Chapter 6
Fiber Optics Overview (III)
Objectives

- List of main features of fiber optics cables
- Fix problems with:
  - Splicing
  - Laser and LED transmitters
  - Driver incompatibility
  - Incorrect bending radius in installation
  - Shock and other installation issues
  - Interface to cable connectors
6.8 Troubleshooting

• 6.8.1 Introduction
  – Deal with problems on optical fiber cables
  – Problems can be caused by poor installation practices
  – Fibers are subjected to excessive tension or bending forces
  – Basic methods of testing fibers
  – How to locate faults on fiber optic systems
6.8.2 Standard troubleshooting approach (I)

- The standard approach for troubleshooting fiber optic systems:
  1. Observe the system status indicators and determine whether signals are being transmitted and received at both terminals.
  2. Determine whether the appropriate fibers are functional by either a continuity test or a qualitative insertion loss measurement between the patch panels.
  3. Once the faulty fiber is identified, clean the optical connectors and repeat the test.
  4. If the fault remains, swap the system onto a spare fiber by rearranging the patch cords on the patch panels at both ends.
6.8.2 Standard troubleshooting approach (II)

- The standard approach to troubleshooting fiber optic systems:
  5. Update the records to indicate the faulty fiber
  6. When a link does not have sufficient spare fibers available to maintain system integrity, then attempt fault localization using an OTDR
  7. On short lengths of fiber, total replacement may be more cost effective than expensive location and subsequent repair. This is particularly appropriate where a spare duct is available for the cable replacement
6.8.3 Tools required (I)

- **Continuity tester**
  - A fiber optic transmitter with a suitable fiber optic connector
  - Transmits a visible red light @ 650 nm
  - Transmits visible light over several kilometers
  - Finding fractures in fibers or bad splices by observing leaking out light and for identifying fibers at the end of a cable
6.8.3 Tools required (II)

- **Optical source**
  - High intensity light emitting diodes (LEDs) or visible lasers
  - Visible lasers produce a more powerful light and can provide more information to the technician than a LED
  - By coupling the fiber to a visible laser, problems with connectors, breaks in the fiber near connectors or splices can be located
  - Has a calibrated fiber optic transmitter
  - With an optical power meter for insertion loss testing of fibers
6.8.3 Tools required (III)

• Optical power meter
  – A fiber optic receiver with a suitable fiber optic connector
  – Displays the received optical power levels
  – Used with an optical source for insertion loss testing of fibers
6.8.3 Tools required (IV)

- **Optical time domain reflectometer (OTDR)**
  - Sends a short pulse of light down the fiber
  - Measures and records the light energy reflected back up the fiber
  - A reflection may be caused by the presence of a connector, splice, crack, impurity or break in the fiber
  - Calculate the distance to the reflection point by measuring the reflection time and knowing the refractive index of the fiber
6.8.3 Tools required (V)
6.8.4 Fiber installation rules

- General installation rules for installing fiber optic cabling systems
- Avoid long-term reliability problems
- Fibers break at any surface defects if subjected to excessive bending forces while under tension
- Cable bending radius
- Cable tension
6.8.4.1 Cable bending radius (I)

- The cable radius is not less than the minimum installation bending radius, 50 mm for standard fiber
- Avoid sharp bends along the installation route
- Ensure that the conduit or the cable tray is constructed with no sharp edges, use curved construction components
- Ensure the cables are laid on to a flat surface, no heavy objects will be laid on to the cables in the future
6.8.4.1 Cable bending radius (II)

- Avoid putting kinks or twists into the cable, pulling the cable directly.
- A minimum bending radius applies to the long-term installed cable.
- Macro-bends in the fibers are caused by sharp bends which lead to fiber breakage and additional signal attenuation.

Macro-bend losses:
6.8.4.2 Cable tension (I)

– Surface defects and micro-cracks on a optical fiber will be caused by a longitudinal tensile force
– Optical fibers have some elasticity, the fiber may theoretically stretch as much as 9% before breaking
– In practice, to permanent strains of less than 0.2% to avoid promoting premature failures
– The maximum permissible installation cable tension is specified by the manufacturer
– Avoid sudden, short sharp jerking, should be pulled in an easy smooth process
– When pulling cable off a large drum, ensure that the cable drum is smoothly rotated by one team member to feed off the cable
6.8.4.2 Cable tension (II)

– To minimize cable stress after the installation is complete
– A slack final resting condition will help to ensure a long operating life of the fiber optic cable
– Slack is left in the junction boxes at the completion of the installation to reduce overall stress in the cable
– Use intermediate junction boxes to reduce cable tension when a lot of bends in the cable route
– The cable can be pulled through at these points, laid out in a large figure ‘8’ pattern on the ground and then pulled into the next section to avoid kinking and twisting of the cable
– Curved guides or block systems may be used in the junction boxes where the cable changes direction
6.8.5 Clean optical connectors (I)

- Dust particles and other particles can cover the core area of fiber and may damage the connector
- MUST clean connectors completely
- Wipe the end face and ferrule of the connector with some isopropyl alcohol on a lint free tissue
- Cleaning tissues is obtained in sealed packages already impregnated with alcohol
6.8.5 Clean optical connectors (II)

- Cassette type cleaners, a dry tape which is advanced every time the cassette is opened
- Use a can of compressed gas to clean adapters and bare fibers
- Fit dust caps to all unused patch panel ports
6.8.6 Locating broken fibers

• 6.8.6.1 Continuity testing
  – Continuity test simply checks that the fiber is continuous from one end to the other
  – Shining a powerful torch beam (or laser pointer) into one end of the fiber and observing the light coming out of the other end
  – Cost effective method for multimode fibers rather than single mode fiber since the difficulty of light coupling into the fiber
  – 650 nm visible red light to find fractures in fibers or bad splices
  – Limited application, as it is of no use in finding faults in buried cables or aerial cables
  – User should not look into fiber groups at the end of cables if any fibers on the system at any location are connected to lasers
6.8.6.2 Insertion loss testing (I)

- Measure the attenuation of the length of fiber to qualify a fiber optic system
- Carried out with a power source and a power meter
- The power meter is calibrated to the power source by connecting a short piece of optic fiber approximately 2 m in length
- The power source is set to transmit a level of $-10 \text{ dBm} \ (0.1\text{mW})$ and the power meter then adjusted accordingly to read $-10 \text{ dBm}$
- Same optic fiber type between calibrated fiber and tested fiber
- Same wavelength as the installed system equipment
- Same source and detector types
- Same connectors are used for calibration as are used in the installation
6.8.6.2 Insertion loss testing (II)

- The insertion loss through the cable section caused by the optic fiber, splices and the connectors
- Attenuation (dB) = $-10 \log \left( \frac{P_O}{P_I} \right)$
  - $P_O$ is power out of the fiber (in mW)
  - $P_I$ is power into the fiber (in mW)
- Insertion loss measurement be performed in both directions of an installed cable
6.8.6.3 Optical time domain reflectometer (I)

- Optical time domain reflectometer (OTDR)
- The only method of analyzing the losses along an individual fiber
- Sends a short pulse of light down the fiber and measures and records the light energy that is reflected back up the fiber
- A reflection may be caused by the presence of a connector, splice, crack, impurity or break in the fiber
- Calculate the distance to the reflection point by measuring the time, it takes for the reflected light to return to the source and knowing the refractive index of the fiber
- Impurities in the glass will cause continuous low level reflection as the light travels through the glass fiber, due to Rayleigh scattering (backscatter)
6.8.6.3 Optical time domain reflectometer (II)

- The strength of the backscattered signal received at the source gradually drops as the pulse moves away from the source. This is seen on an OTDR display as a near linear drop in the received reflected signal and the slope of this line is the attenuation of the fiber (dB per km).
- Do not provide accurate readings of irregularities and losses in the fiber for the first 15 m of the cable.
- The pulse length and its rise time from the OTDR are comparatively large when compared to the time it takes for the pulse to travel the short distance to the point of reflection within this 15 m and back.
- For shorter local cable running less than 200 m, there is not a lot to be gained from carrying out an OTDR test unless there are connectors and splices along the cable route.
6.8.6.3 Optical time domain reflectometer (III)

Point (6) illustrates a splice where the cores of the fibers are well matched for light traveling in the direction away from the source.

- The y-axis of the plot shows the Relative amplitude of the light signal that has reflected back to the source and the x-axis Represents time. The time base is directly translated and displayed as distance by the OTDR.

- The sudden peaks that appear along the slope are the points where reflections have occurred and light that has reflected back to the source is stronger than the backscatter.

Point (7) shows the noise floor of the instrument. This is the lowest sensitivity of received signal that the device can accept.
6.8.6.3 Optical time domain reflectometer (IV)

- **Four main reflection points in their order of decreasing magnitude**
  1. Reflection from the un-terminated end of the fiber
  2. Reflection from a connector
  3. Reflection from a splice
  4. Reflection from a hairline crack in the fiber
  5. Backscatter

- **After each of the reflections, the slope of the attenuation curve drops suddenly**

- **Represents the loss introduced by the connector, splice or imperfection in the fiber**
6.8.6.3 Optical time domain reflectometer (V)

- OTDR testing can provide very accurate fault analysis over long lengths of fiber
- A resolution of 1 m for fault location and .01 db for in line losses is available
- Operate with a range up to 200 km
- Relatively easy to use and special analysis software packages are available for downloading the test results and carrying out detailed analysis if required
- Unfortunate downside with OTDR technology is that it is generally very expensive
6.8.6.3 Optical time domain reflectometer (VI)

- Different fibers are joined together, this connection may represent a change in refractive index, core size, modal properties and/or material properties of the fiber.
- The OTDR test should be carried out on every optical fiber in a cable while it is still on the reel prior to installation to ensure that faulty fibers are not installed.
- Once the cable has been installed, the OTDR tests should be carried out again on every optical fiber.
- The results of the pre-installation and the post-installation tests should be kept as part of the commissioning documentation.
6.8.6.3 Optical time domain reflectometer (VII)

- OTDR measurements are a relative measurement rather than an absolute measurement.
- The wavelength at which OTDR operates is not important.
- The loss of a connector or splice might be different when measured from each direction into the optic fiber.
- The length of the cable is not going to be the length of the fibers for the case of some fiber optic cables are constructed so that the fibers are laid in a helical fashion around the center of the cable.
- Difficult to determine the distance to faults.
6.8.6.3 Optical time domain reflectometer (VIII)

- Manufacturer will generally provide a ratio of fiber length to cable length.
- Used to calculate the exact cable distance to the fault from the OTDR distance reading.
- An OTDR measurement is performed on a known length of cable (generally 1 km) and the ratio is calculated as:

\[
\frac{\text{Length of fiber in 1 km of cable}}{1 \text{ km}} = \frac{\text{OTDR Distance Reading}}{\text{Fiber/Cable Ratio}}
\]

Distance to fault = \[
\frac{\text{OTDR Distance Reading}}{\text{Fiber/Cable Ratio}}
\]
Thank you!

Any questions?