**Section D**

**Synchronous Digital Hierarchy (SDH)/Synchronous Optical Network (SONET)**

**Synchronous Optical Networking (SONET)** and **Synchronous Digital Hierarchy (SDH)** are standardized multiplexing protocols that transfer multiple digital bit streams over optical fiber using lasers or light-emitting diodes (LEDs). Lower data rates can also be transferred via an electrical interface. The method was developed to replace the Plesiochronous Digital Hierarchy (PDH) system for transporting larger amounts of telephone calls and data traffic over the same fiber without synchronization problems. SONET generic criteria are detailed in Telcordia Technologies Generic Requirements document GR-253-CORE.Generic criteria applicable to SONET and other transmission systems (e.g., asynchronous fiber optic systems or digital radio systems) are found in Telcordia GR-499-CORE.

SONET and SDH, which are essentially the same, were originally designed to transport circuit mode communications (e.g., DS1, DS3) from a variety of different sources, but they were primarily designed to support real-time, uncompressed, circuit-switched voice encoded in PCM format.The primary difficulty in doing this prior to SONET/SDH was that the synchronization sources of these various circuits were different. This meant that each circuit was actually operating at a slightly different rate and with different phase. SONET/SDH allowed for the simultaneous transport of many different circuits of differing origin within a single framing protocol. SONET/SDH is not itself a communications protocol per se, but a transport protocol.

Due to SONET/SDH's essential protocol neutrality and transport-oriented features, SONET/SDH was the obvious choice for transporting Asynchronous Transfer Mode (ATM) frames. It quickly evolved mapping structures and concatenated payload containers to transport ATM connections. In other words, for ATM (and eventually other protocols such as Ethernet), the internal complex structure previously used to transport circuit-oriented connections was removed and replaced with a large and concatenated frame (such as OC-3c) into which ATM cells, IP packets, or Ethernet frames are placed.

Both SDH and SONET are widely used today: SONET in the United States and Canada, and SDH in the rest of the world. Although the SONET standards were developed before SDH, it is considered a variation of SDH because of SDH's greater worldwide market penetration.

The SDH standard was originally defined by the European Telecommunications Standards Institute (ETSI), and is formalized as International Telecommunications Union (ITU) standards G.707,G.783,G.784,and G.803.The SONET standard was defined by Telcordia and American National Standards Institute (ANSI) standard T1.105.

**Asynchronous Transfer Mode**

**ATM** is a high-speed networking standard designed to support both voice and data communications. ATM is normally utilized by Internet service providers on their private long-distance networks. ATM operates at the data link layer (Layer 2 in the OSI model) over either fiber or twisted-pair cable.

ATM differs from more common data link technologies like Ethernet in several ways. For example, ATM utilizes no routing.

Hardware devices known as *ATM switches* establish point-to-point connections between endpoints and data flows directly from source to destination. Additionally, instead of using variable-length packets as Ethernet does, ATM utilizes fixed-sized cells. *ATM cells* are 53 bytes in length, that includes 48 bytes of data and five (5) bytes of header information.

The performance of ATM is often expressed in the form of OC (Optical Carrier) levels, written as "OC-xxx." Performance levels as high as 10 Gbps (OC-192) are technically feasible with ATM. More common performance levels for ATM are 155 Mbps (OC-3) and 622 Mbps (OC-12).

ATM technology is designed to improve utilization and quality of service (QoS) on high-traffic networks. Without routing and with fixed-size cells, networks can much more easily manage bandwidth under ATM than under Ethernet, for example. The high cost of ATM relative to Ethernet is one factor that has limited its adoption to backbone and other high-performance, specialized networks.

**Frame Relay**

Frame relay is a packet-switching telecommunication service designed for cost-efficient data transmission for intermittent traffic between local area networks (LANs) and between endpoints in wide area networks (WANs). The service, once widely available and implemented, is in the process of being discontinued by major Internet service providers. Sprint ended its frame relay service in 2007, while Verizon said it plans to phase out the service in 2015. AT&T stopped offering frame relay in 2012 but said it would support existing customers until 2016.

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Frame relay puts data in a variable-size unit called a *frame* and leaves any necessary error correction (retransmission of data) up to the endpoints, which speeds up overall data transmission. For most services, the network provides a permanent virtual circuit (PVC), which means that the customer sees a continuous, dedicated connection without having to pay for a full-time leased line, while the service provider figures out the route each frame travels to its destination and can charge based on usage. Switched virtual circuits (SVC), by contrast, are temporary connections that are destroyed after a specific data transfer is completed.

An enterprise can select a level of service quality, prioritizing some frames and making others less important. A number of service providers, including AT&T, offer frame relay, and it's available on fractional T-1 or full T-carrier system carriers. Frame relay complements and provides a mid-range service between ISDN, which offers bandwidth at 128 Kbps, and Asynchronous Transfer Mode (ATM), which operates in somewhat similar fashion to frame relay but at speeds of 155.520 Mbps or 622.080 Mbps.

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