Access network options for interactive video and multimedia services

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The forthcoming introduction of interactive video services such as video-on-demand, which is facilitated by recent advances in source and channel coding as well as modulation, calls for a network platform via which the subscriber can access the appropriate sources of information.

Two such approaches – the use of existing broadband CATV and the use of telephone networks – are detailed in this article. In the case of CATV networks, special emphasis needs to be placed on return channels.

1. Introduction

The advent of novel interactive video services – *services-on-demand* (SoD) – has only been made possible by the dramatic advances achieved in:

– source coding of video and audio signals (e.g. the MPEG-2 standard);

– channel coding of digital signals;

– sophisticated modulation methods (e.g. QAM);

– implementation of these new technologies in the form of integrated circuits.

To make these interactive video services accessible to interested customers, a network platform will be required to connect the terminal equipment (ultimately, the customer) to the source information. This information will be stored on high-capacity servers and the major part of the requested information will be provided by the server that is closest to the customer; the *cache server*. The *SoD exchange* will be located in the immediate vicinity of the cache server and every user terminal (television receiver with set-top box, PC, etc.) will be connected to the SoD exchange via an *access network*.

Fig. 1 depicts that, for each customer, a high-rate forward channel for the transport of the requested data must be provided, along with a bidirectional control channel – for the establishment of the connection as well as for interaction with the cache server – and, if needed, a return channel must also be available. The access network will, in principle, allow bidirectional communications traffic to be handled.

The significance of future interactive video and multimedia services is already reflected in the

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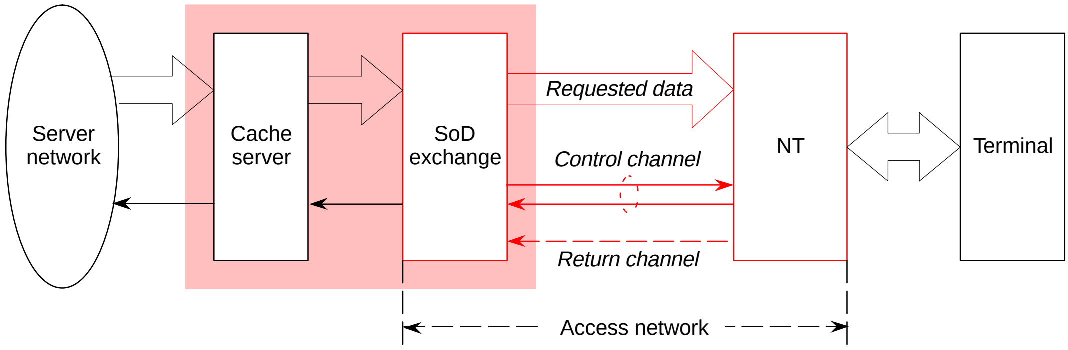


Figure 1
Network elements of SoD.

current standardization efforts. For example, DAVIC is currently trying to set up far-reaching specifications, including those needed for the access network interfaces. Both ATM and the MPEG-2 transport multiplex are envisaged as the transfer mode for the broadband forward channel, whereas ATM has been exclusively specified for the bidirectional control channel.

For reasons of economy, new interactive video services will be introduced on the basis of existing networks. In the first instance, the majority of network operators will use:

– CATV networks;
– the telephone network in conjunction with ADSL.

2. CATV networks as access network platforms for SoD

2.1. Structure of a CATV network

CATV networks will provide an excellent infrastructure for SoD. In Germany, for example, about two thirds of all (34.7 million) households can currently be accessed via these networks. If CATV systems are to be used as a communication network for bidirectional point-to-point connections, as in the case of SoD, particular attention will have to be directed at the tree-and-branch structure of these networks, which were originally planned for point-to-multipoint distribution. This applies to the implementation of channels in both the forward and return directions, as well as to the access protocols.

The basic structure of a CATV network is shown in *Fig. 2*. In the case of the SoD access network described here, network levels 1 and 2 are of minor importance. The access network proper is network level 3, which ends at the network termination (NT). Of special significance is network level 4, which may comprise at least one or, maximally, several thousand accesses.

The access areas of the CATV networks operated by Deutsche Telekom (*Fig. 3*) start at the main amplifier and feed "active" cables of up to 5 km in length, each of which is equipped with a maximum of 23 amplifiers. Each main amplifier is responsible for up to eight A lines. The last amplifier of an A line is called the C amplifier which feeds the NTs via so-called C lines; these exclusively consist of passive elements, i.e. taps,

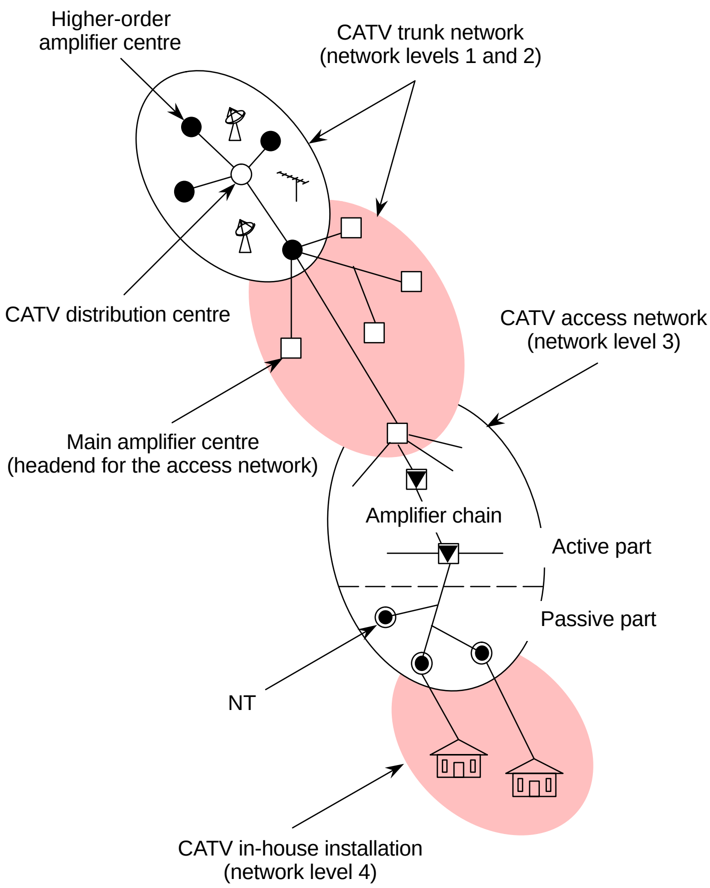


Figure 2
Basic structure of a CATV network.

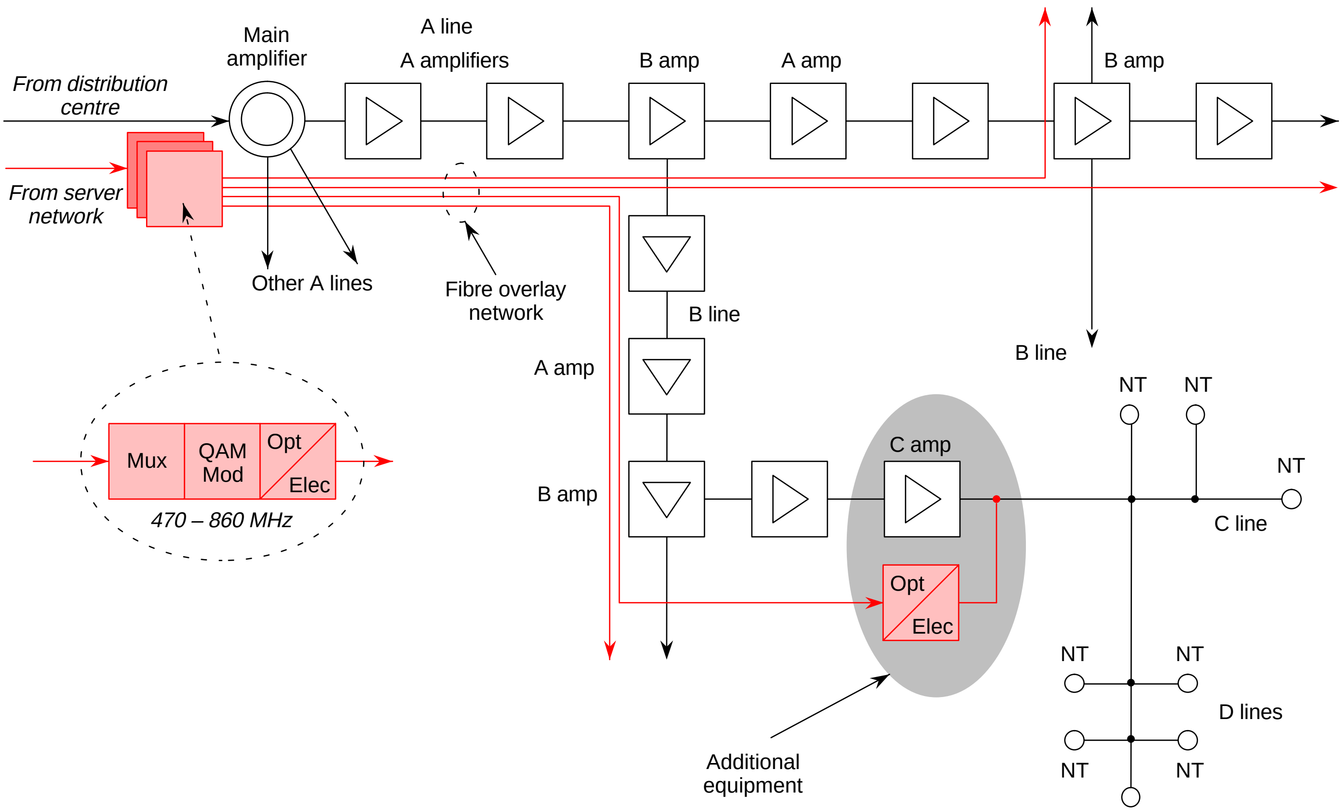


Figure 3
Structure of the access area of a CATV network, showing the network extension by means of optical fibres with "analogue transmission".

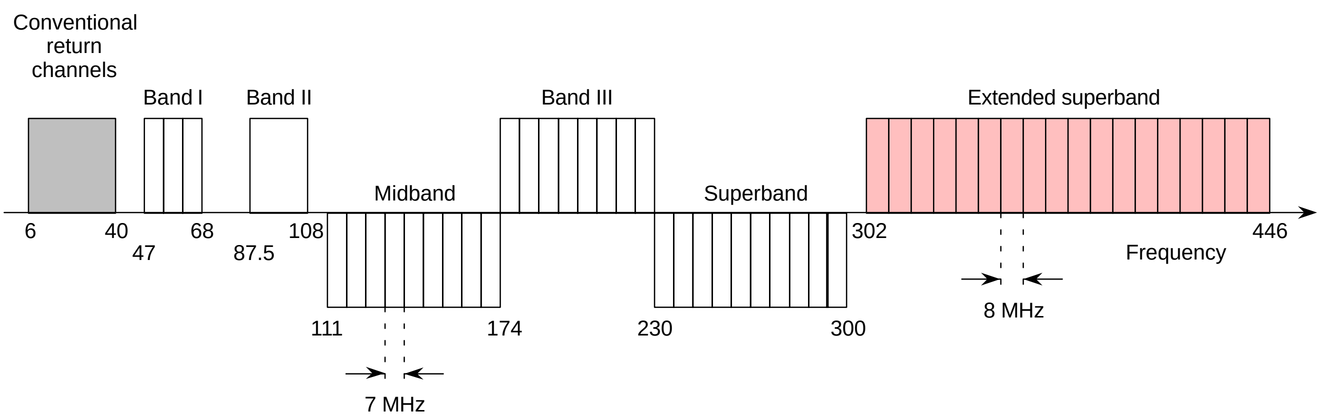
splitters and cables. In large cities, an A line serves about 6,000 households on average. The number of households connected to a C amplifier represents another important factor; this number may vary from less than 10 to several thousand households.

2.2. *Extension of CATV networks by optical fibres*

At first, it was assumed that some of the eighteen 8 MHz channels of the extended superband (i.e. the "hyperband", 302–446 MHz) could be used for the high bit-rate transmission (41 Mbit/s) in the direction of the customers (*Fig. 4*). Meanwhile, however, it appears that this band will in all probability be required exclusively for digital TV transmission according to the DVB standard.

As a consequence, the only alternative for SoD will be to use the frequency band above the hyper-band. Since upgrading of the active part of the CATV network by more broadband amplifiers will not be viable for a variety of reasons, it must be upgraded by the use of new

Figure 4
Occupation of the frequency band in CATV networks.



optical fibres as far as the last amplifier, i.e. the C amplifier. In the case of particularly large access areas, it will probably be necessary to lay the optical fibres beyond the C amplifier. Full signal processing (multiplexing, QAM and electro-optical conversion) for distribution along the A lines will be done at the main amplifier (*Fig. 3*). At the C amplifier, only an opto-electrical conversion and the combining of the SoD signals with the main signals of the distribution services will be required.

2.3. Realization of the return channel and the backward control channel

In principle, a transmission rate of several hundred bits-per-second will suffice for the control of a virtual video recorder (i.e. an interactive video-on-demand service). However, the return channel should exhibit enough flexibility to support higher bit-rates because, in addition to services with more stringent return channel requirements that are already feasible, a future *dynamic assignment* of larger bandwidths (2 Mbit/s and more) on request might be desirable. This will also allow future expansion of the network to provide interactive services with a broadband return channel. For the time being, however, it will be sufficient to aim for a maximum data-rate of 64 kbit/s for the SoD return channel.

Within the frequency range of a CATV network, a bandwidth of at least 20 MHz (e.g. between 11 and 31 MHz) is available for a modern return-channel concept. The access procedure should provide for a collision-free access to the physical medium shared by all the subscribers, and should assign return-channel capacity in compliance with the customer's wishes. It should be possible to provide multiple access by means of:

- FDMA;
- TDMA;
- CDMA

A return channel will be assigned either permanently, semi-permanently or dynamically. Permanent assignment takes place only once – at the time when the network operator provides first access to the service. Semi-permanent assignment is granted if the customer requests this service and lasts only for the duration of the request. Dynamic assignment permits the return channel capacity to be adapted to satisfy the current demand of customers during the period of service usage.

The assignment of a return channel can be controlled distributively or centrally. In the event of distributively-controlled access, the terminal equipment itself tries to find a free channel. This can be accomplished, for example, by the search for (i) an unassigned carrier frequency in the case of FDMA or (ii) a free time-slot in the case of TDMA. In the event of centrally-controlled access, terminals are allowed to be accessed from an operating centre. This requires the use of a control channel operating in the downstream direction from the centre to the terminals.

Although, in principle, all the above-mentioned procedures can be implemented in a CATV network, not all access methods are equally suitable for various reasons. For an average of 500 households connected to the last amplifier, there is the possibility of providing a return-channel data-rate of approximately 64 kbit/s for every access. This means that, with a dynamic allocation of capacity and the expected low take-up of

Abbreviations

ADSL	Asynchronous digital subscriber line
ANSI	Americal National Standards Institute
ATM	Asynchronous transfer mode
CATV	Community antenna television
CDMA	Code division multiple access
DAVIC	Digital Audio-Visual Council
DVB	Digital Video Broadcasting
ETSI	European Telecommunication Standards Institute
FDM	Frequency division multiplex
FDMA	Frequency division multiple access
HDSL	High bit-rate digital subscriber line
ISDN	Integrated Services Digital Network
MMDS	Multipoint microwave distribution system
MPEG	Moving Picture Experts Group
NT	Network termination
PCM	Pulse code modulation
QAM	Quadradure amplitude modulation
SoD	Services on demand
VDSL	Very high bit-rate digital subscriber line

access units for SoD (a small percentage of the overall number of CATV customers), it will also be possible to reach considerably higher data-rates in the individual return channels.

3. The telephone network as an access network platform for SoD

3.1. Structure of a telephone network

With about 70 million kilometres of telephone “twisted pairs” in Germany, the telephone access network represents the largest infrastructure. Ninety percent of the local loops are shorter than 4 km (0.4 mm diameter) and can therefore be used for additional digital transmission. The network starts at the main distributor of the local node (*Fig. 5*) and the feeder cables have an average length of 1,700 m. They are routed to the network terminations either directly, or indirectly via cabinets and distribution cables of average length, 300 m. The terminal equipment, mainly telephone sets, are connected to the network terminations through extension lines.

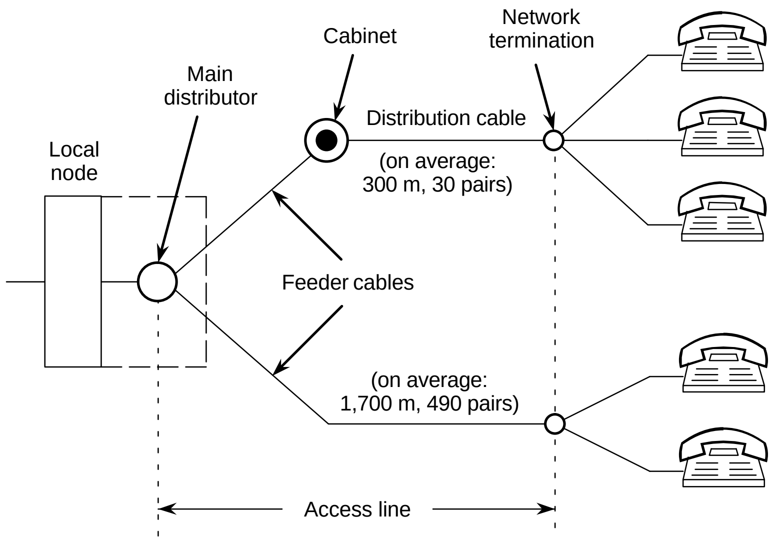


Figure 5
Structure of the telephone access network.

3.2. Transmission of SoD signals by means of ADSL

On the basis of its star-shaped structure, the local exchange area of the telephone network is well suited for point-to-point connections in the case of SoD. Although the network was primarily designed for voice transmission only, attempts were made more than 30 years ago to utilize this network for digital transmission using bit-rates of up to about 2 Mbit/s. Today, a variety of digital systems are operational in the local exchange area of a telephone network , including:

– ISDN basic access;

– PCM2 and PCM4 accesses;

– PCM30 and primary rate accesses.

In contrast to HDSL which is a symmetrical technology for two-way services, the US technique called ADSL is better suited for interactive video services (SoD) because of its return channel capability. ADSL, which was originally intended for the distribution of broadband signals, is an unsymmetrical transmission system with regard to the bit-rates.

ADSL permits a digital signal at 2.048 Mbit/s or more (up to 8 Mbit/s), as well as a control signal with a lower bit-rate – say (16+8) kbit/s – to be transmitted in the direction of the customer as a time division multiplex which also includes the telephone call or ISDN connection. The return channel from the customer to the exchange may have the same bit-rate as the control channel. The individual channels are combined in a frequency division multiplex. The return channel is accommodated in the spectrum above that of the telephone and/or ISDN signal; it uses, for instance, a bit-rate of (16+8) kbit/s with uncoded 16-QAM at an efficiency of 2.4 bit/s/Hz. For the high data-rate channel, and the control channel in the direction of the customer’s terminal, a broad-band utilization of 5.2 bit/s/Hz can be achieved with coded 64-QAM. Line terminal equipment and/or line terminating units are interconnected via appro-priate filters.

With the aid of ADSL, every telephone or ISDN customer could, in principle, be connected to an SoD exchange via the same subscriber line, thus allowing a full-coverage service to be established. That is why this procedure is being discussed intensively by the relevant standardization bodies (e.g. ETSI, ANSI). However, some restrictions exist and several issues must still be studied:

– the range is limited, depending on the wire diameter, because no regenerative repeaters can be used for economic reasons;

– all subscribers who are served via digital multiplex systems, PCM 2, PCM 4 or line multiplexers are excluded from being connected to ADSL (representing perhaps about 8 to 10 % of all customers).

3.3. Transmission of SoD signals by means of VDSL

An interesting solution is provided by combining the telephone network with optical fibres; the latter are used for routeing the SoD or other high bit-rate signals up to the cabinet. From here, the telephone signals – along with these high bit-rate signals – are sent by means of VDSL to the customer via distribution cables with a maximum length of 500 m. The transmission system required for this purpose must be highly sophisticated as regards the signal processing used. It is possible with this method to achieve a total bit-rate of approximately 52 Mbit/s which can be distributed over both directions (forward and return), without restrictions.

On the one hand, this procedure has the essential advantage of a high transmissible bit-rate; on the other hand, it requires additional electronic devices to be accommodated in the distribution cabinet. A basic configuration of the system is shown in *Fig. 6*.

4. Radio links as an access network platform for SoD

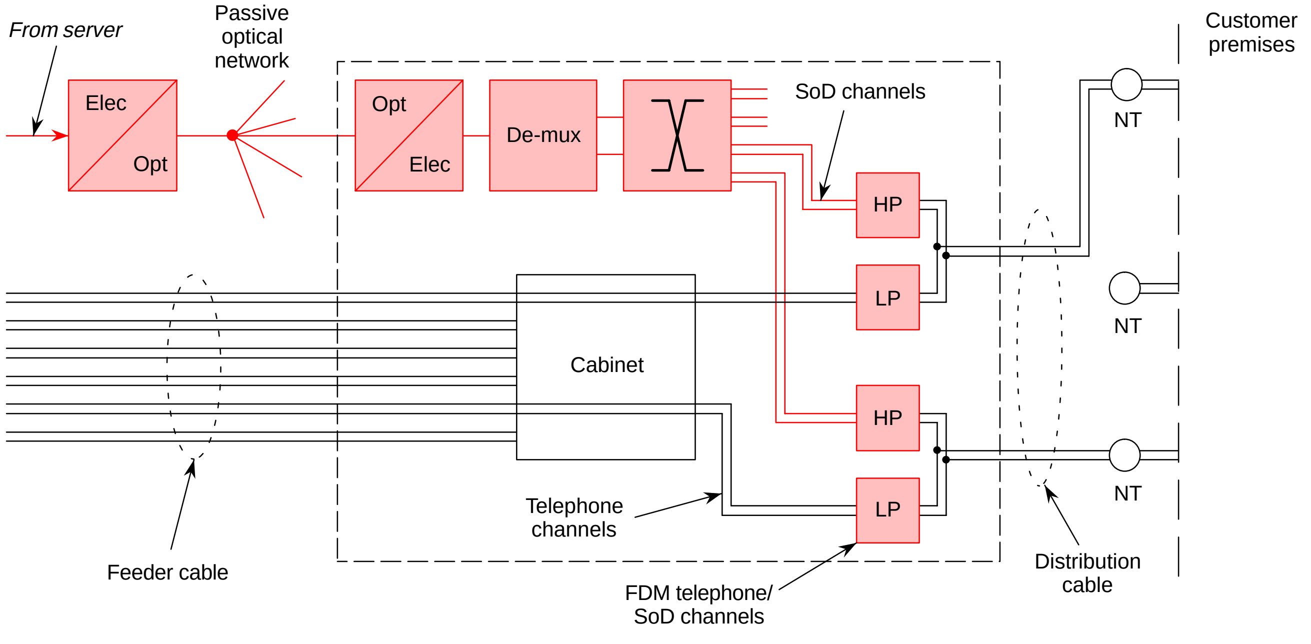
As an alternative and/or supplement to CATV networks, multipoint microwave distribution systems (MMDS) have been developed in some countries (e.g. Ireland, the USA, Canada and Hong Kong). MMDS can transmit the programmes offered by cable networks direct to the customers by means of radio waves. The use of MMDS is not only advantageous for regions where there is no access to a cable network and for which cabling is uneconomical (e.g. in rural, thinly-populated areas), but also for municipal areas which are to be provided with full-coverage cabling in a very short period of time and without considerable pre-investment. In this case, MMDS can be used as a microcellular system. Potential frequency ranges have not definitely been assigned as yet, at least in Europe, and the discussions on the modulation methods involved have not yet come to an end.

Like CATV networks, MMDS systems are well suited as an access network platform for SoD. In this case, too, the provision of customized return and control channels is absolutely necessary. Access to the shared "radio hop" assumes that similar considerations have to be made as for CATV networks. SoD-capable MMDS systems may form an extension to existing cable networks or may be fed via additional optical fibre systems.

5. Transfer mode used for the access network

An important question concerns the selection of the transfer mode applied to the access network (see *Section 1*). The MPEG-2 transport multiplex system will be used for future digital television broadcasting services (DVB, Near Video-on-Demand, etc.) but, in the case of interactive and multimedia services, the MPEG-2 multiplex may probably be used only for combining the signal components of just one channel (i.e. the video, audio and associated data signals). For multiplexing the signals of several channels in

Figure 6
Optical fibre up to the cabinet.



the access network, ATM is considered the better solution. Of decisive importance are: (i) the flexibility required when introducing new systems in the future; (ii) the improved way of accounting, based on the data volume actually transmitted and (iii) the evolutionary possibilities offered by the transition to broadband ISDN.

6. Final remarks

In this article, alternative solutions for designing an access network for interactive video and multimedia services have been described. The various alternatives are currently being discussed intensively by the relevant standardization bodies such as ETSI and ANSI. Pilot tests are in preparation or are already being performed in many areas.

It should be mentioned that this article has been based partly on the discussions of a working group established at the Technology Centre of Deutsche Telekom AG, within the framework of an internal project.

Mr Horst Hessenmüller *was born in 1936 and received a Dipl.-Ing degree in Communications Engineering from the Technical University of Brunswick in 1963. After a short period of work in industry, he joined the Research Institute of FTZ in Darmstadt, now the Technology Centre of Deutsche Telekom AG.*

In 1994, Mr Hessenmüller was appointed head of the Network Infrastructure division. Since then, his main activities have been in the fields of digital transmission and multiplexing, speech and high-quality sound encoding, DBS satellite engineering and access networks for interactive video services.

Over the years, Horst Hessenmüller has been a member of several working parties of the EBU, the ITU and various international projects.