# 2. Physical Media, Network Core

08 January 2025 09:57

## PHYSICAL MEDIA

bit: propagates b/w transmitter / receiver pairs

physical link: lies between transmitter, receiver

**Guided**
solid media

**Unguided**
propagate through air / space

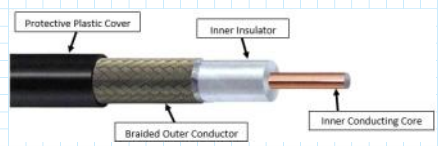
## GUIDED MEDIA

### Twisted Pair

- Two insulated copper wires twisted around each other to reduce noise
- Two types → shielded (STP)
  → unshielded (UTP)

Eg: Cat 5 : 100 Mbps, 1 Gbps Ethernet
Cat 6 : 10 Gbps Ethernet

### Coaxial Cable




- Two concentric copper conductors
- Bidirectional
- Multiple frequency channels on single cable (broadband)

### Fibre Optic Cable

- Thin flexible medium that conducts pulses of light
- Supports extremely high bit rates
- Immune to EM interference, very low attenuation, very hard to tap
- High cost

## UNGUIDED MEDIA

### Wireless radio

types →

- Terrestrial microwave
  up to 45 Mbps channels
- Wireless LAN (WiFi)
  up to 100s of Mbps
- Wide area (eg: cellular)
  4G cellular: ~10's Mbps
- Satellite
  - up to 45 Mbps per channel
  - 280 ms end-to-end delay
  - geosynchronous vs low-earth orbit

- Carried in EM spectrum
- Broadcast and "half-duplex" (sender to receiver)
- Propagation environment effects:
  - Reflection
  - Obstruction by objects
  - Interference

## NETWORK CORE

dark stores

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- Mesh of interconnected routers

## PACKET SWITCHING

- Host break application-layer messages into packets
- Forwards packets from one router to the next across links on path from source to destination
- Packets transmitted over each link at the full transmission rate of the link
- Say packets of length L are transmitted at link transmission rate R (also called capacity / bandwidth)

$$\boxed{\text{Packet transmission delay} = \frac{L\ (\text{bits})}{R\ (\text{bits/sec})}}$$

ideally; there can be other factors

Store and forward: Most packet switches wait until the entire packet is received before it is transmitted through the next link

End-end delay: Total delay from source to destination

Packet queuing and loss (arrival rate to link > transmission rate from link)

- Single packet switch ⟶ multiple links ⟶ output buffer for each link
- If packet arrives and needs to be transmitted on a certain link, but link is busy:
  Packet is queued by storing into buffer ⟶ queuing delays
- If above but buffer is full:
  packet loss occurs ⟶ either arriving packet / already queued packet is dropped

Network forwarding

- Every packet has a header containing destination address
- Every link has a forwarding table that tells it which link to forward the packet on based on destination address
- Local action

determines

traceroute.org

Network routing

- Determine source-destination path taken by packets
- Done by routing algorithms
- Global action

## CIRCUIT SWITCHING

- Unlike packet switching, dedicated path established between source & destination for data transfer

circuit

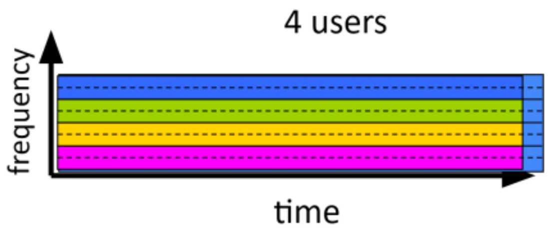
- Once end-end resources have been allocated, sender can transfer data at a guaranteed constant rate
- There is no sharing; if a circuit segment is not being used, it remains idle.

### Multiplexing in circuit switched networks

Frequency Division

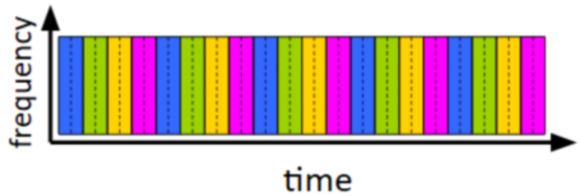
## Frequency Division Multiplexing (FDM)

- optical, electromagnetic frequencies divided into (narrow) frequency bands
- each call allocated its own band, can transmit at max rate of that narrow band



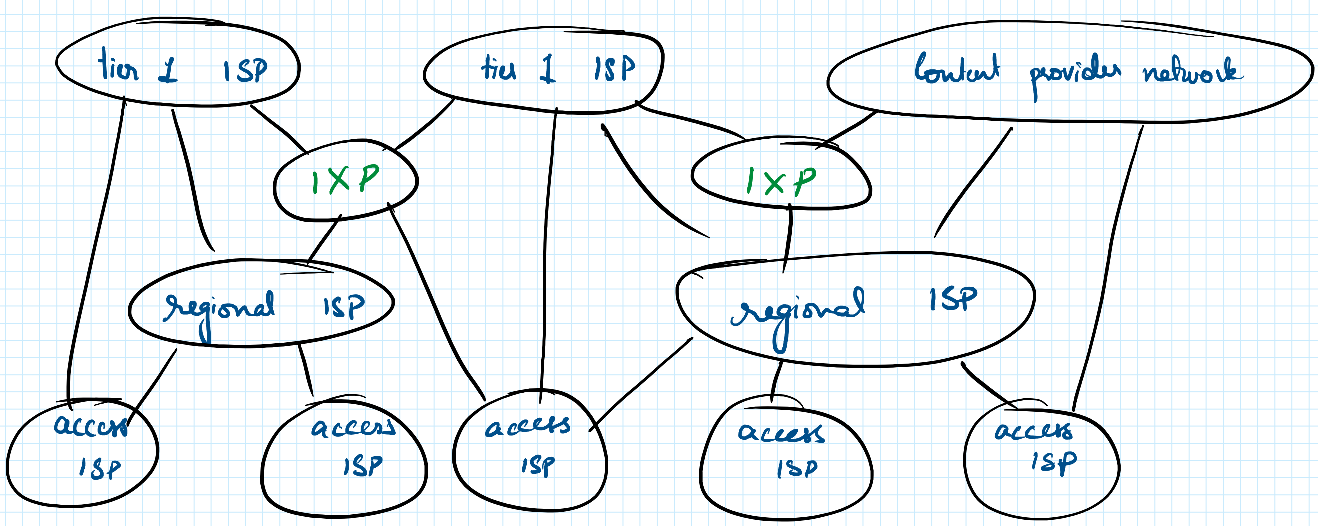

## Time Division Multiplexing (TDM)

- time divided into frames -> slots
- each call allocated periodic slot(s), can transmit at maximum rate of (wider) frequency band, but only during its time slot(s)




| Circuit Switching | Packet Switching |
|---|---|
| Reserved resources, no sharing | Shared resources |
| Reliable, guaranteed performance | No guaranteed performance |
| Costlier; inefficient use of resources | Cheaper; efficient use of resources |
| Slower: dedicated path needed | Faster: no setup time |
| Connection oriented | Connectionless |
| Designed for voice | Designed for data |
| Inflexible | Flexible |
| Physical layer | Network layer |
| FDM/TDM | Store/ Store & Forward |
| Transmission: Source | Transmission: source, routers |
| Bandwidth wasted (fixed) | Bandwidth saved (dynamic) |

## Internet - Network of Networks



PRACTICE

$N_{cs}$ users each need 20 Mbps. link capacity = 100 Mbps

$N_{ps}$ users. " " " " " ". Transmission happens only 10% of the time

① $\frac{100}{20} = \underline{\underline{5 \text{ users}}}$

② Under circuit switching, no. $9 \times 20 = 180 > 100$

③ $P(1 \text{ specific user transmitting}) = 0.1$ $P(\text{all remaining not transmitting}) = (0.9)^8$

$P(1 \text{ specific user not transmitting}) = 0.9$ $P(1 \text{ specific}: ✓ \text{ others}: ✗) = (0.9)^8 (0.1) = \underline{\underline{0.043}}$

④ $P(\text{any } 1: ✓ \text{ others}: ✗) = {}^1C_9 (0.1) \cdot (0.9)^8$

$= \frac{9!}{8!\,1!} (0.1) \cdot (0.9)^8$

$= 9 [0.043] = \underline{\underline{0.387}}$

⑤ $\frac{20}{100} = \underline{\underline{0.2}}$

⑥ $P(\text{any } 4: ✓ \text{ others}: ✗) = {}^4C_9 (0.1)^4 (0.9)^5$

$= \frac{9!}{4!\,5!} (0.1)^4 (0.9)^5 = \frac{6 \times 7 \times 8 \times 9}{2 \times 3 \times 4} (0.1)^4 (0.9)^5 = 7.44 \times 10^{-3}$

⑦ $P(>5: ✓) = P(\text{any } 6) + P(\text{any } 7) + P(\text{any } 8) + P(\text{any } 9)$