APPLICATIONS AND EVOLUTION PATHS OF SATELLITE DELIVERY NETWORKS : A REVIEW

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1. FOREWORD

The DVB -S standard was published in the early 1996 as the EN 300421 ETSI standard and has been widely applied for direct satellite broadcasting of digital video content to the subscriber home. With the migration of some other applications to digital, and the evolution of video services from broadcast to interactive, the use of this standard has been extended as described in this paper to :

- Broadcast and interactive data transmission, including professional applications
- DSNG

Some limitation of satellite delivery can appear in the future when bit rate demanding interactive applications will have to be supported. For this purpose, , the satellite operator can have to interconnect their network with other media like :

- SMATV
- LMDS

More particularly a new cost effective architecture based on satellite and LMDS technologies is presented in this paper.

2. Channel models

Although it is not the purpose of this paper to go deeply into the details of the different media channel models, it is worthwhile to review the reasoning behind the chosen modulation and FEC formats for each medium :

2.1. cable

the downstream channel suffers from the following parasitic :
AWGN : this noise is created by both the coaxial amplifiers and analog optical transmission system along the transmission path; usually, with full channel loading, a C/N around 35 - 45 dB can be fulfilled in a 5 MHz bandwidth, allowing 64 QAM or 256 QAM to be used;

Impulse noise : impulse noise can be created both by poor contacts along the coaxial path, power line switching, and clipping noise in the optical system. The latter can be the main source of noise in the case of full channel loading. This phenomenon is corrected by both interleaving and Reed Solomon error correction

2.2. Terrestrial

The parasitic are mainly fading due to strong echoes, or neighbour station transmission in the case of SFN; this is why single carrier modulation offers poor performances, and therefore the C- OFDM technique shows very good performances; a detailed description is covered in other papers.

2.3. High frequency wireless and satellite

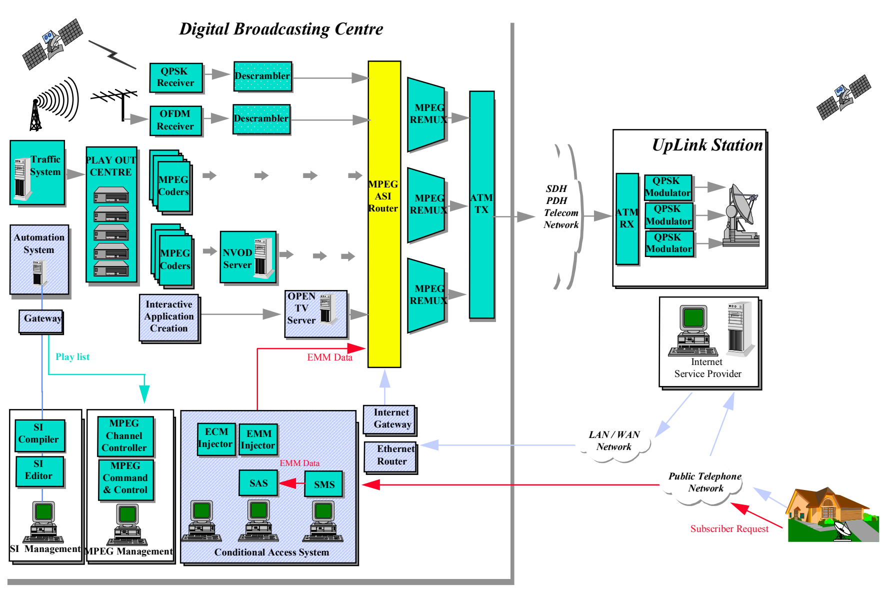
The channel model is quite simple : the main source of parasitic is in this case AWING, and very low C/N ratio is necessary, as the system cost is directly related to the transmission power at this frequency range. QPSK modulation scheme is used; in addition, a variable rate convolutional code is used in combination with a RS (188, 204) on each transport stream packet, allowing C/N ratio in the order of 6 dB to be used. Another characteristic of this channel is the necessity to accommodate important C/N variations as rainfall attenuation is an important factor; service availability is usually planned to be superior to 99.8 %, taking into consideration the worst geographical rain conditions.

3. Use of the DVB-S standard

3.1. Direct Satellite Broadcasting

The main application of DVB-S was so far direct video broadcasting to the home as shown below; the system is very simple, as all the programs are broadcast from one single uplink to all the subscribers of the area covered.

The figure below examplifies a typical system application :



Data transmission

DVB defines the encapsulation of data into transport stream packets, allowing therefore to mix data and video content in the same downstream RF channel.
Data can be transported into private sections, allowing therefore any protocol to be used, or by using multiprotocol encapsulation; in the latter case, IP and ATM packets transport is defined, allowing a broad range of data and telecom application to be supported.

3.2. Interactivity with the Return channel

The use of a satellite return channel is limited for the following reasons :

- In the case of a consumer application, the cost of an outdoor unit capable of transmitting data backward to the satellite is still high
- As a considerable number of subscribers are served, the total upstream bit rate can become prohibitive, and upstream management can be an issue.

Therefore, a commonly used solution is the telephone return channel as shown in the figure above.

3.3. Interactivity without return channel

A commonly used application in the case where noreal time return channel is available is the so called data carrousel. The principle is to reserve a certain amount of data rate for the most commonly used data bases and application. All this content is periodically broadcasted. When the subscriber wants to use an application he sends a request and then waits the next time the request information is available on the data carrousel . This very powerful concept allows the subscriber to really use interactive applications, the Interactivity being performed only during the user and the STB. The application latency will obviously be directly linked to the bit rate allocated to the data carrousel, and to the STB processing power and memory (for example the application can be segmented according to the STB memory capacity).

3.4. Usage of satellite channel for professional applications.

3.4.1. Broadcast TV case

Since video services are not broadcasted the whole day, a broadcaster can use the channels during « off hours » for professional or semi professional applications, such as downloading, data base updating, etc.., taking advantages of :

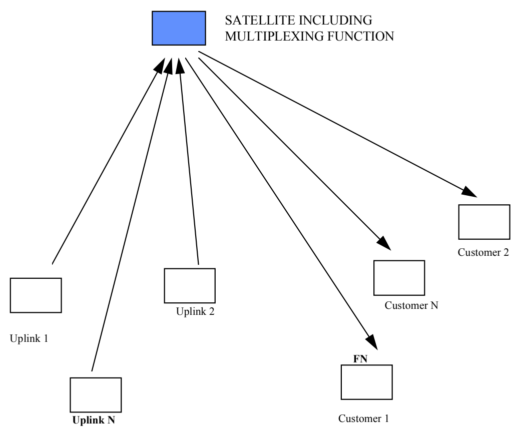
- Bit rate availability
- Low cost of receiving equipment
- The interfaces for various Conditional access system defined by DVB which allow to support both single-cast and multicast applications

3.4.2. Some evolutions for high bit rate applications

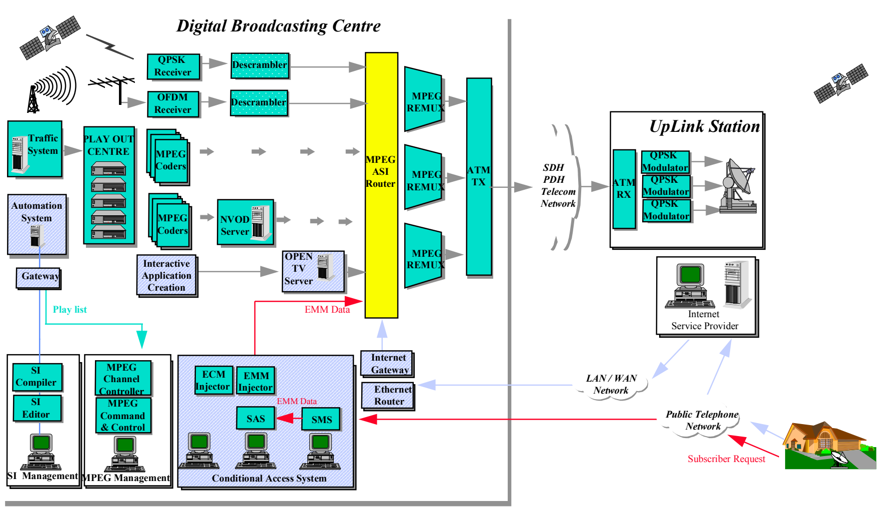
In order to overcome some of system limitations, some variant of this architecture might be used in order to increase the performance, to decrease the overall system cost, and to support real time applications :

1) Multiplexing in the satellite :

When these multicast applications have to be supported, the sources of content are spreaded all over a country; therefore the problem is to transport the contents to the uplink location by using for example leased lines. Some operators have realised a very powerful alternative, which permits the content provider to transmit the content directly to the satellite, the multiplexing function being performed directly in the satellite. Obviously each singlecast or multicast session can be securised with the classical conditional access system.



2) Internet access : the system diagram below shows how a typical satellite broadcast architecture can easily be updated to provide Internet access services to the subscriber. it can also be applied to the variant described above.



3.4.3. Upper layers for data transmission

It is worthwhile to add some comments on the transport layers protocols which have to be used with this kind of applications :
An advantage of DVB-S is that it provide a quasi-error free medium for data transmission, although normal data transmission systems provide a BER of around 10^{-8}. The upper layers will therefore consider DVB-S as an error free physical medium.

For multicast and broadcast applications the UDP transport protocol is typically used, as it doesn't require a bidirectional transmission medium and doesn't generate upstream traffic.

The use of TCP for single-cast sessions implies using a bidirectional system in order to return TCP control information; the most commonly used solution is the telephone return path from the subscriber to the content provider.

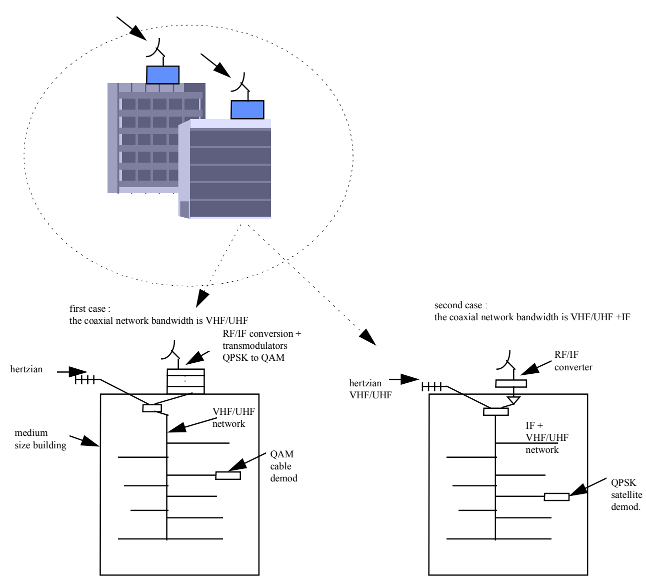
3.5. Digital Satellite News Gathering (DSNG)

A new standard has just been released by DVB, which extends the functionality of DVB-S to the particular requirements of DSNG, like :
- low cost implementation at the transmitting side : for example simple implementation of a CA associated with DVB common scrambling will be allowed
- optimisation of the bit rate use : as explained in prETS 301 210 the C/N can considerably vary according to rain conditions; in the particular case of DSNG which is a single-cast transmission, it is possible to change the modulation scheme according to the link C/N ratio. The standard defines the use of 8QPSK and 16 QAM for that purpose.
- communication channel : in addition to the commonly used telephone transmission for setting up or release of a DSNG session, the standard defines also the use of an In-Band or Out of band satellite communication channel, which uses spread spectrum CDMA technique. The latter is defined in the draft standard prETS301222.

3.6. Connection of a satellite network with other networks

3.6.1. SMATV networks

The satellite network can classically feed existing small and medium size coaxial network already existing in buildings; two solutions can be chosen :
- Either to use transmodulation for DVB-S to the classical DVB-C format used in the cable networks
- Or to use only frequency conversion to satellite IF and use QPSK in the cable network if the bandwidth allows it.



3.6.1.1.Installation of the return channel

As there is no unique SMATV paradigm, DVB describes several solutions, each adapted to a range of situations for return channel installations; the cable return channel standard is extensively described for CATV, and a subset of this standard is recommended to be used for SMATV installation, in order to take advantage of the economy of scale already realised for CATV return channel.

Therefore a simple frequency conversion is needed at the SMATV Headend.

In already existing SMATV cable network, the installation cost estimation can be shared between cost at the subscriber location and the SMATV headend cost :

- subscriber cost : the cost of the CATV return channel has been verified to be in the order of 10% of the total STB cost,
- Headend cost : as the Headend realises only a frequency conversion, the headend cost will be very low; moreover this cost will be shared among the SMATV network subscribers.

3.6.2. LMDS networks

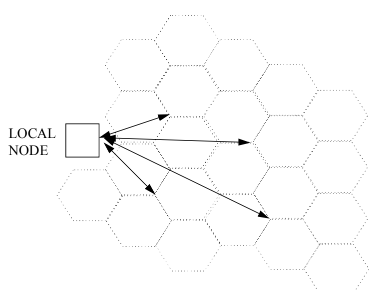
In general the satellite operator will face an evolution of the service offer from video broadcast to multimedia interactive; in order to fulfil this future requirement the operator will have to realise a mix satellite / terrestrial infrastructure. The LMDS cost effective approach is described in this chapter.

3.6.2.1.LMDS overview

LMDS or « Local Multipoint Distribution System ». is a distributed architecture, and is then well suited to support an integrated offer including :

- broadcast video and data
- telephony
- interactive services like Internet access, interactive TV, games, etc..
- professional services

As shown in the figure below, the network is divided into small cells, each cell feeding nominally 500 to 5000 subscriber. The cell radius will vary from 500 m to around 5 km depending upon the geographical subscriber density.



Each group of cells is linked to a central station or « Local Node ». The Local Node delivers the narrowcast and interactive signals to each cell, and routes the upstream communications, either between cells, or between a cell and external networks.
The bidirectional transmission between the Local Node (LN) and each cell can be either wireless or fiber optics. Wireless is cost effective, but fiber optic is more easy to maintain if an intense traffic has to be supported.
The transmission frequency which is used within the cell can vary from 10 GHz to 45 GHz depending on the region.
A high frequency transmission is particularly adapted to LMDS for the following reasons :

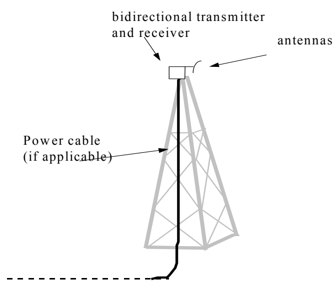
- The cell size being small, the effect of rain attenuation is reduced; obviously frequency in the low range where higher rain rate is expected.
- The available downstream and upstream bandwidth are very important.
- The subscriber antenna can be very small.
- The interference between cell is reduced.

3.6.2.2.Cell configuration

In this microcell configuration , the installation and cable/tower infrastructure costs are of particular importance in the total system cost per subscriber.
In urban areas the existing infrastructure for mobile telephony could be applied to this new application; this can be shared in part or totally to install the high frequency optical and electrical equipment.
In the suburban and rural areas infrastructure possibilities include :
use of existing mobile telephony infrastructure when possible;
use of existing installations where supply power is available, street lamps for example.

<u>Receiver mechanics</u>

The high frequency headed Tx/Rx components should be placed as close as possible to the antenna. As the power amplifier output power is low, it is possible to envisage the integration of all components at the antenna input as shown below :



3.6.3. ECONOMICAL INTEREST

It is interesting to have an approximate idea of the Installed First Cost (IFC) of such a system and to compare this with a more standard HFC solution. The purpose is not to make a detailed comparison, but to make a first evaluation of the interest of an interactive high frequency MMDS system.
The diagram below represents the IFC per subscriber vs. uptake rate for HFC and bidirectionnal LMDS :

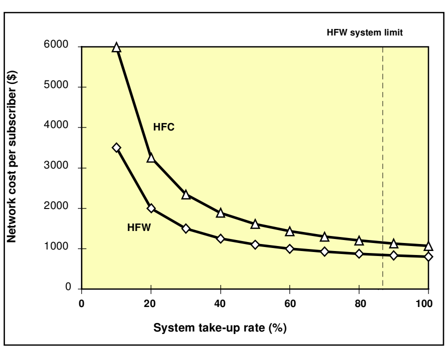


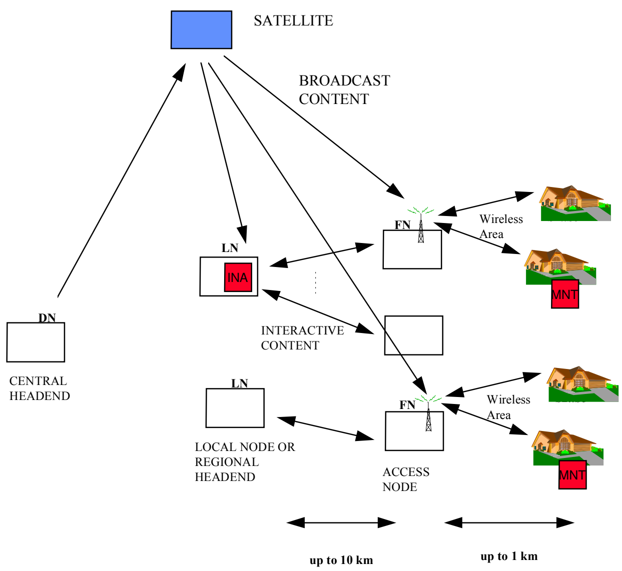
Figure 5 : Economical comparison (HFW refers to LMDS)

It should be noted that above a 70% uptake, this simple comparison shown above is no longer valid due to difficulties in obtaining very high levels of system penetration with the LMDS approach due to the line-of-sight transmission path requirement.

3.7. *Evolution towards a mixed satellite - LMDS network*

Although the LMDS network installation is cost effective in most of the installation scenarios, fiber optic transport between a central headend or local exchange can represent a significant amount of the total cost.
When analysing the upstream and downstream traffic, one can conclude that the traffic associated with broadcast video and data represent the major part of the bit rate, while narrowcasting (multicast and single cast) only take a few percent of the downstream traffic in each cell.
Upstream traffic load will then highly depend on the application, but will certainly be in the first time smaller than downstream multicast traffic.

All these considerations give a significant advantage to the satellite operator as shown below, as all the broadcast content can directly be transmitted to the Wireless node (sometime called base station), while interactive traffic can in most of the case be transmitted in wireless between the wireless node and the Local headend.



4. STANDARDISATION STATUS

A number of ETSI standards have been published around satellite, SMATV and LMDS /MVDS applications

Downstream channel:

RF frequencies for LMDS / MVDS applications
In the USA, the FCC has released the 27.5 to 28.35 GHz frequency band for downstream and the 31 to 31.3 GHz band for upstream. In Europe the CEPT recommends for high frequency MMDS the use of the 40.5 to 42.5 GHz frequency band for broadcast services. Bands in the ranges of 10 to 45 GHz can be chosen in other regions according to local regulations.
DVB - S defines the physical layer for satellite; an identical format is standardised for high frequency MMDS in ETS 300 748. DSNG is covered by prEN 301 210 and pr EN 301 222

Interactive channel

The physical and MAC layer are described in the ETSI standard EN 301 199 in the case of LMDS, and in ETS 300 800 in the case of HFC networks. The SMATV case is described in TR 101 201.
Both specifications are considering a combination of TDMA/FDMA access methods.
The 3 standards are compatible in almost all aspects, as in soma scenarios it may be worthwhile for an operator to connect these different networks together.
The upper protocol layers for interactive services are standardised in ETS 300 802.

In summary a complete set of standards define the broadcast and interactive satellite, LMDS and SMATV channels. Most of them have been ratified by ITU, making them worldwide standards.

5. CONCLUSION

Satellite delivery to the subscriber home has been proved to be a cost effective solution of broadcast digital video to the subscriber location. A short term evolution of the system can be realised to deliver additional content like data or professional services.

However, a limitation exists when bit rate demanding applications and interactive applications have to be supported.

2 alternative solutions have been presented in this paper :

- The well known SMATV architecture where existing can be economically upgraded to interactive;
- A new architecture, based on a mix of satellite and LMDS is a very attractive solution presenting the main following advantages :
    - very high bit rate capacity thanks to the considerable bandwidth available when using high frequency wireless
    - very low Installed first cost due to the absence of distribution infrastructure within a cell
    - The presented solution uses already fully standardised DVB specifications; this will guarantee multisource availability and backward compatible future evolutions

6. Acknowledgements

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