ANx—High-speed Internet access

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ANx is an ATM-based broadband access platform that can be deployed in various access networks. Because ANx-DSL is a network solution that can operate on the existing PSTN, it functions smoothly and reliably with existing customer premises equipment and other networks, such as ISDN and the public land mobile network. ANx-DSL is the first product based on the ANx product family to use asymmetrical digital subscriber line modem technology in copper-wire networks.

Likely users of ANx include people who use the Internet to a great extent from their homes, persons with small offices or home offices, and those who need remote access to a corporate LAN; for example, to telecommute.

The authors describe a high-speed Internet access solution consisting of ANx-DSL products and Ericsson edge routers. The routers concentrate traffic onto permanent virtual connections, allow the selection of Internet service provider, and generally serve as internetworking units with other networks.

ANx—a broadband platform for all media

Key techniques used in the ANx concept are ATM multiplexing, permanent virtual circuits (PVC), and a variety of modem techniques. These "off-the-shelf" techniques are combined with edge routers that provide IP routing, remote authentication, RADIUS and service-provider selection to create a high-speed Internet access solution.

Because ANx is based on asynchronous transfer mode (ATM), it can enhance the speed and flexibility of data transmission over any of several access networks: copper-wire, fiber-optic or fixed-radio networks (LMDS). ATM also enables any such network to carry broadband services, such as interactive TV, remote LAN access, or Internet access. Ericsson designed its ANx-DSL products for copper-wire networks.

All applications—that is, ANx-DSL, ANx-Fiber and ANx-Radio—contain the same basic components:

- an ATM multiplexer;
- a variety of exchange terminations (using SDH/SONET and PDH standards for ATM cells);
- a control system structured around Ericsson's open telecom platform (OTP)[1];
- a network management system based on Hewlett-Packard's OpenView.

High-speed Internet access

Ericsson combines the ANx-DSL solution with the company's edge routers to provide secure, fast, and reliable IP-based access to different applications and sources of content.

Asymmetrical digital subscriber line (ADSL) techniques enable telephony operators to capitalize on their existing copper infrastructure in the local loop. Operators can provide data communication at up to 8 Mbit/s on the end-user's downlink while leaving the telephony function fully operable. In other words, Internet users can log on and establish dial-up sessions and still use their telephone line for voice communication.

The high-speed Internet solution should be regarded as a network solution. ANx-DSL offers high-speed transport of IP traffic, ATM-F 25.6, and Ethernet 10BaseT interfaces to customer premises equipment (CPE) and the self-learning bridge in the network termination.

The main problems that had to be solved to realize a high-speed Internet solution were:

- How can a specific end-user be connected to a specific Internet service provider (ISP)?
- How can the number of PVCs per service destination be reduced?
- How will the platform allow interaction with other networks?

The last problem—how the solution would provide interoperability—was key, because ANx needed to have a communication ar-

Box A Abbreviations

AAS	ATM access subrack
ADSL	Asymmetrical digital subscriber line
ATM	Asynchronous transfer mode
CATV	Cable TV
CBR	Constant bit rate
CHAP	Challenge handshake authentication protocol
CP	Control processor
CPE	Customer premises equipment
DHCP	Dynamic host configuration protocol
DMT	Discrete multitone modulation
DP	Device processor
EPD	Early packet discard
ET	Exchange terminal
HFC	Hybrid fiber coax
HTML	Hypertext markup language
HTTP	Hypertext transfer protocol
IDN	Intermediate data network
IMA	Inverse ATM multiplexing
IP	Internet protocol
ISDN	Integrated services digital network
ISP	Internet service provider
LAN	Local area network
LMDS	Local multipoint distribution system
NT	Network termination
OTP	Open telecom platform
PAP	Password authentication protocol
PLMN	Public land mobile network
POTS	Plain old telephone service
PPD	Partial packet discard
PPP	Point-to-point protocol
PPTP	Point-to-point tunneling protocol
PSTN	Public switched telephone network
PVC	Permanent virtual circuit
PVP	Permanent virtual path
QoS	Quality of service
SDH	Synchronous digital hierarchy
SNMP	Simple network management protocol
SNR	Signal to noise ratio
SOHO	Small office home office
SONET	Synchronous optical network
STM	Synchronous transport module
SVB	Switched video broadcast
SVC	Switched virtual connection
TCP	Transmission control protocol
UBR	Unspecified bit rate
VCI	Virtual circuit identifier
VDSL	Very-high-bit-rate digital subscriber line
VPI	Virtual path identifier

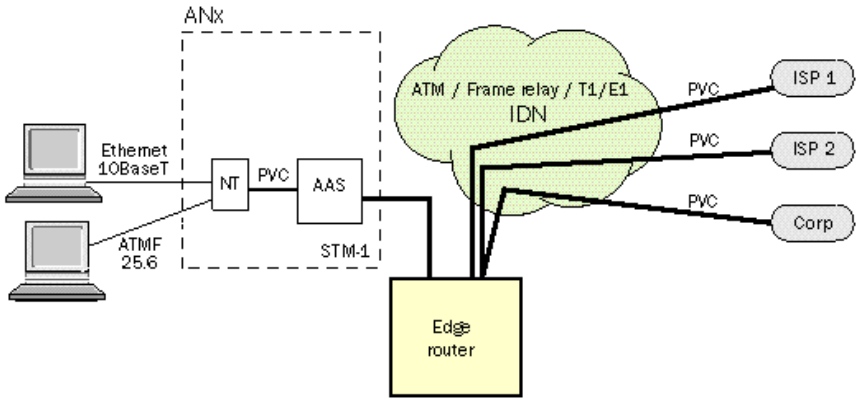

Figure 1
Overview—ANx high-speed Internet access with edge router.

chitecture in order to interface with the installed base of termination equipment, including home personal computers (PC) and routers or servers within ISP domains.

ADSL provides a carrier for broadband

ANx-DSL uses ATM transport all the way to the end-user termination. This constitutes a "multiservice access platform" capable of carrying high-speed Internet and broadcasted and interactive video over one and the same access network. There are no indications that the demand for broadband services will abate or that demands for quality of service (QoS) will ease. ANx-DSL is designed to relieve some of the pressure on network operators: extending the service life and capacity of their current network while allowing a smooth path of migration to broadband access media.

ANx-DSL can help operators to save money by extending the service life and functionality of their current copper infrastructure. The copper-wire portion normally accounts for the majority of investment in a network and, in most cases, the cost of replacing it with new cabling cannot be justified. Even the "last mile"—that is, the cable from the curb into the building (trunk to head-end)—represents a huge investment. The cost of digging and replacing with new cable what appear to be minor sections could actually exceed operator investments in new switching equipment.

ANx-DSL can ease traffic congestion on the public switched telephone network (PSTN)—dial-up Internet sessions can have holding times as long as several hours, which is dramatically different from telephone conversations. An ADSL overlay network can direct broadband traffic to a dedicated data network as early as the local exchange. For ANx-DSL, the broadband channel is superimposed on the frequency domain of the copper wire; thus, the existing telephone service can be carried simultaneously. An end-user can continue to use an existing fax or telephone at the same time as the line is being used by a PC to access the Internet.

The overlay architecture also allows smooth migration for operators. ADSL equipment can be added in phases. That is, operators only pay for incremental installation as the "catchment area" of broadband service expands. In this scenario, an operator may start with low penetration of subscriptions for broadband service, installing perhaps only one ADSL subrack at each narrowband subscriber stage. When the demand for broadband access increases, the operator can gradually add new ADSL subracks.

High-speed transport of IP packets in ANx-DSL

As mentioned above, interoperability with other networks and existing equipment is a key prerequisite for ANx to be commercially viable. Interoperability minimizes operator investments in new equipment when new access methods are deployed. Here, interoperability includes interfacing with the Internet and other sources of IP content, such as LANs or intranets. The end-user software interface need not be limited to an Internet browser. And small office home office (SOHO) solutions are envisioned as

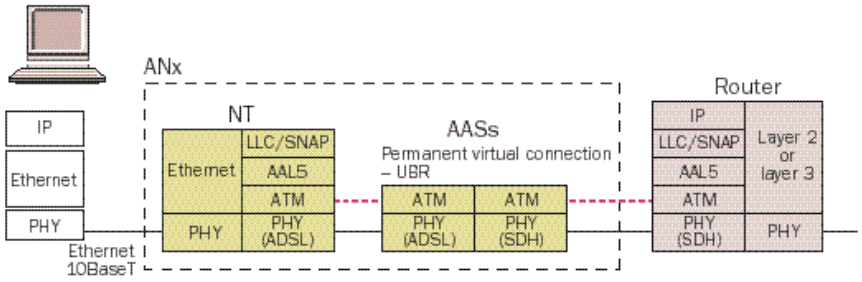

Figure 2
High-speed transport of IP packets through ANx-DSL.

users of a high-capacity ANx solution. ANx-DSL provides high-speed transport for IP-format packets, regardless of whether a user is connected to a 10BaseT interface or to an ATM-F 25.6 interface.

If a 10BaseT interface is used, the Ethernet frames from PCs are encapsulated using logical link control for bridged protocols (RFC1483) in the ATM adaptation layer 5 (AAL 5) payload. This "Ethernet bridge" is transported through ANx on an unspecified-bit-rate (UBR) permanent virtual circuit to a router with an ATM interface, as illustrated in Figure 2.

If an ATM-F 25.6 interface is used instead (Figure 3), the IP frames in the PC are encapsulated in AAL 5 and transparently transported through ANx to a router with an ATM interface. Here, too, a UBR permanent virtual circuit is used.

ANx works with Ericsson's edge router

Ericsson's edge router is designed to support a high-speed Internet access solution with ANx. Initially, two edge router options are offered: a simple router that supports access to a single service provider, and a more extensive solution that offers access to several service providers using the point-to-point protocol (PPP).

Edge routers are included in the high-speed Internet access solution for several reasons: PVC concentration, adaptation to other networks, and the provisioning of service-provider selection. An edge router can also let a user log on and establish a dial-up session while providing authorization, authentication, and accounting for the operator. The edge router developed by Ericsson can provide this functionality.

It connects to the ANx-DSL products and provides the basis for a variety of connectivity options for ISP connections and remote LAN connections. The edge router provides the end-user with equal access to different ISPs. This is an important feature today, since most networks are PVC-based and employ no switched connections. The edge router grooms the PVCs to a single PVC per Internet service provider.

A RADIUS client is included as part of the edge router for providing logon, security, and accounting functionality. The RADIUS server is located in the ISP domain.

The edge router connects to the network

The edge router is connected via an ATM connection to the ANx concentration shelf, which enables it to support up to 480 end-

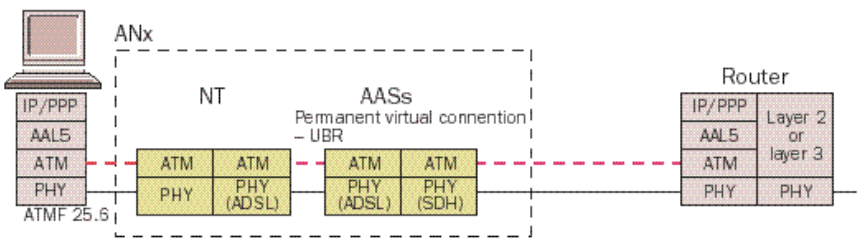

Figure 3
High-speed transport of IP packets in ANx-DSL by using an ATM-F 25.6 interface.

users (PVCs). The connection is a 155 Mbit/s synchronous transport module link (STM-1).

The edge router is designed for users connected to an Ethernet 10Base-T interface at their network terminations (NT). One ATM PVC for each network termination connects to the edge router. Each service provider has an L2TP tunnel from the edge router, and each tunnel can transport several PPP sessions, one per end-user. The L2TP tunnels are transported over a single ATM or frame-relay PVC that originates in the edge router (Figure 9). This means that one ATM PVC exists per Internet service provider.

Ericsson's ANx products

The ANx system is built around an ADSL-AAS (ADSL-ATM access subrack, A-AAS), which is a 19-inch rack that contains 15 ADSL boards (two modems each) and one exchange termination (ET) board connected to an ATM cell bus. The ET board contains one 155 or 45/34 Mbit/s link or four 1.5/2-IMA Mbit/s links carry ATM directly to the ATM backbone or connect it to a concentrating AAS (C-AAS). The latter rack is a variant of the A-AAS, equipped with 17 exchange terminations instead of one exchange termination and several ADSL boards.

Accordingly, up to 480 ADSL lines can be concentrated to a single 155 Mbit/s interface to the ATM backbone network. The A-AASs can be housed in different cabinets and, because the exchange termination boards can be obtained with optical or electrical interfaces, they can also be deployed at remote locations, such as the primary cross-connection point (Figure 4). This allows for an architecture that includes fiber to the curb (FTTC). Operators prefer FTTC deployment where the local loops in existing copper networks are too long to carry the requisite bandwidth at the specified signal-to-noise ratio (SNR). Normally, A-AASs are located at subscriber stages or remote access nodes.

The ADSL boards contain two ADSL discrete multitone (DMT) modulation modems, which comply with ANSI T1.413 (95 edition) and ADSL Forum's TR-002 (ATM over ADSL), and which provide up to 8 Mbit/s downstream and 1 Mbit/s upstream traffic over a copper drop. The actual speed achievable depends on the quality and length of the cable and on noise and interference in the surroundings.

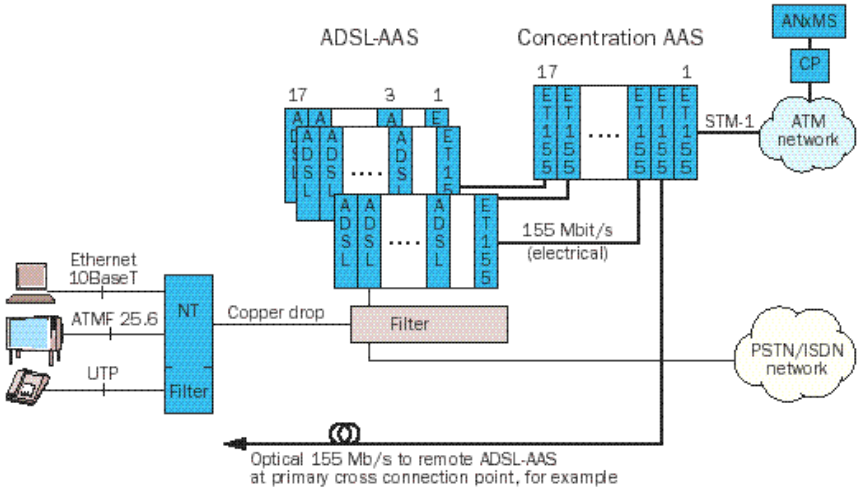

Figure 4
ANx-DSL equipment.

DMT modulation divides the frequency spectrum up to 1.1 MHz on the copper wire into 256 subchannels (Figure 6). The maximum bit rate of each subchannel is different because the different frequencies are more or less attenuated. Also, because the copper wire is unshielded, external disturbances might have an impact on transmission quality.

The head-end side contains high-pass/low-pass filters for inserting and extracting plain old telephone service (POTS) traffic below 30 kHz. Several filters exist, since different markets have different requirements for POTS (for example, reference impedance and meter pulses).

ADSL Lite, with downstream bandwidth of up to 1.5 Mbit/s and up to 500 kbit/s upstream, is a variant of the product described above and is meant for residential Internet access services.

Network termination

A fundamental part of the ANx-DSL prod-

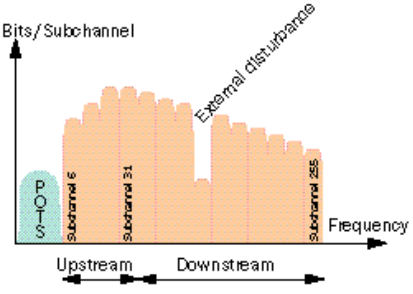

Figure 5
An ADSL-AAS, filtershelf and a network termination with filter.

Figure 6
DMT modulation with rate adaptation. (For further information on ADSL, see Ericsson Review 4/96).

Box B
Cell-bus ports

The cell multiplexer in the ATM access subrack is a bus in the backplane to which each board in the subrack is connected via a cell-bus port. All cell-bus ports contain functions for bus access contention, and one of the ports is configured as the master (normally the exchange terminal) to control the reading and writing of ATM cells at the bus for all cell-bus ports. To avoid cell loss, the speed at the bus is much higher (~850 Mbit/s) than any of the incoming links. The cell-bus port contains a set of translation records for mapping the virtual path identifier (VPI) number or the VPI and virtual channel identifier (VCI) numbers of incoming cells to new VPI or VPI and VCI numbers for outgoing cells.

At the outgoing cell-bus port, the cells are placed in different queues to obtain priority between different QoS levels. Today, two priorities are used:

- constant bit rate (CBR), for video;
- unspecified bit rate (UBR), which is a best-effort service class used for bursty data communication.

ANx thus applies dynamic multiplexing, which is advantageous for datacom services.

uct is the network termination, which is located on customer premises and contains the remote ADSL modem (ATU-R) and a small ATM multiplexer (the ATM MUX multiplexes and demultiplexes traffic to the various customer interfaces, ATM-F 25.6 or 10BaseT Ethernet).

The network termination also performs a bridging function, learning the media access control (MAC) addresses on its LAN by observing the source address of the incoming packet. The bridge function in the network termination helps keep LAN traffic from congesting the first router.

ATM-F 25.6 or 10BaseT Ethernet

The ATM-F 25.6 interface is a twisted-pair copper interface that carries ATM cells to customer premises equipment, which could be a set-top box or a PC equipped with a network interface card. For Ethernet, which is a standard LAN interface complying with IEEE 802.3, the network termination serves as a termination adapter where the ATM connection is terminated. For POTS, the high-pass/low-pass filters for inserting and extracting POTS traffic below 30 kHz could be included in the network termination box or placed in a separate box. Should the filter or the network termination fail—for example, due to a loss of power—the local exchange will continue to provide the "lifeline" service (POTS) transparently through the filters.

ATM multiplexer in the AAS

The ATM multiplexer contains special line boards that use ADSL, ADSL Lite or—in the future—very-high-bit-rate digital subscriber line (VDSL) techniques. ADSL and VDSL are modem techniques that allow broadband transmission over the copper-wire infrastructure of the PSTN. This is how ANx-DSL provides a broadband network overlay in the existing PSTN.

The purpose of the cell multiplexer is to multiplex and demultiplex the ATM cells from the exchange termination link to each line board (or ADSL link). However, the cell multiplexer can also serve as a switch for sending ATM cells between line boards. The cell multiplexer in the ATM access subrack is a bus in the backplane to which each board in the subrack is connected via a cell-bus-port circuit (Box B).

The system contains bottlenecks where the physical bandwidth narrows; for example, the ADSL board, where the bandwidth is converted from 155 to 8 Mbit/s, or the network termination, where bandwidth drops from 10 Mbit/s Ethernet to 1 Mbit/s. Because of these bottlenecks, the platform must be able to prioritize cells and provide adequate buffering. To improve system throughput, an EPD/PPD queuing scheme is used in buffers for UBR connections. This means that if a buffer gets congested and the system is forced to discard a cell that belongs to a frame (an IP or Ethernet packet), the entire frame will be discarded. Thus, since higher layers (such as TCP) detect incomplete frames, the network is never overloaded with faulty IP packets that will be retransmitted later.

The control processor

A control processor (CP) maintains and controls the different ATM access subracks in an ANx-DSL network element (which can consist of several C-AASs). The control processor is either centrally located in the ATM network or located with one of the C-AASs.

The control processor communicates with

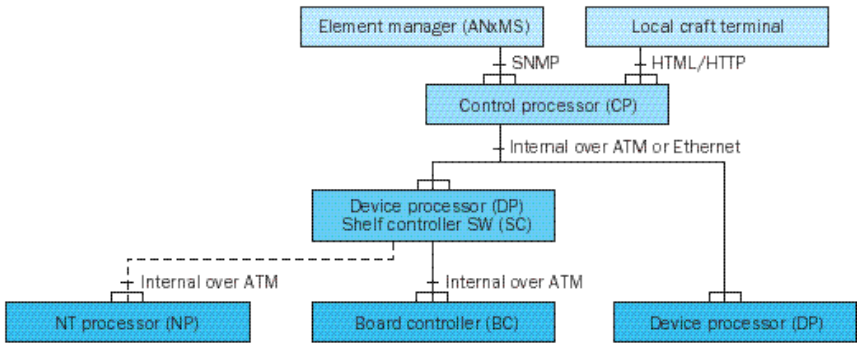

Figure 7
Control system hierarchy.

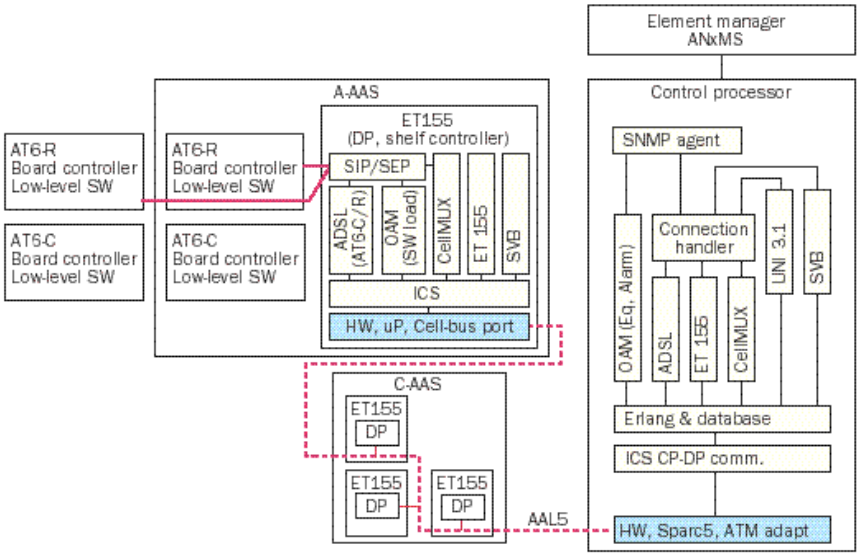

Figure 8
Software partitioning in an ANx-DSL system.

the element manager (ANxMS) via an SNMP interface or with the local craft terminal via an HTML/HTTP (WWW) interface. The ANxMS executes on a UNIX workstation equipped with HP OpenView and contains functions for:

- service management—for example, interactive cable TV over copper wire;
- connection handling—that is, managing PVCs;
- configuration management—for example, equipment handling and software management;
- fault management—for example, event and alarm logging and reporting;
- performance management for ADSL and ATM.

The control processor manages the ATM functionality within ANx and coordinates the management of ATM connections through the system (Figure 4). The operator specifies the end points of the system (one interface in the network termination and the network interface) and considers the system a "black box." The control processor sets up the connection through the network terminations, A-AASs, and C-AASs via the different device processors (DP) and board controllers involved. Point-to-point PVC and permanent virtual path (PVP) connections can be set up; that is, ANx can act as a VC or VP cross-connect. It is also possible to provide point-to-multipoint connections that can be used for interactive cable TV services over the copper-wire network (switched video broadcast).

PVCs are set up from the SNMP agent to the connection handler in the control processor, whereas switched virtual circuits (SVC) for interactive television are set up from the signaling termination software ATM-F UNI 3.1 in the CP. "Leafs" on point-to-multipoint connections for interactive CATV over copper are set up from the signaling termination software in the device processor (Figure 8).

The control system is based on Ericsson's open telecom platform (OTP). The control processor is a UNIX machine running OTP and Erlang software that coordinates and controls the ANx system. The database and the hard disk for secure storage of permanent data are also located at the control processor. Each board in the system has a device processor or a board controller, which is a low-end microprocessor. The device processor communicates with the control processor through in-band ATM communication or via a separate Ethernet LAN. The board controllers communicate via ATM with one of the device processors, which acts as a shelf controller; in other words, the device processor that contains specific software for maintaining the board controllers. In ANx-DSL, the ADSL boards and the network termination

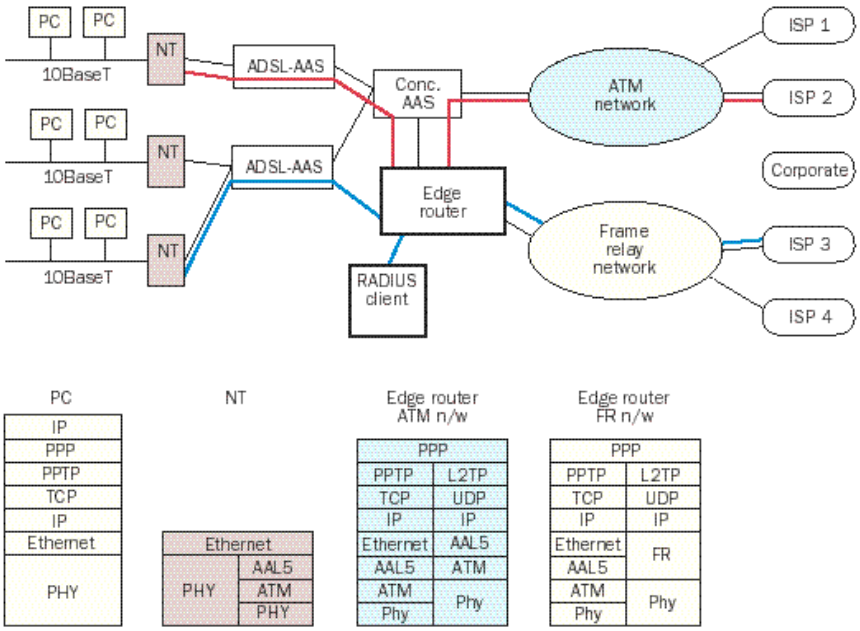

Figure 9
PPP and ISP selection.

boards have board controllers, whereas the exchange termination boards have device processors.

Two basic connection options

Fixed ISP connectivity

In the solution for fixed ISP connectivity, each edge router is dedicated to providing access to a particular ISP. The user connects to the ANx-DSL network termination via Ethernet. A bridged Ethernet over an ATM PVC provides a connection for the user from the network termination to the edge router. Finally, an ATM PVC is set up (supporting RFC 1577 point-to-point and RFC 1483 encapsulation of IP over ATM) between the edge router and the ISP router.

The user logs on to the ISP using a Web-based user interface in the edge router. Logon data is passed to the RADIUS client in the edge router, which is connected to a RADIUS server located in the ISP domain. The ISP RADIUS server performs standard authentication procedures (RFC 2138).

After the user has been successfully authenticated, the Web browser on the client PC begins executing a Java applet that monitors the session. The Java applet informs the edge router that the user is connected and provides support for accounting, which is maintained by the ISP RADIUS server (RFC 2059). For accounting purposes, the start and end times of the session are logged together with the number of packets and octets sent in each direction and to each interface.

The user's PC can have a fixed IP address in the ISP domain or the address can be allocated via the dynamic host configuration protocol (DHCP) from the edge router. The fixed IP address solution is likely to be the most common, because the PC will connect to the same ISP every time.

A user disconnects from the ISP by logging off through the Web interface or powering down the PC. Either action shuts down the Java applet and terminates the session.

PPP solution with ISP selection

Access router 1.2 augments the functionality in edge router 1.1 with two features. The user can dynamically choose his or her ISP and the connection is established using PPP.

The user PC sets up a PPP session with the edge router in much the same way as an existing dial-up connection is authenticated via RADIUS, using

- the password authentication protocol (PAP, RFC 1334);
- the challenge handshake authentication protocol (CHAP, RFC 1334).

To carry PPP over a non-serial Ethernet link, ANx uses the point-to-point tunneling protocol (PPTP). A PPTP client module in the PC sets up a tunnel to the edge router. A PPP session is then established in the tunnel.

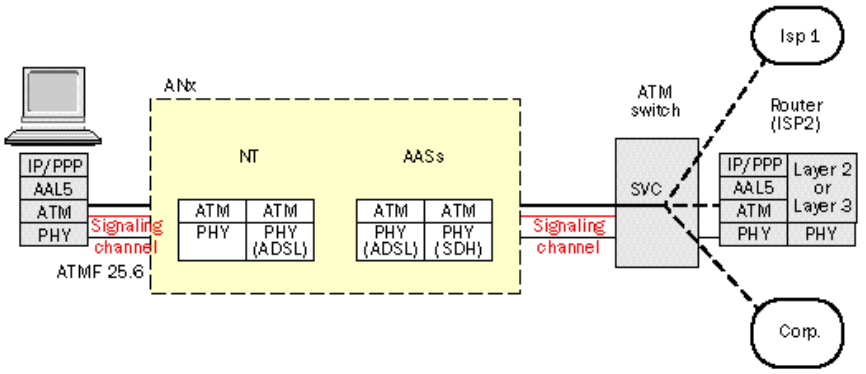

Figure 10
Data communication in ANx DSL using the ATM-F 25.6 interface.

Users can select their ISP in the same way as they select an ISP when accessing it through a dial-up session. However, instead of an ISP phone number, a unique ISP identifier is used, such as user@ISP1, in which ISP1 is the desired ISP. After a user has selected the ISP, an L2TP tunnel is established to the edge router, and the PPP session is passed from the PPTP to the L2TP tunnel. The PPP session is directed— via the L2TP tunnel from the edge router—to the ISP selected by the user.

Authentication data is then passed, via the RADIUS client, to the RADIUS server of the selected ISP. After successful authentication, the RADIUS server allocates an address via the Internet protocol control protocol (IPCP).

Other solutions

When PPP over ATM is available in PCs and in the ISP points of presence and the ATM network provides ATM SVCs, then PPP can be transported transparently over ATM SVCs in ANx (Figure 10). The architecture of this solution is similar to what is currently used in narrowband modem solutions, where SVCs could provide ISP-selection functionality and PPP can be used to provide security and billing functions between the ISP and the host.

Conclusion

ANx is an ATM-based broadband access product platform that can be used for several access techniques, such as copper, hybrid fiber coax, fiber, or radio. ANx-DSL uses ADSL modem techniques for improving the existing copper network.

Since ANx-DSL uses ATM transport all the way to the end-user termination, it provides a multi-service access platform for high-speed Internet, interactive TV and switched video broadcast over the same access network.

For a high-speed Internet access solution, ANx-DSL offers high-speed transport of IP traffic, ATM-F25.6 and Ethernet 10BaseT interfaces to the CPE and self-learning bridge in the network termination. An edge router is also part of the high-speed Internet access solution: it concentrates PVCs, adapts to other networks, and provides the ISP-selection functionality. Furthermore, edge routers support user logon sessions, providing operators with authorization, authentication and accounting functions.

References

1 Torstendahl, S.: Open Telecom platform. Ericsson Review, Vol 74 (1997):1, pp. 14–23.