Satellite as a complementary solution for a global Ultra Broad Band telecommunication infrastructure

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1. Background

Italy, like other countries in Europe, has a commitment with the EU to provide the entire population with internet access featuring more than 30 Mbps and the large majority of the population (85%) with more than 100 Mbps internet access by 2020.

Due to the orography of the country and to the presence of very small and dispersed communities, in Italy, as in other similar countries, it is practically impossible to reach full fibre coverage at economical conditions compatible with a reasonable return on investment.

The latest surveys with operators indicate that the non served households would be from a minimum of 1.4 Millions, already excluded from the survey as they are considered completely out of reach (the so called « case sparse »), up to 9 Millions households, which belong to the cluster « D » defined as the set of households that cannot be served at conditions different from economic loss.

An additional requirement concerns the internet access for local enterprises that are in those areas, which need to benefit of high speed connectivity but again that cannot be provided by terrestrial means, including wireless, other than fibre.

The Italian government has set up a special committee (COnitato Banda Ultra Larga - COBUL) to drive and coordinate the Ultra Broadband deployment plan. Whilst leaving fibre as the priority and baseline solution, COBUL is also analysing alternatives, mainly wireless, satellite or terrestrial based, which could fill the gap still offering a fibre-like quality and a speed above 30 Mbps.
In this context satellites are therefore called to play an essential role to timely meet the targets set by the European Union and by the Italian government. However, to fulfil this role, the satellite system design needs to take into account the specific requirements of the Ultra Broad Band (UBB) networks.

A project, named URBIS (UltRa Broadband Italian Satellite), has been put in place by Eutelsat and Telespazio, in cooperation with the Italian Space Agency (ASI), for a satellite system satisfying the UBB requirements for Italy to be considered as a potential complement to terrestrial based solution. Even if focused on Italy, the URBIS principles can be adopted for similar satellite projects in other countries needing full UBB coverage.

2. **System capacity dimensioning and the UHTS concept**

The capacity dimensioning of the system is one important element of the design. To such purpose we will assume a conservative figure of 1.0 to 1.5 Million households to be served via satellite, which would represent around 6% of the Italian households and consequently around 6% of the overall internet traffic.

Current traffic statistics and traffic increase forecast made by the internet operators and by Cisco, show that the peak hour traffic in Italy would be 11Tb/s in 2019, to grow to 20 Tb/s in 2025.

Terrestrial Internet traffic analyses have shown that the statistical distribution of the aggregate WAN traffic generated by a heterogeneous population of users in a definite time interval are similar to a normal distribution. The mean of the normal distribution follows the daily evolution of demand, with off-peak hours and peak-hours, while the variance is a function of the duration of the measuring interval.

This allows to plan the needed capacity in order to match the demand from a given number of users with a given target quality. The target quality is reached assuring that headroom (over-subscription) is added to the average traffic to allow sufficient room for intrinsic traffic variability. Considering a 10% over-subscription to avoid the congestion risk in the peak hours, the corresponding capacity to be delivered by the satellite system should be in the range of 700 Gbps to 1.3 Tbps over Italy.

It is important to note that this requires a high concentration of throughput on a limited area (Italian surface is about 300,000 sq. km), which dramatically differentiates the design criteria of such a satellite from a standard HTS delivering several tens of Gbps on a much
wider area.

From now on we will identify this specific satellite as a « UHTS » (Ultra HTS), to
differentiate it from standard HTS or VHTS operating on large coverages and more limited
traffic density per square km.

Another important differentiator between HTS/VHTS and UHTS is the level of capacity
provisioning per user, which in the case of UHTS aims at providing fibre like performances.
The minimum provisioning, in the case of UHTS, is in the order of 1.0 Mbps/user or more,
to be compared to 50-100 kbps for a typical HTS system. The higher level of provisioning
means that the investment per connected user is more affected by the satellite cost
(investment per Mbps of capacity) rather than by the user terminals cost. It is therefore
essential to achieve the minimum possible investment per Mbps on the satellite, rather
than concentrating on the terminals cost. As an example today the investment per Mbps
on existing HTS is around 4000 €; URBIS objective is to go below 1000 €, therefore the
satellite investment per provisioned user at 50-100 kbps would be (assuming
1000€/Mbps) in the range 50 to 100 € for a standard HTS and around 1000 € for a UHTS
user provisioned at 1.0 Mbps. This has to be compared to around 250 € of a typical end
user terminal cost. It is therefore evident that for UHTS and UBB the dominating cost is
given by the satellite and not by the terminal, and efforts have to be done in priority to try
to reduce space segment cost.

One additional element to underline is that the above traffic is largely dominated by video
type applications, some of which can be treated by satellite in a much more efficient way
than by terrestrial systems, as it will be outlined in the following sections.

In terms of frequencies, as it is important to maximize the spectrum available to the user
terminals, the system will use Ka band for the satellite-user terminal links but Q/V band
for the satellite-feeder links.

3. Urbis network design

In order to provide a carrier grade service and maximize system capacity, a two satellites
constellation with beams overlapping at 3 dB’s represents the nominal baseline to provide
an UBB service, maximising system throughput and providing at the same time hot in orbit
redundancy and system robustness in general.

The basic design criteria for URBIS are listed here-below:
• Reduced beam spacing (< 3°), providing considerably higher capacity density in terms of kbps/m² while keeping good throughput efficiency
• Adoption of interference mitigation protocols, allowing to dramatically increase throughputs efficiency (target 10 bits/Hz)
• Two satellites, assuring the coverage of the Italian service area from two different orbital positions
• 40 to 80 spots per satellite, 2 beams covering each point in the coverage
• 8-12 on ground gateways
• Switchless gateway redundancy obtained with a specific satellite and network design allowing to cope with gateways failures, as well as with high fade events without traffic interruptions in a quasi-seamless way for the users

Fig.1 URBIS 42 spots example configuration
3.1 Frequency plan

FORWARD LINK

Priority has been given to maximize download bandwidth. As a consequence:

- The entire Ka-band (17.7-20.2 GHz & 21.4-22.0 GHz) is used for the download towards user terminals
- Each spot has therefore a minimum bandwidth of 1500 MHz in a 4 colour scheme
- V band is dedicated to the Gateways’ feeder link

RETURN LINK

To define the return link bands utilisation scheme, the assumption was that the upload bandwidth requirements are lower than the download as the internet traffic is essentially asymmetric, especially video applications, and that in order to minimise regulatory risks priority is to be given to the use of exclusive bands. As a consequence:

- The entire exclusive Ka-band (29.5-30.0 GHz) is allocated to the traffic terminals plus a part of the non exclusive band for a minimum of 1.0 GHz total allocated bandwidth
- Each spot has therefore a minimum of 500 MHz bandwidth when considering a 4 colour scheme
- The Q band is allocated to the Gateway’s feeder link
Each of the URBIS satellite beam dedicates 400 Mbps to video contents delivered in IP multicast format for a total of 800 Mbps of video contents covering any spot area, a single terminal being able to receive 400 Mbps from any of the two satellites.

This capacity is used for all multicast linear video applications, including local TV programming, resulting in a significant saving of bandwidth vis-a-vis pure unicast services and improved service quality.

In addition the URBIS system architecture provides for a native IP multicast CDN function allowing end user terminals, at backhauling or home level, to locally store the most demanded contents, using the huge capacity available during non-peak hours to refresh local storage units.

These satellite features are particularly important when considering that up to 80% of traffic starting from 2020 will be video based. Assuming that just 50% of this will be linear content or manageable in IP multicast using a satellite CDN, the result would be a lower consumption of unicast traffic and a better quality for satellite delivered contents.

Using this live multicast solution each user terminal would have access to 400 Mbps multicast live video content (corresponding to the most popular 100 to 400 TV channels in each spot) from each satellite, which would allow to receive different TV channels simultaneously for fruition by different persons in the same household.

In addition to this, the local Push CDN user terminal function would allow each user
terminal to access several TBytes of locally stored content downloaded offline, updated on a daily basis and available at any time. All of this (live multicast and Push CDN) will be available to each user terminal without any impact to the internet unicast capacity and therefore leaving more resources to typical browsing applications.

When compared to a typical terrestrial based unicast infrastructure, a satellite based solution integrating Multicast and Unicast IP delivery provides superior performance compared to any type of unicast solution, including fibre, perfectly scalable and with a quality of service for premium video services independent from the number of connected end user.

![Capacity per beam: 5.4 Gbps](image)

Fig.4 beam band partitioning

5. Applications

The URBIS infrastructure has been conceived and can be used to flexibly provide internet access services with different configurations.

Differently than terrestrial based systems, in the URBIS system the same infrastructure will be capable to serve individual users as well as concentration points (backhauling landing points) which redistribute loops via radio or copper or local fibre.

An overall capacity of around 1Tbps would be immediately available to serve any site in Italy providing from day one a universal service potentially reaching 100% of the
population. This peculiar feature of a satellite based broadband infrastructure can be exploited to immediately accommodate connectivity requests in any area of the country, including areas where in the medium term it could be economically more convenient to deploy fibre backhauling (about 30% of the population), while insuring long term coverage of areas that cannot be economically reached using terrestrial means on a long term basis (about 10% of the population).

The system is also scalable; in the long term additional satellites may be used if demand grows, whereas in the short term investments in the ground segment (gateways and traffic terminals) can be modulated as a function of the actual traffic growth.

The transparent nature of the proposed satellite infrastructure will also allow to benefit of future innovation on network protocols (e.g. interference mitigation protocols) leading to enhanced throughput and thus increased capacity available to the users.

The system will offer 30 Mbps browsing to all connected users wherever they are; it is fully ready to support higher user rates for enterprises applications, as well as simply to cope with increasing internet demand (e.g. 100Mbps services).

![Gateway](image)

**Fig.3 URBIS services**

6. **Latency in broadband satellite connections**

TCP protocol performance enhancements able to mitigate performance degradations due to latency have been put in place since the initial days of Internet service by satellite, achieving equal performance than terrestrial for file transfer applications. However, eliminating the effects of satellite propagation delay for TCP and improving TCP protocol performances over satellite to the same level of terrestrial networks is not sufficient to provide similar performances at application layer. Other technologies have been developed to mitigate additional negative effects that satellite latency introduced at
application level.

The Satellite Broadband Technology has addressed those applications that are negatively impacted by latency. Solutions are available in the market to enhance the performance of the most used applications.

APPLICATION ACCELERATION

The protocols used by many enterprise applications were designed for the LAN and perform poorly over satellite WANs. These protocols make many sequential requests over the network to satisfy a single user request; the round-trip transmissions multiply any network latency, quickly degrading response time. Application accelerators speed transactions by reducing the number of round-trip transmissions for a broad set of application protocols:

- Windows file shares and other CIFS-based applications
- Outlook/Exchange email
- Web-based applications and internet browsing
- Other TCP traffic

ADVANCED DATA COMPRESSION

Delta coding is used to compare new data against previously transmitted data and only send the compressed differences. Special features include:

- Byte-level data differencing algorithm for files of all sizes
- Bi-directional, cross-protocol acceleration
- Single-instance server history for scalability
- Configurable encryption of client-side history

NETWORK OPTIMIZATION

Technologies are available adapting to variable network conditions such as jitter in packet switched wireless networks, noisy WiFi and DSL connections and temporary cellular and WLAN disconnects.

- Enhanced performance on cellular, wireless networks
- Dynamic bandwidth allocation for real-time data (VoIP)
- Acceleration maintained through network interruptions
PRESERVATION OF CORPORATE SECURITY POLICY INTEGRITY

- IPsec and SSL VPN compatibility
- Signed SMB file transfer acceleration
- Secure HTTPS web application acceleration

IPsec VPNs are built to operate on top an IP infrastructure; they cannot use TCP acceleration due to the protocol which encrypts the complete packet.

In this case, the IP-sec layer is kept inside the satellite-accelerated segment. Acceleration and compression takes place outside the IPsec VPN tunnel, intercepting and enhancing the unencrypted packets.

The result is a secure end-to-end accelerated VPN connecting the head-quarter to the regional offices.

TERMINAL EMULATION

Some legacy systems may still be in use in organizations that haven’t yet completed the modernization of their IT infrastructure. The use of satellite to transport similar applications is very challenging for a number of reasons related to the way they send input typed by the user on the keyboard to the receiving.

Character mode (one character-at-a-time mode): in this mode, typed input is sent immediately to the receiving system.

Line mode (one text line-at-a-time mode): in this mode, the terminal provides a local line editing function, and sends an entire input line after it has been locally edited, when the user presses a Return key.

Block mode (a screen-at-a-time mode): In this mode, the terminal provides a local full-screen data function. The user can enter input into multiple fields in a form on the screen (defined to the terminal by the receiving system). The terminal sends only the completed form, consisting of all the data entered on the screen, to the receiving system when the user presses an Enter key.

Terminals also implement echo functions. Echo can be either local, where the sending device itself displays the sent data, or remote echo, where the receiving device returns to the sender the sent data that had been received. This latter functionality introduces additional delay, especially when transmitted over a satellite link.
While block-mode and line-mode terminals can still be supported by high latency communications systems like satellite, 0.5 seconds delay is not impairing operation of a terminal when a full screen or full line editing must be acknowledged by the remote server before moving to the following screen or line; applications using terminals operating in character mode (and in general applications processing single elementary commands, like remote desktop applications) are very severely impaired by high latency systems like satellite.

In this case an application gateway needs to be used in order to identify the data streams relevant to the terminal applications and forward them to a low latency communication channel. This additional channel does not need to be a broadband channel: the needed capacities to support terminal applications rarely exceed 30-50 kbps and can easily be supported by such as a standard fixed or 2G/3G mobile telephone systems. The remaining broadband traffic, which is not impaired by latency, can efficiently use the satellite connection.

7. Conclusions

In order to completely solve the UBB digital divide problem existing for a relevant part of the population even in highly developed countries a UHTS satellite infrastructure is the best solution both in terms of cost, time to market and scalability.

The UHTS system architecture allowing ultra high capacity density as that provided by URBIS using a national coverage approach can be easily replicated in each country with specific designs matching the peculiarities of a given territory.

In this paper we have illustrated the UHTS satellite architecture that has been designed to solve the specific case of Italy. This design, which can be extended and adapted also to other countries with simple modifications, has been defined and specified under the « URBIS » name.

A new concept of HTS has been introduced, the UHTS (Ultra HTS) featuring very high throughput over a small area (about 100 times more bits/km²) than a typical HTS or VHTS.

URBIS features >1Tbps over Italy, offering fibre quality to HH connected via satellite, and feeding directly the end user as well as providing backhauling for local networks (typically wireless).

The URBIS system exploits the complete Ka spectrum available for the user terminal segment and the Q/V bands for the gateways.
Taking benefit of past experience in Ka, special attention has been devoted to implement fade mitigation techniques and protocols, in particular for the gateways operating in the Q/V bands, to guarantee the required service availability. Moreover, the gateways and satellite network design make the system resilient to gateways failures.

Satellite remains essential to provide 100% coverage; it is often assimilated to a last resource option, because it has limited bandwidth per user which does not allow to offer fibre quality. URBIS demonstrate that through a specific design and extensive re-use of complete Ka and Q/V bands, it is possible to offer performances fibre like also via satellite, at costs lower than fibre in sparsely populated areas.

Bibliography

[1] Strategia Italiana per la Banda Ultralarga - Piano degli Investimenti mediante Intervento Diretto nelle Aree a Fallimento di Mercato - Ministero dello Sviluppo Economico

