Evolution of Broadband Access Mechanisms

A single converged network supporting voice, data and video services is emerging as the network of choice for connecting user equipment to public networks. To know how, read this article

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It has always been a challenge to improve the mechanisms that connect user equipment to public networks. The telephone networks were the default choice for data access from the origin of the data networks. Improved technologies came along and a number of new network access methods were introduced, but still the telephone lines remain the major network access medium. Among the access protocols, Ethernet is emerging as a winner.

Here we discuss various access methods, access networks and access protocols. Stress is given to the new broadband access architecture suggested by the Telecom Engineering Centre of the Department of Telecom. The specification envisages an effective, scalable, flexible and converged network supporting voice, data and video services.

Access mechanisms

Access network refers to a portion of the network that connects the access nodes to the network. The access mechanisms refer to the methods by which the customer accesses the intermediate node. The access is usually called the ‘last mile.’ The access mechanisms are predominantly two-wire copper, though fibre and wireless architectures are becoming increasingly popular.

Public-switched telephone networks (PSTNs) used twisted-pair copper for connecting networks to end users. When the data networks came along, these copper wires were the only available options for data communication between the end user and the networks. The voice networks designed as low-bandwidth circuits posed serious bottleneck to the data traffic.

Digital transmission through last-mile copper started with the invention of integrated services digital network (ISDN), and then continued along with primary rate digital lines (E1, T1). The next generation saw the growth of digital subscriber link (DSL) technologies like asymmetric DSL (ADSL), symmetric high-bitrate DSL (SHDSL) and very-high-bitrate DSL (VDSL).

The first-generation cable modem services had unidirectional data service to downstream and a telephone line modem for upstream transmission. The cost of both the equipment together was high. Phone calls could not be made while data transmission was going on and the downstream traffic was limited due to the slow upstream transport of acknowledgement packets.

Later on, cable modems with bidirectional service capabilities were introduced and the latest standard from CableLabs—the consortium for new cable telecommunication technologies—provides the bandwidth and latency guarantees required to offer toll-quality voice, dedicated business-class data services and multimedia applications across a shared cable modem access network. The concerns over cable modems on the privacy over the shared coaxial medium are being sorted out, but there are limitations on the upstream/downstream bandwidth and there are additional costs on deployment.

Fibre is considered to be superior to other transmission media. Optical transmission has many advantages. Simple modulation techniques, immu-
nity to cross talk, symmetric transmission, absence of emissions and extremely high-bandwidth capability are some of them. There are disadvantages too, like the difficulty in splicing fibres and inability of phantom feeding. However, the biggest disadvantage is that the replacement of twisted pairs with fibre requires a significant investment. Fibre within the metro area is growing rapidly, but it will take considerable time to reach the home.

Wireless digital telephony provided narrow-band services of 9.6 kbps and with the introduction of 3G networks, the bandwidth capabilities are high—2 Mbps for fixed stations and up to 384 kbps for mobile stations. Wireless-in-local loop (WLL) technology is providing still higher bandwidths for data services.

Wireless access methods will dominate in the future, but again, the massive investment, bandwidth crowding, reliability and security issues stand in their way.

Digital satellite television has grown faster than any other communications service, but its inability to provide upstream traffic economically has prevented it from being a major access technology.

**Access networks**

*First-generation telephone networks.* Traditional telephone networks had a pair of copper lines running from the central office (CO) to each of the individual telephones. The lines could be as long as 6 kilometres where the telephone exchange was far from the customer's home or office.

*Digital loop carriers.* Pair gain systems like fibre and digital loop carriers evolved when digital transmission techniques were invented. The individual phone lines were concatenated into a digital line and sent to a distance closer to the customer, which shortened the last-mile distance and made the deployment easier. Equipment vendors provided digital transmission and multiplexing equipment at the CO side (central office terminal, or COT) as well as at the remote side (remote terminal, or RT) and the system remained transparent to the CO.
V5.1/V5.2 DLCs. In an attempt to standardise the digital interface at the CO, ETSI/ITU introduced standard digital trunking protocols like V5.1 and V5.2. Thus the digital interface was standardised, and access equipment vendors no longer needed to do the CO terminal. V5.1 and V5.2 specified single or multiple E1 interfaces, respectively.

DLCs on SDH ring (fibre-in-local-loop). Fibre-in-local-loop architectures run SDH rings as access networks and implement add-drop multiplexers (ADMs) as the remote terminals. The COT has V5.2 primary-rate interfaces as well as SDH ADM interfaces to the network.

DSLAMs. DSL access multiplexers (DSLAMs) with ADSLs usually implement inverse multiplexing for ATM (IMA), which transports ATM cells from the ADSL modems across to the network through primary-rate digital interfaces. The VDSL technology uses Ethernet as the transport medium and Layer-2 Ethernet switching with some Layer-3 capabilities is implemented in these DSLAMs.

Integrated access gateways. Integrated access gateways support both voice and data services and segregate them at the gateway. These are Layer-3 switching systems that have primary-rate interfacing for voice connections to a PSTN and a router interface to an IP for data services.

Broadband and next-generation DLCs. Broadband DLC networks refer to the networks with remote terminals having capacity to provide high-speed access to the user. There are a number of architectures that are possible for broadband DLCs. Here we focus on the suggested implementation by the Telecom Engineering Centre.

The current DLC deployments of the government-owned telecom companies are based on the fibre-in-the-local-loop (FiLL) architecture. The new specifications are based on improving and adding onto the existing infrastructure. The proposed architecture is termed ‘OMSAN.’

Optical multiservice access network

Optical multiservice access network (OMSAN) is the proposed access network architecture based on the multiservice provisioning platform (MSPP), which is cost-effective, scalable, flexible and provides a converged platform for all the possible services. The architecture combines the best of traditional SDH environment of protection mechanisms, robustness and reliability with the packet work of data transparency, scalability, bandwidth sharing and quality of service (QoS) over complex network architectures.

These networks are useful for metropolitan access applications, combining both narrow-band voice applications and broadband applications, envisioning a single converged network for voice, data and video and providing QoS as well as class of service (CoS) and various service-level agreements (SLAs).

OMSAN is envisioned as a three-layer architecture detailing the customer access mechanisms, metro access rings and metro core rings—the rings forming a two-stage traffic aggregation and distribution.

Customer access and services. Two-wire copper pairs representing plain-old telephone service (POTS) interfaces provide voice applications and other time-division multiplexing (TDM) services like payphones, ISDN and E1 are supported. DSL lines over twisted copper pairs provide both DSL and SHDSL connections. Where the remote terminals are directly on a building like multi-tenant/multi-dwelling unit (MTU/MDU) complex, the CAT-5 fast Ethernet connections are also provided. Leased-line traffic can be carried over the E1 interfaces.

Broadband Internet access services, virtual private LAN services, Ethernet private lines, virtual private leased lines, and Layer-2 and Layer-3 VPNs are some of the services offered by the network. The network will also support video-on-demand, video broadcasting and gaming services.

Metro access rings. Metro access rings are the first level of traffic aggregation rings, combining all the telephony, leased lines, broadband access and other Ethernet traffic at the remote terminal and transporting them to the COT. There are specific and detailed
interfaces and services that are supported in both the RT and the COT.

Two types of equipment are suggested for the metro access rings: Category-I equipment to use SDH transport, and category-II equipment to multiplex the narrow-band traffic on the SDH interface and the broadband traffic on the gigabit Ethernet interface to a WDM interface at the RT and then de-multiplex the traffic at the COT.

Broadband remote-access servers (BRAS) act as session managers for broadband connectivity. These terminate PPP sessions and perform subscriber management (including authentication, authorisation and accounting as well as IP address assignment) for each session. The DHCP-BRAS can be part of the RT or the COT.

Category-I equipment. Category-I equipment use STM-1/4 rated rings depending on the traffic requirements. The broadband and the narrow-band traffic is aggregated and groomed into SDH traffic and methodologies like virtual concatenation, link capacity adjustment scheme and generic framing procedure (GFP) are used to be compliant with the SDH transport functionality. Virtual concatenation is used to map the traffic onto SDH, LCAS is used to dynamically increase or decrease the capacity of the container, and GFP helps to encapsulate the variable-length protocol agnostic payload.

Category-II equipment. Category-II equipment use wavelength-division multiplexing (WDM) using 1310/1550nm fibre. The broadband traffic from the Ethernet switch on the GE interfaces and the SDH STM-1 carrying the voice traffic is multiplexed at the RTs and transported across to the COT and split up to the respective traffic forms. There is possibility of using circuit emulation techniques, transparently carrying primary-rate circuit-switched traffic on a packet network, to implement transport of narrow-band services.

Central office terminal. COT is generally co-located at the local exchange and provides interfaces to RTs, PSTN and broadband networks. On PSTN related network interfaces, it supports POTS and 64kbps co-directional data, ISDN-PRI and PABX traffic, and n×64kbps data using SHDSL technology. Splitted/splitter-less ADSL full-rate services as well as splitter-less ADSL lite broadband services are also provided.

Category-I equipment have STM-1/4 interface towards the metro access rings and STM-16 uplink interfaces towards the metro core ring. Category-II equipment have STM-1/4 narrow-band services as well as GE data from the metro access rings, multiplexed and transported over the WDM interface.

The COT passes metering pulse information as well as CLIP information transparently to the RT. There are provisions to support the testing of subscribers’ copper lines directly from the COT DCC channels of SDH SOH bytes.

For category-I equipment the COT provides SDH non-blocking cross-connection capability with granularities of

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**Optical multiservice access network (OMSAN)** is the proposed access network architecture based on the multiservice provisioning platform (MSPP), which is cost-effective, scalable, flexible and provides a converged platform for all the possible services.
VC4, VC3 and VC-12 with the same hierarchal level. Layer-2 switching aggregates all Ethernet traffic from the multiple access rings and then interfaces it to a D-BRAS or the COT router. Apart from per interface rate limiting, loop resolution and link aggregation, the layer 2 switching functionality also provides IGMP snooping and DVMRP and GMRP supports. COT provides conventional Layer 3 IP routing as well as MPLS functionality.

Remote terminal (RT). Interfacing to the customer premises equipment, the remote terminals groom a variety of circuit-switched and broadband interfaces and transport them across to the CO. The RT supports various PSTN related interfaces such as POTS interface, ISDN basic-rate access and coin-collection box/payphone interfaces. It also supports 64/n×64kbps interfaces and E1 interfaces for TDM lease-line applications, and ISDN primary-rate interfaces. All the voice traffic aggregated at the RTs is framed onto V5.2 interfaces, multiplexed into SDH VC paths and transported to the COTs.

The RTs support ADSL G.lite as well as full-rate ADSL connections. These also support SHDSL lines. The DSL lines provide various broadband services like broadband Internet access, VoD, VPNs, VPLS and virtual leased lines by acting as an IP-DSLAM performing DSL aggregation.

Category-I equipment provide SDH cross-connect capability with granularities of VC4, VC3 and VC-12. The Layer-2 switching function aggregates FE output from the DSL aggregation interface and the GE traffic from the previous RT in the metro access ring on a common GE uplink towards next RT. The multicast support provides VoD and video broadcasting services with a content server.

Metro core ring. The metro core ring interconnects all local COs in a metro service area, each represented by a COT. The ring carries IP traffic switched and aggregated at high speeds, with routers connected in a full-mesh, partial-mesh or dual connected form. Any one router or a separate media gateway router can become a gateway router and connect to the national Internet backbone core router or the MPLS/VPN core router.

Access protocols

Internet protocol (IP) is emerging as a global network-layer platform for connecting users together in enterprise as well as in the home networks. Aiming at supporting multimedia applications, the broadband access methods that exist today transport IP traffic from end users’ premises to the access point. Currently, the access goes through a number of protocols and over a wide variety of equipment following a number of different network architectures.

In telephony modems, IP traffic is transported using point-to-point protocol (PPP) and over the underlying physical-layer modem protocol. In ADSL modems, the asynchronous transfer mode (ATM) is used to carry IP. Usually, IP data is carried over the ATM PVC. PPP over ATM or classical IP over ATM is also used. These protocols might be residing on different network equipment, like telephone modems, DSLAMs, routers and switches. Depending on the network architecture, there might be protocol conversions at different network nodes. As the complexity of the protocol conversions and equipment increases, the cost of the network also increases.

Ethernet: universal data-link protocol

Ethernet is the most popular networking technology in home and enterprise networks, with nearly 500 million Ethernet ports deployed worldwide. It is a well-understood technology and popular because it strikes a good balance between speed, cost and ease of installation. Ethernet is widely accepted in the PC marketplace, which is the dominant multimedia device today. The ability to support virtually all popular network protocols makes Ethernet an ideal networking technology for most computer users.

The Institute for Electrical and Electronic Engineers (IEEE) defines the Ethernet standard as IEEE Standard 802.3. This standard defines rules for configuring an Ethernet network as
well as specifying how elements in an Ethernet network interact with one another. By adhering to the IEEE standard, network equipment and network protocols can communicate efficiently.

In an attempt to provide a unifying access platform, Ethernet is envisioned as the access technology of the future. Just as Ethernet revolutionised enterprise networking, it is now poised to be the single technology that will deliver universal broadband access for high-end user applications, and enable a true end-to-end, seamless technology for communication applications. Being a proven global standard, Ethernet can provide complete interoperability in different components of the multimedia applications.

Ethernet will deliver universal broadband access with a range of interoperable components for network service providers, equipment and component manufacturers, and ultimately for subscribers.

Other relevant transport and switching protocols

**Circuit emulation services.** Circuit emulation services (CES) over packet networks transport digital trunks such as E1/T1/E3/T3 as well as SDH/SONET circuits over packet networks. A CES-IWF (interworking function) converts the T–n or E–n frame arriving from the customer premises equipment (CPE) or an access network into CES packets and transmits them across the packet network.

**Pseudo Wire Emulation Edge-to-Edge (PWE3)***—one of the Internet Engineering Task Force (IETF) working groups—defines emulation of services (such as frame relay, ATM, Ethernet E1/T1/E3/T3 and SONET/SDH) over packet-switched networks using IP or MPLS. Another standard for circuit emulation is from the Metro Ethernet Forum, which proposes a draft that discusses the methods to carry TDM traffic over the Ethernet network.

The IETF PWE3 working group focuses on standardisation of the framework and service-specific techniques for pseudo wires. Pseudo wire is a mechanism that emulates the essential attributes of a service (such as frame relay, ATM, Ethernet E1/T1/E3/T3 and SONET/SDH) over a packet-switched network. The pseudo wire functions include encapsulating the traffic, carrying them across a path or tunnel, managing their timing and order, and any other operation required to emulate the behaviour and characteristics of the service as faithfully as possible. Fig. 10 shows the PWE3 network reference model.

Circuit emulation services over packet-switched network (CESoPSN) will use a specific circuit emulation header to encapsulate the TDM traffic and RTP-based mechanisms for carrying clock over the packet-switched network. Fig. 11 shows the proposed packet structure for CESoPSN.

**Generic framing procedure.** Generic framing procedure (GFP) defines a standard framing procedure for octet-aligned variable-length payloads for mapping onto SDH/SONET payload envelopes or optical transport network (OTN) OCh payloads. The client signals may be PDU-oriented (IP with PPP or Ethernet), block-code-oriented (bi-directional connection or fibre channel) or a constant-bitrate stream. Currently, there are two modes defined for GFP: a PDU-oriented adaptation mode (frame-mapped GFP) and block-code-oriented adaptation mode (transparent GFP).

Fig. 12 shows GFP for SONET/SDH and OTN. Through GFP, designers gain access to an efficient transport protocol that provides a rugged link, low latency, transparent Layer-2 connectivity and multiprotocol support.

**Multiprotocol label switching.** Multiprotocol label switching (MPLS) offers simple mechanisms for packet-oriented traffic switching with multiservice functionality with greater scalability. Traffic engineering and VPN support are examples of two key applications where MPLS is superior to any currently available IP technology.

The basic mechanism of MPLS is the generation of a short fixed-length ‘label’ that acts as representation of an IP packet’s header: MPLS routers use the label to make a forwarding decision about the packet. Special routers
called ‘label edge routers’ (LERs) mark the traffic with special labels as it enters the network in order to designate different classes or service. The LER maps IP packets into MPLS packets at the ingress of the MPLS network and MPLS packets into IP packets at the egress. Label switch routers (LSRs) route the traffic across the network once labels have been attached by analysing the packet.

LSRs examine the incoming packets and provided that a label is present, the LSR will look up and follow the label instructions, then forward the packet according to the instructions. In general, the LSR performs a label swapping function. Paths are established between the LER and the LSR. These paths, called ‘label switch paths,’ are designed for their traffic characteristics; as such, they are very similar to ATM path engineering. The traffic-handling capability of each path is calculated. These characteristics can include peak traffic load, inter-packet variation and dropped-packet percentage calculation.

The final word

Broadband access is getting increased focus. Selecting the right architecture and protocols is important in view of network equipment deployment, maintenance and upgradation. The network should also support the customer requirements without constraints, reliably at the lowest cost.

While moving towards a single converged network supporting voice, data and video, Ethernet as the major protocol in the access network reduces equipment cost and complexity. SDH, with its latest support for variable bandwidth allocations, increasing efficiency of transport as well as ability to support multiple services and the installed bases, is the main choice for access transport.

The core networks are evolving to be packet-based resilient packet rings providing efficient statistical multiplexing schemes with CoS support, reliability and survivability with ultra-fast protection switching and operations, administration, maintenance and line provisioning capabilities, and operate independent of the physical layers taking advantage of already available fibre deployments.

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