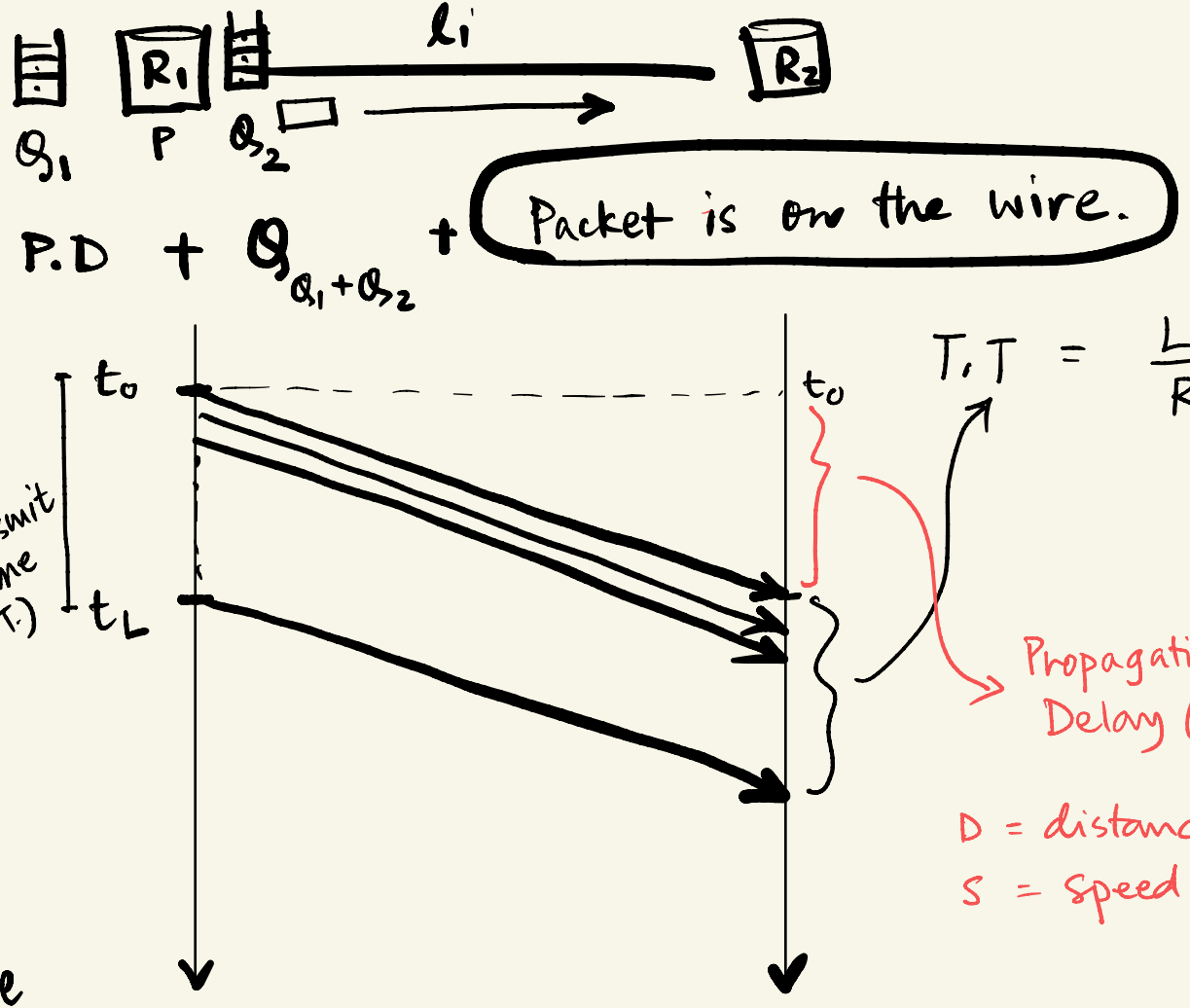
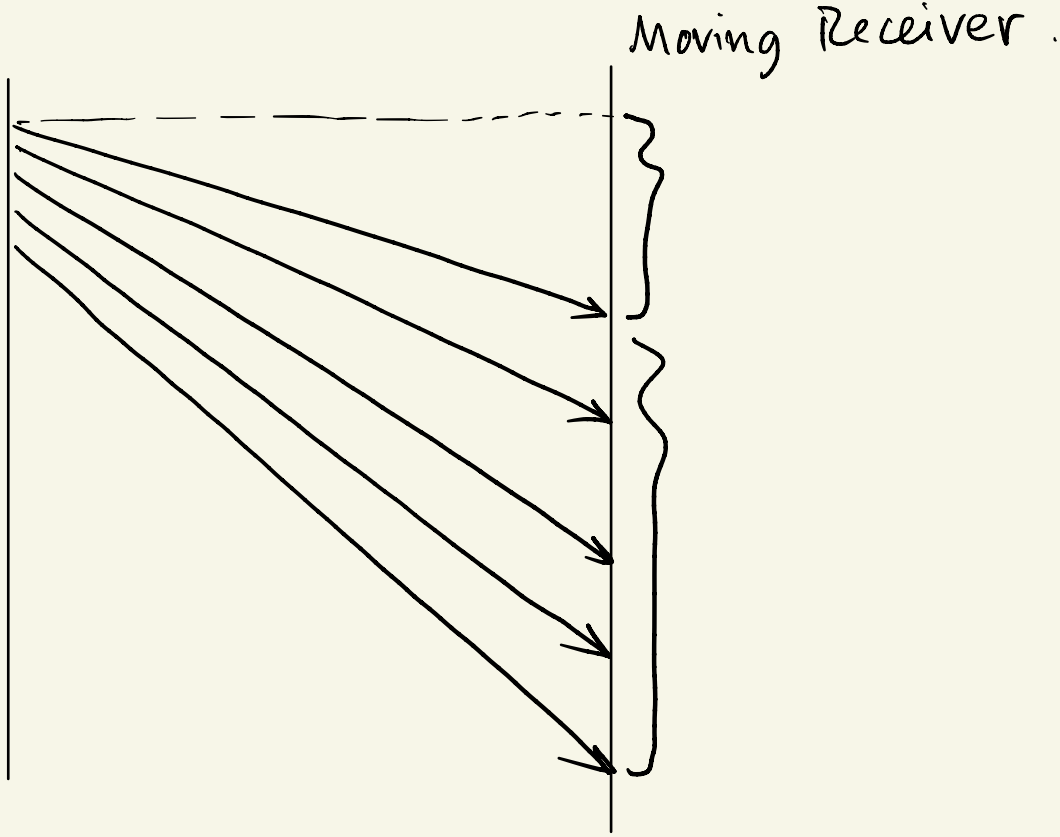
Lecture 6

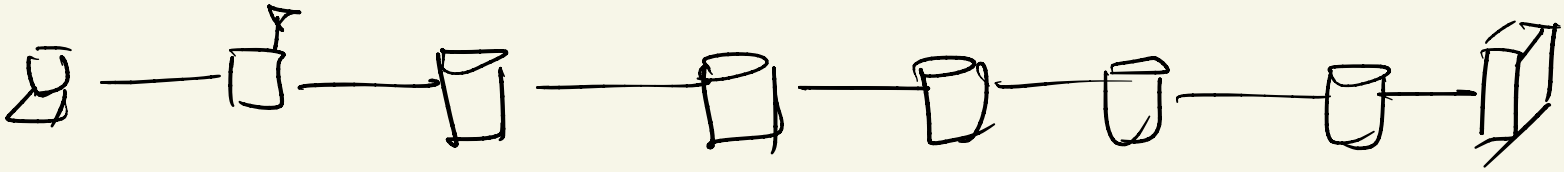
- Latency in the Internet
- Some more keywords

Foundations

- [ ] FFT → Bandwidth → Spectrum
- [ ] Spectrum sharing → Carrier freq. → Modulation
  - amp.
  - freq.
- [ ] Baseband
- [ ] Bit rate → BER → SINR
  - noise
  - interference
  - Received power
- [ ] Shannon Capacity
- [ ] PER → Throughput → Goodput
- [ ] Inter packet time Vs. throughput
- [ ] End to end latency → Processing + Q + T.T + P.D


l_1
R_1
R_2
Q_1
P
Q_2
P.D + $Q_{Q_1+Q_2}$ + Packet is on the wire.
L bits
R bits/s
Transmit time (T.T.)
t_0
t_L
t_0
T.T = $\frac{L}{R}$ seconds.
Propagation Delay (P.D) = $\frac{D}{S}$ sec.
D = distance
S = speed.
time


Moving Receiver.



Traceroute

Facts and Concepts

- Layering : Analogy with airline industry —> protocols --> ISO / OSI architecture —> Success of layering evident today

- Network Edge : Client/server vs. P2P architecture vs. Hybrid

- Network Edge : Connection-less (UDP) vs. Connection-oriented service (TCP)

- Network Edge : Residential access networks : Wired access (DSL vs. Cable)

- Network Edge : Residential access networks : Wireless vs. Cellular vs. Satellite

- Network Core : Circuit switching vs. Packet switching

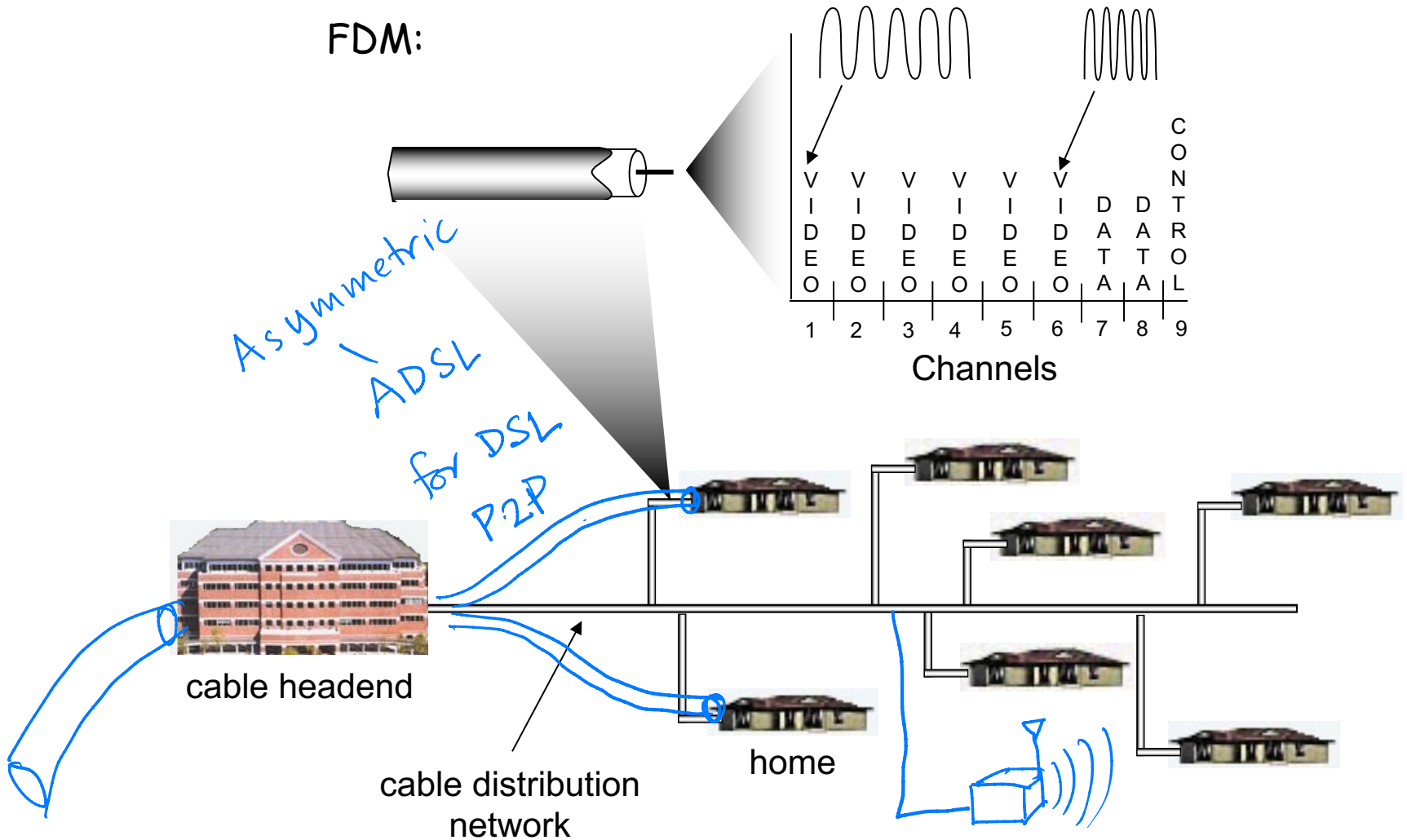
- Network Core : Circuit switching : FDM vs. TDM

- Network Core : Packet switching : Statistical multiplexing

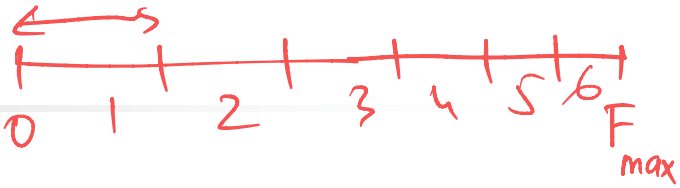
- Network Core : Packet switching : Datagrams vs. Virtual circuits

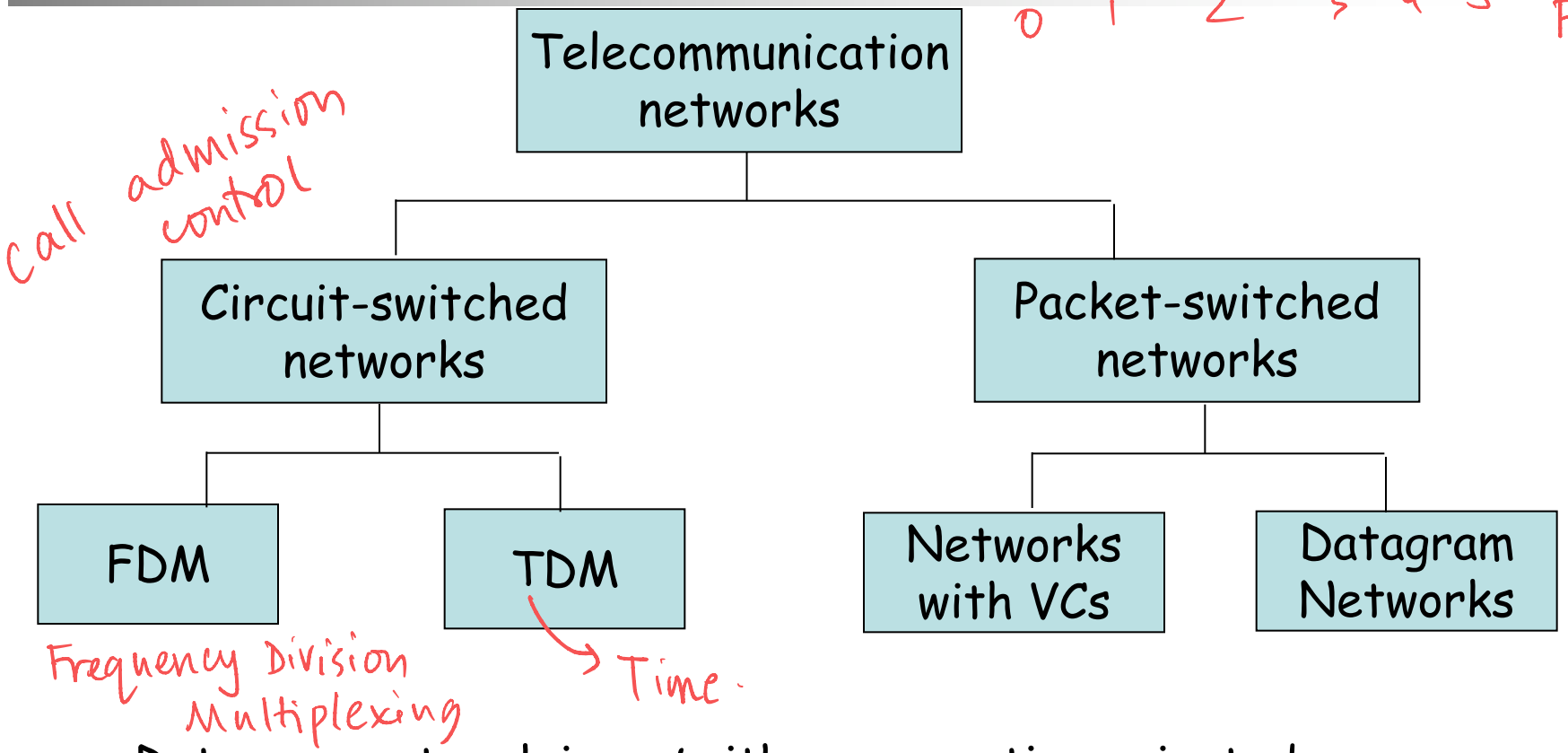
- Network Computing : Cloud vs. Edge

Cable Network Architecture: Overview



Network Taxonomy





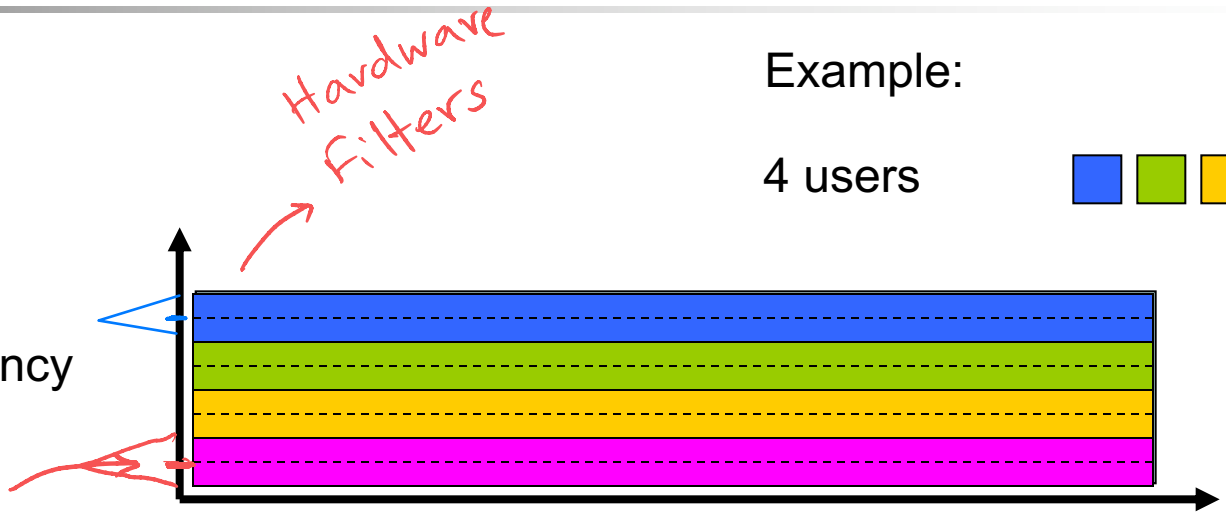
- Datagram network is *not* either connection-oriented or connectionless.
- Internet provides both connection-oriented (TCP) and connectionless services (UDP) to apps.

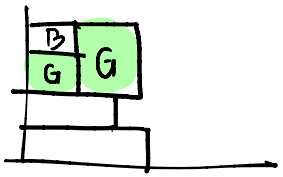
Circuit Switching: FDM and TDM

FDM

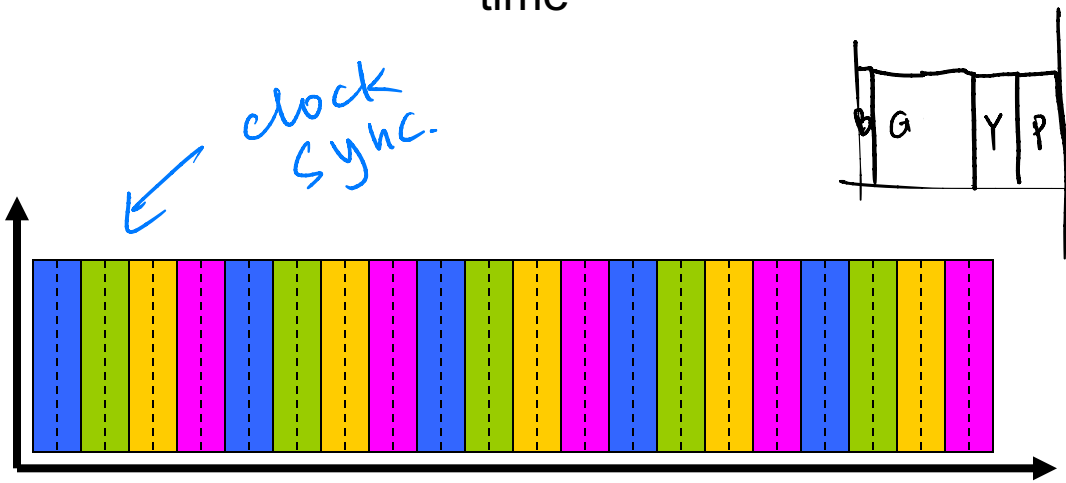
Example:

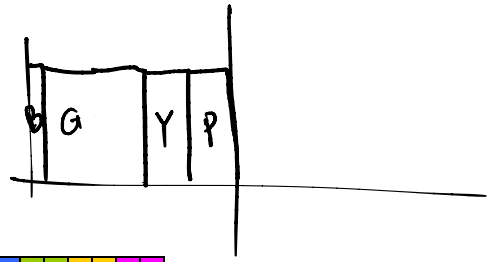
4 users



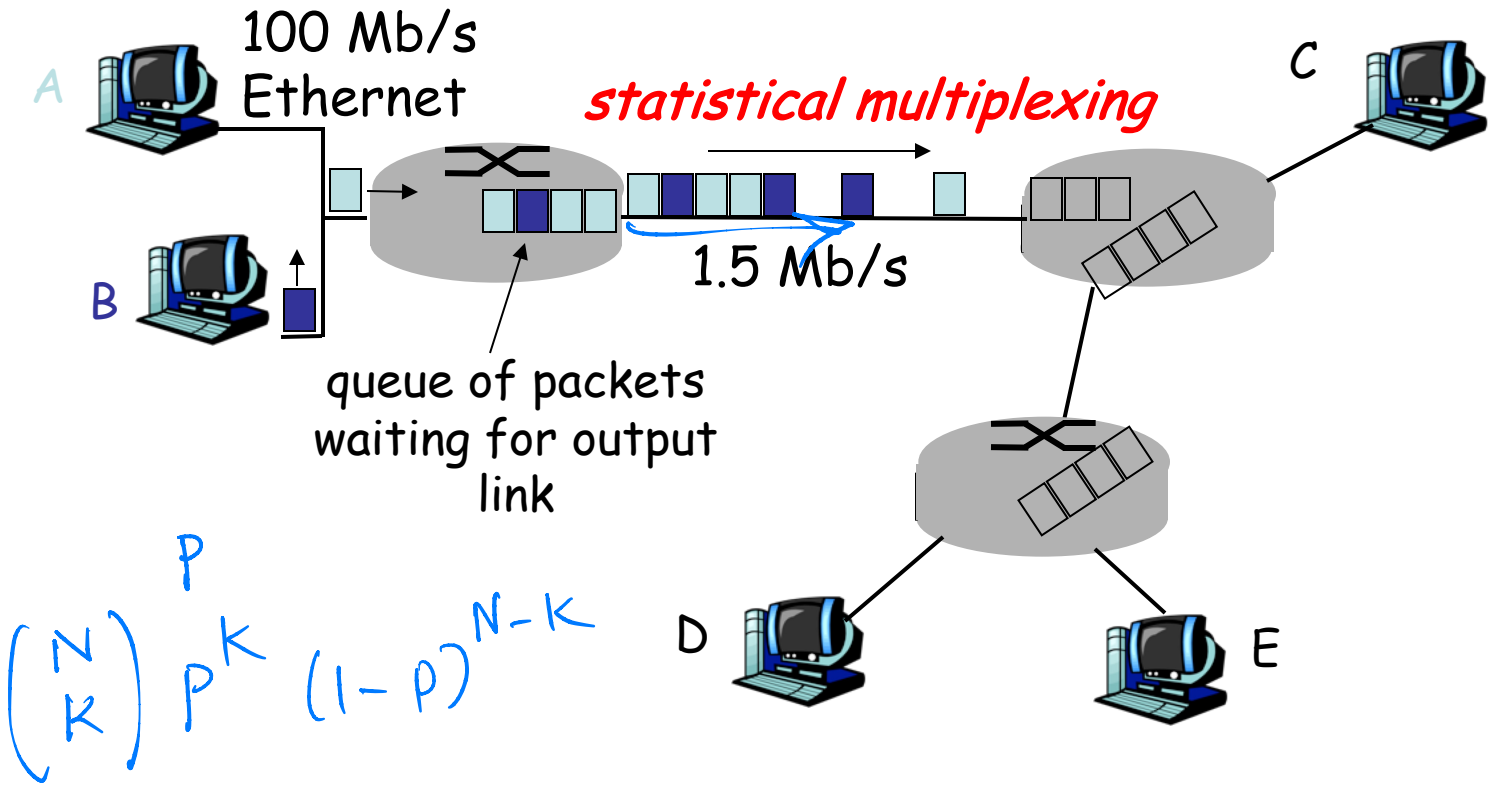


TDM





Packet Switching: Statistical Multiplexing



$$\binom{N}{K} p^K (1-p)^{N-K}$$

Sequence of A & B packets does not have fixed pattern, shared on demand ➡ ***statistical multiplexing***.

TDM: each host gets same slot in revolving TDM frame.

Assignment # -1

Watch "City in the Sky" documentary on ~~Netflix~~ BBC

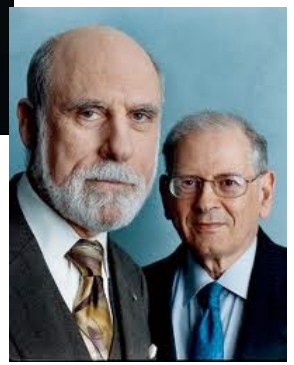
You will appreciate both airline systems and
The Internet much more than you do now …

On the Shoulders of Giants

- 1961: Leonard Kleinrock published a work on packet switching
- 1962: J. Licklider described a worldwide network of computers called Galactic Network
- 1965: Larry Roberts designed the ARPANET that communicated over long distance links
- 1971: Ray Tomilson invents email at BBN
- 1972: Bob Kahn and Vint Cerf invented TCP for reliable packet transport







On the Shoulders of Giants …

- 1973: David Clark, Bob Metcalfe implemented TCP and designed ethernet at Xerox PARC
- 1975: Paul Mockapetris developed DNS system for host lookup
- 1980: Radia Perlman invented spanning tree algorithm for bridging separate networks
- Things snowballed from there on …