

High frequency LMDS architecture : a new approach for the introduction of interactive services

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1. FOREWORD

Three technologies can be foreseen for the introduction of interactive services into the subscriber home :

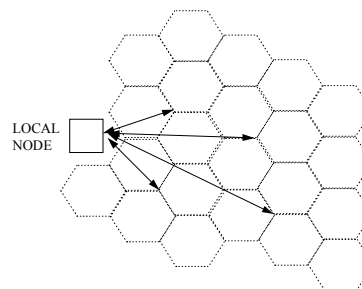
- For local telecom operators, ADSL seems at first sight the right solution to enhance the interactive service offer;
- For cable operators, the right solution would be to provide a return path connection by using the existing cable network.
- In the case where highly interactive services, or professional services are envisaged, high frequency LMDS distribution, combined with optical transport, will provide an economically attractive solution in combination with HFC networks. A brief description of this last approach and preliminary cost analysis is provided in this paper.

2. LMDS overview

LMDS means « Local Multipoint Distribution System ». It is a distributed architecture, therefore well adapted to the provision of 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 according to the geographical subscriber density.



Each group of cells is linked to a central station named « Local Node ». The Local Node delivers the broadcast 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 50 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. SERVICES DEFINITION

3.1. Consumer Multimedia services segmentation on cable TV

All multimedia services can be segmented into three types :

- motivators (desirable features leading to consumers subscriptions);
- additional revenue generators (features not exciting enough to cause the initial purchase, but attract additional expenditure) ;
- finally churn inhibitors (services to which consumers will not pay for but to which they attach a value, and will lead them not to cancel their subscription).

Initial Purchase Motivators
Sports
Hit movies
Cheap telephony*
Additional Revenues Sources
VOD/NVOD
On-line services
Home shopping
Churn Inhibitors
News
Special interest
Local information

* : Cheap telephony is understood as telephony with the same level of quality as usual telephony; the consumer behaviour in front of a lower quality service with cut prices is still to be studied.

3.2. Professional service segmentation

The LMDS architecture allows the introduction of mixed professional/consumer applications on the same access network. Without going into the detail of these services, the following main drivers for LMDS deployment are :

- Leased links
- LAN interconnection
- Server downlink : in dense areas, we can imagine that there will be a significant number of small servers in the access network, taking advantage of the extra bandwidth available in the upstream.

3.3. Quality of service

Traffic profiles definition

The consumer and professional services described above can be segmented into several classes according to their respective traffic profile and quality of service requirements :

Internet browsing : requiring high variable bit rate downstream without latency constraint; low burty traffic upstream (small packet from time to time) with response time requirements

VOD, video games with high bit rate downstream with tough latency requirements; low bursty traffic with response time requirement

FTP download : Useable bit rate traffic in downstream; low traffic in upstream with no time constraint

telephony : symmetrical bit rates with tough latency requirements

professional application requiring high suymetrical bit rates with stringent QOS constraint

One have to note that the traffic profile is linked both to the application payload profile, and to the trasport and network protocol used; as an example, TCP will generate additional traffic both in upstream and downstream.

QOS support

In order to signal and support the QOS between 2 end points, 2 basic functions have to be performed when an application is initiated :

- To signal the required QOS between the 2 end points
- To signal the QOS between each intermediate network elements (also known as routers in the IP world); these 2 first functions are performed by a signalling or session layer
- to support the Quality of Service between each network element, this last function being the role of the MAC layer of this particular network

In order to build interoperable communication systems, several « things » must be defined in addition of the signalling and MAC protocols

:

- a communication model which explains the sequence of communication set up and release
- a set of primitive which permits to the different protocol layers to communicate the QOS required.

4. STANDARDISATION STATUS

4.1. Downstream channel:

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.

The DVB transmission standard defined for these services is the same as that defined for digital satellite services (QPSK, MPEG2).

4.2. 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. Both are considering a combination of TDMA/FDMA access methods.

The 2 standards are compatible in almost all aspects, as the LMDS network is assumed to be deployed in conjunction with the HFC network. The high bit rate capability both in downstream (38 Mb/s) and upstream (6 Mb/s) allows the introduction of professional services.

5. SYSTEM OVERVIEW

5.1. Hybrid Fibre Coaxial/Wireless architecture

Figure 1 presents a generic HFC/W architecture

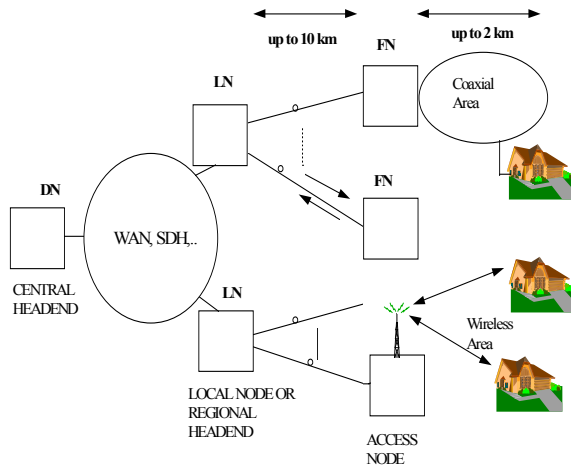


Figure 1 : HFC/W architecture

The Distribution Node (DN) or « Central Headend » concentrates all the programs and services to be broadcast in the network. The DN can serve a large city or a whole country.

The Local Node (LN) or Regional Headend (typically 100 000 subscribers) receives and reassembles the services dedicated to each Access area. The LN is the interface point for interactive services distribution and routing.

The Access Node (FN) is the interface point between optical and access network, which can be in our case either coaxial or wireless :

- The cable return channel bandwidth, which is typically 20 to 40 MHz, limits the coaxial area coverage population to 500 to 1000 subscribers.
- In the case of the LMDS network, rain attenuation limits the range of the system approximately to 5 km, which corresponds to 500 to 5000 subscribers per cell.

5.2. ETSI standard description

The physical layer uses burst DQPSK modulation for upstream; the MAC layer uses a slotted TDMA

access method to optimise the throughput. The slot size is 64 bytes, corresponding to an ATM packet with preamble, RS FEC and guard byte.

3 types of access method can be managed by the MAC layer : slotted ALOHA, RESERVATION, and CONSTANT BIT RATE. This permits a great flexibility for the applications support.

Channel models

It is not the purpose of the paper to go into the details of the upstream channel model as extensive work and measurements have already been made on the subject, but to give an overview of the type of disturbances which can exist on the cable and wireless areas.

CABLE

3 kinds of parasitic can limit the return channel throughput :

- gaussian noise, which is rarely the most important parameter; theoretically, the existing network can allow coaxial area size as large as 10000 subscribers (using QPSK modulation and at 3.088 Mb/s bit rate, which is the maximum specified in DVB).
- Ingress noise, which is due to poor cable or connectors shielding, especially close to the subscriber premises (an important part can come from the subscribers themselves); this kind of noise consists of both fixed frequency carriers parasitic and impulse noise; some bands (up to 10 MHz and around 27 MHz) are often difficult to use. This disturbance can be combated by network measurement and maintenance managed by the MAC layer (frequency change, retransmission)
- Impulse noise which is mainly due to power supply switching inside (poor contacts) and outside the network; these pulses are both filtered and clipped by the return path amplifiers and optical transmitters; the pulse statistics shows periods in the order of several μ s. It means that a significant part can be corrected by the RS code of each slot, thus allowing to recover the disturbed ATM packet.

HIGH FREQUENCY WIRELESS

Ingress noise and impulse noise don't appear to be a significant limitation; multipath is not important as long as engineering rules (direct line of sight, sufficient height) are respected.

The main factor is the effect of rain attenuation, which prevents in practice the use of cell radius greater than 2 km if 99.99 % service availability is required.

5.3. Traffic analysis

On the basis of the services described above, some traffic analysis which are out of the scope of this paper can be performed.

In the HFC case where areas of 500 to 1000 passing are considered, the upstream bandwidth can vary from 5-25 MHz in old networks to 5 - 65 MHz on more recent installations. The 5 - 10 MHz and 26-27 MHz bands are difficult to use, due to the different types of parasitic in these bands. According to these assumptions, a total upstream bandwidth of approximately 15 to 50 MHz is practically available. This would correspond to an available bit rate of 15 to 50 Mb/s, taking into account the modulation scheme defined in DVB (QPSK) and the MAC layer throughput.

This figure is more than sufficient for most consumer application scenarios, but can be limited for cases with extensive traffic and high uptake rate.

Moreover, the introduction of professional applications in some dense or industrial areas requires several hundred Mb/s upstream traffic per cell which can only be addressed using a HFW infrastructure.

An example of the downstream and upstream spectrum allocation is given in Figure 2 :

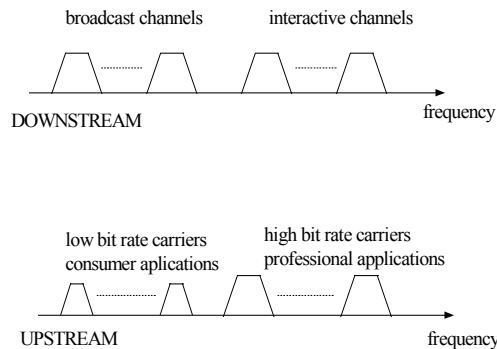


Figure 2 : Spectrum allocation

In Europe, the downstream frequency range is 40.5 GHz - 42.5 GHz, shared between carriers transporting broadcast programs and data; the upstream frequency range is as not yet defined, but could be implemented in an extended band above 42.5 GHz; it can be dedicated, thanks to FDMA, both to low bit rate carriers (3 Mb/s) for consumer and semi professional applications, and in the future to higher bit rate carriers dedicated to professional use.

In other countries any RF band can be used, since the specification is independent on that aspect;

only the IF to RF converters would change, both at the subscriber premises and at the LN location.

5.4. Optical transport

The LN (Local Node) can serve hundreds of cells; in the full service network scenario, the LN throughput can be of several tens of Gb/s, thus making it difficult to imagine a wireless transport.

Bi - directional optical transport between the LN and Access Nodes appears as a simple, evolutionary and reasonable cost solution.

The picture below shows a block diagram of downstream and upstream optical transport between the Local Node and the Access Node

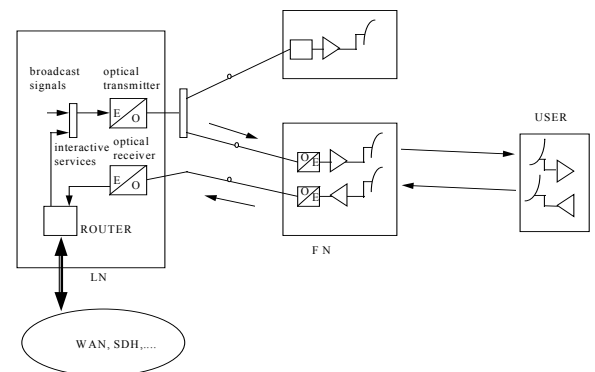


Figure 3 : Optical transport

2 possibilities can be envisaged :

The current available solution is to transport the downstream and upstream signals at low intermediate frequencies; in this case an IF to RF conversion has to be performed at the Access Node level :

The IF satellite band can be used for the downstream;

for the upstream, if the LMDS is used in conjunction with a coaxial distribution, the 5 - 65 MHz band which is used for cable return path can be used; if a higher rate is to be transmitted, a larger band can be used (47 to 1000 MHz for example).

A future solution under investigation is the use of direct optical transport in the high frequency band. The issues with this solution are the price and system performance.

5.5. 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.

Receiver mechanics

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 :

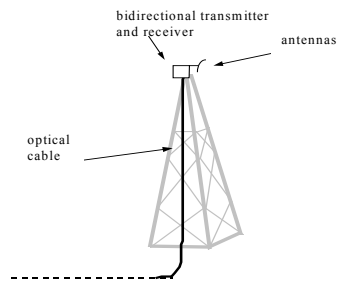


Figure 4 : Receiver mechanics

6. 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 :

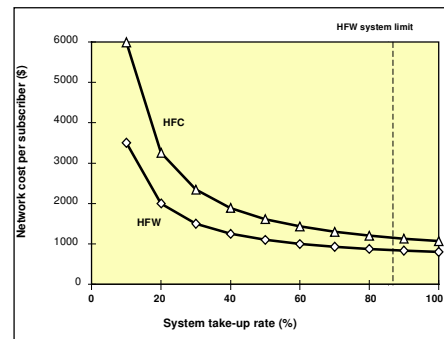


Figure 5 : Economical comparison

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.

7. SOME EXAMPLES OF HFW IMPLEMENTATION

7.1. CATV network extensions in suburban areas

The coaxial distribution infrastructure cost in the HFC network becomes the most important issue in suburban areas, especially where underground cabling is required.

The benefit of a direct wireless cell feeding becomes obvious as shown in figure 4, as no transmodulation equipment is needed.

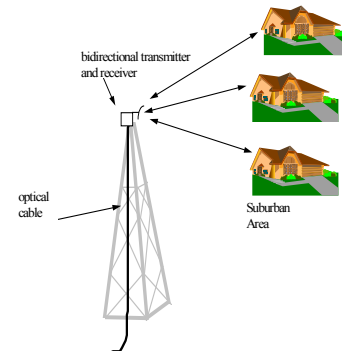


Figure 6 : Network extension

7.2. SMATV networks interconnections by LMDS

Some areas currently use SMATV or MATV networks extensively; if this local network is only usable in the VHF/UHF range, transmodulation from QPSK to QAM can be envisaged. These services can be combined with existing analogue broadcast programs or transmodulated satellite programs.

If the coaxial SMATV network can be used in the IF satellite frequency range, transmodulation of the LMDS programs is no longer necessary and

the programs can be delivered as they are in QPSK

If not, the LMDS and satellite programs can be transmodulated to QAM for distribution in the VHF/UHF band

The 5 -65 MHz cable return channel bandwidth can be used in the SMATV local network upstream; a simple conversion to the high frequency band is made at the SMATV node location.

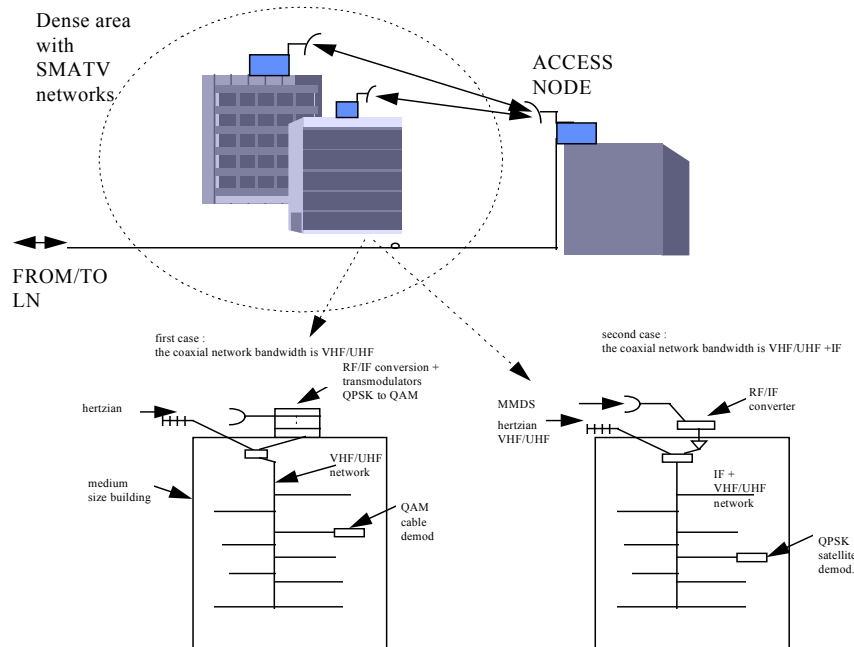


Figure 7 : SMATV networks connections

7.3. LMDS cells in urban areas : coverage of shadow areas

As previously explained, more than 70% subscriber coverage is difficult to achieve in these areas; 2 solutions can be implemented : either to install a repeater or to extend the LMDS cell with cable extension using RF to IF conversion.

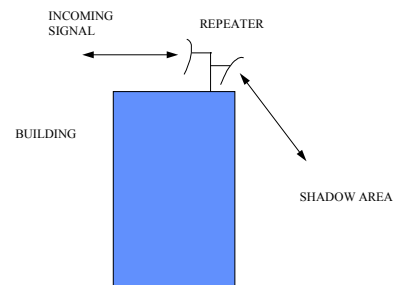


Figure 8 : LMDS repeater

8. Introduction scenarios

The advantages and limitations of LMDS can be reviewed in some examples of introduction scenarios :

8.1. Green fields :

where no infrastructure exists already, LMDS has the following advantages :

- Low installed first costs
- capability to deliver a complete service offer both to the professional and to the residential subscriber

The issues to consider are :

- As line of sight must be provided, the cost in the case of high uptake rate must be analysed (addition of repeaters, cable cells in shadow areas..)
- The limited range due to range attenuation makes it not suitable for low density areas

8.2. Local Telco

The local telecom operator has the challenge to provide video and multimedia services in excess of the classical telephone services :

- ADSL is a possible solution, but it has some limitations, as the cost and the bandwidth limitations; If video has to be provided to the subscriber, a bit rate of 6 Mb/s is required, which makes this technology difficult to implement everywhere. Moreover switched video must be delivered which increases significantly the cost of the Local Node equipment.
- LMDS can therefore be considered as an alternative for delivering high bit rate services; obviously the Telco infrastructure can be used to feed the LMDS shadow areas, if a 100% penetration is mandated to the operator.

8.3. Second operator

LMDS is well suited for a second operator as :

- It provide a complete service offer with one technology, including telephony
- 100 % penetration, which can be an issue for LMDS, must not be reached.

8.4. Cable operator

As explained in this paper, LMDS is the ideal complement to Cable network as :

- Low density areas can be fed with LMDS, while cable is used in high density areas and LMDS shadow areas
- LMDS can provide a high bit rate in upstream in the case of a professional subscriber in the network
- The architecture of LMDS and HFC are the same, so that a LNG can feed cable and wireless areas independently

9. CONCLUSION : TOWARDS A MIXED CABLE / LMDS ARCHITECTURE FOR INTERACTIVE SERVICES

The well know HFC architecture serving coaxial areas of 500-1000 homes is a viable and economical solution for the provision of interactive services in combination with analogue and digital broadcast services.

Higher frequency LMDS systems operate in either the 27.5-29.5 or 40.5-42.5 GHz frequency bands. These systems have limited range due to the effects of rain attenuation but have greater bandwidth capacity than lower frequency MMDS systems. Due to their short range and large bandwidth LMDS systems are well adapted to the broadband Hybrid Fibre Wireless (HFW) interactive services. Both consumer and Headend hardware is now becoming available in these frequency bands.

Finally, the figure below gives an example of full service network, based on HFC/HFW architecture.

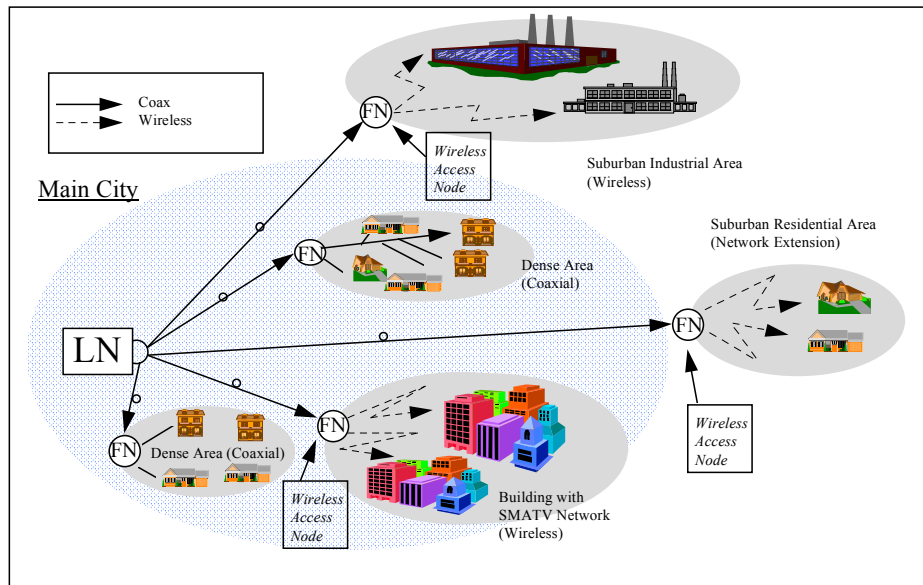


Figure 9 : Full service network.

10. GLOSSARY

LMDS	: LOCAL MULTIPOINT DISTRIBUTION SYSTEM
HFC	: HYBRID FIBRE COAXIAL
HFW	: HYBRID FIBRE WIRELESS
DN	: DISTRIBUTION NODE
LN	: LOCAL NODE OR REGIONAL HEADEND
FN	: FIBRE NODE OR ACCESS NODE
DVB	: DIGITAL VIDEO BROADCASTING
ETSI	: EUROPEAN TELECOMMUNICATIONS STANDARD INSTITUTE
FCC	: FEDERAL COMMUNICATION COMMISSION
RF	: RADIO FREQUENCY
IF	: INTERMEDIATE FREQUENCY
VHF/UHF	: VERY HIGH FREQUENCY/ ULTRA HIGH FREQUENCY
IFC	: INSTALLED FIRST COST