Supporting Cabling and Physical Installations

Networks Module 2.0

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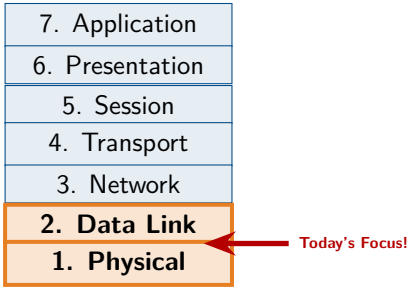
Intro to Networking

Outline I

Review: The OSI Model Foundation

- In Module 1, we learned the OSI model has seven layers that work together for network communication.
- Today we focus on **Layer 1 (Physical)**—the actual cables, connectors, and electrical/light signals.
- Layer 2 (Data Link) depends entirely on Layer 1 working correctly.
- Remember: if Layer 1 isn't working, *nothing else matters!*



Layer 1 = The Foundation

The fanciest software can't send data through a broken cable.

Review: Why Physical Infrastructure Matters

- In Module 1, we learned that data travels as **bits** (1s and 0s).
- Today's big question: *How do those bits actually travel from one device to another?*
- Three main options for transmitting bits:
  - **Electrical signals** on copper cables
  - **Light pulses** through fiber optic cables
  - Radio waves (wireless—a future module)
- The cable type you choose affects **speed**, **distance**, **reliability**, and **cost**.

Module 1 Recap

- Bits: 1s and 0s
- PDU at Layer 1: Bits
- Layer 1 devices: Cables, hubs, NICs

Today's Goal

Learn which cables to use and when—and how to install and troubleshoot them.

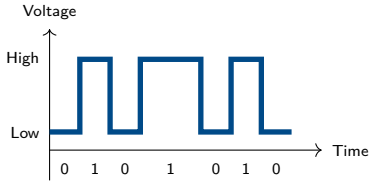
Learning Outcomes I

After completing this module, you will be able to:

- Explain how **electrical signals** and **light pulses** represent data at the Physical Layer.
- Identify and compare **copper cable types** including UTP, STP, coaxial, and twinax.
- Describe **cable categories** (Cat5e, Cat6, Cat6a) and their speed/distance capabilities.
- Differentiate between **multimode fiber (MMF)** and **single-mode fiber (SMF)**.
- Apply **T568A** and **T568B** wiring standards for structured cabling installations.
- Select appropriate **connectors** (RJ-45, LC, SC, ST) for different cable types.
- Diagnose common cabling problems using **cable testers** and troubleshooting tools.
- Plan physical infrastructure considering **environmental factors**, safety codes, and best practices.

How Does Data Travel on a Wire?

- Computers represent data as **bits**—1s and 0s.
- On copper cables, bits travel as **electrical voltage changes**.
- Higher voltage = 1, lower voltage = 0 (simplified).
- **Baseband signaling**: The entire cable carries one signal at a time—like a one-lane road.
- This is why cable quality matters: poor cables distort the voltage changes, corrupting your data!



Analogy

Think of Morse code with a flashlight: on = 1, off = 0. Now imagine doing that billions of times per second!

Key Point

Ethernet uses baseband: one conversation at a time per cable.

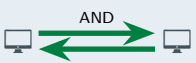
Half-Duplex vs Full-Duplex

Half-Duplex

- Only **one device** can transmit at a time.
- Like a **walkie-talkie**: "Over!"
- Must wait for the other person to finish.
- Old **hubs** forced half-duplex.
- If two devices transmit together = **collision**.

Full-Duplex

- **Both devices** can transmit simultaneously.
- Like a **phone call**: both people can talk.
- No waiting, no collisions.
- Modern **switches** enable full-duplex.
- Effectively **doubles** throughput!

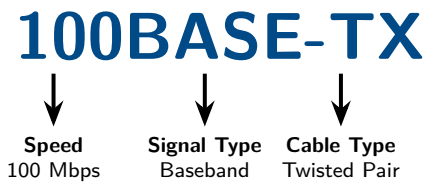


Why This Matters

A 1 Gbps connection in full-duplex can send AND receive 1 Gbps simultaneously—twice the effective bandwidth of half-duplex!

Ethernet Standards: Reading the Code

- The **IEEE 802.3** committee defines Ethernet standards.
- Standard names follow a pattern—once you crack the code, they're easy to read!



Common Suffixes

T/TX = Twisted pair copper
SX = Short-range fiber
LX = Long-range fiber
SR/LR = Short/Long reach (10G+)

Practice Reading

1000BASE-T = ?
1000 Mbps, baseband, twisted pair

10GBASE-SR = ?
10 Gbps, baseband, short-range fiber

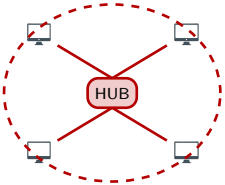
Collisions: A Problem We Solved

- A **collision** occurs when two devices transmit at the same time—the signals get scrambled.
- Old solution: **CSMA/CD** (Carrier Sense Multiple Access with Collision Detection).
- CSMA/CD means: "Listen before you talk; if someone else is talking, stop and wait."
- **Hubs** share one collision domain—all devices compete for the same "airtime."
- **Switches** give each port its own collision domain—no more collisions!

Analogy

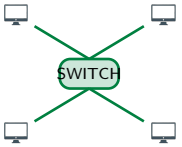
Hub = one conversation in a crowded room (everyone talks over each other). Switch = private phone lines for everyone.

Hub (Shared)



1 Collision Domain

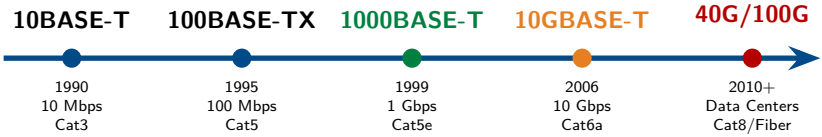
Switch (Separate)



4 Collision Domains

Ethernet Speeds: Then and Now

- Ethernet has evolved dramatically since the 1980s—each generation brought faster speeds.
- Importantly, each speed increase often required **better cables** to work reliably.



Today's Standard

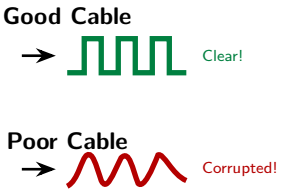
Gigabit Ethernet (1000BASE-T) is the default for most offices and homes.

Legacy Alert

If you see 10 or 100 Mbps, the network likely needs an upgrade!

Why Do Faster Speeds Need Better Cables?

- Faster speeds mean more bits packed into the same amount of time.
- It's like speaking faster—you need **clearer audio** to understand rapid speech.
- Higher frequencies (more bits/second) are more vulnerable to:
  - **Attenuation**: Signal gets weaker over distance
  - **Crosstalk**: Signals bleed between wire pairs
  - **EMI**: External interference corrupts data
- Better cables have: tighter twists, better shielding, stricter manufacturing standards.



Cable Categories

Higher **Cat** numbers mean cables built to stricter specs for faster speeds.

The Bottom Line

You can't run 10 Gbps on old Cat5 cable—the signal degrades too much!

Ethernet Standards Comparison

Standard	Speed	Cable	Max Distance	Common Use
100BASE-TX	100 Mbps	Cat5	100 m	Legacy networks
1000BASE-T	1 Gbps	Cat5e	100 m	Office standard
10GBASE-T	10 Gbps	Cat6a	100 m	High performance
1000BASE-SX	1 Gbps	MMF	550 m	Building backbone
1000BASE-LX	1 Gbps	SMF	5 km	Campus links
10GBASE-SR	10 Gbps	MMF	400 m	Data center
10GBASE-LR	10 Gbps	SMF	10 km	Long-distance

Copper (Top Section)

Best for: Short runs inside buildings. Limited to 100 meters maximum.

Fiber (Bottom Section)

Best for: Long distances, between buildings, high-interference areas.

Rule of Thumb

For new installations: Cat6 minimum (future-proofs for 10G at shorter distances), Cat6a if budget allows.

Case Study: The Addams Mansion Network

▶ Case Study: The Addams Mansion Network

Gomez Addams wants to upgrade the mansion's aging network. Currently, the network uses old 100 Mbps switches, and Wednesday complains that her downloads are painfully slow.

Lurch inspects the wiring closet and reports:

- All cables are labeled "Cat5e"
- The longest cable run is 80 meters (from Pugsley's room to the basement)
- The cables appear to be in good condition

Gomez asks: "How fast can we go without replacing all the cables?"

Review Questions

1. What is the maximum speed Cat5e cabling can support?
2. Is the 80-meter cable run within acceptable limits?
3. What would the Addams family need to change to achieve 10 Gbps?

Case Study Solution: The Addams Mansion Network

✓ Solution: The Addams Mansion Network

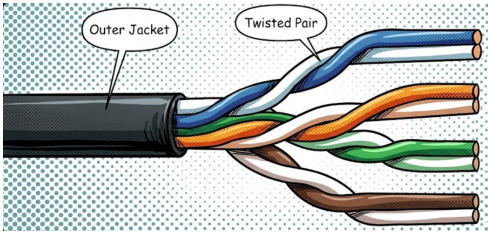
1. Cat5e supports **1000BASE-T (1 Gbps)**—that's a 10x improvement over their current 100 Mbps network!
2. Yes! Cat5e supports runs up to **100 meters**, and 80 meters is well within spec.
3. For 10 Gbps (10GBASE-T), they would need:
   - Upgrade cabling to **Cat6a** throughout the mansion
   - Purchase new **10 Gbps switches**
   - Ensure all network adapters support 10 Gbps

Key Insight

Sometimes you only need new **switches**, not new cables! The Addams family can get 10x faster speeds just by upgrading their switches to Gigabit—the Cat5e cables they already have will work fine.

Why Twisted Pair? The Science of Interference

- Electrical signals create **electromagnetic fields** around wires.
- Nearby power cables, motors, and fluorescent lights cause **EMI (Electromagnetic Interference)**.
- EMI can corrupt your data—turning 1s into 0s!
- **The solution**: Twist the wire pairs together.
- When wires are twisted, interference affects both wires equally—the receiver can **subtract out** the noise.
- More twists per inch = better protection.



Fun Fact

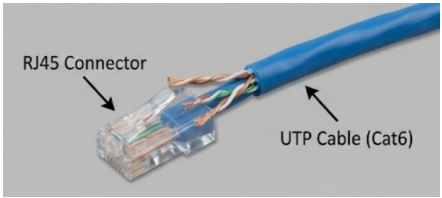
This technique was invented for telephone lines in the 1880s—it's been protecting signals for over 140 years!

Why Twisting Works

Each wire in a pair picks up the *same* interference. The receiver compares the two signals and cancels out anything that's identical—the noise disappears!

Unshielded Twisted Pair (UTP)

- **UTP** is the most common network cable—probably what's in your walls right now!
- Contains **4 pairs** of wires (8 wires total), each pair twisted at a different rate.
- **No metal shielding**—relies on twisting alone for EMI protection.
- Why different twist rates? Prevents **crosstalk** between the pairs inside the same cable.



Advantages

- Inexpensive
- Flexible and easy to work with
- Simple to terminate (attach connectors)

Disadvantage

Susceptible to strong EMI—not ideal for factories or near

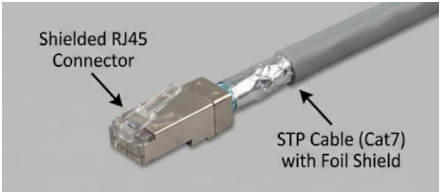
The 4 Pairs

- Orange pair
- Green pair
- Blue pair
- Brown pair

Each pair has one solid and one striped wire.

Shielded Twisted Pair (STP)

- **STP** adds metal shielding for extra EMI protection—like armor for your cable!
- Different shielding types exist:
  - **STP**: Each pair individually wrapped in foil
  - **ScTP/FTP**: One overall foil shield around all pairs
  - **S/FTP**: Both individual AND overall shields (maximum protection)
- **When to use STP**: Factories, hospitals, near electrical motors—anywhere with heavy EMI.



Important: Grounding Required!

STP cables **must be properly grounded**. Ungrounded shielding actually becomes an antenna and makes interference *worse*!

STP vs UTP

	UTP	STP
Cost	$	$$$
Flexibility	High	Lower
EMI Protection	Good	Excellent
Installation	Easy	Harder

Cat Ratings: What Do the Numbers Mean?

- **Category (Cat)** ratings are performance specifications—like a grade for cable quality.
- Higher category = tighter manufacturing tolerances = better performance.
- Each category specifies:
  - Maximum **frequency** (measured in MHz)
  - Maximum **crosstalk** allowed
  - Maximum **attenuation** allowed
- Higher categories are **backward compatible**—Cat6 cables work with Cat5e equipment.
- The cable is only as good as its weakest component—connectors and patch panels must match!

Analogy

Cat ratings are like car safety ratings. A 5-star car isn't "better" in normal driving, but performs better in demanding situations.

Frequency Matters

Higher frequencies carry more data but are harder to transmit cleanly.

Cat5e	100 MHz
Cat6	250 MHz
Cat6a	500 MHz
Cat7	600 MHz
Cat8	2000 MHz

Pro Tip

Install one category **higher** than you need today—it's cheaper than rewiring later!

Cat Cable Comparison

Category	Max Speed	Bandwidth	10G Distance	Typical Use
Cat5	100 Mbps	100 MHz	—	*Obsolete*
Cat5e	1 Gbps	100 MHz	—	Home, small office
Cat6	10 Gbps	250 MHz	55 m	Office standard
Cat6a	10 Gbps	500 MHz	100 m	Recommended minimum
Cat7	10 Gbps	600 MHz	100 m	Specialized uses
Cat8	25–40 Gbps	2000 MHz	30 m	Data centers

For New Installations

Cat6a is the sweet spot—supports full 10 Gbps at 100 meters and is reasonably priced.

Watch Out!

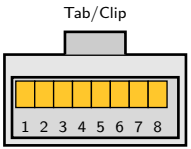
Cat6 only supports 10 Gbps up to **55 meters**. Beyond that, it falls back to slower speeds.

The "e" and "a" Suffixes

The "e" in Cat5e means "enhanced." The "a" in Cat6a means "augmented." Both indicate improved versions of the base standard.

The RJ-45 Connector

- **RJ-45** is the standard Ethernet connector you see everywhere.
- Technically called **8P8C**: 8 positions, 8 contacts—uses all 4 wire pairs.
- The clear plastic body lets you visually inspect the wire order.
- **Proper crimping is critical**—most cable problems trace back to bad connectors!
- The tab (clip) locks the connector into the port—a broken tab means an unreliable connection.



Pin 1 is on the LEFT
(with tab facing away)

Common Mistake

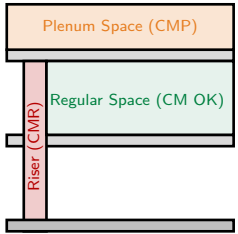
Don't confuse RJ-45 with **RJ-11** (telephone)! RJ-11 is smaller with only 6 positions. Forcing the wrong connector damages ports.

RJ-45 vs RJ-11

	RJ-45	**RJ-11**
Positions	8	6
Contacts	8	2–4
Use	Ethernet	Phone/DSL
Width	Wider	Narrower

Plenum and Riser Cable: Fire Safety Matters

- **Plenum space**: The area above ceilings or below floors used for air circulation (HVAC).
- Standard PVC cable jackets produce **toxic fumes** when burned—HVAC systems spread these fumes throughout the building!
- **Plenum-rated (CMP)**: Special fire-resistant, low-smoke jacket required in air handling spaces.
- **Riser-rated (CMR)**: For vertical runs between floors—prevents fire from "climbing" through cable holes.
- **CM/CMX**: Standard jacket—fine for open areas but **not** for plenum or riser spaces.



Building Codes Are Serious

Using the wrong cable type can fail inspection, void insurance, and endanger lives. Always check local codes!

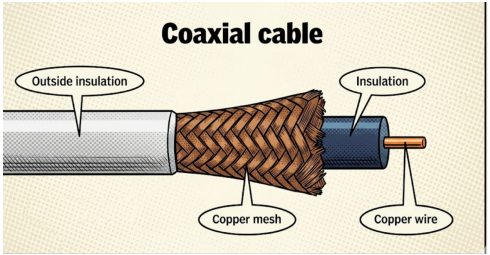
Cost Comparison

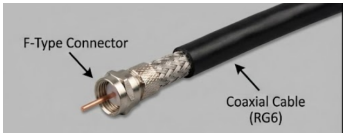
CM (Standard)	$
CMR (Riser)	$$
CMP (Plenum)	$$$

Plenum costs 2–3x more, but it's required by code.

Coaxial Cable: Still Around!

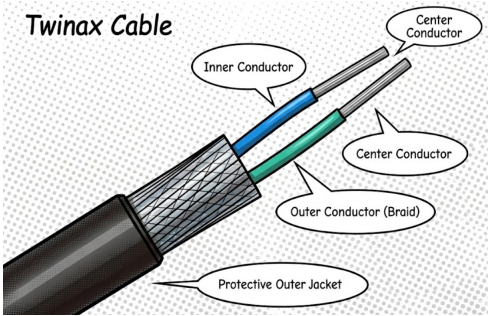
- **Coaxial cable** has a single copper conductor surrounded by insulation, braided shield, and outer jacket.
- Different design than twisted pair—the shield completely surrounds the signal wire.
- **Where you'll still see it**:
  - Cable TV and cable internet modems
  - Older security camera systems (CCTV)
  - Some legacy network connections
- **RG-6**: Modern standard, thicker, better for longer runs and higher frequencies.
- **RG-59**: Older/thinner, shorter distances only—being phased out.





Twinaxial Cable and Direct Attach Copper (DAC)

- **Twinaxial (Twinax)** cable has **two** conductors instead of coax's one.
- **Direct Attach Copper (DAC)**: Pre-made twinax cables with connectors already attached.
- **Where it's used**: Short connections in data centers (between switches, to servers).
- Maximum distance: Only about **7–15 meters**.



Why Use DAC?

- **Cheaper** than fiber
- **Lower power** consumption
- **Simpler** installation

Common DAC Speeds

- 10 Gbps (SFP+)
- 25 Gbps (SFP28)
- 40/100 Gbps (QSFP+)

Case Study: Wiring the Addams Mansion Conservatory

▶ Case Study: Wiring the Addams Mansion Conservatory

Morticia wants to add network connections to her conservatory (greenhouse) where she tends her carnivorous plants. The network cables need to run through the air handling space above the hallway ceiling.

Additionally, Gomez wants to connect the mansion's old security cameras, which use RG-59 coaxial cable. Some camera runs are over 150 meters to cover the cemetery.

Uncle Fester offers to buy the cheapest cables he can find online.

Review Questions

1. What type of cable rating is required for the air handling space?
2. Why can't Fester just buy the cheapest cable available?
3. Is RG-59 a good choice for the 150-meter camera runs? What would you recommend?

Case Study Solution: Wiring the Addams Mansion Conservatory

✓ Solution: Wiring the Addams Mansion Conservatory

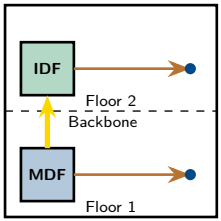
1. The air handling space requires **plenum-rated (CMP)** cable.
2. The cheap cables are likely standard **CM/CMX rated**:
   - Using them in plenum space violates building codes
   - They produce toxic fumes if burned—endangering the whole family
   - The installation would fail inspection
3. **RG-59 is NOT recommended** for 150 meters—it's designed for shorter runs and will have too much signal loss. Better options:
   - Upgrade to **RG-6** coaxial (better for long runs)
   - Even better: Replace with **IP cameras** using Cat6—more flexible and higher quality

Key Lesson

"Cheap" cables can cost more in the long run: failed inspections, safety hazards, and poor performance. Always match the cable to the requirements!

Structured Cabling: Organizing the Chaos

- Without a plan, cabling becomes a tangled mess—impossible to troubleshoot or expand.
- **Structured cabling** is a standardized approach to organizing network infrastructure.
- **MDF (Main Distribution Frame)**: The primary network room with core equipment.
- **IDF (Intermediate Distribution Frame)**: Secondary closets on each floor or wing.



Benefits

Easier troubleshooting, simpler moves/adds/changes, professional appearance, meets standards.

Key Terms

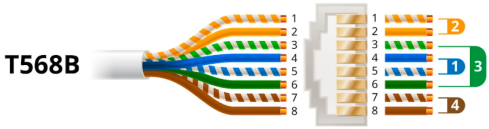
Backbone: MDF to IDF (often fiber)
Horizontal: IDF to wall jacks (copper)

T568A and T568B Wiring Standards

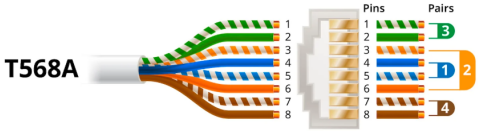
- These standards define which colored wire goes to which pin in an RJ-45 connector.
- Both work equally well—the key is **consistency**.
- **T568B**: Most common in commercial installations.
- **T568A**: Required for U.S. government contracts.

Critical Rule

Use the **same standard on both ends** of a cable! Mixing creates a crossover cable (usually not what you want).



T568B (Most Common)



T568A (Government Standard)

Straight-Through vs Crossover Cables

Straight-Through Cable

- Same standard on **both ends** (T568B–T568B)
- Connects **unlike** devices
- PC to switch, switch to router
- **99% of cables you'll make**

Crossover Cable

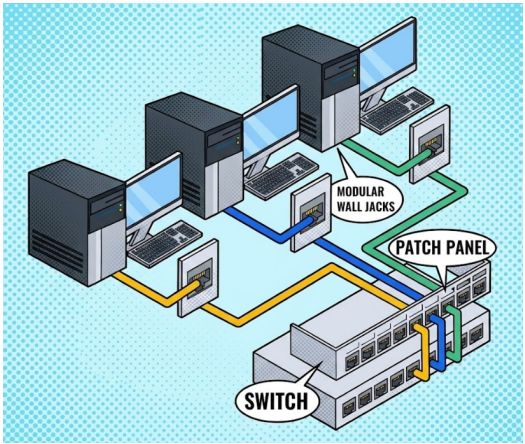
- Different standard on each end (T568A–T568B)
- Connects **like** devices
- PC to PC, switch to switch
- **Rarely needed today**

Good News: Auto-MDI-X

Most modern switches and NICs have **Auto-MDI-X**—they automatically detect and adapt to either cable type. Crossover cables are becoming obsolete!

Patch Panels

- A **patch panel** is a central termination point for horizontal cabling.
- **Rear**: Permanent cables from wall jacks are "punched down."
- **Front**: RJ-45 ports connect to switches via short patch cables.
- This design protects permanent wiring—only patch cables get plugged/unplugged.



Why Use Patch Panels?

- Moves and changes are easy—just swap patch cables
- Permanent wiring stays untouched
- Clean, organized cable management

Termination Tools

Crimping Tool

- Attaches RJ-45 connectors to cable ends
- Squeeze firmly for solid connection
- A bad crimp = unreliable network

Punchdown Tool

- Pushes wires into 110 blocks
- Cuts excess wire automatically
- Listen for the “click”!

Cable Installation Best Practices

Do This

- Maintain proper **bend radius**—no sharp bends (minimum 4x cable diameter)
- Keep runs under **90 meters** for horizontal cabling (10m for patch cables)
- Cross power cables at **90° angles**
- **Label both ends** immediately
- Test every cable after termination

Don't Do This

- Don't bend cables sharply—damages internal wires
- Don't run parallel to power cables—causes EMI
- Don't exceed 25 lbs pull tension
- Don't untwist pairs more than 0.5 inch at terminations
- Don't leave cables unlabeled

The 90/10 Rule

Total cable path = 100 meters max. Permanent horizontal cabling $\leq$ 90m, patch cables $\leq$ 10m combined.

Why Fiber Optic?

- Copper cables transmit **electrical signals**—fiber transmits **pulses of light**.
- Light is immune to **electromagnetic interference**—no crosstalk, no EMI problems!
- Fiber supports **much longer distances**: kilometers instead of 100 meters.
- Higher **bandwidth potential** for future upgrades.

Trade-offs

More expensive, harder to terminate, requires special tools, more fragile than copper.

When to Choose Fiber

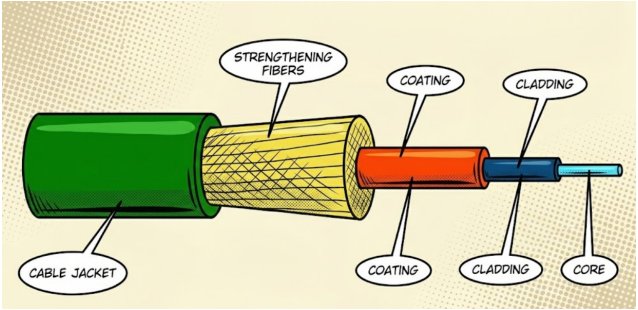
- Distance over 100 meters
- High EMI environments
- Between buildings
- Need for extreme speed
- Security (harder to tap)

Fun Fact

Light in fiber travels at about 200,000 km/sec—fast enough to circle Earth 5 times per second!

Fiber Optic Cable Structure

- **Core**: Thin glass or plastic center where light travels.
- **Cladding**: Surrounds the core; reflects light back inward through **total internal reflection**.
- **Buffer coating**: Protective layer around cladding.
- **Jacket**: Outer protection (may include strength members).



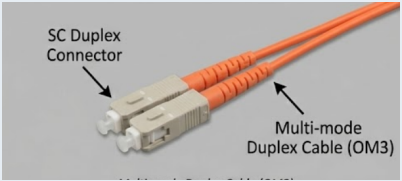
How Light Stays Inside

The cladding has a lower *refractive index* than the core. When light hits the boundary at a shallow angle, it bounces back—like skipping a stone on water.

Single-Mode vs Multimode Fiber

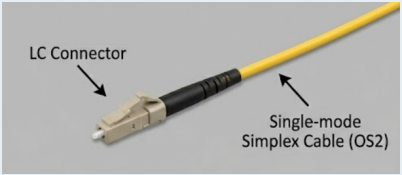
Multimode Fiber (MMF)

- Larger core: 50–62.5 microns
- Light bounces along multiple paths
- LED or VCSEL light source
- Shorter distances: up to 550m
- **Orange** or **aqua** jacket
- Less expensive equipment



Single-Mode Fiber (SMF)

- Tiny core: 8–10 microns
- Light travels straight path
- Laser light source
- Long distances: up to 80+ km
- **Yellow** jacket
- More expensive equipment

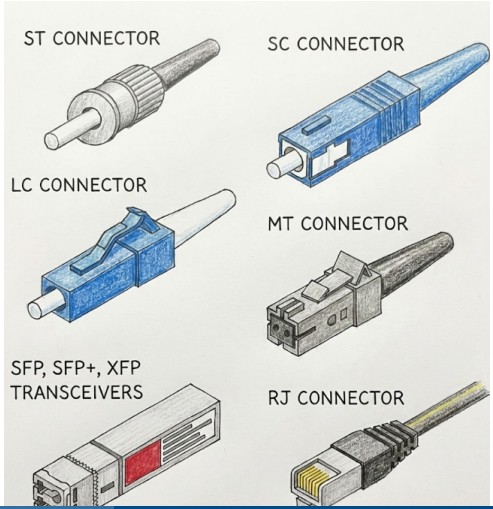


Quick Decision Guide

Inside a building? Use MMF—cheaper and sufficient. **Between buildings?** Use SMF—handles the distance.

Fiber Optic Connector Types

- **LC (Lucent Connector)**: Small form factor, most popular today, push-pull latch.
- **SC (Subscriber Connector)**: Square shape, push-pull, still common.
- **ST (Straight Tip)**: Bayonet twist-lock, legacy installations.
- **MPO/MTP**: Multi-fiber connector (12–24 fibers), used in data centers.



Fiber Splicing and WDM

Fiber Splicing

- **Fusion splice**: Melts fibers together permanently—lowest signal loss (0.1 dB)
- **Mechanical splice**: Aligns fibers in a holder—quicker but higher loss (0.5 dB)
- Fusion requires expensive equipment; mechanical is field-friendly

Fiber Distribution Panel

Central termination point for fiber cables—similar to copper patch panels.

WDM: More Data, Same Fiber

Wavelength Division Multiplexing sends multiple signals on different colors (wavelengths) of light simultaneously.

- **CWDM**: Coarse WDM—up to 18 channels, cheaper
- **DWDM**: Dense WDM—80+ channels, expensive

Analogy

WDM is like sending red, blue, and green flashlight beams through the same fiber—each carries different data!

Case Study: Wednesday's Cemetery Office

▶ Case Study: Wednesday's Cemetery Office

Wednesday is setting up a writing office in the cemetery gatehouse, which is 300 meters from the mansion. She needs a fast, reliable network connection for uploading her novels.

Uncle Fester suggests running Cat6a cable underground through the old electrical conduits (which still have some active 240V lines for the crypt lighting).

Lurch suggests fiber optic cable instead.

Review Questions

1. Can Cat6a reach 300 meters? Why or why not?
2. What two advantages would fiber have in this scenario?
3. Should Wednesday use single-mode or multimode fiber?

Case Study Solution: Wednesday's Cemetery Office

✓ Solution: Wednesday's Cemetery Office

1. **No**—Cat6a maximum distance is 100 meters. At 300 meters, the signal would be completely unusable (3x over the limit!).
2. Fiber advantages for this scenario:
   - **Distance**: Easily handles 300 meters (MMF goes to 550m)
   - **EMI immunity**: Won't be affected by the 240V electrical lines in the conduit
3. **Multimode (MMF)** is the better choice:
   - 300m is well within MMF range (up to 550m)
   - MMF transceivers cost less than SMF
   - No need for SMF's multi-kilometer capability

Key Lesson

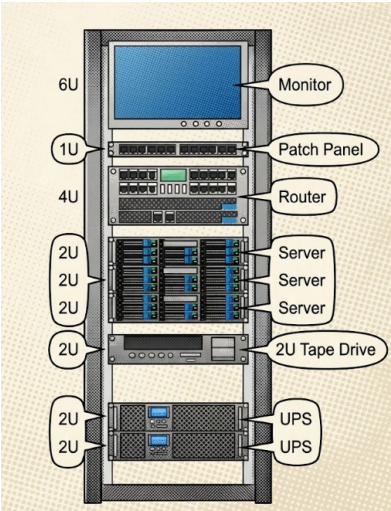
When copper can't reach and EMI is present, fiber is the answer. Choose MMF for building-scale distances, SMF for campus or beyond.

Rack Systems

- Network equipment mounts in standardized **racks** for organization and airflow.
- Height measured in **rack units (U)**—each U is 1.75 inches.
- Standard width: **19 inches** (universal fit).
- **Two-post racks**: Open design for patch panels, lighter equipment.
- **Four-post racks/cabinets**: For servers, heavy equipment; lockable for security.

Planning Considerations

Weight capacity, cable management, airflow (front-to-back), physical security, future expansion.



Environmental Factors: Temperature and Humidity

Temperature

- **Ideal**: 64–75°F (18–24°C)
- **Too hot**: Components overheat, fail early, data corruption
- **Too cold**: Condensation when warming up—water damages electronics

Equipment generates significant heat—proper **HVAC** cooling is critical!

Humidity

- **Ideal**: 40–60% relative humidity
- **Too dry**: Static electricity discharge damages components
- **Too humid**: Corrosion and potential electrical shorts

Use **environmental monitoring** systems with alerts.

Hot Aisle / Cold Aisle

Data centers arrange racks so all equipment intakes face one aisle (cold) and exhausts face another (hot). This prevents hot air from recirculating into equipment.

Power Management

UPS (Uninterruptible Power Supply)

- Battery backup during outages
- Keeps systems running for graceful shutdown
- Also conditions power (removes spikes/sags)

PDU (Power Distribution Unit)

- Distributes power within a rack
- Like a smart power strip
- May include monitoring/remote control

Other Power Considerations

- **Surge protector**: Guards against voltage spikes
- **Generator**: Long-term backup after UPS depletes
- **Grounding**: Essential for safety

Calculate Before Installing!

Add up all equipment power requirements (watts). Don't overload circuits—leave 20% headroom.

Fire Suppression

- Standard **water sprinklers destroy electronics**—avoid in server rooms!
- **Clean agent systems** (FM-200, Novec 1230) suppress fire without damaging equipment.
- **Pre-action sprinklers**: Require two triggers (smoke AND heat) before water flows.
- **VESDA**: Very Early Smoke Detection—catches fires before they start.

Fire Extinguisher Classes

- **Class A**: Ordinary combustibles
- **Class B**: Flammable liquids
- **Class C**: Electrical fires

Use **Class C** (or ABC-rated) near network equipment!

Never Disable Fire Systems

Equipment is replaceable. Data can be backed up. Lives cannot be replaced.

Common Cable Problems

Signal Problems

- **Attenuation**: Signal weakens over distance—like shouting across a field
- **EMI**: External interference corrupts the signal
- **Crosstalk**: Signal bleeds between wire pairs inside the same cable

Physical Problems

- **Open**: Broken wire—no connection
- **Short**: Two wires touching that shouldn't

The #1 Cause of Problems

Bad terminations! Improperly crimped connectors or poorly punched patch panels cause most cable issues.

Signs of bad termination:

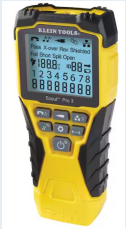
- Intermittent connection
- Works when wiggled
- Slower than expected speeds

Cable Testing Tools

Basic Testers

Cable tester: Verifies all 8 wires are connected (continuity).

Wire map tester: Shows which pins connect to which—catches crossed pairs.



Tracing Tools

Tone generator & probe: Inject a tone at one end, trace the cable through walls with the probe.

Essential for finding unlabeled cables!

Limitation

Basic testers only check *if* wires connect—not *how well*. A cable can pass but still have performance problems.

Advanced Testing Tools

Copper Testing

TDR (Time Domain Reflectometer):

- Sends signal, measures reflection
- Tells you WHERE a break is
- "The break is 47 meters out"

Certification tester:

- Verifies cable meets Cat specs
- Tests attenuation, crosstalk, length
- Required for warranty compliance

Fiber Testing

OTDR (Optical TDR):

- TDR for fiber optic cables
- Finds breaks, splices, connectors
- Shows signal loss at each point

Visual fault locator:

- Shines visible red laser
- Breaks glow or leak light
- Quick and inexpensive

Case Study: Pugsley's Flickering Connection

▶ Case Study: Pugsley's Flickering Connection

Pugsley's computer keeps losing network connectivity intermittently. The link light on his switch port flickers randomly.

Lurch investigates and finds:

- Basic cable tester shows all 8 wires have continuity—PASS
- The cable run is only 40 meters (Cat5e)
- When Lurch wiggles the cable near the patch panel, the connection drops

Review Questions

1. If the cable passed continuity testing, what type of problem might this be?
2. What should Lurch inspect closely at the patch panel?
3. What tool would definitively identify the issue?

Case Study Solution: Pugsley's Flickering Connection

✓ Solution: Pugsley's Flickering Connection

1. This is likely a **bad termination**. The wires make contact (passing continuity) but aren't solidly connected—movement breaks the connection.
2. At the patch panel, Lurch should look for:
   - Wires not fully seated in the 110 block
   - Too much untwisted wire (should be $<$0.5 inch)
   - Jacket stripped too far, causing strain on wires
3. A **certification tester** would show marginal or failing results for crosstalk and return loss—problems a basic tester misses.

Quick Fix

Re-punch the cable at the patch panel. If that doesn't work, re-terminate both ends. Termination problems are the most common cable issues!

Module 2.0 Summary I

Key Concepts:

- Physical Layer transmits data as electrical signals (copper) or light pulses (fiber).
- **UTP** (Unshielded Twisted Pair) is standard; **STP** (Shielded Twisted Pair) for high-EMI environments.
- Cable categories: **Cat5e** supports Gigabit Ethernet; **Cat6/6a** supports 10 Gigabit Ethernet.
- **Fiber optic**: **MMF** (multimode, orange) for short distances within buildings; **SMF** (single-mode, yellow) for long distances between buildings.
- Wiring standards: **T568A** and **T568B**. Use same standard on both ends for straight-through cable.
- Common connectors: **RJ-45** (copper), **LC/SC/ST** (fiber).

Module 2.0 Summary II

Installation & Troubleshooting:

- Use **plenum**-rated cable in air handling spaces (fire code requirement).
- Maximum copper run: 100 meters. Fiber can go much farther (300m MMF, 10+ km SMF).
- Common problems: bad terminations, **attenuation** (signal loss), **crosstalk** (interference).
- Tools: cable testers, tone generators, TDR (Time Domain Reflectometer), certification testers.
- Always start troubleshooting at Layer 1—if the cable isn't working, nothing else matters!