interface. Rather than letting every mobile host (MH) sending reports back to the gateway - which implements the IGMP querier functionality - one of the multicast group members is elected as the group representative for IGMP proxy functions for the whole group. The functionality implied by the term proxy in this case is different than the one in the "IGMP proxying" principle of 8.6.1.1; however the two concepts can be applied in combination. From now on the term "group proxy" refers to the IGMP signalling overhead reduction, while the "IGMP proxy" term refers to the IGMP-based multicast forwarding, as described in 8.6.1.1. The other hosts trigger a timer whenever they see a report from the designated group proxy and only send their own report when this timer expires. The underlying principle is that the gateway does not have to be aware of the exact number of MHs participating in a given group but rather whether there is one or more MH(s) in a specific beam so that a copy of the message is forwarded to this beam. The requirement for the *Max Response Time* field is to be higher than the roundtrip time but reasonably low so as to reduce the number of membership report messages sent after the receipt of the *General Membership Query*.

The overhead reduction technique that can be employed in order to suppress membership report messages as effectively obtained with standard IGMP is illustrated in figure 8.8.

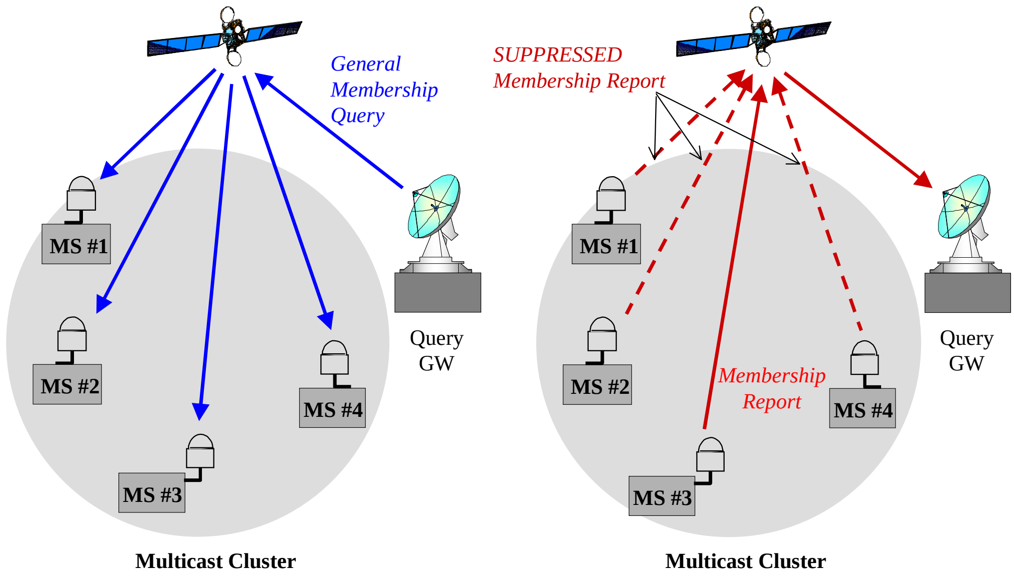


Figure 8.8: Principle of IGMP overhead reduction

An instance of IGMP messages exchange, when both the aforementioned optimizations are adopted, is shown in figure 8.8. The figure illustrates the case of three Mobile Stations (MS) associated with a given Gateway (GW) which acts as querier. Contrary to the fixed broadband access systems case, it is assumed that MS terminals are not connected to a CPE (Customer Premises Equipment, a device with layer 3 functionality in this case), which would take on the role of the IGMP proxy for them.

A periodic *General Membership Query* (GMQ) message is broadcast to the cluster by the GW, which contains the selected *Max Response Time*.

Upon receipt of the GMQ, the MS sets a delay timer for each group of which it is member. Timers are set to a random value selected from the range [0, *Max Response*]. In our example, MS#2 and MS#3 wish to receive traffic sent to the multicast address IP@1, while MS#1 has no active memberships. The first *Membership Report* message that is received comes from the MS#2, which, according to the overhead reduction protocol, becomes the elected group proxy.

The GW broadcasts a Network signalling message, namely the *Group_Proxy_Indication* to inform all MSs in the cluster that MS#2 has been elected the group proxy for the address IP@1. From now on, all members of the group IP@1 except MS#2 can suppress membership report and leave messages.

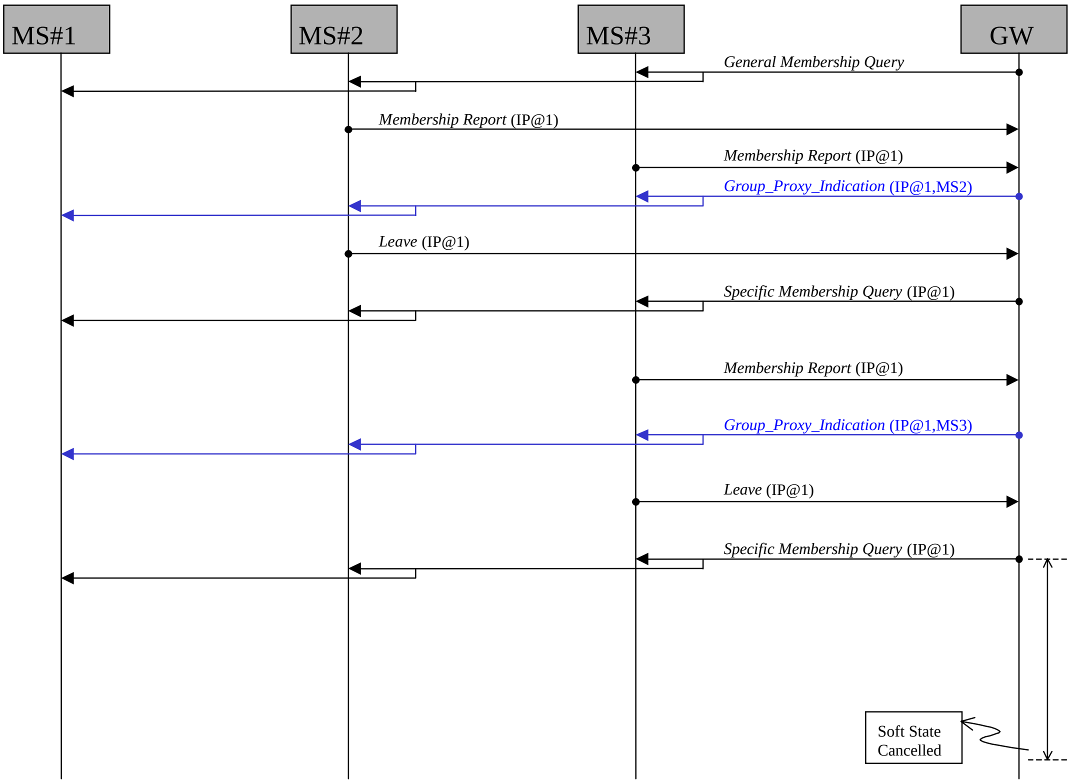


Figure 8.9: Example of IGMP proxying with overhead reduction

At the end of the session, MS#2 cancels its subscription to group IP@1 by sending a *Leave* message to the GW. As in standard IGMP, the latter sends a *Specific Membership Query* to make sure that no other member of the group is active in the cluster. In our example, MS#3 is the remaining member of the group IP@1, therefore it shall send a *Membership Report* to the GW, and will become the new group proxy for address IP@1. When MS#3 - last and single member of the group IP@1 - finally leaves this group there is no reply to the *Specific Membership Query* sent by the GW. When the timer for the subscription to the group IP@1 expires, the GW cancels the relevant soft state.

The extra difficulty, when applying the second principle (IGMP signalling overhead reduction technique) in the case of mobile hosts, featuring no proxy device in front of them, is that modifications can no longer be transparent to the end hosts. Hence, it is necessary to modify the IGMP "client" software at all hosts, while in the fixed satellite systems with end-hosts in a LAN behind a router, it would be enough to modify the latter.

8.6.2 Multicast in a GPRS-based CN

The implementation of multicast in this case seems to be a different case. The main reason for this is the different business paradigm of the two networks, namely the current, best-effort Internet and the T-UMTS.

In the former, there is intensive, time-based, signalling at the edges of the network, between the hosts and the closest, multicast-capable router because there is no detailed state at the router upon the exact number or addresses of the hosts that receive multicast content. In other words, the only thing required from the router is to know whether there are one or more hosts that want to participate in a multicast session. In order to facilitate this, the end hosts are subject to this frequent IGMP message exchange. In effect, the trade-off between signalling overhead and router complexity is determined in favour of the latter, the underlying assumption being that at the edge of the network the luxury of wasting some bandwidth on additional signalling is feasible.

On the contrary, in a mobile, wireless network like T-UMTS, there is generally much more information for the end user available at the network nodes. This information is available anyway in order to support the user mobility and AAA (Authentication, Authorization and Accounting) functions.

The additional capability in the GPRS networks is the capability to use this information when "routing" each packet in pre-established tunnels that are created during the multicast PDP contexts. Therefore it is feasible for the SGSN to route traffic between the two access networks (T- and S-UMTS), since it is only necessary to set up the tunnels initially and make the respective bindings. This is not feasible, at least on the basis of the standard datagram routing paradigm in a all-IP CN.

Therefore the IGMP-related issues become of less (or even no) relevance in this case, since the information provided by IGMP is "there" and - most significantly - can be used for routing packets to the users.

8.7 Unidirectional link routing (UDLR) protocol

The UDLR protocol functionality becomes relevant in the case only a unidirectional link is used and, under the assumption of the Mobile IPv6-based CN. In this case, it is necessary to come up with a solution to the problems posed to the IGMP by the unidirectional nature of the satellite link. The IGMP, similar to the IP routing protocols, has been designed and engineered assuming a bi-directional link. Since this does not exist in the unidirectional link, it has to be emulated somehow over the T-UMTS link.

Such problems have been mainly addressed in the context of fixed satellite networks, where the unidirectional link is a satellite broadcast link (e.g. DVB-S) and there is a return terrestrial channel (e.g. dial-up line, PPP) that allows some form of interaction between the end-user and the provider/network operator. The IETF UDLR WG concluded the first part of its activities with the specification of a link-layer tunnelling mechanism, which effectively allows the emulation of a bi-directional link over a unidirectional link. The current focus of the group is the efficient, scaling function of multicast protocols over unidirectional links; the main difference is that end-hosts/terminals are positioned behind a multicast-capable router that can take proxy action in case of IGMP proxying.

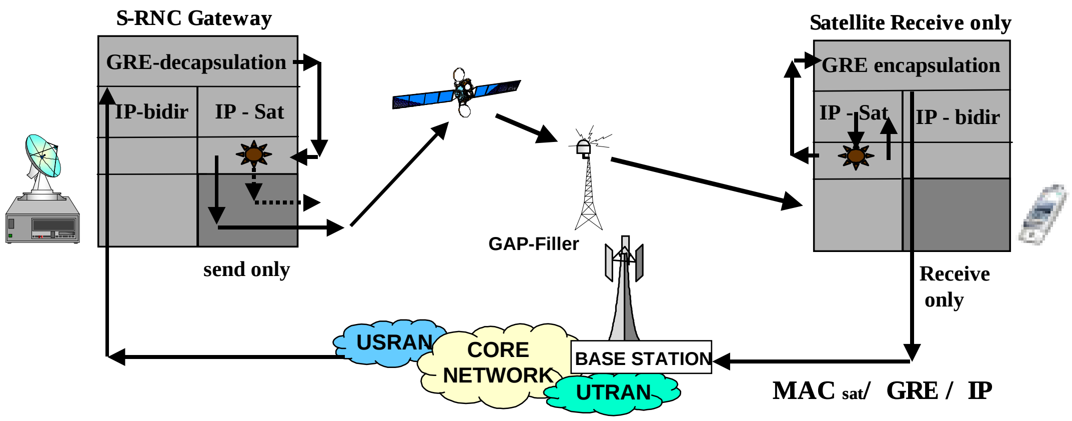


Figure 8.10: UDLR functionality in the unidirectional scenario

In the unidirectional context, UDLR feeder/hub functions are required in the GW and UDLR receiver/host functions are required in the terminals (figure 8.10).

8.8 TCP and RTP/UDP flows transport

The TCP/IP suite provides applications mainly with two transport capabilities, expressed by Transport Control Protocol (TCP) and User Datagram Protocol (UDP). The former provides a reliable, byte-stream, connection-oriented service and is the workhorse protocol for the traditional (and most popular) Internet applications, while the latter a connectionless service that is often used by real-time services, with an intermediate session/application level protocol providing the respective control functions.

8.8.1 TCP flows

The provision of asymmetric, TCP-based services is envisaged only in the bi-directional link, given the interactivity these services require.

8.8.1.1 Issues

The problems TCP faces over satellite links have been a subject of research for quite some time, although it experienced a peak in the last 5-6 years. The propagation delay related to a GEO satellite and the wireless nature of the satellite link are the main factors of TCP performance degradation. The former reduces the effectiveness of the window-based flow control of the protocol and its responsiveness to congestion incidents. The latter interacts badly with the protocol congestion control mechanisms. Although the requirement to be accommodated over satellite links was identified from the very early days of what today is called Internet, the main TCP congestion control algorithms were devised subsequently with the underlying assumption of an error-free link, where any indication of packet loss implied congestion incidence at the terrestrial network. TCP flows are adaptive, in the sense that when they sense congestion they cut down on their sending rate and adjust to the capacity that is available to them, at least their estimation of it. In a wireless network, especially one with a one-hop link without any buffer intervening (like in the case of the non on-board switching capable satellite) losses are due to link errors. Given that TCP works end-to-end, it cannot differentiate between a corruption and congestion loss and reduces its sending rate even when there is no reason for that (e.g. congestion), leading to reduced throughput.

The proposed architecture features another reason for TCP performance degradation: asymmetry, which is expressed as bandwidth asymmetry in the optional case and as both path and bandwidth asymmetry in the baseline case, where the T-UMTS network provides the return link. In fact this asymmetry is most of the times an engineering choice that fits the asymmetrical nature of some applications (traditional IP client-server applications). Asymmetric effects may be the result of asymmetry in the available capacity in the two directions of a TCP transfer, additional latency in one of the links due to medium sharing, usually in the return link, and can be exaggerated or smoothed depending on the traffic load and the respective queuing delays in each one of the two directions.

Such phenomena can have a negative impact on the TCP throughput, since the pacing of the ACK packets in a slower return link limits the sending rate of the TCP sender in the forward direction and prevents it from using potentially available capacity. When bandwidth asymmetry is combined with increased traffic load at the return link the effect can be even more dramatic due to the high queuing delays or losses of ACK packets, depending on the buffer sizes at the slow return link.

The bit-rates mentioned in tables A.3, A.2 for the TCP-based asymmetric services imply that the bandwidth asymmetry is not that dramatic, although it may become considerable for some streaming applications that make use of the TCP services

8.8.1.2 Countermeasures

A number of ways to attack these problems have been proposed. Maybe the most comprehensive summary of those is given in [44], which concluded the activities of TCPSAT group, a group established within IETF and dedicated to the study of the specific problems TCP faces in satellite environments. The majority of the solutions suggest transport (TCP)-level modifications, introducing different implementations of either the TCP sender or the receiver - or both. Timestamps, window scaling and larger initial window are considered a MUST in "long fat networks", that is networks with a large bandwidth-delay product. Furthermore TCP implementations with more elaborate flow control mechanisms (like TCP Vegas) or better response to congestion (Selective Acknowledgements, New Reno) than the standard Tahoe and Reno TCP have reported performance improvement, although they are not tailored for satellite links.

Proxying techniques [25] report much more promising results. TCP Spoofing, TCP Splitting and even TCP-aware link level schemes like Snoop outperform the standard end-to-end TCP connections. Although there are some arguments against their use - associated mainly with the extent to which they adhere to the "end-to-end" principle and their incompatibility with the use of network-level security mechanisms like IPSEC - such techniques are known to the satellite community and have been widely used in fixed satellite networks. In fact a combination of split connections with link-level retransmissions yields superior performance and guarantees some resilience to the terrestrial network level of congestion [26].

The use of asymmetric PEP implementations is deemed necessary, in order to avoid inefficient radio resource use in the return satellite link, inherent to the configuration of that optional case (i.e. impact of satellite transmission delay and impairments).

The RLC retransmission protocol may be a further subject of differentiation with respect to T-UMTS. The ARQ protocol deployed in the case of optional scenario cannot have the persistence of the terrestrial analogues. It is also established that typical connection-oriented link layer protocols, attempting in order delivery of packets/frames interact badly with TCP.

Regarding asymmetry: for a start, the range of possible solutions that can smoothen the asymmetric phenomena may be divided into host-side and network-side ones: in the former case the improvement comes from modifications in the protocol stacks of the sender, the receiver or both, while in the latter, changes in the network elements - transparent to the end TCP host - are responsible for any performance enhancement. There are also proposals that necessitate combined action by network and users in order to yield some positive result.

A significant number of techniques are in an experimental stage; regarding the end-to-end mechanisms, an agreement appears to exist upon the benefit of the TCP connections from the use of the Path MTU Discovery mechanism that can save performance degradation due to potential network-level fragmentation. TCP Pacing is also promising [45] in the sense that it does not necessitate major changes that could affect other standard connections in an adverse manner. ACK Congestion Control, a technique that attempts to expand the TCP data congestion control algorithms to the ACK packets, is in an experimental stage. Cruder solutions like Modified Delayed ACKs, that reduce the number of ACK packets sent at the return direction, are not favoured since they increase the TCP sender burstiness and may trigger unwanted effects in the forward direction.

It will be mainly the network side, end-user transparent solutions that will be invoked in order to alleviate any asymmetry effects. The complexity argument that usually acts preventively in such cases is well outweighed by the promised performance improvement and the scalability of the approach. It is also the centralized, radio access architecture that favours such solutions; the bottleneck link is placed between the mobile terminal and the gateway, allowing the latter to exercise a number of techniques to alleviate any undesirable asymmetry effects - note that in this case asymmetry is the result of engineering action rather than a physical medium limitation (as would be the case in terrestrial, dial-up connections for example).

The use of header compression techniques can limit the traffic load of ACK packets at the return link. Both the traditional Van Jacobson algorithm and more recent algorithms investigated mainly by the IETF ROHC (Robust Header Compression) group [46] fitting better to the non error-free wireless environments are going to be adopted in the system design. Furthermore, differentiation in the treatment of ACK packets will be provided by the use of appropriate scheduling mechanisms at the S-RNC node. More innovative solutions like ACK Reconstruction and ACK Compaction/Companding that provide some form of the ACK packet stream regeneration, and are exercised immediately after the bottleneck router are not favoured, given that the experience from the use of such techniques is rather limited and their use not recommended.

8.8.2 UDP flows

The efficient support of real-time, interactive services (e.g. VoIP) is not possible if the selected satellite constellation is a GEO based. The GEO satellite network introduces a latency of 250 ms, leading to a tolerable end-to-end delay, within the upper limit of 400 ms required by ETSI TIPHON WG specifications [47] (see table 8.10). It would far exceed though this limit in case of an MS-MS connection, where two satellite hops would be involved, unless a regenerative, on-board switching capable payload is available.

On the other hand, UDP is also the common choice for the transport of audio and video services. A whole family of protocols, namely the Real Time Protocol (RTP), the Real Time Control Protocol (RTCP) as well as the Real Time Streaming Protocol (RTSP), have been devised for the support of IP-based (streaming) multimedia services. Multicast transport channels are often used for the transport of these services.

There is recently a lot of interest in the efficient modelling of this type of traffic, given the growth of the respective services and despite the problems posed by the proprietary, in many cases, technology/protocols lying behind them.

Table 8.10: End-to-end delay for TIPHON classes of service [47]

	3 (WIDEBAND)	2 (NARROWBAND)			1 (BEST EFFORT)
		2H (HIGH)	2M (MEDIUM)	2A (ACCEPTABLE)	
End-to-end Delay	< 100 ms	< 100 ms	< 150 ms	< 400 ms	< 400 ms
NOTE: The delay for best effort class is a target value.					

8.9 IP QoS

Support of IP quality of service brings a number of issues that need to be investigated.

Making the assumption that the core network will be based on an IP DiffServ solution - given its proven scalability compared to IntServ - careful considerations must be made with respect to how DiffServ or IntServ will be used in the user and access domains taking also into account the mappings between the IP mechanisms and the underlying UMTS capabilities.

The baseline scenario assumes a bi-directional communication where each direction follows a different path, i.e. the forward link is via gateway/satellite/gap filler, whereas the return link is via T-UMTS. This has an impact on the way the IP QoS mechanisms will be used.

According to the RSVP specifications (within the context of IntServ), the RSVP PATH and RESV message objects must traverse the same route. This is done since the PATH message records the path along which the reservations will be made when the remote end send back the RESV messages. However, this is not necessarily the case in every possible S-UMTS architecture. The concept of the RSVP proxy may be used to overcome this problem. RSVP proxy functionality can also be used when RSVP client functionality is not implemented in the MS. More specifically, if the MS does not have the required IP QoS capabilities in order to provide end-to-end QoS, IP layer signalling may be performed in the IP and RAN gateway (e.g. RNC/GGSN) and be transferred transparently through the DiffServ core. The required QoS information can then be signalled between the MS and the RAN gateway using UMTS mechanisms. Moreover, admission control plays a vital role in the IntServ framework, as it is required in each RSVP-capable node. In contrary to wire-line networks, a number of additional factors need to be considered such as mobility and its interaction with other RRM functions. Indeed RSVP signalling should be avoided over the air. If SIP is being used then RSVP messages can be created by the GGSN by combining UMTS and SDP QoS information. The mapping of the IntServ service classes and associated QoS parameters to the UMTS classes is another aspect that needs investigation, taking particular care of the satellite link characteristics.

With DiffServ, the implications are mainly related to handover and mobility. When a mobile terminal with a specific SLS moves from one domain to another, there are no guaranties that the new domain will have enough resources to comply with the SLA because of the shared nature of the access network. In addition, the new domain may belong to another Service Provider that utilizes a different pricing scheme thus complicating things more. The application QoS is interpreted (PDP), the Serving RNC controls admission of new flow to the pre-established Iu-Packet Switched bandwidth pipe (DiffServ IP, IP bearer/QoS guaranteed pre-negotiated with ISP, traffic control is set based on SLS) and QoS mappings are performed inside and at the border of UMTS RAN (mapping between UMTS QoS Class and DiffServ done in the SGSN for Forward/Downlink and in the RNC for the Return/Uplink).

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: ITU-R (Radio Communication Sector) IMT-2000 Recommendations

ITU-R Recommendation M.687	International Mobile Telecommunications-2000 (IMT-2000)
ITU-R Recommendation M.816	Framework for services supported on International Mobile Telecommunications-2000 (IMT-2000)
ITU-R Recommendation M.817	International Mobile Telecommunications-2000 (IMT-2000) - *Network architectures*
ITU-R Recommendation M.818	Satellite operation within International Mobile Telecommunications-2000 (IMT-2000)
ITU-R Recommendation M.819	International Mobile Telecommunications-2000 (IMT-2000) for developing countries
ITU-R Recommendation M.1034	Requirements for the radio interface(s) for International Mobile Telecommunications-2000 (IMT-2000)
ITU-R Recommendation M.1035	Framework for the radio interface(s) and radio sub-system functionality for International Mobile Telecommunications-2000 (IMT-2000)
ITU-R Recommendation 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 Recommendation M.1167	Framework for the satellite component of International Mobile Telecommunications-2000 (IMT-2000)
ITU-R Recommendation M.1224	Vocabulary of terms for International Mobile Telecommunications-2000 (IMT-2000)
ITU-R Recommendation M.1225	Guidelines for evaluation of radio transmission technologies for International Mobile Telecommunications-2000 (IMT-2000)
ITU-R Recommendation M.1308	Evolution of land mobile systems towards IMT-2000
ITU-R Recommendation M.1311	Framework for modularity and radio commonality within IMT-2000
ITU-R Recommendation 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 Recommendation M.1455	Key characteristics for the IMT-2000 radio interfaces
ITU-R Recommendation M.1457	Detailed specifications of the radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)
ITU-R Recommendation 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 Recommendation 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 ITU-T 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. 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: ITU-T (Telecommunications Sector) IMT-2000 Recommendations

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

9.3 ASMS Task Force

The ASMS-TF has a focus period of approximately 10 years consisting of a short term scenario of 1 to 4 years and a more long term scenario of 4 to 10 years. For the short term scenario it has been concluded that possible implementations must be based on existing technologies/architectures with minor modifications. It has been anticipated that development will take place in several phases determined by factors like market demands, the terrestrial introduction and development from 2.5 G into 3.0 G, and the potential of available satellite technologies.

The approach taken is based on evolution from the present situation for both satellite and terrestrial networks in the short term scenario. For the satellite segment this means that only existing systems or systems planned for operation in the near future are of interest for the short term. The long term scenario has possibilities for and must include a transition into the future of multimedia communication with more advanced and complex approaches depending on development in the first critical phase. Basically it is required that the same services as those intended to be delivered by terrestrial UMTS should be supported, but there are additional requirements for multicast/broadcast. Further information on the ASMS-TF can be found on http://www.cordis.lu/ist/ka4/mobile/proclu/c/satcom/satcom.htm

Table 9.3: ASMS-TF Recommendations

ASMS-TF	Report on Regulatory issues
ASMS-TF	Report on Technology Directions and RTD requirements
ASMS-TF	Vision Report on Advanced Mobile Satellite Systems

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.

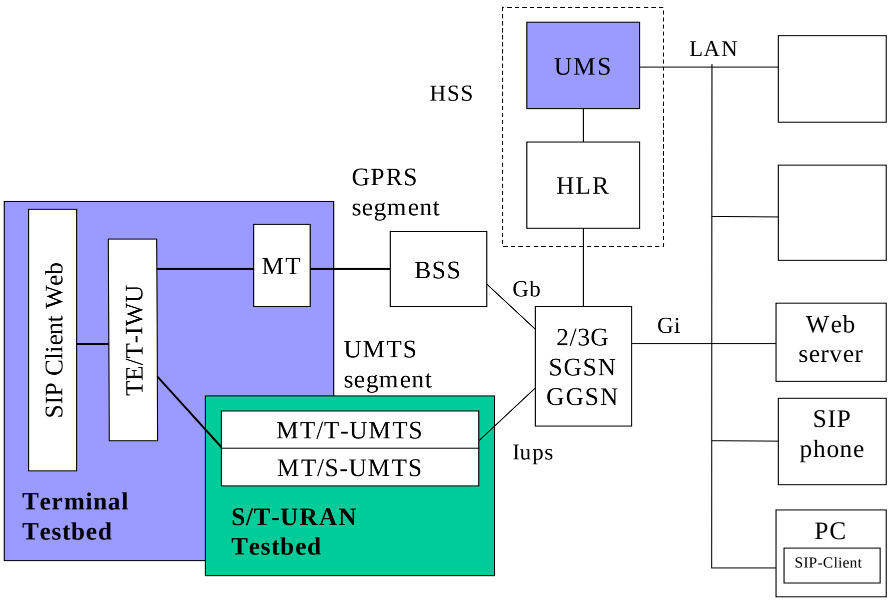


Figure 10.1: VIRTUOUS demonstrator architecture

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 a 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.

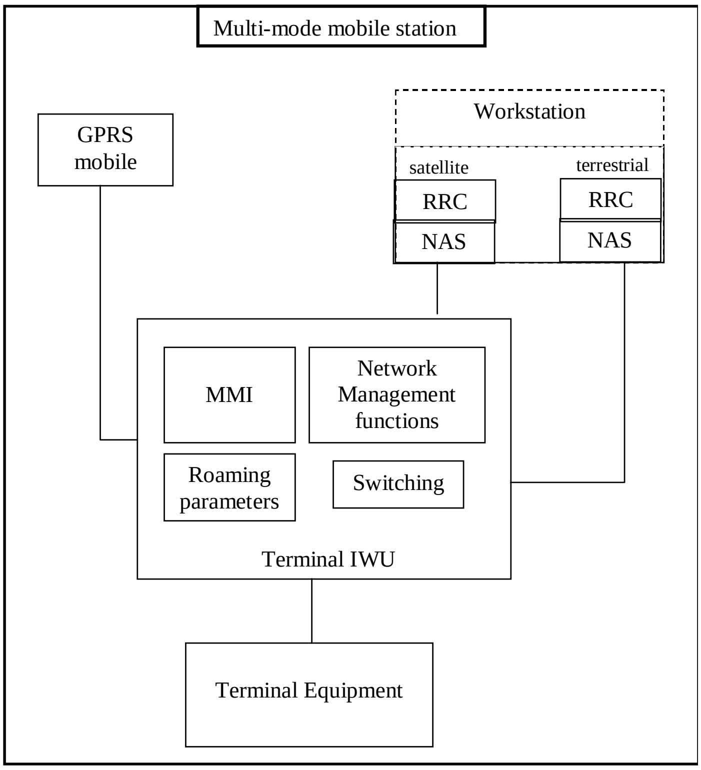


Figure 10.2: Multi-mode mobile terminal

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 and ATB

10.2.1 Overview of the *ROBMOD* ESA project

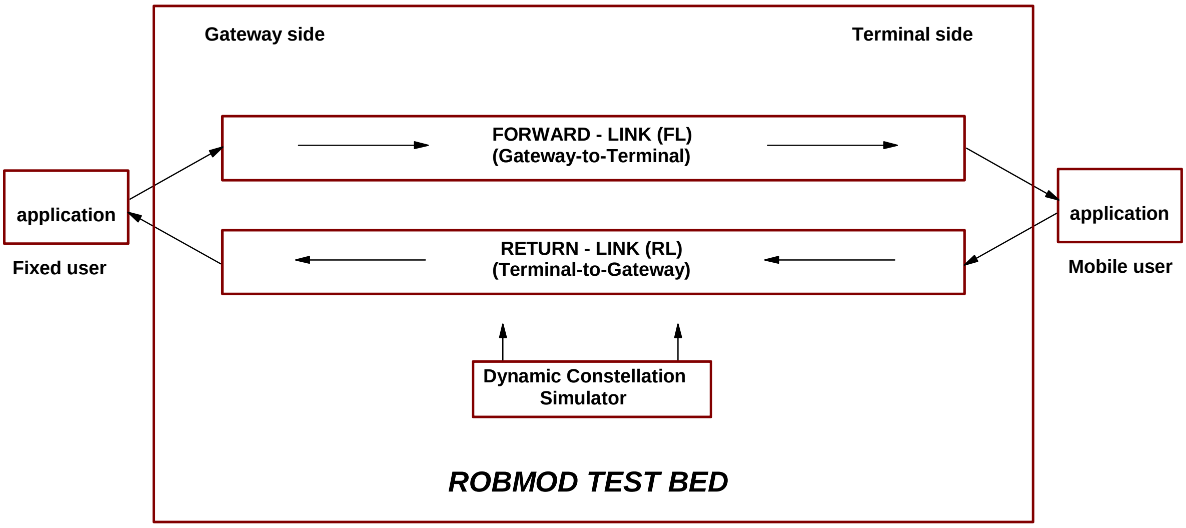
The ESA ROBMOD project (Robust Modulation and Coding for Personal Communications Systems) aims at defining and validating a candidate physical-layer approach for the satellite component of UMTS. ROBMOD saw the participation, under Space Engineering (I) prime-contractorship, of Ascom (CH), CoRiTel (I),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

A summary of the Phase I achievements can be found in the paper "Wide-Band CDMA for the UMTS/IMT-2000 Satellite Component" [48].

Phase 2 has covered 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 in figure 10.3.



- 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: ROBMOD Test Bed

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. The GW modulators and the terminal demodulator are implemented on a custom made 20-layer PC board hosting six Altera APEX FPGAs (400k useful gates) and one Analog Devices Shark DSP for board and interfaces control functions. The terminal modulator and GW demodulator are implemented via a custom PCI board with six XILINK Virtex FPGAs, for high-speed processing, a Daytona dual-DSP board for lower clock-speed operations (e.g. symbol-level algorithms) and a multi-purpose ADC board.

- realistic channel representation, by means of hardware providing independent emulation of free space losses, delay, Doppler, user-defined propagation channel, etc., as shown in the block diagram below. Each channel simulator path is implemented via a custom ISA board with one XILINK Virtex FPGA and 312-kByte RAM and dual-DSP Daytona PCI board (TMS320C6201@200 MHz) support fading, shadowing, and path delay, doppler and loss.

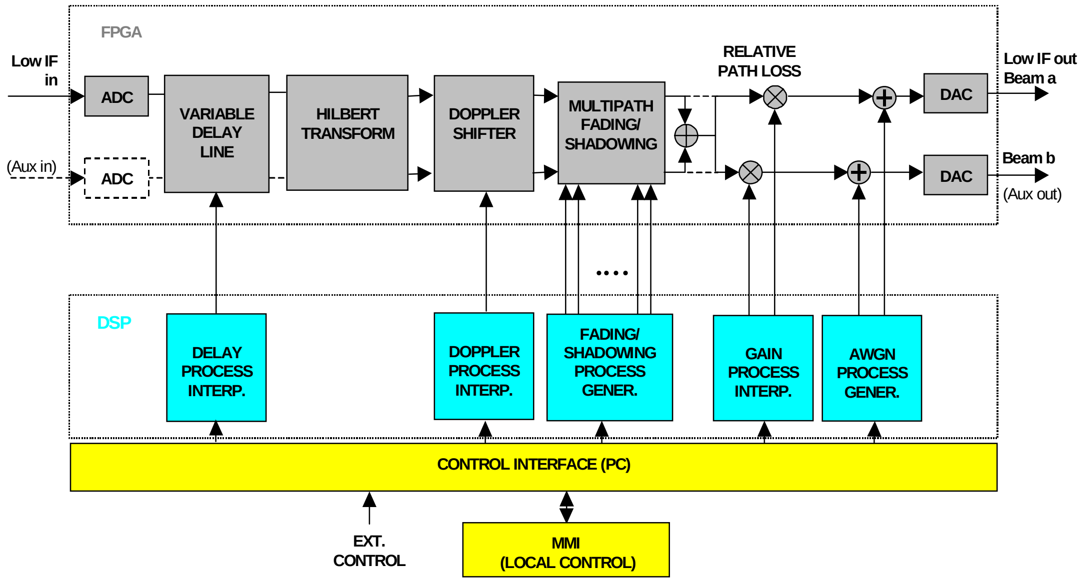


Figure 10.4: Channel Simulator block diagram

- 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 - and 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. The top-level block diagram is presented in figure 10.5.

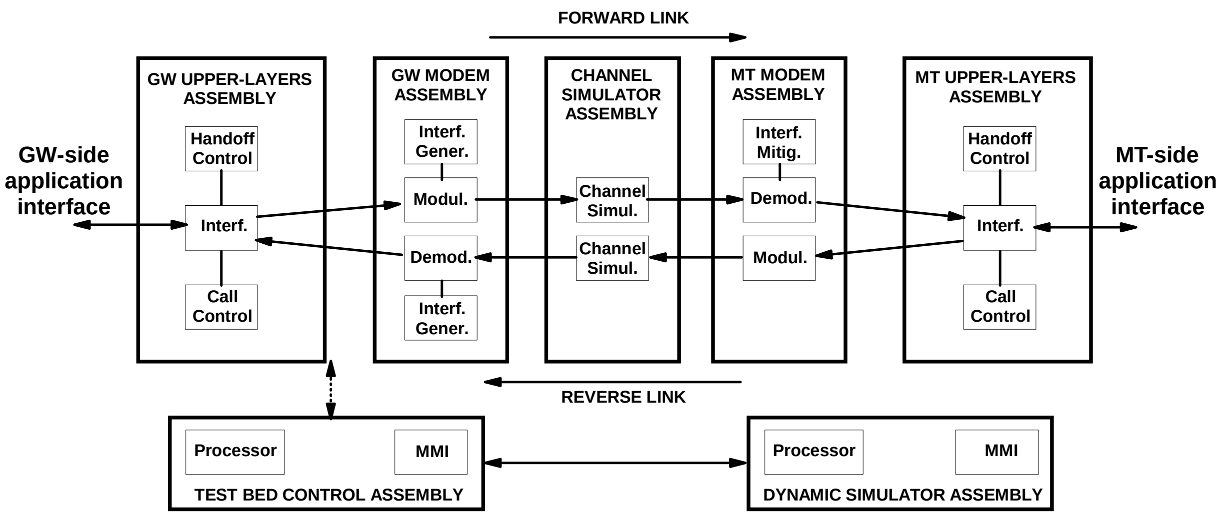


Figure 10.5: Top level diagram of ROBMOD

The ROBMOD Test Bed, which is presently under final testing before delivery to ESA, 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.

Figure 10.6: The *ROBMOD* Test Bed

10.2.2 Overview of the *ATB* ESA project

The ESA project "Advanced S-UMTS Test Bed" (ATB) represents the follow-on of ROBMOD (see ref. [1] for a description of the ESA early project), an activity which has resulted into the implementation of a comprehensive hardware Test Bed intended to validate the W-CDMA physical layer in a context faithfully representative of a real S-UMTS service.

Among the major objectives of the ATB project is that of defining, assessing and optimizing new operational modes, such as packet and multicast, which are expected to boost up data transmission efficiency and hence to be particularly helpful in increasing the appeal of future S-UMTS systems. To this end, the new Test Bed will further develops the remarkable testing and validation capabilities offered by the ROBMOD Test Bed (RTB), by incorporating new features allowing to satisfactorily experiment those new modes.

Another remarkable objective of the project is that of performing over-the-air trials intended to further validate the proposed new operational modes in presence of real via-satellite links, and not only in the laboratory as it was the case for the RTB.

Finally, demonstrations to the public of a meaningful S-UMTS service will be performed via a geostationary satellite, with the aim to promote the utilization of satellites as a necessary complement to the terrestrial UMTS infrastructure.

The whole project if scheduled to complete by the mid of year 2003.

The ATB will be an experimental set-up, representative of an S-UMTS system, basically designed for laboratory trials but also ready to demonstrate a multimedia service via a real geostationary satellite link. As already mentioned, the ATB is obtained enhancing the RTB by suitable additions and modifications. The ATB, as well as the RTB, envisages IF interfaces among its constituting elements, and it shall therefore be interfaced to external radio equipment and facilities (e.g. converters, RF front-ends, etc.) for out-of-laboratory tests. In addition to the features already offered by the RTB, the ATB:

- Supports new advanced modes such as packet and multicast (by suitable modification of the MAC layer and addition of upper layers). At this regard the study phase which has just been concluded has investigated for the Forward Link the adaptation to the satellite environment of the 3GPP DSCH (Down-link Shared Channel). For the Reverse Link, a derivative of the 3GPP CPCH, a fully random Spread Aloha access and a reservation based access scheme (referred as dynamic Rate on Demand, dRoD) were investigated with particular emphasis on a GEO satellite environment. As a result of the investigation a combination of Spread Aloha and dRoD was finally selected for implementation on the RL.

- Includes the equipment needed for verifying the correct operation of such advanced modes, i.e. a second Mobile Terminal (MT), additional channel simulators, interference generators programmed to emulate a packet-access by the other system users, etc.

- Can operate with the MTs fully detached from the Test Bed (this was not the case for ROBMOD, where MTs had to be kept inside the laboratory).

- It incorporates all those modifications allowing it to work properly both when operated as a stand-alone unit (e.g. in the laboratory) or as a part of a trial set-up comprising real via-satellite link(s). Such regard e.g. the ability to support different chip - and bit-rates and to withstand higher carrier frequency errors, the possibility to rearrange the interference generators (due to possible link budget constraints).

The ATB includes an application representative of an S-UMTS service and meeting the ESTEC requirements. Said application, to be developed ad-hoc, will be selected by a service operator forming part of the bidding team.

The utilization plan of the ATB encompasses three main trial phases, namely:

- **experiments:** this first phase, in which the ATB is used in the so-called *stand-alone mode*, aims to verify, in the laboratory, the proper operation and the performance of the new packet - and multicast modes in conjunction with different satellite constellations and in presence of diversity, handoffs and interference generated by other system users. Two detached MT breadboards will be used during this phase. In other words, the final aim is that of verifying the correctness and the adequacy of the new operational modes specifications. Clearly, this activity can only start when the ATB will have been integrated and tested. The ATB is designed such as to be self-sufficient for support said experiments, hooked up to external PCs (and/or other suitable HW if required) supporting a suitable multimedia service (respectively connected at the Gateway-side and the MT-side of the ATB, similarly then to the RTB configuration). Obviously, an ad-hoc application, exploiting the packet - and multicast modes, shall have been developed in time for the ATB experiments;

- **validation:** this phase, in which the ATB is used in the so-called *collocated mode*, will be performed in the context of an "extended laboratory" also including equipment for getting access to the satellite and the satellite itself. The validation phase should be regarded as a means to gather additional experimental results specifically regarding the (possible though unexpected) influence of satellite links transmission performance and the impact of the propagation medium on service quality, for the particular case of a geostationary satellite, and to perform an overall system line-up in preparation for the subsequent demonstration phase, with the aim to achieve a stable and dependable channel. For said purposes a simpler operating context than that possible in the laboratory will be adopted;

- **demonstration:** main aim of this phase, in which the ATB is used in the so-called *detached* mode, is to demonstrate to the public the performance of a future S-UMTS system based upon a geostationary constellation. Demonstrations are orientated to increasing the public awareness on S-UMTS and, as well as the validation activities, need then not repeating many of the technical verifications already performed during the experiments phase.

The ATB project is expected to yield valuable results with regard to the optimization of the S-UMTS W-CDMA access, with particular regard to the packet and the multicast modes.

The trials campaign will permit to not only to validate on the air the proposed solutions, but also to demonstrate, for the first time and via a real satellite, the operation of a multimedia application through a system well representative of S-UMTS.

10.3 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.

Further information can be found on http://www.ist-satin.org/.

10.4 IST: GAUSS

10.4.1 Objectives

GAUSS 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 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.

2) 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 GEO 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.

3) 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.

10.4.2 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 and GIS (Geographic Information System) technology, 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 and tracking of professional users;
- remote monitoring and control of the vehicles;

- emergency operations support and management;
- fleet management;
- assisted navigation.

They are mainly oriented to professional users.

Info-Mobility Services will consist of the development of advanced driver information and emergency assistance and management applications, oriented to mass-market:

- advance driver information service;
- emergency and risk management.

In this context, the GAUSS project is expected to contribute to the S-UMTS Standardization, as far as the following aspects are concerned:

- Packet Transmission Technology;
- 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 (see annex A for further information). 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 3G 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.

2) 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, traffic information, newspapers). Complementary services has no to be seen as a replacement of the terrestrial component, but as a way to deliver the same service on a more efficient way from a resource point of view.

An interesting perspective is also represented by concept derived from the evolution of current DARS (Digital Audio Radio Systems) 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 mainly 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/GPRS is acceptable, later T-UMTS will be a possibility.

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

- Terminal and antenna size and power consumption is not a big concern.
- 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.

The mobile phone market represents as well a good candidate for the reception only mode of S-UMTS. Services can be profitable from the moment that a good coverage in urban area is provided. Such coverage can be obtained by using a repeater-based system as described in the present document.

11.2 Standardization objectives

Two parallel objectives have been identified:

1) An alignment of mobile satellite systems with terrestrial standards, especially with GSM 2+/GPRS and T-UMTS. This would apply to all areas of design but especially to mobile user equipment 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:

1) Start and/or continue the standardization of packet, broadcasting/multi-casting modes for S-UMTS.

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

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

4) 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.

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

6) Evaluate the different return link scenarios (GSM/GPRS/T-UMTS/S-UMTS and IMR).

7) Follow up of the MBMS activities in 3GPP SA group.

Specific attention has to be given to the following items:

8) Definition of QoS for satellite-UMTS (as defined in 22.105v3.9.0).

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

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

11) Paging of a MS which is S-UMTS mode.

12) Use of a fixed terrestrial repeater transmitting in the MSS band allocated to Space-to-Earth systems.

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

Annex A: 3G services overview

A.1 The Vision of 3G Applications

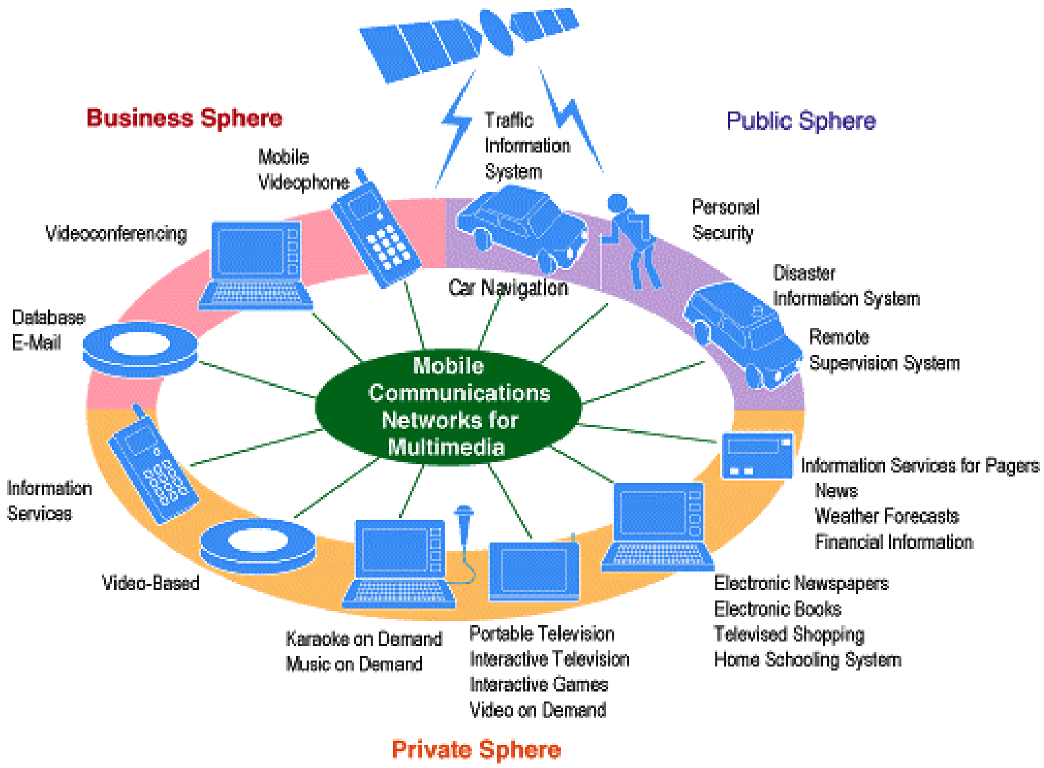


Figure A.1: 3G multimedia applications

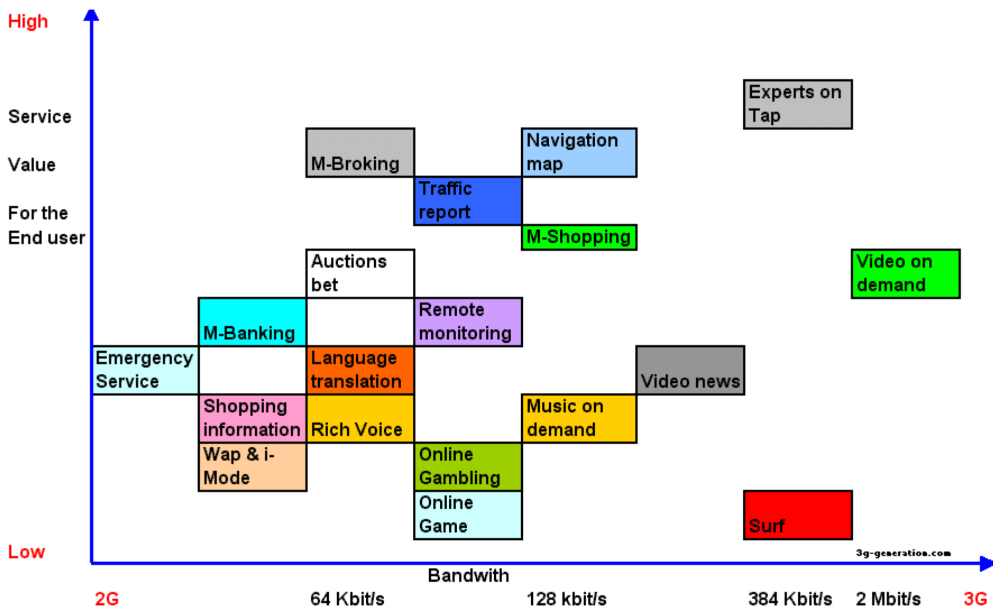


Figure A.2: Bandwidth requirement width with applications

The vision of 3G communications is to move from single media to multimedia technologies in order to support diverse applications spanning from tradition telephony applications to audio/video entertainment applications, while the end-user is on the move. The whole range of the integrated multimedia applications and their bandwidth requirements are shown in figures A.1 and A.2 respectively from [21]. Therefore 3G is expected to support high speed, interactive services for different type of mobile terminals. Some of the important applications are given under five generic categories from UMTS forum No. 8 [8].

Passive audio-visual services:

- Pay-TV (cable and DTH satellite)
- Video-on-demand (as an alternative to video sales/rentals)
- Narrowcast business TV

These services are extremely asymmetric, characterized by medium-high downlink bandwidth requirements and a tolerance to a range delays.

Passive audio services:

- Audio-on-demand (e.g. audio clips as an alternative to CDs, tapes, radio)

These services are characterized by low-medium bandwidth requirements. The low interactive nature of this service and its high asymmetrical nature make requirements for transmission delay less stringent than other real time application.

Information, education, and entertainment services:

- Highly interactive services such as education, training and games
- Public information services such as tourist information and booking services, traffic information, route guidance and navigation
- Home shopping/banking
- Online media services such as newspapers and magazines
- Business information services such as stock data and business analysis reports online

These services are largely asymmetric and are characterized by low bit/rate requirements.

Personal communication services:

- Videotelephony, e.g. telemedicine (i.e. remote consultation)
- Videoconferencing, e.g. remote training
- Telemedicine

These are person-to-person services, where the uplink and the downlink bit rate tend to be equal (symmetric) and characterized by a moderate bandwidth request. These services have more stringent requirements on performances expressed in terms of delay and jitters.

Corporate Communication Services:

- LAN-LAN interconnect and Intranet access, for example, access to journalism database of video clips of news events
- Remote collaborative working, for example, the simultaneous development of architectural design or fashion design, and remote diagnostics

These are corporate communications which support key business processes and are, in general, asymmetric. These services can be both Real-Time and Non-Real-Time. Due to the wide range of its applications, this category includes several bit-rate and service requirements.

A.2 3G Service Classification: industry view and technical perspective

There are different ways to classify the services depending on the different parameters in consideration. Different standardization bodies and working groups have already identified 3G services and classified them in different ways. This clause explains the service classifications from UMTS Forum, ITU and 3GPP and tries to present them in a clearer form in order to remove the confusion between different methods of classifications.

Service classifications from UMTS forum, ITU and 3GPP are shown in figure A.3 with numbering I, II and III respectively. The first one (I) discriminates between basic mobile services and mobile multimedia services. The second one (II) distinguishes broadcast/multicast services and non-broadcast/multicast services. The third one (III) is based on a QoS characteristic, mainly the delay sensitivity. Each classification is discussed in detail below.

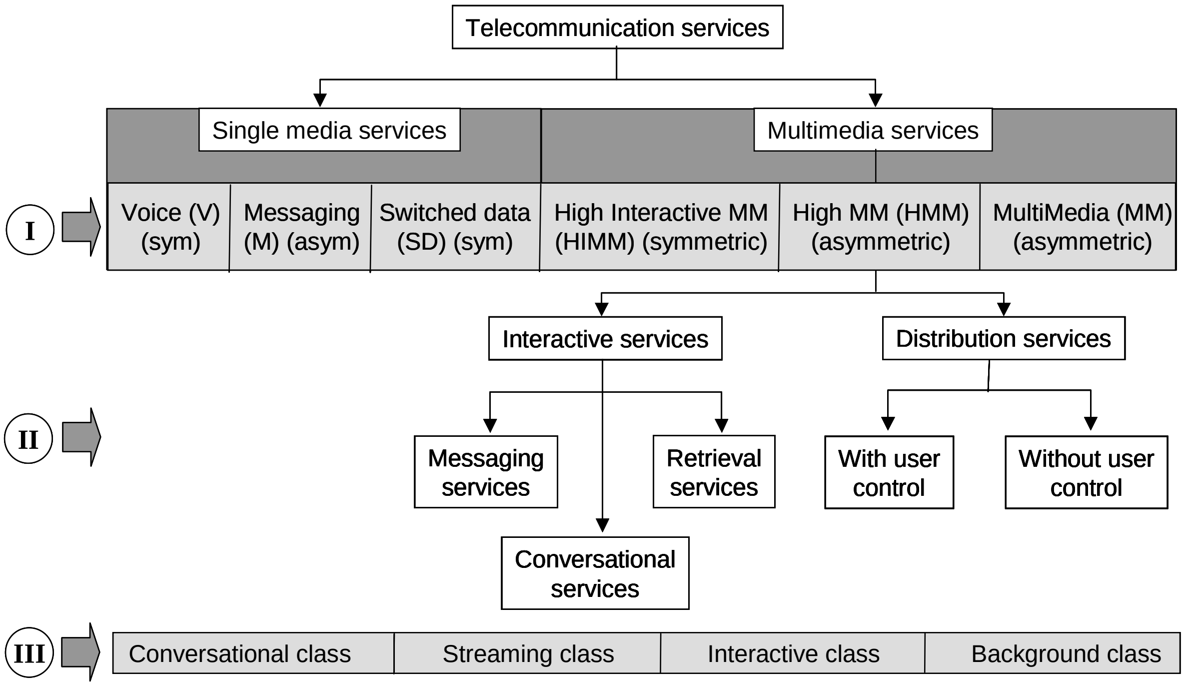


Figure A.3: 3G service classifications

A.2.1 UMTS Forum service classification

In UMTS forum report No. 8 [8], the services are divided into two main types called basic mobile services and mobile multimedia services. The first three service types mentioned below come under basic mobile services and the rest come under mobile multimedia services.

A.2.1.1 Basic mobile services

Voice (V): (symmetric)

- Simple one-to-one and one-to-many voice (teleconferencing) services
- Voicemail

Simple Messaging (M): (asymmetric)

- SMS (short message delivery) and paging
- Email delivery
- Broadcast and public information messaging
- Ordering/payment (for simple electronic commerce)

Switched Data (SD): (symmetric)

- Low speed dial-up LAN access
- Internet/Intranet access
- Fax

Legacy services - mainly using radio modems such as PCMCIA cards, are not expected to be very significant by 2005.

A.2.1.2 Mobile multimedia services

Medium Multimedia (MM): (asymmetric)

Asymmetric services, which tend to be "bursty" in nature, require moderate data rates, and are characterized by a typical file size of 0,5 Mbytes, with a tolerance to a range of delays. They are classified as packet switched services.

- LAN and Intranet/Internet access
- Application sharing (collaborative working)
- Interactive games
- Lottery and betting services
- Sophisticated broadcast and public information messaging
- Simple online shopping and banking (electronic commerce) services

High Multimedia (HMM): (asymmetric)

Asymmetric services, which also tend to be "bursty" in nature, require high bit rates. These are characterized by a typical file size of 10 Mbytes, with a tolerance to a range of delays. They are classified as packet switched services. Applications include:

- Fast LAN and Intranet/Internet access
- Video clips on demand
- Audio clips on demand
- Online shopping

High Interactive MM (HIMM): (symmetric)

Symmetric services which require reasonably continuous and high-speed data rates with a minimum of delay. Applications include:

- Video telephony and video conferencing
- Collaborative working and tele-presence

A.2.2 ITU service classification

Multimedia services are typically classified as interactive or distribution services. It should be noted, that this classification is also adopted by the ETSI S-UMTS working group.

A.2.2.1 Interactive services

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

Conversational services: They 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: They 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: They 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.

A.2.2.2 Distribution services

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

Distribution services without user control: They 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: They 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.

A.2.3 3GPP service classification

In 3GPP, the services are divided into four QoS classes (traffic classes) based on delay sensitivity TS 123 107 [20]. The first two classes, conversational and streaming classes are intended for real-time traffic and the remaining, interactive and background classes correspond to traditional internet applications such as, WWW, Email, Telnet, FTP and news.

Conversational services: Conversational class services are mainly for conversational real-time applications. The real time conversation scheme is characterized by the transfer time. The maximum transfer delay is given by the human perception of video and audio conversation. Therefore the limit for acceptable transfer delay is very strict.

Fundamental characteristics for QoS:

- Preserve time relation (variation) between information entities of the stream
- Conversational pattern (stringent and low delay)

Applications:

Voice, Videophone, Interactive games, Two-way control telemetry, Two-way control telemetry, Telnet.

Streaming Services: When the user is looking at (listening to) video (audio) the term streams applies. The real time data flow is always aiming at a live (human) destination. It is mainly a unidirectional stream with high continuous utilization (i.e. having few idle/silent periods.) It is also characterized by the fact that the time relations (variation) between information entities (i.e. samples, packets) within a flow must be preserved, although it does not have any requirements on low transfer delay.

Fundamental characteristics for QoS:

- Unidirectional continuous stream
- Preserve time relation (variation) between information entities of the stream

Applications:

Audio streaming, One-way video, Bulk data, Still image, Telemetry (monitoring), FTP, Paging.

Interactive Services: When the end-user, that is either a machine or a human, is on line requesting data from remote equipment (e.g. a server), this scheme applies. It is characterized by the request response pattern of the end-user. At the message destination there is an entity expecting the message (response) within a certain time. Round trip delay time is therefore one of the key attributes. Another characteristic is that the content of the packets must be transparently transferred (with low bit error rate).

Fundamental characteristics for QoS:

- Request response pattern
- Preserve payload content

Applications:

- Human interaction with the remote equipment - Voice messaging and dictation, Data, Web-browsing, High-priority transaction services (E-commerce), E-mail (server access).
- Machines interaction with remote equipment - Polling for measurement records and automatic data base enquiries (tele-machines).

Background classes: When the end-user - typically a computer - sends and receives data-files in the background, this scheme applies.

Fundamental characteristics for QoS:

- The destination is not expecting the data within a certain time
- Preserve payload content

Applications:

Facsimile, Background download of e-mails and files E-mails, SMS, calendar applications and reception of measurement records.

The summary of the 3GPP UMTS service classes and characteristics are given in table A.1. The detail characteristics are given in clause A.2.5.

Table A.1: 3GPP UMTS service classes and overall characteristics

Traffic class		Conversational class (delay << 1 sec)	Streaming class (delay < 10 sec)	Interactive class (delay ≈ 1 sec)	Background class (delay > 10 sec)
Fundamental characteristics		- Preserve time relation (variation) between information entities of the stream - Conversational pattern (stringent and low delay)	- Preserve time relation (variation) between information entities of the stream	Request response pattern Preserve payload content	Destination is not expecting the data within a certain time Preserve payload content
Application	Error tolerant	Voice, Video	Streaming Audio and Video	Voice messaging	Fax
	Error intolerant	Telnet, Interactive games	FTP, still image, paging	Web browsing, E-commerce	Arrival notification/ download of emails

A.2.4 Service Attributes

Depending on specific network requirements, several attributes can be used to characterize services and help classify them in a suitable fashion. Some of the important attributes are presented in the following.

A.2.4.1 Mobility

The mobility of the terminal influences greatly the maximum available bit rate. Mobility can be classified into three categories as follows:

- Low: static or pedestrian.
- Medium: terrestrial vehicle (car, low-speed train) or maritime environment.
- High: aircraft and high speed train.

A.2.4.2 Bit rate

Considering the behaviour of the traffic source (delivering constant/variable bit rate data streams) we have (similarly to ATM):

- Constant Bit Rate (CBR) sources.
- Variable Bit Rate (VBR) sources.

Current UMTS systems propose data rates up to 2 Mbit/s in both directions. Actually, the data rate depends on the mobility condition. This figure corresponds to a static or low mobility condition of the terminal with respect to the base station. It refers also to a condition of short distance to the base station. This corresponds typically to indoor and low range outdoor environments. Data rate as high as 384 kbit/s will be supported in other environments. UMTS further distinguish between urban/suburban outdoor and rural outdoor environment with achievable data rate of respectively 384 kbit/s and 144 kbit/s.

A.2.4.3 Topology

Depending on the nature of the service and users, multiple topologies can be considered:

- Point-to-Point (P-P).
- Point-to-Multipoint (P-MP).
- Multipoint-to-Multipoint (MP-MP).
- Broadcast (B).

A.2.4.4 Traffic symmetry

Traffic symmetry is frequently associated with interactivity. Most common highly interactive applications (e.g. telephony/video-telephony) rely on bi-directional symmetric connections, whereas low interactive applications (e.g. file transfer) generate asymmetric data-flows - short request messages and variable-length server answers. We define:

- Bi-directional Symmetric traffic (SYM).
- Bi-directional Asymmetric (ASYM).
- Unidirectional (UNI).

A.2.4.5 Interactivity

Regarding the degree of interactivity requested by the application, ranging from highly interactive (typically, all conversational services) to no interaction at all (i.e. passive services such as message broadcasting), we have:

- High Interactive (HI) Real Time (RT).
- Low Interactive (LI) Real Time, Quasi Real Time (QRT) or non-real-time (NRT) on-demand.
- Not Interactive (NI) services.

A.2.5 Characteristics of services

Based on the service classifications explained in clause A.2.3 and the attributes defined in clause A.2.4, the characteristics for the services are listed in tables A.2 and A.3.

Table A.2: Characteristics of UMTS Forum classified services

Type		Bit rate	Asymmetry Factor	Switch Mode
HIMM	High Interactive Multimedia	128 kbit/s	1/1	circuit
HMM	High Multimedia	2 000	0,005/1	packet
MM	Medium Multimedia	384	0,026/1	packet
SD	Switched Data	14	1/1	circuit
SM	Simple Messaging	14	1/1	packet
V	Voice	16	1/1	circuit

Table A.3: Characteristics of 3GPP classified services

Type	Medium	Application	Degree of symmetry	Data rate	Delay	Delay variation	Reliability
Conversational	Audio	Voice	Two-way	4 kbit/s to 25 kbit/s	< 150 ms	< 1 ms	< 3 % FER
	Video	Videophone	Two-way	32 kbit/s to 384 kbit/s	< 150 ms		< 1 % FER
	Data	Telemetry (control)	Two-way	< 28,8 kbit/s	< 250 ms		≈ 0 % FER
	Data	Interactive games	Two-way	< 1 kbit/s	< 250 ms		< 3 % FER
	Data	Telnet	Two-way	< 1 kbit/s	< 250 ms		< 3 % FER
Interactive	Audio	Voice messaging	Primarily one-way	4 kbit/s to13 kbit/s	< 1 s		< 3 % FER
	Data	Web browsing	Primarily one-way		< 4 s		≈ 0 % FER
	Data	e-commerce	Two-way		< 4 s		≈ 0 % FER
	Data	Email (server access)	Primarily one-way		< 4 s		≈ 0 % FER
Streaming	Audio	Streaming Audio	Primarily one-way	32 kbit/s to 384 kbit/s	< 10 s	< 1 ms	< 1 % FER
	Video	Video	One-way	32 kbit/s to 384 kbit/s	< 10s		< 1 % FER
	Data	Telemetry	One-way	< 28,8 kbit/s	< 10s		≈ 0 % FER
	Data	Blank data transfer/ retrieval	Primarily one-way		< 10s		≈ 0 % FER
	Data	Still image	One-way		< 10s		≈ 0 % FER

A.3 Services classification: The "User" perspective

UMTS Forum Report No. 9 [22] is proposing a different, "user" driven, way to classify the UMTS services. It is based on the following definition of "services" and "applications".

Services are the portfolio of choices offered by services providers to a user.

Services are entities that service providers may choose to charge for separately. They will be a prime differentiator between service providers in the 3G environment. Users are likely to select their preferred 3G service providers based on the options available in that product portfolio.

Applications are service enablers - deployed by services providers, manufacturers or users.

Applications are invisible to the user. They do not appear on a user's bill. A banking service, for example, would require a secure transaction application to be implemented by the service provider. A unified messaging service would require voice recognition and text-to-speech applications deployed on the network or in the terminal device. Individual applications will often be enablers for a wide range of services. The [22] study identifies six service categories that, according to the authors, represent the majority of the demand for 3G services over the next years. The six service categories are defined determinedly from a user perspective and are intended to reflect the perception of the market. Technological distinctions have been deliberately ignored in the service definitions. The compelling logic behind the six service categories (that are illustrated in figure A.4 and defined in the subsequent table) is that 3G will be an "always-on" data environment as opposed to the voice-centric environment that has dominated the mobile industry.

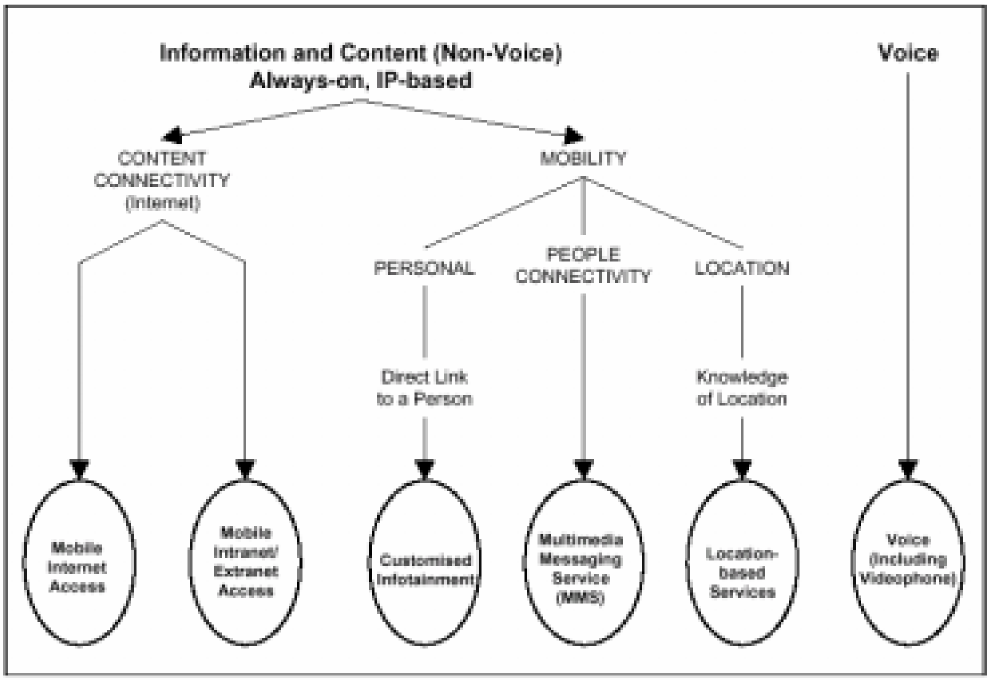


Figure A.4: Main categories of services in 3G environments - [22]

The service categories as described in [22] are:

- Mobile internet Access.
- Mobile Intranet/Extranet Access.
- Customized Infotainment.
- Multimedia messaging Service (MMS).
- Location based Service (LBS).
- Rich voice.

Table A.4: Services categories classification as per UMTS forum report (9)

Mobile internet Access	A 3G service that offers mobile access to full fixed ISP services with near-wireline transmission quality and functionality. It includes full Web access to the Internet as well as file transfer, email, and streaming video/audio capability.
Mobile Intranet/Extranet Access	A business 3G service that provides secure mobile access to corporate Local Area Networks(LANs), Virtual Private Networks (VPNs) and the Internet.
Customized Infotainment	A consumer 3G service that provides device-independent access to personalized content anywhere, anytime via structured-access mechanisms based on mobile portals.
Multimedia messaging Service (MMS)	A consumer/business 3G service, that offers non-real-time, multimedia messaging with always-on capabilities allowing the provision of instant messaging. The business service includes personalization, and user-to-user Networking. Targeted at closed user groups that can be services provider - or user/customer-defined.
Location based Service	A business and consumer 3G service that enables users to find other people, vehicles, resources, services or machines. It also enables others to find users, as well as enabling users to identify their own location via terminal or vehicle identification.
Rich voice (Voice, Video, and Multimedia Communications)	A 3G service that is real-time and two-way. It provides advanced voice capabilities (such as voice over IP (VoIP), voice-activated net access, and Web-initiated voice calls), while still offering traditional mobile voice features (such as operator services, directory assistance and roaming). As the service matures, it will include mobile videophone and multimedia communications.

History

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V1.2.1	September 2002	Publication