**Network Cabling I**

* **Twisted pair network cabling**
* **Twisted pair network connectors**
* **Categories of twisted pair**

**Twisted Pair Network Cabling:** Most people are familiar with twisted pair cables, as hey are the standard in the modern LAN

* Twisted pair cables are composed of four pairs of wires contained within an insulating sheath. Each pair of wires is twisted together to reduce electromagnetic interference (EMI). The twist rates differ between the pairs of wires to reduce crosstalk between the pairs. The colors of the pairs are: white, orange/orange, white blue/blue, white green/green, and white brown/brown
* **Unshielded vs. Shielded twisted pair (UTP vs. STP)**
  + STP has an additional shield that is either wrapped around each pair of wires or around all four pairs
    - STP reduces the opportunity for Emi or crosstalk, but is more expensive and a little harder to work with
  + UTP is deployed in the network much more often than STP.
* **Plenum vs. non-plenum twisted pair**
  + Most twisted pair is non-plenum grade
  + Building codes often call for plenum grade cable to be run in plenum spaces (areas designed to assist in the airflow of a building for HVAC purposes).
    - Plenum cable is jacketed in either a fire-retardant cover or in a low-smoke PVC jacket
    - Plenum cable often has a polymer or nylon strand woven into it to help take the weight of hanging cables. This reduces the chance for the cable to stretch, which can cause the pair inside to break
  + Twisted pair is usually either a straight-through cable or a crossover cable, but it can also be used to create a rollover (console) cable.
  + A straight-through cable is used to connect different types of devices together (computer to switch, or switch to router) while a crossover cable is used to connect similar devices together (PC to PC, or switch to switch). They use a different pinout to achieve the connection.
  + A rollover or console cable is often required to connect to the console port on a switch or router. It is quite common for end of the rollover cable to use an RJ45 connector, while the other end utilizes an RS 232 (DB 9) connector.

**Twisted Pair Network Connectors**

* **RJ11:** 
  + Uses a 6-position 4-contact (6P4C) modular connector
  + Can carry data or voice; common usage is voice communication (telephony)
* **RJ45:**
  + Uses an 8-position 9-contact (8P8C) modular connector
  + Can carry data or voice; common usage is data networking (Ethernet)
* **RJ48C**
  + Uses a 8-position 8-contatin (8P8C) modular connector
  + Used as the terminating connector at the demarc for T1 lines
    - It is often confused with an RJ45, but the active pins are different
* **UTP coupler**
  + Used to connect UTP cables back to back and still maintain adherence to industry standards
* **66 block**
  + A punch down block initially developed to terminate and distribute telephone lines in an enterprise environment
    - It was also used in slower speed networks, as it can handle data traffic rated for CAT 3 cabling
* **110 block**
  + A punch down block developed to terminate and distribute twisted pair network cabling. It is capable of handling the signaling requirements of the modern network
* **DB9 (RS-232)**
  + A nine pin D-subminiature connector developed for asynchronous serial communication between nodes
    - It was a common type of connection between a computer and an external analog modem
    - It often makes up one end of the rollover cable
* **DB25 (EIA-232/RS-232 serial).**
  + A 25 pin D-subminiature connector developed for asynchronous serial communication between nodes
    - It was a type of connection between a computer and an external analog modem

**Categories of Twisted Pair**

* **Cat 3:** 
  + Rated for up to 10 Mbps speed, 10BaseT
    - Max distance of 100 meters
* **Cat 5**
  + Rated for up to 100 Mbps speed, 100BaseT
* **Cat 5e**
  + Rated for up to 1 Gbps, 1000BaseT
* **Cat 6**
  + Rated for up to 10 Gbps, 10 Gigabit Ethernet (GbE)
    - Max distance of 55 meters when used for 10 GbE
* **Cat 6a**
  + Rated for up to 10 Gbps, 10 GbE
    - Max distance of 100 meters when used for 10 GbE

**Summary:**

* **Twisted Pair Cabling:** Twisted pair cabling is the modern LAN standard. It is composed of four pairs of color coded wires, where each pair of wire sis twisted together to reduce interference. It may contain extra shielding to further reduce interference. In some cases, a plenum grade cable may be called for by building code. The most common types are: straight through, crossover, and rollover cables
* **Twisted pair network connectors:** The RJ11 is a modular (6p4C) connector commonly used for telephony. The RJ45 is a modular 8P8C connector that is used to carry network traffic. The RJ48C is a modular 8P8C connector that is commonly used to terminate a T1 line. Punchdown blocks are used to terminate and distribute network runs of twisted pair wires. The DB-9 and DB-25 may be used for serial communication between nodes
* **Categories of twisted pair:** CAT3 can achieve speeds of 10Mbps, CAT5 can achieve speeds of 100Mbps, CAT5e can achieve speeds of 1000Mbps, and CAT6 can achieve speeds of 10 Gbps (over a max of 55m), and CAT6a can achieve speeds of 10 Gbps

**Network Cabling II**

* **Coaxial cabling**
* **Fiber optic cabling**

**Coaxial cabling**

* **Coaxial cabling**
  + Coaxial cabling is one of the oldest Ethernet cabling standards (1973)
  + It has been used for baseband (carries single digital signal)
  + It has been used for broadband (carries multiple digital signals)
  + It is composed of a central conductor that is covered by an insulating layer, which is covered by an outer metal mesh or foil layer that is finished with an outer insulating layer
  + The inner metal mesh or foil layer helps to protect against EMI
* **Coaxial cable types**
  + **RG58:** 10Base2, max distance of 185m, 50Ohms impedance
    - A close-up of a cable

      Description automatically generatedNo longer commonly found in modern network
  + **RG59:** Commonly used to provide a broadband connection between two devices over a short distance, has a 75Ohms impedance value.
  + **RG6:** cable TV or broadband, distance varies, has a 75 Ohms impedance value
    - Commonly used to make the connection to cable modems by cable companies
* **Coaxial cable connectors**
  + **BNC (Bayonet Neill-Concelman)**
    - Also known as a bayonet connector
    - Used with coaxial cable; is now considered obsolete
    - The connection from the cable to the device was achieved through a twist-lock type connection
    - A BNC coupler can be used to connect two coaxial cable segments back to back
  + **F connector**
    - A threaded bayonet connector
    - Used with coaxial cable
    - An F connector coupler can be used to connect two coaxial cable segments back to back

**Fiber Optic Cabling**

* **Fiber optic cabling described**
  + IT is relatively expensive and harder to work with
  + It is not that common in the LAN environment
  + IT resists all form of EMI and cannot be easily tapped
  + It can cover long distances at high speed
  + It is designated by fiber type, cladding size (the cladding is what the light bounces down), and jacket size
    - Size of cladding and jacket listed in micrometers
  + Most applications require that fiber cables be run in pairs (basically a send cable and a receive cable).
  + The type of connector use on fiber optic cabling can impact the performance of the transmissions.
    - The **UPC** (Angled Physical Contact) connector has a back reflection rating of around -55 dB
    - The **APC**  (Angled Physical Contact) connector has a black reflection rating of around -70 dB, making it the better performing connector.
* **Fiber types**
  + **Multimode fiber (MMF)**
    - It uses an infrared LED system to transmit the light
    - It uses multiple rays of light going down the cable
    - It is used for shorter fiber runs, under 2 km
    - It is less expensive to implement than SMF
    - The most common application in networking is MMF 62.5/125micro, which is good for up to 275mA diagram of a cross with arrows pointing to the center

      Description automatically generated with medium confidence
  + **Single-mode fiber (SMF)**
    - It uses a laser-diode arrangement to transmit the light
    - It uses a single ray of light transmitted down the cable
    - It is used for longer runs that require high speed
    - A black line with white text

      Description automatically generatedIt can traverse 40+ km
* **Fiber optic cabling connectors**
* **SC**
  + Subscriber Connector, or Square Connector, or Standard Connector (Stick and Click).
  + A push-pull type of connector
* **ST**
  + Straight Tip (Stick and Twist)
  + A twist lock type of connector
* **LC** 
  + Local Connector, or Lucent Connector, or Little Connector
  + A type of connector that uses a locking tab to secure the connection
* **MTRJ**
  + Mechanical Transfer Registered Jack
  + A small form factor connector that contains two fibers and that utilizes a locking tab to secure the connection
* Fiber optic coupler
  + Used to connect two fiber optic cables back to back

**Summary:**

* **Coaxial cabling:** Coaxial cabling is composed of a central conductor covered by an insulating sheath, covered by a foil or metal mesh sheath, covered by an outer insulating layer. RG58 is no longer found in the modern network. RG59 is used to provide a short distance broadband connection between two devices. RG6 is the most commonly used grade of cable used by cable companies to connect to the cable modem
* **Fiber optic cabling:** Fiber optic cabling is expensive and canbe difficult to work with, but resists all forms of EMI and can span long distances. The grade of connector can influence the quality of the signal. Fiber optic cabling is classified by its type of transmission as either being MMF or SMF. Currently there are four common types of connectors –SC, ST, LC, and MTRJ

**Network Cabling III**

* **Media converters**
* **Cabling tools**

**Media Converters:** It is not uncommon to be in a situation where a network contains more than one type of cabling

* This can lead to situations where there is a desire to connect different types of media together in order to make a cohesive network.
* Thankfully, media converters are readily available. The issue mostly comes into play when joining fiber optic transmissions to a copper wire infrastructure.
* Some common media converters will connect: SMF to Ethernet, MMF to Ethernet, SMF to MMF, and fiber to coaxial cabling.

**Cabling Tools:** Every technician should put some thought into the tools that are in his toolbox

* IGNORE

**Network Topologies**

* **What is a topology?**
* **Peer-to-peer vs. client/server**
* **Network topology models**

**What is a topology:** A topology is basically a “map” that can describe how a network is laid out or how the network functions

* The network topology can be described as either logical or physical. A logical topology describes the theoretical signal path while the physical topology describes the physical layout of the network.

**Peer-to-peer vs. client/server**

* **Are these really topologies?**
  + No: they don’t describe the signal path or the physical layout of the network
  + Yes: they describe the how the network functions
* **Peer-to-peer topology**
  + Nodes control & grant access to resources on the network
  + NO 1 node or group of nodes controls access to a specific type of resources (no server is present)
  + **A computer network diagram with words

    Description automatically generated**Each node is responsible for the resources it is willing to share
* **Client/server topology**
  + Network resources access is controlled by a central server(s)
  + A server(s) determines what resources get shared, who is allowed to use the resources and even when the resources can be used
* **Hybrid topology** 
  + A combination of peer-to-peer & client/server networking

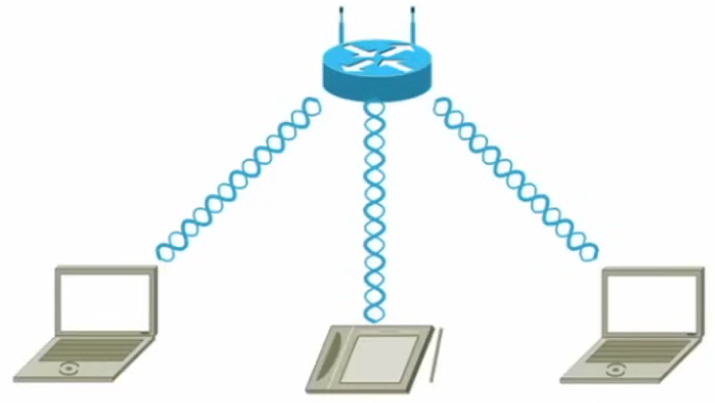
**Network topology models:** The original Ethernet standards established a “bus” topology for the network, both logically & physically

* As time went on the “bus” developed some mechanical problems. That let to the development of different physical topologies, but the logical topology remained the same in order to maintain backward compatibility. So when discussing Ethernet networks, the logical topology is always a “bus” topology while the physical topology can be different
* **Bus**
  + The signal traverses from one end of the network to the other
  + A break in the line “breaks” the network
  + The ends of the “line” must be terminated in order to prevent signal bounce.
  + The network cable is the central point
  + A computer with a red line

    Description automatically generated
* **Ring**
  + A bus line with end points connected together.
  + A break in the ring breaks the ring
  + Often implemented with multiple rings () that counter rotate
  + Not very common in the LAN anymore, but still used in the WAN (SONET especially)
  + A computer network with computers

    Description automatically generated
* **Star**
  + Nodes radiate out from a central point
  + When implemented with hub a break in a segment brings down the bus
  + When implemented with a switch, a break in a segment only brings down the segment
  + Most common implementation of the modern LAN
  + A star with a star and a blue square with computers connected to it

    Description automatically generated
* **Mesh**
  + Multiple connections between nodes on the network
  + Full mesh means that every node has a physical connection to every other node
  + Partial mesh means that there are multiple paths between nodes
  + A full mesh topology is expensive to install because of the wiring constraints
  + A network of computers connected to a red line

    Description automatically generated
* **Point-to-point**
  + Two nodes or systems connected directly together
  + Two PC connected with a crossover cable create a point-to-point topology.
  + No central device is required to manage the connection
  + A common topology when implementing a WAN connection
  + 
* **Point-to-multipoint**
  + A central device that controls the paths to all other devices
  + Differs from a star in that the central device is intelligent
  + Wireless networks often implement point-to-multipoint topologies
  + When the WAP sends, all devices on the network receive the data, when a device sends it message is only passed along to the destination
  + Also a common topology when implementing a WAN connection.
* **MPLS**
  + Multiprotocol Label Switching is a topology used to replace both Frame Relay switching and ATM switching
  + It’s a topology because it specifies signal path and layout both
  + It is used to improve the Qos and flow of network traffic
  + Label edge router (LER): adds MPLS labels to incoming packets if they don’t have them
  + Label switching router (LSR): forwards packets based on their MPLS labels

**Summary:**

* **What is topology?:** A map that can be used to describe the signal path or physical layout of a network. The logical topology will describe the signal path while the physical topology is more of a wire schematic.
* **Peer-to-peer vs. client/server:** In peer-to-peer networking there is no central control of network resources. Each node determines what it will share and what it will not share. In client/server networking there is central control of shared network resources with a server controlling access. A network can have aspects of both and this is considered a hybrid topology
* **Network topology models:** Ethernet networks are logical bus networks regardless of the physical layout. Bus topology: signal goes end-to-end. Ring=bus with the ends connected. Star=nodes radiate out. Mesh=multipath. Point-to-point=direct connection. Point-to-multipoint=central control. MPLS=a topology used to improve Qos and network traffic flows

**Network infrastructure implementations**

* **Design vs. function**
* **Categories of networks**

**Design vs. function:** When describing a network you have a couple of different options. Are you going to describe is design or its function?

* If you are going to describe the network’s design, then the first place to start is to describe its topology (e.g., bus, star, or point-to-point). If you are going to describe the network’s function, then the first place to start is to describe its category or infrastructure implementation.

**Categories of networks**

* **Local area network (LAN)**
  + Most LANs are encompassed by single network address range.
    - The address range may be broken into subgroups
    - Each of these subgroups is called a virtual local area network
  + LANs can span from a small area (a single room) to a building or a small group of buildings
  + They tend to be high speed.
  + 802.3 (**Ethernet**) and 802.11 (wireless local area network, **WLAN**) are the most common types of network found in the LAN
* **Metropolitan area network (MAN)**
  + Is larger than a LAN
  + Most often it contains multiple LANS
  + They are often owned by municipalities
  + When a MAN is owned by a private entity, it is sometimes called a campus are network (CAM)
* **Wide area network (WAN)**
  + A network which spans significant geographic distances
  + They can be described as a network of networks
  + The best example is the Internet
  + As a general rule, if the all of the infrastructure implementation has a single owner, then it is not a WAN
* **Personal area network (PAN)**
  + Extremely distance and size limited
    - Most often it is a connection between only two devices
  + Common examples include:
    - **Bluetooth** connection between a keyboard and computer
    - **Infrared (IR)** connection between a smartphone and a printer
    - **Near field communication (NFC)**  between a smartphone and a payment terminal.
  + They tend to provide low throughput of data and have a low power output.
    - As the distance between devices increases, throughput decreases
* **Supervisory control and data acquisition (SCADA)**
  + A type of industrial control system (**ICS**) that is designed to control large scale deployments of equipment. The controlled equipment is usually at more than one site.
    - SCADA is often deployed in energy distribution systems by utility companies
  + Uses a distributed control system (**DCS**) to communicate with programmable logic controllers (**PLC**s) and/or remote terminals to control equipment and processes from a central location
  + These systems are often proprietary and often require additional training to understand and operate
* **Medianet.**
  + Networks designed and implemented specifically to handle voice and video
  + Designed and implemented to remove quality of service (**QoS**) issues (e.g., latency and jitter) that can occur in other infrastructures
    - A video teleconference (**VTC**) network is an example
  + It may be implemented as its own infrastructure or as a sub infrastructure.

**Summary:**

* **Design vs. Function:** A network can be described by its design or by its function. When describing the design (e.g., bus, star, or point-to-point) the topology is actually being described. When describing the function (e.g., LAN, WAN, or SCADA) of a network, it is actually the category or infrastructure implementation that is being discussed.
* **Categories of networks:** The LAN spans a small area, like a building. While there is not a distinct line between the LAN and thee MAN, the Man is larger than the LAN. WANs span large geographic areas. As a rule, if the infrastructure is owned by one entity, it is not a WAN. PANs are very small, low powered networks that tend to only span two devices. A SCADA network is a special purpose network used to control equipment and processes across multiple industrial sites. A medianet is a purpose built infrastructure designed and implemented specifically to handle voice and video traffic.

**Introduction IPv4 I**

* **Purpose of IP addressing**
* **IPv4 address properties**

**Purpose of IP addressing:** When Bob on network A wants to view a Web page hosted on a server on network C, how does his computer know where to send Bob?

* Well somehow Bob has gotten the server’s IP address (either IPv4 or IPv6 format). IP addresses are the location of the PC or server, identified as both network location and host location within that network.
* IP addressing provides a logical addressing scheme for out computers so that they can communicate on networks
  + Being logical means that an IP address can be changed with minimal fuss at any time, unlike a MAC (media access control) address, which is physically embedded into devices

**IPv4 address properties:** As IPv4 is made up of a 32-bit binary number, there are 2^32 possible address combinations

* That’s 4,294,967,296 possible combinations. With all of these possibilities, a process needed to be developed to keep everything neat and tidy and, most of all, findable. The implementation of the subnet mask was the answer
* **Initial properties of IPv4**
  + 32-bit binary number
  + Divided into four sets of eight (called octets) that are separated by periods (each octet is 8 bits, which is equal to one byte).
  + Represented in human friendly format by a dotted decimal format
  + Requires the use of a mask to determine which portion defines the network and which portion defines the node. This is called the subnet mask.
  + The subnet mask has the same format as the IP address (32-bits and represented in dotted decimal format)
* **Interaction of IP address and subnet mask**
  + 192.168.1.9.255.255.255.0
  + 192.168.1.9 = the IP address
  + 255.255.255.0 = the subnet mask
* **Deconstructing the IP address**
  + First octet = 11000000
  + Second octet = 10101000 = 168
  + Third octet = 00000001 = 1
  + Fourth octet = 00001001 = 9
* Subnet mask characteristics
  + Anything other than a 0 defines the network address
* Network address
  + The network address = 192.168.1
* Node address
  + The node address = 9

A close-up of numbers

Description automatically generated

**Summary:**

* **Purpose of IP addressing:** IP addressing is logical in nature so it can be easily changed. It provides the means of identifying the pathways between networks and nodes
* **IPv4 address properties:** IPv4 is made up of a 32-bit binary number (base 2). There are over 4 billion possible combinations. A subnet mask is used to allow for the identification of the network and node portions of the IP address

**Introduction to IPv4 II**

* **Classes of IPv4 addresses**
* **Classless IPv4 addressing**
* **Subnetting IPv4 addresses**

**Classes of addresses:** Internet Protocol v.4 (IPv4) is a binary addressing scheme that is used for networking. It was finalized as a standard in 1981.

* IPv4 is a common network addressing scheme that is deployed today. There is an issue though. Because of its structure and the growth in popularity of the Internet, most of the world has run out of assignable IPv4 addresses. Thanks to some forethought though, it is still a valid scheme.

**Classes of IPv4 addresses**

* **Class A network address:**
  + Address range = 0 to 127 in the first octet.
  + 0.0.0.0 to 127.255.255.255
  + Binary representation = 0XXXXXXX
  + Node addresses available = 16,777,214
  + Subnet mask = 255.0.0.0
* **Class B network address:**
  + Address range = 128 to 191 in the first octet
    - 128.0.0.0 to 191.255.255.255
  + Binary representation = 10XXXXXXX
  + Subnet mask = 255.255.0.0
* **Class C network address:**
  + Address range = 192 to 223 in the first octet
    - 192.0.0.0 to 223.255.255.255
  + Binary representation = 110XXXXX
  + Node addresses available = 254
  + Subnet mask = 255.255.255.0
* **Class D network address**
  + Address range = 224 to 239 in the first octet
    - 224.0.0.0 to 239.255.255.255
  + Binary representation = 1110XXXX
  + Subnet mask = not defined
  + Used for multicast communication
* **Automatic Private IP Addressing (APIPA)**
  + In some, causes the Dynamic Host Configuration Protocol (DHCP) process may fail; in these cases, a node will self configure an APIPA address
  + Address range = 168.254 in the first octet
  + POTENIAL SOURCE OF ERROR | FAILURE
* **Public IP addresses**
  + Routable
  + Each must be unique. (For any of you “Highlander” fans out there, remember: “There can only be one.”)
  + Not flexible; you are assigned to your network space
* **Private IP addresses**
  + Non-routable
  + 10.0.0.0 to 10.255.255.255 (1 Class A license)
  + 172.16.0.0 to 172.31.255.255 (16 Class B licenses)
  + 192.168.0.0 to 192.168.255.255 (256 Class C licenses)
  + Highly flexible; you assign the network space.

**Classless IPv4 addressing**

* **Classes of addresses limited flexibility**
  + First routing protocols required the class structure
* **Classless addressing.**
  + Classless Inter-Domain Routing (CIDR)
  + Slow the growth of routing tables
  + Slow the exhaustion of IPv4 addresses
  + Create more flexibility
    - The subnet mask becomes fluid
  + Does not affect the private address space ranges
  + Subnetting is now possible and desirable
* **CIDR notation:**
  + 192.168.0.9.255.255.255.0 becomes 192.168.0.9/24
  + 192.168.128.0/23 = subnet mask of 255.255.128.0
    - Network = 192.168.128.0
    - Host range = 192.168.128.1 to 192.168.129.254 (512)
    - Broadcast address = 192.168.129.255

**Subnetting IPv4 addresses**

* **Subnetting cuts the address space into smaller pieces**
  + Creates flexibility in network design
  + Creates efficiency in address space utilization
* **Small office network example**
  + 223.15.1.0/24 network = 254 hosts available (hosts can’t use 223.15.1.0 or 223.15.1.255)
  + All hosts can get to all other hosts
  + For security considerations, you want two separate networks
  + You could use 223.15.1.0/25 and 223.15.1.128/25 by subnetting the original address as follows
    - Network 1 host address range: 223.15.1.1 to 223.15.1.126 (broadcast address is: 223.15.1.127)
    - Network 2 host address range: 223.15.1.129 to 223.15.1.1254 (broadcast address is: 223.15.1.255)

**Summary:**

* **Classes of IPv4 addresses:** Classes consist of A, B, c, and D. All have a defined subnet mask, except for Class D addresses. They are very structured and rigid and don’t allow for much flexibility. An APIPA address is a special address that denotes the failure of DHCP. Public addresses are routable; private addresses are not. There are very specific ranges of addresses available in the private space
* **Classless IPv4 addressing:** CIDR removes the class structure from addresses, creating more flexibility and efficiency in design and utilization. It allows for subnetting of addresses
* **Subnetting IPv4 addresses:** Subnetting involves talking the network address space that is available and creating small pieces. It is used to create flexibility and security within a network

**Introduction to IPv6**

* **IPv6 address structure**
* **IPv6 network transmissions**

**IPV^ address structure:** is the answer to the question “What do we do about running out of IPv4 addresses?”

* Unlike IPv4, Ipv6 will provide enough Internet Protocol (IP) addresses for the foreseeable future. Shortly after IPv4’s creation and implementation, the Internet Assigned Numbers Authority (**IANA**)—the organization that is tasked with assigning routable IP addresses—realized that the available IPv4 address space would not be enough
* The IANA then set about creating the replacement and started work on IPv5. While working on IPv5, the IANA determined that it was not going to be sufficient for the task. They scrapped IPV5 and began working on IPv6. The IANA is confident that IPv6 will function as the replacement for IPv4 for many decades to come
* **IPv6 works at Layer 3 of the OSI model**
  + Layer 3 of the OSI model is also known as the network layer and its major focus is logical network and host addressing IPv6’s job is to provide logical network and host addresses to devices
* IPv6 is a 128-bit binary addressing scheme
  + The 128 bits are grouped together in sets, with each set being separated by a colon
    - Each set is 2 bytes long (a byte is 8 bits)
  + For human readability, the binary IPv6 number is converted to hexadecimal (base 16) with each hexadecimal number being equal to 4 bits (which can be referred to as a “nibble” because it is half of a byte).
    - An IPv6 address is eight sets of four hexadecimal numbers with each set separated by colons
* There are over 340 undecillion addresses available to IPv6
  + 2^218
* **IPv6 local address structure**
  + The first 64 bits represent the local network and the last 64 bits represent the host
    - The local address structure follows the Extended Unique Identifier (**EUI**) format –**EUI-64.** The 48-bit MAC address is padded with 16 bits to make it 64 bits in length
  + The local address is called the **link local address** and it always begins with **fe80**
* **IPv6 global address structure**