Dedicated Access Solutions for Internet Service Providers

INTRODUCTION

Revenue from business connections to the Internet represents, on average, almost 60 percent of the total revenue to Internet service providers (ISPs). As business use of the Internet grows with new Web-enabled applications, voice over IP (VoIP), and dropping tariffs on leased lines, the demand for high-bandwidth, dedicated connectivity from corporate sites to the ISP point of presence (POP) has swelled. ISPs face significant challenges keeping up with the bandwidth requirements, management and provisioning complexities, and POP space constraints in the face of increased customer demand. This white paper focuses on solutions for dedicated customer connections that address these challenges, including platform and interface selection criteria.

INTERNET SERVICE PROVIDER ACCESS

Large-scale ISP networks have been challenged by the large number of customer connections coming into a single location (POP) for some time. Today a typical POP terminates thousands of DS-0, hundreds of DS-1, and dozens of DS-3 customer connections. This level of scale has been possible only with the advent of channelized and multichannel router interface technologies. However, before discussing these technologies, let's consider the state of a typical Internet POP one or two years ago.

ISP POPs (Figure 1) contain a diverse set of equipment to provide connectivity between POPs (backbone), connectivity within the POP (interconnect), and connections to customer sites (access). Service providers can handle many types of access, including dialup, XDSL, cable, and dedicated or leased lines. Figure 2 shows a typical dedicated access router. Multiple leased-line and Frame Relay customers connect through point-to-point links to a large router. In the past these individual connections were terminated through standard V.35, X21, or RS-232 interfaces on the router, requiring that every connection have a separate physical interface. Additionally, for each interface, a channel service unit/digital service unit (CSU/DSU) or similar device was needed for each connection to convert between the serial interface to the transmission signaling (DS-0, DS-1, DS-3, etc.) on the telecommunication carrier side.

Figure 1. POP Model

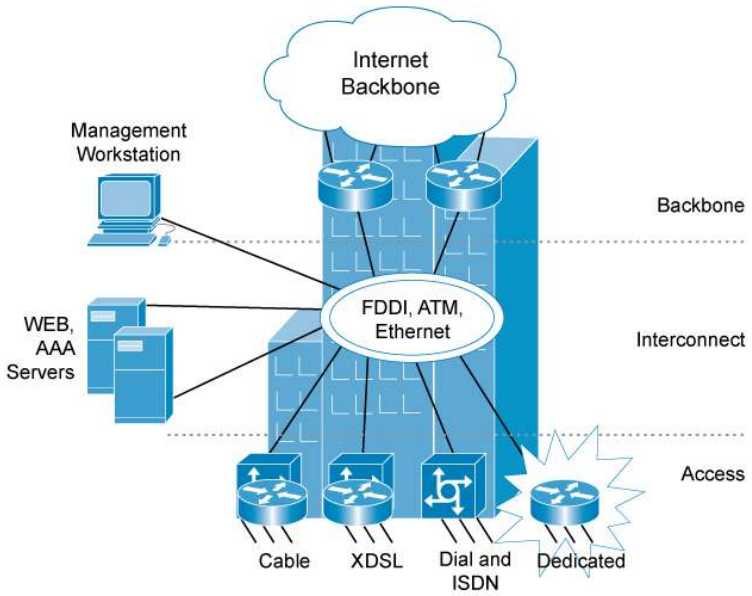
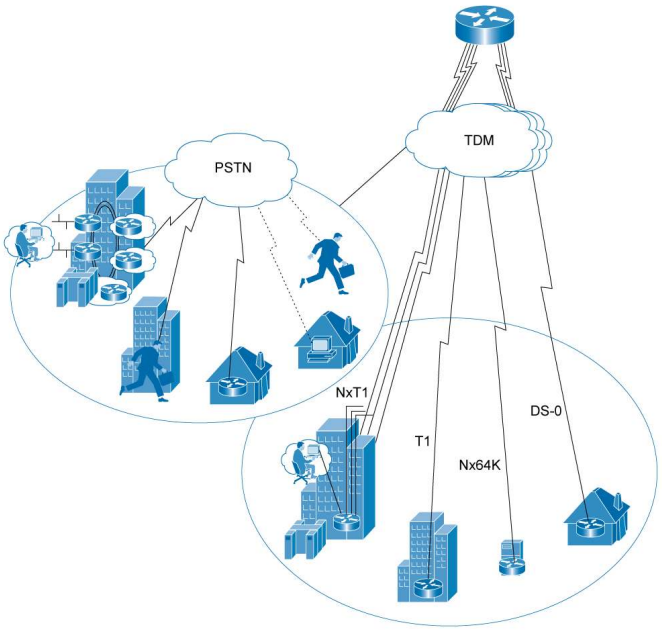
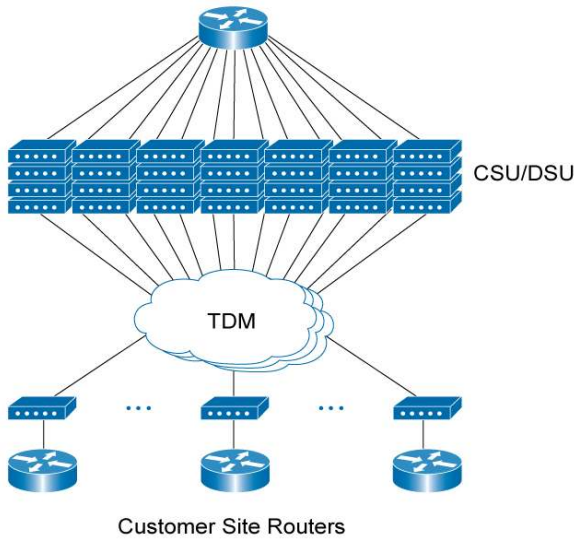


Figure 2. Typical Aggregation Router Connections



In this scenario, bottlenecks arise as the number of these dedicated connections grows. First, a one-to-one correspondence between router ports and customers is costly and inefficient from a slot usage point of view. Second, a large amount of rack space for individual CSUs/DSUs is needed and the cabling becomes hard to manage (refer to Figure 3). Third, as customer connections change over time, the mix of port types in the router must be manually reconfigured (for example, V.35 ports must be removed and replaced by High-Speed Serial Interface [HSSI] ports to accommodate a connection change from DS-1 to DS-3).

Figure 3. Aggregation with Dedicated Interfaces



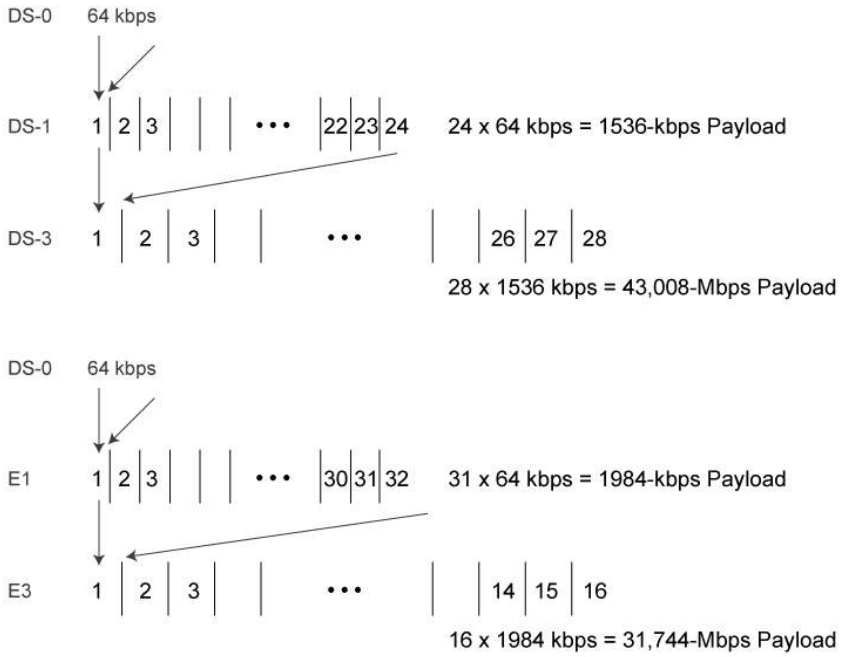
To address these three concerns, vendors began introducing interfaces with integrated CSU/DSU capabilities to remove the requirement for external boxes and spider-web cabling complexity. Although these solutions were well accepted, they still did not address slot usage and port

flexibility. These concerns have been addressed with Cisco Systems® multichannel interface technologies. To understand how these technologies help, consider the telecommunications carrier infrastructure that provides leased-line and Frame Relay connections.

TELECOM CARRIER INFRASTRUCTURE

Within their network, telecommunication carriers use time-division multiplexing (TDM) technology for carrying multiple data streams over a single link, making more efficient use of network resources. TDM is a relatively simple mechanism that assigns equally sized fixed portions of bandwidth to multiple channels. Because of its simplicity, this assignment can be performed at very high speeds. The smallest bandwidth portion that can be accessed is usually 64 kbps, called a DS-0 or timeslot. The next level in the digital hierarchy multiplexes either 24 DS-0 lines into a DS-1 or 32 DS-0 lines into an E1, depending on the carrier. Note that with E1, one timeslot is used for synchronization, leaving only 31 DS-0 lines available for data transport. The next level in the digital hierarchy multiplexes 28 T1 lines into a DS-3 or 16 E1 lines into an E3. Higher-order multiplexing is used within the telephone company infrastructures, for example multiplexing multiple DS-3 lines onto a SONET OC-3 connection. However, these links are rarely available as ISP accessible services.

Figure 4. Digital Multiplexing Hierarchies



Note: Although each DS-0 line is an independent data channel, multiple contiguous DS-0 lines can be concatenated to form a single, higher-bandwidth connection at N times the bandwidth of a DS-0 line; for example 128, 256, or 384 kbps, for N = 2, 4, or 6, respectively. ("Contiguous DS-0s" means that the timeslots are adjacent to each other in the multiplexed DS-1 or E1 frame.)

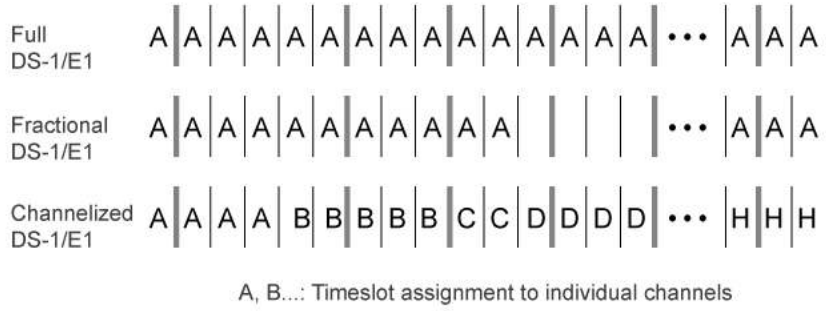
Carriers offer services that multiplex DS-0 channels onto a T1 or E1 link in multiple options:

- Full rate—All the available timeslots are assigned to a single connection, which takes advantage of the full bandwidth of the link.
- Channelized—A DS-1 or E1 link carrying multiple connections at N x 64-kbps bandwidth is called a Channelized DS-1 or E1.
- Fractional—When a DS-1 or E1 link contains a single N x DS-0 connection, leaving the rest of the DS-0 lines empty, the link is called a fractional DS-1 or E1; it uses only a fraction of the available timeslots and bandwidth.

- ISDN Primary Rate Interface (PRI)—Another specific form of a Channelized T1/E1 interface is the ISDN PRI. A channelized interface configured for PRI reserves a specific channel for exchanging signaling information with the central-office switch to handle call setup and teardown. Each of the remaining DS-0 lines represents a single ISDN connection.

Each of these services has a different type of T1/E1 frame: frames carrying a full T1/E1, a fractional T1/E1, or multiple N x DS-0 connections (Figure 5).

Figure 5. Different Types of Payload in T1/E1 Frames



When looking at the next level of the multiplexing hierarchy, all four types of services can be present on a Channelized T3/E3 link at the same time. A DS-3 link, for example, can carry a mix of full T1/E1, fractional T1/E1, and N x DS-0 connections.

Of course, a DS-3/E3 link can also be used for a single connection at either full T3/E3 rates (45 or 34 Mbps) or, using proprietary mechanisms, at sub-T3/E3 rates. Most T3/E3 DSU vendors have their own algorithms for providing subrate connectivity. Many ISPs use this subrate function to offer tiered T3 (and some E3) services.

FRAME RELAY AGGREGATION

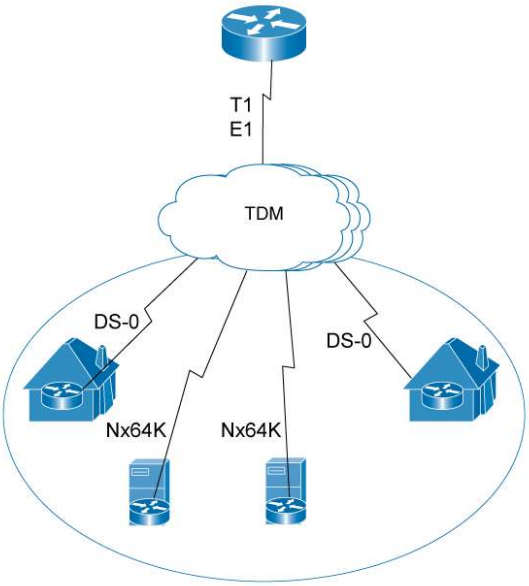
Frame Relay evolved as a way of providing point-to-point connections over shared links, where statistical multiplexing techniques are used to provision many more than 24 connections on a single T1 link. Because Frame Relay links are economical, they have become popular among businesses for accessing the Internet. Solutions for dedicated connectivity for ISPs must be able to handle both leased-line and Frame Relay lines simultaneously.

SOLUTIONS

Connecting the router directly to the multiplexed lines of the telephone carrier infrastructure through specially designed Cisco® multichannel interfaces eliminates the requirement for CSUs/DSUs and multiple physical interfaces. This solution also allows greater connection density because one physical connector can handle many customer connections (up to 128 or more if Frame Relay is used). In addition, because the mapping of timeslots to customer connections is settable in software on these interfaces, reconfiguring customer connection speeds requires no physical intervention.

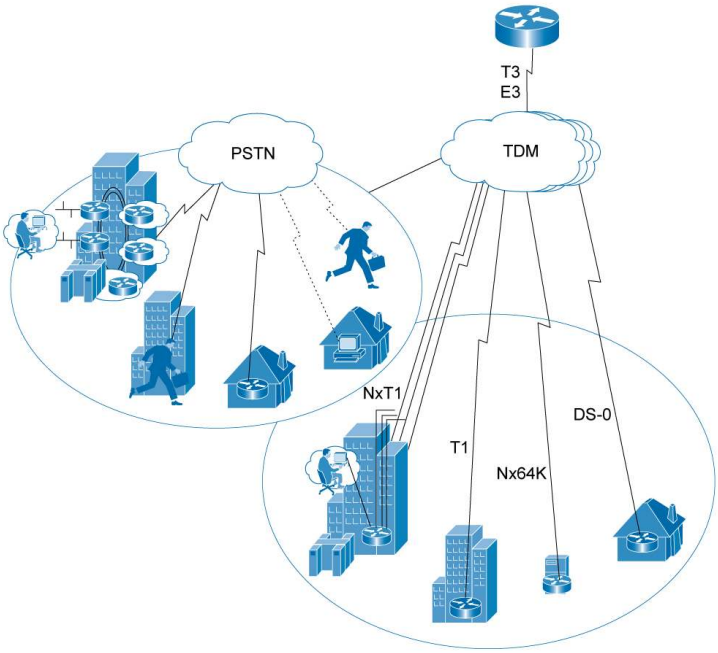
Carriers offer two types of channelized services: lower-speed connections at rates of T1/E1 and the next level carrying multiple T1/E1 lines at DS-3/E3 speed. A Channelized T1/E1 connection provides up to 24 (or 31) individual 64-kbps connections (DS-0 or timeslots) on a single interface that terminate up to 24 (or 31) different destinations across the WAN. Multiple timeslots can be combined to provide N x 64-kbps bandwidth to a single connection.

Figure 6. DS-0 and N x DS-0 Aggregation



Channelized DS-3/E3 interfaces provide an aggregated number of T1/E1 connections. In the simple form this provides 28 T1 or 16 E1 connections. As discussed later, Cisco multichannel solutions take this one step further and allow for access to both T1/E1 lines and the individual DS-0 lines inside the DS-3/E3 interface.

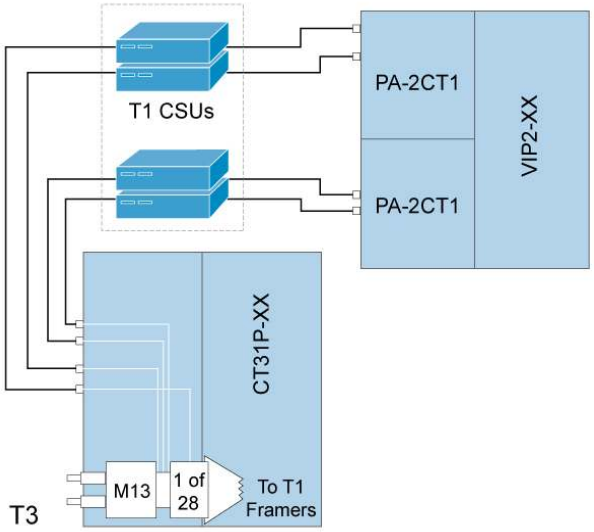
Figure 7. T1/E1 and DS-0 Multichannel Aggregation



CISCO INTERFACES FOR DEDICATED ACCESS

The current generation of interface port adapters for the Cisco 7200, 7301, 7304, 7500, and 7600 series routers now integrates the T1 CSU/DSU function on the port adapter and allows direct connections to the carrier network. Available in 2-, 4-, and 8-port versions, the T1/E1 multichannel port adapters (part numbers PA-MC-2T1, PA-MC-4T1, and PA-MC-8TE1+) provide up to 128 individual connections, taking advantage of the processing power of the supported platform.

Figure 8. Two-Stage Multilevel Channelization



The two-stage approach is not necessary with the multichannel port adapters (part numbers PA-MC-1/2E3, PA-MC-T3, and PA-MC-2T3+). These port adapter types support multilevel channelization and allow access down to individual 64-kbps DS-0 lines. Their flexible channelization can be configured for up to 128 logical interfaces that can be a mix of 64 kbps, N x 64 kbps, fractional T1/E1, and full T1/E1 connections. Table 1 gives an overview of the various multichannel interfaces for the Cisco 7200, 7301, 7304, 7500, and 7600 series routers.

Table 1. Products Supporting Channelized Infrastructure

Product	**1, 2 Port Multichannel T3 (part number PA-MC-1/2T3+)**	**2, 4, 8 Port Multichannel T1 (part number PA-MC-2T1/4T1/8TE1+)**
Link	DS-3	DS-1
Supports DS-1 connections	Yes	Yes
Supports DS-0 connections	Yes	Yes
Supports PRI	Yes	Yes
Direct interface to T1/T3	Yes	Yes
Product	**1, 2 Port Multichannel E3 (part number PA-MC-1/2E3)**	**2 and 8 Port Multichannel E1 (part number PA-MC-2E1//8TE1+)**
Link	E3	E1
Supports E1 connections	Yes	Yes
Supports DS-0 connections	Yes	Yes
Supports PRI	Yes	Yes

Inside the Cisco IOS® Software running on the router, each channel is treated as a physical interface. Most of the functions available on standard serial interfaces are also available on serial connections provided through channelized interfaces. For example, it is possible to run different encapsulations and network protocols on each of the different channels. Advanced network services such as compression and quality-of-service (QoS) support can also be applied to connections through channelized interfaces.

The integration of the CSU/DSU function simplifies network management and troubleshooting. Previously, a managed CSU/DSU was needed to monitor certain parameters of the link. Usually connected to a LAN segment, these CSUs/DSUs are a separate device with its own IP address from the network management systems perspective. The integration onto the port adapters reduces the number of devices to manage. For test purposes the new port adapters support different software-activated loopbacks and onboard bit error rate testing (BERT).

For provisioning of bandwidth, greater T1 or E1 multiple links can be used in parallel. Cisco IOS Software incorporates two different mechanisms to use the aggregate bandwidth. First, load balancing over parallel links can be used. This feature works at the network layer; for example, the parallel links would all comprise a separate subnet. Cisco Express Forwarding provides a very effective mechanism for TCP/IP load balancing on either a per-destination or per-packet basis with full forwarding performance.

Multilink Point-to-Point Protocol (MLPPP) working at the link layer provides functions similar to an inverse multiplexer across multiple parallel links. However, the additional processing overhead may affect overall system performance.

For customer connections beyond N x T1 or N x E1 rates, Cisco offers packet-over-T3 and packet-over-E3 port adapters (part numbers PA-T3+, PA-2T3+, PA-E3, and PA-2E3) that allow T3 and E3 lines to connect directly to the router. These port adapters integrate the DSU function so no external devices are needed to terminate a DS-3 or E3 coaxial cable from the carrier. In addition, Cisco supports the subrate and scrambling modes of Digital Link, Larscom, and Kentrox to allow more a flexible choice of customer-side solutions for tiered DS-3 services.

SUMMARY

As networks grow, new solutions for high-density, dedicated Internet access are required. The growing number of dedicated serial interfaces with external CSUs/DSUs becomes expensive and hard to manage. Multichannel interfaces supporting advanced multilevel channelization can provide connectivity to more than 100 locations on a single physical port or port adapter. The integration of the CSU/DSU function reduces the potential points of failure in the network and number of devices to manage, resulting in an overall lower cost per connection. Solutions for T3 and E3 connectivity that also contain integrated DSUs provide the same benefits for high-speed connections.

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