although 75-ohm video cable and mini-coaxial cable are also used. Copper cabling, when used at a rate of 100 MB/sec, has an effective range of 0 to 25 meters without sacrificing quality. Transmitting at half speed and quarter speed increases the effective distance of transmission. However, few companies manufacture half- or quarter-speed products. Copper is usually terminated with either an HSSDC or DB-9 male connector (on the DB-9 connector, the end with the pins is male). Although at this time DB-9 is a more common connector, HSSDC is quickly becoming more popular. See Table 3.1 for a comparison of media specification.

Table 3.1 Copper Media Type Comparison Chart

Media Type	Speed (MB/sec)	Optimal Distance (Meters)
Shielded Twisted Pair (Active)	100	0–30
Shielded Twisted Pair (Passive)	100	0–15
Video Cable	100	0–25
Shielded Twisted Pair (Active)	200	0–10
Video Cable	200	0–10
Shielded Twisted Pair (Active)	50	0–40
Video Cable	50	0–40

Values in table are estimated lengths based on optimal signal strength.

Copper is highly durable and easy to store, which makes it useful for a lab or area where devices are commonly plugged and unplugged, or when you are constantly connecting and disconnecting a device over a short distance to a number of different hosts. An advantage to using the DB-9 and HSSDC copper connectors is that there is only one way they fit into the complementary connector, which means it is impossible to cross a transmit and receive line, a common mistake for even experienced individuals dealing with fiber optics. Optical cabling is harder to terminate and can be susceptible to scratches. In addition, copper is a better choice in the cabinet short-length connection. For lengths longer than five meters, single or multimode optical fiber might be a better choice.

Multimode Optical Cabling

Multimode optical cable is available in 50 micrometers (µm) and 62.5 µm sizes. These measurements correspond to the diameter of the fiber—there is no speed difference between the two that affects Fibre Channel. Multimode optical cable is

available in 850 nanometer (nm) and 1300 nm wavelengths. The 850 nm wavelength is within the visible spectrum and is not harmful to your eyes. This is not true of 1300 nm wavelength lasers, which are not visible but could severely damage your retinas. Multimode optical fiber is terminated using a variety of optical connectors, including SC, LC, and MT-RJ (we discuss connector types later in the chapter). A 50 μm multimode fiber has an effective range between 0 and 500 meters at a 1 Gbit/sec rate (see Table 3.2 for specifications on other multimode fibers). The 62.5 μm fiber has about half the range of 50 μm fiber.

Multimode fiber is the more common media type and is inexpensive compared to single-mode fiber, although the two are coming closer together in price as the demand for single mode rises. Multimode transmitting and receiving components are also much less expensive, because multimode generally uses a concentrated LED rather than an actual laser. This is because multimode fiber is much wider in diameter than single-mode fiber.

Many multimode fibers have a feature called Open Fiber Control (OFC), which is a feature of the transmitter and receiver pairs. In OFC, the transmitter periodically transmits short bursts of light. When the receiver detects this light, it begins to transmit regularly and causes the other transmitter to go out of OFC mode. The OFC mechanism was designed to avoid the potential hazards of having unconnected lasers transmitting in a work environment. OFC is becoming a less common feature, since most multimode transmitters use LEDs rather than lasers and there is no associated safety risk.

Table 3.2 Multimode Optical Media Comparison

Media Type	Laser/ LED Type (nm)	Speed (MB/sec)	Optimal Distance (Meters)
50 μm multimode	850	100	2–500
62.5 μm multimode	850	100	2–300
50 μm multimode	850	200	2–300
62.5 μm multimode	850	200	2–90
50 μm multimode	850	50	2–1000
62.5 μm multimode	850	50	2–400

Values in table are estimated lengths based on optimal signal strength.

Single-Mode Optical Cabling

Single-mode optical fiber (Figure 3.2) is the most expensive media type, but preferable for long distances. It most often comes in 1300 nm wavelength, which is not visible and can be harmful to your eyes.

Figure 3.2 Single-Mode Fiber with SC Terminators

Single-mode optical fiber is approximately 9 μm in diameter. The small diameter makes light waves less likely to be altered over long distances, so for long-distance SANs, single-mode fiber is the best solution. Because of its small diameter, it also theoretically has the highest transmission speed potential (the theoretical limit is around 25 Tbit/sec, as opposed to multimode, which is around 10 Gbit/sec). Single mode is the ideal media to use for long interconnects.

Single-mode fiber itself is not significantly more expensive than multimode fiber or even copper—the added price is in the transmitting components, which use lasers rather than LEDs. Since the fiber has such a small diameter, it takes added precision to align the laser in the transmitter with the fiber. See Table 3.3 for specifications on single-mode fibers.

Table 3.3 Single-Mode Optical Media Comparison

Media Type	Laser/LED Type (nm)	Speed (Mb/sec)	Optimal Distance (Meters)
9 μm single mode	1300	100	2–10,000
9 μm single mode	1300	50	2–10,000
9 μm single mode	1300	200	2–2,000

Values in table are estimated lengths based on optimal signal strength.

WARNING

Any single-mode or multimode laser can damage your eyes if it is transmitted at 1300 nm. The 1300 nm wavelength is not in the visible spectrum, so you will not see a laser being transmitted like in 850 nm fiber. A 1300 nm laser is dangerous, because it can cause severe retina damage.

Connecting with Connectors

There are many different types of connectors, and no particular connector makes a difference in performance as long as the connection is clean. Some connectors are bonded, which means that the transmit and receive fibers are physically mounted in the same piece of plastic. This is usually acceptable, but for some less orthodox wiring systems it might be preferable to select connectors that have loose transmit and receive fibers. This section covers the most well-known types of connectors.

You should try to minimize the total number of connections and patches when building your SAN. As discussed earlier, light is reflected by poor connections and patches in the path between devices, so minimizing the number of patches between devices makes your SAN less susceptible to loss-of-signal errors.

The DB-9 Copper Connector

DB-9 is the standard copper connector, although more organizations are switching to HSSDC because of its improved reliability and smaller size. DB-9 has the same appearance as DB-9 serial cabling, so it is important to understand that they are not the same (Figure 3.3). DB-9 connectors have a metal D-shaped connector rim