Work Package 5
Consensus Building & Validation

Deliverable 3:
Report of Likely Future Technology Developments

Version 1.0

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Reference documents

[1] **Next Generation High throughput Satellite System** (May 2012 – PhD work of O.Vidal supported by Airbus DS and ISAE school in Toulouse, France)

[2] **BATS project (Broadband Access via integrated Terrestrial & Satellite systems**) - Deliverable 2.2 - Broadband technologies, Capabilities and Challenges (March 2013 - European Commission Collaborative Project – ICT-2011.1.1)

[3] **ECC/DEC/(05) 01: ECC Decision of 18 March 2005 on the use of the band 27.5-29.5 GHz by the Fixed Service and uncoordinated Earth stations of the Fixed-Satellite Service** (Earth-to-space).

[4] **ECC/DEC (05) 08: ECC Decision of 24 June 2005on the availability of frequency bands for high density applications in the Fixed-Satellite Service** (space-to-Earth and Earth-to-space).

Glossary

BFM	Beam Forming Management
CEPT	Conférence européenne des administrations des Postes et Télécommunications
CPE	Customer Premises Equipment
DVB-S	Digital Video Broadcasting - Satellite
DVB- RCS	Digital Video Broadcasting - Return Channel Satellite
EOR	Electric Orbit Raising
FMT	Frequency Modulation Technique
FR	Frequency Re-use
GEO	Geostationary
GTO	Geostationary Transfer Orbit
HTS	High Throughout Satellite
HPS	Heat Pump System
IMT	Interference Mitigation Technique
EIRP	Equivalent Isotropic Radiated Power
FSS	Fixed Satellite Services
FMT	Fading Mitigation techniques
FPGA	Field Programmable Gate Array
NAS	Network Attached Storage
RCS	Return Channel Satellite
SNR	Signal to Noise Ratio
SRC	Strategic Research Cluster (H2020 Space terminology)
SSPA	Solid State Power Amplifier

Executive summary

Starting by recalling where we stand today, this deliverable provides **an overview of the various ways to move to the next generation of satellite broadband services with the target to offer 50 Mbps consumer subscriptions in ~2017/18 and 100 Mbps by ~2020/22.**

Broadband services enhancement and evolutions are looked at from three angles: the **space segment** (satellite manufacturers), the **ground segment** (ground infrastructures manufacturers) and the **operational and services aspects** (operators). The global services evolution results from the combination of performance enhancement in each component, but also from a global optimization of the service value chain.

A drastic enhancement of satellite broadband services has taken place in the last few years with the arrival on the market of High Throughput Satellites (HTS). The first generation of broadband satellites was providing a total capacity up to 20 Gbps in a first attempt to make satellite communications suitable for broadband market. Since 2011, the 2nd generation of Ka-band satellites is achieving an economy of scale thanks to higher Frequency Reuse factor allowed by multiple narrow satellite antenna beams, combined with higher spectral efficiency modulation and coding schemes, thus reaching total capacities from 90 Gbps to 140 Gbps. For improving further satellites' systems throughput and reach the terabit/ps total capacity, manufacturers will have to increase the satellite's power in order to enhance spectral efficiency (going one step further with frequency re-use) and increase the usable bandwidth. Working along those lines, it is foreseen that larger antennas reflectors and more performing feeds will allow multiplying the number of spot beams by 2 to 3 by 2020, the current generation of HTS featuring 50 to 90 spots for a regional coverage. To cope with this increase of spot beams, wideband and power/mass efficient repeater technologies will be developed, allowing maintaining the overall satellite within a "launchable" volume and mass envelope. In parallel, user bandwidth will be freed thanks to the move of feeders links to higher frequencies such as QV or optical. Besides, flexible broadband payload will be developed to allow operators to adapt to the market evolution throughout the satellite life-time. Also, to improve the broadband systems economic performance, more powerful platforms, possibly boarding full electric propulsion system are being developed. The resulting system capacity will likely not be offered by a single satellite, but rather by a constellation of GEO satellites. Most of the technology and techniques evoked here are already developed or undergoing a sustained R&D effort. However, a few areas which would be well suited for the new H2020 Space and ICT work programmes remain unaddressed, such as the Optical Feed and the gateway diversity management systems.

The review also mentions the possibility of completely disruptive systems architectures, based on constellations of microsats, nanosats or even balloons. Such solutions are more and more evoked in the press by global and innovative players such as Google and could tackle the constraints inherent to the geostationary orbit, namely the access cost, the frequency allocations constraints, the latency and the long life time preventing to plan for easy in-orbit adaptation to a quickly evolving market.

Beyond the deployment of so-called Terabit satellite and systems, operators are adapting to the communication and media usage trends, and are in particular developing **new operational and services principles** and smart CPE devices to draw advantages of i) terrestrial/space networks hybridation ii) broadcast/broadband convergence. Both concepts are relevant for this roadmap since, in practice, they lead to a drastic enhancement of the downlink data rate performance, the traditional broadcast link being used as return link.

Lastly, this review describes how, in coherence with the Space technologies evolutions and the communication usage trends, the **ground-segment** also needs to continuously adapt to innovations.

This deliverable thus allows to **pin-point the areas where support for Research and/or Innovation through H2020 would be relevant**, in order to address new topics, complement Space Agencies work, support validation and demonstration or address the market.

H2020 SPACE **Frequency re-use**	Interference Mitigation Technique in high frequencies, Ka band Antenna > 5m, Antenna Pointing Systems, RF/optical frequency converters (V/Ka-Ka/Q)

Higher Frequencies	Antenna > 5m deployment systems (booms and mechanisms); QV feeder link end-to-end demonstration, 1.55 □m spatialised technologies for the optical feeder link, optical feeder link end-to-end demonstration (diversity techniques).
Flexibility	Foundry capacity in Europe (ASICS as critical technology) for transparent channeliser; Technologies leading to cheaper active antennas (GaN technologies, meta-materials, Rotman lense),
Platform	Novel solar arrays mechanical design (non longitudinal); NG batteries with regenerative fuel cells; Heat Pipe Systems; deployable radiators; NG electrical propulsion enablers
Disruptive architectures	Nano-technologies spin-in; spectrum management in LEO
Ground-segment	Development low cost multi-service / multi-network ground equipment, to support hybridation and convergence; support low TRL focused research, for example the area of the optical feeder link (ground-station and diversity management).
H2020 ICT	
Take the BATS research findings to Innovation	E.g in the field of Multi-path routing architecture, Adaptations to network management systems for integrated satellite and terrestrial networks, Novel satellite radio interfaces: evolutionary and disruptive, Interference mitigation techniques, Radio resource management schemes.
Enable, validate or demonstrate the role of SatCom for future broadband applications (such as In-flight services, Connected home and enhanced mobile services)	Network interoperability (network management, core network), possible spectrum coexistence (e.g. Cognitive Radio techniques), possible commonalities of radio interface (same Chipset for narrow band service), Satellite IP networks architectures, 5G networks specific research etc
Air Interface	DVB-S2 evolution or DVB-S3
H2020 FAST TRACK TO INNOVATION PILOTS	
Support to satellite broadband market take-up and adaptation to	H2020 Fast Track to Innovation pilot projects could be used to demonstrate the possibility to combine the

communications usage trends	use of satellite and terrestrial base services, and advertise the performance and cost effectiveness of those solutions

1 CONTEXT AND OBJECTIVES

While SABER aims to raise awareness about the current satellite broadband services and help to remove non-technological roadblocks which prevent their smooth deployment across Europe, discussions with the SABER public partners have highlighted the necessity for also informing about future satellite broadband technologies. Indeed, it appears very important to provide reliable information to the Public Authorities about satellite technologies sustainability and evolution and their capability to serve the DAE 2020 targets with a viable economic model. Indeed, justifying today's investment often requires to demonstrate how they fit into the long term context.

Market trends elements provided in [Ref 2] confirm the necessity to debate right now about future satellite broadband technologies. Indeed, data on current broadband coverage indicates that over 20% of premises will either not be covered or not take up superfast broadband (>30Mb/s) by 2020. [Ref 2] analyses also establish that an average of 14.4% of households will only have the satellite available for broadband connectivity (based on predicted roll out of rural BB). ADSL, while mature, is limited in performance; the fiber, while highly performing, will not reach all households for obvious economic reasons; VDSL is by nature limited to local exchange and LTE will not meet the higher demand and will leave 20% of unserved areas.

There is thus a real place for satellite service solutions at the Horizon 2020 which will need to start addressing now. Indeed, satellite at Ku band cannot reach the traffic demands, current HTS satellites at Ka band can cover consumer demand up to 30 Mbps but not the highest rates targeted by the DAE 2020 objectives with a viable economic model. This generates the need to start now designing broadband satellite systems reaching the Terabit/s capacity or beyond while drastically reducing the cost of the Mbps in orbit. The challenge for the satellite sector is thus twofold:

- <u>At technology, system and technique level</u>: One needs to act all along the technology chain and evolve ground (§ 3.3), platform (§ 3.5) and payload (§ 3.4) technologies to reduce the bit-per-second cost while increasing the total throughput (competition outside Europe is already progressing). To achieve this goal, the logical way is to increase satellite capacity by both increasing the usable bandwidth and further improving system spectral efficiency. Beside, operators shall also work on innovative operational approaches to address the market (§ 3.2).

- At market level: satellite services rely today on fully privately funded infrastructures. Investment in broadband services evolution will be pursued only if the market environment, including the public framework, encourages the operators by setting the conditions enabling satellites services deployment. In this respect, accounting for SABER findings and recommendations would help; beyond this, supporting awareness raising effort on the long term and the R&D effort inherent to this High-tech industry is necessary.

As done outside Europe and especially in the US and in Australia, the deployment of very high speed satellite broadband service need European public support and accompanying measures on both fronts.

Starting by recalling where we stand today (§ 2), this deliverable will provide in § 3 an overview of the various ways to move to the next generation of satellite broadband services with the target to offer 50 Mbps consumer subscriptions in ~2017/18 and 100 Mbps by ~2020/22. The roadmap under implementation will be summarized in § 4.

2 WHERE DO WE START

It is worth recalling a few contextual elements upon which the current solutions relies, before looking at the future broadband technologies evolutions. In particular, this chapter provides some history regarding the evolution of the broadband satellite systems, describes the principles of HTS satellites systems and last but not least, recalls the current services performance over under-estimated.

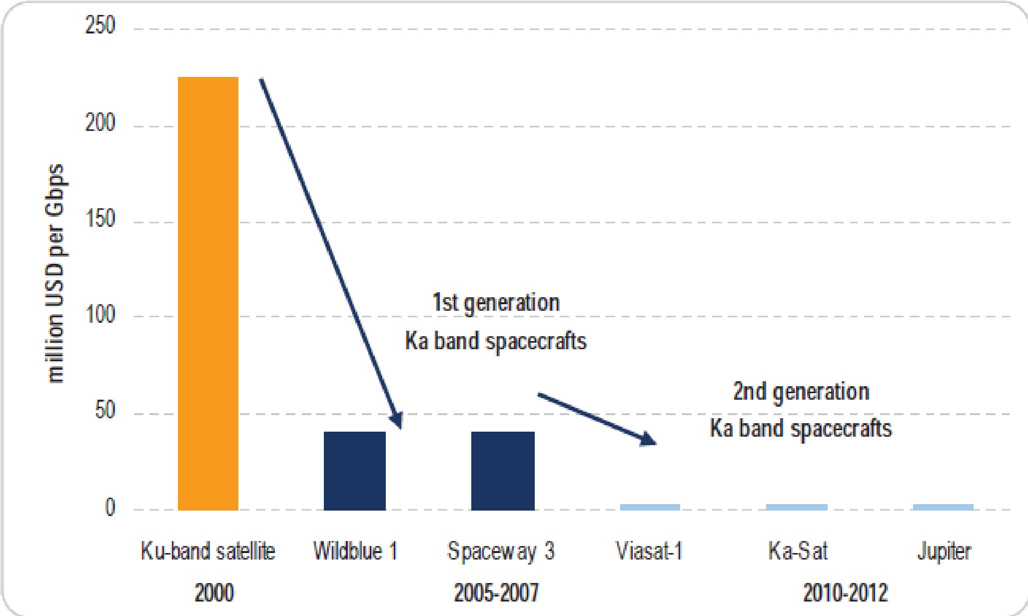
2.1 The recent (r)evolution

A drastic enhancement of satellite broadband services has taken place the last few years with the arrival on the market of High Throughput Satellites (HTS). Broadband satellite services deployment world-wide (even if at lower pace in Europe) are now significantly growing year by year thanks to the relevance of broadband satellite solutions in areas unserved or underserved by terrestrial and mobile networks.

As recalled in [ref1], the first generation broadband satellites such as iPSTAR, WildBlue I or SpaceWay 3 was providing total capacities up to 20 Gbps in a first attempt to make satellite communications suitable for broadband market. The 2nd generation of Ka-band satellites (i.e. Ka-Sat, Viasat-1) is achieving an economy of scale thanks to higher Frequency Reuse factor allowed by multiple narrow satellite antenna beams, and higher spectral efficiency modulation and coding schemes reaching total capacities from 70 Gbps to 140 Gbps. Furthermore, signal processing techniques further optimize the use of the available bandwidth; for example, Fade Mitigation techniques (FMT), such as Adaptive Coding and Modulation (ACM), allow coping with the variable rain attenuations impairments characterizing the use of Ka-band.

For improving a satellite system throughput, a trade-off must be made between the increase of the satellite power in order to enhance spectral efficiency and the increase of usable bandwidth. A proportional increase in power and bandwidth leads to capacity gain 6.6 times greater than an equivalent increase in power at constant bandwidth: **thus, the technology challenge is mainly a quest for bandwidth.** This has been a clear trend in the past decades, moving satellite operation frequencies up to Ka-band and beyond in order to make use of larger available bandwidths. Along the same line, frequency re-use strategies and optimized frequency plans in multibeam architectures have played an important role to make the best possible use of bandwidth resources. Next, once spectral resources are maximized, increasing power has been sought especially to increase the radiated power (EIRP – Equivalent Isotropically Radiated Power), either enhancing antenna gain or further increasing transmitted power.

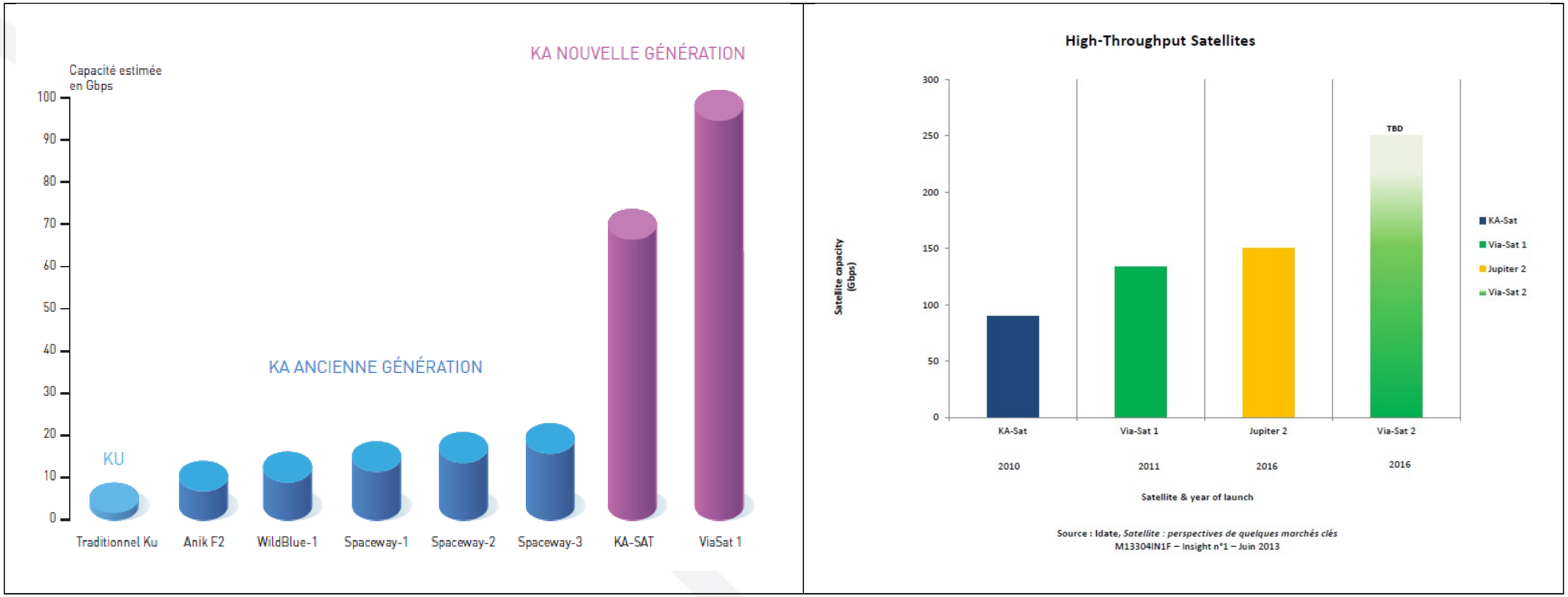
The combination of those technology breakthroughs has led to the introduction of the current generation of broadband payload and HTS at the start of the decade. Operators decide whether to embark broadband specific payloads or to fully dedicate the satellite to broadband services: the choice is dictated by their own market analysis and business plan.



Source: IDATE

Figure 2.A: Cost of the Gbps in orbit evolution

In the last decade, the cost of the Gbps in orbit has already been taken down by more than an order of magnitude. To meet the Digital Agenda 2020 objectives, it is necessary to investigate the next generation of broadband payload and HTS systems providing a further order of magnitude improvement (Terabit/s satellite capacity) at viable economic conditions.

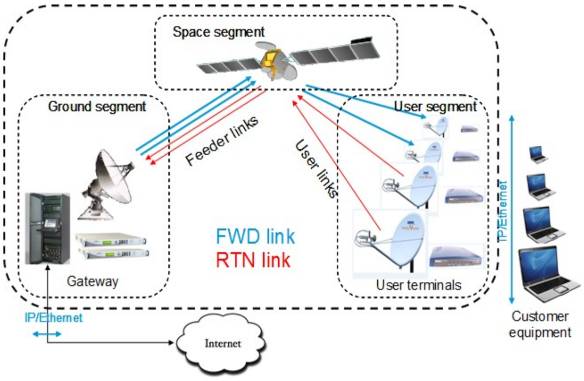


<u>Figure 2.B: High Throughput Satellites capacity since early 2000's years</u>

Currently, HTS total capacity reach about 150 Gbps. Viasat2 to be launched in 2016, is said to have "focused on total capacity at the expense of wide area coverage" and to be "designed to double the bandwidth economics of ViaSat-1 and provide seven times the coverage area" (Viasat web-site, April 2014).

2.2 The principle of an HTS satellite

To connect the end-users to the Internet backbone, a satellite broadband service system embeds:



- two-way connectivity terminals between the satellite and the end-users equipment (e.g. personal antennas)
- a few gateways which connect the satellite to the Internet backbone (each gateway serves several spot beams stemming from the satellite).

Compared to traditional broadcasting satellites which illuminate the target area through a single beam, new generation HTS make use of the maximum available spectrum and increase their performance mostly thanks to:

- Frequency reuse to increase the use of the available bandwidth: this is achieved thanks to a set of narrow spot beams, each active in a given bandwidth interval while ensuring enough physical separation between the beams operating in the same allocated bandwidth (no interference).
- Increased power per beam (and isolation) to enhance the spectral efficiency.

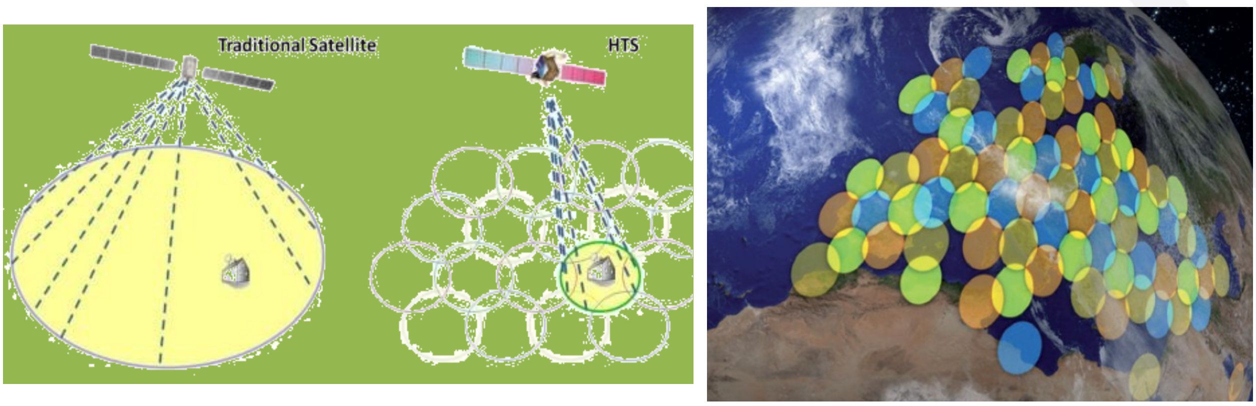


Figure 2.C: From traditional broadcast to new generation HTS satellites

Right: KA-SAT beams pattern (two spot beams operating in the same frequency band/same color never touch)

2.3 Killing a myth: satellite already enables 20 Mbps consumer offers

Awareness raising efforts deployed in the last year regarding the performances of satellite internet services have without doubt already convinced many public stakeholders that those services are definitely of broadband quality. However, the myth remains, which has to be killed, that for some technological reasons satellite services cannot deliver more than 20 Mbps downlink data rates. This is absolutely untrue as explained in this chapter.

While broadband satellite consumer's offers currently propose at most 20 Mbps downlink data rates, 50 Mbps subscriptions are already proposed to professional users. Higher capacity customized services are also available. Also, Eutelsat announced in spring 2014 that consumers terminals able to support 30 Mbps offers will be distributed already in 2015; for existing customers, this will only require changing the modem (the antenna remains unchanged).

It is thus important to explain why citizens cannot benefit right now from very high speed subscriptions: it all depends on the economical equation around « data rate/monthly volume ».

A spot beam has a given volume, and a certain cost for the operator, which can be shared among a certain numbers of users:

- The volume sharing granularity is thus a major driver of the subscription fees
- Within the monthly volume allowance, the offered speed is adapted so as:
  - to enable the service use over a month: downloading 1 movie in 1 second is not worth if no other service is available for the rest of the month!
  - to run the service with affordable personal equipment.

In the future, increasing the spot beam capacity will allow:

- Higher monthly allowance for the same number of users OR
- Lower monthly fee with more users and the same monthly allowance OR

- a combination of both.

The right balance has to be found between the monthly allowance and the data rate to allow reasonable subscription fees while permitting a sustainable economic model for the operator: with the current technologies, the right balance seems to be reached around 20/ to 30 Mbps consumers offer. To allow affordable while higher data rates consumer offers, the price of the Space-to-ground Mbps must be taken down: that's what all the actions described in paragraph 3 are aiming at.

3 IMPROVING BROADBAND SATELLITE SERVICES PERFORMANCES WHILE REDUCING THE MBPS PRICE

To meet the Digital Agenda 2020 objectives*, the next generation of satellite broadband systems will have to further enhance their performance by an order of magnitude. This will be achieved through improvement actions at all levels of the service chain in Space and on Earth. This chapter provides a flavor of the means already identified to achieve this goal. Chapter 3 does not aim to provide exhaustive nor detailed technical information; it gives an insight of the technology improvement possibilities with the goal to demonstrate that the satellite industry is already preparing services which will address the DAE 2020 targets.*

3.1 A combination of paths towards the DAE 2020 targets

To set the scene, it is important to recall that satellite services rely on a value chain involving many competencies and actors.

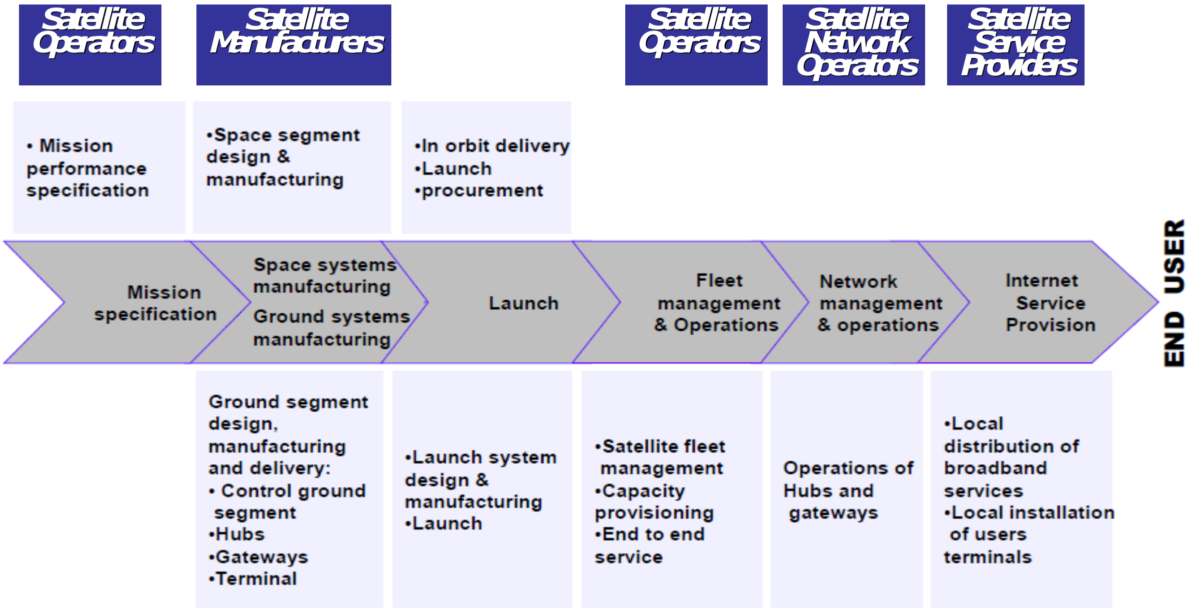


Figure 3.1/A: The satellite services value chain

Improving the performance of satellite broadband services will stem from each building block of the value chain where the stakeholders can act independently or concurrently at a more global system level, for example:

- Satellite operators are considering deploying hybrid ecosystems supporting converged broadband and broadcast services to consumers equipped with smart CPE devices across the EU. This can already be carried out using the currently flying satellites.
- Ground infrastructure manufacturers constantly enhance the performance of gateways and personal equipment (more efficient signal modulation, errors corrections, filtering etc.), already enhancing the services based on already flying satellites.
- Space infrastructure manufacturers run a continuous R&D effort to further increase the throughput delivered by the satellite while reducing the overall cost of the mission (satellite and launcher) to keep the economic model viable.
- And as an overarching starting requirement, all actors involved act at their level to secure the availability of spectrum for satellite services.

3.2 Innovative and/or integrated operational approaches

3.2.1 Context

Today, high speed broadband delivered via satellite efficiently completes the coverage of European citizens unserved or underserved by high speed terrestrial network. Indeed, Vice-President of the European Commission (EC) Neelie Kroes recognised at the Broadband-for-All event (17 October 2013) that: "*Thanks to the extra coverage provided by satellite broadband, we have achieved our 2013 [Digital Agenda for Europe] target of broadband for all*".

Tomorrow, very high speed broadband delivered via satellite will help to achieve the new DAE 2020 objectives stating that all Europeans get access to internet speeds of 30Mbps and 50% of European households subscribe to internet connections above 100 Mbps by 2020. In order to fulfill these new objectives, **satellite manufacturers** are implementing research activities to improve the technology for broadband connectivity both from a cost reduction and a quality improvement perspective. Then, to deploy Very High Speed Broadband services, satellite operators can either:

- develop a small number of wide beams to specific regions. The available spectrum resources are then allocated to each beam.
- go for the so-called Terabit satellite and consider providing Very High Speed Broadband all over Europe through a single (or 2) dedicated High Throughput Satellite.

In parallel, the audiovisual sector is witnessing an evolution in users' behavior and services supported by very high speed broadband. One such example is the same content accessibility through multiple devices. This trend appears to be confirmed by major consumer electronics manufacturers to enable new services by piggybacking on existing devices for which customers have already paid for.

In this framework, broadcast satellites also have a role to play to fulfil the new expectations of consumers. Hybrid solutions are designed where broadcast and multicast services are most efficient and thus inevitable.

3.2.2 Convergence

In conventional TV services, the content is broadcasted at a specific time. In many ways, the broadcast controls the customer by selecting the time of broadcast. This may remain the mainstream broadcasting avenue but it will certainly not be the only one. With the development of Internet, the consumer has access to content anytime. Today, internet, telephone and TV are still considered as three different services, although they are delivered by one service provider in the framework of triple play - where broadband, TV and telephone are bundled together. Therefore, consumer's behaviour and expectations are evolving. For example, in the case of non-linear TV including video-on-demand (VOD) and interactive TV, the customer selects what and when to view content and even interact with it in real time.

The example of VOD is particularly relevant as video traffic will be growing for the next years. According to Cisco, the sum of all forms of video will be approximately 86% of the consumer IP traffic by 2016. This figure single-handedly summarises the importance that video traffic will have in future networks and the fact that video traffic through internet is now in competition with traditional broadcast services.

Therefore, beyond the deployment of Very High Speed broadband service delivered by the future generation of space infrastructure (described later in § 3.4), **operators are adapting to the communication and media usage trends. In particular developing new operational principles and smart CPE devices will answer the new expectations of users in terms of interactivity and customised purchase.**

The next thing happening is the marring of the frontiers between the service so that IPTV is delivered via broadband. TV is no longer linear but becomes connected and interactive. One no longer watches what is available on the TV but can decide when to watch what he wants to watch (e.g. VOD and catch TV). One is no longer a spectator of a show, but a participant. All this requires interactivity since it changes broadcasting from a unilateral link to a bilateral link. One no longer just receives video but now needs to send information.

Part of the current terrestrial network (especially networks in rural areas and/or without Fiber To The Home) does not and will not have the capacity to provide quality video, including HDTV and ultra-HDTV, to a large number of the users. It will not be able to provide an adequate quality of service (QoS) during the peak period and support the growing video traffic. This is despite the continual and increasing investment of telcos in the terrestrial infrastructure. Relying on broadband techniques only implies the failure of adoption of connected TV by a large portion of the customer base.

Therefore, satellite has a role to play to complement the terrestrial network. Traditionally broadcast has been an established satellite service since the 1980's while broadband satellite is relatively recent. In broadcast a single source attempts to reach several customers while broadband systems aim to connect bilaterally customers to nodes that are typically connected to the web. Indeed, broadcast satellites remain an efficient way of delivering content to many customers simultaneously, and High Throughput Satellite systems have their advantages for nonlinear applications.

As Fiber To The Home is not to be implemented in the short to mid-term for economic and technical reasons, **satellites can proficiently be part of a hybrid network configuration, consisting in a mix of broadcast infrastructures and broadband infrastructures, managed in such a way that it brings, seamlessly and immediately, converged services to all end-users in the EU**.

Indeed, the concepts of i) terrestrial/space networks hybridation and ii) broadcast/broadband convergence are relevant for this roadmap since, in practice, the use of all available broadband and broadcast resources lead to a drastic enhancement of the downlink data rate performance, the traditional broadcast link being used as return link.

That is why the focus in the coming years will be to have the future media content to be delivered with a combination of fiber, cable networks, wireless terrestrial networks and satellites based on several factors such as sustainability, financial feasibility, and strategic plan for connectivity (hybrid satellite-terrestrial network).

3.2.3 Hybrid networks

A terrestrial/space hybrid network will therefore:

- improve the reach of satellite services (the delivery of both high quality TV and interactivity being a good solution in remote areas where terrestrial broadband solutions are not available or not economically viable) and in doing so enhance the user's experience and contribute to the tackle of the digital divide: it is a configuration where all users can enjoy full interactive experiences regardless of their location (ADSL2 broadband speed + satellite would enable experiences comparable to fibre)

- improve the overall network performance by preventing congestion of terrestrial networks (offloading). Regarding the future IP video traffic, terrestrial networks will not be able to cope with those volumes alone: satellite will have to be used for offloading traffic.
- Provide users with a standardised access to the installed user base to deliver enhanced contents.

Already, Hybrid Broadcast Broadband TV (HbbTV), which aggregates different IP streams into one media experience, is gaining huge popularity in the market. These gateways provide an integrated data/media stream for the TV or media player. This trend is mainly fuelled by the emergence of tablet PCs, smartphones and other connected devices where every device needs access to the Internet.

We consider that the evolution from the current, separated provisions of the linear TV (unidirectional) service and broadband (bidirectional) services to the development of a fully integrated (bidirectional) hybrid broadband-broadcast service provision (figure 4), **calls for a few technological steps,** each one raising specific issues:

1. The first step consists in **converting the format of the transport of content** from different sources (broadband / broadcast) into a unified format -typically IP- compatible with the distribution in the local / domestic network and with the use on different devices and screens.
2. The second step introduces an **early and limited interaction between network operators / content providers and final users** (with issues regarding users' preferences, the popularity of contents and DRM).

3. The third step allows a fu**ll interaction between the final users and network operators / broadcasters**. Sub step 3.1: In particular, the broadcast channel is also used to push content directly at the user's premises (push VOD)

4. The last step foresees **native IP audio-visual content on the broadcast channel**, thus replacing the MPEG Transport Stream multiplexing. All contents will then have the same format, regardless whether they are delivered via the broadband or the broadcast channel.

CURRENT SITUATION

Linear TV and broadband are mostly provided through separated connections. In the example shown below, the linear TV is delivered via a DTH Satellite via a DVB-S/S2 standard transport, which can carry video and data content.

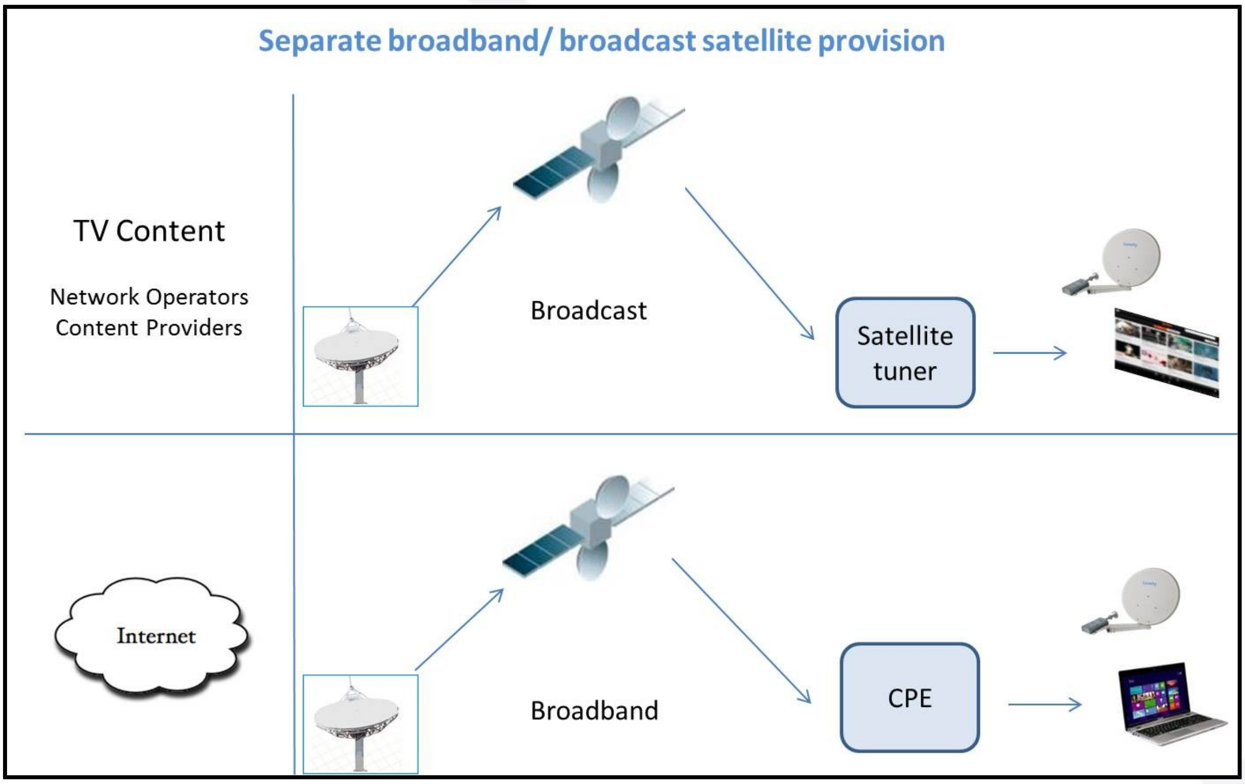


Figure 3.2/A: Separate provision of broadband and broadcast satellite services

STEP 1: Transport of content from different sources (broadband / broadcast) in a unified format (such as IP), compatible with the distribution in the local /domestic network and for the use on different devices and screens

Description

The first step towards integration consists in a function which receives the broadcast signals, converts all transport formats into an IP format for distribution in a local / domestic network of the requested contents which are accessed by multiple devices and screens.

Limitations

- The server is rather costly, at least as per today.
- IP is just the transport format in the local / domestic network: it is not extended to the other devices receiving the signal.
- The content protection is neither modified nor improved.

STEP 2: Early, limited interaction between network operators / broadcasters and final users through a narrowband return link

Description

The capability of an early interaction between broadcaster and final users can be implemented through a narrowband return link. Its availability enables some limited applications, including a dynamic control of the Digital Rights Management (DRM) if a conversion from CAS to DRM is implemented. It can also enable automatic audience share measurement.

In the case of broadcasting via satellite, the narrowband return channel can also be implemented via satellite, through a function integrated in the receiving equipment, thus enabling interactions without the need of a terrestrial connection.

Limitations

A narrowband return link (10-100 kbps) can be provided almost everywhere by terrestrial networks, especially in Europe (phone lines or 2G/3G can implement a return link at low cost).

STEP 3: Towards a full interactivity between broadband and broadcast

Description

In a full hybrid broadcast/broadband network, the final user has access to both linear and non-linear audio-visual content in a fully integrated way. This requires a broadband return link. (2+ Mbps)

The Home Gateway (or a similar functionality that could be implemented directly in the TV set and / or in other devices) is the network element that allows an extensive interaction. It enables:

- Network operators to provide users with relevant content of the basis of the continuous collection of each user's preferences.
- Network operators to select the most appropriate channel to deliver content.
- Users to access to content in a fully transparent way still benefitting from the best of each technology.

The fully integration calls for a standardised protocol on the unidirectional broadcasting channel to transport additional information along with the TV signal, in order to provide a direct link between the program and online content and enable to management of the interaction between the forward and the return link.

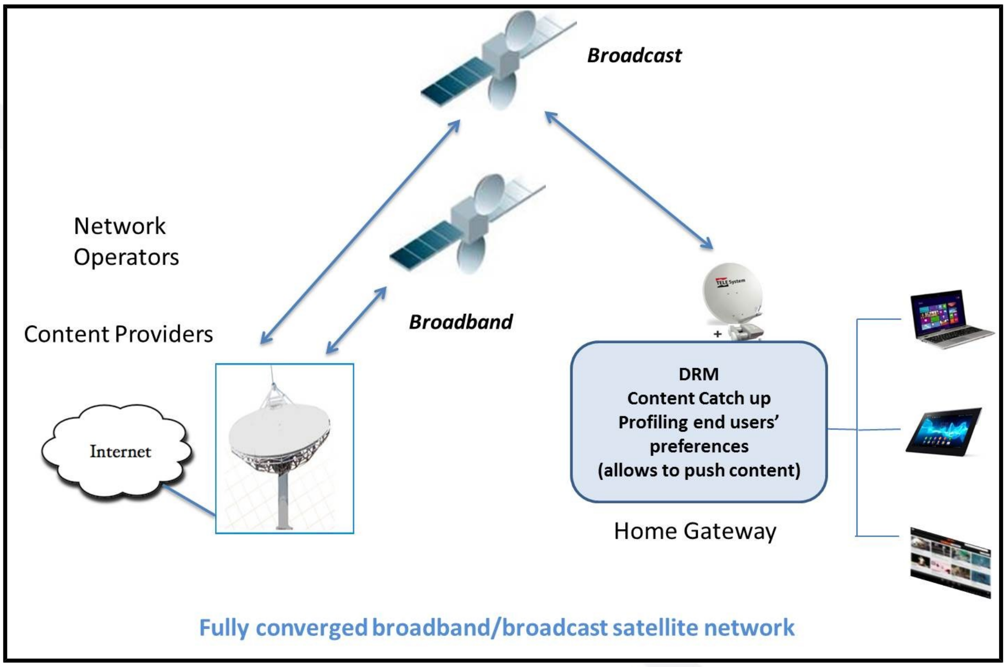


Figure 3.2/B: Fully converged broadband/ broadcast satellite network

Sub-Step 3.1: Pushing content directly at the user's premises

Description

An additional function of a full hybrid broadcast/broadband network is content pushing directly into a storage (e.g. an in-home Network Attached Storage – NAS), or an equivalent device inside the set-top box or the home gateway) which, although positioned at the user's premises, remains however a network termination unit, controlled by the network operator or the content rights' owner, and is not user equipment.

This function, also called Push VOD, which takes full advantage of the inherent broadcast capability of satellite while facilitating the user access to the most demanded content, also enables the offer – and the on-demand consumption - of very high-quality contents (e.g. in 4K format) even in the absence of adequate broadband network resources.

Challenge and limitations

- The right management and the risk of content piracy.

- The NAS is used to store the most frequently asked contents. Economic and technical rules should be established by the ISP on the basis of the user's preferences to select the most appropriate resource to provide a specific content to a given user.
- The control and managed use of the NAS can be a conflicting point between ISPs and content rights' owner such as broadcasters, as it often deals with the "ownership" of the subscribers. Ideally, an agreement should be found between the ISP and the content providers on the access to the NAS. Finally, the user might be allowed to use part of the NAS for his own storage (e.g. private copies).

Step 4: Native IP audio-visual content on the broadcast channel

Description

The ultimate step for a full integration calls for native IP audio-visual content on the broadcast channel, thus replacing the MPEG Transport Stream multiplexing. All contents will then have the same format, regardless whether they are delivered via the broadband or the broadcast channel.

Challenge and limitations

Large OTT, such as Netflix, are likely to be favourable to this approach to extend their reach. However the transmission of content in native IP format would oblige current bouquet providers, such as Canal+, to replace the currently installed base of receiving user equipment.

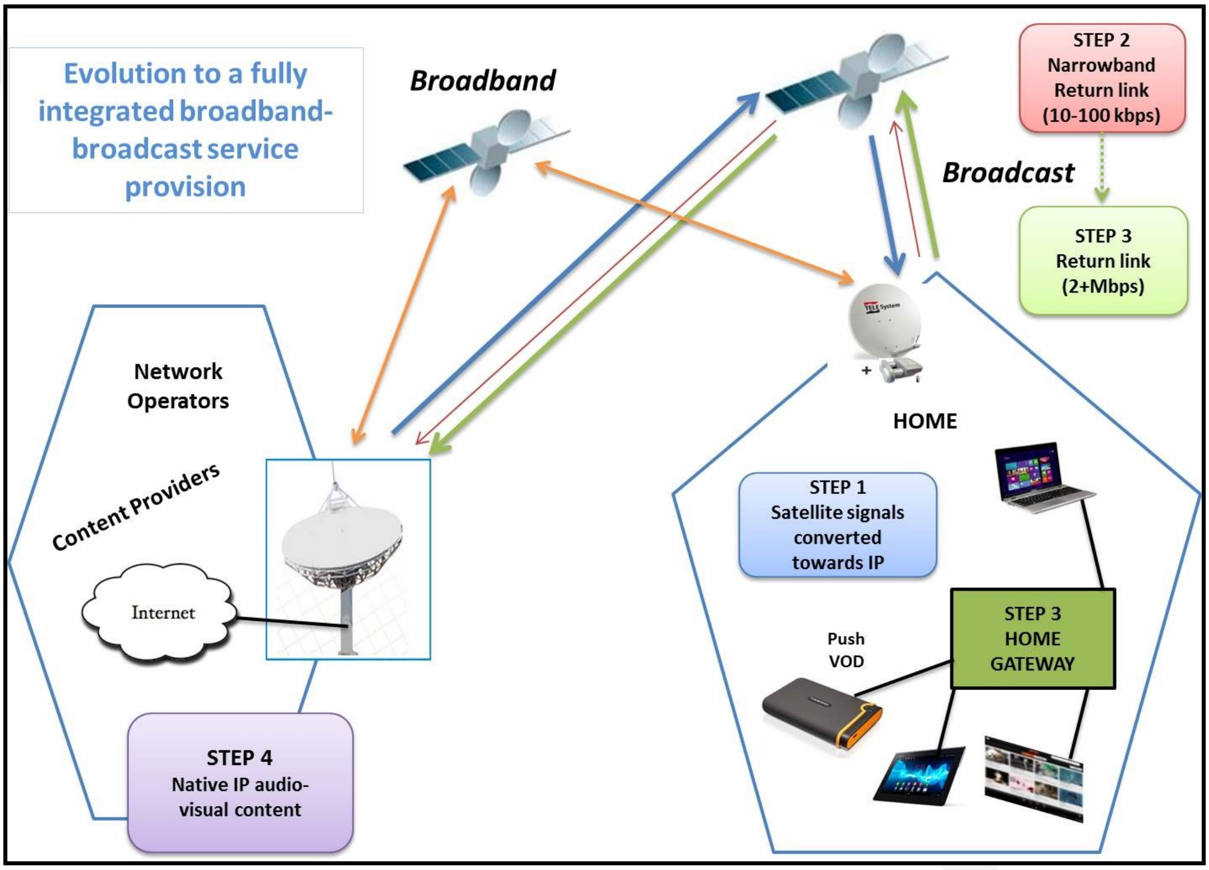


Figure 3.2/C: Four steps leading to a fully integrated broadband/broadcast network[1]

3.2.4 Hybridation enablers

The current changes in the audio-visual landscape, with the *"the progressive merge of traditional broadcast services and the internet"* within the convergence phenomenon, will have deep impacts on (a) content consumption and viewing behaviours, (b) equipment and devices and (c) the number and role of market players. For instance:

a) the converged services will further increase the user's requirement to have access to audio-visual content in a "ATAWADAC"[2] way.

b) This transformation goes along with a transformation of the equipments and devices, addressing all screens of the connected home and even outdoor.

[1] This process can also be adapted for an hybrid terrestrial and space network.

[2] ATAWADAC: Any Time, Any Where, Any Device, Any Content

c) The convergence between TV and internet contents also leads to a multiplication of players and offerings: new actors coming from the internet are increasingly playing a role among other TV actors, whereas traditional broadcasters have to adapt themselves to this new environment.

The smart use of a mix of broadcast and broadband infrastructures to provide interactivity in a hybrid network configuration responds to the requirements quoted above. A hybrid network configuration is a mix of broadcast infrastructures (DTT, cable and/or satellite) and broadband infrastructures managed in such a way it brings converged services seamlessly to the end-users.

The main features of such a hybrid network are:

a) the smart and interactive management of networks: there is an interaction between network operators, broadcasters and final users. For the most popular contents (that could be evaluated thanks to the communication of users' preferences) there could be a push to use the broadcast network; for less popular contents, broadband network could be used: the choice of the network to provide content shall be seamless for the end-user (depending on the cost, the demand, the quality required)

b) the secure delivery of content: the digital management of rights (DRM) prevents unauthorized use of content or services, allowing to directly comprehend what the user has access to.

3.2.5 Symmetry

The constraint of upload/download data rates symmetry is often put forward as a requirement for new generation access networks. In practice, it is rather a "psychological" requirement: an asymmetrical system is not necessarily un-compliant with the actual needs.

Regarding satellite broadband, HTS systems typically have equal capacity for forward and return link in terms of spectrum. Thus, in theory they are capable of delivering symmetrical capacity in terms of megabits per second. When we look at the protocols, the forward link is much more sophisticated in exploiting the available spectrum. DVB-S2 is the reference for the forward link. Its adaptive coding and modulation does a very good job at exploiting the available spectrum to deliver the maximum of information and is very close to the theoretical limit. DVB-RCS is the reference for the return link and invests more effort in ensuring that the terminal cost remains low than maximizing spectral efficiency. Typically the return link is 70% less efficient.

Notwithstanding the above, almost by definition broadband is asymmetrical and we have seen that in general on a HTS system there is a surplus of return capacity that confirm the asymmetry what the market requires at the most cost effective fashion.

The need for symmetry is truly a myth that arises from the fact terrestrial networks are intrinsically symmetrical. It is technology driven and does not reflect the market requirements.

3.3 Improving the user segment performance (ground infrastructure)

Improvements on the ground-segment are triggered by the need to adapt to innovations on the satellite side, but also by the search for more efficient use on the bandwidth and by the need to adapt to the market.

3.3.1 Following-up innovation at satellite level

To fit the increasing performance of the future satellites, the ground segment infrastructure must evolve through a number of new key improvements:

- The ground Segment will become wideband carrier (>250MHz) capable This will lead to more efficient use
- Furthermore ground segment will be improved and innovated to fully exploit the new dynamics of satellite payloads
- The new innovative DVB-S2X standards and future enhancement will be introduced within the ground segment equipment.
- The number of required satellite ground segment gateways will increase in case of HTS satellites; therefore further innovation on more “dense” and cost efficient gateways allowing also for flexible and adaptive beam-hopping will need to be researched and developed.

- Also, research on ground-component for future Terabit satellite relying optical feeder-links need to be started now to enable implementation at the horizon 2020.

3.3.2 Searching for more efficient use of bandwidth

Searching for more efficient use on the bandwidth is a continuous stand-alone research topic implemented around two major work areas:

- Look for a better signal modulation and adaptivity such as HRC (HighResCoding) and Mx-DMA (Multi cross dimensional – Division Multiple Access) will increase the satellite capacity efficiency.
- Combine the adaptivity benefits realised at the transmission layer with cross layer optimisation, and port and exploit them up to the level of the application layers on top of TCP/IP.

3.3.3 Adapt to the market

The ground-segment must also adapt to the market needs, typically in the following areas:

- For the consumer market, further research and development towards low cost terminals with combined and integrated terrestrial capabilities will be key. This might require the development of specific key components for those terminals.
- Satellite ground segment will need to be capable of provide and operate multiple services related to various markets. Some specific developments such as cost efficient and compact antennas for mobility also need to be on the development roadmap.

3.4 Increasing on-board payload performance and throughput

This paragraph develops what to expect for fixed broadband space systems in the coming years that may lead us even beyond the challenging Terabit/s capacity. At system level (§ 3.4.1) this can be achieved by i) increasing the frequency re-use factor through reduced beam sizes ii) increasing the available user link spectrum (moving to higher frequency for the feeder link) iii) increasing the number of user beams iv) and improving the signal transmission efficiency, in particular in higher frequency bands. At system level, the improvement of the economic performance will also be enhanced by the deployment of flexible payloads allowing adapting the services to the actual evolving needs, after launch and throughout the satellite lifetime.

At technology level (§ 3.4.2), this translates mainly into i) future antennas allowing more throughput per beam and/or working in higher frequency bands ii) lighter, smaller and more efficient repeaters iii) more powerful and flexible payload and iv) more efficient Air Interface standards.

The elements presented in this chapter are largely inherited from [Ref1] and [Ref2] where many details are provided. In summary, they conclude that while the current generation of HTS features 50 to 90 spots for a regional coverage such as Europe, the evolution described in this chapter will allow multiplying by 2 to 3 the number of spots by 2020. Moreover, a capacity per spot spanning between 2.5 to 4 Gbps could be envisaged while the capacity density could be increased by more than 10. In parallel more bandwidth in Ka band will be used so as to also increase the total capacity devoted to user links. It shall be noted at last that the resulting system capacity will not likely be offered by a single satellite, but rather by several geostationary satellites.

3.4.1 System level evolution for an enhanced payload performance

3.4.1.1 Frequency re-use and interferences mitigation techniques

As already evoked in § 2.2, multibeam coverage permits to reuse several times the same frequency/polarization sub-band and so increase the allocated usable bandwidth by the same factor. The way to increase frequency resource could appear unlimited (just increasing the number of beams) but it has a physical limit due to the maximum antenna size which can be accommodated on the satellite, the maximum achievable pointing accuracy and inter-beam isolation. When it comes to select the appropriate frequency re-use (FR) pattern, trade-offs should be made depending on system requirements knowing that in any case, there is no generic or unique solution.

Since the goal in our case is to increase final user data rates, it seems logical to try increasing the capacity density per Km2. To reach this goal, the trend is to work on

- reducing the beam width to have narrower spot beams with higher gain: this approach also generates more payload equipment on-board and the need for more gateways on Earth.
- and/or searching for FR patterns with the highest bandwidth-per-beam allocation: this approach necessitates largest reflectors and increased power.

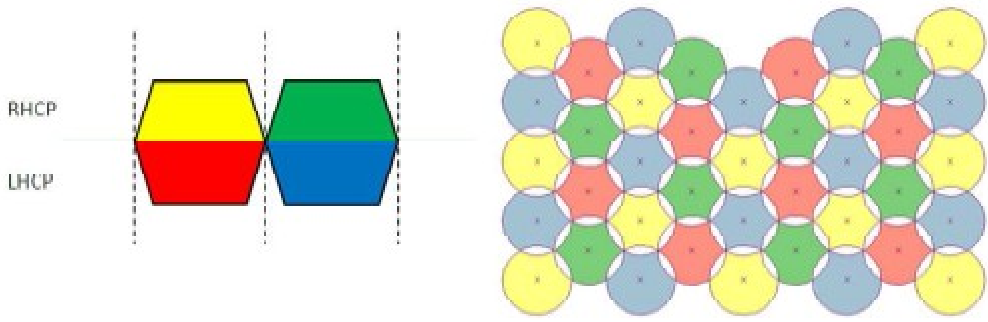


Figure 3.4/A: generic 4-color frequency re-use pattern

To enable the maximum use of the FR technique, strategies such as Interference Mitigation Techniques (IMT) are implemented to cancel terrestrial interference. Interference Mitigation Techniques based on MIMO information theory (Multiple Input Multiple Output) have been investigated and results show great potential in terms of overall enhanced capacity and performance when applied to broadband satellite systems. The aim of these techniques is to cope with the interference issues resulting from the increasing number of beam trend in HTS like scenarios, but they also allow the implementation of full FR pattern. Some high potential techniques are for example based on the joint encoding of all co-frequency carriers transmitted by a gateway to a set of beams in order to minimize the mutual interference that each user will experience from the other co-channel beams.

The optimum has to be found to best share the burden on-board and on-ground while minimizing the development costs and risks, the operational and the launch costs. For example, the most recent studies recommend sharing the total the provision of a terabit/s capacity across a constellation of Geostationary satellite than have it provided by a single one.

3.4.1.2 Feeder link in higher wavelength

A satellite broadband system capacity increases linearly with the amount of available spectrum (at constant EIRP density values). This simple assessment is one of the key design drivers of broadband FSS systems. The current generation of HTS satellites uses the Ka-band, where more bandwidth is available with fewer coordination issues with respect to more exploited lower bands. However, only 2x500MHz is exclusively allocated for FSS which clearly is a limiting factor when trying to significantly improve total system capacity. Therefore, the trend is going towards the full use of the allocated Ka bandwidth for user links and a shift of the feeder link to higher bands such as Q/V-band or optical. The FSS Ka-band spectrum would then fully be allocated to user links (otherwise occupied by feeder links), increasing the available downlink user bandwidth from 500MHz up to 2.9GHz per polarization. Also, that would allow locating the gateways within the service areas since the risk of interference between the users and the feeder links is de facto removed. Lastly, working in higher frequencies would allow much more capacity per gateway.

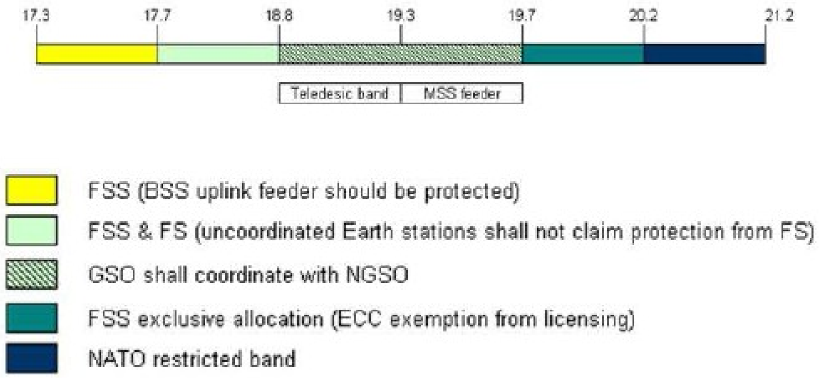


Figure 3.4/B: CEPT Ka-band downlink segmentation ([ref3] and [ref4]

It should be noted the 2.9 GHz considered bandwidth takes advantage of the Ka-band extension (17,3GHz – 17,7GHz) allocated to Fixed Satellite Services (FSS) in primary basis only in Region 1 (Europe, Africa, the Middle East west of the Persian Gulf including Iraq, the former Soviet Union and Mongolia). A 2.5GHz bandwidth is available for user uplink, with 1.2GHz exclusively allocated for FSS.

To ensure an acceptable overall link availability requirement (e.g. around 99.7%), feeder link availability larger than 99.9% should be considered. With such high availability requirement, the use of diversity techniques (optimum management of several gateways) is the sole option: it is mandatory to thus carefully define the overall network (architecture and operations). A trade-off between connectivity requirements and payload complexity (i.e large pool of gateways versus potential capacity loss but fewer gateways) should indeed be made. Further research needs to be done on those scenarios issues.

Q/V feeder links

A Q/V feeder link would necessitate smaller gateway antennas than the current Ka ones (circa 5m). Typical QV frequencies used for broadband feeder links would be:

- Feeder Uplink: V-band (44,5 – 51,4 GHz)
- Feeder downlink: Q-band (37,5 – 42,5 GHz).

The major drawback for the adoption of Q/V band is the fading due to atmospheric phenomena (mainly rain, but also clouds, gasses and scintillations), which is much higher compared to Ka and Ku bands. The definition and implementation of smart diversity techniques is thus necessary to ensure the overall link availability requirement (e.g. around 99.7%) and be able to adapt to propagation impairments. This calls for the installation and smart management of a network of gateways positioned in strategic locations w.r.t environmental conditions. A quite high number of gateways is necessary to transmit the increased data rate:

- A few tens of gateways (<50) must be deployed to serve hundreds of spot beams
- A few diversity gateways (<5) must be deployed to ensure service availability.

The low maturity of Q/V band technology is also a limiting factor to fully exploit this band right now, but R&D work is carried out by manufacturers at European and national levels.

Optical feeder link

The intrinsic high operating frequency (200 to 400 THz) of optical link leads to very high antenna gain. This allows extremely high data rate above several hundreds of Gbps; only one gateway is thus necessary to manage the full data flux and less than 10 diversity gateways are needed to ensure the required signal availability. Furthermore, optical terminals exhibit small volume, low mass and power consumption.

There are however drawbacks to further investigate, the major one being the fact that optical feeder links (like our own eyes) do not work through clouds. As for the QV band feeder links, one need to implement sites diversity to fulfil the requested system availability.

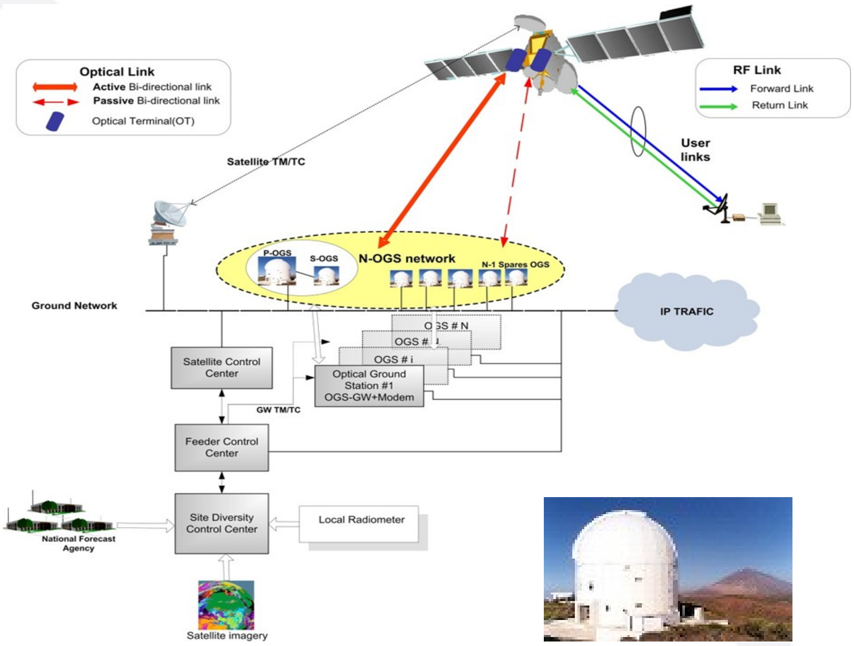


Figure 3.4/C : A typical satellite broadband system relying on optical feed links

3.4.1.3 Payload flexibility to adapt to the demand

Most operators have now experienced the fact that the broadband market is very difficult to predict. The possibility to reallocate capacity after launch (for example to relocate the capacity from a region where the fiber has arrived to a region where demand is growing) would allow the operators to adapt to the market evolution throughout the satellite life-time and secure their business plan.

To offer such capacity, one need in practice to implement on-board enhanced resources management in term of frequency, power and coverage (service area). The payload architecture, depending on requirements of each operator, can then be adapted by proposing the most balanced combination of flexibility between coverage and spectrum at the right cost.

3.4.2 Enabling technologies

3.4.2.1 Future antennas

As described in § 3.4.1, achieving an enhanced frequency re-use and working in higher frequencies requires to develop new generations of antennas.

Reflectors:

Ka band: To allow a higher level of FR in Ka band, the antenna subsystem will have to propose beam width below 0.3° and thus larger reflectors (typically 5m and beyond). These large reflectors might be large solid reflectors (with foldable tips) or mesh reflectors unfurled in orbit. Solid 3.5m reflectors which are under development will already be useful to enhance the performance. The natural length provided by the spacecraft body is not sufficient to enable the several meters long focal length necessary for those new generation payload; booms (3 to 6 meters) and associated deployment mechanisms will be required as well.

QV band: HTS architectures based on a QV feeder link consider a Q/V band reflector size up to 2.4m. The key design driver will be the surface accuracy requirement.

Feeds

Increasing the number of spot beams necessitates to accommodate more antenna feeds on-board and thus to further work on the feeds size and mass reduction. There are two families of feeds: Single Feed Per Beam (SFPB) and Multi Feed Per Beam (MFPB):

- Improvement axes around SFPB products to be used for 0.2° wide beam, include enlarged bandwidth, further miniaturization and compactness, integrated systems etc.
- MFPB are able to generate typically 4-color from a single reflector, and thus considerably simplify the antenna accommodation on the spacecraft (2 reflectors s of 3). On a MFPB, feed arrays are combined to generate the feed pattern of each beam, which necessitates complex combination processing behind the feeds.

Pointing performance

Large apertures and high frequencies targeted for new generation HTS render the antenna pointing accuracy an even more important parameter to master. State of the art technology achieves a Beam Pointing Error (BPE) of 0.05° using an Antenna Tracking System and ground beacon. A target BPE of 0.025° is envisaged, which can be achieved through an improved antenna tracking system together with improved platform pointing i.e. using star trackers.

3.4.2.2 Repeaters

With respect to the current generation, the number of spot beams will typically be multiplied by 3, while the payload power will be multiplied by 2 and the spectrum by 5.8. The mass and volume of all the equipment allocated to each spot beam shall be reduced in order to comply with the maximum satellite mass and volume. This is in particular true for the on-board repeaters transferring the signals across the satellite. The introduction of optical technologies within the repeater (e.g. V/Ka and Ka/Q optical frequency converters) could help in improving the mass efficiency of the repeater.

3.4.2.3 Feeder link optical technologies

The optical feeder system is made of three major components:

- The Telecom chain involving laser Tx & Rx communication technologies
- The Opto-mechanical chain, embedding telescope , optical bench and pointing mechanisms with associated pointing loops on sensor
- The network chain, embedding the diversity techniques associated to the clouds, the networks management and the interfaces with the ground networks.

The objective to use the 1.55 µm frequency will ease the interface with on ground communication fibre networks and inter-operations with future US/Japan optical satellite communication systems.

Lowest TRL level technologies are today found in:

- The Telecom chain: Erbium doped fiber amplifier pre-receiver, Wavelength Division Multiplexing (WDM) mux & de-multiplexer, modulation & coding adapted to the atmosphere behavior and BER requirements
- The Optomechanical chain: Acquisition and Tracking Sensor that needs to be evolved from 0. 8 µm to 1.55 µm, bulk optics multiplexer, high power optical amplifier.

3.4.2.4 Flexible payload technologies

Architectures and equipments enabling enhanced flexibility in frequency, coverage and power management are key to address future market trends.

A complete portfolio of products is already demonstrated in orbit for flexible payloads. In particular, Airbus DS already uses analog processing, digital processing, active antennas, etc… to propose flexible coverage, flexible spectrum management and flexible power management asked for by the mobile communication market. Indeed, the Alphasat programme, stemming from a PPP between ESA and the Inmarsat operator already allowed working on advanced digital processors (transparent channelisers).

Efforts are thus now focused on the development of new solutions providing enhanced flexibility in frequency, coverage, power management, while fitting the constraints imposed by the next generation of HTS. Indeed, the use of such technologies is being extended to the FSS business in C, Ku and likely soon in Ka which will serve the broadband applications.

Current R&D in this area is thus focusing on the development of:

- A lighter and smaller transparent channeliser, able to process more capacity
- Payload equipments allowing to flexibly manage more signal capacity while lighter and more compact
- Equipments allowing to flexibly process wider frequency bandwidth and with a finer granularity
- Technologies allowing to reduce the cost of active antennas, thus better suits to the commercial market, e.g:
    - using GaN technologies
    - investigating meta-materials. i.e materials with unique physical properties offering new control possibilities at high frequencies and power
    - developing a so-called Rothman lense for Beam Forming Management (the US are already ahead and use it for phased-array antennas).

3.4.2.5 Air Interface

DVB-S2 (Digital Video Broadcasting) air interface standard has been proven to be a reliable and effective solution for satellite broadcast/broadband systems. The introduction of efficient Frequency Modulation Techniques, such as Adaptive Coding and Modulation, allows optimizing the transmission parameters for each individual user, dependent on path conditions, enlarging the Signal-to-Noise ratio dynamic range and so, being more adaptable to propagation phenomena and increasing the overall system spectral efficiency and availability.

In the last year, recent advances and innovative techniques are being proposed in the DVB group in order to push further S2 performances (most of them applicable to Return Channel Satellite - RCS), aiming at a "DVB-S2 evolution" or a new DVB-S3. DVB-S2X has been recently (February 2014) released.

3.5 Acting at overall mission performance level

To reduce the cost of the Mbps-in-orbit, major actions are run at satellite level. In particular, improvement actions aim at

- reducing the satellite mass to in turn reduce the launch cost (e.g. replacing chemical propulsion by electrical propulsion or using lighter materials);
- reducing the platform volume to maximize the payload volume to increase services scope while remaining compliant with the launcher constraints (e.g. accommodate large antennas);
- increase the power offer to the payload
- and improving the thermal control to allow boarding more highly dissipating telecommunications equipments.

This chapter will address the three major improvement areas: power generation, thermal control and electric propulsion.

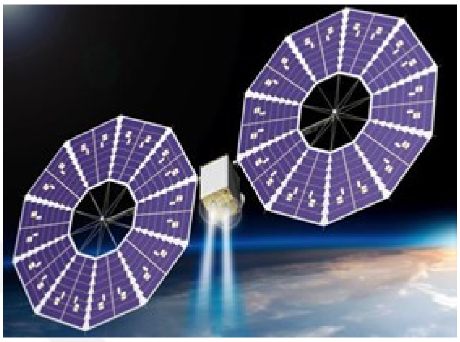
3.5.1 Generating more power

The most promising ways to obtain more performing power generation consist in the new generations of solar arrays and batteries.

3.5.1.1 Next generation solar array

The major technical challenge for the power generation consists in allowing high power (typically well above 20 kW for high-end satellite), while contributing to the mass efficiency. With respect to current Si cells, ultra-thin GaAs cells will allow both to increase the mass efficiency and the power efficiency. The targeted efficiency amounts to 33 - 37% for flexible substrate.

Beside, new mechanical lay-out of the solar arrays should be designed to avoid flying very long arrays rendering the satellite too sensitive to flexible modes in orbit (thus generating attitude perturbation). Concept like the one shown on the artist view on the right must be looked at.



(source: Ultraflex concept from ATK)

3.5.1.2 Next generation batteries

Batteries have two main roles:

- they are providing power during the eclipse seasons when the solar arrays are not illuminated by the sun
- they provide the needed complementary power to the satellite in solstice and equinox seasons when the satellite power need becomes higher than what the solar array available can provide.

While the current generation of Li-Ion batteries features a massic energy amounting to 155 Wh/kg, new generation Li-Ion batteries target 250 Wh/kg and a wide voltage range. Beside, completely new technologies are being envisaged, such as batteries based on regenerative fuel cells.

3.5.2 Achieving a more efficient thermal control

The next generation broadband payload envisaged to address the DAE 2020 objectives are characterized by high power dissipation within a limited volume. The thermal control efficiency shall thus be further enhanced.

Two types of Mechanically Pumped Loops are considered as alternatives to the traditional heat pipes, one being already mature (Single Phase Mechanically Pumped Loop), and the other one being at TRL 4 (Two Phase Mechanically Pumped Loop). Heated Pump Systems (HPS - TRL3), where the pump is replaced by a compressor, are also considered for even higher dissipation performance (up to 1000 W/m2).

It is envisaged to use those equipments in association with deployable radiators.

3.5.3 Electric Propulsion to reduce satellite mass and volume

In 2012 occurred the first sale of a fully electrical propulsion GEO satellite by Boeing, leading to a global decrease of the mission price. Concretely, the price attractiveness of this solution results from the use of a new generation of economically attractive medium-lift launcher introduced by Space-X, namely Falcon-9. An all-electrical satellite being lighter than a traditional chemical propulsion one, it can indeed be launched by Falcon-9 which reduces the overall mission prices. It is important to understand that if the all-electric satellites are lighter, their price and mission capability (number of transponders) is comparable to the traditional chemical satellites; the global mission price reduction is realized through a cheaper launcher price.

Hence, the major interest of Electric propulsion for operators is to get better in-orbit acquisition costs (e.g. by using the lower position of A5, or launch compatibility with vehicles which would not be possible otherwise like Falcon 9 – up to 30% cost saving per transponder in-orbit), and / or get access to a more capable envelope of payload mission for the same launch mass. Longer time to transfer in final orbit (several months instead of 10 days) is the main counterpart to these advantages: the operational duration of the mission is shortened (and so are the revenues).

The mass saving coming with Electric Propulsion is also expected to boost the demand for very large payload missions like HTS and large multi-beam payloads (dedicated or in combination with other missions, Ka or Ku-band) for which the use of conventional CPS limit the total launch mass and hence mission envelope.

This capability to raise the perigee of the GTO orbit only by using electric thrusters has since then been studied in Europe thanks to combined significant R&D investment efforts from ESA, national agencies and industry. Full Electric Orbit Raising (EOR) satellites are now proposed by European manufacturers (Airbus DS with its E3000 EOR platform or the ESA Alphabus-EOR platform).

The European industry pursues its satellite optimization efforts and is now developing further enhanced platforms, conceived for an EOR option from start, and relying on the core concept NEOSAT developed with the European Space Agency. The Airbus DS platform is named Eurostar-NEO, should be ready for the market mid-2016 and could target a first launch in 2020. In parallel, the propulsion technology is also being enhanced and capabilities are being developed in Europe. Research on more performing power management equipment is also needed.

3.6 Disruptive systems architecture

In the recent months, information has been released by major internet companies about their willingness to propose new broadband connectivity to users worldwide through air and space assets. Google and Facebook have announced projects and have reportedly been in talks for acquisitions of starts-up with innovative technologies. Amazon has performed space to ground connectivity tests and Apple has purchased patents related to satcom technology.

The common point of these projects is that they do not rely on classical GEO RF systems. The use of solar UAVs, balloons, optical communications, microsats or even nanosats can be considered. Although many technical and regulatory issues are preventing a quick development of such systems, the advantages would be obvious :

- CAPEX approach can be scalable
- orbital lifetime of assets can be in line with terrestrial communications business cycles
- technology and capacity can be updated constantly
- reduced latency
- better resilience for military coms systems through disaggregation.
- no barrier to entry due to orbital slots controlled by a few operators.

It is probably of Europe’s interest to investigate technologies and architectures which could cause a breakthrough in providing broadband access to the citizens of Europe and the world.

4 TECHNOLOGY & SYSTEM DESIGN ROADMAP

Research work along the tracks identified in chapter 3, have started some years ago using industry and public funds (national, ESA and EU to a much lesser extent). This chapter summarises, for each identified area of improvement, the need for research and the public research programmes already addressing it, or planning to.

This exercise highlights in particular the very limited support of European research to this Satellite Broadband Services topic. Indeed, FP7 did not give much opportunity for satellite related topics selection: in the period 2007-2013, FP7 ICT lead to a handful of user-centric network oriented projects, while FP7 Space did not address specific SatCom issues. H2020 ICT acknowledges satellite as part of the global networks and hopefully will allow for investigating some specific satellite issues such as the Optical Feed network chain (in particular, diversity management). H2020 Space is today hardly considering the SatCom technologies in its work programme, and cruelly lacks a structuring vision to embed SatCom research.

This chapter helps to pinpoint where H2020 Space could advantageously address Low TRL issues and/or complement other agencies work.

4.1 Innovative and integrated operational approaches

The objective of operators R&D activities is to make the satellite communications services to be specifically focused for its strengths compared to other technologies. Satellites can provide services where other technologies struggle or fail, such as decongesting airwaves for air-traffic management in complex and dense airspace, or providing broadband access to aerial or maritime users, or providing communication to unstable countries through innovative solutions.

- One such example was the *Sat Elections* project where “the elections took place in Africa with an appropriate monitoring and voting system, thanks to the satellite technology”.

- Another example relates to on-air services. About 10% of commercial and business aircraft provides Internet access while in travel. Satellite operators are keen to increase this; the recent SES and GOGO partnership has marked a milestone in this niche section of the market.

Most novel operational approaches pursued by the operators are mature or nearly, and some only require some more innovation to go to market. For example:

- One such interactivity enabling technology is the “smart LNB” developed by Eutelsat, a new-generation electronic feed connected to the standard 80cm antenna, using the standard existing cabling to the premises, with an embedded transmitter for interactive applications such as HbbTV, pay-per-view, social networking, personal subscription management and live show participation (voting, comments …). The basic principle of this cost-efficient device (target price: 30€) is that it receives in Ku-Band since this is the most widely used downlink band for broadcasting.

- The uplink can be in practically any band depending on the satellite neighbourhood. C band available is already available while the Ka-band version will be available in the beginning of 2014 and the Ku-band available towards the end of the same year.

- The return link uses the new Enhanced Spread-Spectrum Aloha (ESSA) protocol that has been designed for large number of low data-rate terminals while maintaining high spectrum efficiency. The new Enhanced Spread-Spectrum Aloha (ESSA) protocol is a result of collaboration between Eutelsat and ESA.

It is IP based technology and virtually compatible with any application running on any device. In 2013, Eutelsat has made demonstrations with early prototypes and has performed the type approval of prototype reference designs. Mid 2014, pilot trials will be organised with partners and customers with a go to market expected within the year that follows.

This form of technological complementarity, relying on network hybridation, is already a reality. Indeed, Orange proposes a Triple Play offer (internet, TV, phone) relying on the ADSL network for the internet service and on the satellite for the TV services to those subscribers who cannot receive it through ADSL.

Beside some service-oriented and user-centric researches have started, ran through FP7 ICT lines (no technology development). For example, the project BATS studies the integration of next generation satellite systems with established terrestrial infrastructure to supply communications to 'unserved/underserved' regions and improve the communication availability at urban areas all across Europe. As an illustration, BATS research findings today address among other things:

- Joint satellite system / backbone network design optimisation
- Multi-path routing architecture
- Adaptations to network management systems for integrated satellite and terrestrial networks
- Novel satellite radio interfaces: evolutionary and disruptive
- Interference mitigation techniques
- Radio resource management schemes
- Cost benefit analysis
- Comparison of the carbon footprint of the different BB delivery systems and BATS
- Contributions to standardisation.

H2020 ICT would be well suited to complete H2020 Space research through studies and pilot projects and address **user-centric satellite research eligible in two areas of work programme: Future Internet and 5G**. The SatCom community is working within the Networld 2020 ETP and the 5GPPP association to elaborate the research roadmap that will allow the smooth integration of satellite communication solutions within the future communication and media ecosystems.

- In particular, the H2020 ICT work programme should be well suited to address the role of SatCom for the **following future broadband applications** such as in-flight services (e.g entertainment), connected home or enhanced mobile services.

- Those applications would require working on the **new network Services areas** such as: high quality multimedia service delivery, global service continuity, backhaul service to local area networks on board aircraft, vessels and remote areas, terrestrial network back-up (resiliency) and off-loading, outdoor location services with high accuracy and integrity, very high speed broadband satellite networks(>30 Mbps) etc.

- **Associated research themes** would encompass: network interoperability (network management, core network), possible spectrum coexistence (e.g. Cognitive Radio techniques), possible commonalities of radio interface (same Chipset for narrow band service), Satellite IP networks architectures, 5G networks specific research etc.

4.2 Improving the user segment performance (ground infrastructure)

As for the Space component, much research is undertaken by or through the European Space Agency to support the evolution of the ground-segment.

H2020 SPACE could however be an excellent complementary tool to support low TRL focused research, for example the area of the optical feeder link (ground-station and diversity management).

Also, H2020 could help addressing the market issues:

- H2020 SPACE could the development low cost multi-service / multi-network ground equipment, to support hybridation and convergence.

- H2020 Fast Track to Innovation pilot projects could be used to demonstrate the possibility to combine the use of satellite and terrestrial base services, and advertise the performance and cost effectiveness of those solutions.

4.3 Roadmap towards improved Space segment overall performance

The table below summarises the various system and technology areas currently investigated in order to globally increase HTS capacity while reducing the cost of the Mbps in orbit.

One can see that almost all areas are today addressed in the R&D roadmaps of national agencies or ESA; however the available budget does not always allow pursuing the work up to the required level of maturity. In addition, some areas remain unaddressed or not sufficiently addressed today, in particular the Optical Feed and the gateway diversity management subjects. The support provided by the European Union Research programme is today very limited but could become really "enabling" if the H2020 Space work programme would consider HTS in its activities, with the rationale that it does serve a major EU societal challenge, namely the DAE.

System area	System, Equipment or technique	Targeted evolution or new development	Funding support (existing and/or needed on top of own industry investment)
Frequency re-use	Feeds for smaller beams (SFPB and MFPB)	From 0.7° to 0.2/0.3°	ARTES & National (France and Germany)
	Interference Mitigation Technique	MIMO based	Some ARTES and national support in Ku band. H2020 SPACE would be well suited to address work in higher frequency bands.
	Ka band Antenna	3.5 to 5 m Beyond 5 m	National (France) Not planned yet. H2020 Space would be well adapted
	Antenna Pointing Systems	From 0.05 to 0.025° BPE	ARTES and some national work. H2020 Space would be well suited to pursue

			activities.
	Repeaters' lighter and smaller optical technologies	RF/optical frequency converters (V/Ka-Ka/Q)	Not planned yet. Well adapted to development through H2020 Space.
Higher frequencies	Antenna deployment systems (booms and mechanisms)	Several meters to support dishes > 5m	ARTES and national work for antenna up to 5m. H2020 Space could help assessing the potential impact beyond 5m antennas.
	QV band antenna	2.4 m reflectors	National (France)
	QV Feed	New development	National for equipment development. H2020 Space could address the end-to-end demonstration, incl. IOVD.
	Optical feeder link / Laser and communication chain (amplifier, de/multiplexers pre-receiver)	1.55 □m spatialised technologies	Today at TRL 2/3. Well adapted to development through H2020 Space (much spin-in). WDM technology proposed to H2020 Space 2014.
	Optical feeder link / Pointing chain (ATS at 1.55 □m)	1.55 □m technologies (today partly existing for 0.8 □m)	Today at TRL 3 to 6. Well adapted to development through H2020 Space.
	Optical feeder link / Network	Diversity management technologies and techniques	Not planned yet. Well adapted to development through H2020 Space IOD/V exercise.
Flexibility	Transparent channeliser	Lighter and smaller for FSS applications	ARTES partly. H2020 would be well suited to secure foundry capacity in Europe (ASICS as critical technology)

	Active antennas	Technologies leading to cheaper antennas, such as GaN technologies for SSPA/FPGA at high frequencies, meta-materials and Rotman lense for BFM.	ARTES partly. H2020 would be well suited to complement. E.g, call Space 2014 allowed to propose a Tx for active Ku band antenna.
	Other signal management equipments	Manage more signal capacity, frequency bandwidth with a finer granularity (e.g filters, splitters etc.)	ARTES and national.
Air Interface	Standard	DVB-S2 evolution or DVB-S3	H2020 ICT would be well suited to complement DVB group work.
Overall mission cost reduction	Solar Arrays	>> 20 kW with Ultra-thin GaAs cells	ARTES (Neosat)
		New mechanical design (non longitudinal)	Not addressed yet. Well suited to H2020 SPACE.
	NG batteries	NG Li-Ion	ARTES (Neosat)
		Regenerative fuel cells	Technology roadmap established through ARTES. H2020 SPACE well suited to implement research work.
	Mechanically Pumped Loops	Two Phase MPL	ARTES.
	HPS	Today at TRL3	ARTES but still low TRL. H2020 SPACE well suited to pursue research.
	Deployable radiators		Some ARTES support. More work needed: proposed to H2020

			Space 2014
	Platform fitted with EOR Propulsion	Eurostar NEO	National – French PIA ESA - NEOSAT
	Future generation electric propulsion (beyond NEOSAT)	Increase operating range by a factor 3. Disruptive technologies.	H2020 Space along with Electric propulsion SRC
Disruptive architectures	Application of nano-technologies to the space sector		Not addressed. Would be well suited to H2020 Space.
	Spectrum management in LEO		Not addressed. Would be well suited to H2020 ICT.