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Foreword

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Executive summary

The present document proposes and analyses an hybrid access network combining one or several terrestrial access technologies (Fixed or Mobile Service) together with a satellite broadband access network (Fixed Satellite Service) in order to enhance end users' Quality of Experience of broadband service delivery primarily in under-served areas where Internet service is available over terrestrial access technologies but delivering rates below that expected of Next Generation Access.

This hybrid access network will support all the telecommunications services typically offered on Next generation access technologies, including high bandwidth applications such as video conferencing, live streaming and video on demand via the satellite link along with the latency sensitive applications such as highly interactive online game play via the relatively slow terrestrial link.

Intelligent Gateways route the traffic between terrestrial and satellite access technologies according to the Quality of Service requirements associated to the various service components with the objective to maximize the overall Quality of Experience for the users (large bandwidth and low latency). In addition, the hybrid network ensures a higher resiliency towards potential interruption of service on the terrestrial access link.

The present document aims at:

- Providing an overall description of the hybrid access network architecture with special emphasis on integration aspects with a public packet switched core network on one hand and the home network environment on the other hand;
- Proposing suitable metrics to compare the Quality of Experience (QoE) over such hybrid access network with respect to single access network technology;
- Identifying existing standards that have to be modified and additional standards that have to be created for enabling this kind of scheme.

1 Scope

The present document details the benefit of an intelligent combination of satellite and terrestrial broadband access technologies for the benefits of users mainly in underserved areas.

2 References

2.1 Normative 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.

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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 302 307 (V1.3.1) (2013-03): "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.2] ETSI TS 101 545-1: "Digital Video Broadcasting (DVB); Second Generation DVB Interactive Satellite System (DVB-RCS2); Part 1: Overview and System Level specification".

[i.3] ETSI EN 301 545-2 (V1.1.1): "Digital Video Broadcasting (DVB); Second Generation DVB Interactive Satellite System (DVB-RCS2); Part 2: Lower Layers for Satellite standard".

[i.4] Recommendation ITU-T E.800: "Quality of Telecommunication Services: Concepts, Models, Objectives and Dependability Planning. Terms and Definitions Related to the Quality of Telecommunication Services".

[i.5] IETF RFC 3697: "IPv6 Flow Label Specification**"**.

[i.6] IETF RFC 3917: "Requirements for IP Flow Information Export (IPFIX)".

[i.7] Recommendation ITU-T M.3400.

[i.8] IETF RFC 2722: "Traffic Flow Measurement: Architecture".

[i.9] IEEE 802.1Q: "IEEE Standard for Local and Metropolitan Area Networks - Virtual Bridged Local Area Networks".

[i.10] ETSI TR 102 274: "Human Factors (HF); Guidelines for real-time person-to-person communication services".

[i.11] IETF RFC 4594: "Configuration Guidelines for DiffServ Service Classes".

[i.12] TR-069 DSL Forum.

[i.13] Recommendation ITU-T P.10: "Vocabulary for performance and quality of service".

[i.14] ITU TD 109rev2 (PLEN/12): "Definition of quality of experience (QoE)".

[i.15] Recommendation ITU.T G.100: "Definitions used in Recommendations on general characteristics of international telephone connections and circuits".

3 Definitions and abbreviations

3.1 Definitions

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

access link: link established between the IUG and the ING via a satellite or a terrestrial network

NOTE: One access link corresponds to one network interface.

application: program running on a device that requests or generates data that will form a Traffic Flow through a Network Interface

broadband access: service rate is greater or equal to 2 Mbps on the downlink

high speed broadband: service rate is greater or equal to 30 Mbps on the downlink (Target set by the Digital Agenda for Europe)

hybrid access network: access networks combining a satellite component and a terrestrial component in parallel where the delivery of a service using both the satellite component and the terrestrial component intelligently to maximize the Quality of Experience for end users in under-served areas

Intelligent User Gateway (IUG): Intelligent User Gateway (IUG) is a home device providing broadband access, security, cached storage capacity and QoE provisioning in an hybrid access network

intelligent network gateway: intelligent network gateway is the counterpart device of the IUG in an hybrid access network

network Interface: interface that connects the IUG or ING to an access link

next generation access network: access network with high speed broadband capabilities

Quality of Experience (QoE): subjective measure of the user's experiences with a service or an application (e.g. web browsing, phone call, TV, call to a Call Centre)

Quality of Service (QoS): objective measure of a service delivered by a network

service component: application may carry out multiple functions each producing a unique traffic flow

NOTE: The resultant set of traffic flows related to one application is referred to as a service component.

traffic flows: sequence of packets sent from a particular source to a particular unicast, anycast, or multicast destination that the source desires to label as a flow (see in IETF RFC 3697 [i.5])

NOTE: More specifically it refers to a set of IP packets passing an observation point in the network during a certain time interval (see IETF RFC 3917 [i.6]).

under-served area: area where Internet Service is available via a terrestrial access network but with no Next Generation Access capabilities

3.2 Abbreviations

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

.mpg	file extension for Moving Picture Experts Group video and audio compression
3D	Three Dimensions
ACM	Adaptive Code and Modulation
BSS	Business Support System
CDN	Content Delivery Network
CoS	Class of Service
CPE	Customer Premise Equipment
DSLAM	Digital subscriber line access multiplexer
E2E	End to End
FCAPS	Fault, Configuration, Accounting, Performance, and Security
FR	Full Reference
GEO	Geostationary satellite
HD	High Definition
HD/3D	High Definition/3 dimension (TV format)
HDTV	High Definition Television
HSPA	High Speed Packet Access
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
ING	Intelligent Network Gateway
IP	Internet Protocol
ISP	Internet Service Provider
ITU	International Telecommunication Union
IUG	Intelligent User Gateway
IUG	Intelligent User Gateway
LAN	Local Area Network
MDI	Media Delivery Index
ModCod	Modulation and Coding index
MOS	Mean Opinion Score
MPLS	Multiprotocol Label Switching
MTOSI	Multi-Technology Operations System Interface
NCC	Network Control Centre
NGA	Next Generation Access Network
NI	Network Interface
NMS	Network Management System
NR	No Reference
OAM	Operations, administration and management
OSS	Operations Support System
OTT	Over The Top multimedia content
PEP	Performance Enhancing Proxy
QoE	Quality of Experience
QoS	Quality of Service
RF	Radio Frequency
RFC	Request For Comment (IETF document)
RR	Reduced Reference
RTD	Round Trip Delay
Satco	Satellite Service Company
SCC	Satellite Control Centre
SCN	Satellite Communication and Navigation
SLA	Service Level Agreement
TTC	Telemetry, Tracking and Control susb-system
TV	Television
TX	Transmit
VDSL	Very high bit-rate Digital subscriber line
VoD	Video On Demand
WAN	Wide Area Network
xDSL	Digital Subscriber Line (any version)

4 Hybrid access network for high speed broadband access

4.1 Concept and rational

The proposed hybrid access network aims at delivering a resilient High Speed BroadBand service especially in 'underserved' areas at a comparable quality of experience to Next Generation Access networks capabilities.

The underlying concept can be illustrated with the following use cases:

- Business: Mrs McMiggins needs to work from home - a challenge with a highly IT intensive job. She frequently needs to upload and download large data files, typically several Gbytes. The download time experienced using a small capacity rural ADSL service causes problems, with on-line collaborators having to wait whilst files are transferred. They install an hybrid access which selects the satellite communications system to provide massive capacity on demand and also copes well with the bursty demand: this solves the problem.

- Gaming: John, their 12 year old son has a friend who lives 13 km away. They enjoy playing competitive pseudo-sport games using their game console stations. But when parents and sister also use on-line applications the contention between the traffic types causes delays and glitches in the games which were no-longer playable. However, the hybrid network solves this problem by routing data that needs low latency over the terrestrial ADSL system (e.g. the game console connection), with the satellite link used for delay-tolerant higher capacity services (e.g. down-streaming video from an internet multimedia server - a habit of his sister Jane who is particularly enthusiast about this internet multimedia server.

- Resilience: with the hybrid network installed, Mrs McMiggins can work from home whilst the children play computer games etc. On one occasion other residents complain that a construction company has cut through the Telco cables and cut off the telephone lines and the connection to the mobile mast in the village. Most people's phones and Internet will be cut off for over a week. However, at the McMiggins house all the traffic has been routed automatically over the satellite with very little loss of performance.

4.2 General architecture

The general architecture of the hybrid access network delivering High speed broadband service is depicted in Figure 1 below:

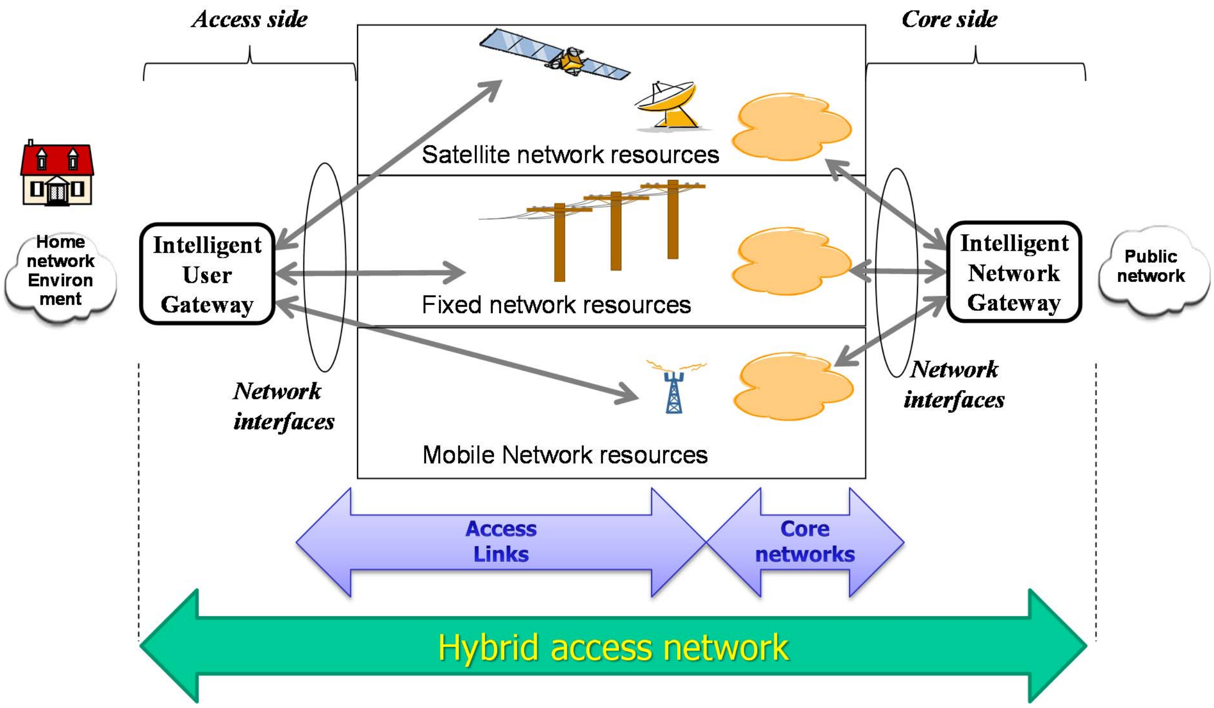

Figure 1: Hybrid access network architecture

On both edges of the hybrid access network, access and core side, a traffic classifier and a routing entity are located. These will be in the IUG and ING. While the first aims at identifying the type of application or service component, the latter selects the most suitable access link to transmit a certain flow of traffic. The criteria for this selection is threefold:

- first, the QoS requirements of the traffic are taken into account;
- second the capabilities of the available access links are considered; and
- finally policies defined by operator and/or subscriber might have an impact.

The Intelligent User Gateway (IUG) is a Customer Premises Equipment (CPE) providing secured broadband access, cached storage capacity and QoS provisioning. It not only provides an interface to several access links, but the IUG will select access delivery routes in multi operator and service provider domains, matched to the QoE needs of the different applications and service components. The IUG would be able to determine in real time the QoS requirements of each application or service component and accordingly make routing decisions to optimize the QoE. It also exploits the storage resources of the IUG for high bandwidth low priority traffic caching during off-peak hours, to support applications such as OTT TV service.

The Intelligent Network Gateway (ING) of is a counterpart device of the IUG and is located at the core side. It is a convergence point for the different user traffic flows handled in the different access links (e.g. satellite, xDSL, Mobile network resources). The ING works in conjunction with the IUG to select the relevant individual or combined access links for the forwarding of the different traffic flows for the downlink direction (traffic from the Public network to the end user premises).

In order to allow for operating with several different network technologies used for the links between the IUG and ING, a link abstraction is implemented at each Network interface (NI) and exploited by the routing decision in both the IUG and the ING. This link abstraction will define the network performances solely by certain key parameters including for example bandwidth, latency, jitter, error rate and cost, all of which may vary over time. The different characteristics of each individual link can be described in a systematic and efficient manner by this set of well-defined parameters.

4.3 Satellite network technology

4.3.1 Overview

A GEO based satellite access network is typically composed of the following parts:

- A space segment composed of one or more High Throughput satellites in geostationary orbit. The satellite connects the GWs of the ground segment to the user terminals, thanks to a set of feeder and user beams.
- A ground segment which includes:
  - A main Network Control Centre (NCC) which has the responsibility to control and synchronize the overall network.
  - A main Network Management System (NMS) which handles the management of the resources in the network.
  - A Satellite Control Centre (SCC) which aims at monitoring and controlling the space segment.
  - A Telemetry Tracking and Control (TTC) station to transmit and receive information to or from the space segment.
  - A set of Gateways operating which are in charge of transmitting and receiving data, control and management traffic to or from the user terminals. Each Gateway is equipped with their own local NCC/NMS to ensure their individuality and their operation sequence in case of a total system malfunction originating from a main NCC/NMS failure. The Gateways provide access to the public internet via an Internet Point of Presence.
  - An aggregation network segment or backbone interconnecting the Gateways.
- A user segment which is composed of a set of user terminals.

The network that interconnects the User Terminals with the Gateways is based on the DVB-S2/DVB-RCS2 standard and their future variants (see references [i.1], [i.2] and [i.3]).

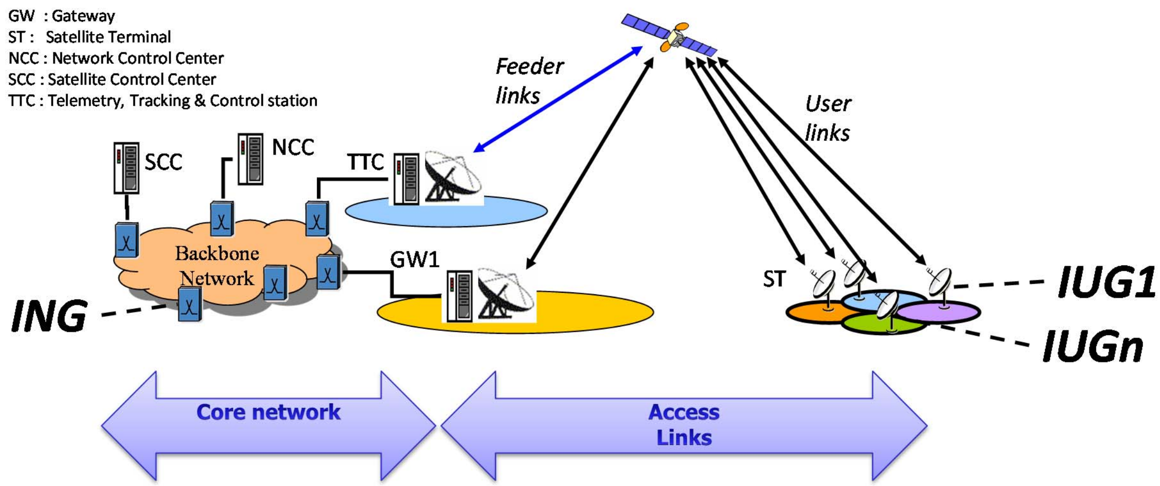

Figure 2: Satellite access network architecture with the IUG and ING

The Gateways interface with the Intelligent Network Gateways (INGs) while each User Terminal interfaces with an Intelligent User Gateway (IUG). Each IUG connects to one ING, while the INGs may connect to multiple IUGs.

Typical performances for Satellite broadband network is reported here under.

Table 1: Typical performances of GEO based satellite network roadmap

TIMELINE	2005	2010	2015	2020
Technology	Ku-band satellites	1st Gen Multi beam Ka-band satellites	2nd Gen multi beam Ka-band satellites	3rd Gen multi beam Ka-band satellites
Typical Max service rate (downstream)	2 Mbps to 3 Mbps	10 Mbps to 20 Mbps	30 Mbps to 50 Mbps	100 Mbps

In addition the typical RTD over a GEO based satellite access network is approximately 600 ms.

4.3.2 Multicast over satellite

In addition to the management of unicast traffic the potential of multicasting selected streams of OTT video content and selected cached OTT video content to reduce the total satellite traffic has been identified. The multicast data will be sent on one of the forward link carriers in each spot beam so the user terminal may implement a second receiver.

The potential benefit of applying group ACM for the multicast traffic lies in a useful bandwidth increase. The anticipated scheme sets the modcod for multicast transmission to the modcod needed for delivering successfully the data in unicast transmission to 99,x % of the targeted user terminals (where x is to be defined).The multicast traffic would be created in the core network and sent over the satellite access network and converted back to unicast transmissions in the IUG. This would be implemented in a transparent fashion so that no changes would be required in the content provider and CDN systems nor in the end user devices.

4.4 Terrestrial network technology

This clause considers here only broadband network technologies deployed in underserved areas.

The xDSL access technologies that are currently available are listed in Table 2.

Table 2: Typical performance of xDSL network technologies

Technology	Max Downstream rate	Max Upstream rate	Typical range (Modem to DSLAM using 0.4mm cable)	Typical RTD
ADSL2	12 Mbps	3 Mbps	5 460 m	< 100 ms
ADSL2+	24 Mbps	3 Mbps	2 400 m	< 100 ms
VDSL2	50 Mbps	50 Mbps	1 500 m	< 100 ms

Given the focus on the more remote under-served locations it is likely that if the end user has xDSL it will be at the end of a long link ADSL2 or VDSL delivering rates somewhat below the maximum rates stated above which are only available in short range.

The mobile network technologies available are depicted in Table 3.

Table 3: Mobile network technologies

Technology	Max Downstream rate	Max Upstream Rate	Typical Cell Range (Macrocells)	Typical RTD
EDGE	236,8 kbps	236,8 kbps	500 m - urban 5 000 m -rural	< 300 ms
UMTS	384 kbps	384 kbps	500 m - urban 5 000 m -rural	< 200 ms
HSPA	7,2 Mbps	2 Mbps	3 500 m	< 100 ms
LTE	300 Mbps	75 Mbps	> 10 km depending on location and antennas	< 50 ms

Note that the max range associated to the above mentioned service rate performances depends on the environment profile as well as the base station installation configuration (transmit power, antenna gain, height and tilt). At cell edge, the maximum downstream rates are likely to be well below those shown above.

A large LTE (LTE Advanced) network deployment is foreseen in urban and suburban areas whereas in rural and very rural areas 2G (EDGE), 3G (UMTS) and possibly enhancements to 3G (HSPA) are likely to be the predominant mobile network standards in operation.

4.5 Intelligent Gateways

4.5.1 Overview

The Intelligent Gateways consist of complimentary devices; the Intelligent User Gateways (IUG) at the end user locations and the Intelligent Network Gateways (INGs) located in the core network. Their fundamental purpose is to detect different traffic and route this along the best access network at that time for that data.

There are three main traffic flows within the Intelligent Gateways:

- **User data flows:** This is to carry the end user data that is processed and routed through the IUG.
- **Management flows:** This is for synchronization with the ING, managing local resources within the IUG as well as other management policies required in components of the IUG.
- **Control flows:** This is to exchange with all components of the IUG to ensure various policies defined in the management plane are executed in organized patterns.

There is an important exchange between the management plane of the IUG and the ING. This helps the operators to implement remote firmware updates as well as push policy updates to the IUG. Policies defined in the management plane are enforced by the control plane in all related components. For a coordinated operation of the IUG and ING, there are exchange of user data flows, management flows and control flows between the control and data plane. A pictorial representation of their major functions and their interconnection is shown in Figure 3.

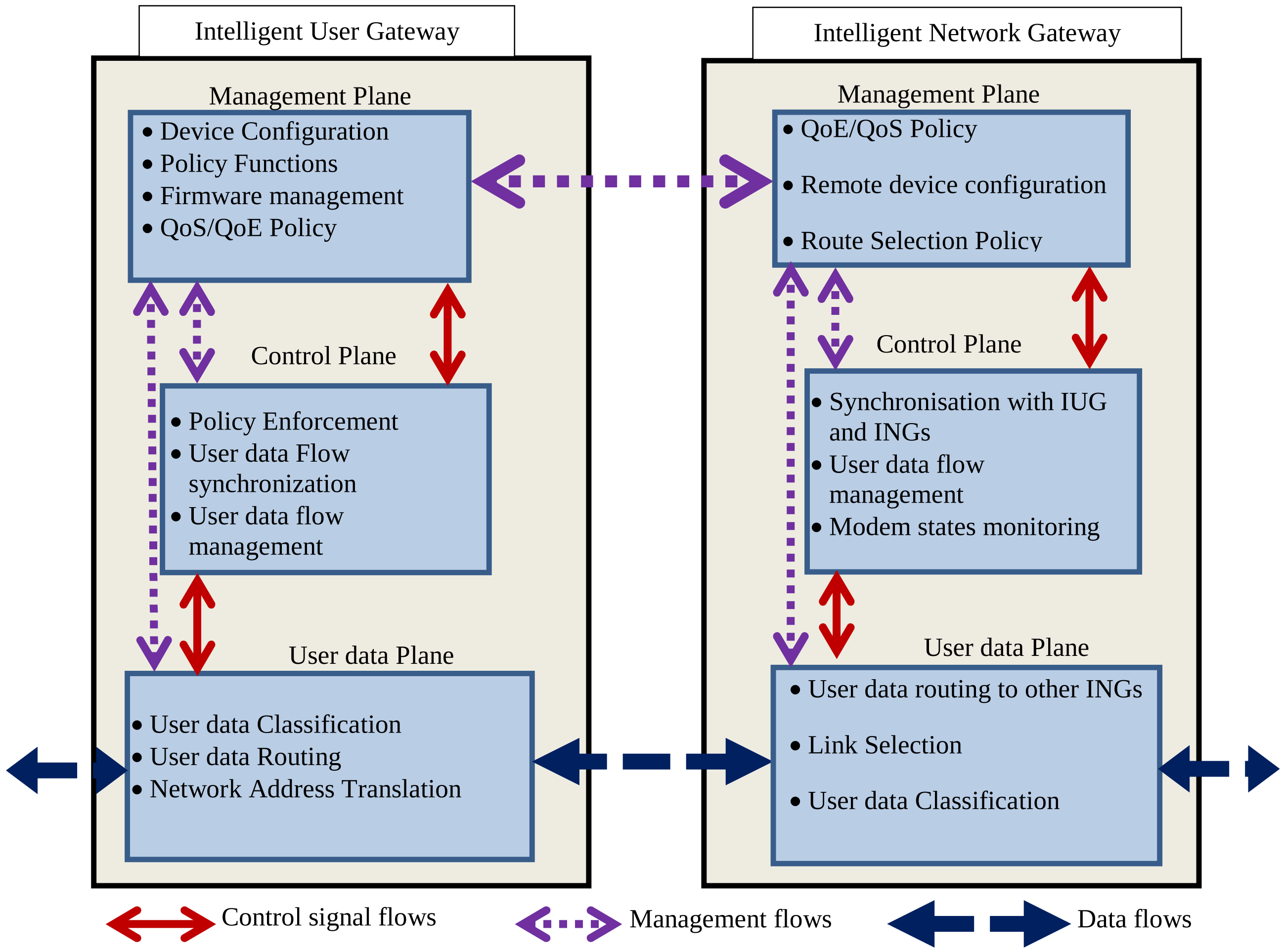

Figure 3: Interactions between the IUG and ING User data, Control, and Management Planes

The key information being routed through the IUG are bidirectional data flows through the communication media. Within the IUG, the management plane pushes policies to the control and data plane. The control plane is distributed in different components and their signalling aids organized intra traffic flow coordination. The signalling function is executed during the traffic splitting and combining phase. Different interfaces are required for communication between the components.

4.5.2 Intelligent User Gateway

The IUG is responsible for:

a) Keeping track of each access link capability.

b) Detecting, characterizing and intelligently routing data from the end user to the Internet.

c) Other data management functions.

All the key functional modules in the proposed integrated system is depicted in Figure 4.

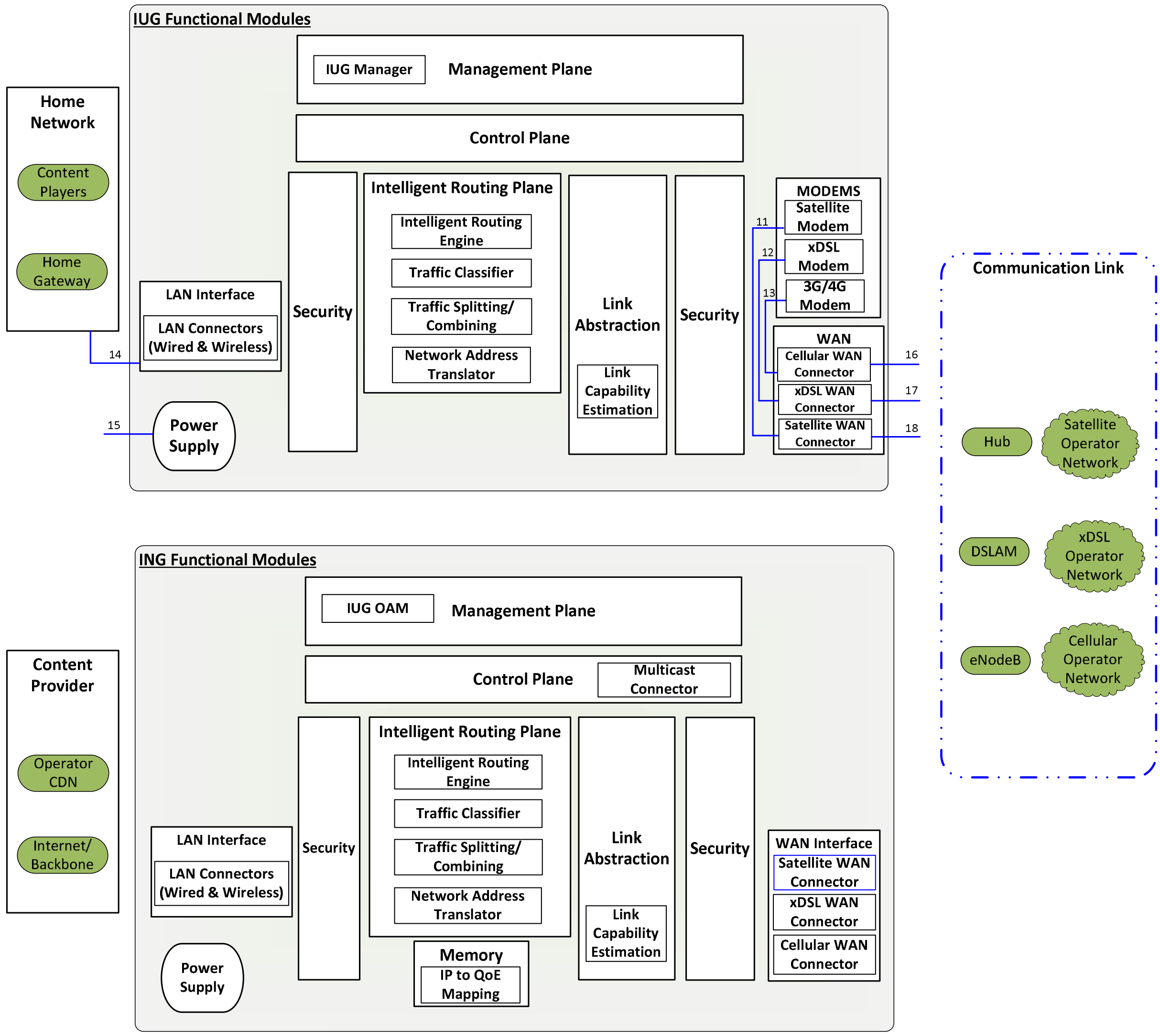

Figure 4: IUG and ING Functional Diagram

In describing functional components, the IUG is used as reference as most modules carry out similar functions in both the IUG and ING. Figure 4 shows the main components of the IUG, ING and communication network grouped into different functional modules.

Link Abstraction: Link abstraction relies only on technology independent parameters to characterize a connection and, thus, hides the technology specifics from entities utilizing this model. It can be a sub-set or a super-set of the characteristics of the underlying technologies, or it can be completely different which would require certain adaptation. A technology agnostic link abstraction module is required for this system so that different characteristics of each individual connection can be described in a systematic and efficient manner by a set of well-defined parameters. Due to integrated satellite links this link layer abstraction needs to deal with unicast links as well as multicast delivery mechanisms. This abstraction defines the Link Capability - that is the capabilities of each link in terms of parameters such as packet error rate, latency and throughput.

Management Plane: The management plane groups all functions related to the system operation and tasks between various components. This also includes traffic flows, synchronization with the ING, policy management, power state management and managing local resources within the IUG. In managing the local resources, this plane is directly connected and oversees the operation of all other functional modules within the IUG. This logical module also supports the data processing unit for efficient admission control of traffic. All local functions within the IUG such as initial setup, remote configuration, firmware updates, power usage and other high level policy functions are executed here. The policy function contains various policies required for service requests from other modules in the IUG. For example, information on the QoS/QoE mapping policy is evaluated by a specific policy function which activates the required service flows in the data processing unit (e.g. traffic classifier). In general, it provides a plane for managing all service flows through the IUG with their respective policies.

The management plane of the IUG and ING are consistent and support the FCAPS operations defined by Recommendation ITU-T M.3400 [i.7] recommendation. The present document specifies five management functional areas (FCAPS) that need to be supported by the IUG to be operated by an operator:

- **Fault management:** Detect, isolate, notify, and correct faults encountered in the network. This will include system level reconfiguration: revising the association of each IUG to an ING, if the normally used ING develops a fault.
- **Configuration management:** Configure aspects of network devices, such as configuration file management, inventory management, and software management.
- **Accounting management:** Collect usage information of network resources. It also coordinates network usage rights for example if different price plans exist for one or more of the WAN access services or fair usage policies.
- **Performance management:** Monitor and measure various aspects of performance so that overall performance can be maintained at a defined level.
- **Security management:** Secure access to network devices, network resources, and services to authorized individuals.

Control Plane: The control plane ensures that interactions between various components of the IUG do not take place in an ad-hoc way but are synchronized in organized pattern flows. In general, the control plane can be viewed as a module that ensures that various defined policies are executed in an organized and efficient way. For specific traffic flows to the data processing unit, user and flow authentication with the security module and flow control synchronization in the modems are all coordinated here. The amount of control plane traffic is critical in the IUG design as it increases with the number of possible traffic paths and even further when traffic splitting is initiated.

Intelligent Routing Plane: The main module of the IUG provides a variety of routing functions. These include network address translation, traffic classification, traffic splitting/combining and intelligent routing of traffic flows. It also ensures proper flow control between these components in synchronism with the control plane. To distribute user traffic among the available network connections, inputs from the link abstraction module on the link state of the various communication links, defined QoS policies, QoS/QoE mapping tables and input from its embedded traffic classifier are all required to make intelligent routing decisions. In general, this module is responsible for all components that receive, process and transmit data within and through the IUG.

To aid routing decisions for selected service flows, the ING will allow its associated IUGs access to its central resource. This is to facilitate the determination of the QoE requirement for a service operated from a specific IP address or port, and to interpret the findings using schemes such as Deep Packet Inspection.

Memory: This is the local storage module of the IUG and contains both volatile and non-volatile memory units. Its capacity will be determined from further tests and the various types of applications it would support. A local partition that stores information required by the management plane such as QoS/QoE mapping tables and routing tables can be supported.

Security: This supports basic authentication of users and intrusion prevention features. Policies defining the connection to home network, access lists of connected devices, firewalls, and well as preventing potential misuse of the operator's communication links. It also provides encryption and decryption of data through the IUG. In defining the security policies, it should be noted that to enable intelligent routing, periodic information of link states from the modems might be required.

LAN Interfaces: The LAN interface and its associated wired/wireless LAN connectors provide a means for the customer's local home network access to the IUG. The de facto connection is via a fast Ethernet 100BASE-TX connector. Its main functionality will include the serving as an ingress point of all the traffic from the home network with a unique IP address to the intelligent routing unit. The potential capability of the IUG to be upgraded to serve as a home eNodeB (Femto) prompts the provisioning of both a wired and wireless LAN connectors.

WAN Interfaces: This consists of the physical WAN connectors to the satellite, xDSL, cellular modems or any other future access technology. They support primarily unicast traffic and multicast traffic will be supported over a satellite link. It should be noted that the functionality of the xDSL and Cellular modems need not be duplicated in the WAN connectors unit as their modems can be embedded in the same unit. Link status information will also be carried over these interfaces. These WAN interfaces are internal to the IUG in the reference design.

Power supply: This provides the basic system powering of the components in the IUG. It receives triggers from the management and control plane in order to be able to drive the unit into sleep mode depending on its activity. The IUG is expected to be always on but to minimize the energy consumption, it can be preconfigured to go into low power state, while being able autonomously to become active to execute scheduled firmware updates as well as receive link state event updates.

Modems: Modems will interface between the IUG and the communication links, modulating (and demodulating) RF signal with the digital information they carry. In the context of this project, it is desirable to convert received RF signal to IP. Key functionalities of the modems will also include flow control, error correction as well as header compression for certain links. These modems are also capable of providing information of the status of their links using predefined link state updates. The modems also execute functions such as header compression and PEP enhancement especially for the satellite link. The vision is for the modems to be integrated within the IUG and managed by a single operator and lower levels of integration are also allowed for.

The types of IUG and ING's external interfaces and their functions are summarized below in table 4.

Table 4: IUG external interfaces

Interface	Description
11	Connection from the satellite WAN interface to the satellite modem.
12	Connection from the xDSL WAN interface to the xDSL modem.
13	Connection from the cellular WAN interface to the cellular modem.
14	Connection from the IUG LAN interface to the home LAN.
15	Prime power.
16	This is the satellite link between the hub at the satellite gateway and end user location.
17	This interface is the xDSL to an operator's DSLAM or cabinet.
18	This interface is a GSM/UMTS/LTE link to an operator's cell mast and related equipment.

4.5.3 Intelligent Network Gateway

The Intelligent Network Gateway (ING) is the IUG counterpart in the core network. It has dual functionalities of remotely managing all associated IUGs as well as acting as an interface/gateway to the public internet. It has similar responsibilities to the IUG but on the outer edge of the hybrid network, i.e. classifying the traffic and intelligently distributing it among the available connections while taking into account QoS requirements and link capabilities. In the upstream link, the ING also acts as a concentrator of the different flows sent by the IUGs over the different access networks. One ING serves multiple IUGs; an IUG communicates with a single ING. The ING may be one or multiple physical devices or multiple virtualized devices. The ING contains similar functional components as the IUG and these have been described in clause 4.5.2.

4.6 Integration aspects

4.6.1 Overview

The hybrid access network is designed to use a satellite link to augment the data delivery capability of one or several terrestrial access links such as an xDSL link or a 3G or LTE mobile network access link. There are no specific requirements for these access links but in general the satellite link is expected to introduce a much higher data rate capability and a more predictive link when compared to the other technologies.

The connection formed between the IUG-ING pair allows for easy integration into existing ISP networks without the need to significantly change the routing policies of its existing core network beyond ensuring that the relevant addresses are being correctly advertised.

For the purpose of this clause, an Internet Service Provider (ISP) is the connection provider that sells to the end user interconnection with the public Internet and the end user's equipment. The wholesale provider provides network connections to the ISP but does not sell direct to the end user.

Each access link between the IUG-ING pair is separately identified with either public or private addresses with a single public address being advertised upstream to the public networks (public Internet). The IUG-ING combination then transparently selects the optimum routing over the access links to achieve the highest composite level of QoE.

The hybrid access network will be integrated, managed and operated in a range of ways to best suit the commercial and technical requirements. As examples, three scenarios have been envisaged. In all cases an ISP provides broadband service via the hybrid access network to end-users, the differences between the scenario lies in what resources the ISP will use and how does they get them:

a) An ISP who already provides xDSL and/or mobile data terrestrial access connections to end users that purchases satellite connections to provide hybrid network connections to the end users. The satellite service provider owns and operates the ING.

b) The ISP purchases broadband service capacity from a wholesale provider that owns xDSL and/or cellular network and from a satellite service provider. The ING is owned and operated by the wholesale provider.

c) A satcom ISP that sells retail solutions to end users purchases xDSL and/or mobile data terrestrial access connections to provide hybrid network connections to the end users. The satellite service provider owns and operates the ING.

While the scenario where the user purchase separate contracts with a mobile network provider, an xDSL network supplier and a satellite broadband provider and purchase the IUG from a retailer has not been widely explored it is possible to envisage a cloud based service offered by the owner of an ING to provide this service. However, this market development is outside the scope of this technical description.

Equally, the terrestrial access networks may be provided by other parties to the ISP but given the focus of the present document is the adoption of the satellite access network by parties already offering terrestrial networks then these scenarios are not explored in the present document.

The integration of these scenarios at a physical and a management level are discussed in the following clauses 4.6.2 and 4.6.3.

4.6.2 Network Level

Scenario (a) - ISP

The network connectivity is shown schematically in Figure 5.

The satellite service provider owns and operates the ING and supplies its satellite access network connection capability to the terrestrial network provider or ISP so that is can become a hybrid network provider. The ISP is responsible for the connection to the public IP network (access point A in the diagram). The traffic to be routed to the Users of the Hybrid Network is first routed towards the ING of the satellite service provider via its core network.

The ING then decides which access network to use to route the traffic to the User IUG. Selected traffic routed is routed over the satellite access network while traffic to be routed over the terrestrial network is redirected towards the ISP's terrestrial access network(s) via access point B.

In the reverse direction, the IUG selects the access network to be used, either the terrestrial access network(s) or the satellite access network and directs the traffic towards the ING. The ISP directs traffic received from the terrestrial access network via access point B towards the satellite service provider's ING which in turn directs the composite traffic towards the public IP network via the ISP's access point A.

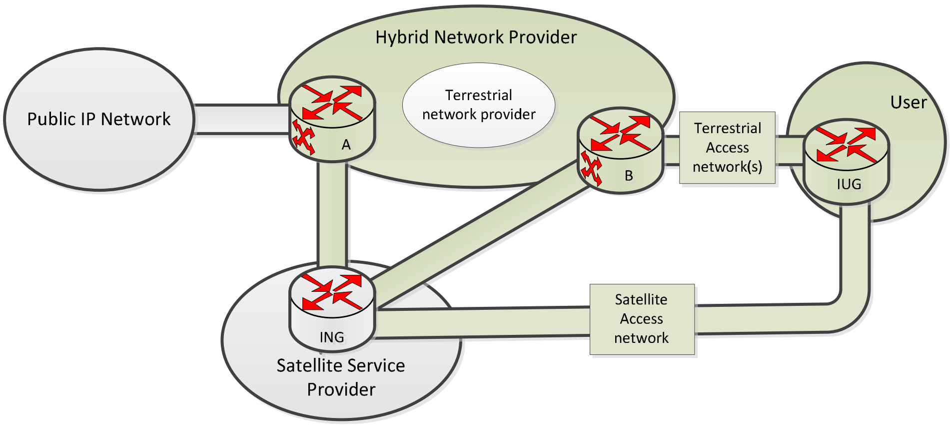

Figure 5: Satellite service provider ownership of ING - option (a)

Scenario (b) - wholesale provider

The network connectivity is shown schematically in Figure 6.

This is similar to that of scenario (a) but differs in that the ISP maintains the end user commercial relationship and responsibility for connection to the public IP network while purchasing the hybrid network capability from the wholesale hybrid network provider. The ISP is also responsible for the deployment of the IUGs to the end user. The terrestrial network provider purchases the ING capability and acquire the satellite access network capability in order to offer the hybrid network connectivity. The ING selects that traffic to be directed over the terrestrial network via the access point B, or that traffic to be directed over the satellite connection via access point C. The return traffic is the reverse of this with the path selection performed by the IUG.

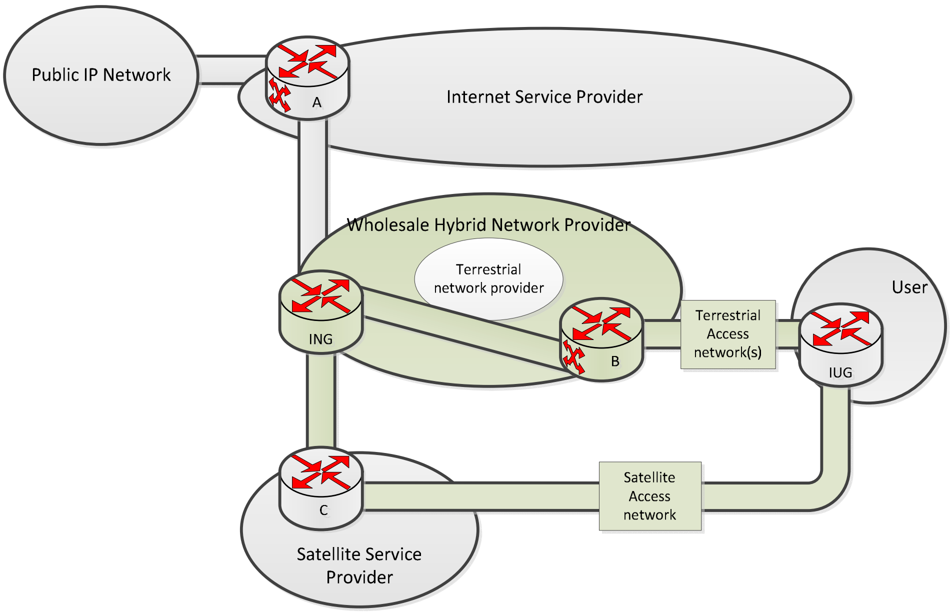

Figure 6: Wholesale provider ownership of ING - option (b)

Scenario (c) - Satellite Service provider

The network connectivity is shown schematically in Figure 7.

The satellite service provider/ISP, who provides the satellite access network, owns and operates the ING and acquires terrestrial access capability from a wholesale service provider. The satco is then able to offer hybrid network connections to the end user. The ING, which form the interface to the public IP network and is installed at a point of presence owned by the satco, selects that traffic to be directed over the terrestrial network via the access point B, or that traffic to be directed over the satellite connection via access point A. The return traffic is the reverse of this with the path selection performed by the IUG.

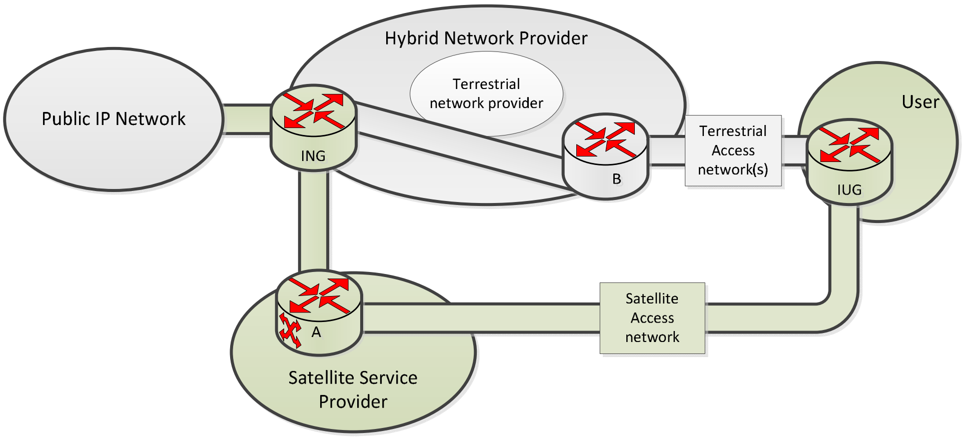

Figure 7: Hybrid Network Operator Ownership of ING - option (c)

4.6.3 Management Level

In the same way that there is a need to integrate the network element at physical level then there is also a need to ensure that the service can be managed with tools familiar to all operators of terrestrial networks. Accordingly a hierarchical structure complimentary to OSS standards such as FCAPS (ITU) or MTOSI (TM Forum) are envisaged that will communicate with various element managers within the system.

Conceptually for the three scenarios, (a), (b) and (c) discussed in the previous clause, there are three entities involved in the provision of the hybrid network to the end user which are:

- The ISP who provides the hybrid access network to the end user.
- A wholesaler who supplies the hybrid network to the ISP.
- The satellite service provider who supplies the satellite access network to the wholesaler or to the ISP.

Each party conceptually operates its own Operational Support System (OSS) to provide its services. Each OSS provides the functionality highlighted in Figure 8.

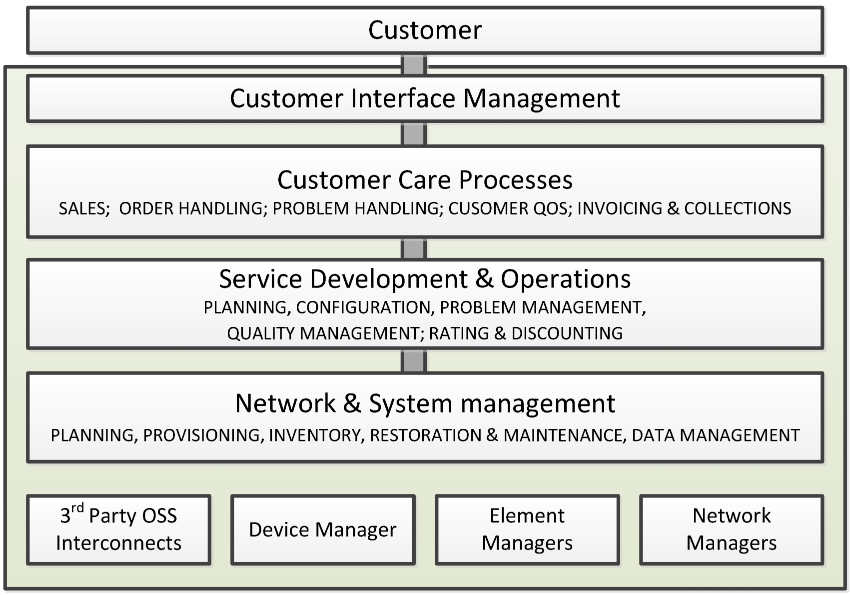

Figure 8: Conceptual OSS System for each provider

The end user service is therefore managed by a cascade of these OSS systems. Each network technology is managed by its own element manager system (EMS) and the IUGs are managed by a device manager. The ING is, for the purposes of this description, considered as part of the core network managed though the central Network Management System (NMS).

The aim of the element managers for the network technologies is to be able to associate a subscriber record denoted by a unique subscriber ID with a set of equipment that forms the devices located at the subscribers homes including the termination devices for the various network technologies and the IUG. This same subscriber ID will also be associated with specific access network set-up and the configuration requirement of the IUG.

Management of the IUG will be performed by a manager compatible with TR-069 [i.12] family of device managers or something similar. Northbound interfaces will allow modification of these associations by the hybrid access network provider and ISP.

For each of the scenarios introduced in clause 4.6 above the management system integration is discussed below.

For scenario (a) the envisaged management system architecture is shown in Figure 9. The IUGs are managed by the ISP whereas the ING is managed by the satellite service provider. The terrestrial network(s) are managed by the ISP. The association of the IUG with the ING is managed through the OSS of the satellite service provider.

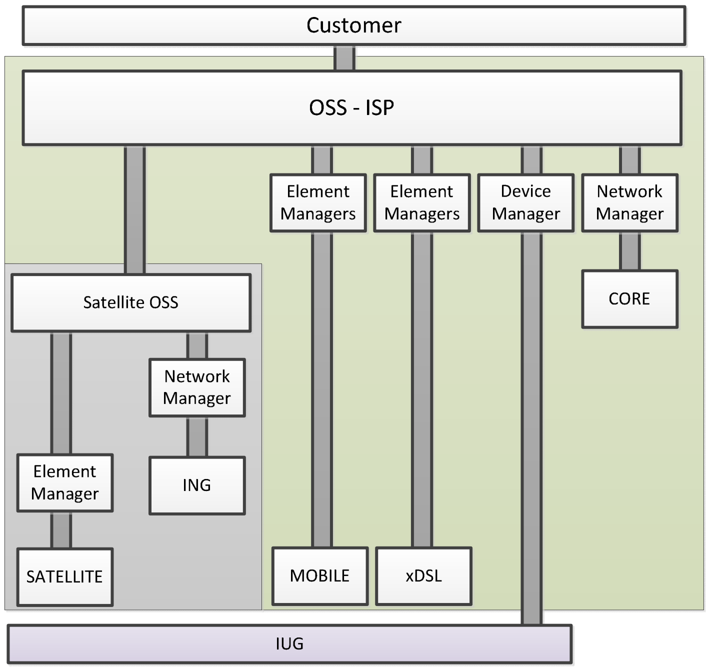

Figure 9: Management structure for scenario (a)

For scenario (b) the envisaged management system architecture is shown in Figure 10. The IUGs are managed by the ISP whereas the ING is managed by the wholesale network provider. The terrestrial network(s) are managed by the wholesale network provider. The association of the IUG with the ING is managed through the OSS of the wholesale network provider. Only the satellite network is managed by the satellite service provider.

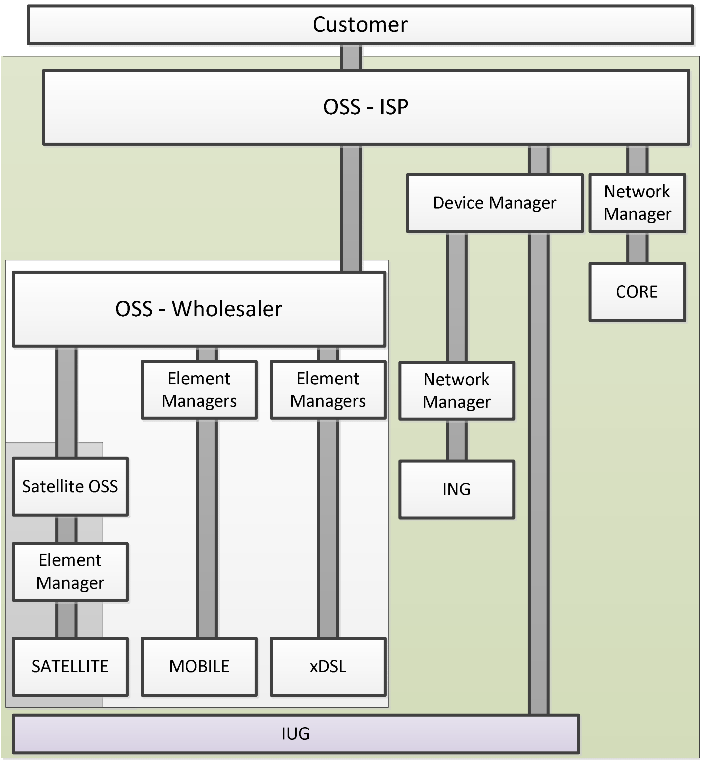

Figure 10: Management scenario for scenario (b)

For scenario (c) the envisaged management system architecture is shown in Figure 11. The IUGs and the ING are managed by the satco. The terrestrial network(s) are managed by the wholesale company who provides a northbound interface from their OSS to the satco OSS. Note that the core network, mobile access network and/or xDSL network may be provided by different wholesale companies each with their own OSS.

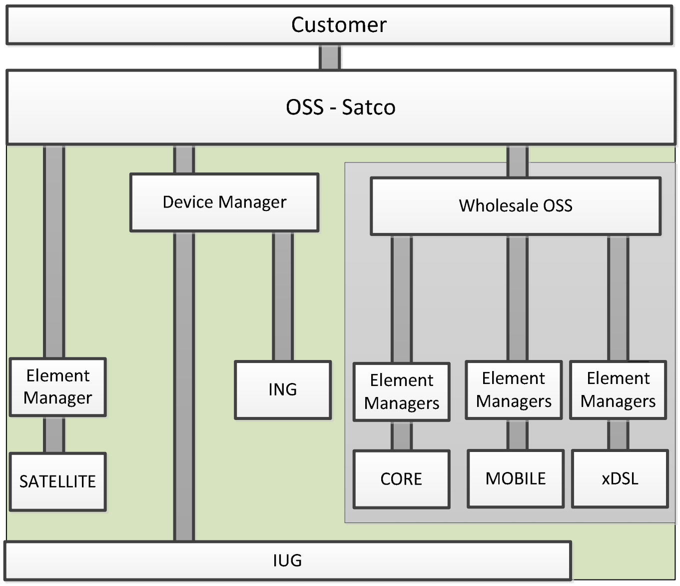

Figure 11: Management structure for scenario (c)

Table 5 compares the key relationships for these three scenarios.

Table 5: Comparing management scenarios

	Scenario (a) - ISP	Scenario (b) - Wholesale Provider	Scenario (c) - Satellite Service Provider
End user "owner"	ISP	ISP	Satellite operator
Responsible for ING	Satellite operator	Wholesale operator	Satellite operator
Responsible for IUG	ISP	ISP	Satellite operator
Responsible for satellite elements	Satellite operator	Satellite operator	Satellite operator
Responsible for mobile and xDSL elements	Wholesale operator	Wholesale operator	Wholesale operator

5 QoE in hybrid access network

5.1 Introduction

This clause addresses Quality of Experience (QoE) in hybrid access networks described in clause 4:

- It first introduces Quality of Service (QoS) and Class of Service (CoS) concepts which characterize the abstracted link parameters and explains their relationship with the QoE (clause 5.2).
- It then describes a QoE aware architecture for hybrid access networks (clause 5.3) and define the mapping function between QoE and QoS/CoS.
- Last, suitable metrics are proposed to assess the Quality of Experience (QoE) of an hybrid access network and compare with the QoE of a single access network technology (clause 5.4).

5.2 QoS and QoE concepts

Quality of service (QoS) is defined in Recommendation ITU-T E.800 [i.4] definition as the collective effect of performance which determines the degree of satisfaction of a user of the service. QoS is a service attribute, a measure of performance of the network itself. QoS provides the collective effect of service performances which determine the degree of satisfaction of a user of the service. The aspects of QoS are restricted to the identification of parameters that can be directly observed and measured at the point at which the service is accessed by the user.

QoS also refers to a set of technologies (QoS mechanisms) that enable the network administrator to manage the effects of congestion on application performance as well as providing differentiated service to selected network traffic flows or to selected users. QoS mechanisms are those that contribute to the improvement of the overall performance of the system and hence improving end user experience. QoS mechanisms are:

- Admission control for call, connection, flow or packet
- Bandwidth allocation
- Buffer management and scheduling algorithms

Quality of Experience (QoE) is defined in Recommendation ITU.T P.10 [i.13]/ Recommendation ITU.T G.100 [i.15] as the overall acceptability of an application or service, as perceived subjectively by the end user. It covers the complete end-to-end system effects (client, terminal, network, service infrastructure) and it is influenced by the user expectations and context. QoE is a measure of end-to-end performance at the service level from the user perspective and it is an indication of how well the system meets the user's needs. In order to deliver acceptable service quality. Subscribers to network services do not really care how service quality is achieved.

QoE is built upon two dimensions:

- Objective (quantitative): influenced by the complete end-to-end system effects (i.e. user devices and network infrastructure)
- Subjective (qualitative): influenced by user expectations

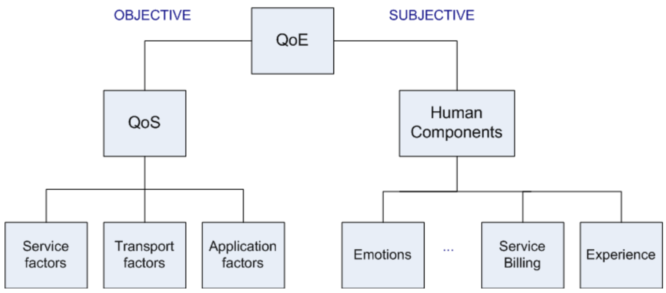

Figure 12: QoE dimensions

Subjective metrics

The level of QoE experienced and/or perceived by the customer/user may be expressed by an opinion rating.

The abbreviation MOS (Mean Opinion Score) is defined in Recommendation ITU-T P.10 [i.13] as the mean of opinion scores, i.e. of the values on a predefined scale that subjects assign to their opinion of the performance of the telephone transmission system used either for conversation or for listening to spoken material. This is used for voice and video communication to dictate whether the experience is good or bad one. The MOS provides a numerical indication of the perceived quality of the media received after being transmitted and eventually compressed using codecs. MOS is expressed in one number, from 1 to 5, 1 being the worst and 5 the best. The MOS is quite subjective, and it is based on what is perceived by people during the tests. However, there are software applications that measure MOS on networks.

The MOS numbers are quite easy to grade:

5 - Perfect. Like face-to-face conversation or radio reception.

4 - Fair. Imperfections can be perceived, but sound still clear. This is (supposedly) the range for cell phones.

3 - Annoying.

2 - Very annoying. Nearly impossible to communicate.

1 - Impossible to communicate.

MOS can simply be used to compare between VoIP services and providers. But more importantly, they are used to assess the work of codecs, which compress audio and video to save on bandwidth utilization but with a certain amount of drop in quality and error protection.

There is no equivalent measure of quality for data services. Data services may encompass a wide variety of content types and usage patterns (including email, social media applications, app store downloads, file transfer, etc.) all with different characteristics. Depending on the application used, users have varying quality of expectations for data performance and usability. Users QoE for data is based on factors such as:

- The amount of stalling in the video being viewed.
- The time required to download a webpage.
- The resolution of the video content being viewed.
- The responsiveness of an application.

The following figure represents the different QoE depending on the media. Different user perception of the same video content will depend on different video codecs.

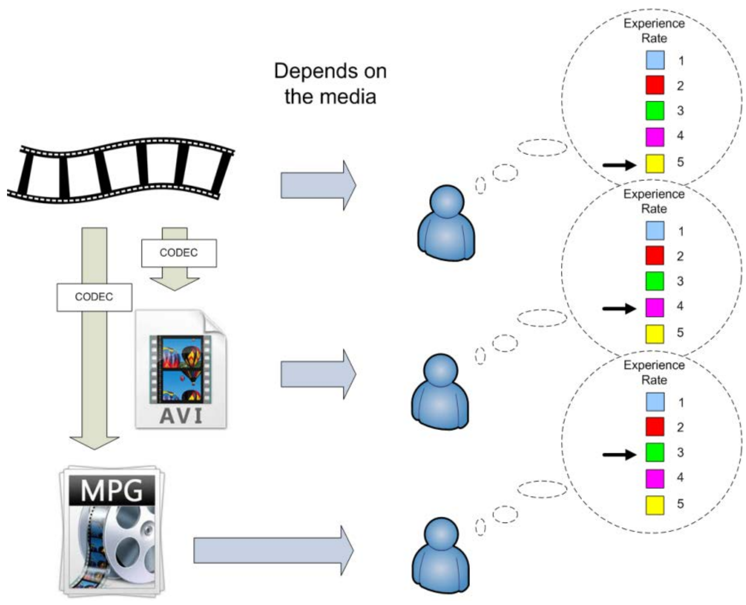

Figure 13: Qualitative QoE factors: user perception of QoS (experience rate) depending on the media for service delivery

Objective metrics

They use instrumental methods to obtain and indication that approximates the rating that would be obtained from a subjective assessment test. Objective measures of QoE are calculated algorithmically and can be integrated in to automated test and analysis routines. Although these methods may not reflect exactly the user's perception, they are repeatable and can be performed very quickly.

One of the following approaches can be used:

- Full reference (FR) metrics: Both reference and outcome are available, and allow for detailed subjective and objective comparisons.
- No reference (NR) metrics: Quality information has to be extracted from the outcome, as no reference is available.
- Reduced reference (RR) metrics: For reference and outcome, the same set of parameters are derived and compared in a very condensed manner.

Figure 14 illustrates the different FR, NR, and RR quality metrics and their required inputs:

- For the FR metric, the reference A as well as the outcome B are available, allowing to estimate the QoE by $FR(A, B)$.
- For the NR metric, only the outcome B is available, yielding $NR(B)$.
- For the RR metric, in addition to the outcome B, the measured parameters X are available on the receiver side and potentially even communicated from the sender side. Thus, the quality is estimated as $RR(B, X)$.

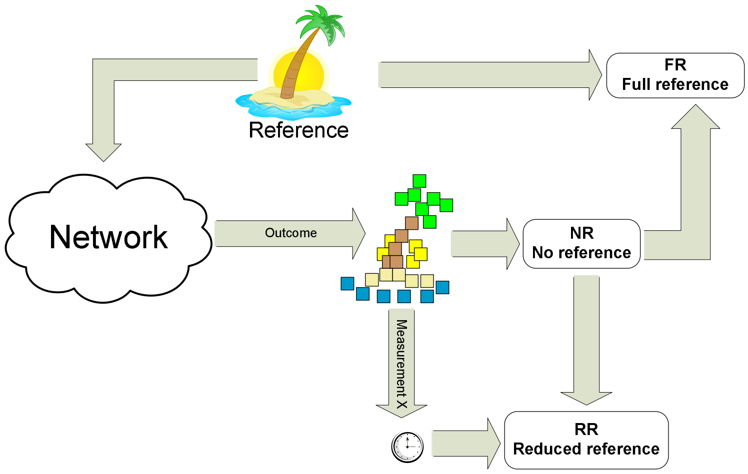

Figure 14: FR, NR, and RR metrics

A simpler method uses packet network parameters to extrapolate quality; and although it will not provide a complete characterization of QoE, it can provide an indication of quality at a cost effective manner. Media Delivery Index (MDI) is in this category of methods.

Objective metrics involve comparisons of original and reconstructed video sequences. These metrics are computationally intensive and time consuming to perform, hence, the need for objective techniques that can predict user QoE in real time for any given network health condition (using the delay, jitter and packet loss QoS metrics). A possible strategy is the combination of various objective methods to measure content quality including network parameters approach as in ETSI EN 302 307 [i.1].

5.3 Flows/CoS/QoS/QoE relationship

The expected QoE can be predicted from a QoS measurement. A target QoE may indeed, determine the net required service layer performance. To ensure that the appropriate service quality is delivered, QoE targets should be established for each service taking into account the system design and engineering processes that translate QoE to objective service level performance metrics.

If all flows of a given service are mapped onto the appropriate CoS then the user will experience a good QoE for the service".

The aim is to:

Apply a [CoS] to a [flow] to obtain a [QoS] that complies with the [QoE]

Where the above concepts are defined as follows.

[Flow] Following definitions of a **flow** are possible in various context:

- IETF RFC 2722 [i.8]: "an artificial logical equivalent to a call or connection".
- IETF RFC 3697 [i.5]: "a sequence of packets sent from a particular source to a particular unicast, anycast, or multicast destination that the source desires to label as a flow".
- In packet switches, the flow may be identified by IEEE 802.1Q [i.9] Virtual LAN tagging in Ethernet networks, or by a Label Switched Path in MPLS tag switching.

However, within this Framework a flow can be understood as a sequence of packets from a source device to a destination in line with IETF RFC 3697 [i.5]. An application can generate various flows.

Figure 15: Different application flows

[QoS]: QoS stands for Quality of Service and is the ability to provide different priority to different data **flows**.

In Switched networks **QoS** are requirements on all the aspects of a connection, such as service response time, loss, signal-to-noise ratio, cross-talk, echo, interrupts, frequency response, loudness levels, and so on.

In Packet networks **QoS** is the resource reservation control mechanisms rather than the achieved service quality.

In this context **QoS** parameters are those guarantying a certain level of performance to a data flow, assuring restrictions in:

- required bit rate,
- delay,
- jitter,
- packet dropping probability,
- bit error rate.

In addition the cost of a connection may be considered.

[CoS]: A certain Class of Service (**CoS**) is a set of **QoS** parameters used to differentiate the types of flows. The objective of such differentiation is generally associated with assigning priorities to the flow in different transmission queues.

[QoE]: Quality of Experience stands for:

- ITU TD 109rev2 [i.14]: The overall acceptability of an application or service, as perceived subjectively by the end-user:
  - Quality of Experience includes the complete **end-to-end system effects** (client, terminal, network, services infrastructure, etc.).
  - Overall acceptability may be influenced by **user expectations and context.**
- ETSI TR 102 274 [i.10]: User perceived experience of what is being presented by a communication service or application user interface.

The quantitative relationship between QoS parameters and MOS (simple metric to qualify the QoE) can be represented using a mapping function. The mapping function is characterized by two thresholds, x1 and x2. For QoS variations below the x1 threshold, user is not disturbed and above the x2 threshold user will give up using the system.

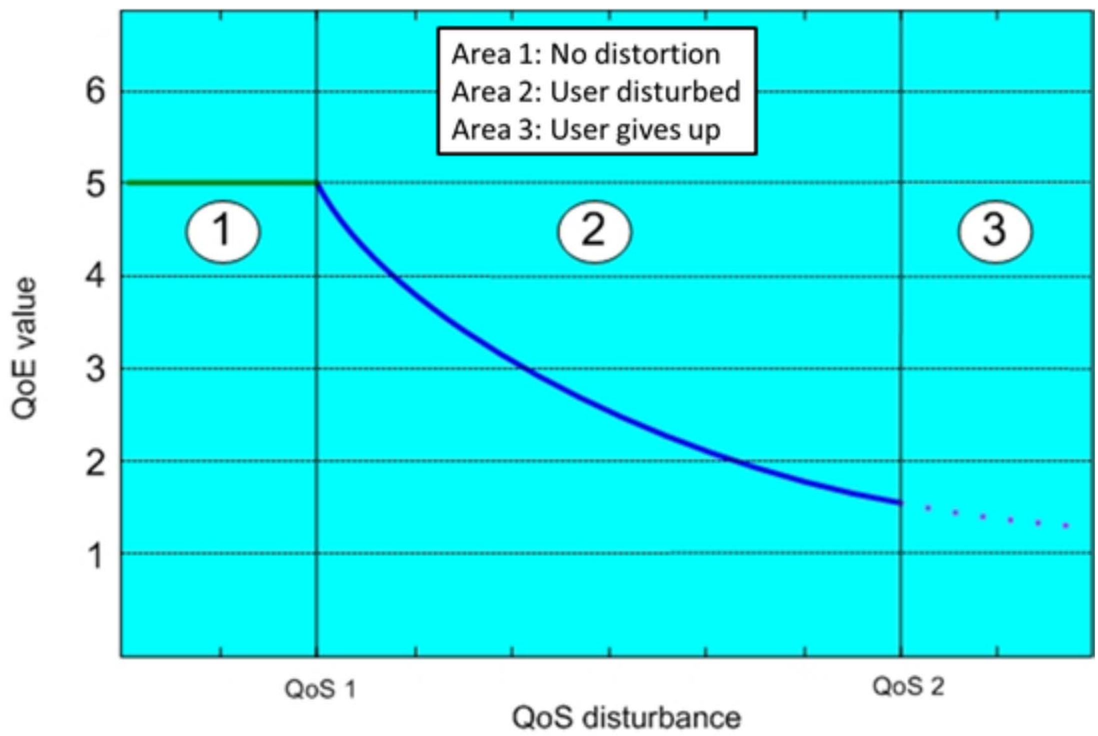

Figure 16: User Quality of Experience example

End user applications and services are made up from one or more Basic Service Elements - each Basic Service Element will create a traffic flow. These traffic flows are classified into Class of services, linked to different Quality of Service requirements. The QoS parameters thresholds mapping to QoE can be provided thanks to an offline method, meaning that a set of experiments will justify the QoS thresholds parameters linked to different QoE levels.

5.4 QoE aware architecture for hybrid access networks

End-to-end QoE relates to the end user satisfaction while using a particular service transparently to the involved intermediate nodes or technologies, i.e. a direct association between the user and the content provider. That is to say that the end user should not care about the underlying access technology in use. Taking as a starting point this end to end principle, this clause focuses on how the IUG and ING elements of the hybrid network contribute to the QoE maximization.

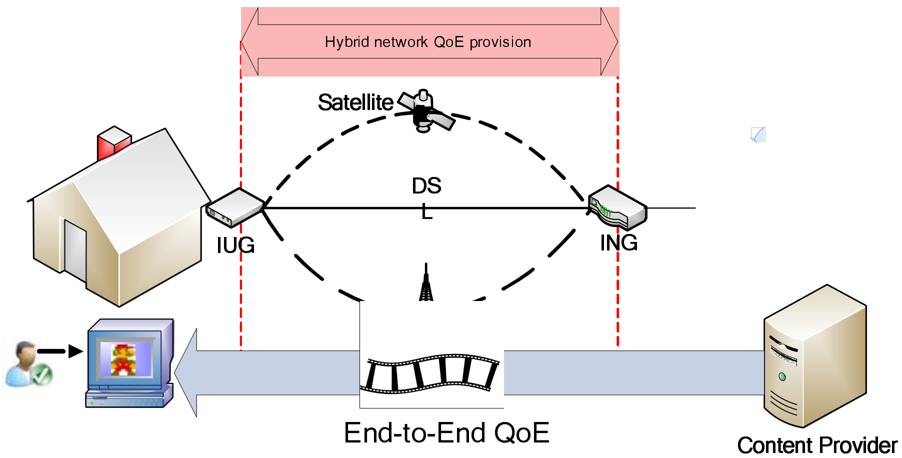

Figure 17: QoE of the hybrid network vs. E2E QoE

To achieve the desired E2E QoE the IUG/ING makes use of intelligent routing (as described in clause 4.5.2). The objective is to selectively route the user traffic over one of the multiple access networks that provide the best delivered QoE (which in general implies first using the link providing the best QoS). However, as the total traffic increases over all links then the routing needs to use alternative paths and it will choose to route that application traffic which is more tolerant to the QoS of the alternative path or paths but such that the overall QoE of all applications is maintained at the highest practical level. Consequently this mapping process is key to making the user experience of the hybrid network comparable to the that of one using a single high QoS network in addition to the higher degree of resilience that hybrid networks bring.

Intelligent routing together with traffic classification are essential elements in the QoE aware IUG/ING architecture. Figure 18 shows these functionalities in the IUG.

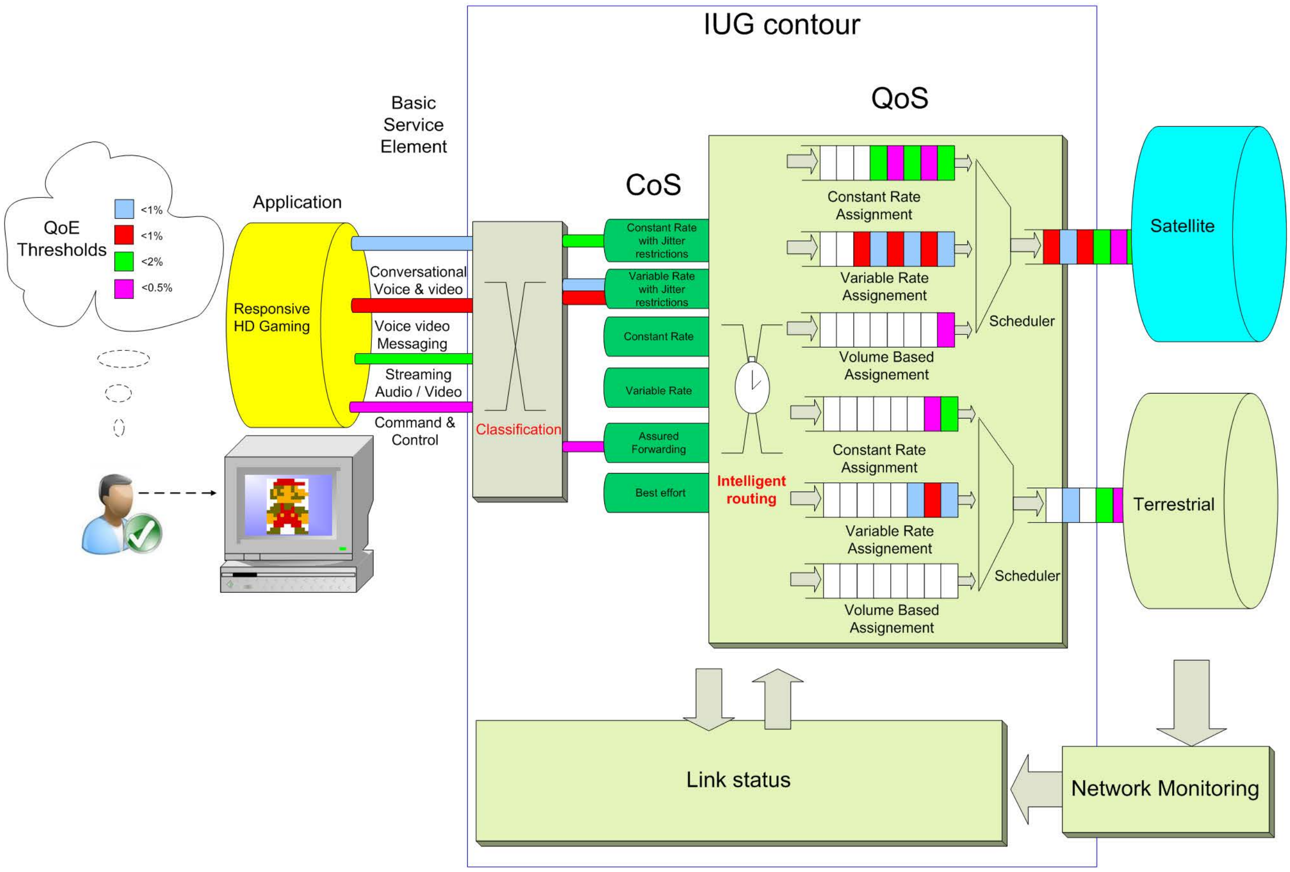

Figure 18: QoE elements in the Intelligent Gateway architecture

Figure 18 represents the Intelligent Gateway from the user perspective. One user with an on line connection to the network, may experience a service application constituted by set of flows. Each one of these flows is built upon basic service elements. The user can be more or less tolerant to unexpected failures, delays or jitters in the different flows. The basic service elements have an associated expected quality of experience threshold.

Each one of these basic service elements are classified in the IUG/ING into different classes of service. Even if their nature could be different, they may have the same final expectations in terms of classification to obtain a certain QoE. The different key service flows may be aggregated into the same class of service (as seen in previous clause).

Depending on the network management and the final user Service Level Agreement (SLA), different QoS parameters are applied to the different Classes of Services. Note also that the various networks may report different link status (including QoS parameters) that allow to determine the best connectivity link. The link selection is based on the constraints imposed by the CoS for a given flow and the link status.

The final result is different flows, scheduled in different manners but globally controlled and routed using different networks.

For the architecture to be complete, the QoE thresholds need to be mapped onto quantifiable QoS parameters and the IUG provisioned accordingly.

5.5 QoE to QoS mapping in the hybrid access network

The QoE to QoS mapping following previous architecture, requires an offline process used to reduce the system complexity and improve the compatibility with lower cost end user devices. In contrast, real-time QoE/ QoS processing poses feasibility issues because it may not be possible to measure the metrics and verify compliance with the QoE threshold on a timely fashion. The result is a poor user experience especially for the first round trips of a session. The offline process is described below.

Based on experiments, data collection, or analysis software (offline processing), the relationship between QoE and QoS parameters for the various flows is derived.

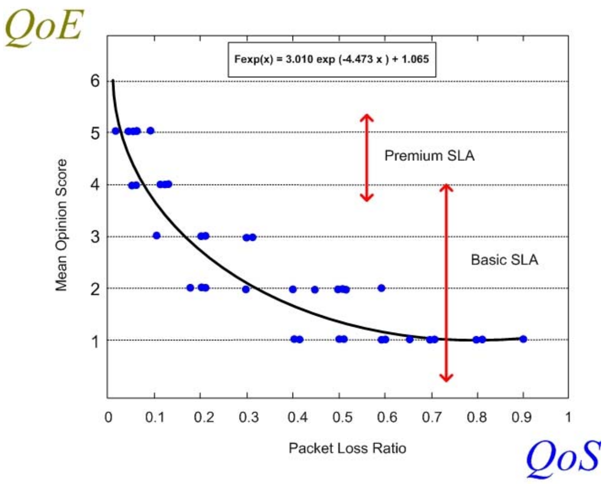

Figure 19: Example of mapping of QoE to packet loss ratio QoS parameter

The Service provider through the BSS decides the Service Level Agreements per service type. This SLA would be linked to certain QoE levels. The OSS would be in charge of defining the QoS parameters for each QoE level per service.

Once the QoS parameters threshold values are obtained in the previous step, the IUG is provisioned accordingly. Meaning that the IUG will be configured with:

- The mapping of flows into CoS
- The CoS made out of QoS parameters with their respective thresholds

Finally, once the IUG is provisioned, an incoming flow will be identified and associated to a CoS. The IUG will apply the QoS thresholds to the flow to maintain a certain QoE for a given SLA.

The proposed QoE/QoS mapping method previously described is illustrated in Figure 20.

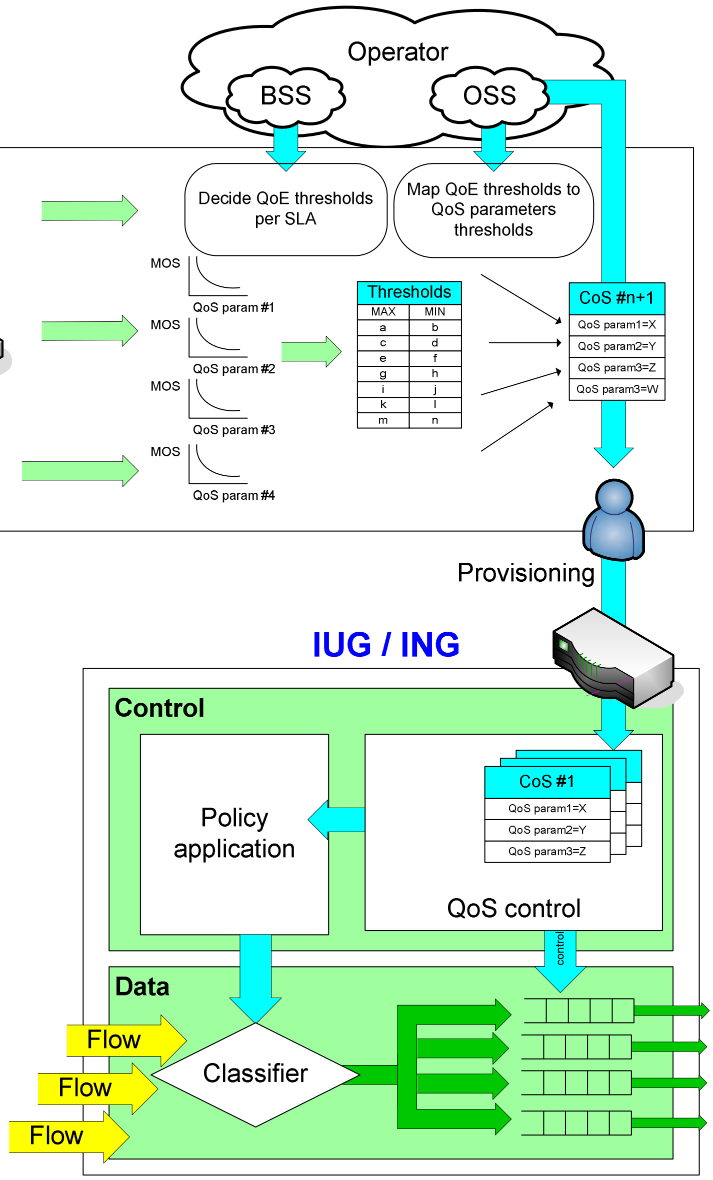

Figure 20: Proposed solution for QoE to QoS mapping implemented in the IUG / ING

Table 6 shows a result of this process from service classification, into QoS parameters thresholds associated to different QoE levels.

Table 6 shows the allocation from the expected user services in the 2020 framework and basic service elements to the Classes of Service as defined in IETF RFC 4594 [i.11].

Table 6: Relating basic service elements and CoS to user services expected around 2020

User Services	Basic Service Elements									
	Conversational Voice	Conversational Video	Voice / Video Messaging	Streaming Audio/Video	Broadcast Video	Command / Control	Messaging/Text Communications/ Web Transactions	Downloads	Back ground data	Network Management
	Classes of Service									
OTT HD VoD Streaming				Multimedia Streaming					Low priority data	
OTT HD Video Broadcasting					Broadcast Video				Low priority data	
Responsive HD Gaming			Real-Time Interactive	Multimedia Streaming		Real-Time Interactive		High-Throughput Data	Low priority data	
HD/3D Video Downloading								High-Throughput Data		
HDTV VoD Streaming				Multimedia Streaming					Low priority data	
3D VoD Streaming				Multimedia Streaming					Low priority data	
Interactive 3D Gaming			Real-Time Interactive	Multimedia Streaming		Real-Time Interactive		High-Throughput Data	Low priority data	
Multi-screen Concurrent Entertainment			Real-Time Interactive	Multimedia Streaming					Low priority data	
HD VoIP	Telephony									
HD Video-Conferencing	Telephony	Multimedia Conferencing							Low priority data	
3D Telepresence	Telephony	Multimedia Conferencing				Real-Time Interactive			Low priority data	
Backup, Software Updates								High-Throughput Data	Low priority data	
Media Editing & Sharing			Real-Time Interactive				Low-latency data	High-Throughput Data	Low priority data	

User Services	**Basic Service Elements**									
	Conversational Voice	**Conversational Video**	**Voice / Video Messaging**	**Streaming Audio/Video**	**Broadcast Video**	**Command / Control**	**Messaging/Text Communications/ Web Transactions**	**Downloads**	**Back ground data**	**Network Management**
Health Monitoring & Management	Telephony	Multimedia Conferencing				Real-Time Interactive	Low-latency data		Low priority data	
Home Monitoring, Automation, Security				Multimedia Streaming		Real-Time Interactive			Low priority data	
IUG/ING Network management signalling										OAM

Table 7 shows the **QoS** parameter thresholds applicable to the **CoS** defined above, and how the various flows are aggregated in the different Classes of Service (note that different **flows** can be aggregated in the same **CoS**).

The mapping of QoS parameters to QoE is performed following an off-line method, meaning that thanks to experiments the QoS parameters are linked to certain QoE value.

Table 7: Flows, CoS, QoS parameters thresholds and QoE mapping

Flows	CoS	QoS parameters								
		Loss ratio			Latency (one way)			Jitter		
		QoE-Optimal	QoE-acceptable	QoE not acceptable	QoE-Optimal	QoE-acceptable	QoE not acceptable	QoE-Optimal	QoE-acceptable	QoE not acceptable
Conversational voice	Telephony	< 1 %	1 % to 4 %	> 4 %	< 150 ms	150 ms to 550 ms	> 550 ms	< 10 ms	10 ms to 30 ms	> 30 ms
Conversational video	Multimedia Conferencing	< 0,5 %	0,5 % to 1,5 %	> 1,5 %	< 150 ms	150 ms to 300 ms	> 300 ms	< 20 ms	20 ms to 50 ms	> 50 ms
Streaming audio/video	Multimedia Streaming	< 0,3 %	0,3 % to 1,3 %	> 1,3 %	< 5 s	< 5 s	> 5 s	< 125 ms	125 ms to 225 ms	> 225 ms
Broadcast Video	Broadcast Video	< 0,3 %	0,3 % to 1,3 %	> 1,3 %	< 300 ms	300 ms to 700 ms	> 700 ms	< 20 ms	20 ms to 50 ms	> 50 ms
Voice/Video messaging	Real Time Interactive	< 1 %	1 % to 2 %	> 2 %	< 80 ms	80 ms to 300 ms	> 300 ms	< 20 ms	20 ms to 50 ms	> 20 ms
Command & control										
Messaging/Text communication/ Web transactions	Low-Latency Data	< 1 %	1 % to 4 %	> 4 %	<1 s	1 s to 2 s	> 2 s	N/A (jitter tolerant)		
Downloads	High-Throughput Data	< 1 %	1 % to 2,5 %	> 2,5 %	High tolerance to delay			N/A (jitter tolerant)		
Network management	OAM	< 1 %	1 % to 2 %	> 2 %	High tolerance to delay			N/A (jitter tolerant		
Background data	Low-Priority Data/Best Effort	High tolerance to loss			High tolerance to delay			N/A (jitter tolerant)		

6 Topics for future standardization

The hybrid access network architecture described above can be based on existing standards and technologies. However it assumes several innovative topics such as:

- Multi-link routing scheme.
- Optimization of multicast service delivery.
- Embedded caching management scheme to support efficiently content delivery services.

In addition, one should take into account increasing concerns about the environment impacts of ICT technologies among which satellite network infrastructures should be reviewed.

In view of the above, several topics that should be considered for standardization:

- Interoperability between equipment provided by different vendors of hybrid networks.
- Interoperability of the hybrid network with both home network environment and telecom core network.

Among these topics, this clause recommends to undertake the following standardization activities:

Table 8: Recommended standardization activities

Proposed standardization goals	Existing related standards	Proposed standardization bodies
Definition of the hybrid satellite/terrestrial access network architecture including an assessment method to qualify the QoE and enablers to support efficient Content Delivery Service	Broadband Satellite Multimedia network architecture defined in ETSI Currently, DVB defines the coding techniques for unicast services in DVB-RCS based satellite networks ITU with QoE metrics for "single component" networks	ETSI TC-SES for architecture definition
Definition of the multi-link routing architecture and impacts on transport protocols.	Transport protocols are usually defined in IETF while ETSI	ETSI TC-SES for architecture definition IETF for protocols
Definition of Adaptive Coding and Modulation techniques for multicast service over the satellite link.		DVB or possibly in ETSI
Definition of an energy efficiency framework to characterize the energy consumption associated with this hybrid access scheme	Energy efficient framework for mobile broadband (ETSI)	ETSI TC-SES

Annex A: Bibliography

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History

Document history		
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