Perhaps a more appropriate description for long-haul networks would be “switched networks.” These networks have long enough runs of wiring for repeaters to be occasionally necessary to reinforce the signals between nodes. The nodes can be end offices, toll offices, CSPs, or other telephone switching centers. The objective here is not to discuss the entire switching hierarchy—telephone plant facilities are much too large in scope—but only its fiber-optics applications. For the reader interested in communication systems based on switching circuits, see Reference 1.

A subscriber-to-subscriber connection is shown in Fig. 10-1. The end office is where all subscribers are connected (although only one to an office is shown here) by a two-wire loop, which is the common connection found in most homes. The transmission is bidirectional on this loop and separated at the subscriber instrument with two- to four-wire converters. The trunk between the end office and toll office may be either two-wire bidirectional or four-wire unidirectional (two wires in each direction). The long-haul transmission between two toll offices is usually a four-wire connection.

The two-wire subscriber loop usually consists of twisted pairs, and replacement of these facilities with fiber-optic waveguides is not very feasible at this time. Toll trunks and intertoll trunks, however, are of paramount interest. These require a high-capacity transmission; i.e., each of the lines may carry a multiplicity of subscriber transmissions at the same time over FDM channels, TDM channels, or combinations of both. As one may observe, Fig. 10-1 is somewhat simplified, but it illustrates where the trunks are located and how they relate to the subscriber loops.

In 1962, the first commercial digital PCM baseband system was installed for distances less than 50 miles. This system, designed for paired cables, was the T1 system. The T1 is composed of a TDM digital frame with 24 voice channels. The voice sampling rate is 8000 frames/sec and the total number of bits per frame is 8 bits/sample times 24 samples/frame, plus one framing bit, for a total of 193 bits/frame. The channel transmission rate is 1.544 Mbits/sec.

Before discussing the T1 format, a comparison should be made to determine how fiber optics can be used in place of wire pairs. Standard multimode fiber-optic cable has a bandwidth of 600 to 800 MHz-km. Therefore, multimode cable has a bandwidth of 7 to 10 MHz at 50 miles (80 km), which is adequate to meet the bandwidth requirement. The system may be attenuation-limited.
lowest loss multimode waveguide is approximately 1 dB/km. A system constructed with multimode waveguide would require a loss budget of approximately 80 dB, a figure very difficult to achieve. Single-mode waveguides, on the other hand, have bandwidths of 2 to 40 GHz-km and losses of 0.15 to 0.5 dB/km for certain wavelengths. Their use will reduce the loss budget to 12 to 16 dB, which can easily be accommodated with single-mode transmitter and receiver pairs. Later in the chapter, a complete loss budget will be generated for the T1 carrier system. This will give the reader some insight into why fiber optics is gaining such popularity.

A single-mode waveguide has sufficient bandwidth to accommodate a multiplicity of T1 carriers. The optical waveguide is physically much smaller than the wire pair and sometimes seems to offer nothing but advantages; in every bowl of cherries, however, there are a few pits. Water vapor is particularly damaging to optical cable. It increases loss brought about by OH\(^-\) and produces stress corrosion in the waveguide. Care must be taken when cabling fiber-optic