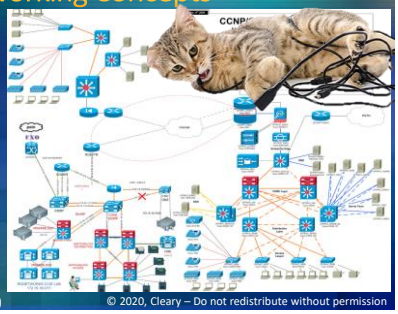
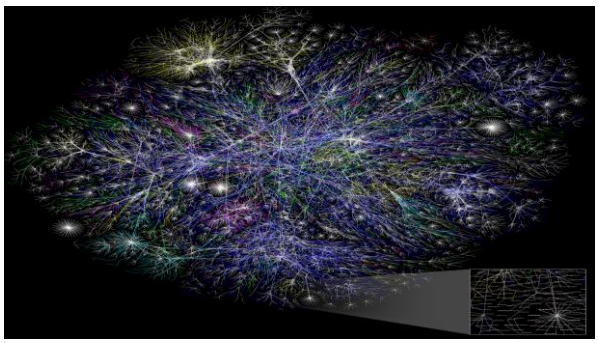
Advanced Networking Concepts

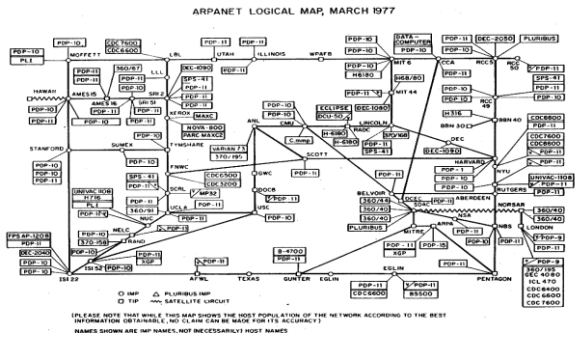


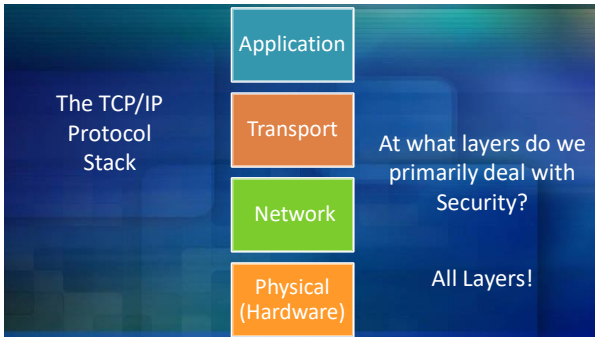
Cyber Defense
Kevin Cleary
Tuesday, March 10, 2020

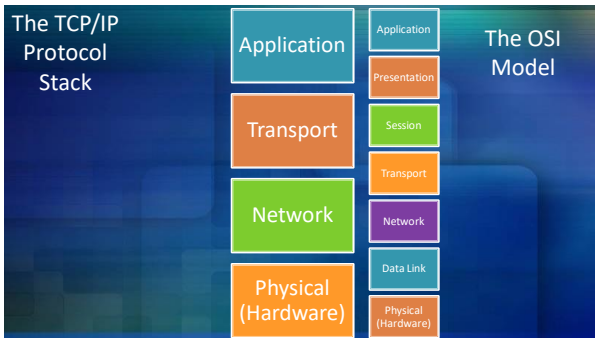
The Internet

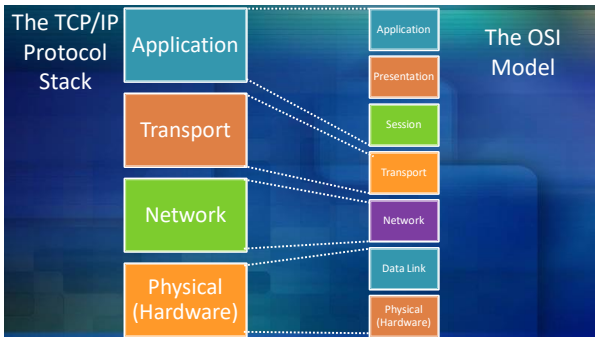
- The Internet is governed by a series of protocols that form the rules for how communications should happen
- The Internet is a network of networks.
  - There is no centralized point.
  - There are no boundaries.
- Information sent from one location on the internet to another is broken down into smaller, more manageable pieces called "packets".




ARPANET LOGICAL MAP, MARCH 1977
IMP
TIP
PLURIBUS IMP
SATELLITE CIRCUIT
(PLEASE NOTE THAT WHILE THIS MAP SHOWS THE HOST POPULATION OF THE NETWORK ACCORDING TO THE BEST INFORMATION OBTAINABLE, NO CLAIM CAN BE MADE FOR ITS ACCURACY)
NAMES SHOWN ARE IMP NAMES, NOT (NECESSARILY) HOST NAMES

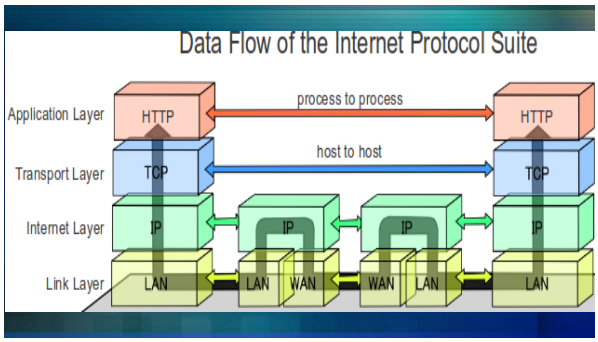

The TCP/IP Protocol Stack
Application
Transport
Network
Physical (Hardware)
At what layers do we primarily deal with Security?
All Layers!

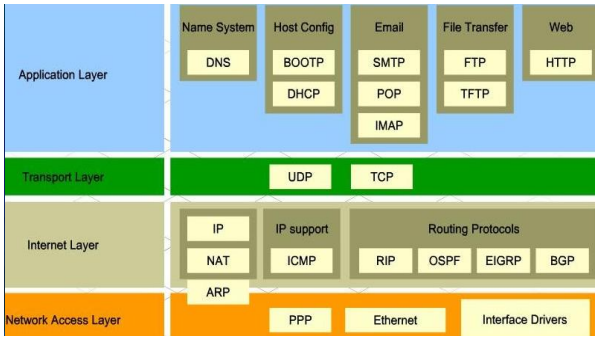

The TCP/IP Protocol Stack
Application
Transport
Network
Physical (Hardware)
The OSI Model
Application
Presentation
Session
Transport
Network
Data Link
Physical (Hardware)



Protocol Stacks

- The protocol stack used by every computer on the Internet is known as TCP/IP.
- The stack includes:
  - Network (Internet) - packet switched
  - Transport Layer - circuit switching
- The TCP/IP protocol stack takes care of how computer communications get routed to the correct computer and how the applications assemble and make sense of newly arrived packets.



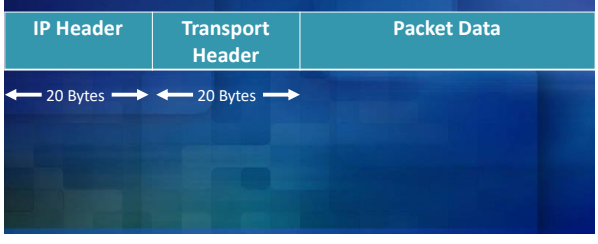


Protocol Stacks

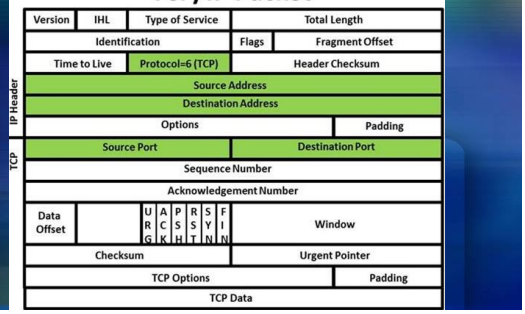
- When an applications whishes to send a message over the Internet it hands the message down the protocol stack. Each protocol within the stack has some task.
- The transport layer provides management overhead to be sure messages are sent and received in a reliable way, ensuring message integrity and authenticity.
- The IP layer takes care of steering these packets in an efficient, redundant way across many multiple, heterogeneous networks.
- The Hardware physical transmits packets (frames).

Protocol Stacks

- Each layer places its information in the "packet header".
  - This is information needed to deliver and re-order the packet once it has arrived to its destination.

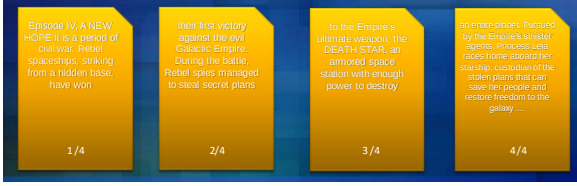


TCP/IP Packet



Breaking a Message Down Into Packets

Episode IV. A NEW HOPE It is a period of civil war. Rebel spaceships, striking from a hidden base, have won their first victory against the evil Galactic Empire. During the battle, Rebel spies managed to steal secret plans to the Empire's ultimate weapon, the DEATH STAR, an armored space station with enough power to destroy an entire planet. Pursued by the Empire's sinister agents, Princess Leia races home aboard her starship, custodian of the stolen plans that can save her people and restore freedom to the galaxy….

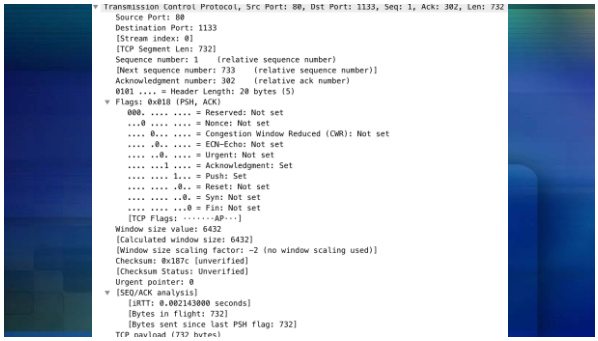


The Transport Layer

- Your application passes information on to the Transport layer to be broken up in to manageable chunks called packets.
  - Information is added to the packet headers for re-assembly.
    - Sequencing numbers
    - Session IDs
- The Transport layer is a connection-oriented, message switched, reliable, byte stream service.
  - Connection-oriented means:
    - semi-permanent connection is established before any useful data can be transferred
    - a stream of data is delivered in the same order as it was sent
  - TCP must first establish a connection before exchanging data (a handshake).
  - For each packet received, an acknowledgement is sent to the sender.

The Transport Layer

- The Transport layer, using the Transmission Control Protocol (TCP) takes care of breaking application messages into chunks, known as **packets** and assigning information such as:
  - Port number - help to separate what data is destined to which applications.
    - Email and Web browsers have a specific, unique port number
  - Number of packets sent.
  - The number the packet in the series being sent.
  - Packet sequencing numbers.
  - On the receiving end the TCP protocol helps to arrange packets as they arrive in the correct order for the applications.
- A cousin of TCP, User Datagram Protocol (UDP) is commonly used for streaming. A connectionless, unreliable protocol



The IP Layer

- IP is an unreliable, connectionless, packet switched protocol.
  - IP's job is to send and route packets to other routers / computers.
  - IP packets are independent entities and may arrive out of order or not at all.
  - IP does not guarantee packet delivery.
  - A series of diagnostic tools exist at the IP layer, the Internet Control Messaging Protocol ICMP. ("ping" and "traceroute".)
- Advantages:
  - More tolerant to failures
  - Better utilization of an internet connection
- Disadvantages:
  - Packets may arrive out of order
  - Packets may not arrive at all!
  - Controlled chaos from a messaging perspective

Packet Routing at the IP Layer

- IP packet routing is similar to mailing a letter.
- The steps you take in mailing a letter include…
  - Sealing your message in to an envelope.
  - Looking up the address to write on the envelope.
  - Determine if you can hand deliver your message or if it needs to be given to the mail man.
  - If the mailman must deliver the message you must hand the message off to them. The mailman works with other mailmen to then deliver your envelope.
  - Wait for a response.

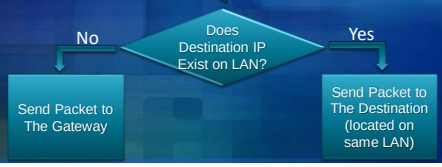

```
▼ Internet Protocol Version 4, Src: 10.10.10.1, Dst: 10.10.10.11
    0100 .... = Version: 4
    .... 0101 = Header Length: 20 bytes (5)
  ▼ Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
      0000 00.. = Differentiated Services Codepoint: Default (0)
      .... ..00 = Explicit Congestion Notification: Not ECN-Capable Transport (0)
    Total Length: 772
    Identification: 0x519d (20893)
  ▼ Flags: 0x02 (Don't Fragment)
      0... .... = Reserved bit: Not set
      .1.. .... = Don't fragment: Set
      ..0. .... = More fragments: Not set
    Fragment offset: 0
    Time to live: 64
    Protocol: TCP (6)
    Header checksum: 0xbe37 [validation disabled]
    [Header checksum status: Unverified]
    Source: 10.10.10.1
    Destination: 10.10.10.11
    [Source GeoIP: Unknown]
    [Destination GeoIP: Unknown]
```

IP Client Information

- To route packets correctly, a device must be configured with:
  - IP address: Every IP address on the internet is unique*:
    - 4 x 8 bit (32 bit) numbers represented in decimal notation separated by '.'s. For example 128.205.34.66. – IPV4
    - 8 x 16 bit (128 bit) alphanumeric addresses in decimal notation separated by '.'s. For example 2001:0000:3238:DFE1:63:0000:0000:FEFB – IPV6
    - IP addresses (To and From) are placed in packet headers, similar to an envelop.
  - Subnet Mask – used to determine the boundaries of a Local Area Network.
    - A subnet mask resembles an IP address. Ex 255.255.255.0
  - Gateway IP Address – where packets destined for outside our LAN are handed off.
- some IP ranges are designated as internal ranges and are repeatable
  - 192.168.0.0 - 192.168.255.255 (65,536 IP addresses)
  - 172.16.0.0 - 172.31.255.255 (1,048,576 IP addresses)
  - 10.0.0.0 - 10.255.255.255 (16,777,216 IP addresses)

The Flow of Internet Data

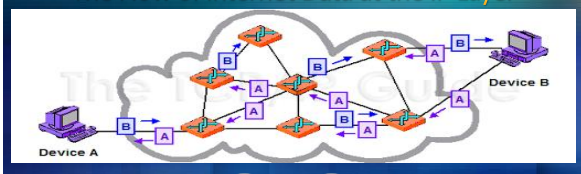
- The IP layer determines if the client your sending a packet to resided on you LAN by looking at:
  - Your client's IP address
  - Your client's subnet mask
  - Your destination's IP address

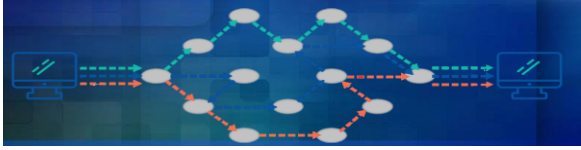


The Flow of Internet Data at the IP Layer

- Gateways will communicate with one or more other gateways and devices called "routers".
  - Routers are usually connected between subnets and take care of handing off massive amounts of packets.
  - Gateways make convenient locations for Firewall and Monitoring measures.
- Routers maintain multiple connections to one another.
- Routers constantly keep track of other routers around them.
  - They will look at things like:
    - link speeds
    - delay times
    - network congestion.
  - Routers are connected to "backbones". Backbones are the information super highways of the internet.
- Routers have a role in security but are not security devices.

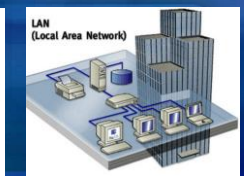
The Flow of Internet Data at the IP Layer





Local Area Networks

- LANs are the most basic type of network.
  - These small networks are the building blocks of the Internet!
  - Can be thought of as a "local neighborhood" of computers or devices
  - All devices on the same LAN communicate directly with one another across a "switch" (collision domain).
  - LAN communication DOES NOT require a gateway.

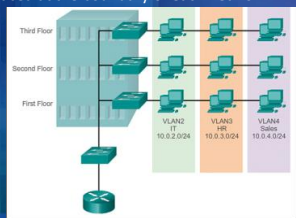


Wide Area Networks

- LANs are interconnected together to form WANs
- LANs get connected to WANs through routers and gateways.
- The "Internet" is one big WAN.
- We can connect LANs to WANs through both wireless and Wired Connections.
- WANs can span much larger geographic distances than LANs.
- WANs typically boast higher speed connections for each LAN member.
- It's typical and necessary for enterprise IT operations to have many LANs interconnected.
- WANs may be defined by their geographic reach
  - CAN – Campus Area Network
  - PAN – Personal Area Network
  - MAN – Metropolitan Area Network
  - * but these are just fancy names for WANs.

Network Segmentation

- Network and LAN segmentation is a fundamental security concept.
- Segmenting a network:
  - Limits the broadcast reach of devices on a subnetwork
  - Enables additional firewalls to be placed at the boundary of each network
- LANs can be organized by :
  - Geographic area
  - Device type / Function
  - Administrative boundary
  - Data or work classification
  - Department or entity
  - Type of service



Network Segmentation

- Demilitarized Zone (DMZ) - a perimeter network or screened subnetwork
  - A separate network for services that may require less restive access and firewall rules.
  - Exposes an organization's external-facing services to an untrusted network, such as the Internet.
  - This provides an additional layer of security to the LAN as it restricts the ability of hackers to directly access internal servers and data via the internet.
- Multiple DMZ networks should exist, based on access needs
  - Pinhole firewall rules should be leveraged to provide only the minimum requires access – **Remember the importance of "Least Privilege".**
- Enterprise services should be placed on separate subnetworks based on type of service and need for access.

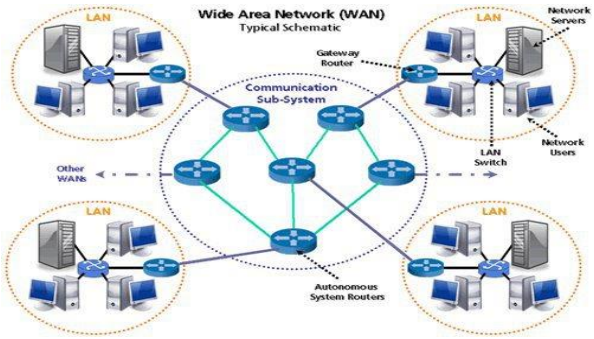
The Hardware Layer

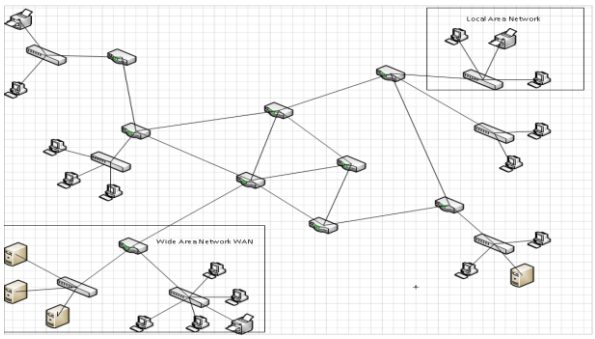
- The "hardware" layer (AKA "Link Layer") of the Internet is in charge of transmitting data over a physical medium (wired or wireless).
- The physical medium for transmitting data can take on many forms and is implemented with a wide variety of technologies.

The Hardware Layer

- All machines have a hardware address called a “MAC” address, or “Media Access Control Address”.
  - address is hardcoded on the network interface card (NIC) and usually* cannot be changed.
  - MAC address is used when delivering messages within subnet.
- Possible for a MAC address to have multiple IP addresses bound to it.
- The binding between MAC and IP address is handled through “Address Resolution Protocol” (ARP).

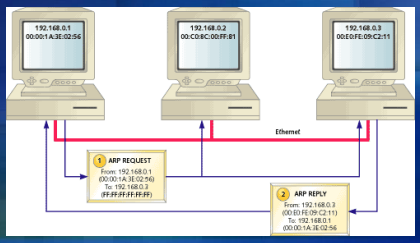
```
Media State . . . . . . . . . . . : Media disconnected
Connection-specific DNS Suffix  . :
Description . . . . . . . . . . . : Intel(R) 82579LM Gigabit Network Connection #2
Physical Address. . . . . . . . . : D4-BE-D9-95-EA-C7
DHCP Enabled. . . . . . . . . . . : Yes
Autoconfiguration Enabled . . . . : Yes
```





The Hardware Layer

- Your machine will only use ARP to communicate with other devices on your own subnet.



Connecting It All

	LANs	WANs
Wired	Ethernet (NICs and Switches) • 1 GB/S • 10GB/S	Modem DSL/ISDN Cable Fiber Optic
Wireless	Wifi (802.11 B/G/N/AC/AD/AH)	Satellite (Microwaves) 4G/5G (Cell service) Infra-red

Connecting to LANs - Ethernet

- Ethernet can be thought of as:
  - Hardware communication devices
  - Topologies of devices being used
- Common Ethernet speeds are
  - 1,000Mb/s (1000Base-T) - gigabit.
  - 1,000Gb/s (10GBase-T) - 10 gigabit.
- Most Ethernet devices such as network interface cards and switches have the ability to negotiate the highest available speed.
- Power over Ethernet (PoE) allows the transmission of power through an Ethernet network cable. This is useful for things like VOIP phones.
- Can connect using:
  - Copper (RJ45 and SFP+)
  - Fiber

Connecting to LANs - Ethernet

- Switches - devices that physically connect multiple computers together to form a subnet.
  - Switches use a star topology and work by joining electrical pathways together, so that devices can talk to each other.
  - Hubs look similar to switches but use a ring topology, relying on each member node to pass along a packet of information.
  - More advanced switches support Virtual Local Area Networks (VLANS), SPANing, TAPing, port filtering, etc…
  - VLANs give us the ability for nearly unlimited network segmentation and network level isolation, without needing multiple switches.

Home Networks

- What are home "routers"?
  - A Router?
  - A Switch?
  - A Gateway?
  - A Firewall?
  - A Server?
  - A DSL/Cable Modem?

Home Routers

- Most Home Routers will function as a Network Address Translation Firewall (NAT).
  - NAT allows a single device, such as a home router, to act as an agent between the Internet (public network) and a local (private) network.
  - Only a single, unique, IP address is required to represent an entire group of internal or private computers, such as a home network.
  - In a home setup, a NAT firewall allows several home devices to share a single IP provided by an ISP
  - NATs help to hide the internal setup of your network.

Home Networks

- Home Routers provide a combination of:
  - IP address routing (gateway)
  - Network address translation (NAT)
  - DHCP functions
  - DNS
  - Firewall functions
  - LAN connectivity like a Network switch
  - Modem Functionality
  - Some allow you to connect an external USB or E-Sata drive as a means of providing shared storage.

Home Networks

- Home Routers are connected to the internet through an Internet Service Provider (ISP).
  - An ISP provides you a way to connect to their own WAN, providing access to the Internet.
  - An ISP will provide you a modem or home router to connect through their preferred transmission medium.
    - Sometimes these devices must be connected to a local switch to form your own LAN

Home Routers

- Most Home Routers will function as a Network Address translation Firewall, or NAT.