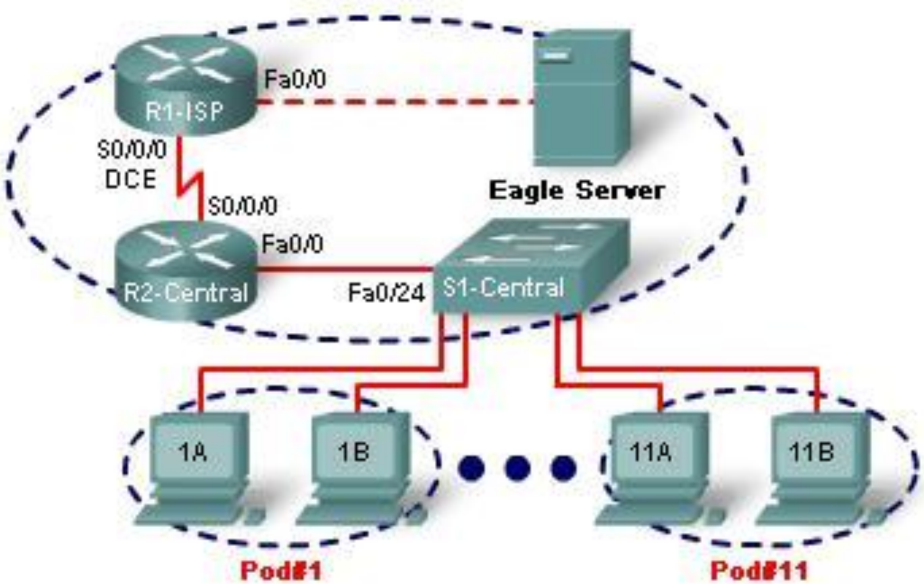
CCNA Exploration Network Fundamentals

Chapter 10

Planning and Cabling Networks

Updated: 15/07/2008

10.0.1 Introduction

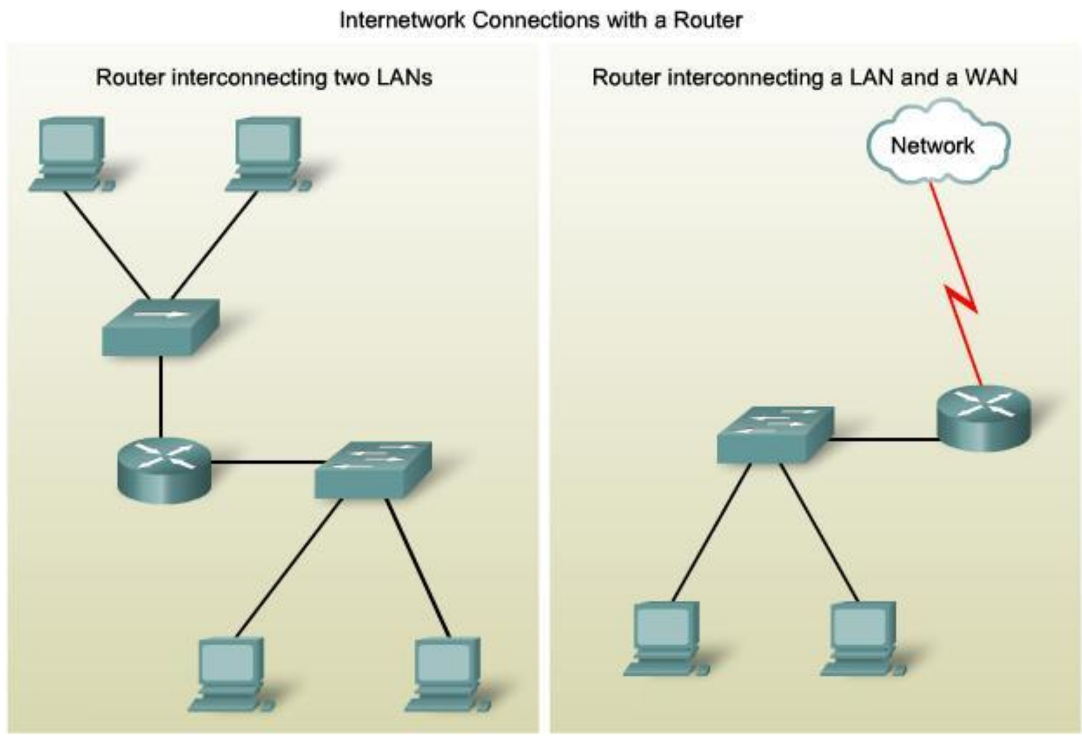


Planning & Cabling a Network

10.0.1 Introduction

- The following have been covered in previous chapters: considered the services that a data network can provide to the human network, examined the features of each layer of the OSI model and the operations of TCP/IP protocols, and looked in detail at Ethernet, a universal LAN technology. The next step is to learn how to assemble these elements together in a functioning network.
- Topics covered in this chapter: various media and the distinct roles they play with the devices that they connect, cables needed to make successful LAN and WAN connections and device management connections, selection of devices and the design of a network addressing scheme.

10.1 LANs – making the Physical Connection
10.1.1 Choosing the Appropriate LAN Device



- For this course, the choice of which router to deploy is determined by the Ethernet interfaces that match the technology of the switches at the center of the LAN. Routers offer many services and features to the LAN. Each LAN will have a router as its gateway connecting the LAN to other networks. Inside the LAN will be one or more hubs or switches to connect the end devices to the LAN.

10.1.1 Choosing the Appropriate LAN Device

Internetwork Devices

- Routers are the primary devices used to interconnect networks. Each port on a router connects to a different network and routes packets between the networks. Routers have the ability to break up broadcast domains and collision domains.
- Routers are also used to interconnect networks that use different technologies. They can have both LAN and WAN interfaces.
- The router's LAN interfaces allow routers to connect to the LAN media. This is usually UTP cabling, but modules can be added for using fiber-optics. Depending on the series or model of router, there can be multiple interface types for connection of LAN and WAN cabling.

10.1.1 Choosing the Appropriate LAN Device

Intranetwork Devices

- To create a LAN, we need to select the appropriate devices to connect the end device to the network. The two most common devices used are hubs and switches.

Hub

- A hub receives a signal, regenerates it, and sends the signal over all ports. The use of hubs creates a logical bus. This means that the LAN uses multiaccess media. The ports use a shared bandwidth approach and often have reduced performance in the LAN due to collisions and recovery. Although multiple hubs can be interconnected, they remain a single collision domain.
- Hubs are less expensive than switches. A hub is typically chosen as an intermediary device within a very small LAN, in a LAN that requires low throughput requirements, or when finances are limited.

10.1.1 Choosing the Appropriate LAN Device

Switch

- A switch receives a frame and regenerates each bit of the frame on to the appropriate destination port. This device is used to segment a network into multiple collision domains. Unlike the hub, a switch reduces the collisions on a LAN. Each port on the switch creates a separate collision domain. This creates a point-to-point logical topology to the device on each port. Additionally, a switch provides dedicated bandwidth on each port, which can increase LAN performance. A LAN switch can also be used to interconnect network segments of different speeds.
- In general, switches are chosen for connecting devices to a LAN. Although a switch is more expensive than a hub, its enhanced performance and reliability make it cost effective.
- There is a range of switches available with a variety of features that enable the interconnection of multiple computers in a typical enterprise LAN setting.

10.1.2 Device Selection Factors

Factors to Consider in Choosing a Device

COST

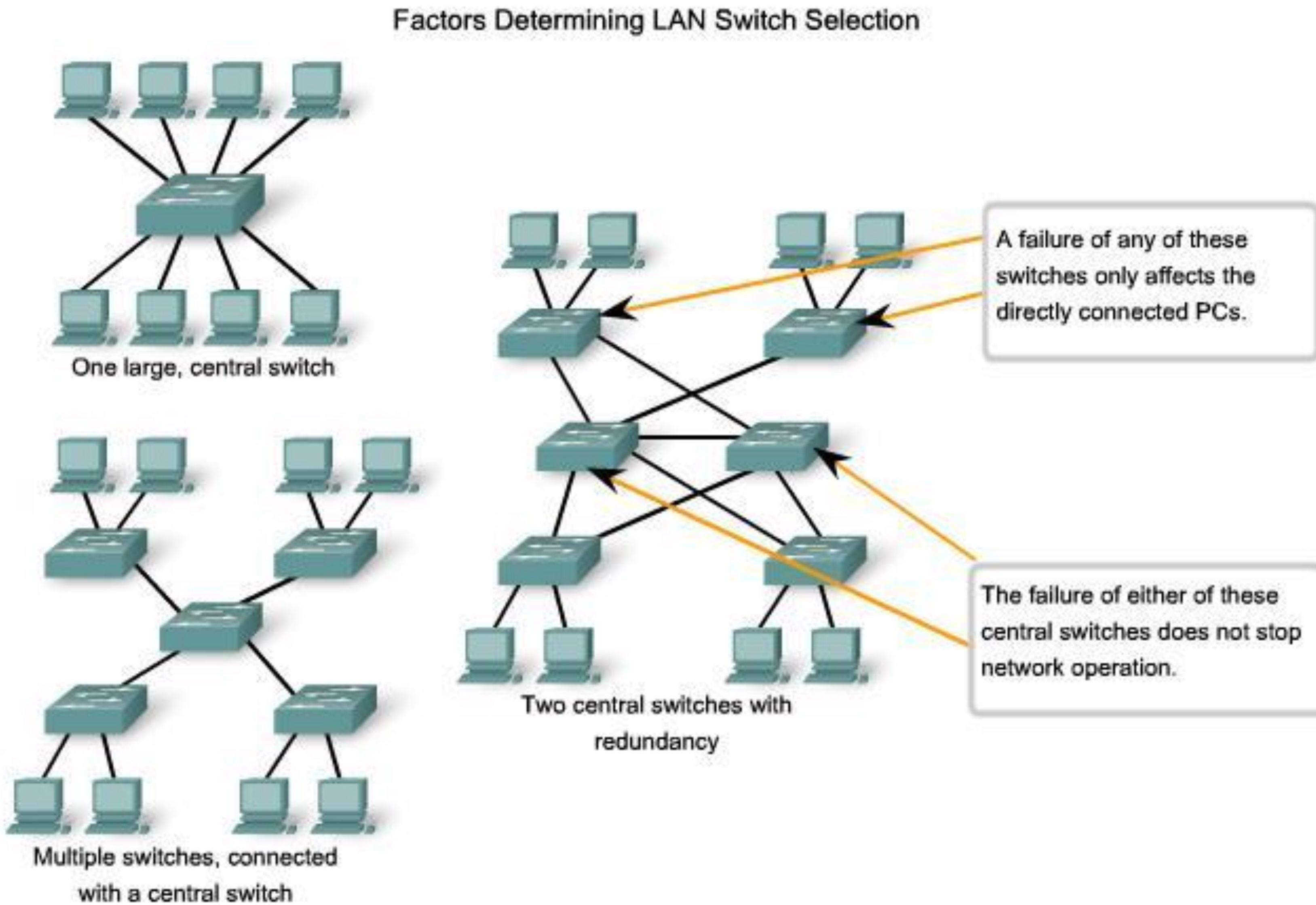
PORTS

SPEED

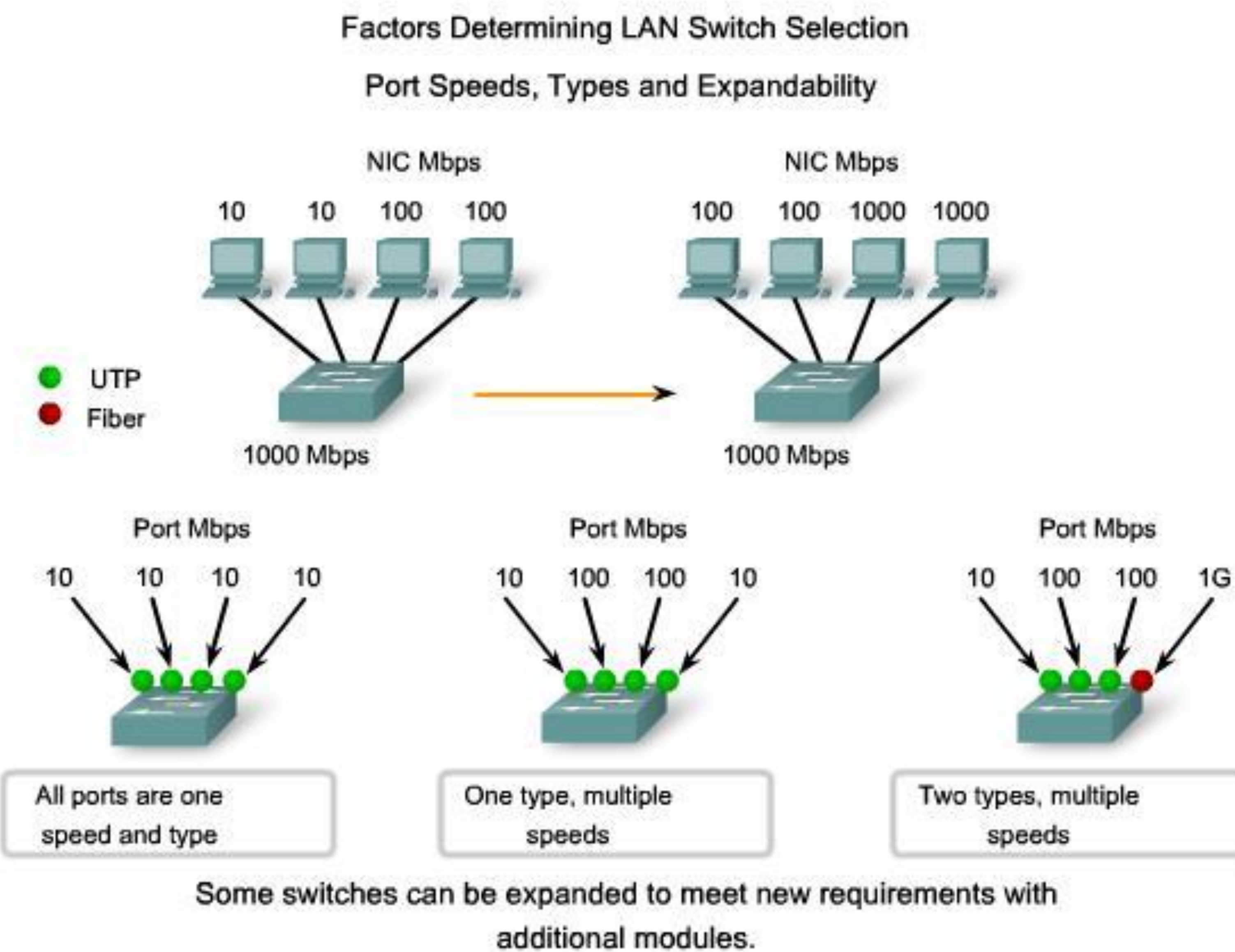
EXPANDABLE/ MODULAR

MANAGEABLE

10.1.2 Device Selection Factors



10.1.2 Device Selection Factors

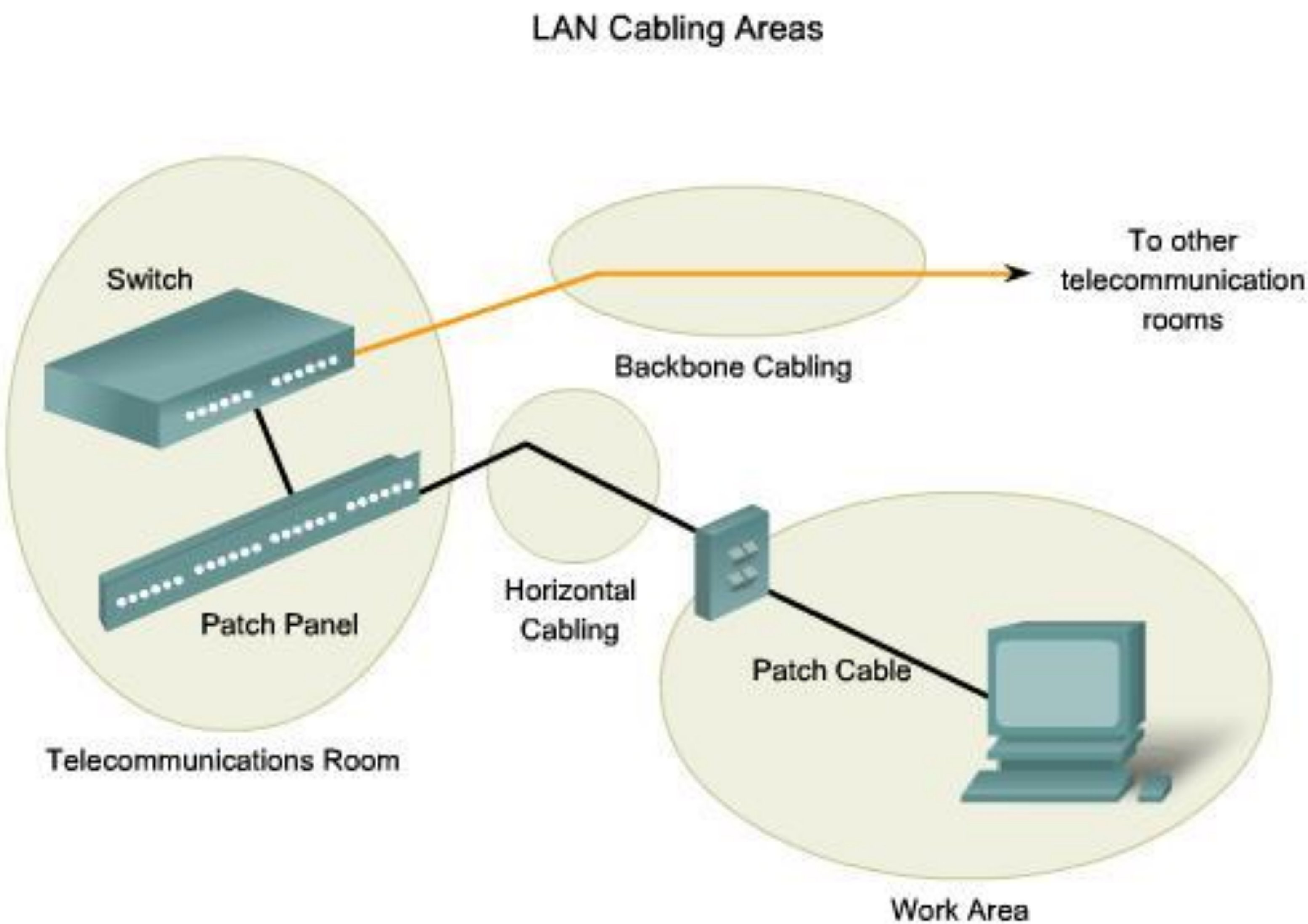


10.1.2 Device Selection Factors

Cisco Routers

Each series of Cisco router provides expandability, support for multiple media types, and various system features and services.

10.2 Device Interconnections
10.2.1 LAN and WAN – Getting Connected



10.2.1 LAN and WAN – Getting Connected

Types of Device Interconnection

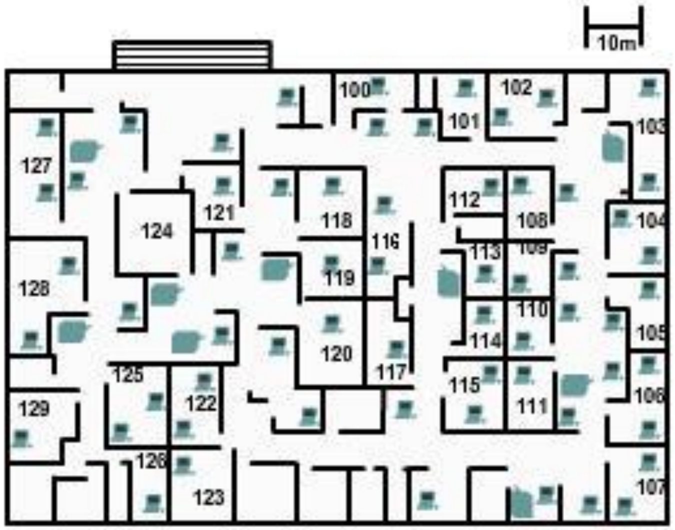
Fiber

UTP

Wireless

10.2.1 LAN and WAN – Getting Connected

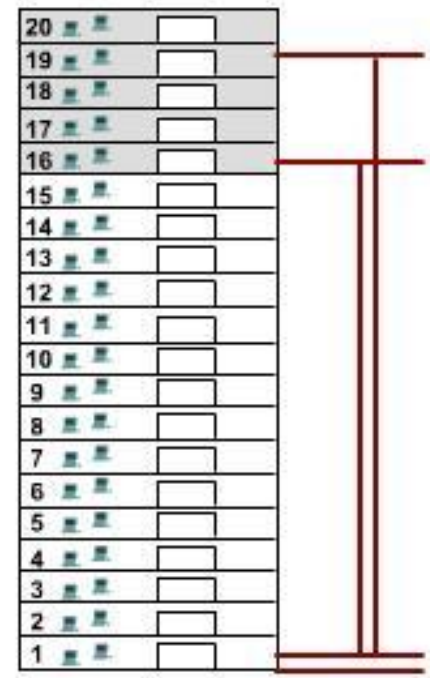
Cable Length and Cost



Floor Plan

Cable lengths need to be determined and matched with the technology used.

Multi-Floor Building

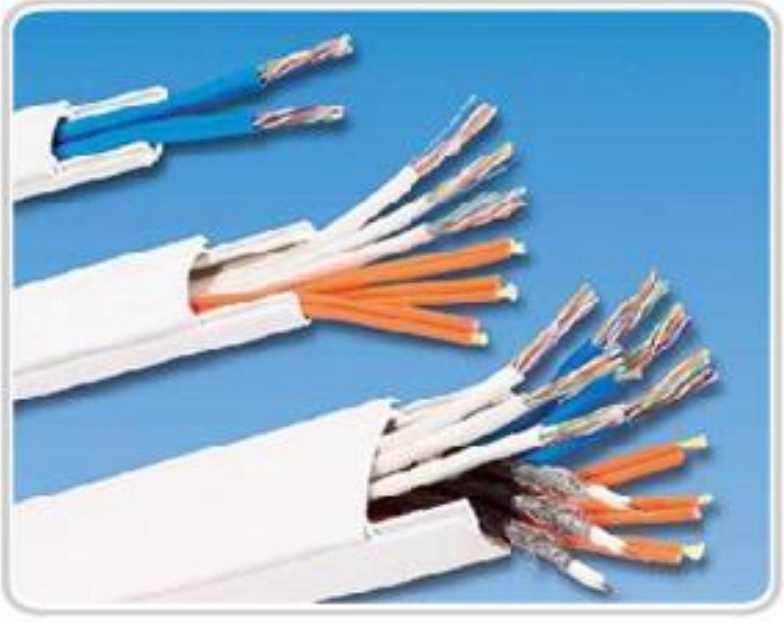


Ethernet Type	Bandwidth	Cable Type	Maximum Distance
10Base-T	10Mbps	Cat3/Cat5 UTP	100m
100Base-TX	100Mbps	Cat5 UTP	100m
100Base-TX	200Mbps	Cat5 UTP	100m
100Base-FX	100Mbps	Multi-Mode Fiber	400m
100Base-FX	200Mbps	Multi-Mode Fiber	2Km
1000Base-T	1Gbps	Cat5e UTP	100m
1000Base-TX	1Gbps	Cat6 UTP	100m

10.2.1 LAN and WAN – Getting Connected

Ease of Installation

UTP and fiber have different installation requirements.



UTP Cable Raceway

Fiber Cable Raceway

10.2.1 LAN and WAN – Getting Connected

- When planning the installation of LAN cabling, there are four physical areas to consider:
  - Work area
  - Telecommunications room, also known as the distribution facility
  - Backbone cabling, also known as vertical cabling
  - Distribution cabling, also known as horizontal cabling

Total Cable Length

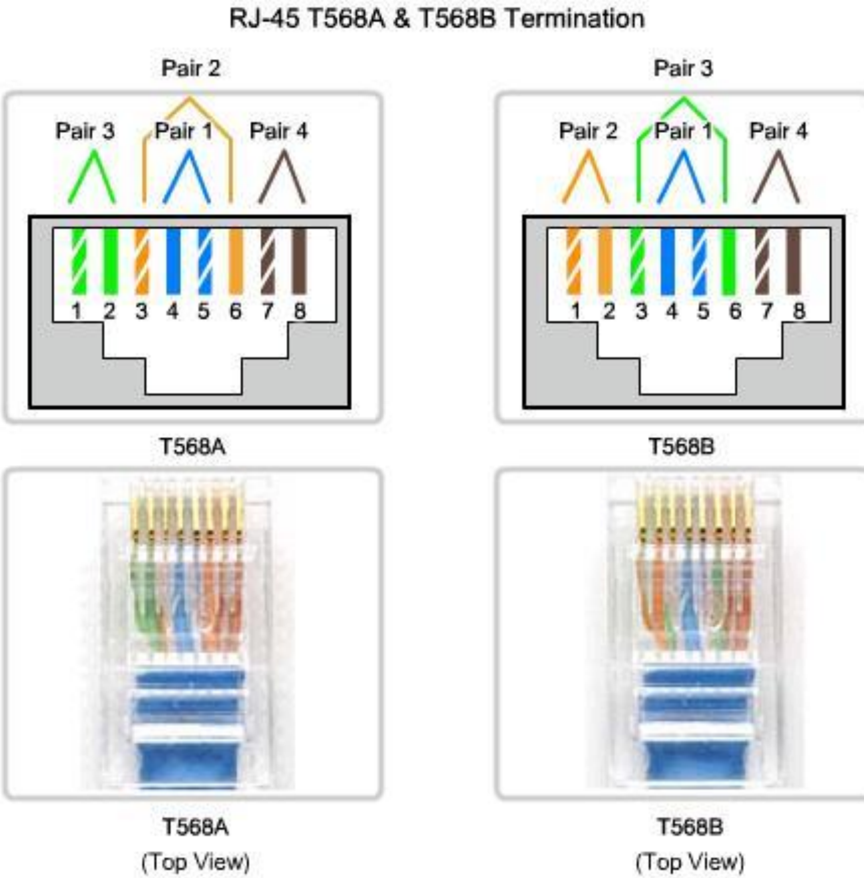
- For UTP installations, the ANSI/TIA/EIA-568-B standard specifies that the total combined length of cable spanning the four areas listed above is limited to a maximum distance of 100 meters per channel. This standard specifies there can be up to 5 meters of patch cable for interconnecting patch panels. There can be up to 5 meters of cable from the cable termination point on the wall to the telephone or computer.

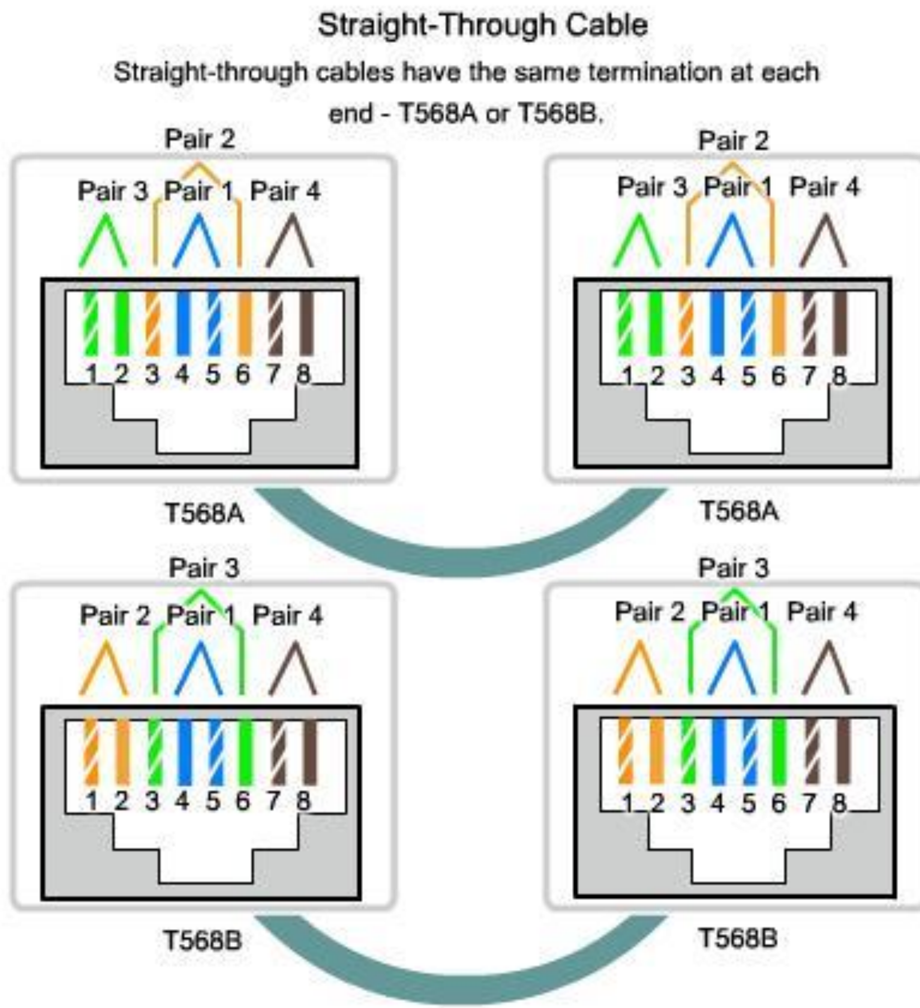
10.2.1 LAN and WAN – Getting Connected

Types of Media

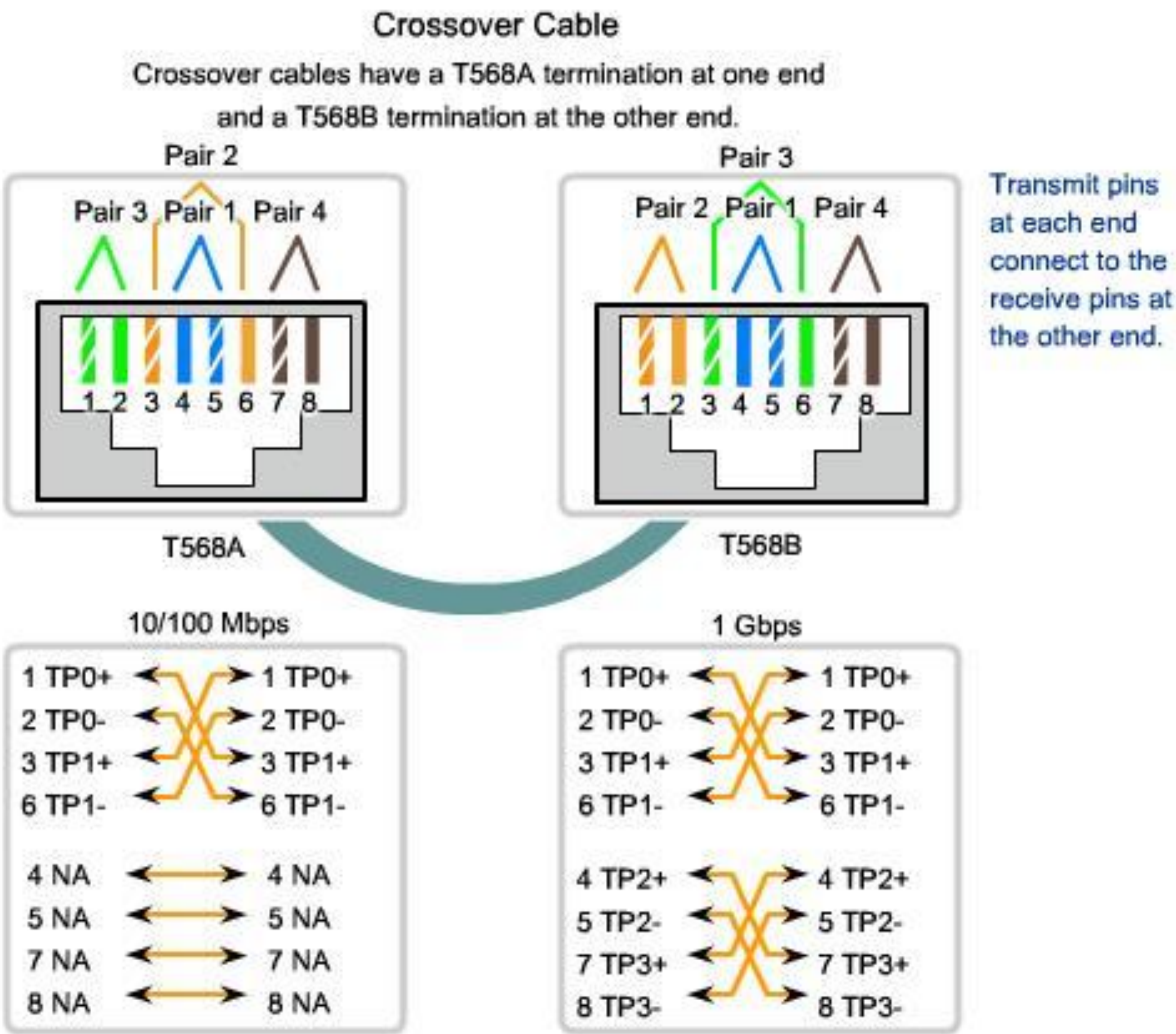
- Choosing the cables necessary to make a successful LAN or WAN connection requires consideration of the different media types. There are many different Physical layer implementations that support multiple media types:UTP (Category 5, 5e, 6, and 7), Fiber-optics, Wireless
- Each media type has its advantages and disadvantages. Some of the factors to consider are:
- Cable length - Does the cable need to span across a room or from building to building?
- Cost - Does the budget allow for using a more expensive media type?
- Bandwidth - Does the technology used with the media provide adequate bandwidth?
- Ease of installation - Does the implementation team have the ability to install the cable or is a vendor required?
- Susceptible to EMI/RFI - Is the local environment going to interfere with the signal?

10.2.2 Making LAN Connections

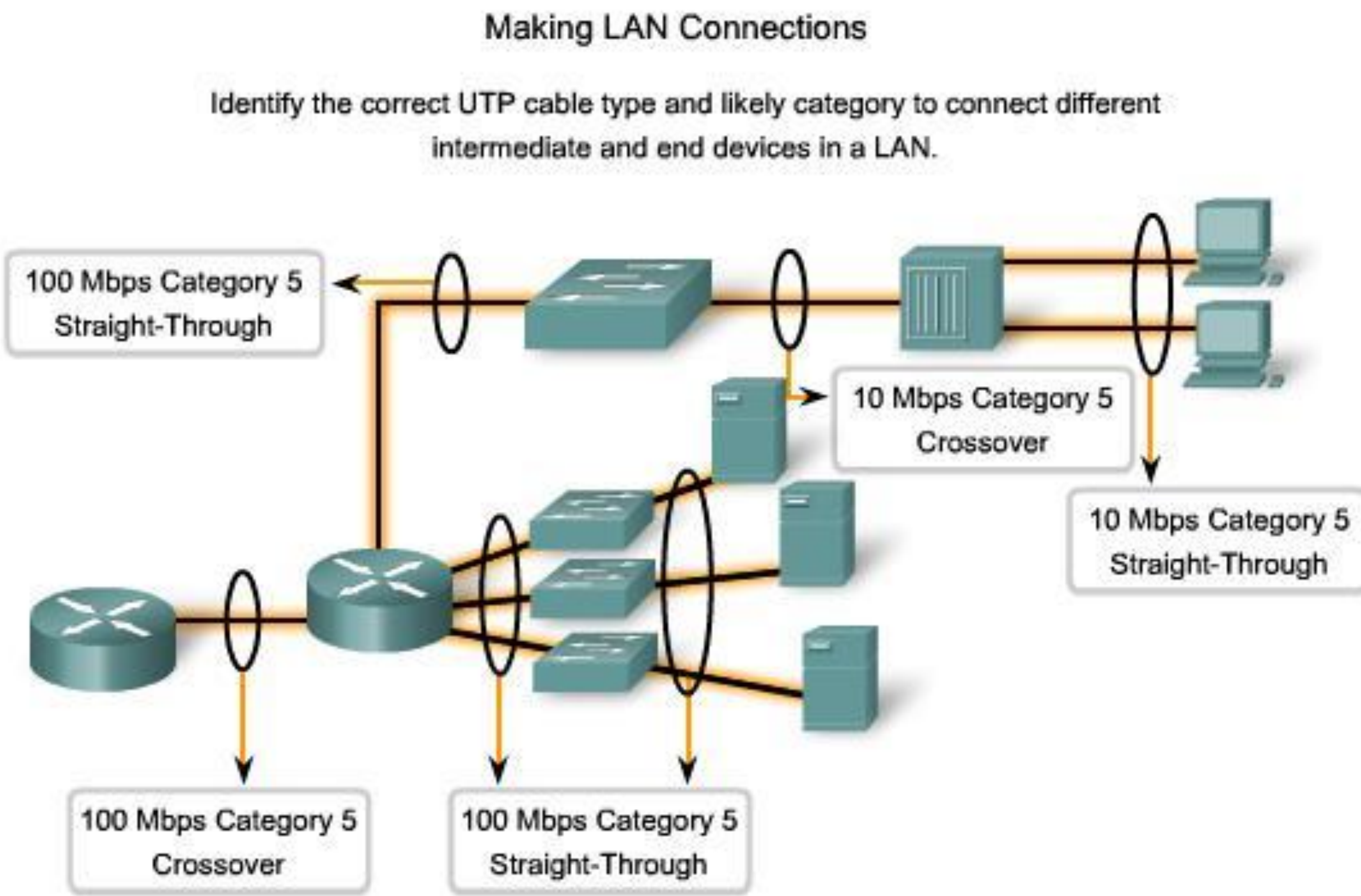




10.2.2 Making LAN Connections



10.2.2 Making LAN Connections



10.2.2 Making LAN Connections

Types of Interfaces

- In an Ethernet LAN, devices use one of two types of UTP interfaces - MDI or MDIX.
- The MDI (media-dependent interface) uses the normal Ethernet pinout. Pins 1 and 2 are used for transmitting and pins 3 and 6 are used for receiving. Devices such as computers, servers, or routers will have MDI connections.
- The devices that provide LAN connectivity - usually hubs or switches - typically use MDIX (media-dependent interface, crossover) connections. The MDIX cables swap the transmit pairs internally. This swapping allows the end devices to be connected to the hub or switch using a straight-through cable.
- Typically, when connecting different types of devices, use a straight-through cable. And when connecting the same type of device, use a crossover cable.

10.2.2 Making LAN Connections

- The common uses are listed again:
  - Use straight-through cables for connecting:
    - Switch to router
    - Computer to switch
    - Computer to hub
  - Use crossover cables for connecting:
    - Switch to switch
    - Switch to hub
    - Hub to hub
    - Router to router
    - Computer to computer
    - Computer to router

10.2.3 Making WAN Connections

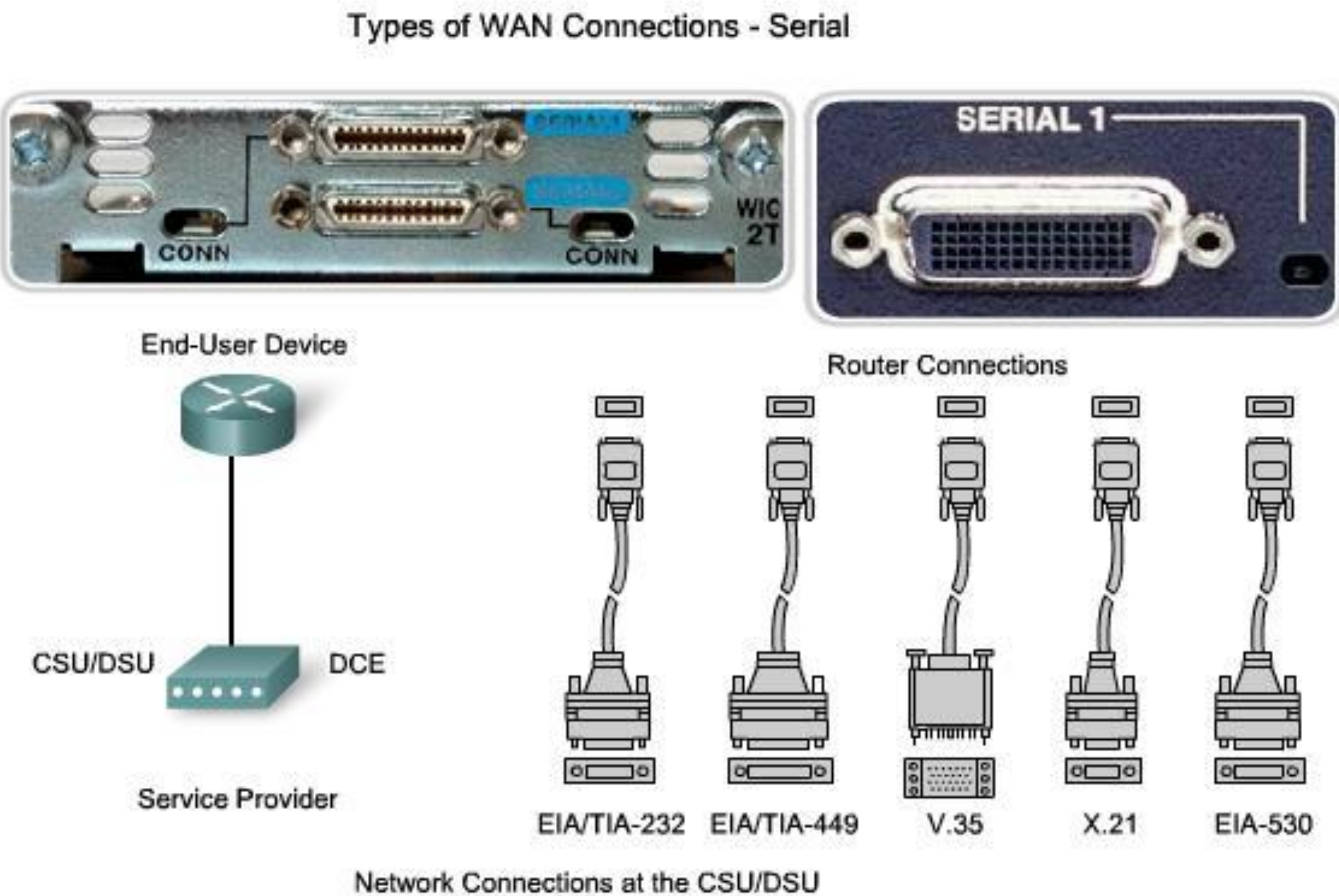
Types of WAN Connections

Cisco HDLC	PPP	Frame Relay	DSL Modem	Cable Modem
EIA/TIA-232 EIA/TIA-449 X.21V.24 V.35 High Speed Serial Interface (HSSI)			RJ-11 Note: Works over telephone line	F Note: Works over Cable TV line

Router: Male Smart Serial

Network: Male Winchester Block Type

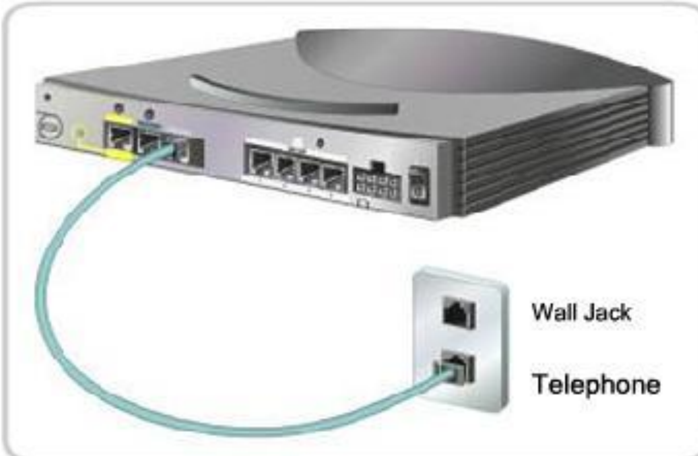
10.2.3 Making WAN Connections



10.2.3 Making WAN Connections

Types of WAN Connections - DSL

Cisco 827-4v router



Serial DCE and DTE WAN Connections

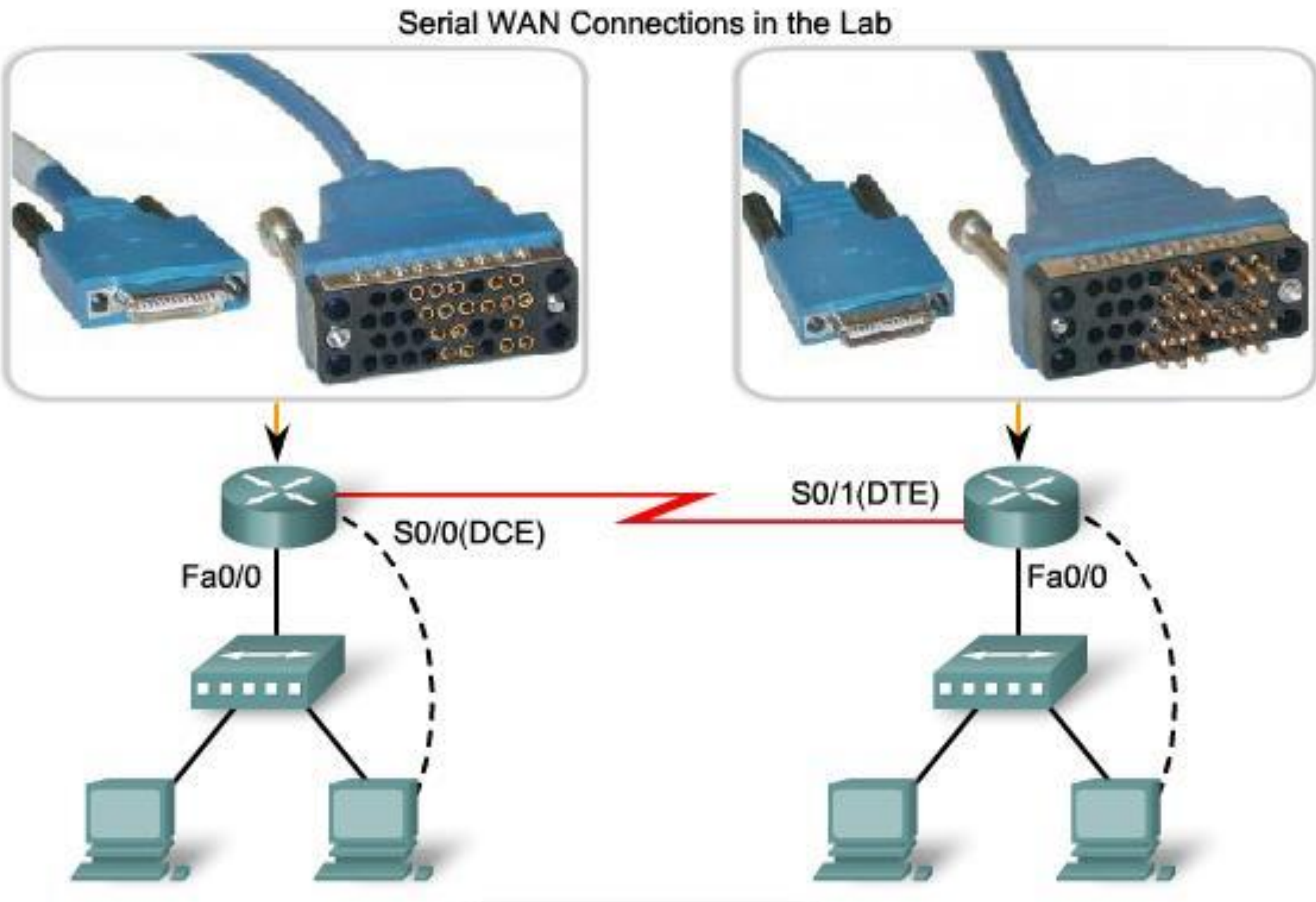
Data Terminal Equipment:

- End of the user's device on the WAN Link

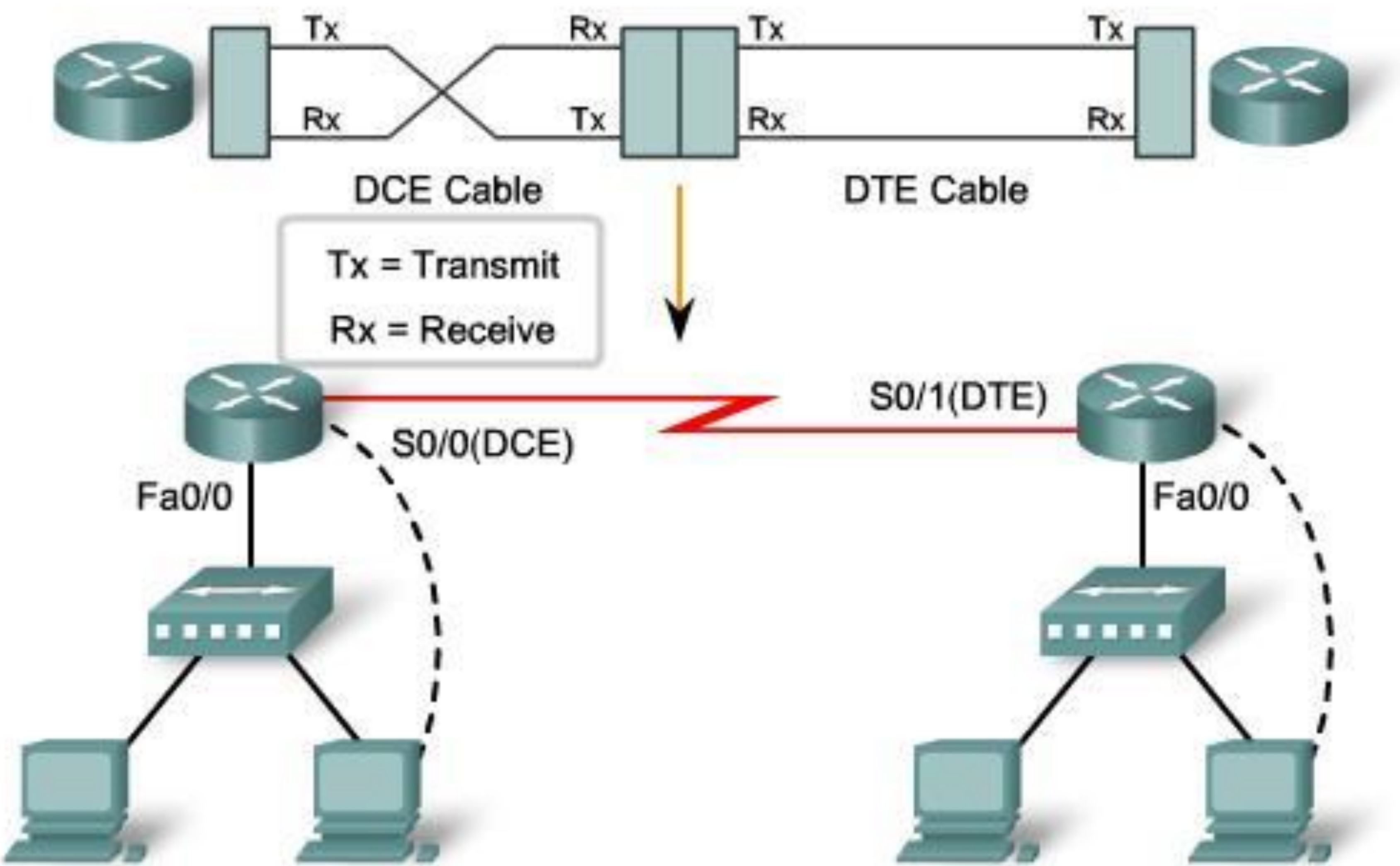
Data Communications Equipment:

- End of the WAN provider's side of the communication facility
- Responsible for providing clocking signal.

10.2.3 Making WAN Connections



10.2.3 Making WAN Connections

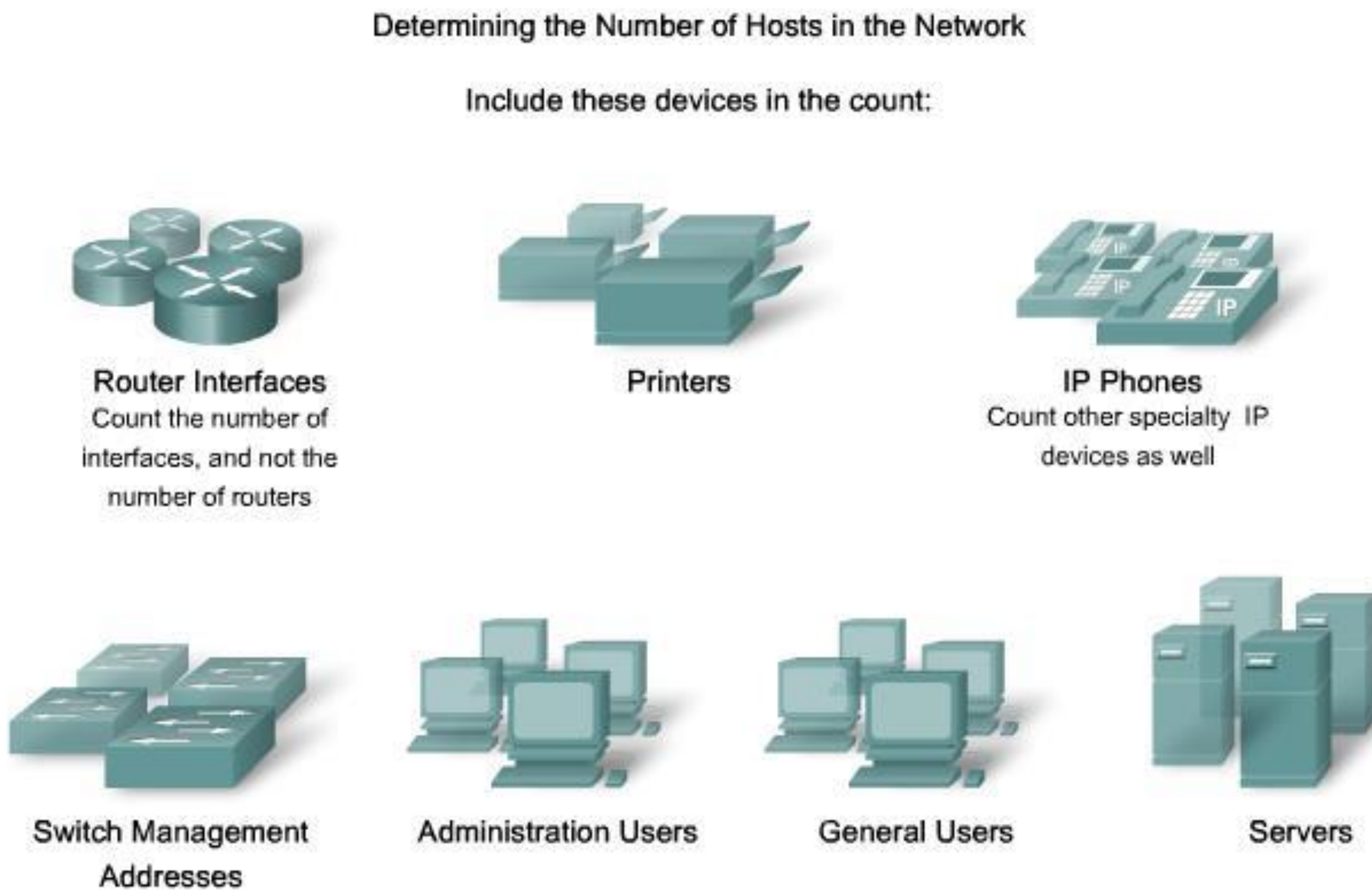


10.2.3 Making WAN Connections

In the Lab

- When making WAN connections between two routers in a lab environment, connect two routers with a serial cable to simulate a point-to-point WAN link. In this case, decide which router is going to be the one in control of clocking. Routers are DTE devices by default, but they can be configured to act as DCE devices.
- The V35 compliant cables are available in DTE and DCE versions. To create a point-to-point serial connection between two routers, join together a DTE and DCE cable. Each cable comes with a connector that mates with its complementary type. These connectors are configured so that you cannot join two DCE or two DTE cables together by mistake.

10.3 Developing an Addressing Scheme
10.3.1 How Many Hosts in the Network



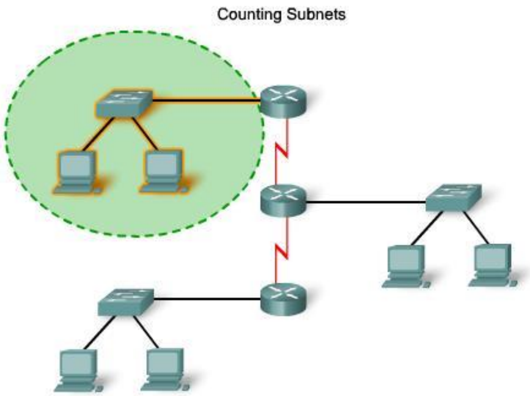
10.3.1 How Many Hosts in the Network

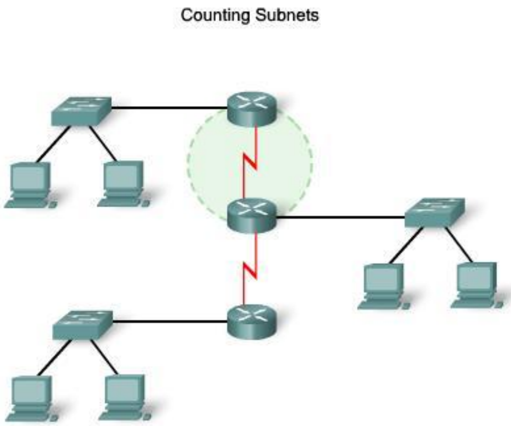
- To develop an addressing scheme for a network, start with determining the total number of hosts. Consider every device that will require an IP address, now and in the future.
- The end devices requiring an IP address include:
  - User computers
  - Administrator computers
  - Servers
  - Other end devices such as printers, IP phones, and IP cameras
- Network devices requiring an IP address include:
  - Router LAN interfaces
  - Router WAN (serial) interfaces
- Network devices requiring an IP address for management include:
  - Switches
  - Wireless Access Points

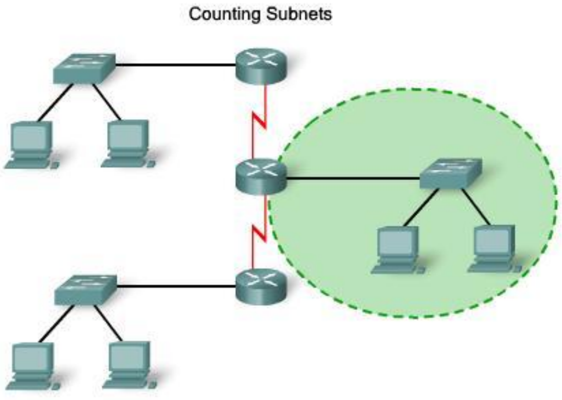
10.3.1 How Many Hosts in the Network

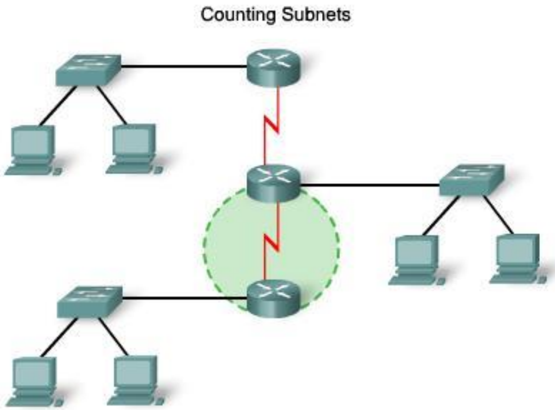
- There may be other devices on a network requiring an IP address. Add them to this list and estimate how many addresses will be needed to account for growth in the network as more devices are added.
- Once the total number of hosts - current and future - has been determined, consider the range of addresses available and where they fit within the given network address.
- Next, determine if all hosts will be part of the same network, or whether the network as a whole will be divided into separate subnets.
- The number of hosts on one network or subnet is calculated using the formula 2 to the nth power minus 2 (2^n - 2), where n is the number of bits available as host bits. Two addresses cannot be assigned to hosts need to be subtracted (the network address and the network broadcast address).

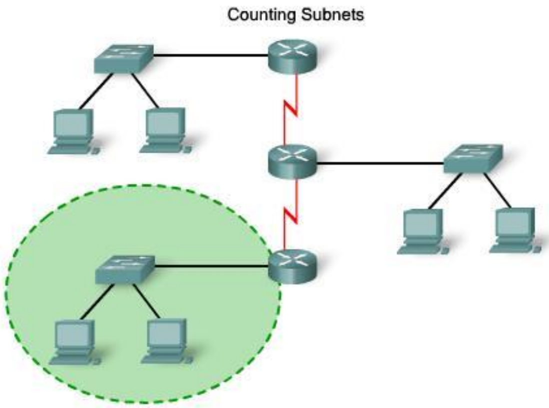
10.3.2 How Many Networks?











10.3.2 How Many Networks?

There are many reasons to divide a network into subnets:

- Manage Broadcast Traffic - Broadcasts can be controlled because one large broadcast domain is divided into a number of smaller domains. Not every host in the system receives every broadcast.
- Different Network Requirements - If different groups of users require specific network or computing facilities, it is easier to manage these requirements if those users who share requirements are all together on one subnet.
- Security - Different levels of network security can be implemented based on network addresses. This enables the management of access to different network and data services.
- Counting the Subnets - Each subnet, as a physical network segment, requires a router interface as the gateway for that subnet. In addition, each connection between routers is a separate subnet. The number of subnets on one network is also calculated using the formula 2^n, where n is the number of bits "borrowed" from the given IP network address available to create subnets.
- Subnet Masks - Having determined the required number of hosts and subnets, the next step is to apply one subnet mask for the entire network and then calculate the following values
    - A unique subnet and subnet mask for each physical segment
    - A range of usable host addresses for each subnet

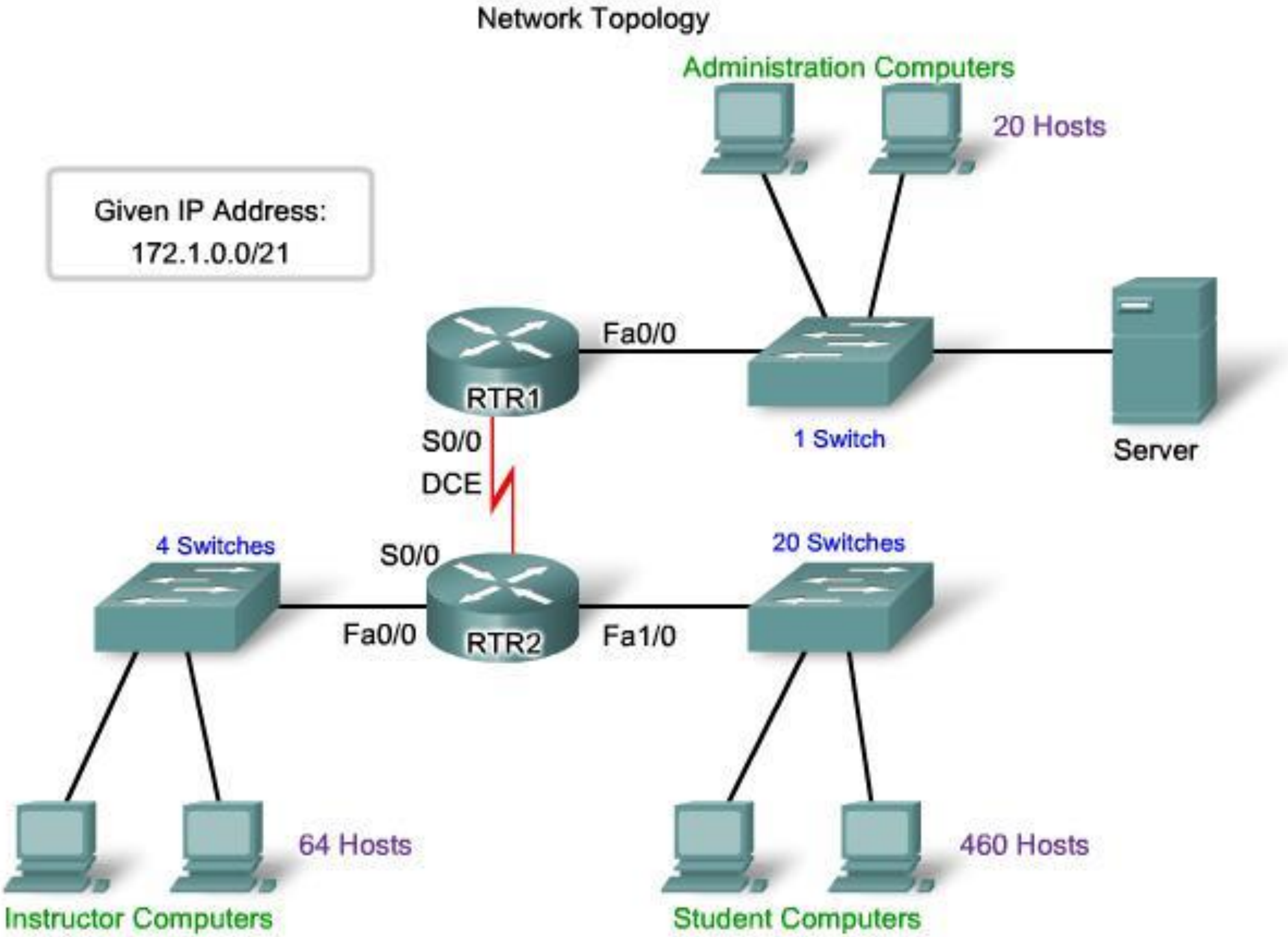
10.3.3 Designing the Address Standard for our Internetwork

- To assist troubleshooting and expedite adding new hosts to the network, use addresses that fit a common pattern across all subnets. Each of these different device types should be allocated to a logical block of addresses within the address range of the network.
- Some of the different categories for hosts are:
  - General users
  - Special users
  - Network resources
  - Router LAN interfaces
  - Router WAN links
  - Management access

10.3.3 Designing the Address Standard for our Internetwork

- For example, when allocating an IP address to a router interface that is the gateway for a LAN, it is common practice to use the first (lowest) or last (highest) address within the subnet range. This consistent approach aids in configuration and troubleshooting.
- Similarly, when assigning addresses to devices that manage other devices, using a consistent pattern within a subnet makes these addresses easily recognizable. For example, in the figure, addresses with 64 - 127 in the octets always represent the general users. A network administrator monitoring or adding security can do so for all addresses ending in these values.
- In addition, remember to document your IP addressing scheme on paper. This will be an important aid in troubleshooting and evolving the network.

10.4 Calculating the Subnets
10.4.1 Calculating Addresses: Case 1

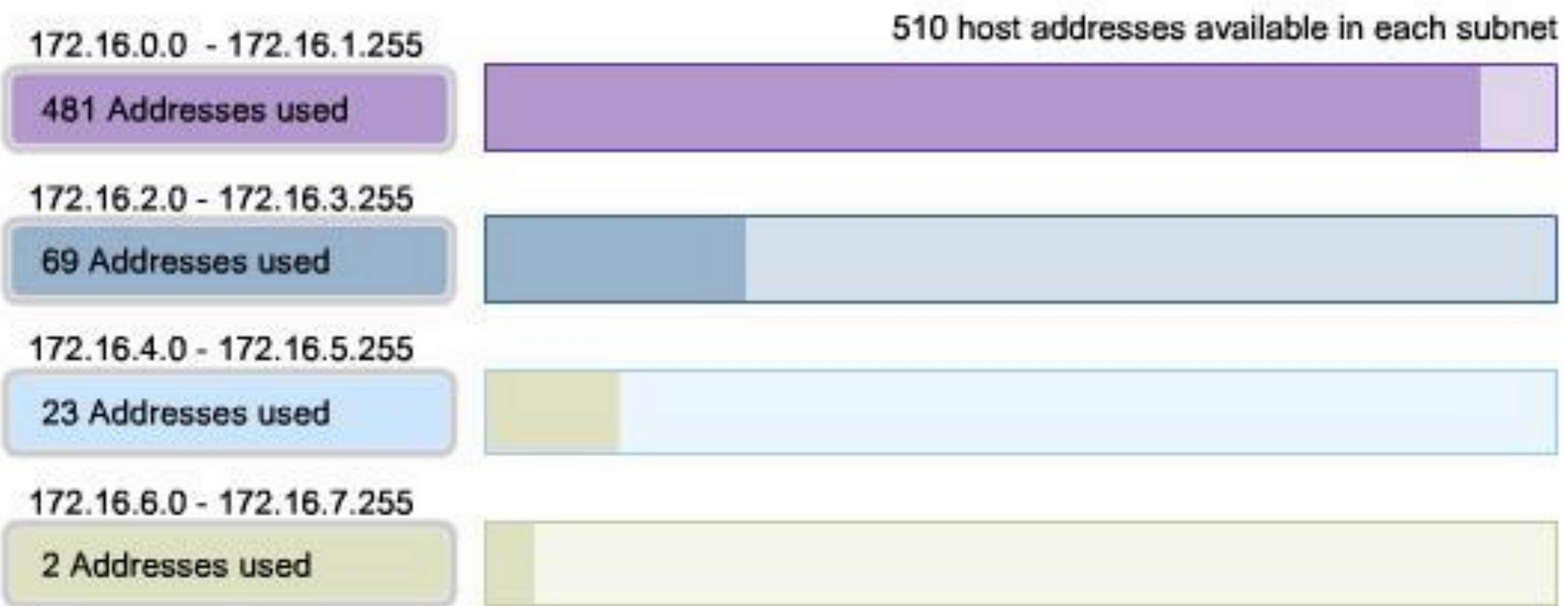


10.4.1 Calculating Addresses: Case 1

Calculating Addresses without VLSM Address Ranges for Subnets

Case 1

Network	Subnet Address	Host Address Range		Broadcast Address
Student	172.16.0.0/23	172.16.0.1	172.16.1.254	172.16.1.255
Instructor	172.16.2.0/23	172.16.2.1	172.16.3.254	172.16.3.255
Administration	172.16.4.0/23	172.16.4.1	172.16.5.254	172.16.5.255
WAN	172.16.6.0/23	172.16.6.1	172.16.7.254	172.16.7.255

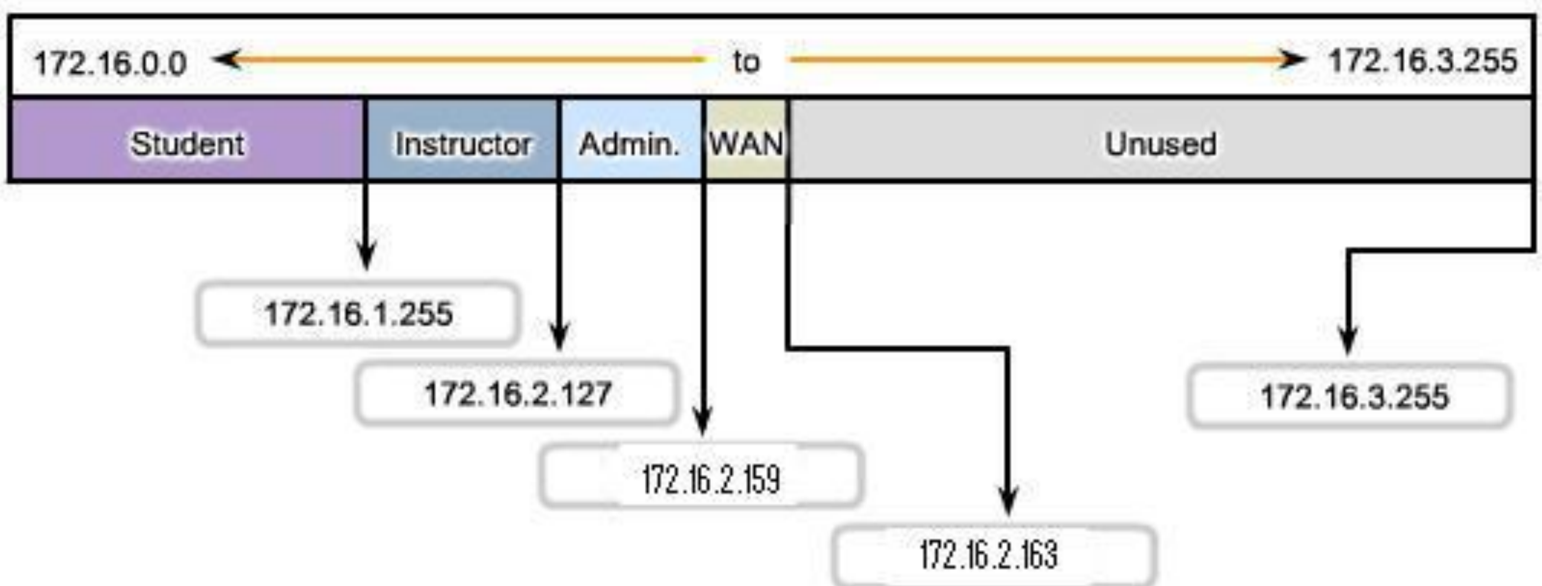


10.4.1 Calculating Addresses: Case 1

Calculating Addresses with VLSM Address Ranges for Subnets

Case 1

Network	Subnet Address	Host Address Range		Broadcast Address
Student	172.16.0.0/23	172.16.0.1	172.16.1.254	172.16.1.255
Instructor	172.16.2.0/25	172.16.2.1	172.16.2.126	172.16.2.127
Administration	172.16.2.128/26	172.16.2.129	172.16.2.190	172.16.2.191
WAN	172.16.2.192/30	172.16.2.193	172.16.2.194	172.16.2.195
Unused	na	172.16.2.197	172.16.3.254	na



10.4.1 Calculating Addresses: Case 1

- The number and grouping of hosts are:
  - Student LAN - Student Computers: 460, Router (LAN Gateway): 1, Switches (management): 20. Total for student subnetwork: 481
  - WAN - Router - Router WAN: 2. Total for WAN: 2
  - Instructor LAN - Instructor Computers: 64, Router (LAN Gateway): 1, Switches (management): 4. Total for instructor subnetwork: 69
  - Administrator LAN - Administrator Computers: 20 , Server: 1, Router (LAN Gateway): 1, Switch (management): 1. Total for administration subnetwork: 23

Allocation Methods

- There are two methods available for allocating addresses to an internetwork. We can use Variable Length Subnet Masking (VLSM), where we assign the prefix and host bits to each network based on the number of hosts in that network. Or, we can use a non-VLSM approach, where all subnets use the same prefix length and the same number of host bits.
- For our network example, both approaches will be demonstrated..

10.4.1 Calculating Addresses: Case 1

Calculating and Assigning Addresses-without VLSM

- When using the non-VLSM method of assigning addresses, all subnets have the same number of addresses assigned to them. In order to provide each network with an adequate number of addresses, we base the number of addresses for all networks on the addressing requirements for the largest network.
- In Case 1, the Student LAN is the largest network, requiring 481 addresses.
- The following formula to calculate the number of hosts: Usable hosts = 2^n – 2
- 9 is used as the value for n because 9 is the first power of 2 that is over 481.
- Borrowing 9 bits for the host portion yields this calculation: 2^9 = 512
- 512 - 2 = 510 usable host addresses
- This meets the current requirement for at least 481 addresses, with a small allowance for growth. This also leaves 23 network bits (32 total bits - 9 host bits).

10.4.1 Calculating Addresses: Case 1

- Because there are four networks in our internetwork, Four blocks of 512 addresses each are needed, for a total of 2048 addresses. The address block 172.16.0.0 /23 will be used. This provides addresses in the range from 172.16.0.0 to 172.16.7.255.
- Let's examine the address calculations for the networks:
- Address: 172.16.0.0
- In binary: 10101100.00010000.00000000.00000000
- Mask: 255.255.254.0
- 23 bits in binary: 11111111.11111111.11111110.00000000
- This mask will provide the four address ranges shown in the figure.
- Student LAN
  - For the Student network block, the values would be:
  - 172.16.0.1 to 172.16.1.254 with a broadcast address of 172.16.1.255.

10.4.1 Calculating Addresses: Case 1

- Administrator LAN
  - The Administrator network requires a total of 66 addresses. The remaining addresses in this block of 512 addresses will go unused. The values for the Administrator network are:
  - 172.16.2.1 to 172.16.3.254 with a broadcast address of 172.16.3.255.
- Instructor LAN
  - Assigning the 172.16.4.0 /23. block to the instructor LAN, assigns an address range of:
  - 172.16.4.1 to 172.16.5.254 with a broadcast address of 172.16.5.255.
  - Only 23 of the 512 addresses will actually be used in the Instructor LAN.
- WAN
  - In the WAN, we have a point-to-point connection between the two routers. This network only requires two IPv4 addresses for the routers on this serial link. As shown in the figure, assigning this address block to the WAN link wastes 508 addresses.
  - We can use VLSM in this internetwork to save addressing space, but using VLSM requires more planning. The next section demonstrates the planning associated with the use of VLSM.

10.4.1 Calculating Addresses: Case 1

Calculating and Assigning Addresses - with VLSM

- For the VLSM assignment, we can allocate a much smaller block of addresses to each network, as appropriate.
- The address block 172.16.0.0/22 (subnet mask 255.255.252.0) has been assigned to this internetwork as a whole. Ten bits will be used to define host addresses and sub networks. This yields a total of 1024 IPv4 local addresses in the range of 172.16.0.0 to 172.16.3.0.
- Student LAN
  - The largest subnetwork is the Student LAN requires 460 addresses.
  - Using the formula usable hosts = 2^n - 2, borrowing 9 bits for the host portion gives 512 - 2 = 510 usable host addresses. This meets the current requirement, with a small allowance for growth.

10.4.1 Calculating Addresses: Case 1

- Using 9 bits for hosts leaves 1 bit that can be used locally to define the subnet address. Using the lowest available address gives us a subnet address of 172.16.0.0 /23.
- The Student subnet mask calculation is:
- Address: 172.16.0.0
- In binary:10101100.00010000.00000000.00000000
- Mask: 255.255.254.0
- 23 bits in binary: 11111111.11111111.11111110.00000000
- In the Student network, the IPv4 host range would be:
- 172.16.0.1 through 172.16.1.254 with a broadcast address of 172.16.1.255.
- Because the Student LAN has been assigned these addresses, they are not available for assignment to the remaining subnets: Instructor LAN, Administrator LAN, and the WAN. The addresses still to be assigned are in the range 172.16.2.0 to 172.16.3.255.

10.4.1 Calculating Addresses: Case 1

- Instructor LAN
  - The next largest network is the Instructor LAN. This network requires at least 66 addresses. Using 6 in the power of 2 formula, 2^6 - 2, only provides 62 usable addresses. We must use an address block using 7 host bits. The calculation 2^7 -2 will yield a block of 126 addresses. This leaves 25 bits to assign to network address. The next available block of this size is the 172.16.2.0 /25 network.
  - Address: 172.16.2.0
  - In binary: 10101100.00010000.0000010.00000000
  - Mask: 255.255.255.128
  - 25 bits in binary: 11111111.11111111.1111111.10000000
  - This provides an IPv4 host range of:
  - 172.16.2.1 to 172.16.2.126 with a broadcast address of 172.16.2.127.
  - From our original address block of 172.16.0.0 /22, we allocated addresses 172.16.0.0 to 172.16.2.127. The remaining addresses to be allocated are 172.16.2.128 to 172.16.3.255.

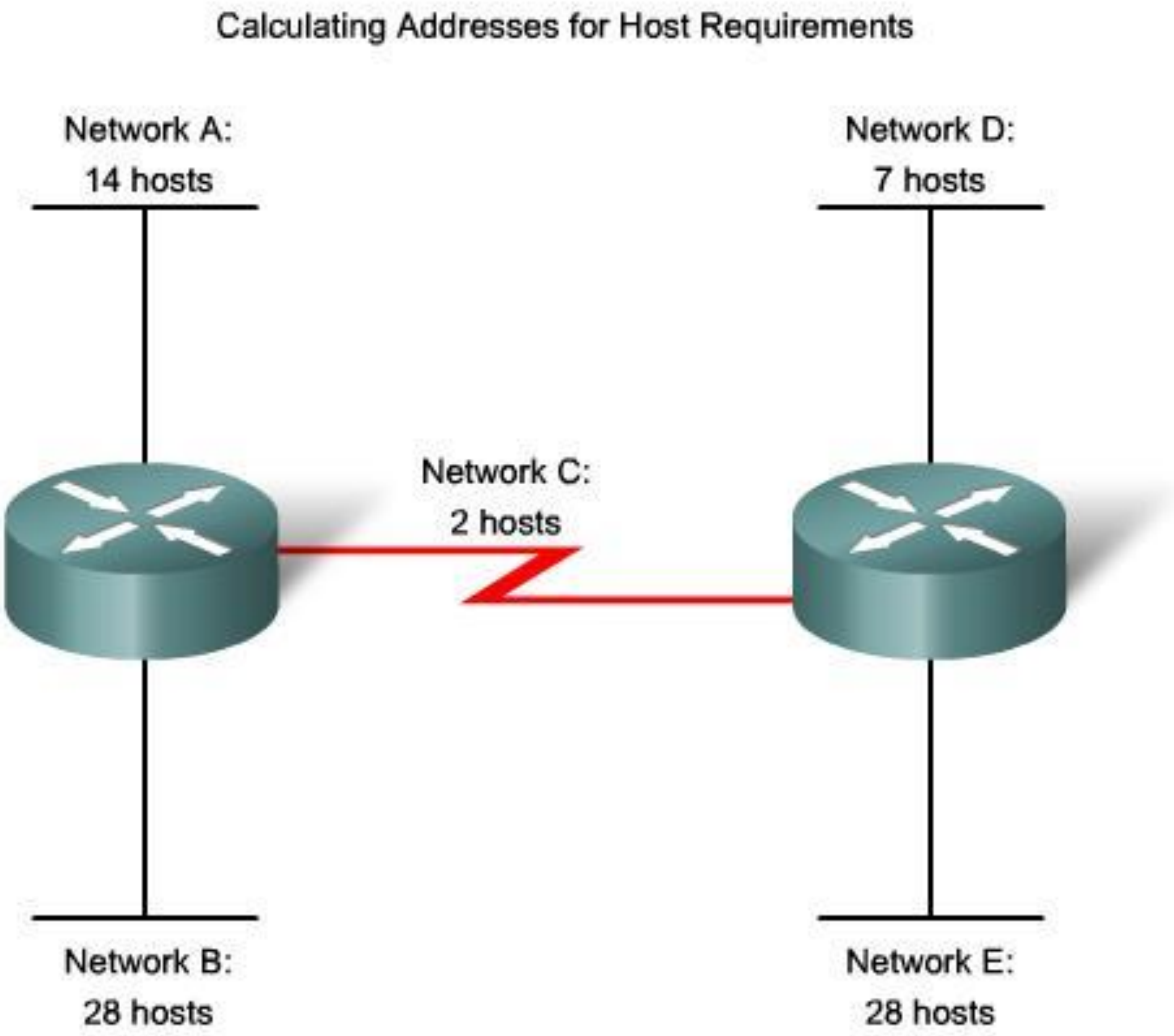
10.4.1 Calculating Addresses: Case 1

- **Administrator LAN**
  - **For the Administrator LAN, we need to accommodate 23 hosts. This will require the use of 5 host bits using the calculation: 2^5 - 2.**
  - **The next available block of addresses that can accommodate these hosts is the 172.16.2.128 /27 block.**
  - **Address: 172.16.2.128**
  - **In binary: 10101100.00010000.0000010.10000000**
  - **Mask: 255.255.255.224**
  - **27 bits in binary: 11111111.11111111.1111111.11100000**
  - **This provides an IPv4 host range of:**
  - **172.16.2.129 to 172.16.2.158 with a broadcast address of 172.16.2.159.**
  - **This yields 30 unique IPv4 addresses for the Administrator LAN.**

10.4.1 Calculating Addresses: Case 1

- **WAN**
  - **The last segment is the WAN connection, requiring 2 host addresses. Only 2 host bits will accommodate the WAN links. 2^2 - 2 = 2.**
  - **This leaves 8 bits to define the local subnet address. The next available address block is 172.16.2.160 /30.**
  - **Address: 172.16.2.160**
  - **In binary: 10101100.00010000.0000010.10100000**
  - **Mask: 255.255.255.252**
  - **30 bits in binary: 11111111.11111111.1111111.11111100**
  - **This provides an IPv4 host range of:**
  - **172.16.2.161 to 172.16.2.162 with a broadcast address of 172.16.2.163.**
- **This completes the allocation of addresses using VLSM for Case 1. If an adjustment is necessary to accommodate future growth, addresses in the range of 172.16.2.164 to 172.16.3.255 are still available.**

10.4.2 Calculating Addresses: Case 2



10.4.2 Calculating Addresses: Case 2

- In Case 2, the challenge is to subnet this internetwork while limiting the number of wasted hosts and subnets.
- The figure shows 5 different subnets, each with different host requirements. The given IP address is 192.168.1.0/24.
- The host requirements are:
  - NetworkA - 14 hosts
  - NetworkB - 28 hosts
  - NetworkC - 2 hosts
  - NetworkD - 7 hosts
  - NetworkE - 28 hosts
- As with Case 1, begin the process by subnetting for the largest host requirement first. In this case, the largest requirements are for NetworkB and NetworkE, each with 28 hosts.

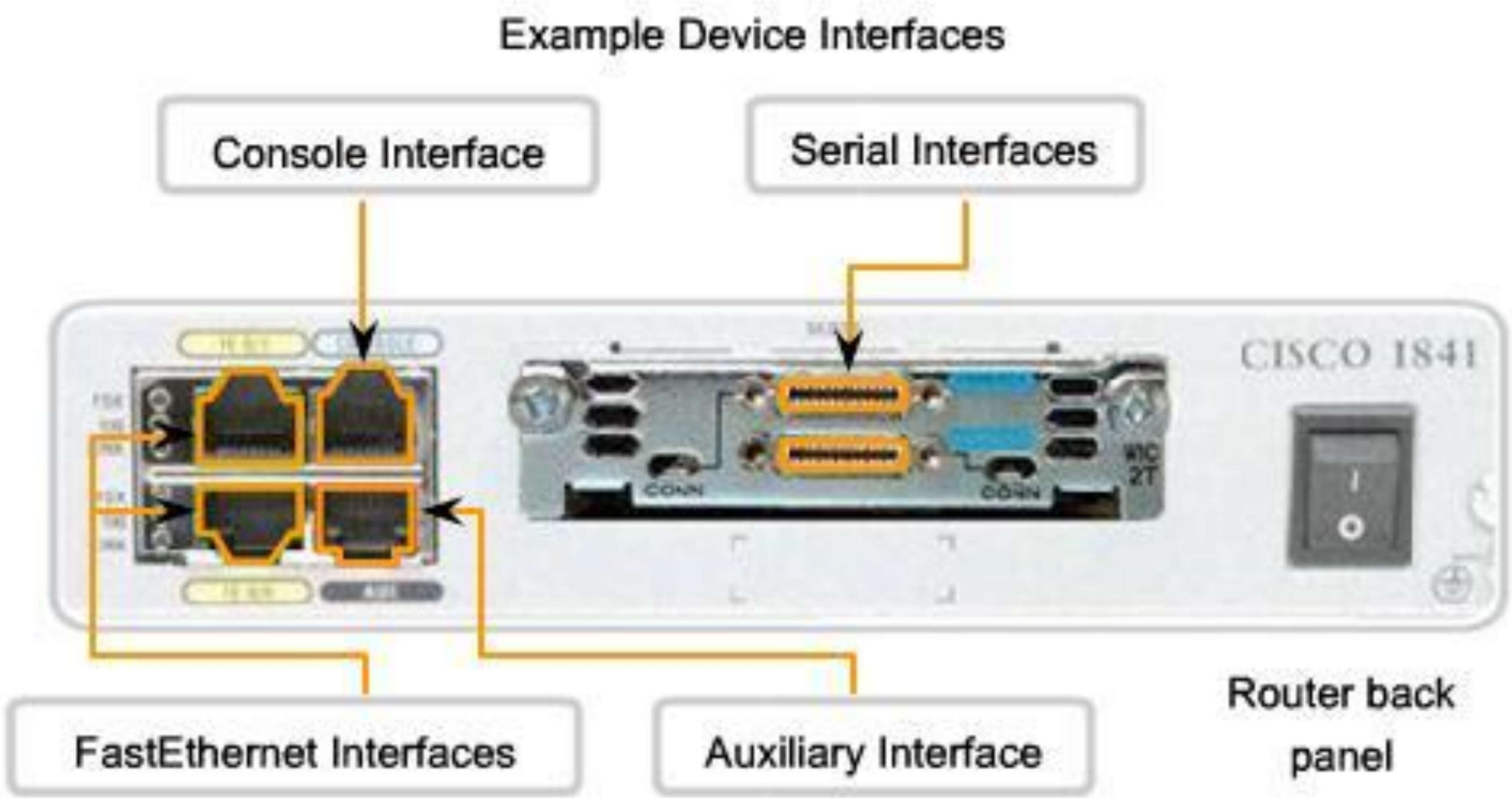
10.4.2 Calculating Addresses: Case 2

- We apply the formula: usable hosts = 2^n- 2. For networks B and E, 5 bits are borrowed from the host portion and the calculation is 2^5 = 32 - 2. Only 30 usable host addresses are available due to the 2 reserved addresses. Borrowing 5 bits meets the requirement but gives little room for growth.
- So may consider borrowing 3 bits for subnets leaving 5 bits for the hosts. This allows 8 subnets with 30 hosts each.
- Allocate addresses for networks B and E first:
- Network B will use Subnet 0: 192.168.1.0/27
- host address range 1 to 30
- Network E will use Subnet 1: 192.168.1.32/27
- host address range 33 to 62

10.4.2 Calculating Addresses: Case 2

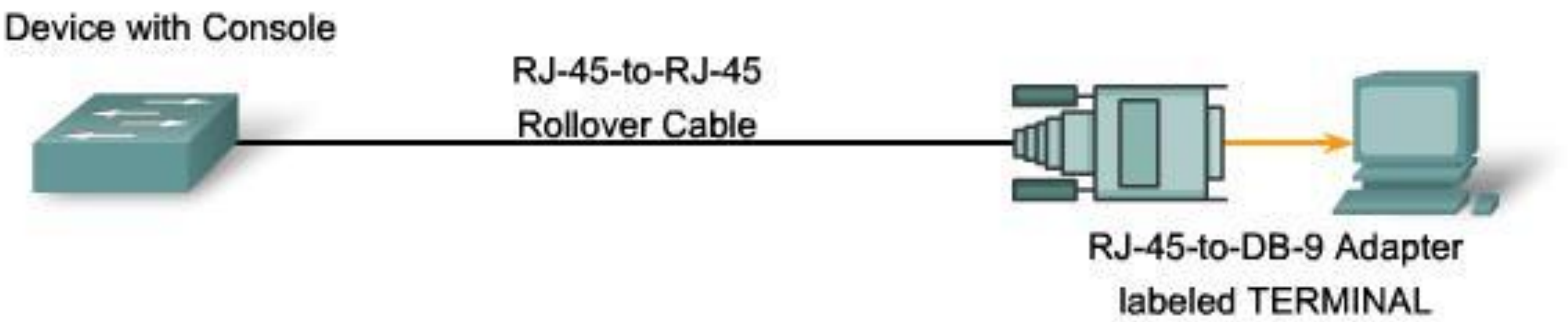
- The next largest host requirement is NetworkA, followed by NetworkD.
- Borrowing another bit and subnetting the network address 192.168.1.64 yields a host range of:
- Network A will use Subnet 0: 192.168.1.64/28
- host address range 65 to 78
- Network D will use Subnet 1: 192.168.1.80/28
- host address range 81 to 94
- This allocation supports 14 hosts on each subnet and satisfies the requirement.
- Network C has only two hosts. Two bits are borrowed to meet this requirement.
- Starting from 192.168.1.96 and borrowing 2 more bits results in subnet 192.168.1.96/30.
- Network C will use Subnet 1: 192.168.1.96/30
- host address range 97 to 98
- In Case 2, we have met all requirements without wasting many potential subnets and available addresses. In this case, bits were borrowed from addresses that had already been subnetted. As you will recall from a previous section, this method is known as Variable Length Subnet Masking, or VLSM.

10.5 Device Interconnections
10.5.1 Device Interfaces



10.5.2 Making the Device Management Connection

The Device Management Connection



- PCs require an RJ-45 to DB-9 or RJ-45 to DB-25 adapter.
- COM port settings are 9600 bps, 8 data bits, no parity, 1 stop bit, no flow control.
- This provides out-of-band console access.
- AUX switch port may be used for a modem-connected console.