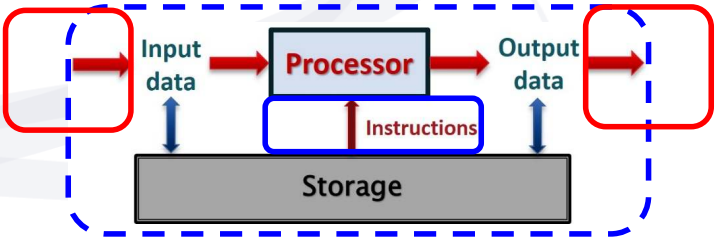
ENS1161 Computer Fundamentals

Module 10
Networking and the Internet

Moving forward..

- Last module:
  - Operating Systems
- Focus of this module:
  - Networking and the Internet



Module Objectives

On completion of this module, students should be able to:

- List the main hardware components of a computer network and describe their function and key operating principles.
- Describe how TCP/IP facilitates communication over the internet and the basic principles of the protocols and addressing involved.
- List and briefly describe the different types of Internet connections.

Introduction

- **Module Scope**
  - Components of computer network
  - How the Internet works
  - TCP/IP protocols and IP addressing
  - Types of Internet connections

Networks and the Internet *(recap Module 1)*

- Networks are communication channels that allow computers to share information and resources
  - *Local Area Networks* (LANs) connect computers in relatively close proximity (within a building or site)
  - *Wide Area Networks* (WANs) cover greater geographical distance
- Today almost all computers connect to a global network of networks – the **Internet**

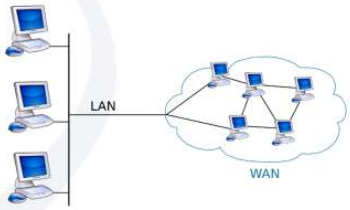


Image: Harald Mühlböck, 2011
https://commons.wikimedia.org/wiki/File:LAN_WAN_scheme.svg

Image: Bastenbas, 2014
https://commons.wikimedia.org/wiki/File:R%C3%A9pr%C3%A9sentation_d%27internet.jpg

Computer networks and devices

- Server
  - Device or application that provides a service
    - Some form of data or shared resource access
    - 'Serves' client requests
- Client
  - Device or application that uses a service

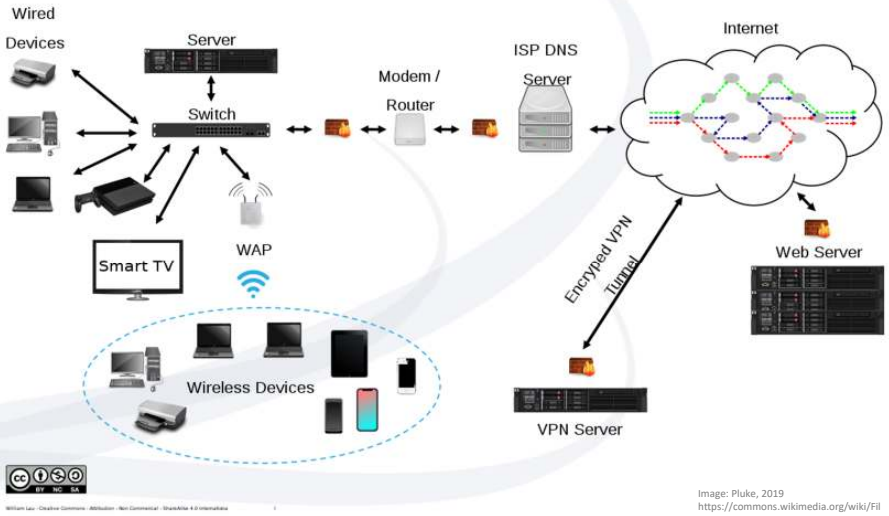
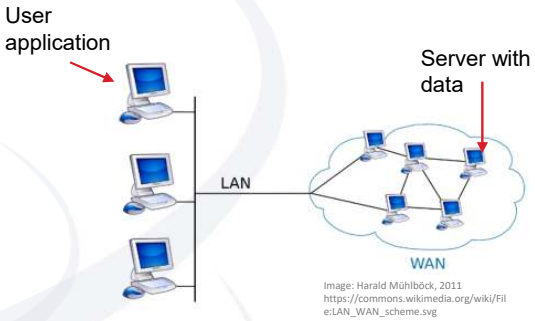


Image: Pluke, 2019
https://commons.wikimedia.org/wiki/File:Computer_Networks_anchor_chart.svg

Sharing information over a network

- User interacts with applications (via UI)
- Applications may read data / use resources over the network
  - E.g. web page, email, music, video
- All data needs to be physically transmitted as bits over the network
- In between there are different processes (*protocols*) involved
  - Divided into 'layers'



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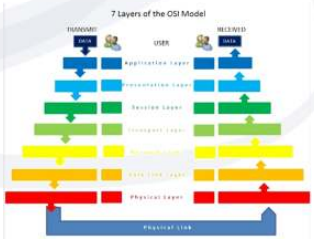


Image: MrsValdry, 2011
https://la.wikipedia.org/wiki/Fasciculus:OSIModel.jpg

OSI 7 layer model

- OSI – Open System Interconnection
  - A generic division of functions that need to be performed in order to communicate over a network
    - *Will be expanded on in other units*
  - More than one protocol / technology available for each layer
    - depends on the type of application and data
  - Focus in this unit will be on the most common protocols / functions

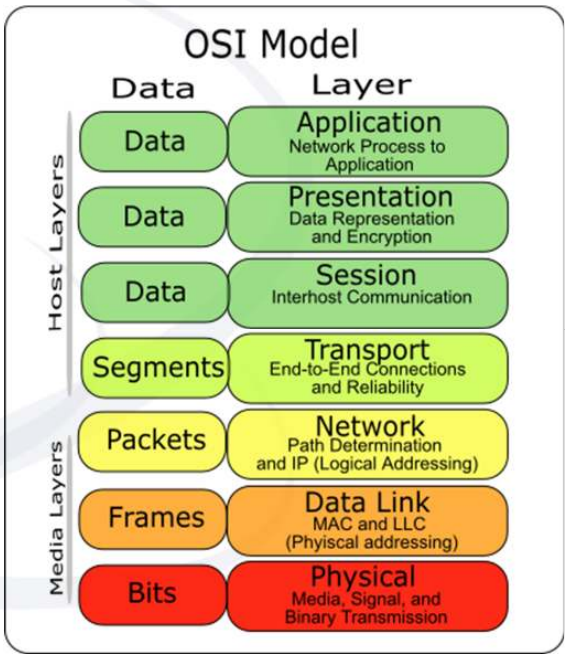


Image: SyamilAshri, 2008
https://commons.wikimedia.org/wiki/File:Osi-model-7-layers.png

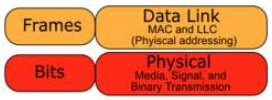
Physical Layer

- Provides the physical connections between communicating devices
- Specifies the mechanical and electrical details of the physical medium
- Handles the transmission of the 'bits'
- Binary signals transmitted in one of 3 forms:
  - Electrical
    - Medium: Some form of cable – generally copper
      - E.g. UTP, coaxial cable
  - Optical
    - Medium: fibre optic cable
  - Radio Waves
    - No medium required (wireless)

Image: Fo0bar, 2005 https://en.wikipedia.org/wiki/Category_5_cable#/media/File:Cat_5.jpg

Image: Hustvedt, 2011 https://commons.wikimedia.org/wiki/File:Fiber_optic_illuminated.jpg

Network Interface *(recap Module 7)*



- Computers send and receive data to other computers via networks
  - Interfaces can be broadly divided into wired and wireless
- **Ethernet**
  - Most common interface for wired networks
  - Common name for the IEEE 802.3 protocol
    - Fast Ethernet: 100 Mbps (megabits per second) data transfer rate
    - Gigabit Ethernet: 1 Gbps
  - Requires an Ethernet adaptor / network interface card
  - Cable connection:
    - UTP (Unshielded Twisted Pair) – most common
    - Coaxial - not so commonly used
    - Fibre optic cable - for higher capacity connections

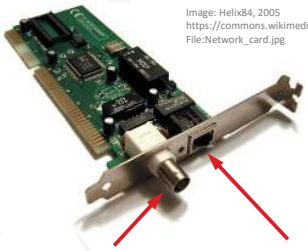


Image: Helix84, 2005 https://commons.wikimedia.org/wiki/File:Network_card.jpg

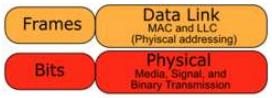
BNC connector (for coaxial cable)

RJ-45 connector (for UTP cable)

Image: Raimond Spekking, 2018 https://commons.wikimedia.org/wiki/File:BNC_connector_with_10BASE2_cable-92170.jpg

Image: Fo0bar, 2005 https://en.wikipedia.org/wiki/Category_5_cable#/media/File:Cat_5.jpg

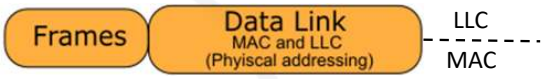
Network Interface *(recap Module 7)*



- **Wi-Fi**
  - Wireless network protocol – IEEE 802.11
  - Computer needs a Wi-Fi adaptor (transceiver)
  - Wirelessly transmits data to an compatible access point
  - Uses radio waves to carry data
    - Typically 2.4 GHz or 5 GHz frequency
  - Various versions of protocol, now with newer simpler naming

Old name	*New name*
802.11n	*Wi-Fi 4*
802.11ac	*Wi-Fi 5*
802.11ax	*Wi-Fi 6*

Data Link Layer



- Frames bits with addresses etc.
- Delivers frames between nodes in a network
- Divided into 2 parts
  - **Media Access Control (MAC)**
    - Used for source and destination addresses
    - Each interface device (e.g. NIC) has a unique MAC address
    - MAC address given by manufacturer
      - Traditional MAC address: 12 hex digits (48 bits)
        - E.g. 9C-35-5B-5F-4C-D7
  - **Logical Link Control (LLC)**
    - Used for data flow control over a single network (LAN)

Local Area Network (LAN) components

- **Main hardware components**
  - Servers
  - Clients
  - Switches
  - Wireless Access Points (WAPs)
  - Other networked devices
    - Printers
    - Scanners, etc

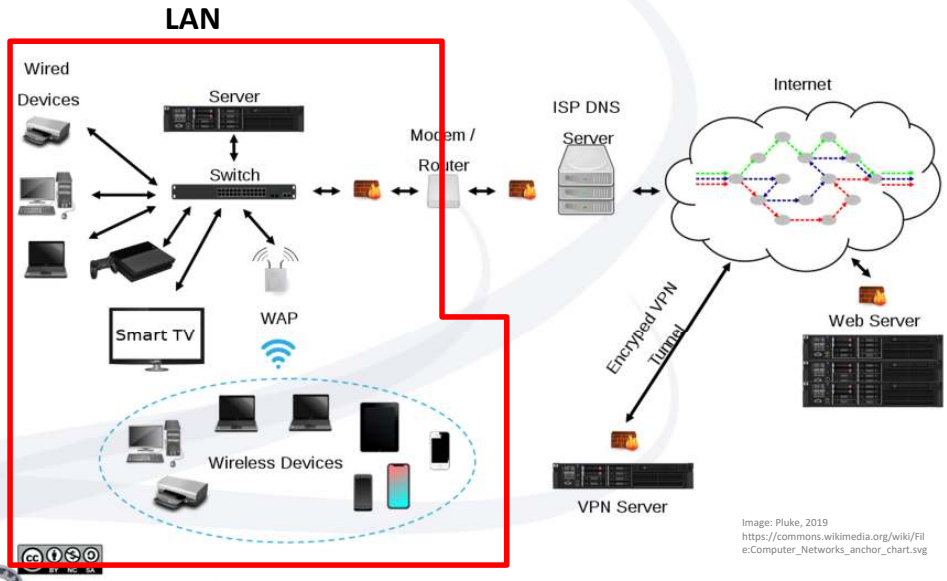


Image: Pluke, 2019 https://commons.wikimedia.org/wiki/File:Computer_Networks_anchor_chart.svg

Local Area Network (LAN) components

- **Switch**
  - Connects wired devices
  - Provides virtual node-to-node connections
  - Directs traffic based on MAC addresses

Image: Jon 'ShakataGaNai' Davis, 2008 https://commons.wikimedia.org/wiki/File:Network_switches.jpg

- **Wireless Access Point (WAP)**
  - Used to connect wireless devices to the network
  - Connected by wired connection to switch
  - Sometimes integrated with switch

Image: Pjpearce, 2011 https://commons.wikimedia.org/wiki/File:Wireless_access_point.jpg

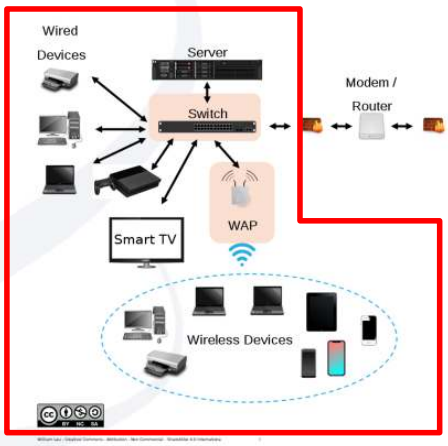


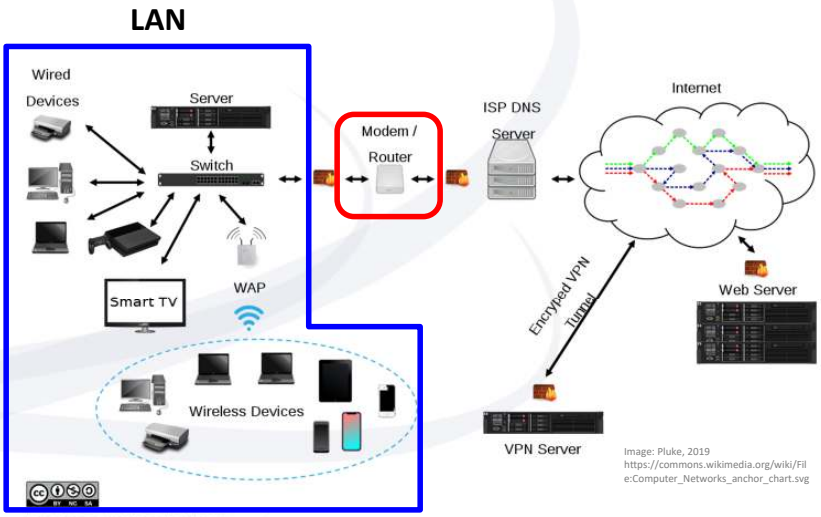
Image: Pluke, 2019 https://commons.wikimedia.org/wiki/File:Computer_Networks_anchor_chart.svg

Typical LAN Services

- Shared Secondary Storage
  - Allows clients to share drives attached to servers
  - Used to store, share, and use application and data files
- Network Printing
  - Allows client devices to print to shared printers
  - Printers can be attached to servers, client devices or directly to the network
  - *Print spoolers* can store print jobs in a *print queue*, to be sent to printer when ready
- Security
  - Authentication of users and regulating access to the various resources

Connecting to the Internet

- A ***router*** is needed to connect a LAN to the Internet
  - Sends data to / from local network to the Internet
  - Forwards data meant for other routers
- May need a *modem*
  - *Modulator / demodulator*
  - Transforms binary data to/from analog waveforms carried over phone lines



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TCP/IP and the Internet

- The Internet is a global network of networks
- Routers are the connection points between networks
- Messages sent across the Internet are chopped up into *packets*
- These packets passed along from router to router until it reaches the destination router
- Packets from the same message may take different paths across the network
  - Based on traffic, faults, etc.
- Message reassembled from packets at the destination
- Done using ***TCP/IP*** protocol suite

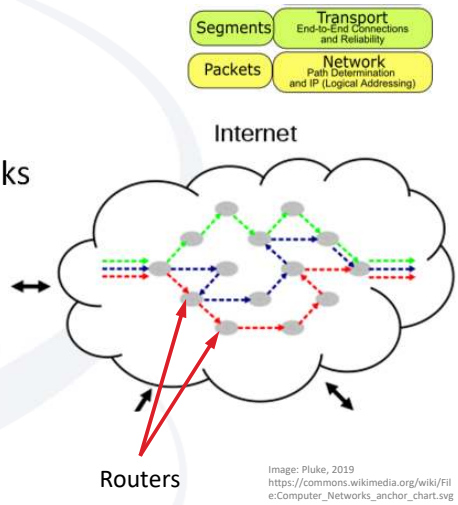
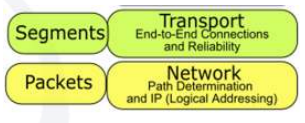


Image: Pluke, 2019
https://commons.wikimedia.org/wiki/File:Computer_Networks_anchor_chart.svg

TCP/IP : Protocol of the Internet

- A collection of protocols
  - define a common set of rules for transmitting data between computers on a network or between interconnected networks
- Primary components are:
  - **Transmission Control Protocol (TCP)**
    - Provides reliable end-to-end message delivery between processes
  - **Internet Protocol (IP)**
    - Allows communication between devices on the same or connected networks



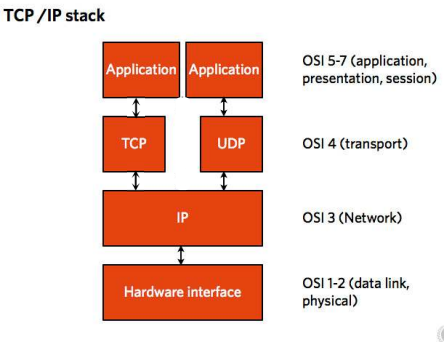


Image: Purple Slog, 2011
https://www.flickr.com/photos/purpleslog/5598305463

TCP/IP Layer services

- The TCP/IP model consists of 4 layers
  - process / application layer
  - transport layer
  - internet layer
  - Link layer
    - Doesn't actually include physical layer
- Each layer effectively communicates with its counterpart layer at the other end of the line

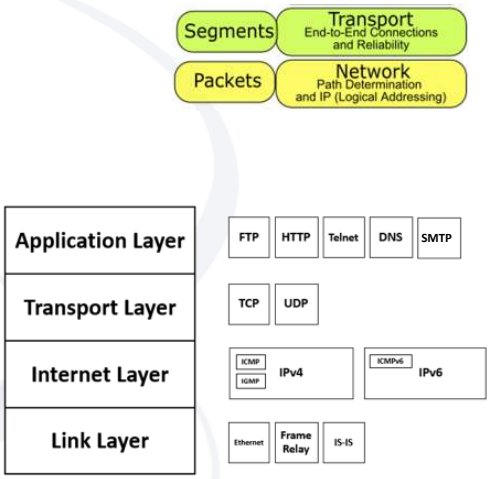


Image: MichelBakni, 2017 https://commons.wikimedia.org/wiki/File:TCP-IP_Model_-_en.png

TCP/IP Layer services

- At sending end:
  - each layer adds its own header information
  - Then passes it to layer below
- At receiving end:
  - Headers are read, interpreted and stripped off by the corresponding layer
  - Then passed to layer above
- Each layer communicates with its own layer counterpart through the header info

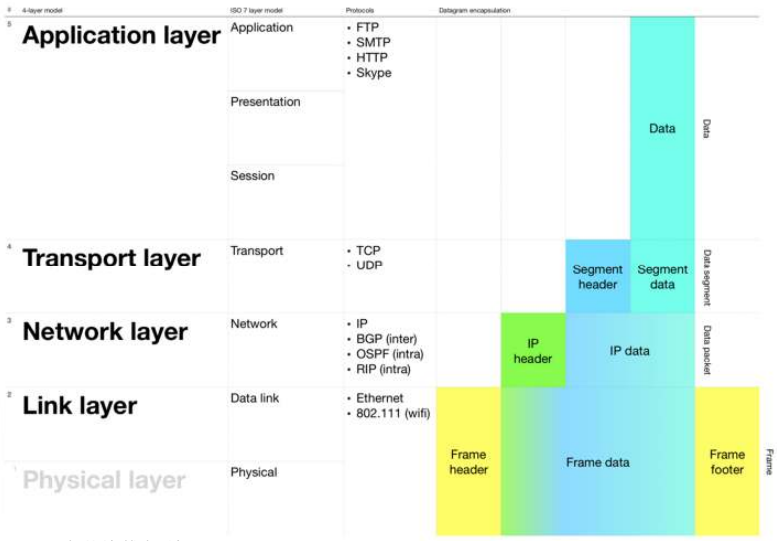
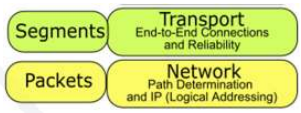


Image: Mo Damsko, 2018 (Public domain) https://en.wikipedia.org/wiki/File:Internet_models_overview.png

How TCP/IP works



- The TCP/IP protocol works based on 3 "agents"
  - Processes
    - fundamental entities that can communicate
  - Hosts
    - computers on which process can run
  - Networks
    - communication pathway between hosts
- Enables transfer to be broken into 2 parts
  - getting the info to the correct host *(IP)*
  - getting the info to the correct process within the host *(TCP)*

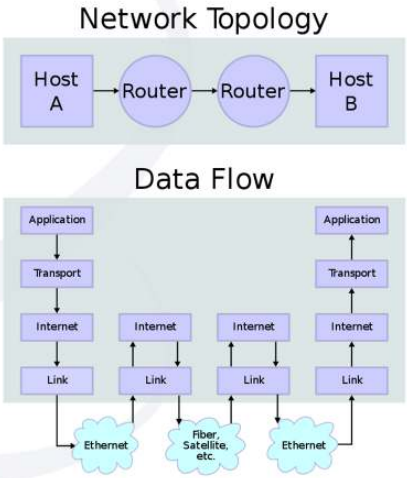
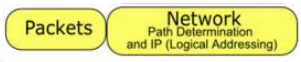
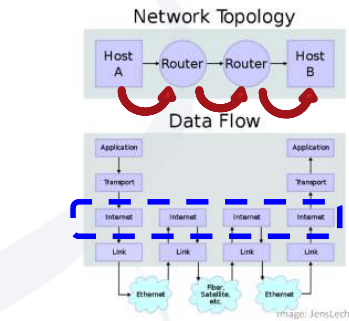


Image: JensLechtenboerger, 2018
https://commons.wikimedia.org/wiki/File:IP_stack_communication.svg

Internet Protocol (IP) Layer



- Main function: To route data
- Node-to-node delivery is performed, but delivery is not guaranteed by IP
- The destination is the target node
  - No further distinction regarding which process is to receive the data
  - The upper layers are insulated from the routing process
- *IP addresses*: given to uniquely identify *each node* on the network
- When a router receives a packet it uses its *routing table* to determine next destination node (*hop*)



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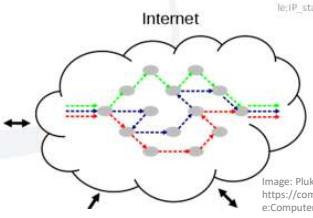

Image: Pluke, 2019
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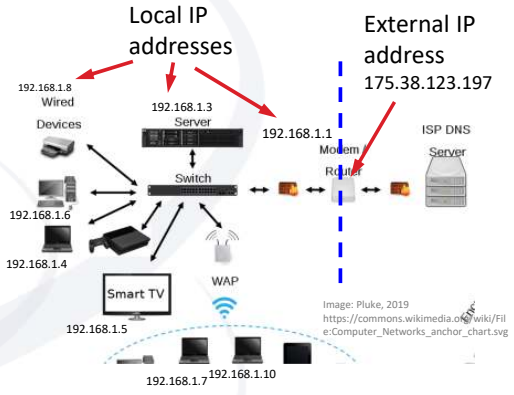
IP Addresses

Packets | Network (Path Determination and IP (Logical Addressing))

- *Logical addresses* given to uniquely identify *each node* on the network
  - Different to physical addresses (MAC addresses)
- **IPv4** (Internet Protocol version 4)
  - 32-bit binary address, so can address up to 2^{32} (approx. 4 billion) nodes
  - Written (for humans), each 8-bits as decimal numbers (0 .. 255) separated by a dot
    - E.g. 175.38.123.197
  - Every device connected directly to the Internet needs an "official" IP address (unique)
    - so even 4 billion could run out – led to development of IPv6
- **IPv6**
  - 128-bit binary addresses (more than 3 x 10^{38} addresses)
  - Written (for humans) in hexadecimal with a colon every 4 hex digits
    - E.g. 3ffe:1900:4545:3:200:f8ff:fe21:67cf

External vs Local (Internal) addresses

- External (public) addresses
  - Each device directly connected to the Internet needs an external (official) IP address
  - These are generally provided by the Internet Service Provider (ISP)
- Local (internal) addresses
  - These are IP addresses given to devices on a private network
    - Normally 192.168.0.*n* or 192.168.1.*n*
  - The router that connects the network to the Internet will have a public address
  - It will then sort out which local device a packet is destined for when it arrives

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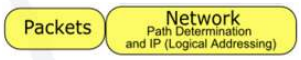
Wireless LAN adapter Wi-Fi:

   Connection-specific DNS Suffix  . : home
   Link-local IPv6 Address . . . . . : fe80::9508:d3b8:8de9:d9f5%8
   IPv4 Address. . . . . . . . . . . : 192.168.0.13
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Default Gateway . . . . . . . . . : 192.168.0.1
```

Dynamic vs Static IP addresses



- Dynamic IP address
  - IP address may change each time (External or Local)
  - Assigned using DHCP (*Dynamic Host Control Protocol*)
  - On connection, DHCP server will 'lease' (assign for a time) the IP address from pool of available addresses
    - External address - ISP server
    - Local address – normally router
- Static IP address
  - Fixed IP address assigned
  - Good for devices that need to have their addresses found (e.g. servers)

DNS Server

- All server requests require IP addresses
- Clients normally use domain names in the URL
  - URL: *Universal Resource Locator*
    - E.g. www.google.com
- The domain names need to be translated to the correct IP address
- Done by *Domain Name System* (DNS) servers
  - Dynamically build up directory of domain names and their IP addresses
  - Client requests using domain names are sent to a *DNS server* that returns its IP address
  - IP address is then used to connect to the domain server(s)

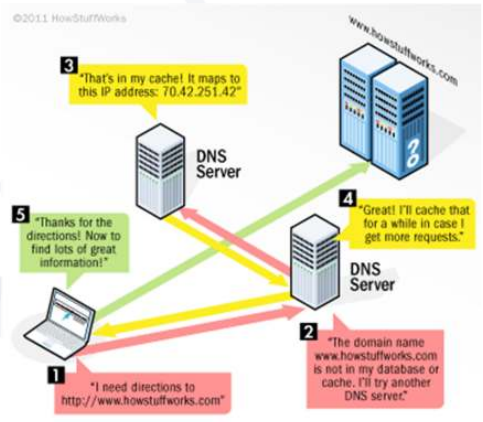


Image: Б.Өлзий , 2016
https://commons.wikimedia.org/wiki/File:Dns-rev-1.gif

Transport Layer

- Moves messages from the sending process to the appropriate target process
- Two protocols are used:
- **TCP - Transmission Control Protocol**
  - Establishes a logical connection between the source and destination applications.
    - TCP uses positive acknowledgement with retransmission
      - Sends back acknowledgement if packet received, resends if not received
    - Numbers segments and handles segments arriving out of order
    - Tracks if segments missing and other error checking
- **UDP - User Datagram Protocol**
  - A connectionless delivery service. No maintained connection between hosts.
    - Similar to TCP but without the acknowledgements and error checking
    - Built for speed not reliability

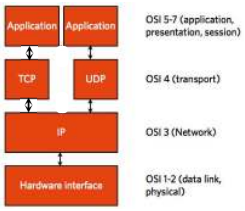


Image: Purple Slog, 2011
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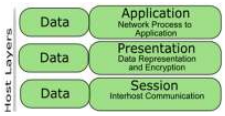
Other protocols



- Some other TCP/IP application layer protocols (OSI layer 5, 6 and 7)
  - HTTP / HTTPS (HyperText Transfer Protocol, HTTP Secure)
    - Used for transferring web pages from a *web server*
    - Web pages are encoded using HTML (*Hypertext Markup Language*)
  - SMTP (Simple Mail Transfer Protocol)
    - For sending emails
  - POP3 (Post Office Protocol v3)
    - For retrieving email
  - FTP (File Transfer Protocol)
    - For transferring files between client and server
  - TLS (Transport Layer Security), SSL (Secure Sockets Layer)
    - Cryptographic protocols to provide security

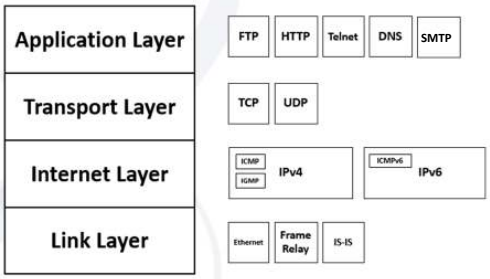


Image: MichelBakni, 2017
https://commons.wikimedia.org/wiki/File:TCP-IP_Model_-_en.png

Computer networks and devices *(again)*

- Firewall
  - A network security device that monitors traffic to /from network.
  - Allows or blocks traffic based on a set of security rules
- VPN
  - Virtual Private Network
    - *See next slide for more details*

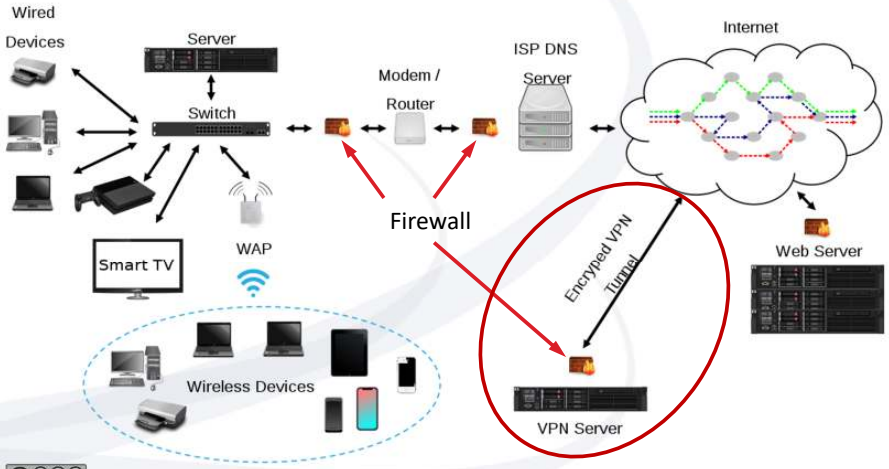


Image: Pluke, 2019 https://commons.wikimedia.org/wiki/File:Computer_Networks_anchor_chart.svg

Virtual Private Network (VPN)

- Creates a private network on a public Internet connection
  - Creates secure and encrypted connections (*tunnelling*)
  - Masks IP addresses by providing own IP address
- Enables organisational users to seem like they are on the one private network
  - Can get through firewalls as looks like they are on a trusted network
- Allows users to use Internet without others knowing what they have been doing
- *Refer to video for more details*

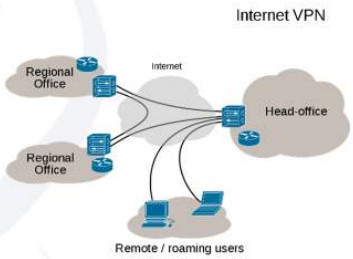


Image: Ludovic.ferre, 2010 https://pt.wikipedia.org/wiki/Ficheiro:Virtual_Private_Network_overview.svg

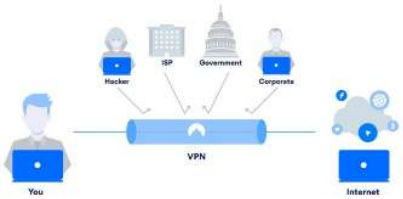


Image: https://pixabay.com/illustrations/vpn-for-home-security-vpn-for-android-4079772/

Other Network Considerations

- Bandwidth
  - Maximum data transfer rate over a network connection or link
    - The 'size' of the *pipe*
  - Measured in Mbps (Megabits/sec) or Gbps (Gigabits/sec)
  - *Note:* This bandwidth is shared between ALL traffic using that link. Too much traffic may result in congestion and much slower transfer rates for each user or process.
- Latency
  - Time taken a packet to make its way to destination
  - A number of factors affect this:
    - *Propagation time* – time for signal to travel down the medium
    - *No. of hops* – each router takes time to examine and update packet headers
    - *Storage delays* – when packets are subject to storage and access at intermediate devices like switches
    - *Anti-virus and other security measures* – message needs to be examined/rebuilt before forwarding on

Types of Internet Connection

- **Dial-up (Analog)**
  - Uses a (baseband) *modem* to connect over the copper phone lines (POTS)
  - Nominally up to 56 kbps connection speed
  - May drop significantly based on quality of phone connection (noise)
  - Telephone cannot be used while modem is in use

Image: Public domain
https://pixnio.com/objects/electronics-devices/computer-components-pictures/external-rs232-serial-dialup-fax-modem#

- **Broadband**
  - High-data rate connection
  - There are many types of broadband connections – based on media used as well as technology
    - *Covered in following slides*
  - The term *'Broadband'* - comes from the use of multiple channels working at different frequencies to transmit data over the same medium
    - Similar to different radio or TV channels

Types of Internet Connection

- **ADSL (Asymmetric Digital Subscriber Line)**
  - Sends digital data over normal copper phone lines using broadband techniques
  - Digital filter separates the frequency channels so phone line can work at same time
  - *Asymmetric* – because download data rates (from the Internet) are higher than upload rates
    - More channels allocated to download
  - Distances limited to about 2 – 3 km to a DSLAM
    - DSLAM (DSL Access Multiplexer) connects many DSL lines to higher speed connection
  - ADSL2+ has maximum download speed of about 24 Mbps (typically less)

Image: Remko van Dokkum, 2014
https://www.flickr.com/photos/remkovandokkum/13924078313

- **Cable**
  - Uses shielded coaxial cables
    - Type used by cable TV providers
  - Less prone to electrical noise interference due to shielding
  - So faster transfer, theoretically up to 100 Mbps download speeds

Image: osde8info, 20018
https://www.flickr.com/photos/osde-info/2681251947

Types of Internet Connection

- **Fibre Optic**
  - Fibre optic cables transfer data using light (optical signals)
  - Have significantly higher capacity and range
  - Typically used for long distance node-to-node connections
  - Now increasingly being used down to the end user
  - FTTP (Fibre To The Premises) connections can reach up to 1 Gbps download rates

Image: Hustvedt, 2011
https://commons.wikimedia.org/wiki/File:Fiber_optic_illuminated.jpg

- **Wireless**
  - Use radio waves to provide Internet connection
  - Typically use towers with antennae that have range up to 50 km
  - Different to *WiFi*
    - Wi-fi only for short distance LAN connections (50 – 100m)
  - Technologies like WiMAX can provide speeds of up to 100 Mbps or more

Image: Stalinas, 2010
https://commons.wikimedia.org/wiki/File:Wimax_base_LTU.jpg

Types of Internet Connection

- **Mobile (cellular)**
  - Use mobile phone (cellular) networks to transfer data
  - Most common connection for mobile devices, especially as data charges drop
  - 4G networks typically provide 20 – 30 Mbps download speeds
    - Theoretical max: 100 Mbps
  - New 5G networks promise speeds of 3 Gbps and reduced latency
    - Theoretical max: 10 Gbps
- **Satellite**
  - Normally only used for very remote areas
  - Signals have to travel up to satellites and back, resulting in large latency
    - Round trip latency typically about 500 milliseconds or more
  - Download speeds of 100 Mbps or more possible
    - Depends on technology & cost factors

Image: Bidgee, 2006
https://commons.wikimedia.org/wiki/File:Bigpond_internet_Satellite.jpg

Summary

- Topics covered:
  - Local Area Networks and the Internet
  - Devices used to create a network
    - Switches, routers, WAPs, modems, media, servers, firewalls,
  - Protocols
    - OSI 7-layer model
    - TCP/IP protocol stack
    - IP addressing
  - How the Internet works
    - DNS servers, routing, VPNs
  - Types of connections to the Internet
    - Dial-up, ADSL, Cable, Fibre, Wireless, Satellite, Cellular

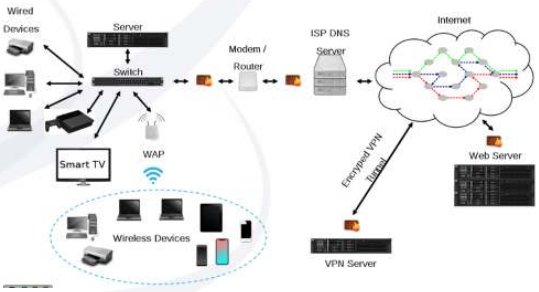


Image: Pluke, 2019
https://commons.wikimedia.org/wiki/File:Computer_Networks_anchor_chart.svg