S-38.201 ATM JA MULTIMEDIA SEMINAARI, SYKSY -96

ACCESS NETWORKS AND MULTIMEDIA REQUIREMENTS

28.11.1996

Ove Strandberg
S 30848N
Nokia Research Center
ove.strandberg@research.nokia.com

Table of contents

Acronyms

ADSL	Asymmetric Digital Subscriber Line
ATM	Asynchronous Transfer Mode
BER	Bit Error Rate
CATV	Community Antenna Television, Cable TV
DAVIC	Digital Audio-Visual Council
FDDI	Fiber Distributed Data Interface
FEC	Forward Error Correction
FITL	Fiber-in-the-loop
JPEG	Joint Photographic Experts Group
HDSL	High bit rate Digital Subscriber Line
HDT	Host Digital Terminal
HFC	Hybrid Fiber Coax network
IP	Internet Protocoll
LAN	Local Area Network
LATM	Local ATM
MPEG	Motion Picture Experts Group
NTSC	National Television Standards Committee
OA&M	Operation, Administration & Management
ONU	Optical Network Unit
PAL	Phase Alternating Line
PCM	Pulse Code Modulation
PDH	Plesiochronous Digital Hierarchy
POTS	Plain Old Telephone Service
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
RF	Radio Frequency

WAN	Wide Area Network
VDSL	Very high bit rate Digital Subscriber Line

Abstraction

The transport of the multimedia in the last kilometer to the customer is different from the trunk network, which is shared. The typical drop network is a single line, dedicated to the customer use. The dedicated line will decline the problems of delay and delay jitter typically present in the trunk network and Multiplexers/switches. The capacity and transmission error is only restrictions present in the drop network.

Many bodies are standardizing different transmission technics for the last kilometer. ATM Forum and DAVIC are the major players concerning ATM transmission specification.

The documentation present technics in the capacity range from 28,8 kb/s up to 51 Mb/s with the use of copper pair, coaxial and fiber cable.

1 Introduction

The network service of multimedia has to fulfill different criteria's for different multimedia services. The main media types are:

- data
- sound
- graphic
- video

However the actual multimedia implementations like interactive video phone will further have specific requirements on the network. Other services will need other requirements. The ATM network is however a packet network technology and therefore will in this presentation mainly the following criteria be used to weight the transmission technic used to carry the MM service *[DistriMM]*:

- Bandwidth
- QoS (Quality of Service) : a) end-to-end delay
  b) delay variation
  c) loss ex. bits, packets etc.

The last drop to the customer is the focus of this presentation and it is also limited to fixed transmission technics. Different access technics will serve the MM service with certain characteristics, but as we look at only the drop then the bandwidth is the main focus. QoS factors will not require a study as the drop line will be dedicated for one user. The bandwidth need is considered in chapter 2 and the different transmission technics are presented in chapter 3. Conclusion is presented in chapter 4.

2 Bandwidth

The last drop from the access multiplexer or switch down to the user is usually a trivial task of establishing a point-to-point connection like for example the telephone line. As the point-to-point connection is only carrying one customers traffic one can really allocate as much bandwidth as imaginable on this line. However as the cost is going to be related to only one customer, will the customer have to pay for the dedicated last drop. This puts some solution limitations on the last drop i.e. the bandwidth and resources (cable) has to be optimized.

The original format of the main media data, sound, graphic and video uses a wide range of bandwidth from 64 kb/s up to 270 Mb/s, even higher bitrates can be imagined. The raw bitrate is with different coding technics dropped to more manageable sizes. For instance the video signal can with MPEG2 compressing be reduced from about 200 Mb/s to 4 Mb/s. The media specific bandwidth use differ between the different services and between the degree of quality expected. The normal quality is usually set by the old services present in today's ordinary life. *[MM90-luku]*

2.1 Basic bandwidths

The capacity will range from 0 to a couple of Mb/s. The trick is to include the old prevalent services with the new demands coming. This means that plain old telephone service will remain for long time and at the same time push video signals of several Mb/s. If the specific service implementations are overlooked can the different media types require *[MMreqs]*:

- Voice = 64 kb/s (no compression)
- Sound (HiFi) > 384 kb/s (no compression)
- Graphics = 1 Mb/s burst (JPEG)
- Video = 2 Mb/s (VCR) and 6 Mb/s (PAL), (MPEG)
- Data > 10 kb/s, => p * Mb/s

2.2 ATM issues

The use of ATM wastes some bandwidth as the cell overhead cuts at least 9,4 % from the actual transmission capacity. The removal of ATM cell formatting on the drop line can be justified as the drop connection is dedicated to one user and therefore no multiplexing technics between different customers will be needed. The lack of ATM cells is evidently good for such transmission solutions that don’t deliver that much capacity.

The drop line can however as earlier noted be made to support an abundant amount of capacity. The case can then be made to allow 1/10 of the capacity to be thrown away and thus over build the drop line to support 10 % more capacity than needed. Thus ATM can be brought to the end-user even though it might not be needed.

3 The drop network

It is possible to have the customer connected directly with a fiber, but typically is the connection done the with a traditional electrical cable. "The last kilometer" to the customer is complex, as many technologies over ordinary copper cable can be used. The main difference between different solutions is really how close to the customer the fiber is drawn. The most used technic today is to connect through the telephone network, a whole range of modem speeds are available. Other interesting technics are mentioned below:

- Telephone modems, new developments
- Fixed radio
- FITL
- ADSL/HDSL
- Fiber/Coax

Except the old modem technic are these technics using some kind of hub or router to connect the electrical or optical signals to the fiber in the trunk network. This hub serves as a demarcation between the drop plant and the shared trunk network.

3.1 Traditional telephone network

Traditional telephone networks offers speeds between 2,4 - 28.8 kb/s with standard modem technology. The modem solution is a end-to-end connection across all the network that simulates digital transfer on an analog channel of 3,3 kHz, the telephone connection. This traditional modem uses amplitude and phase to code the digital signal into the analog signal. The theoretical limit is about 35 kb/s. *[ADSLForum]*

3.1.1 Rockwell 56k

The Shannon information limit can be over come by new developments [Rockwell]. The new modem sees only the drop pair cable as the analog channel, and doesn’t look at a channel end-to-end. The analog signal generated is set to the voltage levels of the digitizing codec at the access node or the exchange. The modem must send an appropriate analog signal with the voltage levels synchronized with the codec to let the codec generates a 64 kb/s digital signal. The 64 kb/s is theoretical as the synchronization and the line equalization is hard to accomplish, especially in the upstream direction.

3.1.2 ISDN

The copper pair has also been used as a digital channel with the introduction of ISDN. The analog bandwidth in the drop line is 120 kHz as the basic rate of 144 kb/s is transferred (2B+D channels). Higher data rates are available at 64 kb/s increments.

3.1.3 Telephone drawbacks

The low speed of normal telephone network indicate that ATM cells are not well seen as they are reducing the available capacity. The ATM cells should be stripped away at the demarcation point, the access node/exchange.

Even if the phone network is globally available and allows for a fast implementation, it has not been built and optimized for anything else than voice conversation. As multimedia services start to use phone connection it also shows that it has a another behavior that breaks the normal traffic pattern of voice connections. The holding time of web service (~ 30 min) is longer than the voice connection (~ 5 min.). This indicate that the overloaded local exchange has to be reconstructed to handle the traffic at reasonable blocking level. This reconstruction could be directed on some new technologies that can offer better throughput at the same time.

3.2 Fixed radio transmission

There are both global and local drop plants: satellite, MMDS and LMDS.

3.2.1 Satellite

The satellite system uses the direct broadcast concept to download big pipes of data to subscribers. Thus the media is shared and scrambling of user data is needed. The return channel is made on another media, now in use is telephone modem by already launched business cases.

3.2.2 MMDS and LMDS

The MMDS (Microwave Multipoint Distribute Services) is an unidirectional transmission over radio QAM-links up to 10 GHz. The bandwidth of 8 MHz can carry 19 - 50 Mb/s depending on the modulation technic. The rates include actions as convolution and FEC. Scrambling will also be needed for privacy. The return channel will use other media as for the satellite system.

LMDS (Local Multipoint Distribute Services) works in the range above 10 GHz, which means more attenuation (shorter distances).The LMDS can be bi-directional; QPSK/QAM with 15 - 54 Mb/s TDM transmission downstream and DQPSK with max. 1,7 Mb/s TDMA upstream. The typical convolution and FEC technics are required.

3.3 FILT

Fiber-in-the-loop (FITL) is a drop plant architecture, where the fiber is brought as close to the customer as possible. The fiber stops either at the home/building or at the curb side with more than one customer sharing the optical end (curb stop is cheaper). The typical implementation is in areas with a not so dense customer base, where the low attention of the fiber comes in good use. Figure 3.5 shows the typical FITL with shared optical network unit, ONU.

The control and service allocation is set at the host digital terminal, HDT. It handles the service of many ONUs through a high speed interface up to the access network and the service nodes beyond like switching centers and servers. The optical network between the ONUs and the HDT can either be fiberrich or fiberlean as figure 3.1 indicate. The fiber rich uses a dedicated fiber between every ONU and HDT, while the fiberlean approach use a splice to divide the signals in the common fiber from the HDT to the ONUs. This will need wavelength diversity of the optical signals for every ONU.

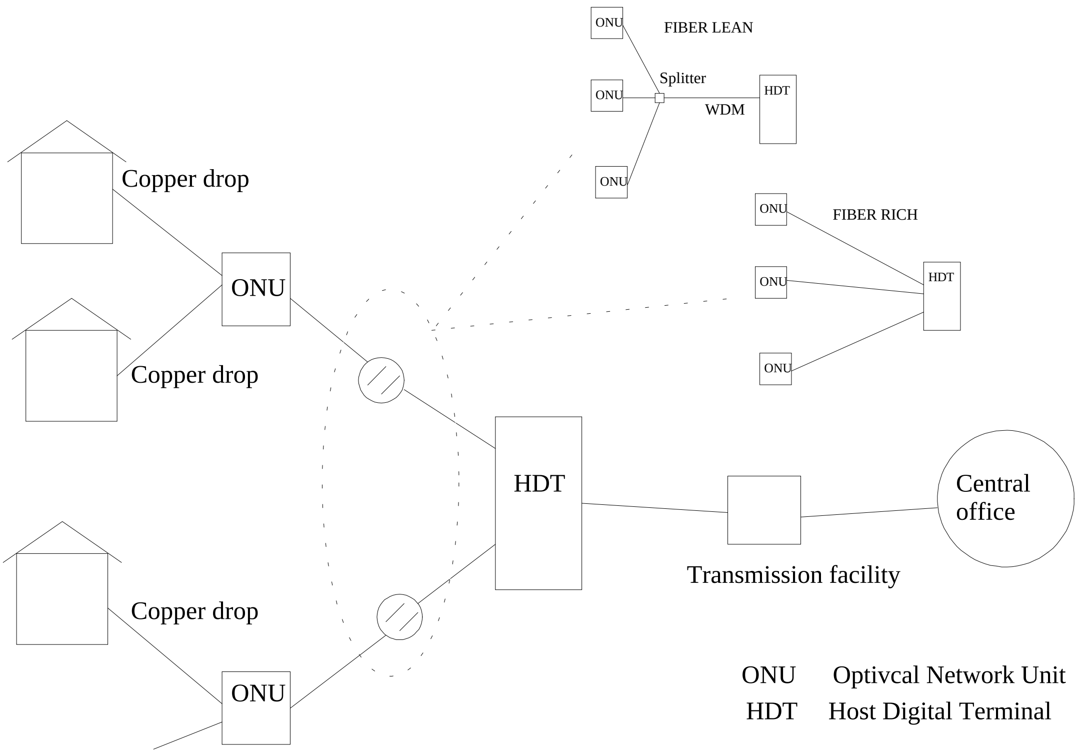

Figure 3.1. The fiber-in-the-loop architecture.

The last drop from the ONU to the customer is copper based either twisted pair or coaxial cable. The length limitation for the copper drop is dependent on bandwidth required and modem coding used. The modem part is seen as a simple modulator with QPSK or QAM modulation. The limit suggestion:

- Twisted pair (100 m) < 100 Mb/s
- Coax (400 m) ~ 155 Mb/s
- Fiber ~ 155 Mb/s

The DAVIC has specified four classes of transmission limits with asymmetrical down- and upstream capacities: 12,96-51,84 Mb/s down and 1,62 - 19,44 Mb/s up *[DAVIC]*. ATM Forum has specified a 25 Mb/s speed also acknowledge by DAVIC. The FITL architecture really doesn't set any bandwidth or QoS limits. The fiber intensive architecture also gives easy surveillance of transmission quality. The installation of new fiber and nodes decrease the feasibility of the FITL, it's an expensive access technic.

3.4 ADSL / HDSL

The asymmetric digital subscriber line, ADSL, and the high-bit-rate digital subscriber line, HDSL, are two similar technics. Both use modem technology to transport signals on twisted pair cable to the customer. The ADSL is asymmetric in the sense that the downstream traffic is higher than the returning traffic. HDSL on the other hand has symmetrical traffic going both down- and upstream. The idea is to use the old POTS twisted pair in place to deliver rather high bit rates over distances used by the normal drop plant. Thus the ADSL and HDSL differ from the FITL in the way that the fiber don't have to be laid so close to the customer. The old switching office of the POTS is converted into a concentrating hub of the ADSL/HDSL traffic. Figure 3.6 shows the ADSL architecture. *[DistriMM, page 169]*

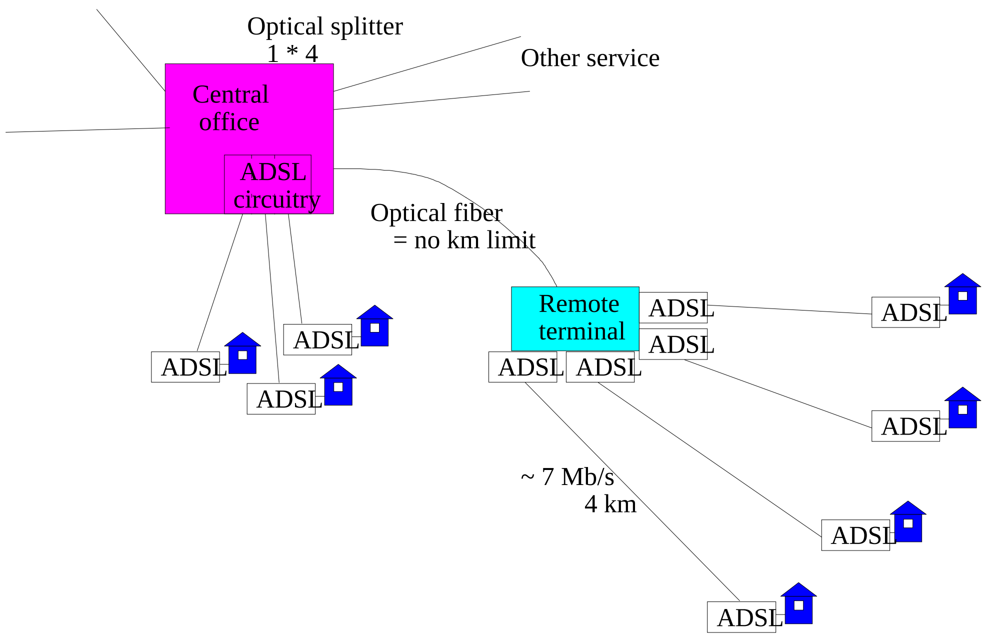

Figure 3.2. The ADSL architecture with some length and bandwidth numbers.

The bandwidth and distance limitations of the modem technology is under study and will be standardized. The final limits are not yet really known and some contradicting values can be found (does someone promise too much?). The modem implementation builds on either of two transmission technics: discrete multitone (DMT) versus carrierless amplitude and phase (CAP). The distance/bandwidth levels are *[ADSLForum]*:

- HDSL: Symmetric (6-wire) 2 Mb/s ~ 4 km
- ADSL: Asymmetric (2-wire) - downstream 6,3 Mb/s ~ 4 km (2 Mb/s ~ 5,3 km)

  - upstream 640 kb/s ~ 4 km

The bandwidth is clearly limited and the modem technic is expensive. However the fast implementation without major reconstruction of network makes it very feasible for low penetration and low subscriber density areas. The ADSL leaves the lowest 4 kHz of bandwidth untouched so that traditional phone can be separately implemented. The SDSL (Single line Digital Subscriber Line) is a version of HDSL with only one copper pair and the distance 3.3 km. An even higher performance VDSL (Very high data rate Digital Subscriber Line) is under development with up to 51 Mb/s downstream and 2,3 Mb/s upstream at distance 330 m.

3.5 Hybrid Fiber/Coax

The architecture of Hybrid Fiber/Coax (HFC) keeps the fiber farthest away from the customer. It is built on the cable TV network, CATV. The CATV is used to interface with the customer and the architecture will use fiber to distribute CATV signals from the headend to several CATV segments. This approach will use already installed cable to realize cheap broadband connections. The figure 3.3 shows the building blocks in the Fiber/Coax architecture *[Telephony]*. Note in the figure that the interconnection between the customer and the miniheadend is the mentioned fiber and coaxial combination. The connection between the miniheadend and the master headend can have several fibers in use.

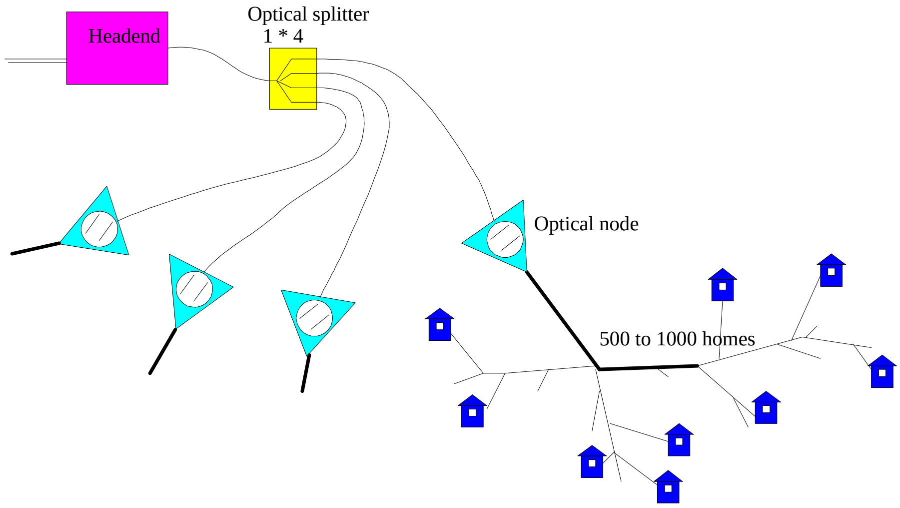

Figure 3.3. The Fiber/Coax network.

The traffic pattern of the architecture is asymmetric. The downstream traffic is using the 45 MHz to 750 MHz (or maybe even up to 1 GHz) frequency on the coaxial cable, while the upstream traffic is using the 5 - 40 MHz. This division of traditional CATV can however be rearranged so that the upper frequency area is also used for upstream traffic. This might be necessary for the need of customer with symmetric traffic. The area between 45 - 550 MHz should be kept for the use of analog RF transmission of TV channels as traditional TV service will remain. The channel allocation scheme is seen in figure 3.4. The analog TV signal has in the figure a little more bandwidth than perhaps necessary.

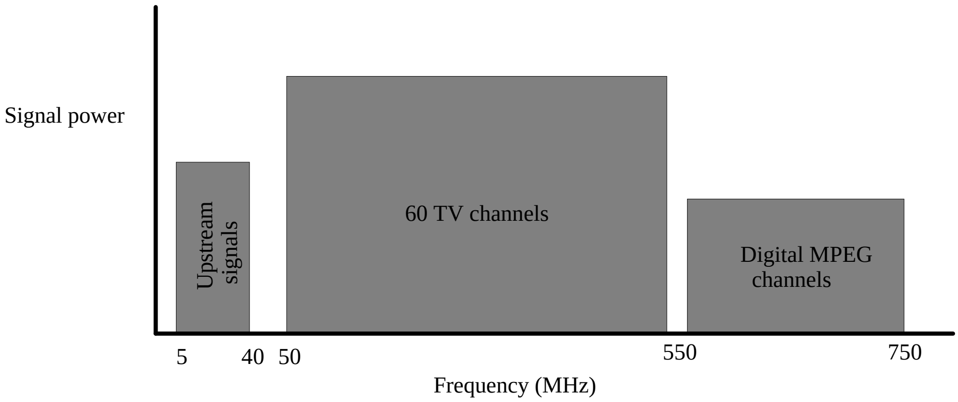

Figure 3.4. The frequency allocation on the Fiber/Coax segment (NTSC type TV)

The digital traffic (downstream) will be modulated into the RF analog signal following the CATV frequency raster division. The raster in EU is in steps of 7 or 8 MHz. With 64 QAM modulation can a 8 MHz channel support at least a 34 Mb/s bandwidth. This means that the headend has to collect the proper combinations of signals to fill up the space of 34 Mb/s. The simplest way is to multiplex ATM signals into the 34 Mb/s bandwidth, that the subscriber can demux to find the right ATM signals. Note that the phone is also multiplexed into 34 Mb/s signals. The comparison of analog and digital video indicate that one 8 MHz analog TV channel uses the same CATV spectra as 5 - 6 digital video signals of 6 Mb/s. Thus CATV will deliver 5 - 6 times more video signals digitally!

The upstream signals, mainly phone and control signals, in the 5 - 40 MHz range can be returned to the headend with three media access methods with their pros. and cons.:

- TDMA - delay calculations to find time slot
- FDMA + simple
  - capacity waste

The TDMA has to include a complex algorithm to calculate the location of the assigned time slot. The FDMA is simple to accomplish but it wastes the bandwidth. The TDMA is more bandwidth efficient but the access window is difficult to calculate, which is seen in cable modem installation handling times. The media access has to have very good noise resilience in the ingress, reflection and distortion rich environment of the CATV network.

The major limiting factor is the return channel shortage as the CATV was built for distribution not interaction. If the upper frequencies (like 750 MHz - 1 GHz) aren't converted into return channels use, must the number of subscribers on a segment (with shared RF) be dropped to suit the return channels (return data, control & phone). The phone service in return channels indicate the size of the segment to be less than 288 users (FDMA). Thus the fiber will be used to keep the traditional headend without relocation or without additional headends. The fiber collect many parallel RF sections (many segments) to the traditional headend. Note that the fiber carry RF not digital signals. If the return bandwidth requirements increases must the segments be downsized. With more return traffic will the situation get closer to the FITL situation, i.e. why pay for RF complexity when FITL can do the job strait digitally. [Future]

The RF generation drawback is highlighted with the heavy headend, see figure 3.5. The headend has to receive different signal types and formats at many different rates. The insertion of the signals to different 8 MHz groups has to be accomplished. All the 8 MHz channels has to be modulated and that for all the underlying CATV segments. The signals in the opposite direction has to go through the reverse actions. The smaller the segments the more segments are needed and the heavier will the headend get.

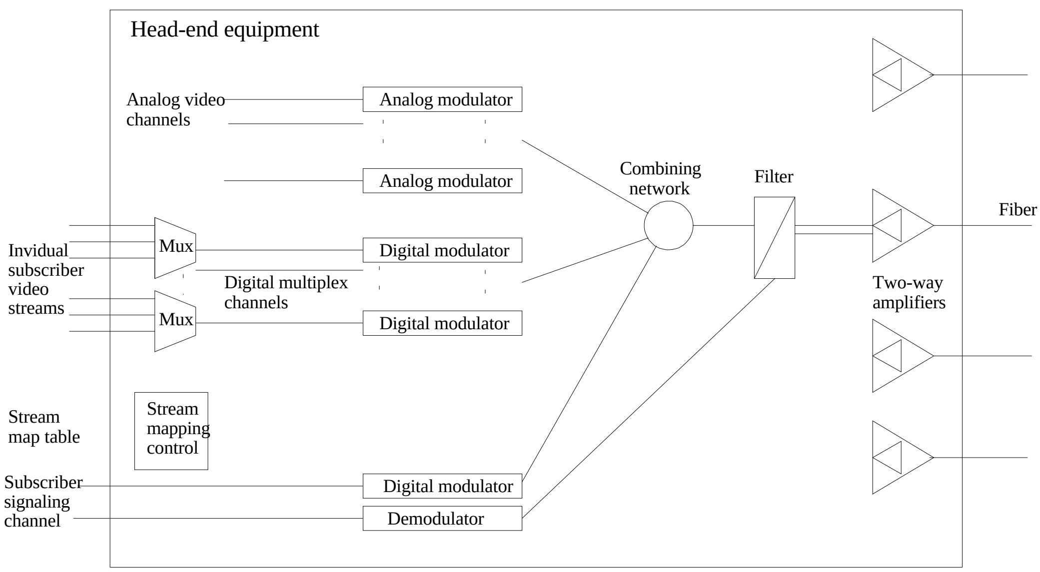

Figure 3.5. A simplified scheme of the Fiber/Coax headend.

The Fiber/Coax has at least in the USA got a hot reception. The fast implementation (small network remodeling) in the already broadband CATV network will deliver the by far cheapest multimedia connections (not symmetrical) when the number of user are low i.e. when there is low penetration.

3.6 Drop plant summary

The aspirants for drop plant transmission architecture are LMDS, FITL, ADSL and Fiber/Coax. They have different strong points and drawbacks and they can be compared on three aspects: Penetration, Capacity and Price. The comparison is made on how well they fit these aspects. The phone modems can't compete in the capacity area for long and the other technics where inconvenient because of unidirectional service, an other type of return channel will typically rely on another operator that will complicate the implementation too much.

Penetration:

LOW:	ADSL Fiber/Coax LMDS	**HIGH:**	FITL

Capacity:

LOW:	ADSL	**HIGH:**	Fiber/Coax FITL LMDS

Price:

Cheap:	Fiber/Coax ADSL LMDS	**Expensive:**	FITL

The comparisons can also be presented on a table with the axis describing percent of penetration and level of capacity, see figure 3.6. The location of the transmission architecture indicate where the technics are most feasible to realize i.e. where the price will be optimally low.

The raw error rate of different solutions is dependent of how long the copper part is. The more fiber the smaller error values. The difficult environments in for instance the Fiber/coax network is combated with randomization, convolution and FEC (forward error correction) technics, FEC mostly Read-Solomon codes. The effect is that the final payload transmission quality is close to fiber transmission (BER 10^{-12}). The price is however the extra overhead of the FEC (capacity loss) and the higher expense of processing these correction technics.

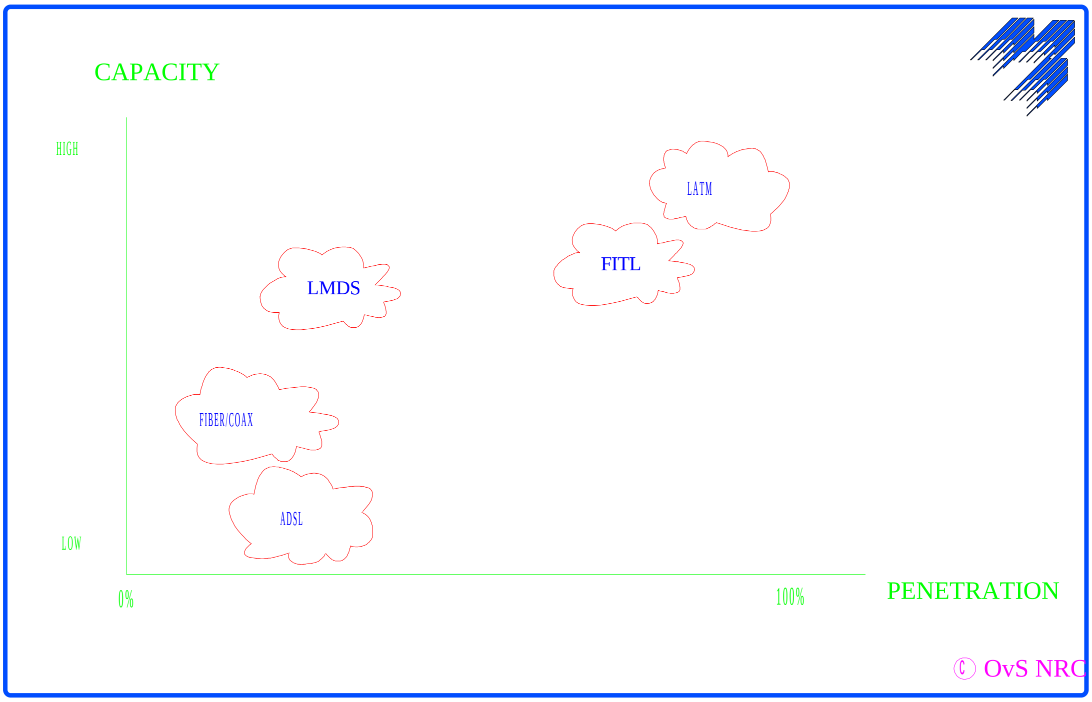

Figure 3.6. The feasibility of the transmission architecture

4 Conclusion

The only real solid bet to see pure ATM on the physical transmission level (without other framing like Fiber/coax) is going to be in the LAN realization. Many other transmission architectures are going to capsulate the ATM (or other signals) in a different framing format because of FEC and transmission control purpose.

"The last kilometer" - solution is not clear. The bandwidth, geography and usage will make the decision. The ideal solution with a fiber to every subscriber is far away for the long time. Only the "rich" corporations can afford to hook up their hubs (LAN and other transmission services) to the optical high bit rate access network. The transmission architectures in the drop diverse according to the opinions of the operators. The traditional operator like British Telecom supports the ADSL approach while the second operator like Nynex (in UK) supports the Fiber/Coax approach. This comes from the simple fact that they have extensive installed networks for telephone (BT) and CATV (Nynex) service. The FITL on the other hand is too expensive to realize yet, the reason is the extensive rebuilding of the "last kilometer"-network for a yet not seen bandwidth demand.

The QoS on the drop plant has no real relevance, the only issue will be the capacity requirements of the MM service. The FITL would be most flexible, but to a reasonable price is the Fiber/coax the most probable solution.

The real main question still waiting for an answer is: "What will be the demand and at what growth rate?". This presentation hopefully gives a hint to the solution technology available, but it solemnly leaves an open question of which access technic will be most appropriate? It will depend of the real bandwidth demand, which has not yet seen. But be prepared for p* 64 kb/s bi-directional data and 2 Mb/s VOD at whatever transmission technic will be in use!

References

[ADSLForum] http://198.93.24.23/adsl_home.html

[Davic1.1] DAVIC 1.1 Specification Part 08: “Lower Layer Protocols And Physical Interfaces”, Technical specification, revision 3.3, 204 p.

[DistriMM] Minoli Daniel, Keinath Robert: "Distributed multimedia through broadband communications", Artech House, Boston, 1994, 311 p.

[Future] Hawley G: "Back to the future of the local loop", Telephony, September 26 1994, page 62-69.

[MM90-luku] Kerttula Esa: "Multimedia 90-luvun tietojärjestelmissä - Teknologia, sovellukset, markkinat", Liikenneministeriö V 55/94, Helsinki 1994.

[MMreqs] Strandberg Ove: "Multimedia requirements on the transmission network", Multimediaseminaari AEL-INSKO, Toukukuu 17 1996.

[Rockwell] http://www.nb.rockwell.com/mcd/K56Plus/

[Telecom] Joshi Bhaquat: "Residential broadband access networks and technologies", Telecommunications, July 1995.

[Telephony] Swenson Jerry: "A new concept for the roadwork on the Superhighway", Telephony, march 21 1994, vol. 226, no. 12