As demand for data traffic continues to outpace voice traffic, carrier networks will convert to data-centric architectures, transforming the way in which switching is performed in the transport network. Data traffic will be packetized—sent in discrete packets of varying size. However, that does not mean all switching in telecom operators’ networks will be packet switching. In fact, there is a need to add packet switching into the network and, at the same time, optimize the transport network to meet the needs of packet switching. This will occur with intelligent optical switching.

The term “intelligent” refers to the addition of protocols for automatic connection control. We are used to having packet networks, especially IP networks, behave intelligently. Now transport networks are catching up and bringing their own set of value-added features. Before we can see where such technology will take us, however, we must first understand the state of the art today.

Transmission control protocol/Internet protocol (TCP/IP), X.25, frame relay, and asynchronous transfer mode (ATM) protocols are all based on packet-switching technologies. The systems send traffic at a variable bit rate, meaning resources are assigned as needed on a first-come, first-served basis. Packet switching is best suited for transmitting bursty data traffic that is not affected by delays. E-mail messages and Internet traffic are prime examples.

In comparison, circuit switching is best for transmissions of real-time data such as voice and video, in which even the slightest delays can affect quality. Circuit switching applications require guaranteed bandwidth and low latency.
and they use a dedicated bandwidth for the duration of the transmission. The data is transmitted at a constant bitrate in the exact same order in which it was sent. The most obvious example is the telephone network.

**packet protocol**

Generically speaking, packets vary in length from 50 to 10,000 bytes, and their headers vary in complexity from five to 50 bytes. Each packet is switched based on the information contained in the header. Packet switching can be connectionless or connection-oriented.

In connectionless packet switching, network switch nodes store the packets, process the headers, and send the packets to the next step along their journey. There is no connection state stored in the switches. As a result, successive packets don’t necessarily follow the same path or arrive in the order in which they were sent.

IP is an example of connectionless packet transport. With IP, each packet is routed independently, so carriers must offer “best effort” delivery to their customers. Because service delivery is not completely reliable, quality of service (QoS) is difficult to guarantee. Well-engineered connectionless networks thus deploy significant excess capacity to ensure that customers are generally satisfied with the quality of service they receive.

In contrast, connection-oriented packet switching, typified by ATM, offers reliable QoS. In this type of packet switching, a connection is prepared through a management action or a signaling protocol. This enables service providers to engineer the network for bandwidth guarantees or statistical multiplexing, though not both at the same time. One benefit of connection-oriented packet switching is the simplification of packet forwarding, although this simplification is not seen as an important advantage today.

ATM captures the advantages of both circuit and packet multiplexing techniques (see figure 1). With ATM, a connection is requested, a path selected, resources confirmed and reserved, the destination alerted, and then acceptance is received from the destination. The ATM network transmits packet-like cells containing a 5-byte header and a 48-byte payload. The header includes the virtual circuit identifier, which is used to route the cell to the appropriate destination. Because ATM networks are connection-oriented, they are traditionally used in applications where QoS is important.

**looking at layers**

The open systems interconnection (OSI) networking suite defines a seven-layer network model. The layers germane to this discussion are the physical layer (Layer 1), the data-link layer (Layer 2), and the network layer (Layer 3). Layer 1 describes the physical and electrical properties of network components; Layer 2 describes how data is exchanged between different nodes in the network, e.g., switching packets based on network layer address.

Link-layer packet switching (Layer 2) can be either connectionless or connection-oriented. Examples of link layer protocols include Ethernet frame switching (connectionless), ATM cell switching (connection), and multiprotocol label switching (MPLS; connection). Ethernet media access control (MAC) addresses are globally unique, but they are not structured in a way so they can be easily summarized and distributed for routing purposes.

In recent years Ethernet has added a new header field called a virtual private network (VPN) that helps expand the networking capabilities of this Layer 2 network. Connection-oriented protocols use header information that has temporary local significance to make packet forwarding decisions. These headers are assigned when a connection is set up. Their address space can thus be small enough that it allows wire-speed packet forwarding.

Network layer packet switching (Layer 3) features a network-wide address space. This layer manages route selection and controls packet forwarding. With an increasing number of applications built on IP, the connectionless packet switching protocol is ubiquitous. The primary advantages of Layer 3 packet switching are that universal connectivity is easy to...
achieve, there are no call setups, and there are no connections to be managed. However, carriers still face issues of how to guarantee QoS and how to engineer a connectionless network.

**transport network**

Today, the North American synchronous optical network (SONET) fiber-optic interface standard and its international equivalent, synchronous digital hierarchy (SDH), are standards for the universal transport network. Despite being a time-division multiplexing (TDM) technology inherently optimized for voice, SONET/SDH can also be used to provide high-speed, high-capacity data transport (see figure 2). This has led to its widespread application in high-speed, IP-based wide area networks (WANs).

SONET/SDH is used as the underlying layer for higher-layer protocols, as in the case of IP over point-to-point protocol (PPP), which allows computers to connect to the network over a dial-up line. By capitalizing on SONET/SDH’s efficient use of available bandwidth, packet over SONET (PoS) has helped service providers in handling the explosive Internet growth. Its flexibility allows it to be used in a variety of transport applications, including in the core (network backbone infrastructures), on the edge, and in the metropolitan area. Other benefits of PoS include security, reliability, scalability, and manageability. The approach is also compatible with dense wavelength division multiplexing (DWDM).

**optical switching**

Engineers are working to develop intelligent optical switches for the data-heavy networks of tomorrow. Intelligent optical switches differ from SONET cross-connects in their cost, ability to scale to larger capacity, and control plane mechanisms. The routing protocols and dissemination of information on bandwidth availability and links are the same as with IP networks. The signaling protocols also are similar to those in packet networks, but these switches are based on circuit switching, which brings with it deterministic behavior. All connections are guaranteed, and the switches do not suffer from issues of contention, congestion, scheduling, or lost packets.

Next-generation optical switches will behave like packet switches in healing network failures—using spare capacity to restore the network following faults. Like connection-oriented packet switches, they can provision connections quickly and simply while moving traffic at eight to 10 times the flow of today’s network.

For the network of tomorrow, we recommend using a combination of SONET, Layer 2 switches, and IP routers in metro and regional networks to collect and aggregate traffic for virtual private networks and the Internet. The packet and circuit switches work together to set up direct connections across the core so the traffic gets assigned the proper bandwidth without passing through a handful of intermediate routers or Layer 2 switches. This architecture optimizes network efficiency.

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