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A platform for the delivery of digitally compressed video and multimedia services over Telecom's access network

Authors: S. Rozental, J. Mc Carter, A. Mc Bride

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Pay TV Technology Project Team
Platform Technologies
Network & Technology Group

Telecom Australia

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ADSL technology using compressed video methods, can be deployed to deliver video services including multimedia services to customers over the existing copper cable access network without the need for special pair selection criteria, or pair conditioning. It is expected that this technology can initially be deployed in a complementary role to CATV deployment, which is more suited towards the higher density urban areas. ADSL technology may find a window of opportunity for application, until fibre and associated customer optical equipment is widely deployed to residential areas.

INTRODUCTION

The distribution of broadcast Pay-TV services in Europe and US, is currently accomplished using technologies based on analogue transmission adopting coaxial cable, microwave radio, or satellite platforms. Until now, telephone companies in the US through regulatory reasons, were not permitted to provide Pay-TV services to their customers. The regulatory situation is now changing to the extent of enabling Telco's to enter the video delivery arena. To avoid the cost and the slow roll-out of a new overlay coaxial infrastructure, to provide video services including emerging multimedia services, Telcos (eg Bell Atlantic, Nynex), are keen to pursue new opportunities based on emerging transmission techniques. One such technique involves the application of digital compression and ADSL (Asymmetric Digital Subscriber Line) transmission for the carriage of digitally coded video signals over existing copper twisted pair cables in the Customer Access Network (CAN). The ADSL technology can be installed to satisfy scattered demand for video services, improving utilisation of the embedded CAN, until fibre deployment becomes economic and ubiquitous. Fig 1 illustrates the basic ADSL system.

The Australian Government has been considering the introduction of Pay-TV service for a number of years, and has recently mandated that the proposed satellite Pay-TV service will use compressed digital video technology. This decision, whilst focusing on the application of the latest technology for the preferred satellite delivery option, does not exclude future delivery of Pay-TV via other means such as microwave MMDS (Multichannel Multipoint Distribution System), hybrid optical/coax networks, or other emerging options such as ADSL.

TELECOM AUSTRALIA'S INTEREST IN ADSL

With the opportunity available for the transmission of Pay-TV services over terrestrial networks, Telecom Australia is investigating all alternative terrestrial delivery options for video services. One promising video delivery technique now emerging is the

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utilisation of the existing copper CAN using ADSL technology, as an alternative or complementary technology to other options including an overlay coaxial based cable Pay-TV network. By adopting this technology, existing access infrastructure could be readily utilised to penetrate the market rapidly, thus providing the delivery of a host of video services including Pay-TV. This technology would be suited for the medium to lower density areas of urban cities where scattered geographical demand for video services may tend to occur. The ADSL technology would play a complementary role to CATV optical/coaxial hybrid technology which is more cost effective for the inner, higher density areas of urban cities. Fig 2 illustrates the complementary role of ADSL and CATV.

The market captured through the application of ADSL and complementary CATV technology may in the longer term be migrated on to fibre if required, to satisfy demand for higher bit rate digital services, eg., HDTV.

In light of the above, Telecom Australia issued a call for Expression's Of Interest (EOI) in March 1993, for the supply of ADSL based system for video services, including Pay-TV. Following the evaluation of the ADSL offers, Telecom has placed an order with AWA Limited for the supply of an ADSL demonstration system to be installed at the Telecom Research Laboratories in 1Q94, to assess the ADSL and related video services technologies. The ADSL demonstration system will initially be used for viewer perception trials.

The demonstration system consists of digital encoding equipment, video storage and retrieval system, switching equipment, ADSL DMT transceiver sets and customer decoding equipment with suitable interfaces for connection to a standard TV unit. The system will be capable of serving up to 6 customer positions with broadcast Pay-TV and Video On Demand (VOD) type services with a capacity of 20 pre-recorded channels and 1 real time channel offering.

Telecom Australia is currently evaluating offers for a Pilot ADSL system which is proposed to be established in the 3Q94, to asses the inter-working capability of the system with existing Inter Exchange Network (IEN) and CAN infrastructure. It is proposed that approximately 200 customers will be connected onto the Pilot system and will have access up to 60 video channels of which 10 channels would be "real-time" channels. The Pilot will provide a video delivery platform using Synchronous Digital Hierarchy (SDH) transmission across the IEN from the Head-End Video Server to one or several local exchange(s), where compressed digital video signals will be delivered to customer premises via ADSL transceiver sets on existing telephone lines. The outcome of the ADSL Pilot, which will be assessed for a period of approximately 6 months, will be used to formulate specifications for a possible bulk system design and development.

SERVICES LIKELY TO BE OFFERED ON ADSL

Recent advances in digital signal processing technology have led to dramatic increases in the amount of digital data that can be transmitted over ordinary twisted pair telephone cable in the CAN. With a recent American National Standards Institute (ANSI) committee endorsing ADSL technology, telephone companies will be able to install systems operating between 1.5 Mbit/s and 6 Mbit/s downstream to the customer, over existing pair cable infrastructure with a reach of approximately 4 km on 0.4 mm cable gauge. The types of services that will be able to be delivered within the above bit rate capacity will include video, data and other multimedia services, which could be grouped under the following service categories.

Entertainment & Gaming

Within the Entertainment and Gaming category, the following services could be offered, some of which may incorporate full customer control capability, eg. pause, fast-forward and rewind.

- Broadcast (Pay TV).
- Concert & sporting events (Live or pre-recorded).
- On Demand Movies or Stereo Digital Sound.
- Broadcast News & News retrieval including current affairs.
- Interactive Games (Nintendo, Atari & Sega games as well as chess, checkers etc).
- Betting (horse races, poker, home casino).
- Virtual Reality.
- Video Conferencing (eg Entertaining & talk back interaction).

Information & Transaction

This category relates to non entertainment, professional and semi professional service offerings eg:-

- Education and Distance Learning.
- Medical, Dental, Home diagnostics.
- Financial News & Transactions (Interest rates, Stock Exchange listing, Forex, Super Funds etc).
- Bill Payment (Gas, Electricity, Phone, Water, Rates, Insurance etc).
- Home Shopping (Browse, select and purchase).
- Travelogue (View holiday location, accommodation & booking).
- Real Estate (View properties inside & outside prior to visit and purchase).
- Entertainment and Travel Booking.
- Directories (Yellow & white pages, catalogues).
- Databases (National & International).

Measurement

This type of information is suited for the Service Provider's who are interested in monitoring statistical data and customer preferences associated with service delivery eg :-

- Voting (may include eg local council voting or answers to questions).
- Quiz Shows.
- Market Research.
- Ratings.
- Customer viewing habits.
- Focused Advertising feedback.

Control Functionality

The control functionality will enable customers to maintain control of the ADSL service offerings through the upstream channel signalling path. Some of the control functions could include for example:-

- Perspective (Select different camera view on sports/concerts).
- Viewer interface (Select Windows type or Text type menus).
- Service access control (Encryption, Parental Control, PIN).
- Video quality selection (High quality for sports & medium quality for News).
- Channel capacity selection (Lower quality video for more channels versus high quality for fewer channels).

ADSL TECHNOLOGY

The transmission of compressed digital video within the CAN has been made possible through ADSL technologies incorporating recent advances in Digital Signal Processing (DSP) and Very Large Scale Integration (VLSI) techniques. ADSL offers asymmetric, high bit rate digital transmission from the exchange to the customer over the existing pair cable.

The ADSL system is comprised of two parts; the exchange-end transceiver and the customer-end transceiver. The transceiver set is in effect a very advanced modem, optimised for the transmission of high bit rate signals over a pair cable network. The asymmetrical nature of the system relates to a high bit rate transmission of video signals downstream to the customer, and low bit rate from the customer to the exchange for control signalling. Refer to Fig 1 which illustrates the basic ADSL system. The ADSL system allows also for bi-directional control signalling, enabling the customer to be able to control the incoming source material interactively . The same transceiver also allows the customers to place or receive phone calls over the same pair cable without affecting the digital transmission signal. The telephone service is inserted via a low pass filter and transformer splitter on to the ADSL path, thus maintaining a full physical connection. The telephone service will continue to be operational in the event of any ADSL system fault condition or power outage.

DMT

Discrete Multi-Tone (DMT) is a multicarrier modulation method that has been endorsed by the ANSI T1E1.4 committee as a working standard for ADSL transmission. DMT offers ADSL rates from 1.544 Mbit/s up to 6.3 Mbit/s, including the recent acceptance of the proposal from Telecom Australia for a 2 Mbit/s rate to be included in the ANSI standard for applications using the 2 Mbit/s standard.
As shown in Figure 3a, DMT utilises Frequency Division Modulation (FDM) to separate the low bit rate upstream control channel (16 kbit/s) from the high bit rate downstream channel (1.5 to 6.3 Mbit/s). As shown, the POTS channel also occupies its proportion of the spectrum at a lower frequency than the other two channels. DMT is capable of adjusting its power spectrum around sources of interference. This is performed initially on start up when the line is tested over the DMT spectrum to

determine the SNR at individual sub-carrier frequencies. If excess interference is detected over a certain frequency band (eg due to AM radio interference, NEXT etc) then the DMT system process will attempt to move and adjust its spectrum so as to avoid this interference. This procedure is continually performed dynamically, shuffling the spectrum around sources of noise interference, therefore preventing possible transmission errors.

The mechanism that makes it possible for DMT to alter its downstream spectrum is achieved by dividing the spectrum into 256 individual bins (carriers), each which can occupy a maximum of 11 bits per symbol period, as shown in Figure 3b. The SNR of each bin is computed and stored in a bit table. The bit table for all the 256 bins, drives an encoder which buffers data in groups and assigns appropriate number of bits to each bin according to the bit table pattern. The lower frequency bins generally contain a higher number of bits than the higher frequency bins. An encoder subsequently assigns constellation values based on the particular bit combination for each bin. The constellation values are then processed via an Inverse Fast Fourier Transform (IFFT) processor. The IFFT in turn generates the complex (real & imaginary) 256 windowed Quadrature Amplitude Modulation (QAM) signals into 512 real subcarrier signals, in digital format. A digital-to-analog (D/A) converter and a band separation filter compose the analogue signal, which is coupled onto the line.

The receiver essentially mirrors the transmitter to decode the incoming DMT signal. The upstream channel also operates similarly to the downstream channel, except only nine bins are generated.

Unlike other noise interferences, impulsive noises may only be present for a short period of time and may therefore not be detected by the DMT system operating dynamically. The DMT system overcomes such noise problems through the application of a Reed Solomon (RS) forward error correction code, with convolutional interleaving process. The data is split into delay tolerant and delay intolerant data. To reduce the latency of the delay intolerant data, interleaving is not performed and a reduced number of check bit are used in the RS code. The data that is not as sensitive to delay has greater RS coding with interleaving and therefore less susceptible to impulsive noise.

DMT is specified to operate at a transmit power level from the exchange end in the range of -10 dBm to a maximum of 26 dBm. The transmit power level is adjusted according to the power level detected at the receiver, (which will signal the information to transmitter) when the power level exceeds the AGC level.

If greater noise immunity is required, an additional coding, such as Trellis coding technique can be implemented. Echo cancellation can also be implemented, which enables both the upstream and downstream frequency bands to overlap, thereby increasing the systems transmission distance limit. A trade off between the advantages and disadvantages of each of the two noise immunity systems is needed to achieve an optimum performance/cost ratio.

CAP

Carrierless AM/PM is a form of QAM (Quadrature Amplitude Modulation) designed essentially for higher bit-rate services (1.5 to 6 Mbit/s). It offers greater flexibility than QAM and is generally less expensive to implement. This technology is ready for implementation now and will initially be less expensive than the DMT alternative, due to its reduced complexity. The CAP alternative however, does not offer the distance reach capability that can be expected from the DMT solution.

Unlike DMT, CAP has a fixed frequency spectrum depending on the chosen bit rate. Even though this spectrum is not dynamically self adjusting as is the case with DMT, it is possible to alter the spectrum during commissioning and therefore avoid frequency bands of known interference. As shown in Figure 4, CAP provides a high bit rate downstream channel which transports video and audio signal together with the control and overhead signal to the customer. In the upstream direction, a low speed channel contains control signal to the network plus overhead, and a POTS or ISDN basic rate channel.

The CAP implementation encodes the input digital bit stream data into a signal constellation made up of real and imaginary symbols. The constellation signals are fed via quadrature and in-phase band-pass filters, in order to make the signal suitable for transmission over the band limited channel. The transfer function of these two filters has the same amplitude characteristics and phase characteristics that differ by 90o. The outputs of the filters are combined with the resultant signal passed through a D/A converter, followed by a low-pass filter. The signal is then demodulated at the receiver using "soft decision" techniques and a decision feed-forward equaliser, to adapt to cable gauge changes and bridge taps.

CAP implements trellis coding to provide greater immunity to cross-talk, whilst the RS code is used, if required, to correct errors that may occur due to impulsive noise effects.

Video Compression

Continued progress in digital compression technology in the coding/decoding equipment enables the current bandwidth inefficient analogue channels to be converted to digital streams and significantly compressed to bit rate levels in the range of 1.5 Mbit/s to 2 Mbit/s, to provide "VCR" type quality performance. Higher quality video signals require digital encoding in the higher range to 6 Mbit/s line rate.

Motion Picture Expects Group (MPEG) activities cover the compression of video and audio signals and the issue of synchronisation and multiplexing of multiple compressed video and audio bit streams. In effect full motion video and audio become part of a digital bit stream able to be transmitted over the telecommunication infrastructure. Telecom is looking at providing video services using MPEG-2 coding scheme at 2 Mbit/s level, which can readily be transported over the evolving SDH transmission network for delivery, to video distribution switches and associated ADSL systems.

International MPEG representatives have recently defined a profile incorporating minimum complexity scalability to be incorporated in the MPEG-2 standard. This will provide a two layer signal at 6 Mbit/s transmission rate, with both layers required for high quality 6 Mbit/s compressed video, and only the lower layer required for a reduced quality 2 Mbit/s compressed video signal.

ADSL Transmission Reach & Video Quality Aspect

Digitally compressed video signals operating at 2 Mbit/s rate over ADSL systems in the CAN, can easily reach normal cable loop length limits in Telecom Australia's urban exchange areas. Signals operating at 6 Mbit/s have until recently not been able to reach the same distances, due to power limitations. Discussions are currently proceeding within the ANSI T1E1.4 standards committee to increase the ADSL transceiver transmit output power level at the exchange-end to 26 dBm. The increased power level would thus improve the transmission reach of the 6 Mbit/s video delivery, making it capable of achieving the maximum loop lengths in urban exchanges. At 6 Mbit/s it will be possible to offer multiple channels (eg 3 channels at 2 Mbit/s) simultaneously to each location, or a single higher quality channel operating at 6 Mbit/s.

In addition to video service delivery, other services have been proposed for inclusion in the ADSL payload. These extra services, if adopted, may result in reduced distance reach, (unless the ADSL transmit power level is increased as discussed above). The additional services may include for example:-

- ISDN basic rate channel (144 kbit/s). Allowing customers to access a wide range of emerging ISDN services without the use of an additional dedicated copper pair or an NT1.

- ISDN H0 channel (384 kbit/s). Allowing videoconferencing to the home at fractional E1 rates (N x 64 kbit/s).

NETWORK INFRASTRUCTURE

The ADSL transceiver is responsible for the transport of digitally compressed video signals to the customers premises over the CAN, in the presence of any line impairments such as cross-talk, impulse noise and echoes resulting from cable gauge changes and possible bridge taps. At the local exchange the ADSL transceiver provides suitable interfaces for:-

- Exchange line for telephone service.
- Digital bit stream access (1.5 Mbit/s, 2 Mbit/s and above up to 6 Mbit/s).
- Control signalling access for ADSL system control function (16 kbit/s).
- Possible access for ISDN basic rate services.
- Possible 384 kb/s for low speed video conference link service.

telephone service, possible ISDN basic rate and 384 Kb/s video conference services appearing at the exchange-end ADSL transceiver units would be through-connected to their appropriate networks.

At the local exchange, the 2 Mbit/s digitally compressed video signals would be interfaced on to a digital switch or Add Drop Multiplexer (ADM) equipment. The ADM equipment could be configured to perform broadcast type switching for Pay-TV services and point to point switching for Video On Demand (VOD) services. Using ADM makes it possible to utilise the SDH inter-exchange network for the transport of a number of 2 Mbit/s digital channels from a Head-End location to local exchanges, for cross-connection onto the customer ADSL lines. Fig 5 illustrates the network infrastructure for compressed video delivery.

The Head-End would contain for example, a Main Video Storage and Retrieval Server unit. The Main Server is essentially a mainframe processor with magnetic storage devices and associated Dynamic Random Access Memory (DRAM) caching equipment. It would contain a library of movies which could be accessed directly, under customer control. The Main Server could also download most popular films to Distributed Video Servers which could be sited at some of the local exchanges or within a group of local exchanges. Video traffic loading consideration, ratio of Pay TV to VOD channel usage, popularity of films and the cost of video servers versus SDH transmission cost would determine the optimal server network topology and dimensioning. At the Head-End facility, video tape and optical storage units could also be used for archiving, and also downloadable onto the magnetic Video Servers when required. The pre-recorded channels would constitute the non-real time channels.

In addition to the above, real-time channel encoding could also be arranged or aggregated at the Head-End location for subsequent re-distribution via the SDH inter-exchange network. The real-time channels would for example, relate to news and current affairs programs including live sport programs, whilst the pre-recorded channels would relate for example, to movies.

In the longer term, when cost effective, it is possible that the video switch will be based on Asynchronous Transfer Mode (ATM) technology. The ATM platform will allow more flexibility in grooming and transporting emerging services operating at different transmission rates.

NETWORK & SERVICE MANAGEMENT

Two distinct type of network management functions would be required to manage the overall ADSL video delivery network.

Network Management System

The Network Management System relates to the control functionality of individual network element configuration and system performance monitoring including alarm reporting functionality. The system would provide from a centralised or distributed location the following features:-

- Remote provisioning, connection or disconnection of service.
- System status monitoring, alarm reporting, alarm clearing.
- Network re-configuration.
- Interfacing & control of local video switching, video server & ADSL equipment.

Customer Service & Billing Management System

The customer service & billing management system relates to an automated information database system which would produce reports and could for instance provide the following features:-

- Inventory tracking, work order, outages.
- Marketing & sales information, promotions.
- Billing, accounts receivables.
- Homes passed statistics, penetration details, etc.

CONCLUSION

ADSL technology using compressed video methods can be deployed over the existing copper CAN, to deliver video services including multimedia services to customers. It is expected that this technology may initially be used in a complementary role to CATV deployment, with the ADSL technology finding a window of opportunity for application, until fibre and associated customer optical equipment is widely deployed in residential areas. Telecom Australia has placed an order with AWA Limited for the supply of an ADSL demonstration system to be installed at the Telecom Research Laboratories in 1Q94. The demonstration system will be used to assess the ADSL and related video services technologies, including viewer perception trials. Evaluation of offers for a major Pilot ADSL system is also proceeding. It is proposed to establish this Pilot in the 3Q94 involving approximately 200 customers with access up to 60 video channels.

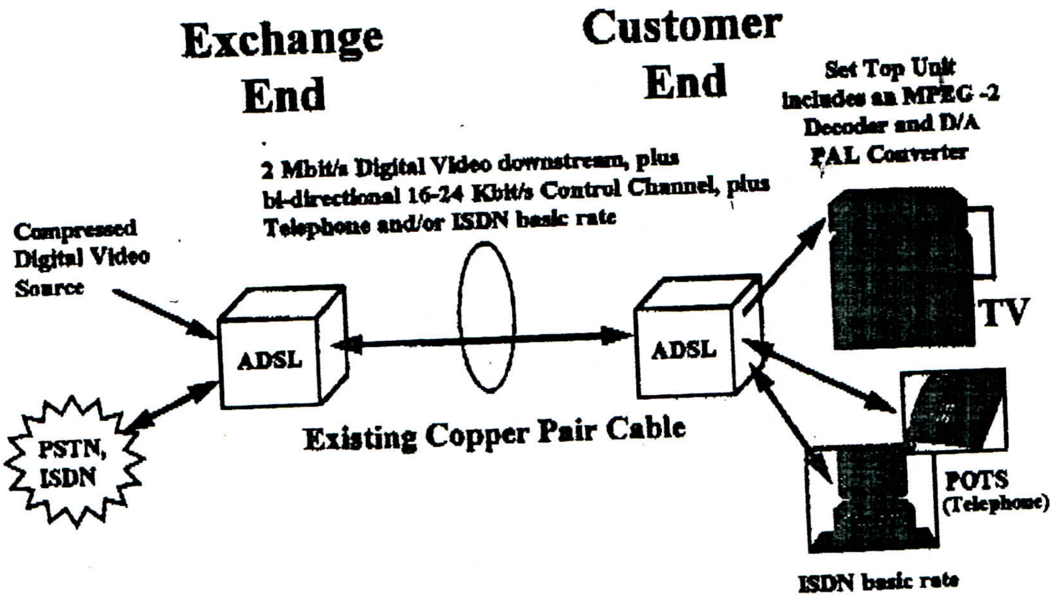

Fig 1 - Basic ADSL System

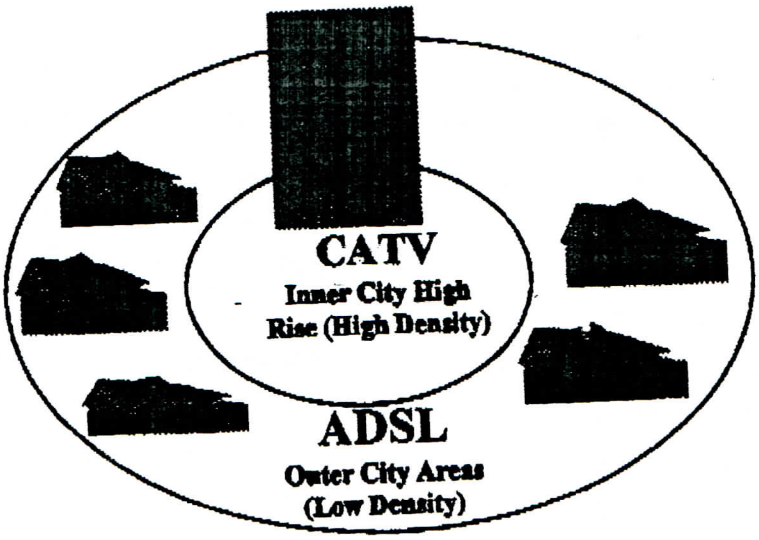

Fig 2 - Complementary role of ADSL and CATV

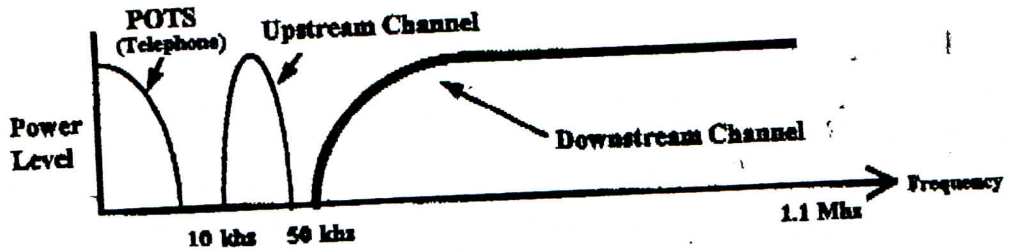

Fig 3 a - ADSL DMT Spectrum

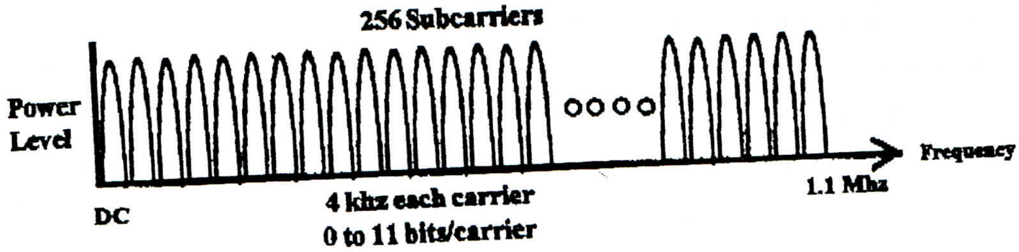

Fig 3 b - DMT Sub carriers (Bins)

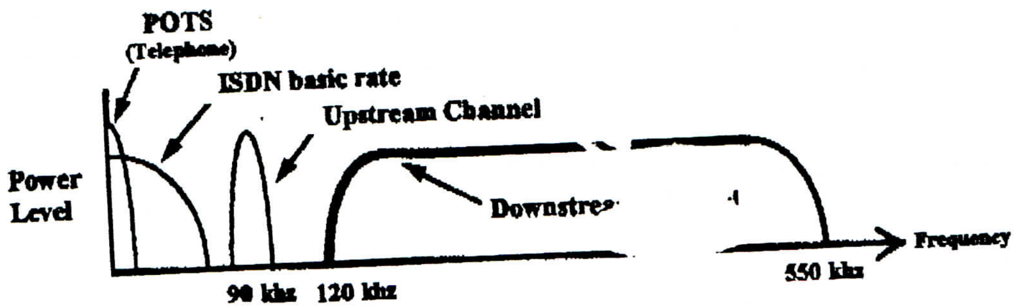

Fig 4 - ADSL CAP Spectrum

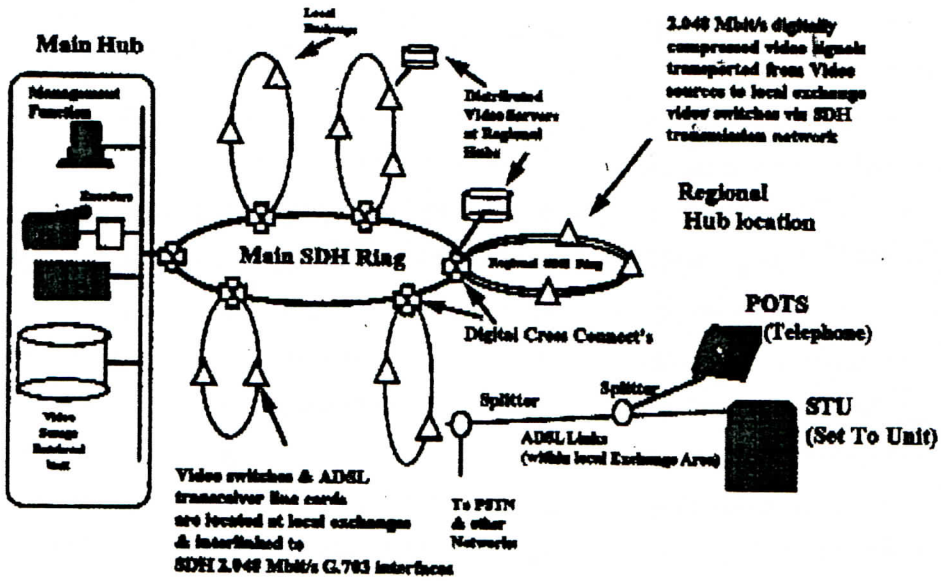

Fig 5 - Network Infrastructure for ADSL