The University of Manchester

Switching, Delays and Performance

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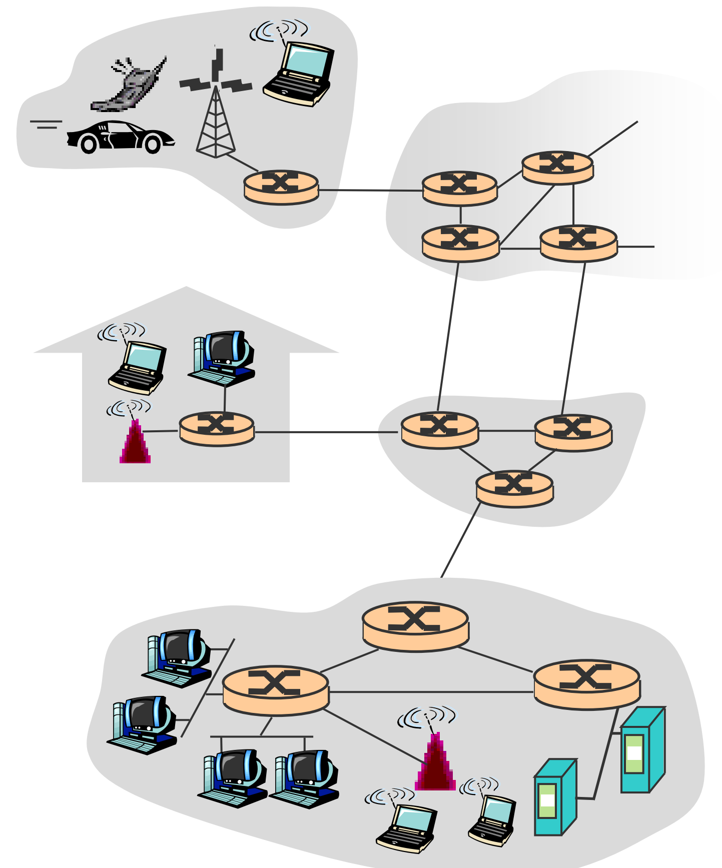
Switching in the Network Core

- Mesh of interconnected routers
- How is data transferred?
- Either:
  - **circuit switching**:
    - fixed path (channel)
    - dedicated resources
  - **packet-switching**, data sent:
    - in discrete “chunks”
    - when resource available



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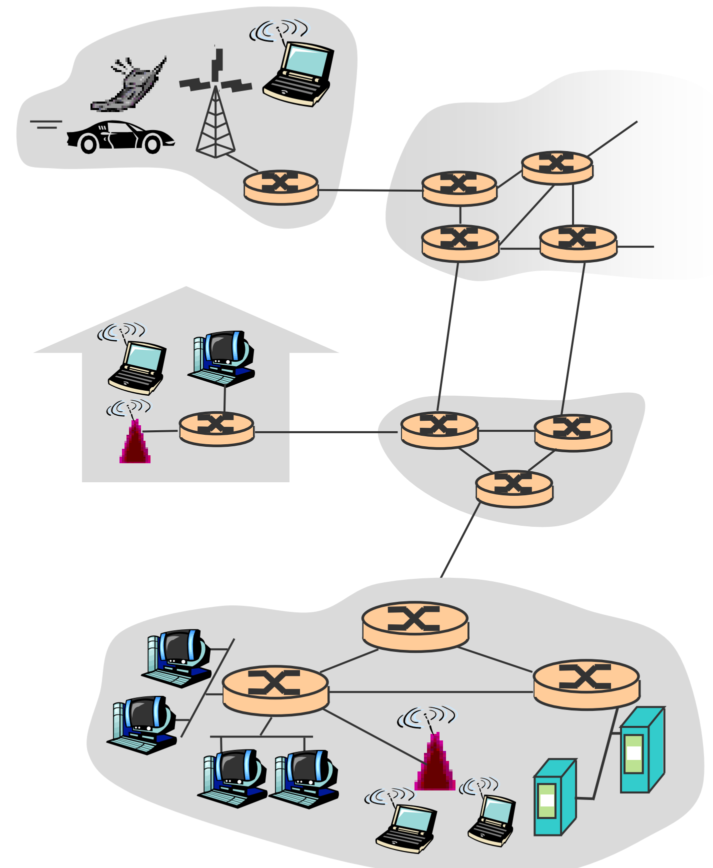
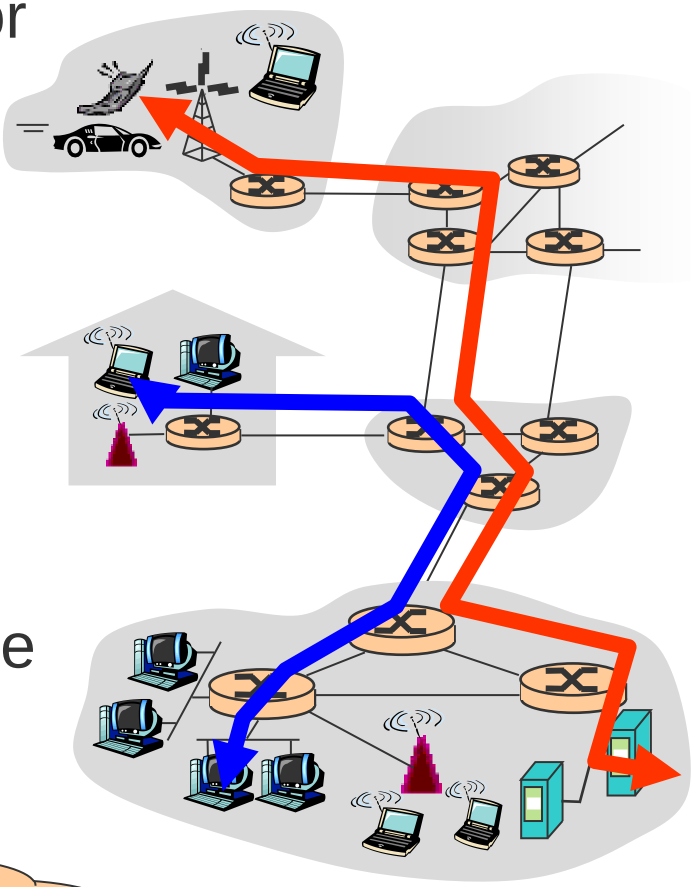


Traditional Circuit Switching

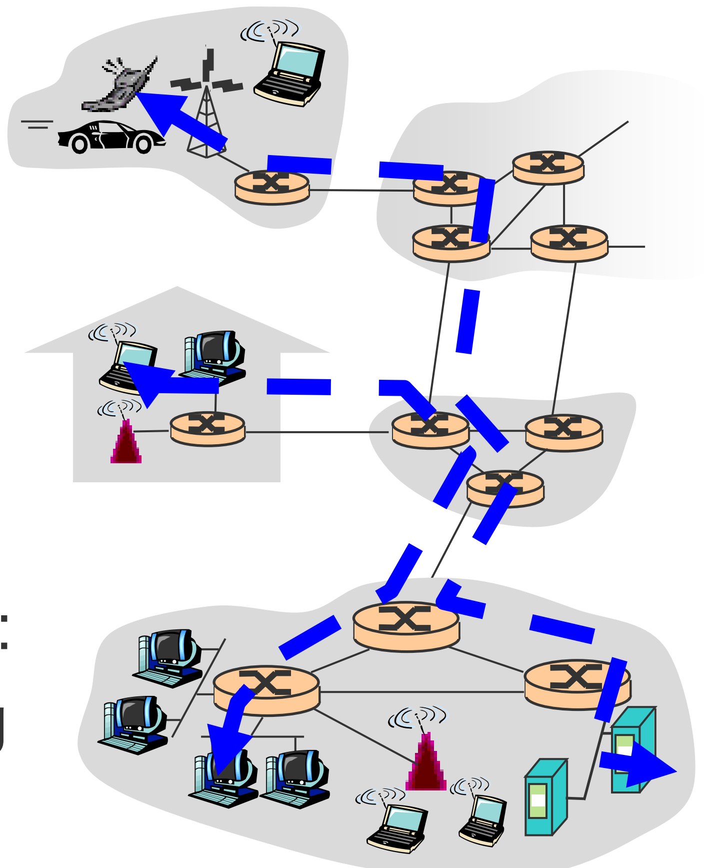
- End-to-end resources reserved for duration of transfer
- Resources are dedicated:
  - no sharing
  - all link bandwidth
  - all switch capacity
- Acts as a circuit; e.g.
  - continuous piece of copper wire
- Get guaranteed performance
- Setup required to configure and establish



Sensible approach?

Networking Circuit Switching

- Network resources shared:
  - divided into pieces
  - normally of a fixed size
- Piece reserved for (**allocated** to) end-to-end transfers
- Resource piece is idle if not used by owning transfer
- For a link, share bandwidth using:
  - frequency division multiplexing (FDM)
  - time division multiplexing (TDM)

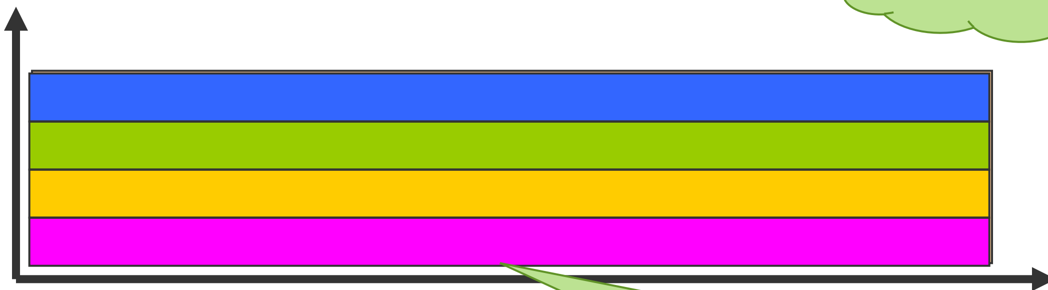


Switching: FDM and TDM

WiFi

FDM

frequency



width = bandwidth

time

User gets continuous low volume of data

TDM

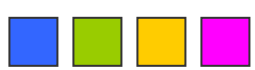
frequency

width = bandwidth

time

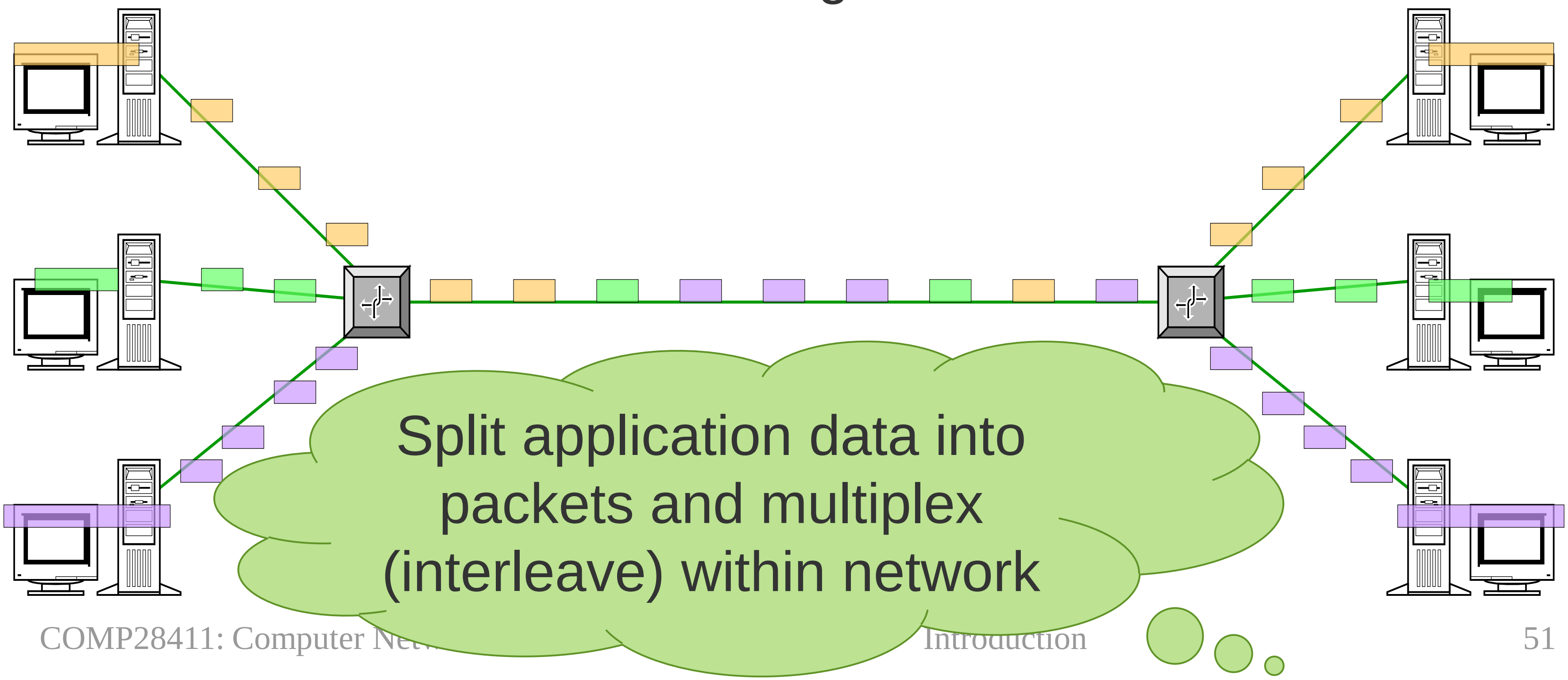
User periodically gets burst of data

Example: 4 users

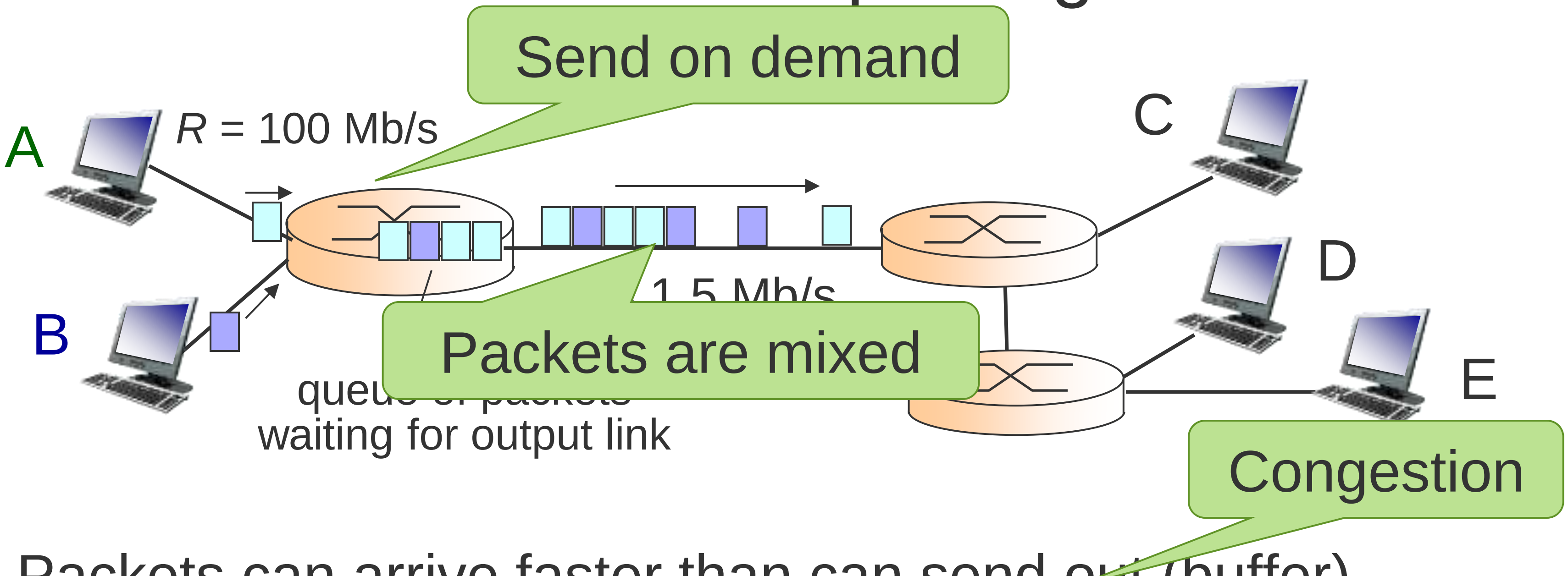


Packet Switching

- Each end-to-end data stream divided into **packets**
- Packets **share** network resources, use as needed
  - each packet uses full link bandwidth
- Packets are transmitted using store-and-forward



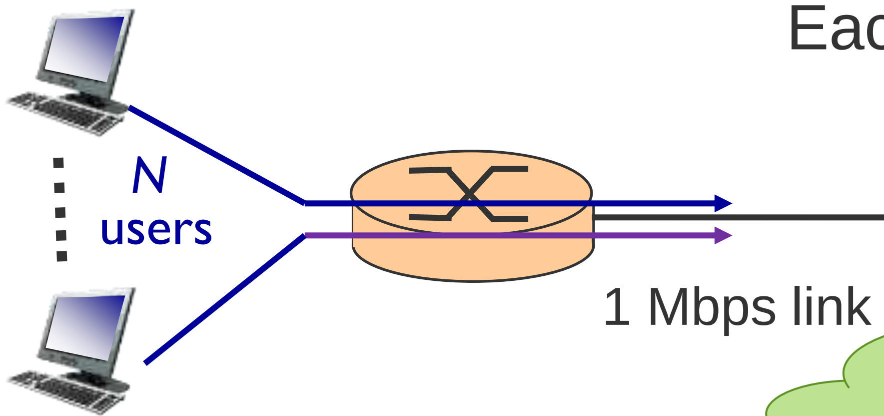
Statistical Multiplexing



- Packets can arrive faster than can send out (buffer)
- Overload normally transitory, will later clear buffer
- If buffer becomes full, drop (lose) packets
- Aim for low probability of packet dropping

K&R 1.3.1, P&D: 1.1.2

Packet versus Circuit Switching



Each user:

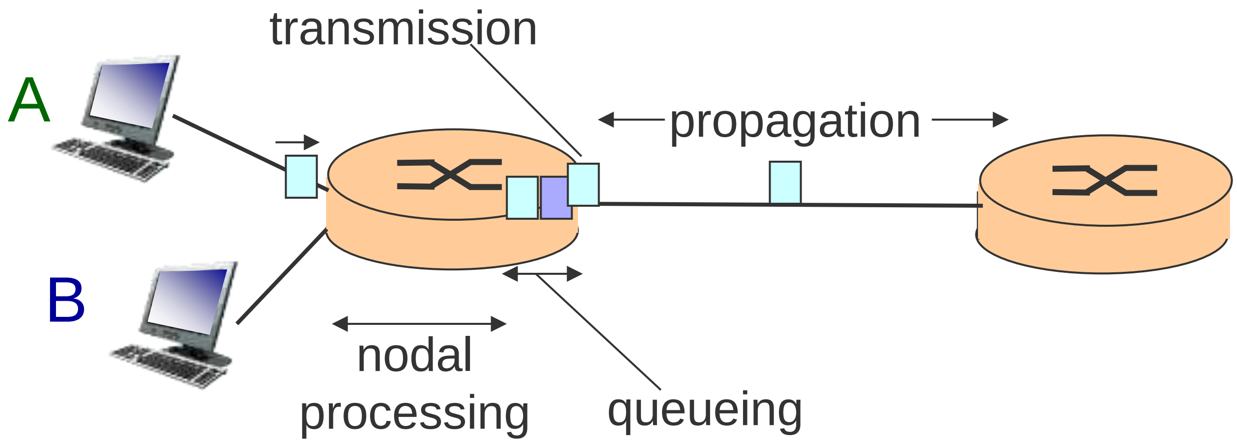
100 Kbps when “active”

active 10% of time

Figures are based on assumptions

- Circuit-switching: 1M/100K = 10 users
- Packet switching: 35 users
  – need statistics theory (why statistical multiplexing)
  – probability > 10 users active at same time < .0004
- Packet switching allows more users to use network!

Packet Delays



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

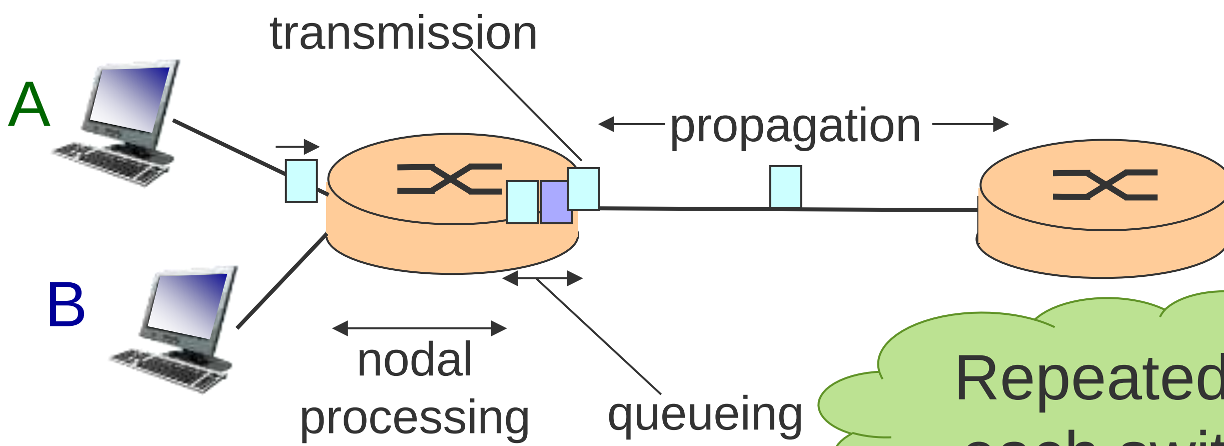
d_{proc}: nodal processing

- check bit errors
- determine output link
- typically < msec

d_{queue}: queueing delay

- time waiting at output link for transmission
- depends on congestion level of router

Packet Delays



Repeated at each switch

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

d_{trans}: transmission delay:

- *L*: packet length (bits)
- *R*: link *bandwidth (bps)*
- $d_{trans} = L/R$

Depends on size

d_{trans} and d_{prop} *very* different

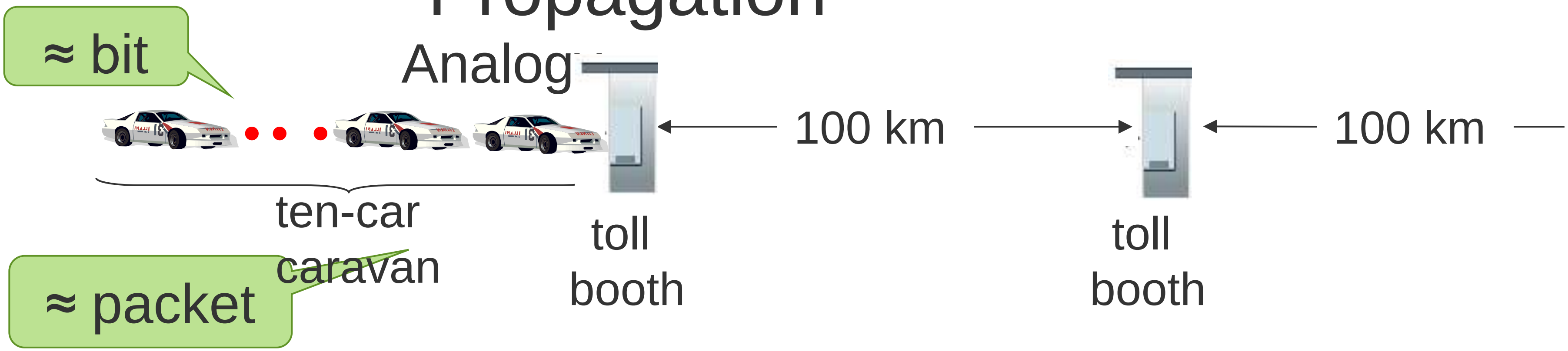
d_{prop}: propagation delay:

- *d*: length of physical link
- *s*: propagation speed in medium (~2×10^8 m/sec)
- $d_{prop} = d/s$

Depends on distance

Delays: Transmission vs. Propagation

Analog



- Cars “propagate” at 100 km/hr
- Booth takes 12 sec to service car (transmission time)
- Q: How long for convoy to get to 2nd booth?
- “push” all cars through booth = 12*10 = 120 sec
- For last car to propagate from 1st to 2nd both:
  - 100km/(100km/hr) = 1 hr
- A: 120 sec + 1hr = 62 minutes

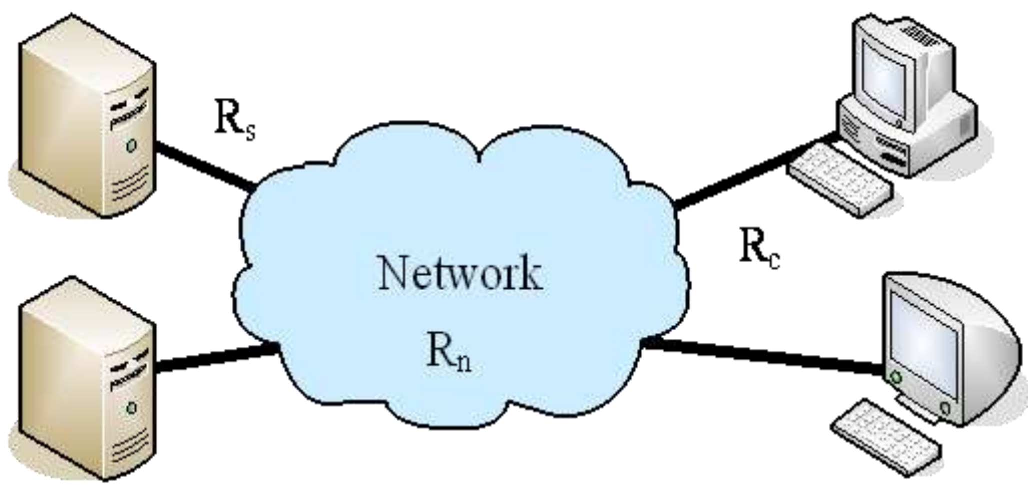
Delays: End-to-End Delay

- Delay between parts of application comes from:
  - individual node delays
  - processing delays in applications
  - waiting for access to shared medium
- Also use round-trip-time (RTT)
  - time source to destination and back
- If no queuing delays, dominant delay predictable
  - sending 1 byte on any link: propagation delay
  - sending 25Mb on 10Mbps link: transfer rate

K&R 1.4.4

Throughput in Computer Networks

- Rate at which data is transferred, GUI may report
- Measuring useful (application data) throughput
- For large transfers, determined by three parameters:
  - remote computer (link), network and local link



Units (Background)

- Link rates in bits per second (bps), with multipliers:

Kilo	K	10^3	2^{10}
Mega	M	10^6	2^{20}
Giga	G	10^9	2^{30}
Tera	T	10^{12}	2^{40}

- Times often small quantities, with multipliers:

milli	m	10^{-3}	
micro	µ	10^{-6}	
nano	n	10^{-9}	
pico	p	10^{-12}	

1Kbps ≡ 1ms per bit
1Mbps ≡ 1µ per bit

Summary

- Aim is cost effective connectivity for set of computers
- Result is a packet switched network
- Use shared links and statistical multiplexing
- Communication services seen as process-to-process
- Delays and throughput define network performance

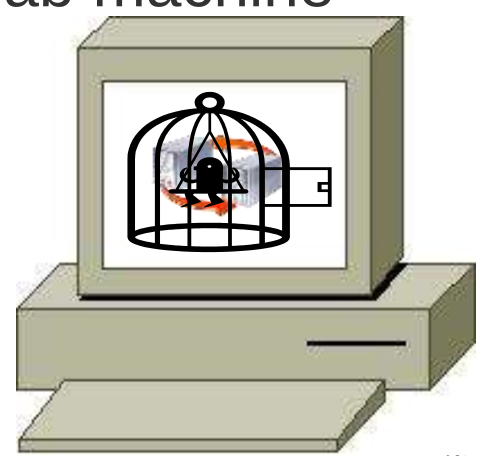
Real aim?

Course Structure

- **Lectures**: 3 per fortnight
  – Mondays week A (3pm)
  – Tuesdays (3pm)
- **Laboratories**: 1 per fortnight, needs preparation
  – week Bs; see myManchester timetable
  – Quiz, experiments in networking
  – provide support to meet deadlines
- **Workshops**: 1 per fortnight, no preparation
  – Mondays (1.00pm) or Tuesdays (3.00pm) week B
  – Quiz, new material, examinable

Laboratory: Overview

- Learn how to configure and use real networks
- Have complete control over network that configure
- But, cannot let you loose on the Internet!
  – physical private unconnected networks needs
    - 3+ machines per student
  – use virtual network of virtual machines:
    - whole virtual network runs on your lab machine
    - no link to the outside world



Laboratory: Core Tool (VNUML)

- Use virtual operating system to emulate machines
- Several virtual machines, so needs to be light weight
  - not VMware, Virtual Box, etc.
- Virtual Networking User Mode Linux (VNUML)
  - each VM runs as a user process
  - each VM has to boot: quite slow
  - you get a partially disabled console
    - username root, password xxxx
    - entirely command line driven
  - installed on School's Linux machines
  - not easy to install elsewhere

Based on User Mode Linux (UML)

Laboratory: Deliverables

- Deadline 9am Friday after your laboratory session
  - No extensions
- Unlike programming laboratories:
  - there is no program to submit and demo
- Instead:
  - configuration files, commands used
  - output from commands, your analysis
- We supply a Quiz, you:
  - fill in the results as you go along
  - submit when you complete the exercise

Reading

- J. Kurose & K. Ross, Computer Networking: A Top-Down Approach, 6^{th} Ed, Pearson, ISBN: 0-273-76896-4
- L. Peterson & B. S. Davie, Computer Networks, 5^{th} Ed, Morgan Kaufmann, ISBN:0123850592.

- There are many good books on networking, if you do not like our selection then pick your own.