## Capitulo 1

Red: conjunto de computadores conectador por enlaces. Deben ser escalables. Internet es red de redes.
Host: end system
Conectividad: punto a punto, de acceso multiple, connexion indirecta (redes de packet switching, se transmiten paquetes o mensajes).
Internetworking: conjunto de redes conectadas con routers.
ISP internet service provider.
Internet: infraestructura que provee servicios a aplicaciones.
Bandwidth: transmission rate
End systems provide socket interface: specifies how (rules) a program asks the internet infrastructure to deliver data to a destination program running on another end system.

Unicast: transmission de datos de un computador a otro.
Broadcast: transmission de datos de un computador a todos los de la red local.
Multicast: transmission de datos de un computador a un subconjunto de la red local.

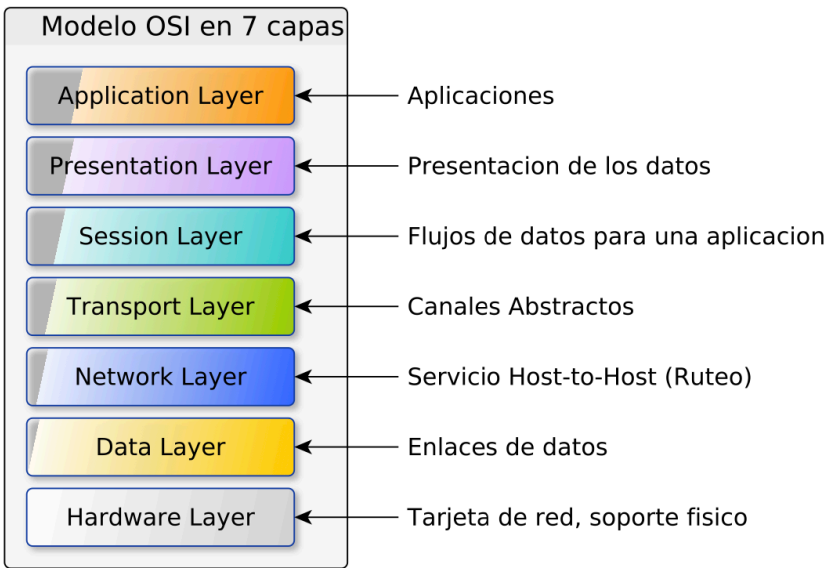
Tipos de redes:
- LAN local area network: redes pequeñas o locales, cobre o fibra óptica.
- MAN metropolitan area network: redes medianas, mixta (cobre y/o fibra optica)
- WAN wide area network: fibra óptica

Multiplexing y demultiplexing
STDM Synchronous time division multiplexing: idea del packet switching, multiples datos usan mismo enlace fisico.

Canales abstractos protocolos:
RRP: request reply o cliente servidor. FTP, HTTP, BD
generalmente no acepta perdida de mensajes
MSP: message stream, flujo continuo, video mp3 telefono IP
asegurar que mensajes lleguen en el mismo orden, no es necesario recibirlos todos

Arquitectura de red: organización fisica de una red (lógica), con requerimientos de seguridad y escalabilidad.

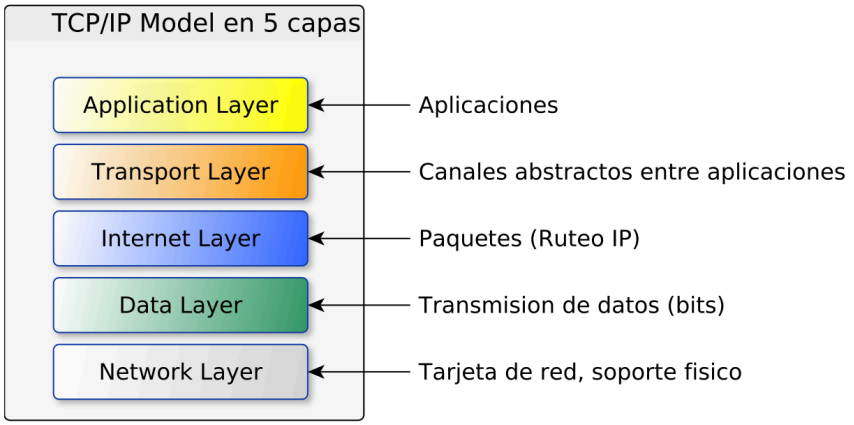
Modelos de capas de red: capas para mejor mantenimiento y update.
- modelo OSI Open system interconnection: norma ISO con 7 capas



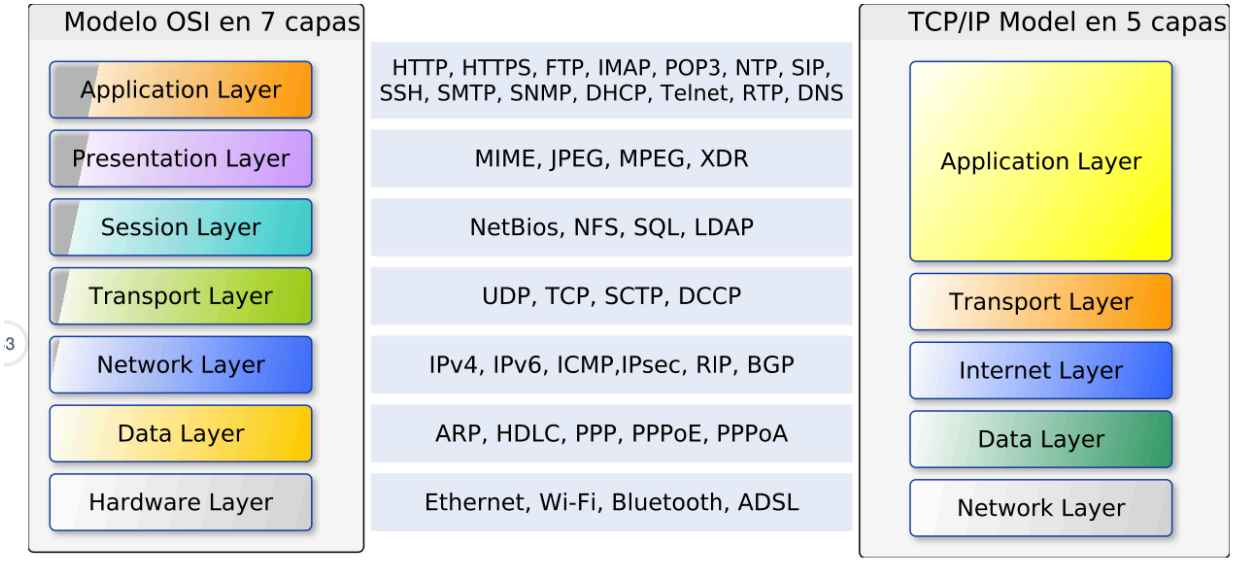

Routers usan solo network, data y hardware.

- Capa aplicación: prover interfaz para app implementando protocolos a nivel app (FTP, HTTP, SIP video conferencia)
- Capa presentación: representación de datos
- Capa sesión: manejo de diferentes flujos de transporte que son parte de misma app. (Ej: audio y video)
- Capa transporte: canal abstracto proceso a proceso.
- Capa red (network): permitir que par de host se puedan comunicar entre si (encontrar camino entre nodos)
- Capa de datos: transmitir pedazos de info a través de enlaces
- Capa fisica (cables, hardware): transmitir bits sin estructura sobre enlaces de comunicaciones. (Convertir bits en señales eléctricas) coaxial, fibra óptica, wifi

- Modelo TCP/IP: 5 capas, mas simple y eficiente




Las aplicaciones acceden directamente a todas las capas




Analogia postal
Protocol: defines format and order of msgs sent and received among network entities and actions taken on transmission and receipt of a message.

Network edge: hosts(clients and servers), acces network physical media (wired and wireless communication links, network that physically connects an end system to the first router called edge router)

- Access network DSL digital describer line: infrastructure from local telephone company. DSLAM digital subscriber line access multiplexer (digital data to frequency and back to digital in DSLAM) asymmetric.
- Access network cable: asymmetric, fiber and coaxial cable, FDM.
- Access network FTTH fiber to the home: fiber path from central office to the home. ONT optical network terminatior, OLT optical line terminator. Single shared optical fiber.
- Access network ethernet: LAN most used, twisted pair copper wire.
- Access network WLAN: based on 802.11(wifi)
- Wide area wireless access: 3G and LTE long term evolution.

-Physical media: bits sent by propagating electromagnetic waves or optical pulses across physical medium.

- Guided media: fiber optics (thin conducts pulses of light, inmune to electromagnetic interference, overseas link, internet backbone), twisted pair copper (LAN, DSL, mas barato), coaxial (concentrico, cable tv)
- unguided media: WLAN, satellite.

Network core: interconnected routers, network of networks. Mesh of packet switches(routers and link layer switches) and links that interconnects the internets end systems.
Packet switching: forward packets from one router to the next. If arrival rate exceeds transmission rate link the packets will queue or the packets can be lost if the memory or the buffer fills up.

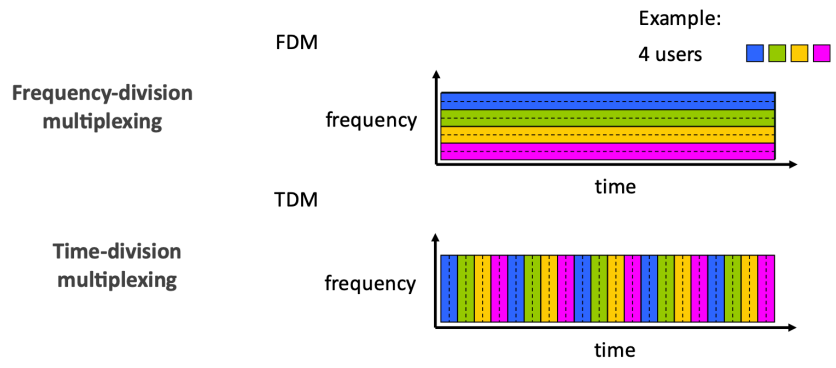
- store and forward: L/R seconds to transmit. 2L/R delay. Full packet needs to arrive.

Network core functions:

- forwarding: move packets from input router to output router
- Routing: determines the source-destination route taken by packets. (Local forwarding table)

Alternative core: circuit switching: telephone networks.

-circuit switching multiplexing:



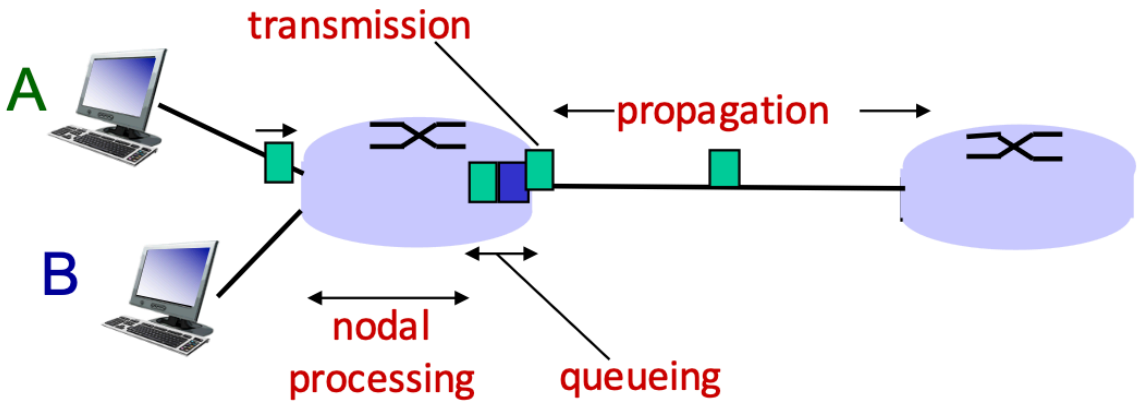

Independent of the number of links

Packet vs circuit switching
Packet switching allows more users to use network, resource sharing, less costly, excessive congestion possible.

ISPs must be interconnected

Internet structure:
- Tier 1 commercial ISP: Telecom, NTT, etc, national and international coverage.
- Content provider network: google, microsoft, private network that connects data center to the internet bypassing tier 1 regional ISPs.

Packet delay:




$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$

Packet loss: buffer has finite capacity, if they arrive to a full queue will be dropped. May be retransmitted or not.

Throughput: rate at which bits are transferred between sender and receiver. Instantaneous and average.

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## Internet protocol stack

*Application:* supporting network applications

• FTP, SMTP, HTTP

*Transport:* process-process data transfer

• TCP, UDP

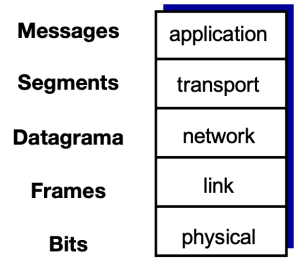
*Network:* routing of datagrams from source to destination

• IP, routing protocols

*Link:* data transfer between neighboring network elements

• Ethernet, 802.111 (WiFi), PPP

*Physical:* bits "on the wire"

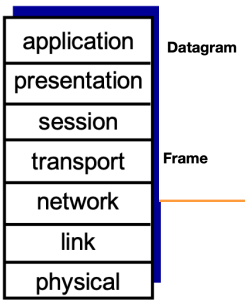


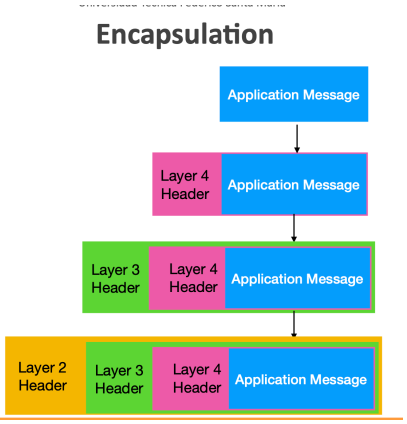
# ISO/OSI Reference Model

*Presentation:* allow applications to interpret meaning of data, e.g., encryption, compression, machine-specific conventions

*Session:* synchronization, checkpointing, recovery of data exchange

- Internet stack "missing" these layers!
  - these services, *if needed,* must be implemented in application
  - needed?



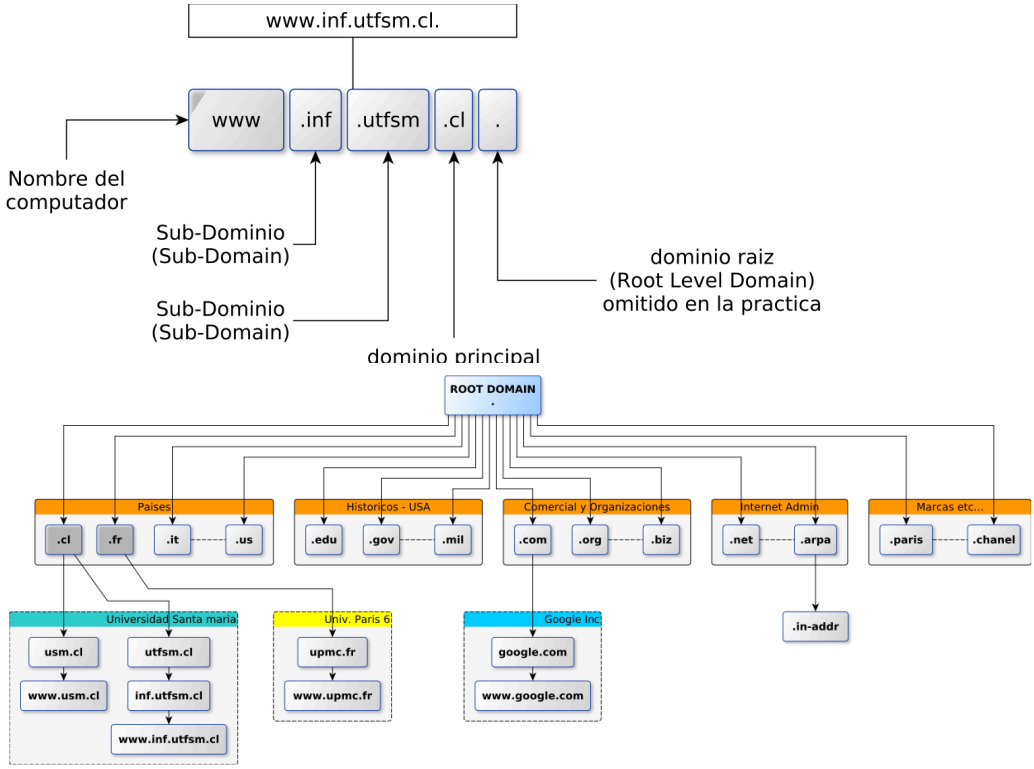




Cada computadora necesita una identificación única en la red:
- direction fisica (de la tarjeta de red) ej MAC (dirección de 6bytes que identifica tarjeta de red ethernet de un aparato, solo red local)
- Direction de red ej: IP (no local, en todo internet, 32 bits, 4 bytes en decimal)

Net mask: determina cual es la parte que identifica la red en la dirección ip de la parte que identifica el host.

Direcciones privadas: usadas para tener gran numero de hosts pero con pequeña cantidad de direcciones publicas, no son ruteables en internet. Arquitectursa típica de red para una empresa. Dirección publica con puerto dinámico. Puente (proxy) entre red privada y red externa (proveída por ISP).

DNS domain name server: asociar un nombre único a cada computador, jerarquía de dominios,



## Capitulo 2: Application layer

Client server architectures:
- Server: on host, permanent IP, data center.
- Clients: communicate with server, may have dynamic ip, do not communicate with each other directly. May be intermittently connected.

P2P architecture:
No always-on server, arbitrary end systems directly communicate, peers request service from other peers, intermittently connected and change ip.
Participants share part of their resources. Self organization, decentralization, fault tolerance, scalability.

Process communicating: a process is a program running within a host, same host (inter process communication defined by OS) different host (exchange messages to communicate)
- client process: initiate communication
- Server process: waits to be contacted.

Sockets: sends and receives messages from to socket, analogy to door. Interface between the app layer and transport layer. API

Addressing processes: they musty have identifiers (Ip, port number)

Transport service:
- reliable data transfer: file transfer needs 100%, others like audio can have some loss.
- Timing: some like games require low delay
- Throughput: some like multimedia require minimum throughput others not.
- Security: encryption, etc.

| Application | Data Loss | Throughput | Time-sensitive |
|---|---|---|---|
| File transfer/ download | No loss | Elastic | No |
| E-mail | No loss | Elastic | No |
| Web documents | No loss | Elastic (few kbps) | No |
| Internet telephony/ Video Conferencing | Loss-tolerant | Audio: few kbps-1Mbps<br>Video: 10kbps-5Mbps | Yes: 100s of msec |
| Streaming stored audio/video | Loss-tolerant | Same as above | Yes: few seconds |
| Interactive games | Loss-tolerant | Few kbps-10kbps | Yes: 100s of msec |
| Instant messaging | No loss | Elastic | Yes and no |

App layer protocols defines: types of messages, syntax, semantics, rules.
TCP: connection oriented. Reliable, flow control, congestion control, does not provide timing, minimum throughput and security

UDP: unreliable data transfer, no reliability, flow control, congestion control, timing, throughput, security or connection setup.
The web and http:
Webs consist of objects (HTML file images, audio, etc) each is addressable by url.

www.someschool.edu/someDept/pic.gif

host name | path name

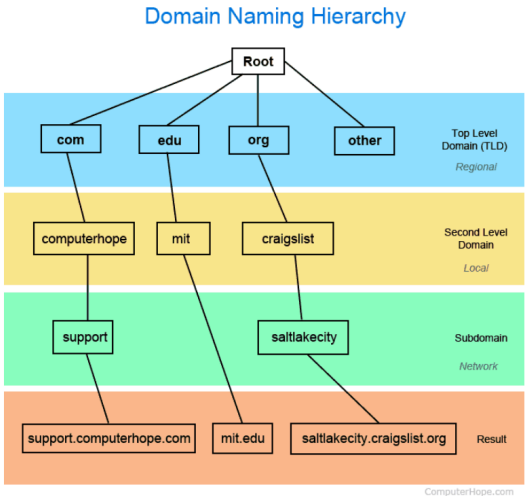
HTTP hyperText transfer protocol: USES TCP, PULL. web app layer protocol. Client (browser) and server (web server) exchange http messages, defines only the communication. Stateless protocol, no state storing.
Non persistent HTTP: at most one object sent over TCP connection. Multiple object require multiple connections. Response time (RTT round trip time, time for packet travel from client to server and back, one RTT to initiate TCP connection, ……. Requires 2RTT per object, OS overhead,
Persistent HTTP: multiple object can be sent over single TCP connection. Server leaves connection open, 1 RTT, closes with timeout.

HTTP messages: request method get post ……(ASCII) and response (code 200, 300, 400 and data).

User server state: cookies: Authorization, shopping carts, recommendations, user session state.
Web caches (proxy server): network entity that satisfies http request. Keeps copies of recently requested objects stored. Reduces response time, reduces traffic and reduces accesses in web server.

Electronic mail: asynchronous communication medium: user agents(mail reader, allows user to read, reply etc), mail servers(core of email infrastructure, mailbox, message queue), SMTP PUSH simple mail transfer protocol(uses TCP, port 25, client server architecture, 7bit ASCII, uses persistent connection, ). POP post office protocol  IMAP  Internet mail access protol. HTTP gmail, hotmail, etc.

DNS domain name system
Hostname: www.usm.cl cnn.com etc but can also be identified by IP addresses
Application layer protocol translates address name. Runs over UDP port 53.




Root name servers are managed by 13 organizations. TLD top level domain com, org, , uk, cl, etc.

## Chapter 3: transport layer

Logical communication between application processes running on different hosts.
Implemented on end systems
Transport layer packets are called segments
TCP AND UDP

Transport vs network layer
Network: logical communication between hosts
Transport: logical communication between processes.

IP protocol: best efforts delivery: unreliable. Transport layer multiplexing and demultiplexing.
Integrity checking error detection in TCP and UDP header

**Multiplexing at sender:** handle data from multiple sockets, add transport header

**Demultiplexing at receiver:** use header info to deliver received segments to correct socket

Demultiplexing: uses IP address & port numbers to direct segments to appropriate socket.
Connection oriented demux: tcp socket identified by source and destination IP, source and destination port number. }

UDP user datagram protocol:
Connectionless, ex DNS, light error checking, finer application level control, no connection stablishment or state, small packet hea<der overhead. Segment header and checksum

Reliable data transfer
ACKs explicitly says OK and NAKs explicit errors. Retransmit packet if receives NAK. Stop and wait.
Sequences number added to packet 0 or 1  to handle duplicates.

Pipelined reliable data transfer protocols
Allows multiple yet to be acknowledged packets, goback N GBN window of up to N unpacked packets and selected repeat SR window of N consecutive sequence numbers .

TCP Connection oriented transport protocol:
Three way handshake, bidirectional dataflow, point to point, reliable data transfer on top of IP unreliable service using pipeline segments, cumulative acks and single transmission timer. Flow control.

### Approaches to Congestion Control

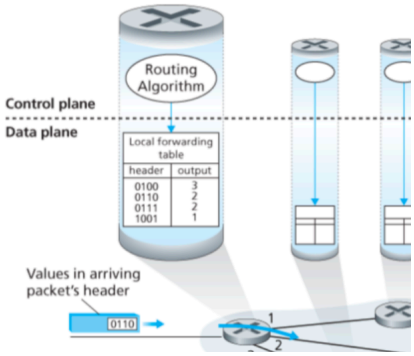
**End-end congestion control:**

- No explicit feedback from network
- congestion inferred from end-system observed loss, delay
- approach taken by TCP

**Network-assisted congestion control:**

- Routers provide feedback to end systems
  - single bit indicating congestion
  - explicit rate for sender

Chapter 4: Network Layer
Move packets from sending host to receiving host
Forwarding(DATA PLANE HW): move the packet to appropriate output link. Forwarding table determined by the routing algorithm (routing algorithm in each router) control plane and data plane relation.
Routing(CONTROL PLANE SW): determine the route taken by the packets,

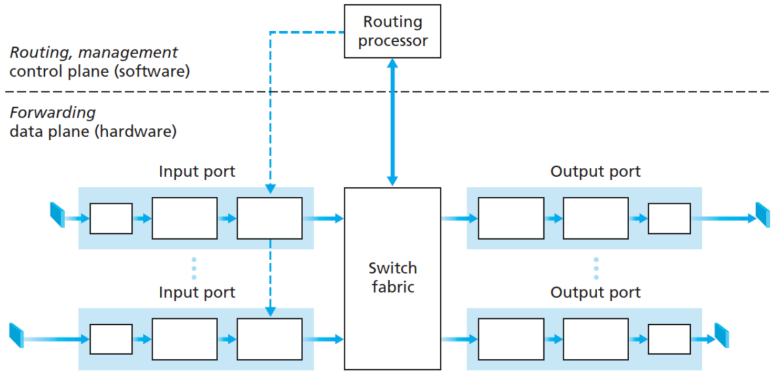



Data plane: per router functions
Control plane: network wide logic



## What is Inside a Router?

High-level view of generic router architecture:




Destination based (based on destination ip) forwarding and generalized forwarding (based on header fields)

Longest prefix matching:

Packet scheduling: choose next packet to send on link FIFO, priority scheduling, RR, weighed fair queuing,

IPV4 datagram format:
20 byte header, network links have MTU maximum transmission unit

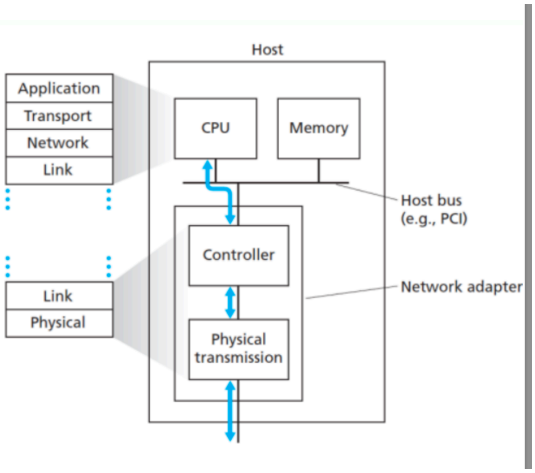
DHCP Dynamic Host Configuration Protocol: network protocol used to automatically assign and manage IP addresses and other configuration information to devices on a network. Client server.

NAT network address translation: ip address for private network.

IPV6
128 bits ip address 40 byte header does not allow for fragmentation and no checksum

## Capitulo 5 Capa de datos (enlace) HW AND SW

transmite bits a través de un medio de comunicación usando técnicas específicas.
Servicios:
- framing: encapsulation datagrams.
- Link access MAC medium access control: especifica las reglas mediante las cuales un frame es transmitido a través del link
- Entrega confiable
- Detection y correction de errores



Encapsula datagrama en frame, y el receptor extrae datagframa y lo pasa a capa superior (red).

EDC (error detection and correction)
- Parity check even parity cantidad de 1 par, odd parity cantidad de 0 par
- Metodos checksum suma bits segmento y el receptor comprueba si es la misma
- Cyclic Redundancy Check (CRC) usado en Ethernet y Wifi 802.11

Multiple Access Links and Protocols
Coordinar para eu no hayan colisiones. Regulación de la transmisión de los nodos dentro del canal de broadcast

MAC se dividend en 3 protocolos
- Partición de canal FDMA El espectro de frecuencias de la señal se divide en canales TDMA Divide el tiempo entre frames, y los frames en slots. combinado: Data Over Cable Service Interface Specifications (DOCSIS)
- Acceso aleatorio random access protocol: utiliza la capacidad completa del medio En caso de una colisión, el frame se retransmite hasta que logra transmitirse exitosamente. ALOHA: nodos se transa,iten tan pronto llegan, no slots. Slotted ALOHA: nodos se transmiten al comienzo de cada slot. Carrier Sense Multiple Access (CSMA). Carrier Sense Multiple Access with Colission Detection (CSMA/CD) tiempo random antes de retransmitir.
- Toma de turnos: polling protocol: RR, no collusion pero si delay. Token passing protocol: el que tiene token puede retransmitir.,

Address Resolution Protocol (ARP): Traducción de las direcciones IP (direcciones de capa red) a direcciones MAC (direcciones de capa link) y viceversa

## Capitulo 6: WIFI

Comunicación inalámbrica tanto WiFi (802.11) como redes terrestres (3G, 4G LTE, 5G)
Wireless host: Dispositivos que implementan comunicación inalámbrica.
Wireless links: Enlaces inalámbricos. Conceptos: Tasas de transmisión, área de cobertura.
Base station: Responsable de enviar y recibir datos desde un host inalámbrico.

**Signal-to-noise ratio** (SNR) = Relación señal-ruid
Proporción entre la fuerza de la señal recibida respecto al ruido ambiente.

- Se mide en dB
- A mayor SNR, más fácil extraer la señal de entre el ruido ambiente.

- **Bit Error Rate** (BER) = Tasa de errores de bit

Problemas: terminal escondido, atenuación de señal.
Code division multiple accès CDMA: usado para que distinto hosts usen mismo medio a la vez

PROTOCOLO 802.11 WIFI
Wifi se usa en redes inalámbricas locales (WLANs)

CSMA/CA

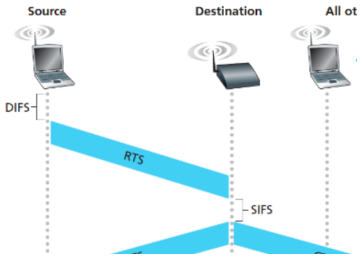
Eficacia inferior a CSMA/CD, similar a CSMA.
NO usa CSMA/CD debido a que no puede enviar y recibir en el mismo canal a la misma

## INTENTANDO EVITAR PROBLEMAS POR HIDDEN TERMINAL

Se reserva el medio

- **Request To Send** (RTS)= ¿Puedo reservar el canal para enviar?
- **Clear To Send** (CTS) = Todo limpio, transmite tranquilo

Generalmente el RTS solo se usa si es que el paquete a enviar es más grande que el treshold considerado en la retransmisión por colisiones o perdidas.




## FRAME 802.11

¿Por que tiene 4 campos de dirección? -> Porque en este protocolo, los frames se mueven distintos dispositivos, por lo que se mueven de manera "particular", entonces cada direcci cumple un rol irremplazable (por ahora y en este protocolo):

1. MAC del **emisor** (Wireless station o Access Point).
2. MAC de la Wireless station **receptora**.
3. MAC de la interfaz del **router que conecta** el Basic Service Set (BSS) con otras subrede
4. Solo se usa cuando un Access Point entrega el frame a otro AP para dirigirlo.

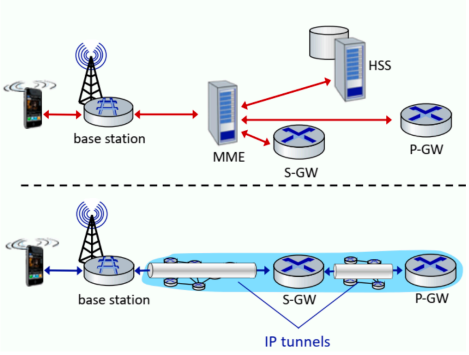
2G -> Solo voz, luego se extendio para data
3G -> Voz y data
4G -> Voz y data de velocidades de decenas de Megabits

# ELEMENTOS DE LA ARQUITECTURA 4G LTE

- **LTE** = Long Term Evolution -> Mejoras significativas respecto a versiones anteriores.
- **Dispositivo Movil**: Dispositivo con SIM (Suscriber Identity Module)
- **Base Station** (BS): En el borde de la red del proveedor
  - A diferencia de un AP, se coordina con otras Bs's para optimizar uso de la red.
- **Home Suscriber Service** (HSS): Guarda información sobre los dispositivos que pertenecen a su misma red
- **S-GW y P-GW**: Routers gateway
- **Mobility Management Entity** (MME): Autenticación de dispositivos, configura el tunneling que implementa P-GW

## TUNNELING

- Tunneling permite mantener la conexión y el flujo de datos sin interrupciones al realizar una transición suave entre diferentes redes, encapsulando y enviando los paquetes de datos a través del túnel a la red de destino
- Los datagramas de conexiones moviles se encapsulan dentro de un "tunel", los cuales son encapsulados dentro de un datagrama UDP y es enviado a los routers Serving-Gateway (S-GW)
- S-GW hace tunneling otra vez hasta P-GW




**Plano de control**:
- Protocolos para administracion de la movilidad, seguridad y autenticación

**Plano de datos**:
- Protocolos nuevos en las capas de enlace (link) y física.
- Uso de tunneling para facilitar movilidad

# FUNCIONAMIENTO DE ACCESO A LA RED LTE

- **Bajada**:
  - Usa TDM dentro de OFDM (Orthogonal frequency division multiplexing, mejora de FDM tradicional)
    - El caracter ortogonal de las frecuencias, permite que la interferencia entre los rangos de frecuencia sean minimas.
- **Subida:**
  - Al igual que la subida se usa TDM dentro de un tipo de FDM similar a OFDM

**¿Como funciona OFDM? y ¿Por que funciona mejor que FDM?**
-> En OFDM, las frecuencias no se superponen ni interfieren entre sí en su dominio. Esto se logra asegurando que las frecuencias de las subportadoras sean **mutuamente ortogonales**.