Industrial Ethernet Training

Network Design
Network Design

Agenda

• Layer 1 Components
• Layer 2 Components
• Layer 3 Components
• Gateways
• Network Topology
• Network Design Considerations
Network Design – Layer 1

Copper

• Twisted Pair Cable
  – UTP: Un-shielded Twisted Pair
  – STP: Shielded Twisted Pair

• Cables
  – Eight AWG-24

<table>
<thead>
<tr>
<th></th>
<th>Cat-3</th>
<th>Cat-5</th>
<th>Cat-5e</th>
<th>Cat-6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth</td>
<td>16 MHz</td>
<td>100 MHz</td>
<td>100 MHz</td>
<td>200 MHz</td>
</tr>
<tr>
<td>Speed</td>
<td>10 Mbits</td>
<td>100 Mbits</td>
<td>1000 Mbits</td>
<td>1000 Mbits</td>
</tr>
<tr>
<td>Crosstalk</td>
<td>High</td>
<td></td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Twisting</td>
<td>Low</td>
<td></td>
<td>High</td>
<td></td>
</tr>
</tbody>
</table>
Network Design – Layer 1

• **RJ45 Terminations (TIA/EIA-568)**
  – Telecommunications Industry Association is a 1988 offshoot of the Electronic Industries Alliance
  – Pin/pair assignments for eight-conductor 100-ohm balanced twisted pair cabling in TIA/EIA-568-B.1-2001 (1 page of 468 in the document)
  – TIA/EIA-568-B specifies that horizontal cables should be terminated using the T568A pin/pair assignments
    - *T568B is equivalent to AT&T 258A*
  – The idea in wiring modular connectors:
    - *The first pair would go in the center positions*
    - *The next pair on the next outermost ones, and so on.*
    - *Signal shielding would be optimized by alternating the "live" and "earthy" pins of each pair.*
  – TIA/EIA-568-B terminations vary a little bit from this concept. That's because on the 8 position connector, this results in a pinout in which the outermost pair are too far apart to meet the electrical requirements of high-speed LAN protocols.
Network Design – Layer 1

**Straight Through**

Wiring Standards Used
T568A  T568A

<table>
<thead>
<tr>
<th>Pin</th>
<th>T568A Pair</th>
<th>T568B Pair</th>
<th>Wire</th>
<th>T568A Color</th>
<th>T568B Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>2</td>
<td>tip</td>
<td>white/green stripe</td>
<td>white/orange stripe</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>2</td>
<td>ring</td>
<td>green solid</td>
<td>orange solid</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>3</td>
<td>tip</td>
<td>white/orange stripe</td>
<td>white/green stripe</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>1</td>
<td>ring</td>
<td>blue solid</td>
<td>blue solid</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>1</td>
<td>tip</td>
<td>white/blue stripe</td>
<td>white/blue stripe</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>3</td>
<td>ring</td>
<td>orange solid</td>
<td>green solid</td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>4</td>
<td>tip</td>
<td>white/brown stripe</td>
<td>white/brown stripe</td>
</tr>
<tr>
<td>8</td>
<td>4</td>
<td>4</td>
<td>ring</td>
<td>brown solid</td>
<td>brown solid</td>
</tr>
</tbody>
</table>

Pin on plug face (socket is reversed)

**Cross-Over**

Wiring Standards Used
T568A  T568B

<table>
<thead>
<tr>
<th>Pin</th>
<th>T568A Pair</th>
<th>T568B Pair</th>
<th>Wire</th>
<th>T568A Color</th>
<th>T568B Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>TX+</td>
<td>1</td>
<td>TX+</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1</td>
<td>TX-</td>
<td>2</td>
<td>RX-</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>1</td>
<td>RX+</td>
<td>3</td>
<td>TX-</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>4</td>
<td>RX-</td>
<td>6</td>
<td>TX+</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>5</td>
<td>RX+</td>
<td>6</td>
<td>RX-</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>7</td>
<td>RX-</td>
<td>7</td>
<td>RX-</td>
</tr>
<tr>
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<td>RX+</td>
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<td>RX-</td>
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<tr>
<td>8</td>
<td>5</td>
<td>8</td>
<td>RX-</td>
<td>8</td>
<td>RX-</td>
</tr>
</tbody>
</table>
Network Design – Layer 1

Fiber Optic Cable

• 1: Core
  – Thin glass fiber to guide the light

• 2: Cladding
  – Confines optical signal in the core

• 3: Buffer
  – Protection from moisture and physical damage

• 4: Jacket
  – Adds strength or other physical characteristics unrelated to the waveguide properties of the fiber
Fiber Media Types

• **Single mode**
  – 5-10 µm diameter
  – Signal travel straight down the middle
  – Long distance (up to 100 km)
  – 1310 or 1550 nm wavelength

• **Multi Mode**
  – 62.5 to 125 µm diameter
  – Signals travel along different paths (i.e. modes)
  – Used for relatively short distances
  – 850 nm or 1300 nm wavelength
## Network Design – Layer 1

<table>
<thead>
<tr>
<th></th>
<th>Multi-Mode</th>
<th>Single-Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sources (laser)</td>
<td>Lower Cost</td>
<td>Higher Cost</td>
</tr>
<tr>
<td>Connectors</td>
<td>Lower Cost</td>
<td>Higher Cost</td>
</tr>
<tr>
<td>Fiber</td>
<td>Higher Cost</td>
<td>Lower Cost</td>
</tr>
<tr>
<td>Distance</td>
<td>Up to 2 km</td>
<td>Up to 100 km</td>
</tr>
<tr>
<td>Installation</td>
<td>Similar Cost</td>
<td>Similar Cost</td>
</tr>
<tr>
<td>Usage</td>
<td>LAN, Data Center</td>
<td>WAN, MAN, Campus</td>
</tr>
</tbody>
</table>
Network Design – Layer 1

Fiber Optic Connectors (most common)

• **SC: Subscriber Connector**
  – Datacom and telcom
  – Extremely common

• **ST: Straight Tip Connector**
  – BFOC: Bayonet Fiber Optic Connector
  – Multimode
  – Rarely single-mode

• **LC: Lucent/Local Connector**
  – High-density connections
  – SFP transceivers
Benefits of Fiber Optic Cable vs. Copper

- Less signal degradation – no interference with signals from other fibers in the same cable
- No interference from noise
- Long distance communication
- Higher bandwidth
- Non-electrical
- Safer and more secure
Hubs

• A multiport repeater/concentrator
• Data received on a port is sent to all ports
• Bandwidth is shared by all clients
• Half-Duplex Communication
• Fast but inefficient
Network Design – Layer 2

Switches

• Data received on a port is sent to the destination port only

• Learns and Remembers MAC addresses of clients

• Reduced chance of collision

• Full-Duplex Bandwidth for all clients
Switch Types

• Unmanaged
  – Simple and easy
  – No configuration

• Managed
  – Support network redundancy and traffic grooming
  – Require some configuration

• Ring
  – Support Ring network redundancy
  – Minimal configuration
Network Design

Hubs vs. Switches

- Switches are almost the same cost as Hubs
- Switches help to increase network performance
- Switches can be managed – for example
  - Monitoring
  - VLAN
  - QoS
  - IGMP Snooping

Rule of thumb:

“Hubs cost about the same as unmanaged switches with poorer network performance”
Network Design – Layer 3

Routers

- Modems
- Forward traffic by IP Address instead of MAC Address
- Connects Subnets at the IP Layer

Layer 3 Switches

- Layers routing on top of switching
- Layer 2 switching still inherent
- Must be managed
Network Design

Switches vs. Routers

• Hardware (switching) faster than software (routing)

• Switches require less configuration than Routers
  – Unmanaged switches require no configuration

• Switches used at the further edges of the network

Rule of thumb:

“Switch when you can, Route when you must”
Network Design - Gateways

• Connects Dissimilar Media
  – Media Converters (e.g. copper to fiber)

• Connects Dissimilar Protocols
  – Protocol Converters (e.g., RS485 to Ethernet TCP/IP)

• Can be at any layer
Network Topologies

- Bus Topology
- Ring Topology
- Star Topology
- Mesh Topology
- Dual Ring Topology
- Extended Star Topology
Network Design
Bus Topology

- **Advantages**
  - Easy to connect devices to a linear buss
  - Requires less cable than other topologies

- **Disadvantages**
  - Multiple Single Points of Failure
  - Terminators are required at both ends of the backbone cable
  - Difficult to identify the problem if the entire network shuts down
Network Design
Star Topology

• **Advantages**
  – Simple Cable Installation
  – Simple Fault Identification

• **Disadvantages**
  – Single Point of Failure
  – Requires more cable than other topologies
Network Design
Extended Star Topology

• **Advantages**
  – More resilient than star

• **Disadvantages**
  – More cable than other topologies
  – More complicated cabling
Network Design
Ring Topology

- **Advantages**
  - Capable of Redundancy
  - Requires less cable length than other topologies
  - Faster recovery times

- **Disadvantages**
  - Requires Managed or Ring Switches
  - More Costly than Other Topologies
Network Design
Dual Ring Topology

• Advantages
  – More resilient than single ring

• Disadvantages
  – More cabling

Two links connected to the same networking device
Network Design
Full-Mesh Topology

- **Advantages**
  - Extremely fault tolerant

- **Disadvantages**
  - Most Costly topology
  - Recovery time can be slow as network gets larger
Network Design
Partial-Mesh Topology

• **Advantages**
  – Highly fault tolerant
  – Lower cost than full-mesh

• **Disadvantages**
  – Costly topology
• **Challenge #1**
  - Eight Ethernet devices to connect

• **Concerns?**
Network Design - Segmentation

- **Challenge #2**
  - Four Ethernet devices in each of two locations that are 80m apart

- **Concerns?**
  - Cabling & installation costs

- **What if?**
  - 1km apart
Network Design - Segmentation

• Challenge #2
  – Four Ethernet devices in each of two locations that are 80m apart

• Concerns?

• What if?
  – 1km apart
  – Device “a” and device “b” need to have a high speed connection
  – Communication between device “a” and device “b” is critical
• **Challenge #3**
  – Four Ethernet devices in each of two locations that are 80m apart
  – Communication between device “a” and device “b” is critical

• **Concerns?**
  – Installation – separate paths for fiber
Network Design - Considerations

• Distance
• Bandwidth (Speed)
• Environment
  – Heat
  – Shock
  – Power
• Data Importance
• Cost