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SIEMENS VDSL SYSTEM FOR DSLAM APPLICATIONS

(SISTEMA VDSL SIEMENS PER APPLICAZIONI DSLAM)

Abstract: in this article is described the new and innovative VDSL unit developed for SIEMENS XpressLink DSLAM. After a brief introduction, that describe the application network scenario, the article analyzes the technical aspects as band plans, cross talk, radio frequency interference and modulations. XpressLink has been defined as a Broadband Access Network solution and it is analyzed as a part of Broadband Network. The internal architecture of XpressLink DSLAM is also described. VDSL unit is analyzed as a part of XpressLink DSLAM. Its internal structure, modulation used, performance and features are described in detail. At the end of this article applications and new services that are available with SIEMENS VDSL systems are analyzed.

Sommario: in questo articolo viene descritto il nuovo ed innovativo sistema VDSL sviluppato per il prodotto XpressLink di SIEMENS. Dopo una breve introduzione, che descrive il campo di applicazione, l'articolo analizza gli aspetti tecnici come le bande utilizzate, la diafonia, l'interferenza radio ed i vari tipi di modulazione. XpressLink è inserito nella rete di accesso ed è analizzato come parte della rete a larga banda. Viene inoltre descritta l'architettura interna del DSLAM. L'unità VDSL viene analizzata come parte integrante del DSLAM SIEMENS e ne vengono analizzati molti aspetti quali l'architettura, la modulazione utilizzata e le prestazioni. Alla fine dell'articolo viene fatta una panoramica delle possibili applicazioni e dei nuovi servizi che possono essere implementati con il sistema VDSL di SIEMENS.

INTRODUCTION

Numerical transmission on twisted pair is one of the main element in the broadband access network.

XDSL systems are the principals actors in this field, these systems allow the providers to use the existent network providing new "high speed" services.

The internet, with all its applications, is changing the way we work. Growing demand for access has produced bottlenecks and traffic jams, which are slowing the Internet down. In an attempt to overcome these restrictions, access has pushed the technology to new and innovative heights with the emergence of Asymmetric Digital Subscriber Line (ADSL) technology. ADSL eliminates bottlenecks, thereby giving all subscribers quick and reliable access to Internet content. Using the existing telephone wiring infrastructure, an operator can offer ADSL applications as a portfolio of service levels or classes. Traditional telephone and Internet services are only the beginning, while the ability to offer video broadcast services is more than a possibility. Cable TV operators are beginning to offer voice and data services, and there is increasing competition from Competitive Local Exchange Carriers and other carriers, making it imperative that traditional telecom service providers introduce video services. In this market's landscape the new Very high bit-rate DSL (VDSL) technology took place. VDSL is able to reach 50 [Mbit/s] and provides symmetrical and asymmetrical services. Due to limited distance reachable (e.g. 1000 [m] in 12 [Mbit/s] symmetrical configuration), VDSL systems are well allocated in the FTTB/FTTC (Fiber To The Building/Cabinet) networks' configurations even if the goal is to use VDSL in FTTE

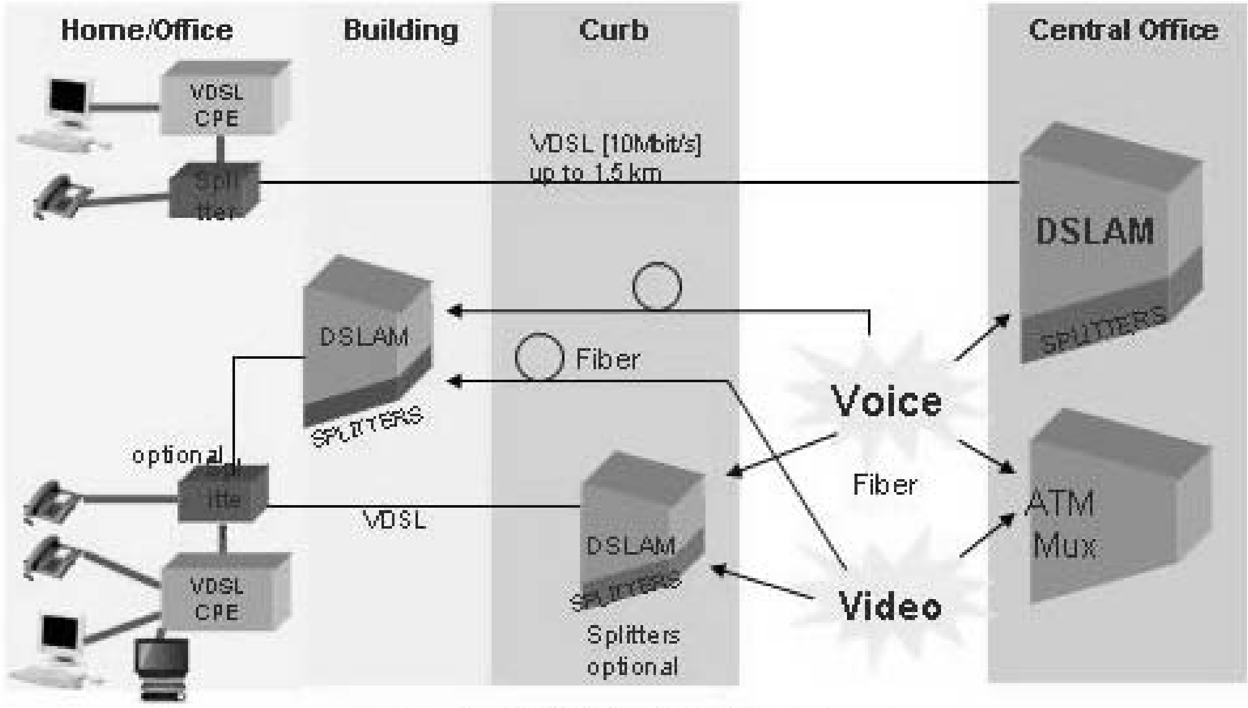

Figure 1 - VDSL FTTX, FTTC and FTTB Scenario

(Fiber To The Exchange) configuration. The aim of this article is to describe the innovative Siemens VDSL unit able to be used in FTTB, FTTC and FTTE scenario (see Figure 1).

TECHNICAL ASPECTS

Like ADSL, VDSL can provide frequency separation from baseband, leaving room for Plain Old Telephone Service (POTS). In addition to POTS other services such as ISDN (Integrated Services Digital Network) can also be run on the same twisted pair as VDSL. Thus each end of a twisted pair carrying VDSL and POTS uses a splitter to separate the two signals. At the subscriber's location, the modem terminating VDSL is called the VTU-R (VDSL Transceiver Unit at the Remote site). The

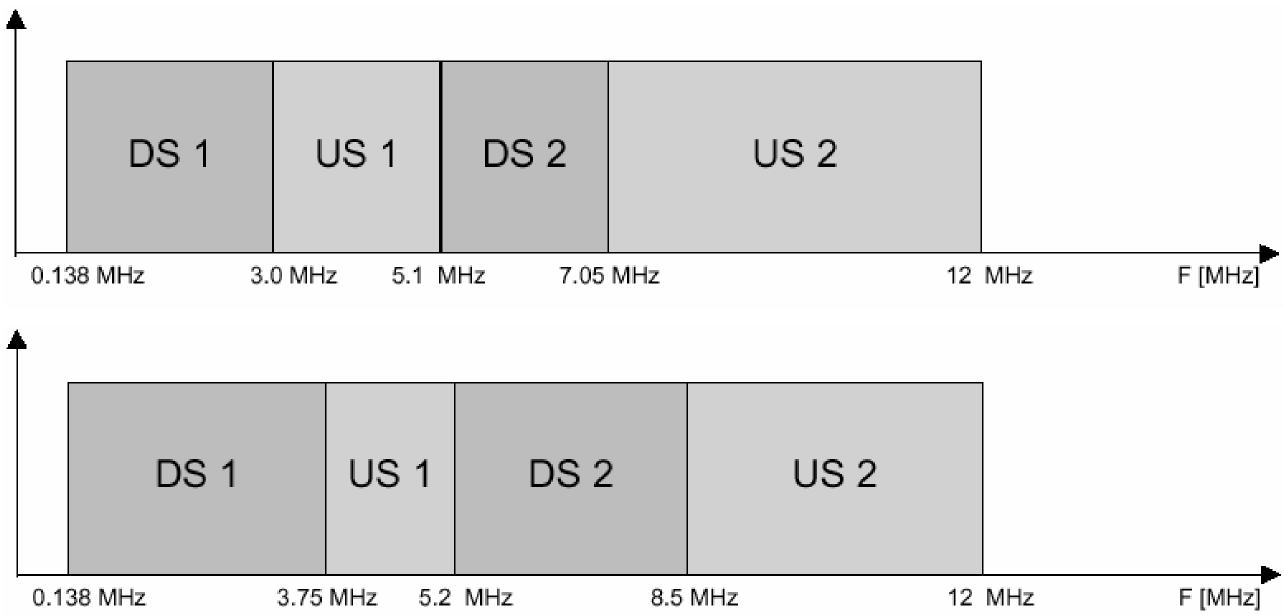

Figure 2 - VDSL ETSI Band Plans

very high speed of VDSL suggest that some sort of high-speed optical network will feed a bank of centralized VDSL modems. This central point might be a CO (Central Office) of some remote optical node. At the ONU (Optical Network Unit) side the peer modem to the VTU-R modem is called the VTU-O (VTU at the ONU).

VDSL transmission systems use the frequency spectrum from 138 to 12000 [KHz], even if the standardization are not yet fixed, two band plans are now possible (see Figure 2). An optional band is also defined by ETSI and ITU from 25 to 138 [KHz], it can be used in both directions DS (Down-Stream) and US (Up-Stream).

Main parameters that influence the transmission are the attenuation and the cross talk of the twisted pair. The attenuation and the cross talk

$$C = \int_{f_1}^{f_2} \ln_2 [1 + 10^{-1.48} \bullet Min\left(10^6, \frac{S(f)}{N(f)}\right)] df$$

limit the channel's transmission capacitance that is related to the signal-to-noise ratio:

enough to attenuate the disturbing signal. However, other FEXT paths may exist as well.

Whether these FEXT signals will be significant or not depends on the lengths of the two channels as well as the frequencies used by the upstream and downstream channels.

VDSL receivers must deal with the issue of Radio Frequency Interference (RFI). Included in RFI issues are ingress and egress. The cause of RFI ingress is in-band radio waves from nearby antennae incident upon a twisted pair carrying the VDSL. An amateur radio antenna is a good example of an RFI ingress disturber.

In Figure 4 this basic situation is illustrated. The factors influencing the amount of ingress include the power output of the antenna, the distance between the antenna and the twisted pair, the relative orientation and shielding of the binder group, and the balance of the twisted pair itself. Normally, the RFI ingress excites each wire in the twisted pair, thus creating a longitudinal ingress signal on the pair, that depends also from the LCL (Longitudinal Conversion Loss). Because the balan-

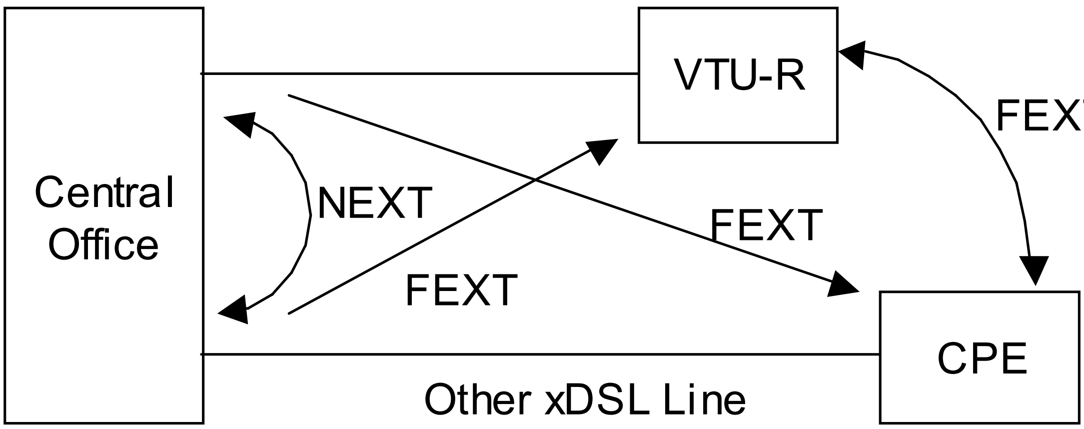

Figure 3 - Cross talk scenario with VDSL and another DSL technology

ce of the twisted pair is not ideal some of the ingress leaks into the differential signal. The VDSL signals is also radiated, as showed in Figure 4, from the twisted pair and can disturb the signal received by local antennae if these received signals overlap the VDSL spectrum. To eliminate this problem, the VDSL transmit power in frequency regions reserved for wireless or radio services must be lowered.

In Figure 3 is showed the cross talk scenario with VDSL.

In Figure 3, VDSL and another xDSL technology are both provided from CO and share a binder group between the CO and some point at which the VDSL is removed. The various types of NEXT (Near End Cross Talk) and FEXT (Far End Cross Talk) that can exist are also shown in Figure 3. The FEXT between the two endpoints is normally not a factor because the distance is usually large

The xDSL systems are characterized by diffe-

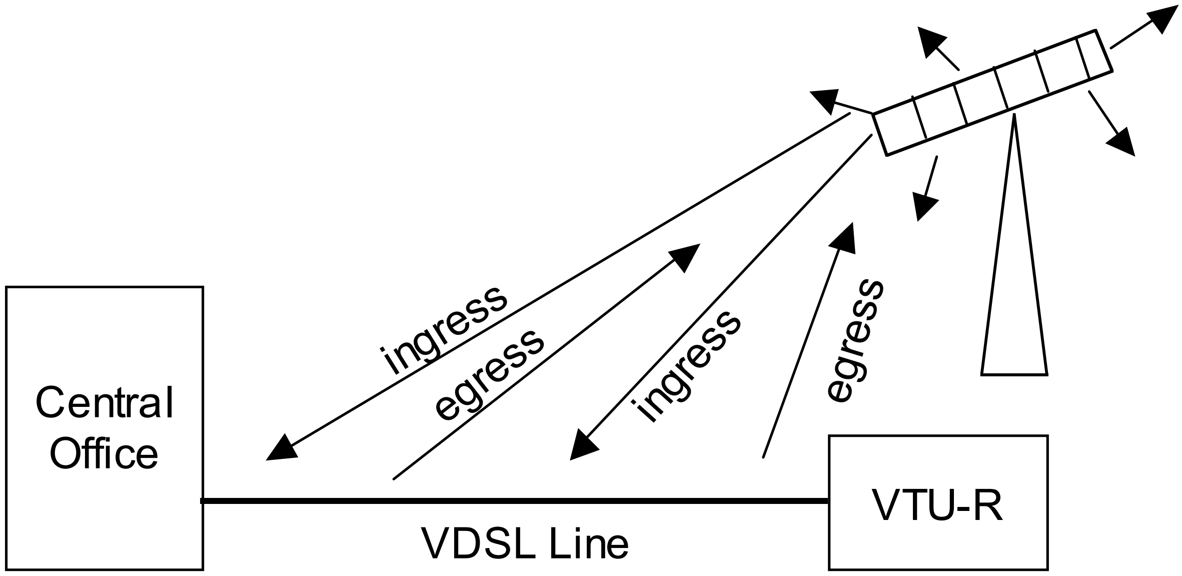

Figure 4 - RFI ingress and egress into/from

rent solutions depending on transport capacitance and modulations (i.e. 2B1Q, CAP, DMT). For the VDSL the standardization process is still open and both CAP (Carrierless AM/PM) and DMT (Discrete MultiTone) have a possibility to be standardized.

The DMT is a multi carrier technique in which each carrier is used to transport a part of information. Each carrier uses QAM modulation and the modulation/demodulation is realized by Fast Fourier Transform (FFT) and Inverse FFT algorithms. For the VDSL-DMT are used 4096 carriers spaced of 4312.5 [Hz]. The blocks diagrams of modulator/demodulator DMT is depicted in Figure 5.

Input bits, at R [bit/s], is divided in b=RT bit's blocks where R is the bit speed and T is the symbol period. The bits' block is divided in N sub-blocks bi (i = 0, …, N-1) to have:

$$b = \sum_{i=0}^{N-1} b_i$$

where N is the number of sub-carriers of the system and bi is the sub-block sent on the carrier i.

CAP modulation technique comes out from QAM (Quadrature Amplitude Modulation) modulation and has the same bandwidth and the same performance. CAP is a special form of QAM that is especially suitable for fully digital implementation. The transmit signals of a QAM and CAP system are about equal. In the CAP system modulation is being done in a Hilbert filter pair. Impulse response of quadrature filter fQ(t) is the Hilbert's transform of phase filter fI(t), in this way the squareness is guarantied.

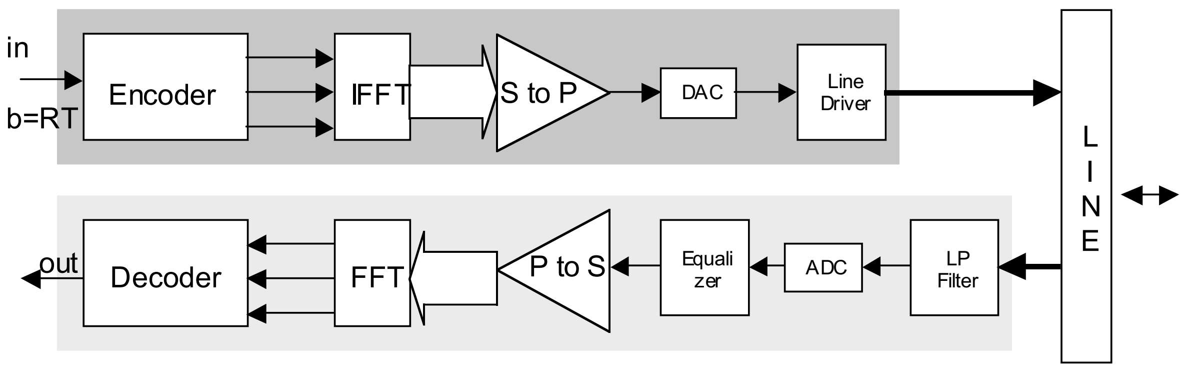

Figure 5 - DMT Transmitter and Receiver

The impulse response of fI(t) and fQ(t) are:

$$f_I(t) = g(t)\cos(2\pi f_C t)$$
$$f_Q(t) = g(t)\sin(2\pi f_C t)$$

where g(t) is:

$$g(t) = \frac{\sin(\pi * f_C * t * (1-\alpha)) + 4 * \alpha * f_C * t * \cos(\pi * f_C * t * (1+\alpha))}{\pi * f_C * (1-(4 * \alpha * f_C * t)^2)}$$

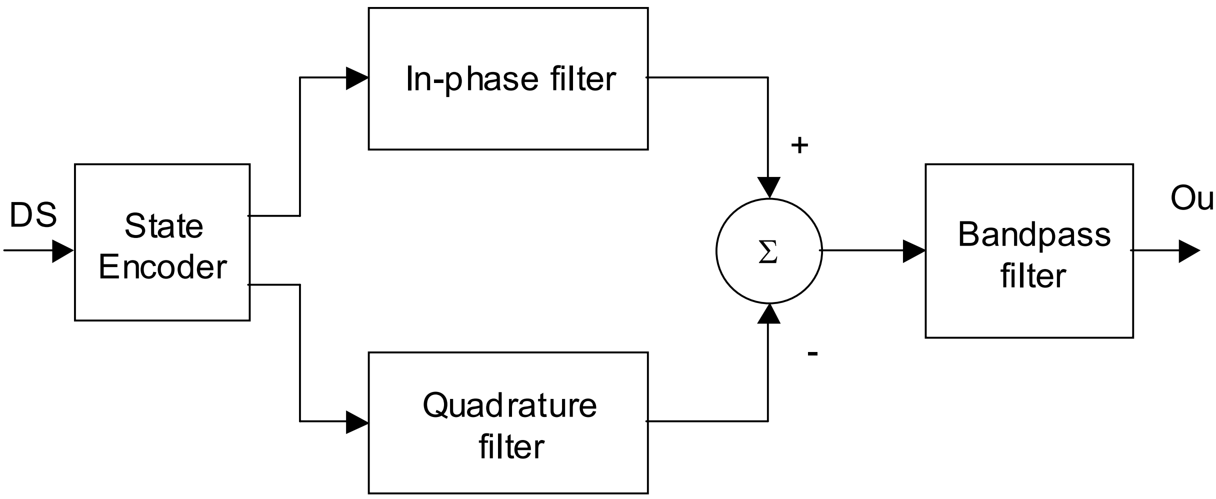

Figure 6 - Modulator Unit of CAP System

Transfer functions have the same amplitude but differ in phase by 90°, this allows to recover the information without any other signal's elaboration.

The CAP modulator/demodulator is depicted in the Figure 6:

Transfer functions have the same amplitude but differ in phase by 90°, this allows to recover the information without any other signal's elaboration.

SYSTEMS DESCRIPTION

XpressLink, part of Broadband SIEMENS portfolio, has been defined as a Broadband Access Network solution for a wide range of applications, covering business oriented as well as residential and SOHO (Small Office / Home Office) scenarios (see Figure 7).

The initial application of XpressLink is the provision of access to the Internet via an Internet Service Provider (ISP) or to a corporate Intranet by means of connections to a corporate network provider. Besides point-to-point connectivity, typical for ATM leased lines, XpressLink allows connectivity to a Broadband Remote Access Server.

XpressLink supports the use of the Internet Protocol (IP) for the support of data applications and other IP-based multi-media applications (e.g., Voice over IP, Fax over IP, Video over IP, ...). Using ATM, other protocols are supported via the ATM interface in a transparent manner.

XpressLink is a solution set incorporating ATM-based network elements including the necessary service adaptation functions in order to support the services relevant to all its application scenarios.

The main components, according to Figure 8, are:

- The XpressLink DSLAM operates as a multiplexer which consolidates the traffic originating from a number of subscriber lines to a single feeder interface. The subscriber lines can be of any type (xDSL).
- The Broadband Remote Access Server (B-RAS) enables the access of IP-based services.

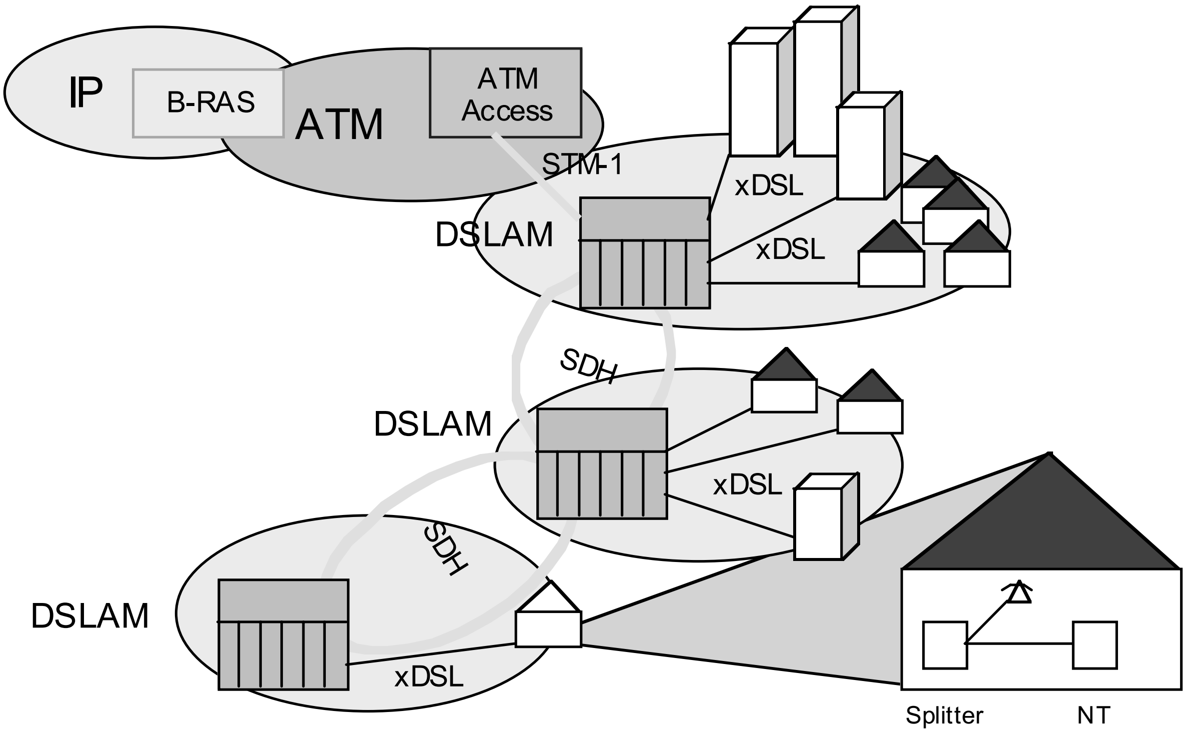

Figure 7 - Network Architecture

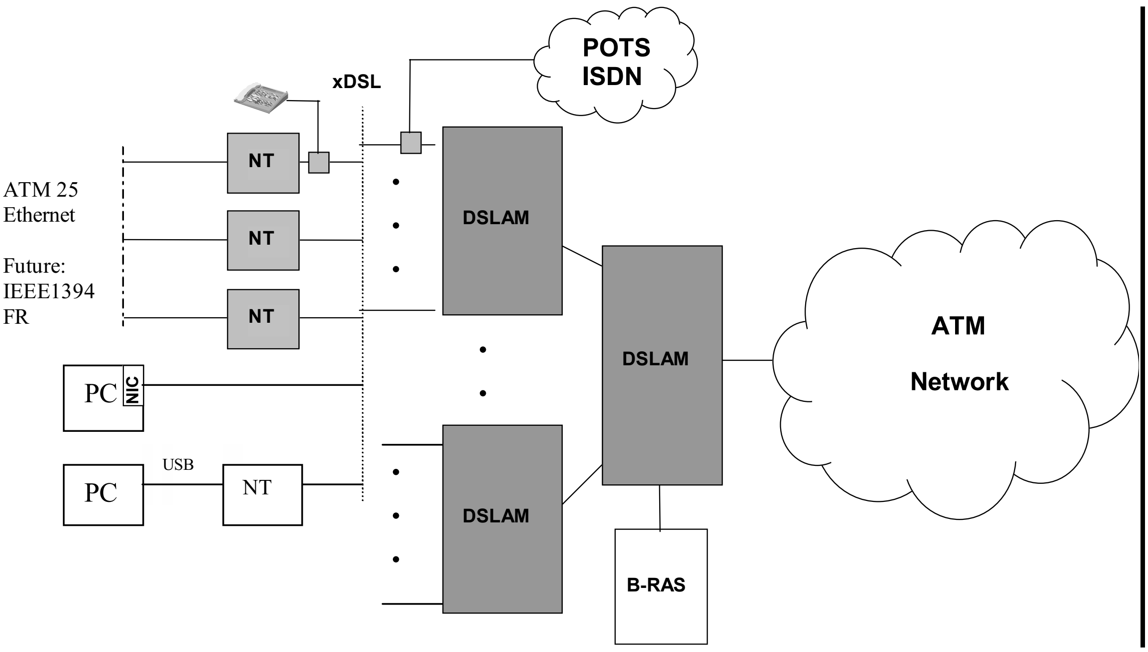

Figure 8 - Broadband Access network configuration

It serves typically as the point of presence for an ISP or performs tunneling functions towards a corporate network.
- The XpressLink DSLAM supports Network Terminations (NTs) and various types of CPE. The Network Terminations serve the purpose of terminating the xDSL transmission at the customer premises in order to present a demarcation point between the end customers' and the network operators' areas.

XpressLink DSLAM is a VP/VC multiplexer providing broadband UNI interfaces on standard xDSL (ADSL,VDSL, ...) drop lines and a broadband UNI or NNI interface on a standard feeder (STM-1, ...) to the network side.

The internal architecture of XpressLink DSLAM is based on cascaded ATM busses, a central ATM bus in a subrack. The subrack provides the SDH/SONET or PDH feeder interface to the network side and the central controller of the DSLAM. The subrack contain also the xDSL subscriber interfaces. The POTS/ISDN Splitter POSU is located remotely in a separate subrack which may be placed in the DSLAM rack or in a separate rack (which can be located close to the narrowband switch or main distribution frame MDF).

SERVICE UNIT VDSL (SU_VDSL)

The Service Unit VDSL board, part of the XpressLink v3.0, provides the VDSL interface towards subscribers CPE equipments.

It uses 24 links with symmetric and asymmetric bit rate for upstream and downstream. SU_VDSL use the 4 bands configuration.

The main tasks of SU_VDSL are the following:

- Physical link to the user's CPE via electrical interface
- VDSL specific TC layer and framing
- VDSL specific ATM framing and cell delineation
- ATM functional block
- Board management by the on-board microcontroller

SU_VDSL has to offer additional TV distribution services on the copper wire high-speed connections to the Internet and EFM (Ethernet in the

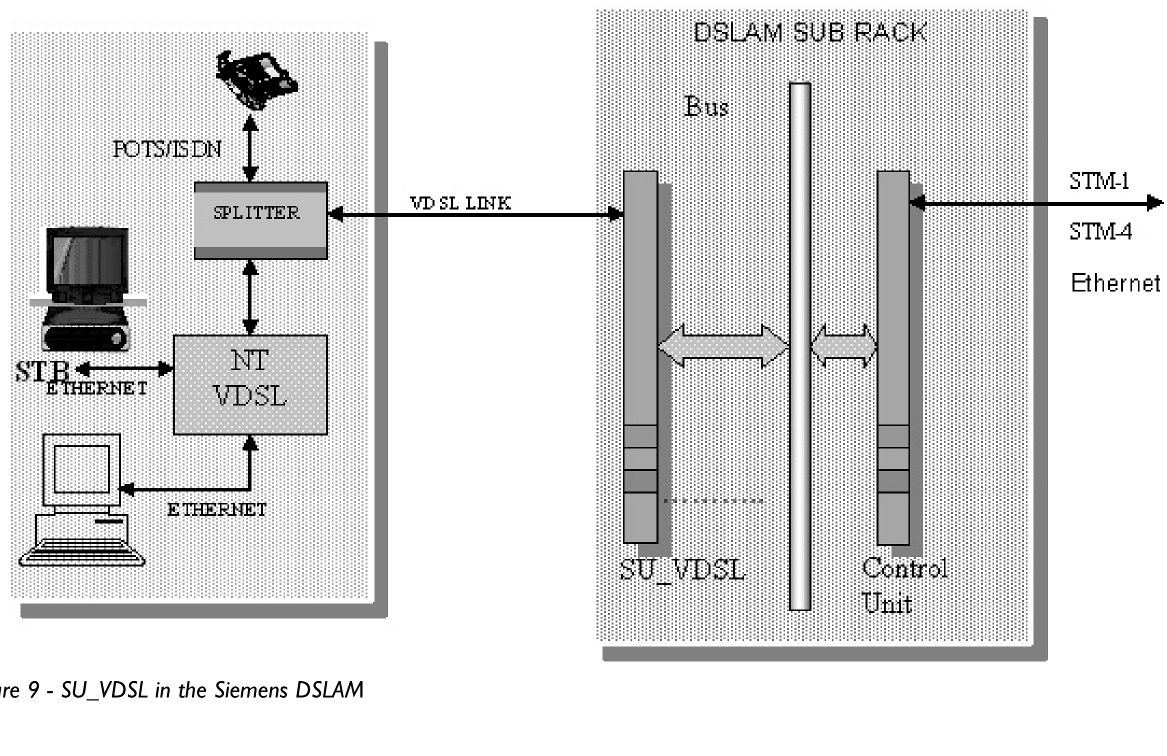

Figure 9 - SU_VDSL in the Siemens DSLAM

First Mile). The communication with the Control Unit boards is done via ATM in-band channel. The main blocks of the SU_VDSL are the VDSL interface, ATM interface and Control interface (see Figure 10).

The VDSL interface is realized by using VDSL QAM chipset, it is composed by a digital data pump, an analogue front-end (AFE) and line interface. The VDSL-D is the chipset digital data pump; it supports ANSI, ETSI, and ITU standards. The VDSL-A chip is the analog part of chipset. It serves as analog front-end for VDSL modems and provides symmetric and asymmetric data rates up to 38 Mbps with a reference frequency of 40 MHz. The VDSL-L chip consists of two wideband amplifiers that are used as a differential line driver and able to reach 14dBm. VDSL-D supports ATM cell transport with POTS/ISDN traffic over the same pair. It presents flexible constellations QAM4 - QAM256. It has a programmable latency, with or without programmable interleaving and an interleaver with internal SRAM. It also has: on-chip Reed Solomon FEC capable of correcting 8 bytes per codeword, transmit notching for amateur radio band compatibility, near end and far end loopback capability, internal processor for stand alone operation and monitoring. It performs the digital functions required by a QAM VDSL modem. This includes the Physical Medium Dependent (PMD) layer functions, the application independent transmission

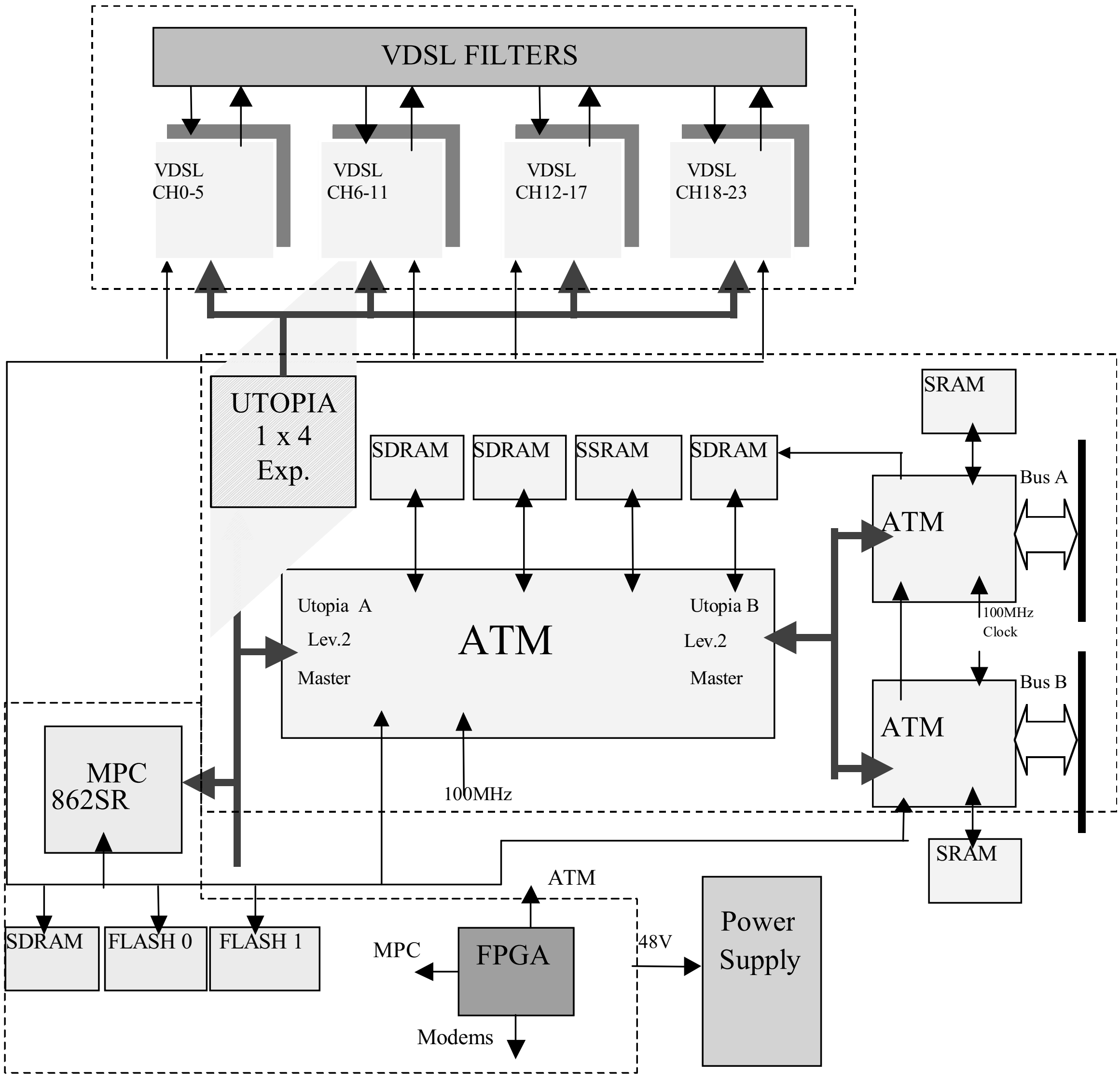

Figure 10 - SU_VDSL functional blocks

convergence functions (PMS-TC) and the transport protocol specific transmission convergence functions (TPS-TC).

The digital functions of the PMD layer (Physical Medium Dependent) consist of the QAM modem core and the interface to the analog front end. The modem core includes the QAM modulator/demodulator, the timing recovery unit, automatic gain control (AGC) support, transmit and receive filters, a linear equalizer and a decision feedback equalizer.

The TC layer (transmission convergence) functions are divided into two parts:

o The first is the PMS-TC (Physical Medium Specific-TC), which is independent from the user application and is part of the modem implementation. The PMS-TC performs generic functions that are required by the transmission format of the VDSL channel and are application independent. These functions include data randomizing, error protection (Reed-Solomon coding), data interleaving and payload framing.

o The second part is the TPS-TC (Transport Protocol Specific-TC) which is application specific and is used to adapt the user application and payload to the format of the VDSL modem. A complete TPS-TC layer for ATM is implemented to the (VDSL-D) Digital Data Pump.

This ATM TPS-TC with its UTOPIA interface is used as the data path interface between the application independent function of the VDSL modem and the external system elements such as the Segmentation and Reassembling (SAR) device. VDSL-D presents two different paths: transmit and receive (see Figure 11).

The Physical Medium Specific Transmission Convergence (PMS-TC) layer resides between the Physical Media Dependent (PMD) and the TPS-TC layers. The PMS-TC layer supports transfer of slow and fast data channels, OC channels and link control information.

In the transmission path, the PMS-TC layer does the following:

Scrambling, Addition of Reed Solomon Code

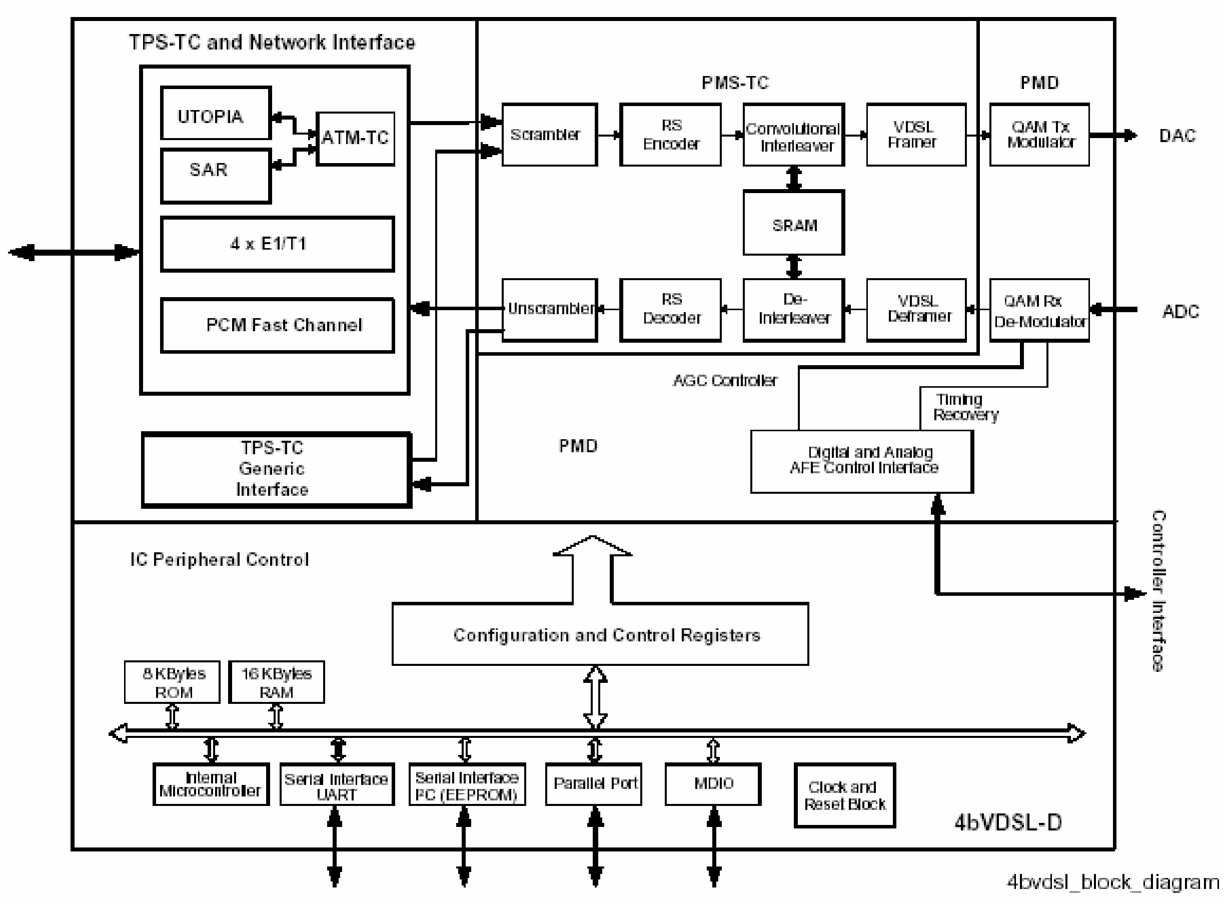

Figure 11 - VDSL Data Pump Block Diagram

Words, Interleaving Construction of a Transmission Frame and Splitting the Transmission Frame into PMD Frames.

Before Reed Solomon encoding, a self-synchronizing algorithm scrambles (randomizes)

the frame header (except the SYNC bytes) and frame payload (except the Reed Solomon code redundancy bytes) in the fast and slow streams in both directions, with the OC channel in the slow stream.

In a separate operation, the same algorithm also scrambles the header (with the SYNC bytes), along with the fast and slow Reed Solomon code bytes.

The scrambling algorithm at both the LT and the NT is:

$$D^n_{out} = D^n_{in} \oplus D^{n-18}_{out} \oplus D^{n-23}_{out}$$

Reed Solomon FEC overhead bytes containing Reed Solomon code words are added to the fast and slow streams. Reed Solomon code words operate on byte-based data streams.

Interleaving on the slow stream improves Reed Solomon error correction when there is pulse noise. Reed Solomon codes in the transmission frame of the slow stream are interleaved before transmission by a convolutional interleaver.

After interleaving, for both upstream and downstream directions, a transmission frame is constructed that includes all information channels (fast, slow, OC and control). The transmission frame contains 405 bytes, a 5-byte header and a 400-byte payload, as shown in Figure 12.

The payload of each transmission frame includes two fast channel fields and two slow channel fields, which are alternated. Each fast channel field (F-bytes) transports one Reed Solomon code (RF), with no interleaving. Each slow channel field (S-bytes) transports one Reed Solomon (RS) code that passes through a convolutional interleaver before transmission to the line. The header consists of a 2-byte SYNC word and a 3-byte Control field. The Synchronization word contains frame alignment information.

In the reception path, the PMS-TC layer performs synchronization on the two PMD frames using a transmission frame alignment algorithm and a state machine that switches states upon detection of events in expected positions.

This state machine has three states, HUNT, PRESYNC and SYNC. See Figure 13.

It operates as follows:

1. HUNT - In this state, no frame synchronization is performed and the state machine attempts to detect an event at certain defined positions. When one event occurs at a defined position, the state machine switches from the HUNT state to the PRESYNC state.

2. PRESYNC - In this state, if no event occurs when one is expected, the state machine returns to the HUNT state. When the same event occurs consecutively, at least twice, at defined positions, the state machine switches from the PRESYNC state to the SYNC state.

3. SYNC - In the SYNC state, the PMS-TC layer performs synchronization. The state machine switches from the SYNC state to the HUNT state when no event is detected when it is expected, at least six times (eight times for data rates higher than 26 Mbit/s).

TPS-TC layer with its UTOPIA interface provides the data path interface between the application independent function of the VDSL modem and external system elements. An UTOPIA bus provides the interface with the external ATM processor.

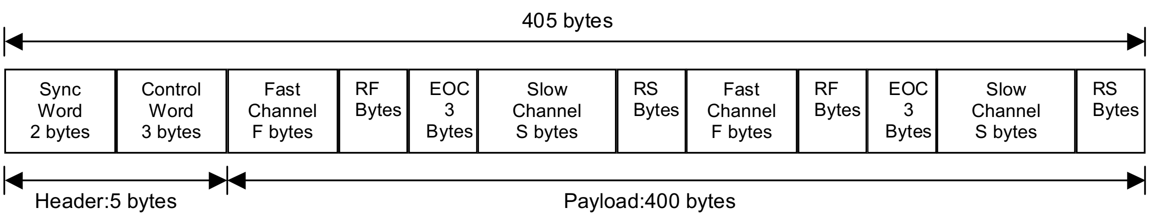

Figure 12 - VDSL Frame Format

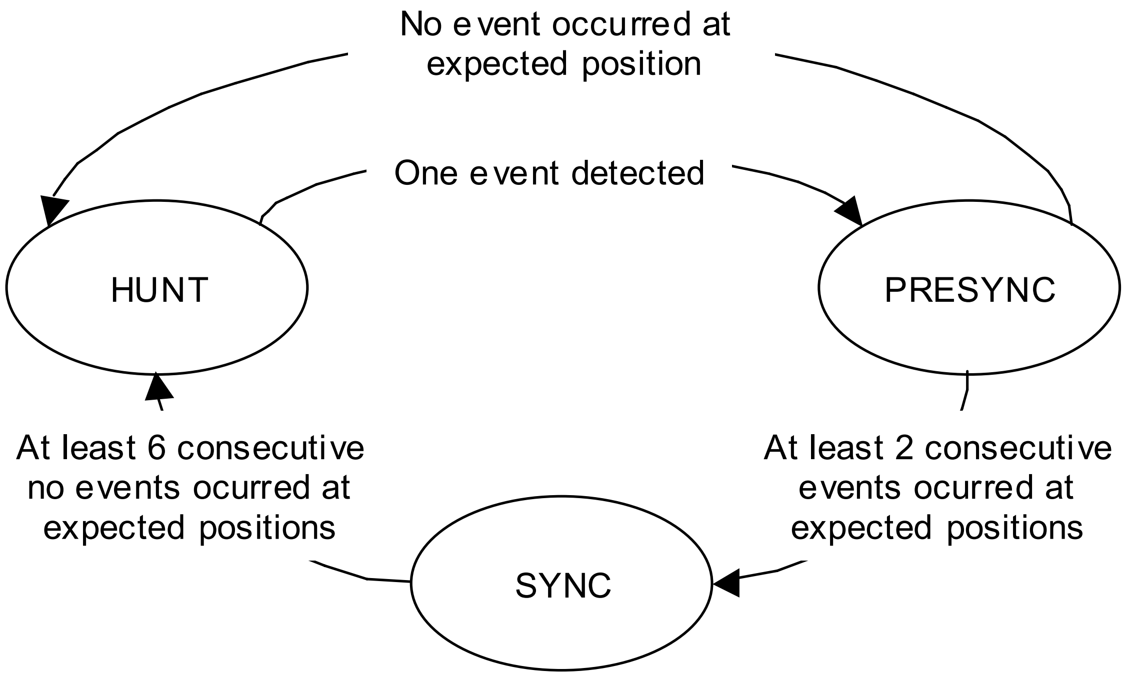

Figure 13 - Transmission Frame Alignment State Machine

APPLICATIONS

Growing, with the new market's necessity, XpressLink system is used to offer new and innovative services like: Tele Learning, Virtual Banking, E-Commerce, Fast Internet, Video Conferencing, Tele Working, Broadcast TV, Video on Demand, Web TV, EFM. From this scenario Fast Internet and Video distribution are services that have an immediate impact to the market.

Video, Internet and Satellite Broadcast network architecture are sowed in the Figure 14.

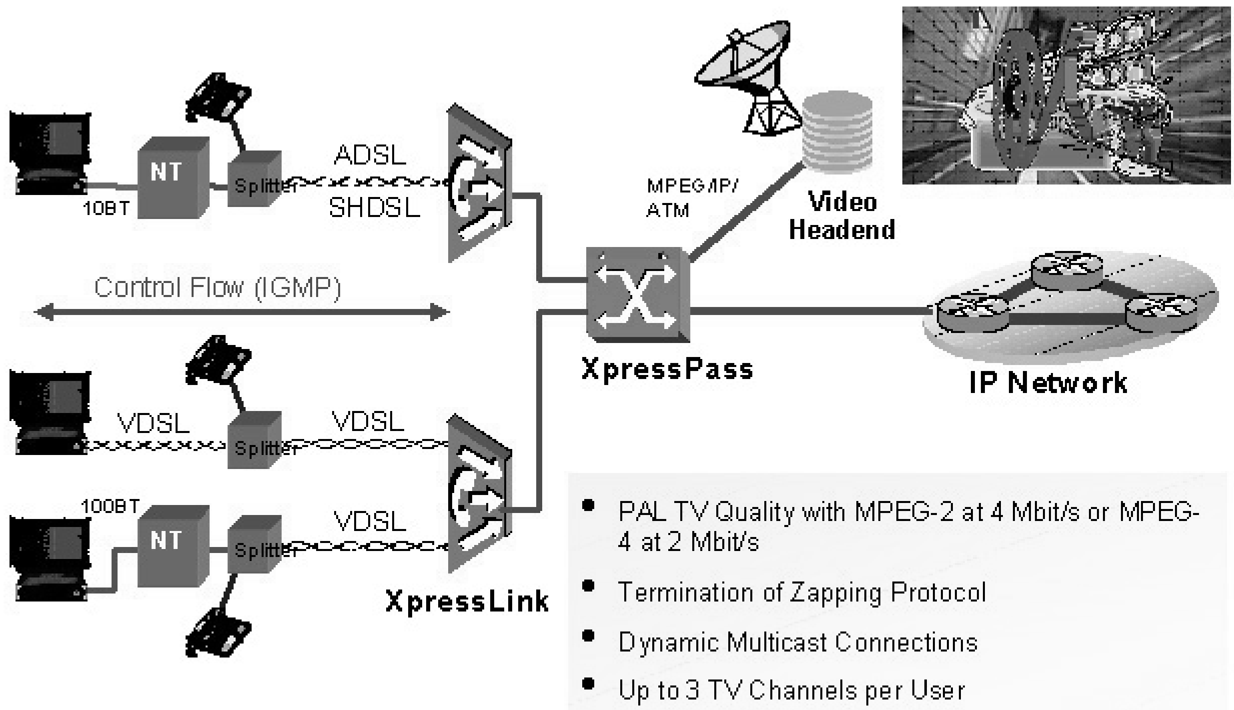

Figure 14 - SIEMENS Broadband Network architecture

In the Access network, ATM is used as OSI Level 2; a video stream could be transported as MPEG (Moving Picture Expert Group) over ATM, MPEG over IP over ATM or as MPEG over IP, the physical layer is, of course, the VDSL. In Figure 14 we can distinguish 3 main blocks: Headend, Transport network and Access network. The Headend is the aggregation point of different services. The transport network have to "transport" the information from Headend to the DSLAM. The network has to be able to transport both multicast and unicast traffic (broadcast and interactive services).

Broadcast traffic can be transported as multicast IP, ATM point-to-multipoint or a combination of both as showed in Figure 15.

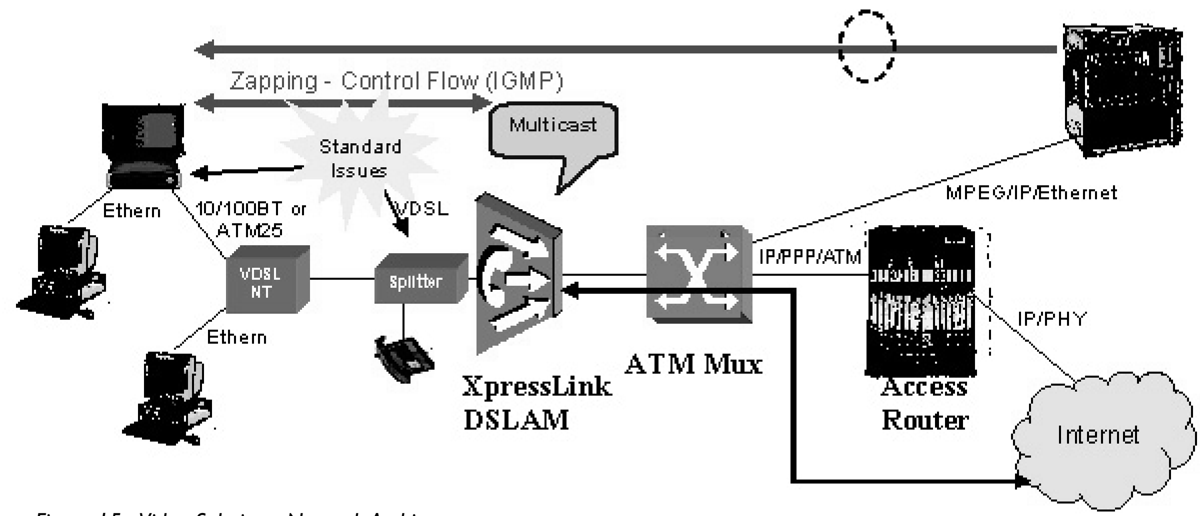

Figure 15 - Video Solution - Network Architecture

A possible solution is to use, as described, an ATM point-to-multipoint solution.

Interactive services need a bi-directional capability of the network, also in this case an ATM network is an appropriate solution.

In Figure 16 are showed protocol stacks in native ATM and IP over ATM solutions.

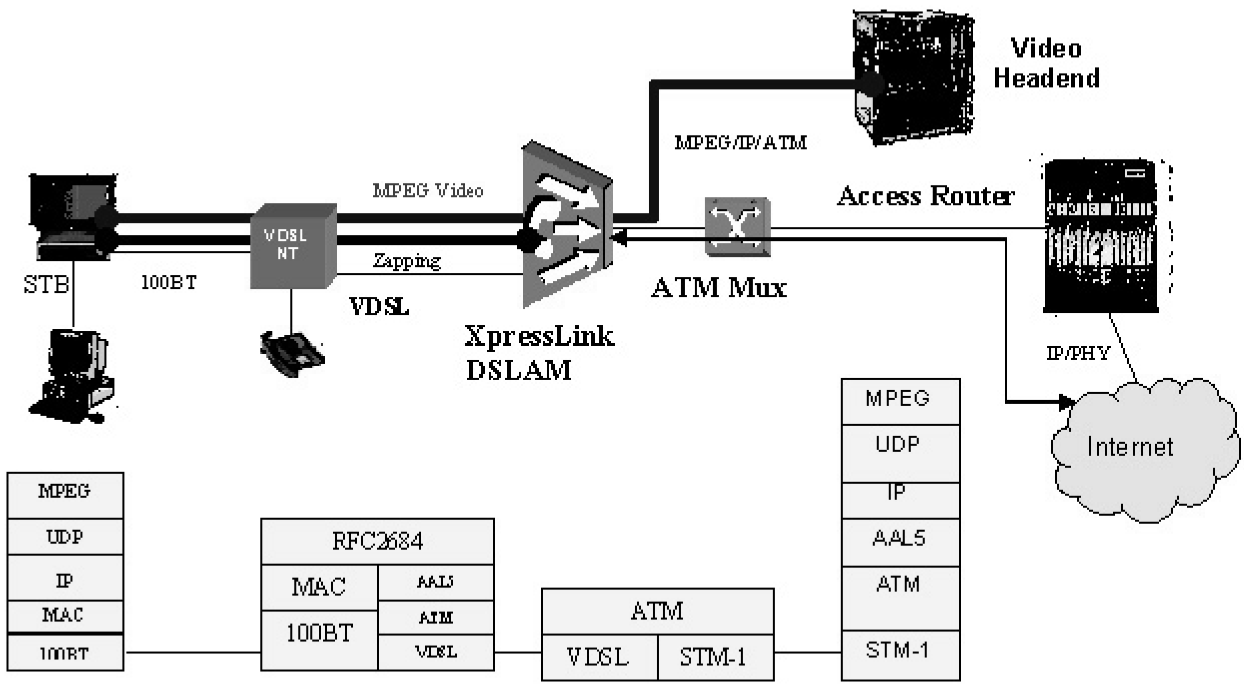

Figure 16 - Native ATM and IP over ATM solutions

CONCLUSION

Using XpressLink solution, equipped with 24 channels SU_VDSL units, the system is able to support:

- Up to 360 VDSL channels.
- Zapping (IGMP) protocol.
- Multicast functionality.
- STM1 and STM4 uplink.
- Choice between 140 video channels.
- Max 1080 user video channels (360 users could receive up to 3 channels).

With these capability the system is able to provide all new services as Broadcast TV, Video on Demand, Web TV, Fast Ethernet and EFM and it reaches up to 10 [Mbit/s] in 1.5 [Km] loop. XpressLink is a system that is evolving; new VDSL units are under development increasing ports' density and performance. Using the Ethernet control unit (10/100 and 1000) XpressLink can also be inserted in an Ethernet network interfacing the VDSL unit to the Ethernet world.

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Andrea Campitelli si è laureato in Ingegneria Elettronica presso l'Università degli Studi "Roma III" di Roma nel 1998.

Nel 1999 si è diplomato presso la SSST (Scuola Superiore di Specializzazione in TLC) presso il Ministero delle Comunicazioni - Roma.

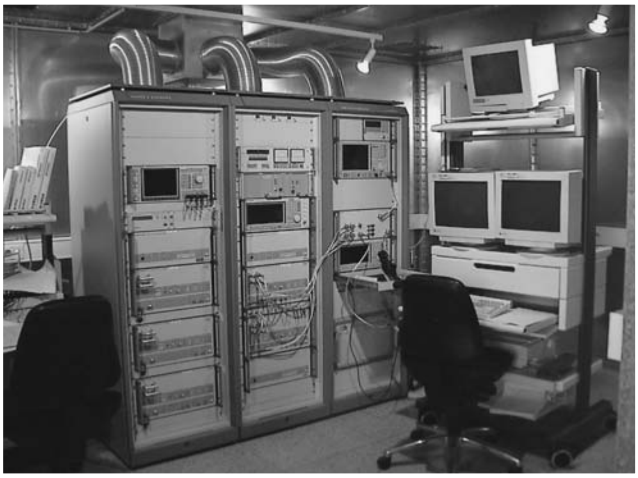
Dopo aver lavorato come borsista presso l'Istituto Nazionale di Fisica Nucleare (INFN) occupandosi di sistemi di acquisizione e trasmissione dati in ambito all'esperimento ATLAS, è entrato a far parte della SIEMENS nel 2000.

Da Maggio 2000 è dottorando di ricerca in Ingegneria Elettronica presso l'Università degli Studi "Roma III" e svolge la sua attività di ricerca presso i laboratori di R&D di SIEMENS S.p.A.

Attualmente si occupa di sistemi di TLC in tecnologia xDSL, in particolare è responsabile dello sviluppo dell'interfaccia utente VDSL in ambito al progetto XLD di SIEMENS.

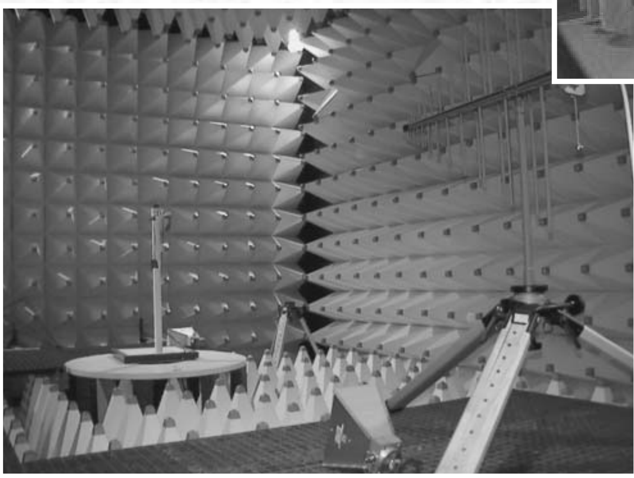
NOTE

ISTITUTO SUPERIORE DELLE COMUNICAZIONI E DELLE TECNOLOGIE DELL' INFORMAZIONE (I.S.C.T.I.)
LABORATORI DI MISURA E PROVA
(MEASUREMENT AND TEST LABORATORIES)



Laboratorio GSM

Laboratorio QoS



Laboratorio Anecoico

Laboratorio Sicurezza/EMC