Computer Networks and Distributed Systems

Computer Networks – Physical Layer

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Physical Layer

- Provides communications path between nodes
- Uses standards
  - Agreed ways of connecting devices and signalling
    - Be able to interpret signals
    - Must deal with limitations of physical world
- Not going into EE details (or physics)!

Properties of Wired Connections

- Signals travel through wires at fixed speed
  - Medium can carry signals at many frequencies
- Attenuation
  - Signals get weaker over distance
- Signals may suffer from interference
  - Shielded wires help with attenuation & interference
  - Often wires require termination
- Network goes only where you lay it
  - Wires costs money, fibre-optics cost even more

Properties of Wireless Connections

- Signal travels through wireless at fixed speed
  - Medium can carry signals at many frequencies
  - Different radio frequencies disperse differently
- Radio signals suffer from attenuation and interference
  - From other transmitters and from reflected signals
  - Need to manage power to avoid interference
- Radio signal goes wherever it can
  - Radio bandwidth subject to regulation
  - Environment can block radio waves

Modulation

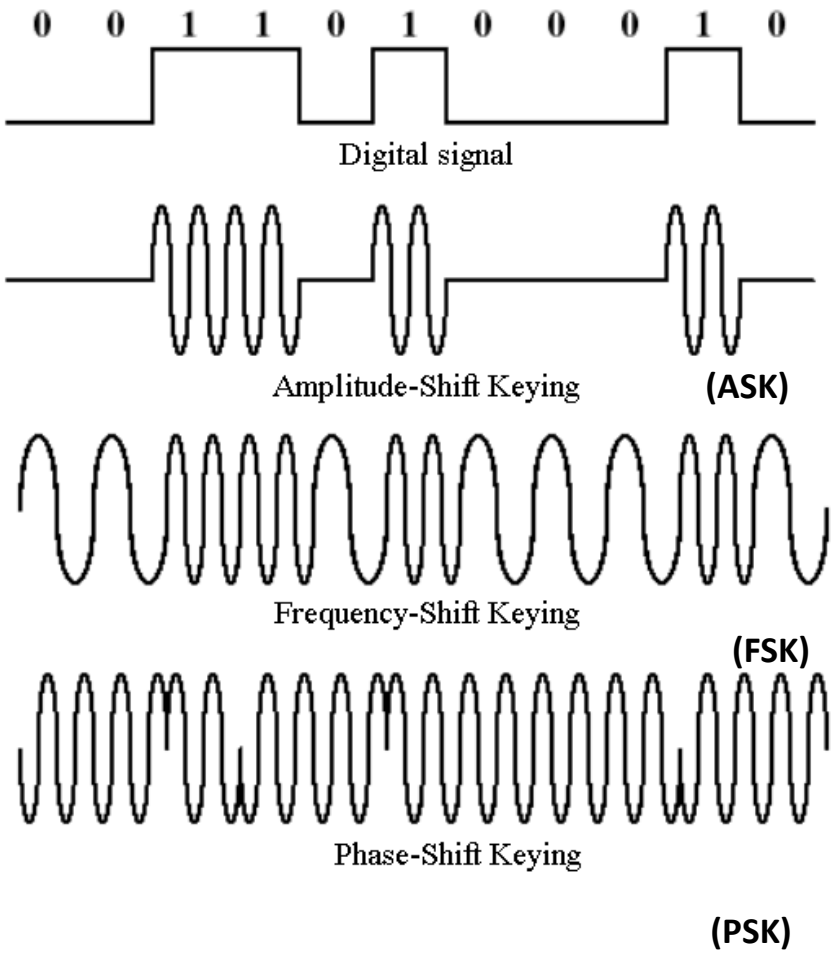
- Modulation: transform information signal into signal more appropriate for transmission on physical channel

- Data and signal may each be digital or analogue
  - Digital ➔ only values are zero and one
  - Analogue ➔ continuous range of values

Baseband vs. Broadband

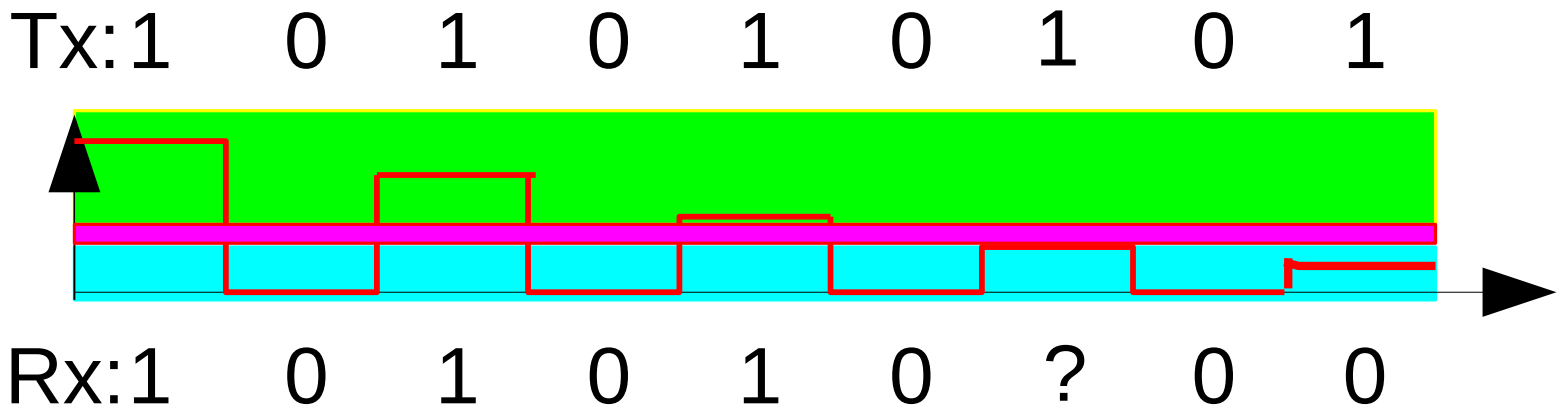
- Baseband network
  - Medium directly transmits digital/analogue data
  - Uses single frequency band (0…f Hz)
  - Very simple
    - E.g. Ethernet, serial, …
- Broadband network
  - Modulate analogue carrier wave to transmit data
  - Can choose good frequency for channel
  - Can use multiple bands (f1..f2 Hz, f3..f4 Hz, …)
  - Can share channel among multiple users
  - E.g. Television, ADSL, …

Broadband Modulation



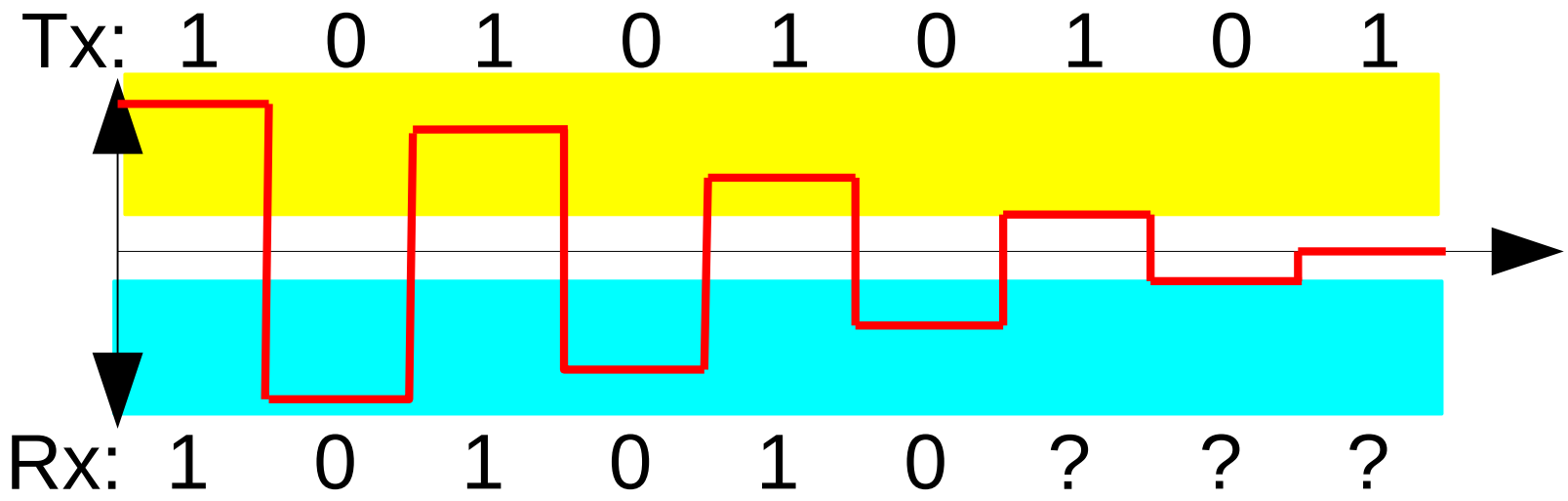
- E.g. to transmit digital data over analogue channel
- Use carrier signal (periodic wave form) and vary:
  - amplitude
  - frequency
  - phase
- Combination of amplitude and phase often used

Line Coding: TTL Signals



- Binary value represented by state
  - "High" voltage defines a 1
  - "Low" voltage defines a 0
  - Undefined between levels
- As signal degrades with distance → 1 becomes undefined and then becomes 0

Differential TTL Signals



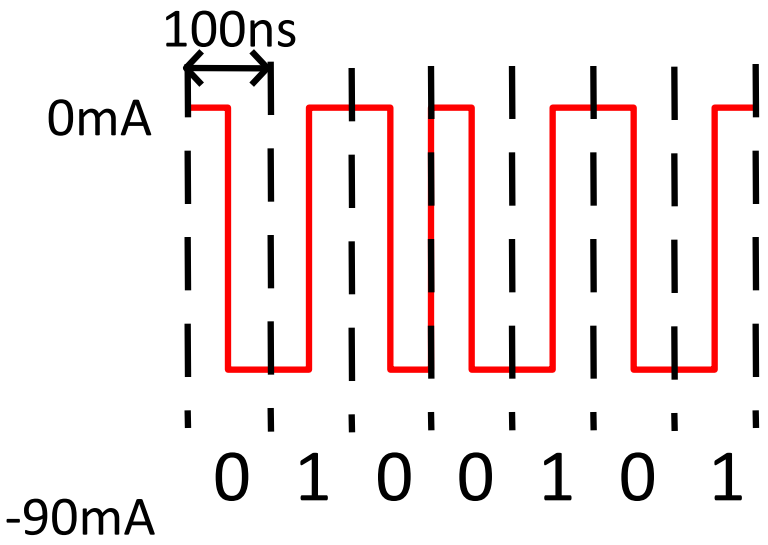
- Binary value represented by state
  - "Positive" voltage defines a 1
  - "Negative" voltage defines a 0
  - Undefined around 0
- Value becomes undefined as signal degrades
  - But never incorrect as polarity not lost

Synchronisation: Clocks

- Receiver must identify which bit of data is being sent
  - Easy if sending 0101010
  - Harder if sending 0001100
    - Could be heard as 001100 if timing wrong

- Need **synchronisation** between sender + receiver
  1. Slow data rate so slight inaccuracy doesn't matter
  2. Separate signal with clock in it
  3. Modify signal so that clock is built in

Manchester Encoding



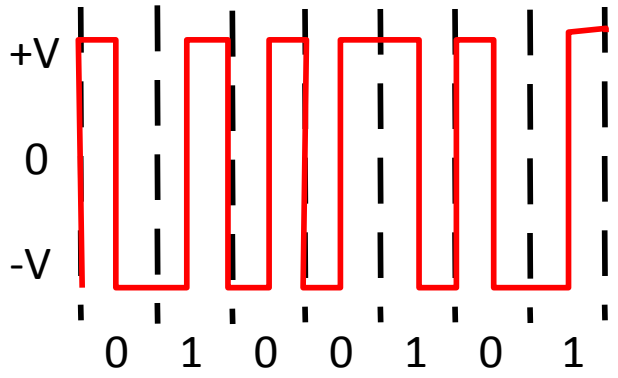
0: high-to-low

1: low-to-high

- Binary value represented by type of transition
  - Every bit has at least one transition
  - Signal changes simplify clock synchronisation
  - Signal changes enable fast detection of signal
  - Requires twice bandwidth of simple binary encoding

Differential Manchester Encoding

- Binary value represented by presence/absence of transitions
  - Every bit has at least one transition
  - Better noise immunity
  - Polarity doesn't matter
  - But requires more complex equipment



0: transition at start

1: no transition at start

More Terminology

- **Baud**
  - Rate at which signal level (modulation) changes (signal elements per second)

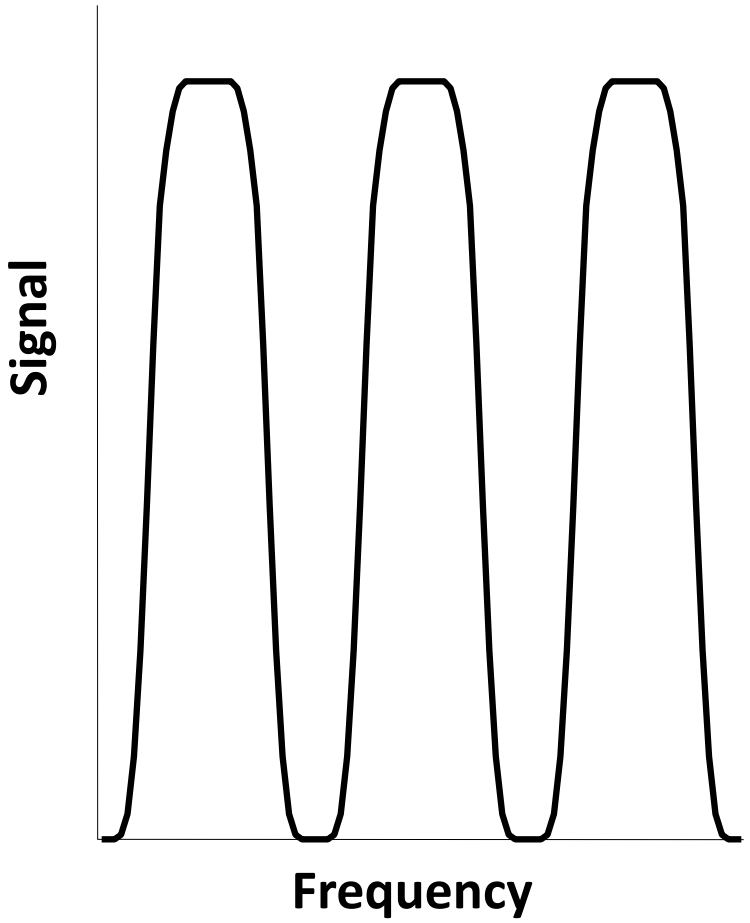
- **Data rate**
  - Rate of data transmission (bits per second)

Multiplexing: Sharing Channels

- Signal occupies bandwidth in channel
  - But it need not occupy whole channel
  - E.g. many radio stations operate in parallel

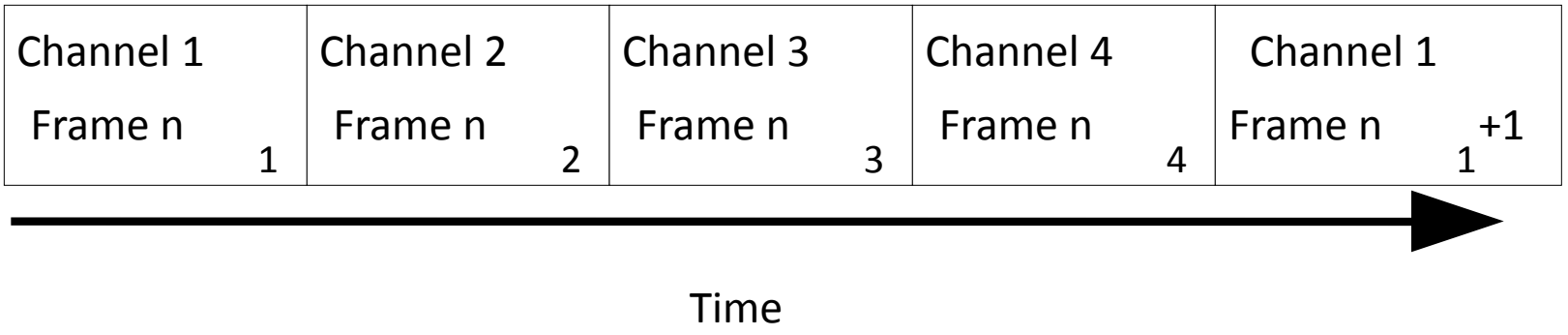
- **Multiplexing**
  - We examine three techniques for sharing a medium

Frequency Division Multiplexing (FDM)



- Encode different signals by sending at different frequencies
  - E.g. Radio, TV, GSM, …
- Need guards bands because filters imprecise
- Someone must allocate frequencies to users

Time Division Multiplexing (TDM)



- Subdivide channel into fixed time **slots**
- Encode many signals by sending at different times
  - E.g. phone calls in trunks, TV schedule, …

Issues in TDM

- Whole bandwidth channel usable for duration of slot
  - But input signals must have bandwidth less than medium bandwidth / number of channels
- Introduces delay while waiting for slot
  - Gap between slots must not interfere with requirements
- Someone must allocate time slots
  - Needs synchronisation to keep track of slots
  - Fixed allocation bad for bursty data

Code Division Multiple Access (CDMA)

- Imagine many groups having conversations in same room
  - TDM ➔ taking turns to talk
  - FDM ➔ talking in isolated groups not heard by others
  - CDMA ➔ everyone talking in different languages
- Stations transmit over entire frequency spectrum
  - Stations combine data bits with own code sequence
  - Interference between signals occurs
  - Separation made using coding theory
- E.g. UTMS, satellite transmission, …

Issues in CDMA

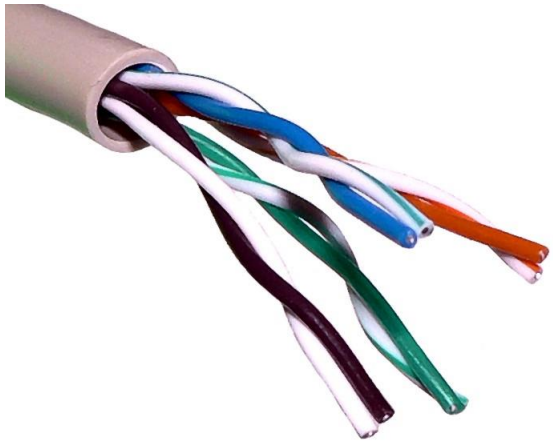
- Only practical for communication with central station
  - Interference needs to be controlled
  - Requires sophisticated signal power management
    - “Everyone can talk as long as no-one talks too loud”
- Flexible allocation of channel resources
  - Soft degradation as number of stations increases

Common Communication Standards

- No Need to know all the details of wiring!

Analogue Phone Lines

- Twisted pair cable
  - Send/receive wires are twisted together to reduce interference/radiation
  - Different versions (shielded/unshielded, CAT3, CAT5)



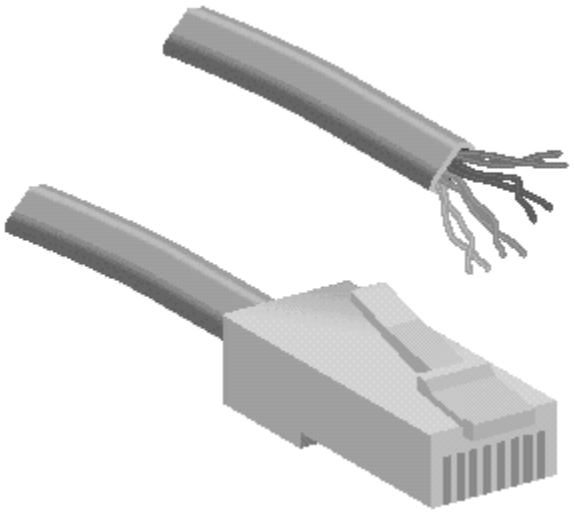
- Use modem to send data using tones
  - Telephone system has filters to limit range of tones
    - Only permits 300Hz–3kHz (human voice)
  - Approx. 2400 distinct tones/sec (2400 baud)
  - 56k bits/sec best practical data rate

Digital Phone Lines

- ISDN Basic Rate Interface (BRI)
  - 2 x 64kb/s bearer/data (B-channels)
  - 1 x 16kb/s control/signalling (D-channel)
- Two twisted pair cables

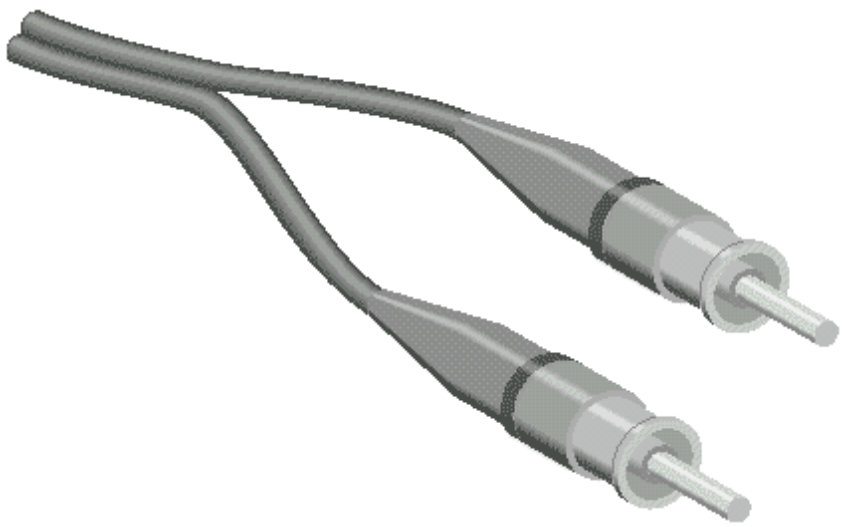
- ISDN Primary Rate Interface (PRI)
  - 23 (US) or 30 (EU) x 64kb/s data channels
  - 1 x 64kb/s control
  - T1=1.544Mb/s (US), E1=2.048Mb/s (Europe & Asia)
- Many others, including OC3 = 155.52Mb/s (optical)

Ethernet (802.3 10/100Base-T)



- 100Base-TX most common cabling in office LANs today (allows 100Mb/s)
- 10Base-T is phone wire, allows 10Mb/s
  - Found in older networks
- 100m max segment length
  - 1024 connections per segment (with hub)

Fibre Optics (10/100Base-F)



- Commonly used for:
  - Backbones
  - High speed networks
  - Environments with high electrical noise
  - Highly secure networks
    - Taps hard to make
- 2km max segment length
  - Max 1024 connections per segment

Wireless Ethernet

- IEEE 802.11, 802.11b, 802.11a, 802.11g, 802.11n, …
- 1Mb/s – 54Mb/s (and more)
- 2.4 GHz and 5 GHz
  - Frequency band not restricted
- 500m range (at 1Mb/s in open)
  - Affected by walls, microwave ovens, …

☛ *More later on this*