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Satellite Earth Stations and Systems (SES); Combined Satellite and Terrestrial Networks scenarios

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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).

1 Scope

The present document aims at clarifying the notion of "integrated" or "hybrid" satellite and terrestrial communication networks for the delivery of FSS, BSS or MSS. These terms are now widely used in regulatory bodies, research communities as well as among business stakeholders. It provides a general view on systems combining a satellite communication component with another communication component which may be useful in the context of future networks including Future Internet.

"Integrated Terrestrial and Satellite networks" or "Hybrid Terrestrial and Satellite networks" refers to a general definition of networks combining *one or more satellite communication system(s) and one or more terrestrial wireless or wireline communication system(s).*

In the present document:

- Firstly, definitions and classification of scenarios combining satellite networks a well as terrestrial networks are proposed.
- Secondly, the rationale for combining both types of component is recalled.
- Thirdly, network scenarios of combined satellite/terrestrial components are listed and described in light of targeted services, architecture and characteristics in terms of level of interactions, operational dependencies and respective capabilities between the network components.
    - Note that detailed payload and system architectures are not described in the present document. It refers to existing or planned solutions and standards or future research areas.
- Fourthly, network scenarios of combined satellite/satellite components are described.
- Last, introduction to "systems of systems" combining satellite communication with other satellite application systems are presented.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

2.1 Normative references

The following referenced documents are necessary for the application of the present document.

Not applicable.

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI EN 302 583: "Digital Video Broadcasting (DVB); Framing Structure, channel coding and modulation for Satellite Services to Handheld devices (SH) below 3 GHz".

[i.2] ETSI EN 302 550 (all parts): "Satellite Earth Stations and Systems (SES); Satellite Digital Radio (SDR) Systems".

[i.3] ETSI EN 303 105: "Digital Video Broadcasting (DVB); Next Generation broadcasting system to Handheld, physical layer specification (DVB-NGH)".

[i.4] ETSI TS 101 376-1-3: (V3.x.y): "GEO-Mobile Radio Interface Specifications (Release 3); Third Generation Satellite Packet Radio Service; Part 1: General specifications; Sub-part 3: General System Description; GMR-1 3G 41.202".

[i.5] ETSI TS 123 101: "Universal Mobile Telecommunications System (UMTS); General Universal Mobile Telecommunications System (UMTS) architecture (3GPP TS 23.101)".

[i.6] ETSI TS 100 500: "Digital cellular telecommunications system (Phase 2+); Principles of telecommunication services supported by a GSM Public Land Mobile Network (PLMN) (GSM 02.01)".

[i.7] ETSI TS 136 101: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception (3GPP TS 36.101)".

[i.8] "Ericsson Satellite Backhaul".

NOTE: http://www.ericsson.com/ourportfolio/telecom-operators/satellite-backhaul.

[i.9] ETSI TS 102 796: "Hybrid Broadcast Broadband TV".

[i.10] ETSI EN 302 307: "Digital Video Broadcasting (DVB); Second generation framing structure, channel coding and modulation systems for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications (DVB-S2)".

[i.11] ETSI TS 101 376-1-2 (V2.x.y): "GEO-Mobile Radio Interface Specifications (Release 2) General Packet Radio Service; Part 1: General specifications; Sub-part 2: Introduction to the GMR-1 family; GMPRS-1 01.201".

[i.12] ETSI TS 101 376-1-2 (V1.x.x): "GEO-Mobile Radio Interface Specifications (Release 1); Part 1: General specifications; Sub-part 2: Introduction to the GMR-1 family ; GMR-1 01.201".

[i.13] ETSI TS 143 064: "Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Overall description of the GPRS radio interface; Stage 2 (3GPP TS 43.064)".

[i.14] ETSI TS 123 110: "Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS); LTE; Universal Mobile Telecommunications System (UMTS) access stratum; Services and functions (3GPP TS 23.110)".

[i.15] Broadband speedchecker.

NOTE: http://www.broadbandspeedchecker.co.uk/guides/adsl_and_distance.aspx.

3 Definitions and abbreviations

3.1 Definitions

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

broadcast service: communication capability which denotes unidirectional distribution from a single source to an unspecified number of access points

multicast service: communication capability which denotes unidirectional distribution from a single source to a number of specified destination access points

telecom service: communication capability which denotes bi directional communication between two access points

3.2 Abbreviations

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

ADSL	Asymmetric Digital Subscriber Line
AS	Access Stratum
ATC	Ancillary Terrestrial Component
BSS	Broadcast Satellite Service
CDM	Code Division Multiplexing
CDN	Content Delivery Network
CGC	Complementary Ground Component
CMBB	China Mobile Multimedia Broadcasting
DFN	Dual Frequency Network
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Access Multiplexer
DVB-SH	Digital Video Broadcasting - Satellite Handheld
EGNOS	European Geostationary Navigation Overlay Service
ESDR	ETSI Satellite Digital Radio
FSS	Fixed Satellite Service
GEO	Geostationary Earth Orbit
GMR	GEO-Mobile Radio
GPRS	General Packet Radio Service
GSM	Global System for Mobile communications
HD	High Definition
HDTV	High Definition TeleVision
HW	Hardware
IPTV	Internet Protocol TeleVision
LAN	Local Area Network
LEO	Low Earth Orbit
LTE	Long Term Evolution
MSS	Mobile Satellite Service
NAS	Non Access Stratum
OFDM	Orthogonal Frequency Division Multiplexing
PEP	performance Enhancing Proxy
QoS	Quality of Service
SACK	Selective ACKnowledgement
SC-FDM	Single Carrier Frequency Division Multiplexing
SCN	Satellite Communications and Navigation Working Group (ETSI)
S-DMB	Satellite Digital Multimedia Broadcasting
SDTV	Standard Definition TeleVision
SFN	Single Frequency Network
STIMI	Satellite and Terrestrial Interactive Multiservice Infrastructure
SW	Software
SW	SoftWare
TCP	Transport Control Protocol
TDM	Time Division Multiplexing
TTA	Telecommunications Technology Association
UAV	Unmanned Aerial Vehicle
UDLR	Unidirectional Link Routing
UMTS	Universal Mobile Telecommunication Service

4 Rationales for combining Satellite and Terrestrial Communication Systems

There is an increasing interest to combine satellite and terrestrial components to form a single telecom network, a "network of networks". There may be one or several objectives or added value associated to the resulting combined network compared to a standalone satellite component among the following.

Table 1: Main drivers for combining satellite with terrestrial networks

Main drivers for combining satellite with terrestrial networks	Possible satellite network roles
Service coverage extension	Address maritime, rural and low density populated areas Aeronautical/UAV communications
Broader range of service provisioning and/or lower costs for customers and operators	Broadcast/multicast capabilities for off-loading video based traffic or other high bandwidth traffic, location based services in exurban areas
Rapid and/or infrastructure independent service deployment	Backhaul solution (fixed or mobile), military communications, disaster recovery
Increase the Quality of Service (QoS) delivered to the operators and end-users alike	Complement terrestrial based Internet access technology with satellite to deliver higher speed broadband service (especially in low density populated areas) by pooling both satellite and terrestrial network resources together so that the service may be enriched
Increased service availability and/or resilience	Doubling of critical communication link, path diversity, fade mitigation. Moreover, the terrestrial and satellite component signals can be combined together to achieve diversity gains (different combining schemes are possible)

Some additional benefits may result from the use of satellite in combination with a terrestrial component:

- Optimization of the operational/overall investment cost when deploying a new service.
- Optimization of the energy required for conveying information to recipients by taking advantage of the broadcast/multicast capability of the solar powered satellite infrastructure.

When combining satellite and terrestrial components, it is expected that the user will benefit from services delivered via both type of components.

The interactions between the satellite and the terrestrial networks may take place at different levels:

- Terminal: access to one component (e.g. backhaul scenarios) or to both types of components (e.g. integrated, hybrid or dual mode scenarios)
- Spectrum: possible sharing of the same spectrum chunk by both satellite and terrestrial components (same or distinct frequency bands)
- Network: pooling of satellite and terrestrial components resources or cascading the components (e.g. backhaul)
- Service level: unifying service delivery via both satellite and terrestrial components
- Application level: defining new applications that take advantage of the specifics of satellite and terrestrial networks

Each stakeholder of such network will mostly be concerned by different aspects:

- Regulators: spectrum optimization and service typology, interference identification and resolution
- End-Users: improved and seamless service access, device ecosystem, subscription fees
- Operators and Service Providers: cost optimization, service differentiation and control of the subscriber, deployment strategy and ancillary services
- Terminal Vendors: HW/SW commonality and reuse
- Network Vendors: equipment synergy

Referring to the ITU-R activity (WP4B) for what concerns integrated and hybrid systems, which are related to the concept proposed here of combined systems, the following definitions have been adopted by ITU-R:

> Integrated MSS system:
>
> "System employing a satellite component and a ground component where the ground component is complementary to the satellite component and operates as, and is, an integral part of the MSS system. In such systems, the ground component is controlled by the satellite resource and network management system. Further, the ground component uses the same portions of MSS frequency bands as the associated operational mobile-satellite system."
>
> Hybrid Satellite/Terrestrial System:
>
> "System employing satellite and terrestrial components where the satellite and terrestrial components are interconnected, but operate independently of each other. In such systems the satellite and terrestrial components have separate network management systems and do not necessarily operate in the same frequency band."

The main difference between integrated and hybrid systems is on whether both space and terrestrial parts use a common network and spectrum. The terrestrial part of an integrated system is a complementary part of the satellite system, and thus it uses the same frequency band allocated to the satellite system and also it is operated by the same network. Such systems are referred to as MSS-ATC (MSS-Ancillary Terrestrial Component) in the United States and Canada, and MSS-CGC (MSS-Complementary Ground Component) in Europe and are implemented in the 1 GHz to 3 GHz bands. On the other hand, a hybrid system may combine a satellite system with a terrestrial one with different frequency bands, networks, and even air interfaces.

Such definitions of integrated and hybrid systems are unbalanced given that the first one relates to a very specific network scenario and service, while the other encompass many other network scenarios combining satellite and terrestrial components. It is suggested to define "Combined satellite/terrestrial network" as:

"*A combined Satellite/terrestrial network is a system employing a satellite component and a terrestrial component to deliver a service set towards its end-users/subscribers. Both components may be controlled by the same network management system and possibly use the same portions of frequency band allocation.*". *The satellite component may operate in parallel to the terrestrial component or may operate as backhaul to the terrestrial component from the end-user terminal point of view*".

Combined Satellite/terrestrial networks can be classified into parallel and backhaul combinations as follows (illustrated in figure 1):

- Networks combining a satellite component and a terrestrial component in **parallel**. This includes:
    - Integrated satellite/terrestrial network characterized by a **unique** spectrum allocation, network management system and tight operational dependencies for both a satellite component and another component (terrestrial or satellite).
    - Hybrid satellite/terrestrial network characterized by the delivery of a service using **simultaneously** a satellite component and another component (terrestrial or satellite).
    - Dual mode satellite/terrestrial network in which a terminal is able to provide a telecom service **either** via a satellite component or another independent component (terrestrial or satellite).

NOTE: These definitions do not specify whether terminals select either the satellite or the terrestrial component or combine both. They also do not specify whether the combined satellite/terrestrial network implements the same or different transmission technology on both components.

- Networks combining a backhaul satellite component and a terrestrial component. This includes:
    - Satellite backhaul to terrestrial network: to ensure the connectivity between a remote terrestrial local area network and the backbone network

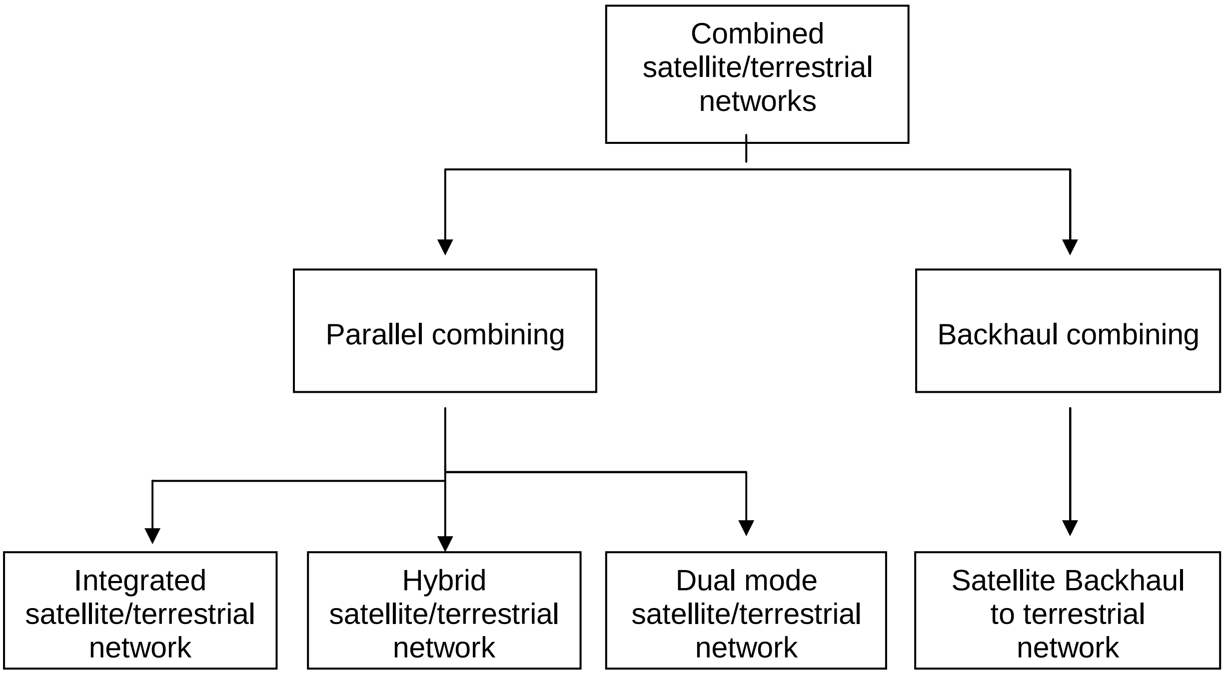

Figure 1: Proposed Combined satellite/terrestrial network scenarios classification

Note that a further classification breakdown could be envisaged distinguishing between:

- scenarios combining satellite broadcast network component and a terrestrial network component; and
- scenarios combining satellite access network component and a terrestrial network component.

5 Network scenarios combining Satellite and Terrestrial communication components

There are several ways to combine satellite and terrestrial communication components. Combined satellite and terrestrial communication scenarios are distinguished by:

- The nature of the satellite link: unidirectional or bi-directional link.
- The type of terminals implementing both satellite and terrestrial technologies:
  - Mobile satellite service terminals typically operating in the MSS frequency bands and characterized by less precise pointing of the antenna. Types of terminal include handportable, nomadic and vehicle mounted.
  - Fixed satellite service terminals typically operating in the FSS frequency bands and characterized by more precise pointing of the antenna. Types of terminals include both fixed platforms (e.g. buildings, towers) and mobile platforms with tracking capabilities (mechanical, electronical or mix of the 2 approaches). Example of mobile platforms include vessels, trains, aircraft and other land vehicles.
- The type of service offered by the satellite component:
  - Broadcast; the satellite network is used in the forward direction only to provide broadcast services directly to the terminals.
  - Access; the satellite network is used in both forward and return directions to provide services directly to the terminals.
  - Backhaul; the satellite network is used in both directions to provide bulk connectivity to a terrestrial network element (e.g. to a cellular base station or to a local area network, etc.).

- Content delivery network (CDN); the satellite network is used to distribute/replicate multimedia content towards multiple data centres in a terrestrial transport network. (This may require broadcast, multicast or unicast resources).

5.1 Satellite component used as an access technology

The satellite component may target mobile (handportable, nomadic and vehicle mounted) or fixed terminals. The same satellite component may target a plurality of terminal types.

5.1.1 Satellite component used for broadcast services; Network targeting portable terminals

Description

The satellite network operates only in the forward direction to broadcast information to a portable terminal (handportable and nomadic). The same terminal can also access a terrestrial cellular network to access other services.

Rationale and satellite added value

Extensive work has been undertaken to develop and deploy systems combining a satellite and a terrestrial component to broadcast media content including radio and TV programs, to vehicular or even handheld devices.

While the terrestrial component (unidirectional) ensures good broadcast service coverage in urban and suburban areas including indoor, the satellite component aims at extending the service coverage in exurban and rural areas for vehicular mounted or even handheld devices but in outdoor conditions.

Both components combined enable to provide a continuous coverage between both types of areas for an enhanced service availability.

Architectural Principles

The terrestrial component is typically made of transmitters that provide cell pattern coverage; in this sense we can consider both terrestrial base stations and repeaters. The coverage range around a transmitter can reach up to tens of km depending on the frequency bands and the associated regulatory constraints. Given that new sites are difficult to acquire, transmitters are expected to be co located with either existing TV or radio broadcast transmitters or with existing cellular base stations.

The satellite component is usually based on GEOstationary or even on High Elliptical Orbit satellites embarking large deployable reflector. The satellites are either generating mono beam but may also generate multi beam for linguistic service coverage.

The preferred spectrum is a frequency band allocated to Mobile Satellite Services (MSS) in L (1,5 GHz and 1,6 GHz) or S band (1,9 GHz and 2 GHz). This allows reception of the broadcast signals by a device equipped with an omni directional antenna.

Each end user terminal should be able to receive both satellite and terrestrial signals for smooth service continuity over the coverage and to allow combining terrestrial and satellite signals when both have acceptable quality in order to achieve diversity gains (e.g. Space-Time Coding).

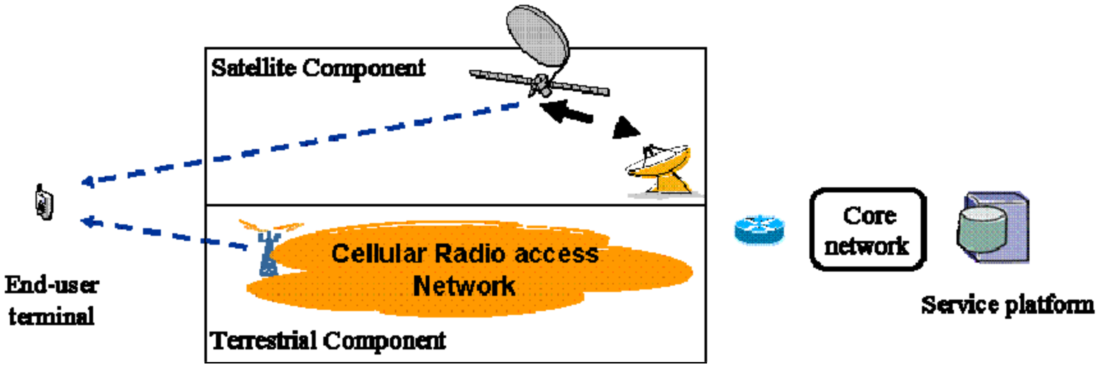

Figure 2: Uni-directional satellite link and mobile terminals

Satellite/terrestrial Integration Issues

The combining scenarios targeting mobile terminals need to take the respective design constraints associated to both terrestrial and satellite components into account.

Table 2: Cellular versus Mobile satellite systems design issues

Design issues	Cellular Systems	Mobile Satellite Systems
Radio link	Primarily limited by the intra cell interferences	Primarily limited by the available power on board and terminal performance
Attenuation	Rayleigh fading proportionate to the distance from base station (< 15 km)	Rice fading proportionate to the free space path
Topology	Cell pattern, up to a few km in diameter	Beam pattern, hundreds of km diameter
Delay spread	Mostly < tens of µs (typical symbol duration)	< few µs (1/10 symbol duration)
Transmission	Unsynchronized base stations	Satellite or the gateway is the clock reference
Regulations	Radio exposure associated to antenna site, more stringent in populated areas. Spectrum scarcity due to traffic growth.	Spectrum scarcity due to traffic growth, Power flux density
Round Trip Time	High ~ 500 ms (e.g. for GPRS networks) Low < 50 ms (e.g. for LTE networks)	High ~ 500 ms for GEO systems. Low (< 50 ms) for LEO systems

Typically, the usage and QoS constraints also differ.

Table 3: Cellular versus Mobile satellite systems usage and QoS

	Cellular systems	Mobile Satellite Systems
Usage	Service outdoors and in most indoor environments	Service mainly outdoors
QoS	Possibly degraded in specific coverage areas or environments	Possibly degraded for certain real time applications due to high latency (for geo stationary satellite systems) and/or in specific coverage areas (shadowing)

There are 2 main integration options for broadcast services:

- Dual Frequency Network (DFN): The terminal receives 2 different carriers transmitted respectively by the satellite and terrestrial components. This allows optimizing the performance of both components taking into account the respective propagation channel characteristics.
- Single Frequency Network (SFN): The terminal receives a single carrier transmitted simultaneously by both the satellite and terrestrial components thanks to a tight synchronization scheme. This enables to reduce the complexity of the terminal with the need to embark a single reception chain.

In addition, it may be possible to combine a broadcast service via both satellite and terrestrial component with two way communication services delivered via the terrestrial component only.

Example of Systems and Standards

Several standards exist although fewer systems are operational.

Table 4: Examples of Satellite systems

Systems	Standard	Architecture option	Satellite radio interface	Terrestrial radio interface
Sirius XM™	Proprietary technology	DFN	TDM	OFDM
S-DMB-TTA	Proprietary technology	SFN	CDM	CDM
ICO MIM™	ETSI standard: DVB-SH [i.1]	DFN or SFN	TDM or OFDM	OFDM
CMBB	STIMI	SFN	TDM or OFDM	OFDM
-	ETSI standard: ESDR [i.2]	DFN or SFN	TDM or OFDM	OFDM
-	ETSI standard: DVB-NGH [i.3]	DFN or SFN	SC-FDM	OFDM
NOTE: Above mentioned trade names of respective companies are given for the convenience of users of the present document and does not constitute an endorsement by ETSI of the product named. Equivalent products may be used if they can be shown to lead to the same results.				

In most cases, terminals are designed to receive the broadcast signals and operate on cellular network.

5.1.2 Satellite component used for telecom services; Network targeting portable Terminals

Description

The satellite network operates in both forward and return directions to provide an alternative access network for a portable terminal. The same terminal can also access a terrestrial cellular network to access the same or other services.

Rationale and satellite added value

Network concepts combining a satellite and a terrestrial component to provide anytime and anywhere connectivity from mobile devices (e.g. vehicular mounted or even handheld) have emerged in the last 10 years.

Similar to the broadcast service scenarios, in the telecom service scenarios the terrestrial component is expected to ensure good service coverage in urban and suburban areas including indoor, while the satellite component aims at extending the service coverage in exurban and rural areas.

Both combined enable to provide a continuous coverage between rural and urban areas.

Architectural Principles

The satellite component is usually based on GEO stationary satellites embarking large deployable reflector. The satellites are typically generating multi beam to maximize the throughput with frequency re-use techniques.

The preferred spectrum for the satellite component is a frequency band allocated to Mobile Satellite Services (MSS) in L (1,5 GHz and 1,6 GHz) or S band (1,9 GHz and 2 GHz). This allows operation of terminal device equipped with omni-directional antenna; e.g. vehicular or handheld terminals.

The terrestrial component is typically made of base stations. Site co-location with existing cellular base stations is expected. More TV or radio channels may be transmitted via the terrestrial than via the satellite component due to power and spectrum limitations.

In all cases, the satellite terminal should be able to operate on both satellite and terrestrial component for smooth service continuity over the coverage. Typically the terrestrial component, when available, will be preferred given scarcity of resources on the satellite component. For specific interactive Multicast/Broadcast services, the satellite can be preferred for the forward link while the terrestrial component is used for issuing service requests.

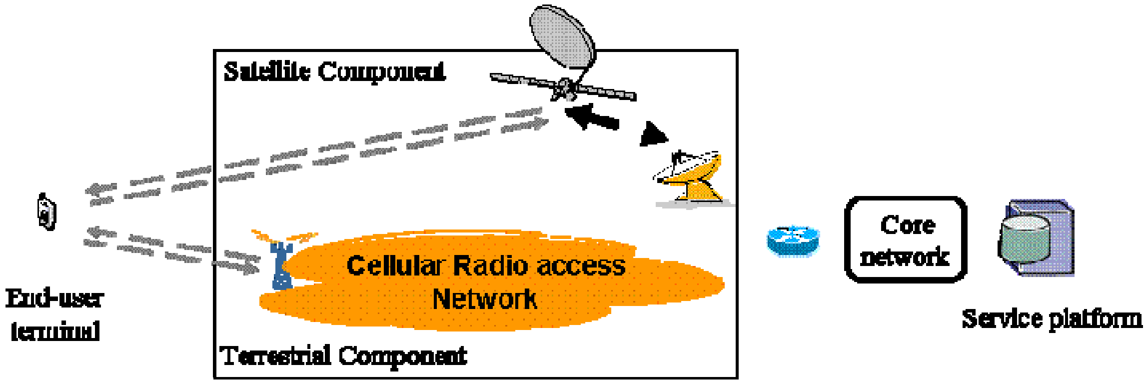

Figure 3: Bi-directional satellite link and Mobile terminals

Satellite/terrestrial Integration Issues

The integration options differ depending on the level of integration between both components.

Table 5: Integrated versus non integrated satellite/terrestrial network

Aspect of integration	INTEGRATED	NON-INTEGRATED
Terminal	Satellite and terrestrial components are **coupled;** i.e. integrated at application layer and at lower layers (e.g. Non Access Stratum NAS and/or Access Stratum AS)	Satellite and terrestrial components are **independent;** i.e. Integration at application level only
Service	Satellite and terrestrial components deliver the **same** types of services to the terminal (or subset of the same type of service)	Satellite and terrestrial components deliver **different** types of services to the terminal
System/network (note)	Satellite and terrestrial components are **coupled** at NAS and/or AS level. **and** Satellite and terrestrial components have **coupled** network management	Satellite and terrestrial components are **independent** at Non Access Stratum (NAS) and/or Access Stratum (AS) level**;** **and/or** Satellite and terrestrial components have **independent** network management
Spectrum allocation	Satellite and terrestrial components operate in the **same** spectrum * Either with coupled radio resource management (planned or dynamic) * Or simply coordinated	Satellite and terrestrial components operate in **separate** spectrum
NOTE: The terms Non Access Stratum (NAS) and Access Stratum (AS) refer to the architecture terminology defined by 3GPP. See TS 123 101 [i.5] and TS 123 110 [i.14].		

Example of Systems and Standards

3 systems are currently operational or under deployment.

Table 6: Examples of satellite systems

Systems	Integration option	Satellite radio interface	Terrestrial radio interface
Thuraya™	Integration at terminal level only	GMR-1 (Rel 1) [i.12] GMPRS-1 (Rel 2) [i.11]	GSM [i.6] GPRS [i.13]
LightSquared™/ SkyTerra™	Integration at terminal, service, system/network levels and spectrum (L band)	GMR-1 3G [i.4]	UMTS [i.5] or LTE [i.7]
Terrestar™	Integration at terminal, service, system/network levels and spectrum (S band)	GMR-1 3G [i.4]	UMTS [i.5] or LTE [i.7]
NOTE: Above mentioned trade names of respective companies are given for the convenience of users of the present document and does not constitute an endorsement by ETSI of the product named. Equivalent products may be used if they can be shown to lead to the same results.			

In the context of IMT-advanced systems, China and Korea are both defining systems using the same radio interface (LTE based) for both satellite and terrestrial components. Furthermore, the systems are expected to achieve an integration of both components at terminal, service, system/network levels and spectrum.

5.1.3 Satellite component used for broadcast services; Network targeting fixed Terminals

Description

The satellite network operates only in the downlink direction to broadcast information to a fixed terminal. The same terminal can also access a terrestrial network (fixed or mobile) to access other services.

Rationale and satellite added value

The performance of most "terrestrial based" fixed internet access technologies (e.g. DSL or radio) is distance sensitive. The maximum available bandwidth will decrease as the distance from the access node (e.g. DSLAM, Radio base station) increases (see annex A).

Combining a satellite broadcast link to a "terrestrial based" fixed internet access (e.g. DSL) technologies is considered to offload part of the video traffic to the satellite link especially for subscribers in exurban and rural areas where the distance from the access node may frequently exceed 3 to 4 km. This enables to offer a triple play service (including TV) to 100 % of ADSL subscribers without having to dense the grid of the terrestrial network in the low density populated areas where deployment cost are excessive in regards to the revenue perspective. In addition, satellite better supports asymmetric consumption of rich content and other data heavy applications. There is much more traffic on the downlink than on the uplink in traditional Internet usage.

Architectural principles

The terrestrial component is typically made of wireline (e.g. ADSL) or wireless access nodes (e.g. Wifi/Wimax, cellular networks).

The satellite component is usually based on GEO stationary satellites providing broadcast/multicast services. The satellites may generate single or multi beams.

The preferred spectrum is frequency bands allocated to Fixed or Broadcast Satellite Services (FSS or BSS) in Ku or Ka band.

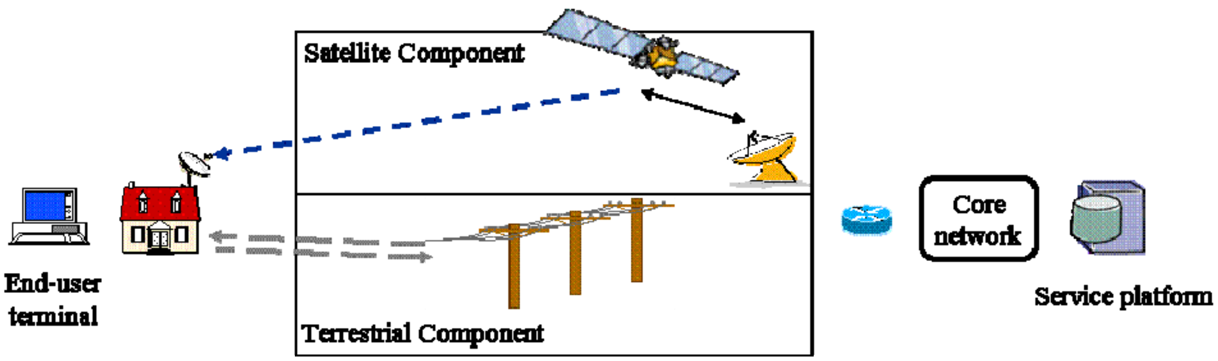

Figure 4: Unidirectional satellite link and Fixed terminals

Satellite/terrestrial Integration Issues

A first integration option consists in a distinction of service offer on both components. TV or video based services via satellite and Internet services via the terrestrial component. While both traffics have to be combined at the user premises, the traffic sources for both components may be independent.

A second integration option consists in the delivery of Internet access via a satellite broadcast link together with a very low data rate terrestrial link such as GPRS using the UDLR protocol (Unidirectional Link Routing). This was developed about ten years ago. It provides a capability for service interactivity but limited.

A third integration option, consists in aggregating the bandwidth of the satellite broadcast component and of the forward link of the terrestrial component to enhance the broadband experience of users. Video content is predicted to dominate the other type of Internet traffic (including web browsing, file transfer, telephony, messaging, etc.). A large part of this video content traffic may correspond to downloads which could be delivered via satellite via smart push and store mechanisms (e.g. caching techniques). The satellite will be used to offload delay insensitive traffic from the DSL or the radio internet access. This scheme requires to dispatch/combine the traffic between the Internet access and the satellite broadcast link. Specific routers may need to be deployed at the satellite gateway and the STBs (Set Top Boxes).

Example of Systems and Standards

First integration option: In Europe, Deutsche Telekom (t-entertainment service) and SFR are currently offering a triple play service including HD TV thanks to an ADSL access and satellite reception. The satellite downlink is used to deliver TV channels to complement the basic Internet service provided by the ADSL connection. The ETSI HbbTV standard (Hybdrid Broadcast Broadband, TS 102 796 [i.9]) with a DVB-S(2) [i.10] interface to access broadcast service can be used to enrich the multimedia service offer with interactivity and personalization.

Second integration option: Limited deployment has occurred for specific applications like adverts in shops of the same organization throughout a country.

Third integration option: Area for Research.

5.1.4 Satellite component used for telecom services; Network targeting fixed Terminals

Description

The satellite network operates in both the uplink and downlink directions to provide Access Network services to a fixed terminal. The same terminal can also access a terrestrial network (fixed or mobile) to access the same or other services.

Rationale and satellite added value

Similarly to the previous scenario, the satellite component aims at boosting the service delivered by the terrestrial based access technology in low density populated areas (ex urban or rural areas) or in hostile environments. Targeted users are firstly residential/professional users (generic Internet access). At a longer term, interconnection of any kind of communicating objects (Internet of Things) and Machine-to-Machine communications (M2M) are expected to increase and, for some scenario, to require satellite (surveillance service, sensor monitoring, etc.)

Adding a satellite bi directional link enables a greater flexibility in routing the traffic between both components while it ensures a higher resiliency towards potential interruption of service on the terrestrial access link (Typically up to several days or weeks of disruptions).

Architectural aspects

The terrestrial component is typically made of wireline or wireless access nodes.

The satellite component is usually based on GEO stationary satellites. The satellites generate multi beams to maximize the throughput with frequency reuse scheme.

The preferred spectrum is frequency bands allocated to Fixed Satellite Services (FSS) in Ka band or higher.

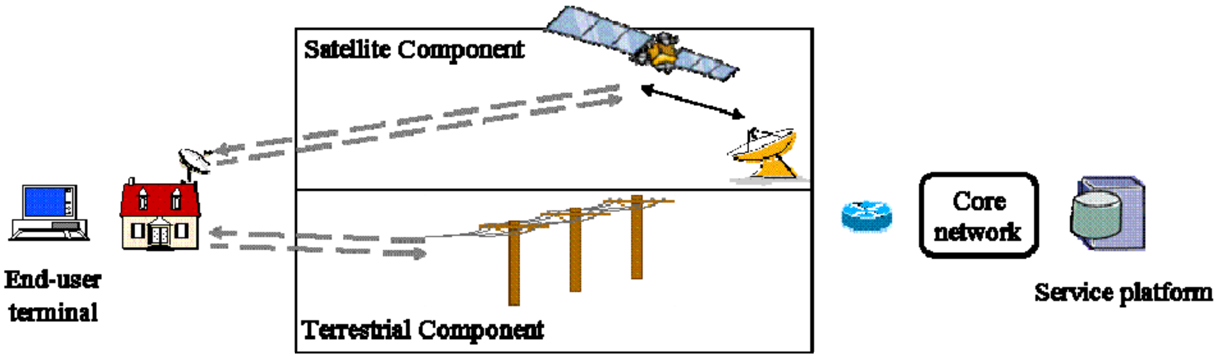

Figure 5: Bidirectional satellite link and Fixed terminals

Satellite/terrestrial Integration Issues

The following scheme refers to an example of a hybrid satellite/terrestrial network.

Typically the two components have varying QoS capability (satellite high bandwidth and long latency; terrestrial narrow bandwidth and low latency). The scheme can then dynamically route the traffic according to the QoS or the operational requirements of the applications. QoS includes service requirements to meet (different set of rate/delays/loss required for different service), and operational adjustments to adapt to varying conditions (variable resource available at system level, variable SNR/rates per user link).

This scheme requires to route the traffic between the "terrestrial based" Internet access and the satellite broadband access and then re combine. Specific routing functions need to be deployed before the satellite gateway and after the satellite terminal at the user premises location.

With such scheme, the long latency associated to the satellite link does not anymore degrade the Quality of experience. It enables to ensure to the users a high Quality of Experience similar to the one on optical fibre access. However some Transport layer adaptations might be needed to optimize the dual-path utilization in terms of congestion control (modification of available resources due to varying traffic loads and to physical channel variations - fading on satellite channel).

NOTE: A number of techniques have been developed to minimize the impact of the long latency on most internet application (e.g. PEP, large windows, SACK, different flavours of TCP, etc.).

Even "gaming" the most challenging application via satellite could be experienced with high quality. Video context information could be delivered via the "fat" satellite channel while all command and controls would be routed to the "thin" terrestrial channel.

Example of Systems and Standards

Area for research (e.g. FP7 BATS research project, see http://www.batsproject.eu/).

5.2 Satellite component used as a backbone technology

5.2.1 Satellite component used for the backhauling of Local Area Network

Description

The satellite network operates in both forward and return direction to provide connectivity to a ground-based network component. The ground based component may be either a fixed platform (buildings or masts) or may be a moving platform (ships, trains, aeroplanes or other vehicles).

Rationale and satellite added value

As detailed by some telecom vendors [i.8], providing voice and data services everywhere is a key requirement for today's service providers. Satellite Backhaul extends the ability to provide these services to difficult or cost-prohibitive areas and segments, including:

- Where topography or distance restricts connection to mobile networks
- Temporary hot spots such as concerts, exhibitions or sporting events
- Disaster areas where emergency communications are needed
- Cruise ships, maritime shipping, oil rigs, and motorized transport, such as commercial trucking
- Aeronautical and railway passenger transports
- Military communications with backhauling of isolated networks deployed in theatre of operation (involving fixed as well as mobile end-users)

The satellite is used to interconnect local area networks, be they, wireless (wifi, cellular or even ad hoc networks) or wireline (Ethernet-based).

Architectural principles

The terrestrial component is typically made of wireline or wireless access nodes.

The satellite component is usually based on GEO stationary satellites. The satellites may generate single or multi beams.

The preferred spectrum is frequency bands allocated to Fixed or Broadcast Satellite Services (FSS) in C, Ku or Ka band but it can also be achieved in L or S band.

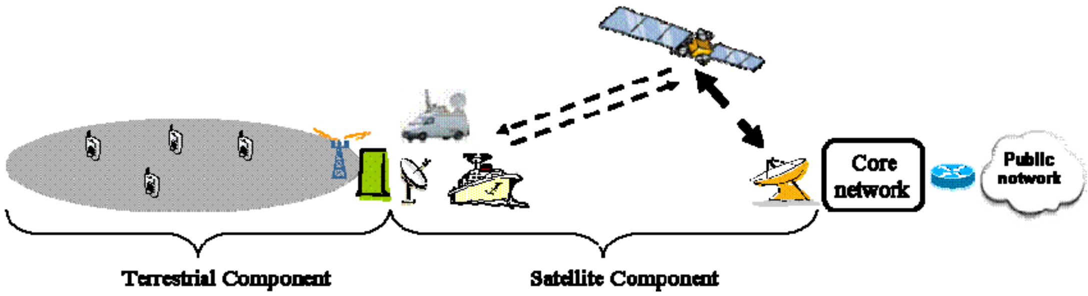

Figure 6: Mobile backhauling of local area network (LAN; e.g. local cellular access network)

Satellite/terrestrial Integration Issues

The challenge is to reduce the bandwidth usage over satellite to reduce the operating cost as much as possible using for example compressing techniques.

In order to prevent a degradation of QoS caused by a double satellite hop, direct connections between users in the "same" remote local area network can be established with local routing functions.

Example of systems and standards

Several solutions are commercialized, the most frequent one being the backhauling of GSM cells at the Abis interface (Interface between the Base Station Controller and the Base Stations Transceivers see [i.6]).

5.2.2 Satellite component used for Content Delivery

Rationale and Satellite Added Value

A content delivery network (CDN) aims at distributing/replicating multimedia content towards data centres in the transport network so that the content is served to end-users with higher service availability and performance by avoiding the effect of a website becoming virtually unreachable because too many people are hitting it or reducing the general load on websites servers in general. CDN is also a mean to lessen the demands on the network backbone and to reduce infrastructure investments: in effect CDNs allow to trade transmission for storage, taking advantage of the diminishing cost of network storage.

CDNs serve a large fraction of the Internet content today, including web objects (text, graphics, URLs and scripts), downloadable objects (media files, software, documents), applications (e-commerce, portals), live streaming media, on-demand streaming media, and social networks.

With the increase of data centres and their deployment further to the networks' edges, the inherent cost effective multicast/broadcast capability of satellite becomes more relevant for CDNs as a complement to terrestrial component.

Satellite systems can be used efficiently in CDN networks to feed CDN servers and caches thanks to multicasting. The benefits of using satellites include the transport of high volumes of bulk data, between any CDN nodes located within the satellite coverage in a single satellite hop.

A secondary advantage is that it can also offload terrestrial networks so that they can handle more easily short haul connections requiring small delays (time-sensitive services).

Architectural principles

The terrestrial component is typically made of wireline/wireless transport/access networks with data centres to distribute the content directly to fixed and mobile end users.

The satellite component is usually based on GEO stationary satellites. The satellites may generate single or multi beams.

The preferred spectrum is frequency bands allocated to Fixed or Broadcast Satellite Services (FSS or BSS) in C, Ku or Ka band.

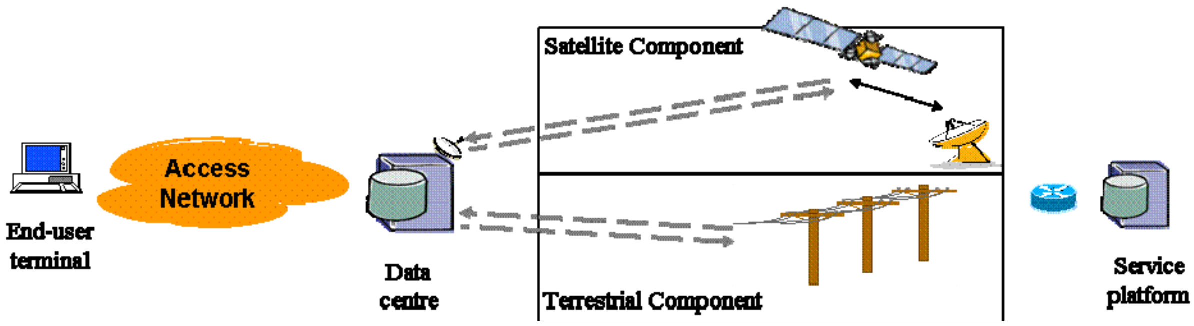

Figure 7 : Satellite based Content Delivery Network (CDN)

Satellite/terrestrial integration issues

Currently, CDNs are mostly based on proprietary protocols. Standardization could favour smooth inter-working between satellite and terrestrial based CDN so that the distribution of content takes the most appropriate route according, for example, to popularity of content.

6 Network Scenarios Combining Several Satellite Communication Components

One should not forget the case of systems that are combining 2 or more satellite communication components. This mainly applies to satellite link used as an access technology.

6.1 Satellite component used as an access technology

Satellite may provide mobile or fixed access service.

6.1.1 Targeting mobile terminals

Rationale and satellite added value

The use of two distinct satellite components each operating in a different frequency band is considered to enhance the service availability.

This scenario targets vehicular, aeronautical or maritime mounted terminals.

Architectural Principles

Typically, one satellite component is operating in L or S band and able to provide narrowband services at high availability to the terminals, while the other component operate in Ku or Ka band and is able to deliver broadband services with much more capacity but at lower availability due to rain fade attenuation.

Combining both components enable to enhance the service availability and quality by ensuring a minimum service rate even in harsh weather conditions.

Satellite/terrestrial Integration Issues

The main issue is to design a dual frequency band antenna compliant with the operational constraints of maritime, aeronautical or vehicular environment and to design the transport/network protocols exploiting both components.

Example of systems and standards

Inmarsat™ has the intent to deploy a service exploiting both its L band and Ka band constellations. Some Service Providers propose bundled L and Ku bands maritime solutions.

6.1.2 Targeting fixed terminals

Rationale and satellite added value

The use of two distinct satellite components each operating in a different frequency band is considered to enlarge the service set.

Architectural Principles

Typically, one satellite component is operating in Ku to deliver broadcast service in a continental beam, while the other satellite component operate in Ka band and is able to deliver broadband services in small beams.

Combining both components enable, for example, to convey TV channels over either a continental beam or several smaller beams according to the audience of the channel. It also enables to provide interactive broadcast service with personalization of content.

Satellite/terrestrial Integration Issues

The main issue is to design a dual band antenna able to operate on both missions especially when they are embarked on different satellites.

The other issue is to implement flexible routing between both types of resources at network layer.

7 System of Systems

New services opportunities will be made available with a combination of SatCom with other satellite applications, namely Earth Observation and Navigation in order to provide innovative services.

Table 7: Rational of coupling scenarios

Coupling scenario	Rational
SatCom and Global Satellite Navigation Systems	To deliver Location based services To optimize the SatCom radio resources management (ex: ensure allocation of radio resource in the correct beam) To improve positioning accuracy: e.g. with Logical assistance channel To improve Navigation service integrity (e.g. EGNOS)
SatCom and Earth Observation Satellite systems	Data relay to overcome the revisit time associated to low earth orbiting earth observation system To help the transport of bulk mission data (High Quality images, etc.)
SatCom, Global Satellite Navigation System and Earth Observation Satellite system	To increase efficiency in tacking grand societal challenges such as crisis management, environmental monitoring, energy sustainability, transport and mobility

Annex A: ADSL Performance

The performance of most "terrestrial based" fixed Internet access technologies (e.g. DSL or radio) is distance sensitive. The maximum available bandwidth will decrease as the distance from the access node (e.g. DSLAM, Radio base station) as illustrated in the figure in http://www.broadbandspeedchecker.co.uk/guides/adsl_and_distance.aspx. Note that optical fiber is much less subject to this phenomenon due to a lower signal attenuation over the distance, therefore combining satellite and optical fibre access network makes less sense.

Typically the maximum distance from exchange to receive one IPTV channel is about 4,5 km for SDTV format (> 2 Mbps) or 3 km for HDTV format (> 8 Mbps). From the figure in http://www.broadbandspeedchecker.co.uk/guides/adsl_and_distance.aspx one can see that the most advanced DSL technology does not improve the broadband speed performance for high distance. When considering the capability of receiving at least 2 IPTV channels in HDTV format (16 Mbps), the maximum distance falls to 2 km for VDSL2, ADSL2+ technology while ADSL and ADSL2 technology cannot support this requirement.

This distance threshold depends on the line quality, which is determined by local standards and practices: the copper wire diameter and the line filters performance, and also some cable installation practices, which vary from country to country as well as the line physical degradation over time (oxidation, etc.).

History

Document history		
V1.1.1	July 2013	Publication