OS & Network Summary

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Chapter 1

Parts of a Network

Component	Function	Example
Application, or app, user	Uses the network	Skype, iTunes, Amazon
Host , or end-system, edge device, node, source, sink	Supports apps	Laptop, mobile, desktop
Router, or switch, node, hub, intermediate system	Relays messages between links	Access point, cable / DSL moden
Link, or channel	Connects nodes	Wires, wireless

Key interfaces

- Network-application interfaces define how apps use the network (Sockets widely used)
- Network-network interfaces define how nodes work together (ex : Traceroute)

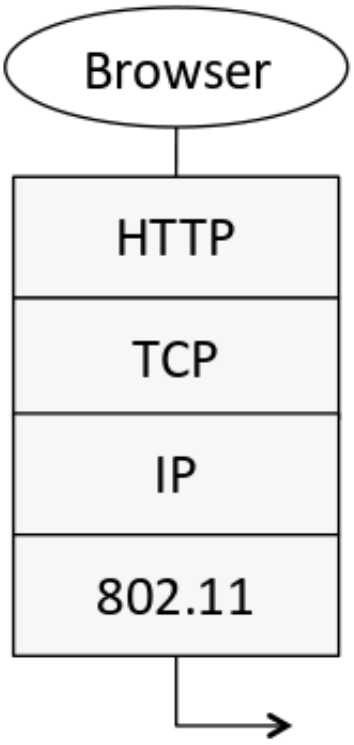
Network service API hides details (Apps don’t know what is inside the network)

Protocols and layers

To divide up network functionality

- Each instance of a protocol talks virtually to its peer using the protocol
- Each instance of a protocol uses only the services of the lower layer

Protocol stack example :



Encapsulation : Lower layer wraps higher layer content and add its own information

Advantage of layering : Information hiding and reusability
Disadvantages of layering : Overhead and hides information

OSI “7 layer” Reference Model

	Layer	Description
7	Application	Provides functions needed by users
6	Presentation	Converts different data representations
5	Session	Manages task dialogs
4	Transport	Provides end-to-end delivery
3	Network	Sends packets over multiple links
2	Data link	Sends frames of information
1	Physical	Sends bits as signals

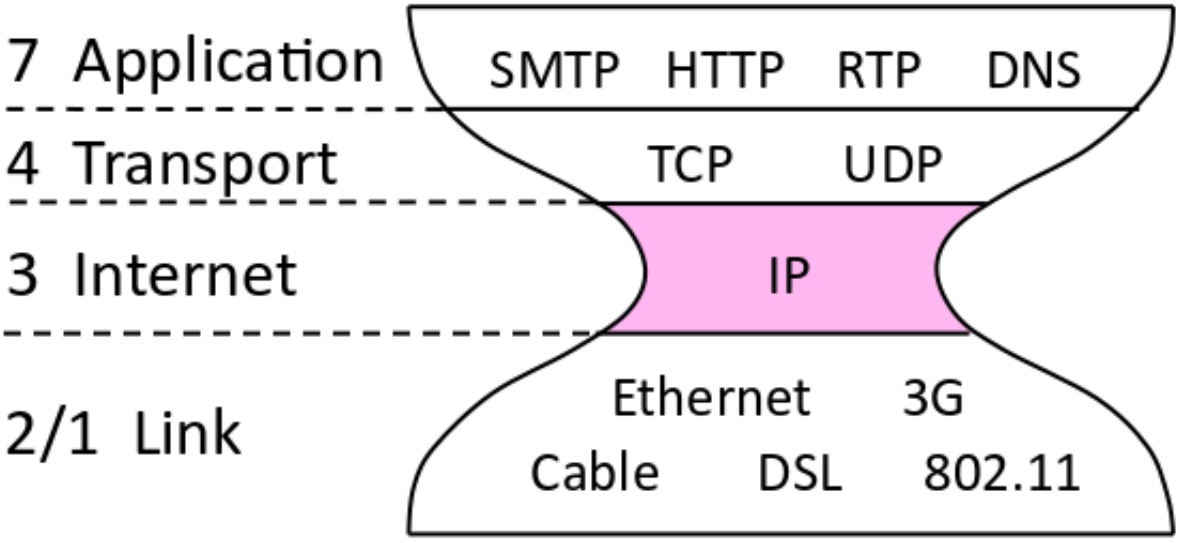
Four layer model

Based on experience

	Layer	Description

7	Application	Programs that use network service
4	Transport	Provides end-to-end data delivery
3	Internet	Send packets over multiple networks
2 (/1)	Link (/Physical)	Send frames over a link (/Sends bits using signals)

Internet Reference Model



Layer-based names

Layer	Unit of Data
Application	Message
Transport	Segment
Network	Packet
Link	Frame
physical	Bit

Devices in the network :

- Repeater (Hub) : Physical/Physical
- Switch (bridge) : Link/Link
- Router : Network+Link / Network+Link
- Proxy (middlebox, gateway) : App+Transport+Network+Link

Chapter 2 : Physical Layer

Socket API

Primitive	Meaning
SOCKET	Create a new communication endpoint
BIND	Associate a local address with a socket
LISTEN	Announce willingness to accept connections; give queue size
ACCEPT	Passively wait for an incoming connection
CONNECT	Actively attempt to establish a connection
SEND	Send some data over the connection
RECEIVE	Receive some data from the connection
CLOSE	Release the connection

Simple link model

Properties : Rate, Delay/Latency, wether the channel is broadcast, its error rate

Rate

Or bandwith, capacity, speed
in bits/second

Delay / latency

- Transmission delay T: Time to put M-bit message on the wire

$$T = \frac{M[bits]}{Rate\left[\frac{bits}{s}\right]} = \frac{M}{R}\,[s]$$

- Propagation delay D : time for bits to propagate across the wire

$$D = \frac{Length}{Speed of signals} = \frac{L}{\frac{2}{3}\,C}$$

- Latency L : delay to send a message over a link

$$L = T + D = \frac{M}{R} + \frac{L}{\frac{2}{3}\,C}$$

Bandwidth-delay product

The amount of data “in flight”

$$BD = R \cdot D$$

Types of Media

Media propagate signals that carry bits information.
Common types :

- Wires
- Fiber
- Wireless

Wireless

- Travel at speed of light
- Spread out and attenuate faster than $\frac{1}{d^2}$
- Interference between signals on the same frequency (=> spatial reuse of same freq)
- Multipath : signal interferes with itself after reflexion

Modulation

How the signals represent bits

- NRZ : A high voltage +V represents a 1 and a low voltage -V represents a 0

Clock recovery

Receiver needs frequent signal transitions to decode bits (synchronisation)

4b/5b

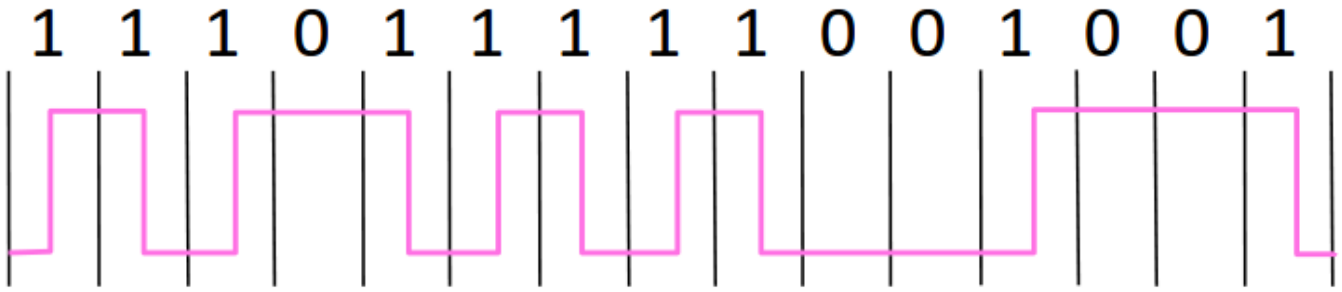
- Map every data bits into 5 code bits without long runs of zeros

4b	5b
0000	11110
0001	01001
1110	11100
...	...

1111	11101

- Invert signal level on every 1 (NRZI)

Example :
message : 1111 0000 0001

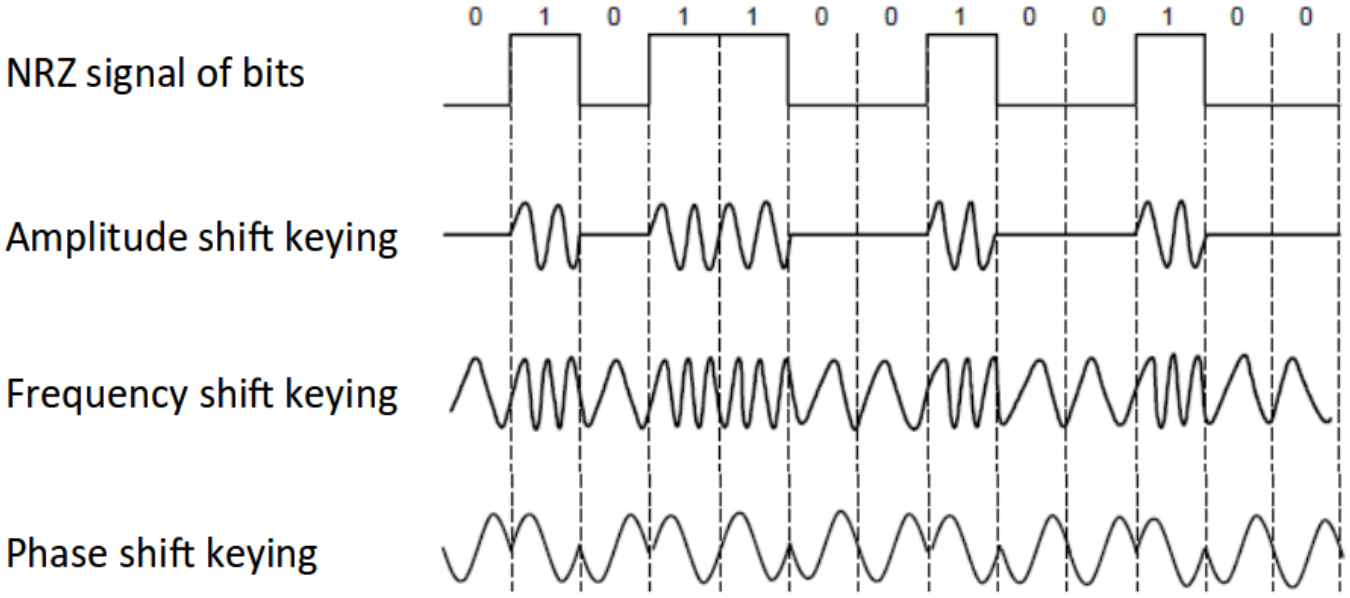


Baseband vs Passband modulation

Baseband : Signal is sent directly on a wire (wires)
Passband : Modulation carries a signal by modulating a carrier (fiber / wireless)

Passband

Carrier is a signal oscillating at desired frequency. We modulate it by changing amplitude, frequency or phase



Fundamental limits

Key channel properties

- Bandwidth B
- Signal strength S

- Noise strength N

Nyquist limit/frequency

If we have a channel with a bandwidth B, the maximum symbol rate is $2B$.
If we have V signal levels ($log_2 V$ different bits), the maximum bit rate is

$$R = 2B \cdot log_2 V \left[\frac{bits}{s}\right]$$

Shannon capacity

The number of levels we can distinguish on a channel depends on the SNR (~ S/N)

The Shannon capacity C is the maximum information carrying rate of the channel

$$C = B \cdot log_2 \left(1 + \frac{S}{N}\right) \left[\frac{bits}{s}\right]$$

Wires / Fiber :
Engineer SNR for data rate

Wireless :
Adapt data rate to SNR (can't design for worst case)

Chapter 3 : Link Layer

Concerns how to transfer messages (frames, of limited size) over one or more connected links

Framing

Transform stream of bits from physical layer to sequence of frames

Byte count

- Start each frame with a length field
- Difficult tu resynchronize after framing error

Byte stuffing

- Use a flag byte value for start/end of frame
- Escape the flag (and the escape code) inside the message replacing (stuffing) it with an escape code

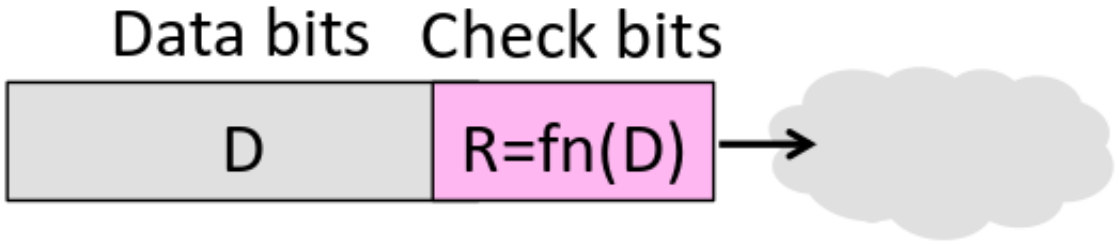
Bit stuffing

- Flag with six consecutive 1
- In the message, insert a 0 after five 1 when sending and remove every 0 after five 1 when receiving
- Slightly less overhead than byte stuffing but more complicated -> byte stuffing used in practice

Error coding

Using error codes

Codeword consists of data bits D plus check bits R



Hamming distance

- The distance is the number of bit flips needed to change $D + R_1$ to $D + R_2$
- The Hamming distance of a code is the minimum distance between a pair of codewords
- For a code of Hamming distance d+1, up to d errors will always be detected
- For a code of Hamming distance 2d + 1, up to d errors can always be corrected by mapping to the closest codeword

Error Detection

- Parity bit : The parity bit is the sum of the bits of D (distance : 2 -> detect 1 error)
- Checksum : Sum up data in N-bit word (Stronger than parity)

Internet Checksum :

Sending :

1. Arrange data in 16-bit words
2. Add
3. Add any carryover back to get 16 bits
4. Negate (complement) to get the checksum

Receiving :

1. Arrange data in 16-bit words (including checksum)
2. Add
3. Add any carryover back to get 16 bits
4. Negate the result and check if 0

Example :

```
1.      0001
        f203
        f4f5
2.    + f6f7
      ------
       2ddf0
```

```
        ddf0
3.    +    2
      ------
        ddf2

4. -> 220d
```

Transmit to physical layer : 0001 f203 f4f5 f6f7 220d

```
1.      0001
        f203
        f4f5
        f6f7
2.    + 220d
      ------
       2rffd
```

```
        fff0
3.    +    2
      ------
        ffff

4. -> 0000
```

- Distance of the code : 2
- Will always detect up to 1 error
- Will detect all burst errors up to 16
- For random errors, probability of miss is $\frac{1}{2^{16}}$ (2^{16} different checksums)

Acronyms

Acronym	Meaning	Description
Pan	Personal Area Network	ex : Bluetooth
Lan	Local Area Network	ex : WiFi, Ethernet
Man	Metropolitan Area Network	ex : Cable, DSL
Wan	Wide Area Network	Large ISP
NRZ	Non Return to Zero	
SNR	Signal to Noise Ratio	S/N