Switching, Delays and Performance

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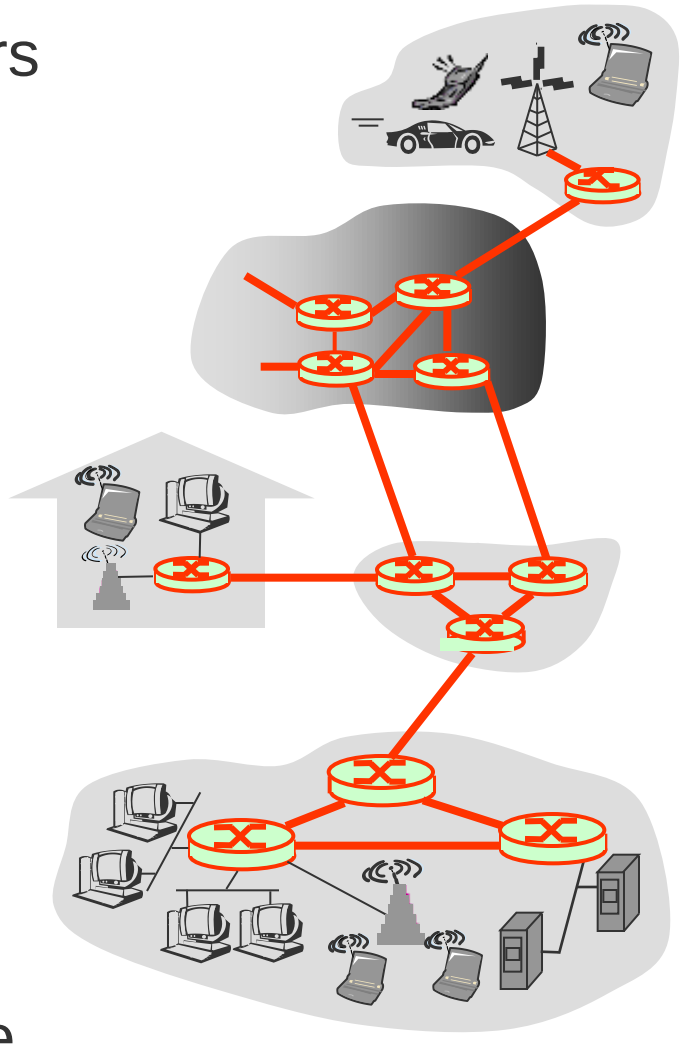
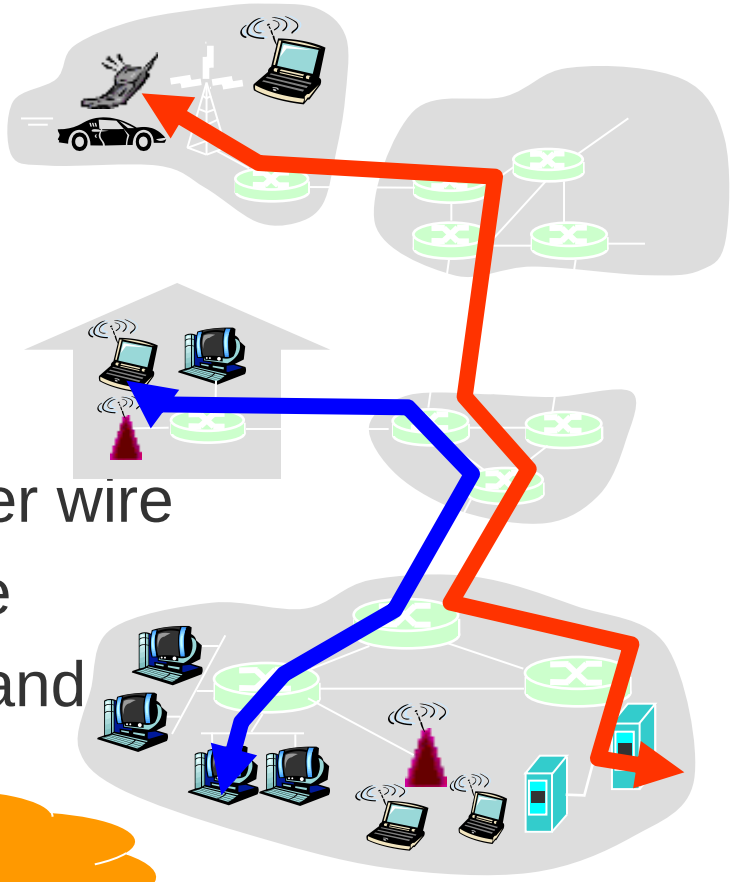
Switching in the Network Core

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



Switching: Traditional Circuit Switching

- End-end resources reserved for 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 path



Sensible approach?

Switching: Networking Circuit Switching

- Network resources shared by dividing into pieces
  - normally pieces are of a fixed size
  - number of pieces fixed when create network
- Bits **reserved** for (**allocated** to) end-to-end transfers
- Resource piece is *idle* if not used by owning transfer
- For a link, divide link bandwidth into pieces using:
  - frequency division multiplexing (FDM)
  - time division multiplexing (TDM)

Switching: FDM and TDM

WiFi

FDM

frequency

width = bandwidth

User gets continuous low volume of data

TDM

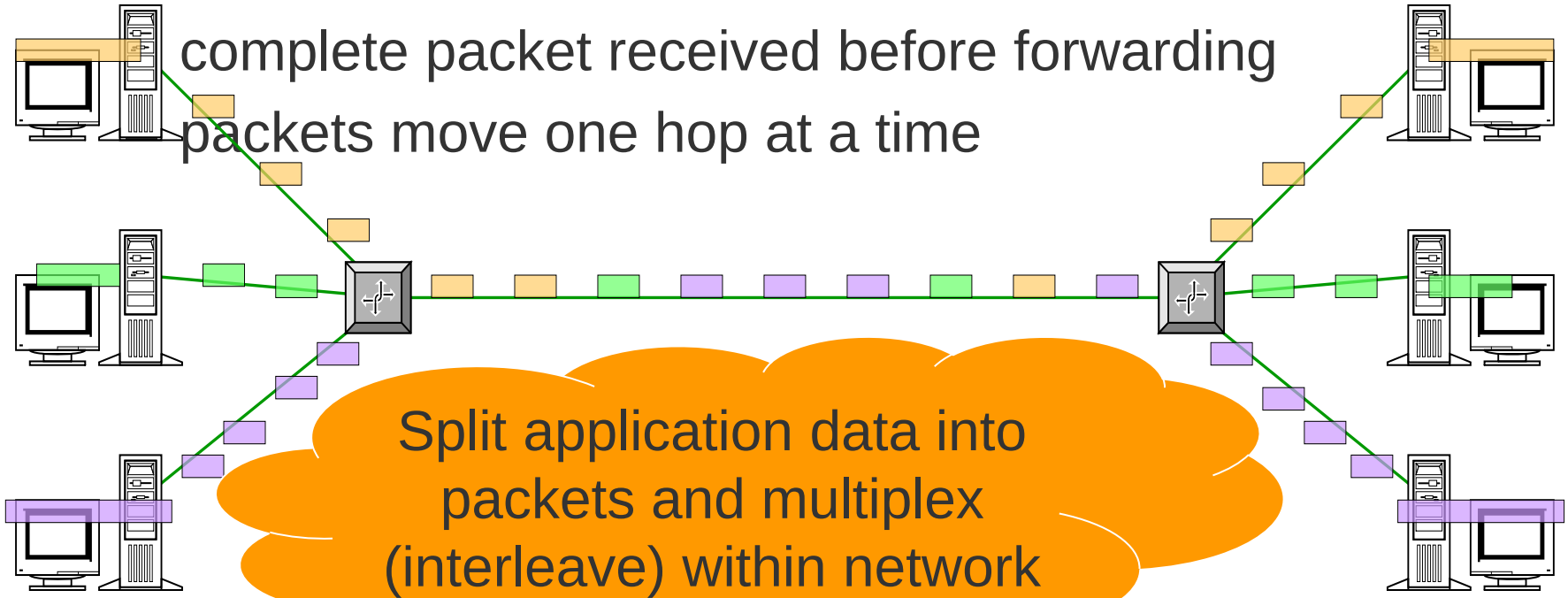
frequency

width = bandwidth

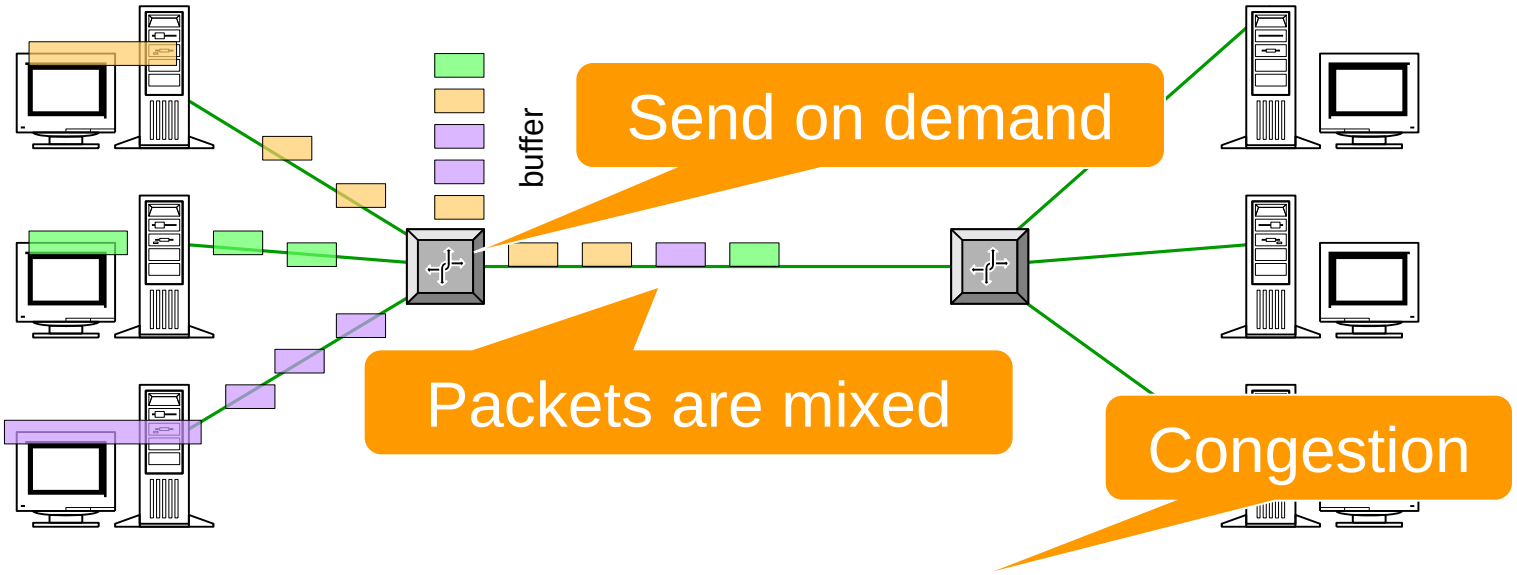
User periodically gets burst of data

Switching: Packet Switching

- Each end-to-end data stream divided into **packets**
- Packets **share** network resources, use as needed
  - each packet uses full link bandwidth
- Store-and-forward:
  - complete packet received before forwarding
  - packets move one hop at a time

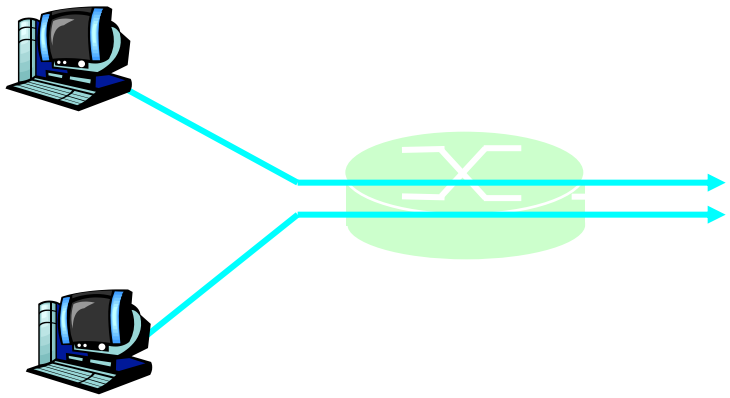


Switching: Statistical Multiplexing



- 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

Switching: Packet versus Circuit



Each user:

100 Kbps when “active”

active 10% of time

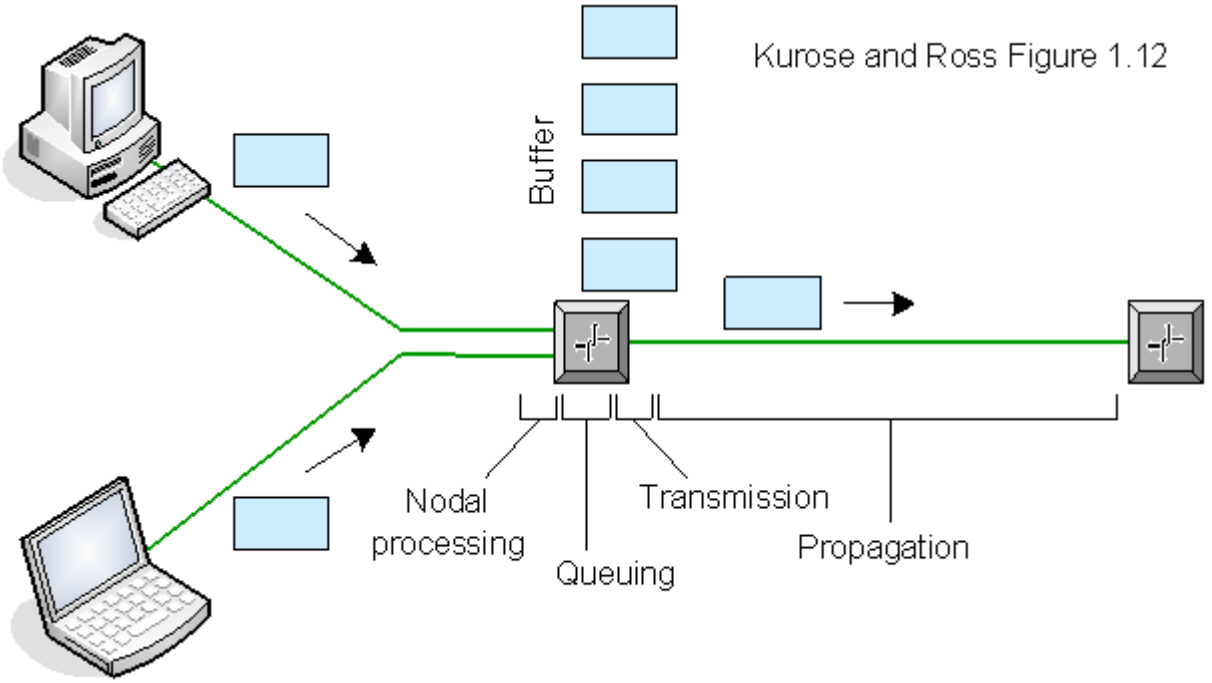
1 Mbps link

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

Delay, Loss and Throughput

- Data does not arrive instantaneously at destination
- Not all data sent arrives!
- Limit to amount of data can send per second



Delays: Transmission and Propagation

- Link has transmission rate: R (in bits per sec, bps)
  - depends on physical medium
  - often referred to as bandwidth of link
- For packet of L bits:
  - transmission delay (d_{trans}) = L/R
- Packets travel (propagate) with speed s (in m/s)
  - depends on physical medium
  - X * c (c = speed of light, ≈ $3x10^8$ m/s), X < 1
- For distance d (in meters):
  - propagation delay (d_{prop}) = d/s

Delays: Transmission vs. Propagation

≈ packet

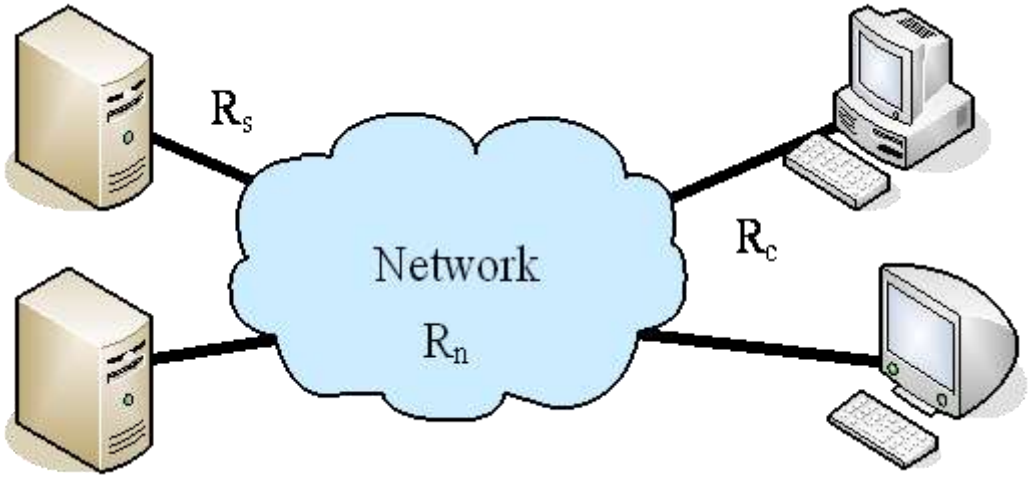
- Cars “propagate” at 100 km/hr
- Booth takes 12 sec to service car (transmission time)
- Q: How long for convoy to get to 2nd booth?
- “push” all cars through booth = 12*10 = 120 sec
- For last car to propagate from 1st to 2nd both:
  - 100km/(100km/hr) = 1 hr
- A: 120 sec + 1hr = 62 minutes

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

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:

- 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
- esult is a packet switched network
- se shared links and statistical multiplexing
- Communication services seen as process-to-process
- Delays and throughput define network performance

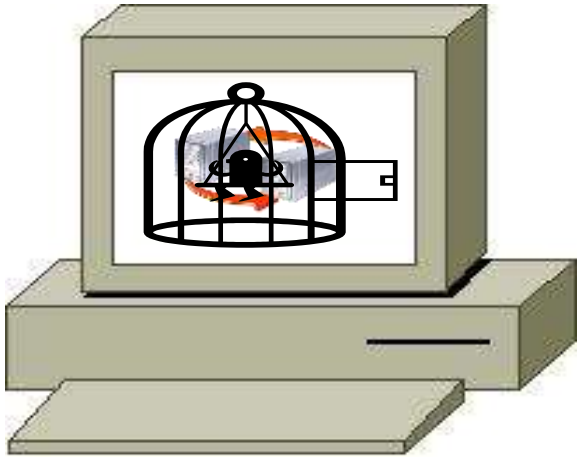
Real aim?

Course Structure

- **Lectures**: 3 per fortnight
  - Tuesdays week A, 9:00-10:00am
  - Thursdays, 3:00-4:00pm
- **Laboratories**: 1 per fortnight, needs preparation
  - week Bs
  - Moodle quiz, experiments in networking
- **Workshops**: 1 per fortnight, no preparation
  - Mondays (1.00pm) or Tuesdays (9.00am) week B
  - Moodle quiz, new material, examinable
- **Self assessment tests**: in your own time
  - Moodle quiz, recap lecture material

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

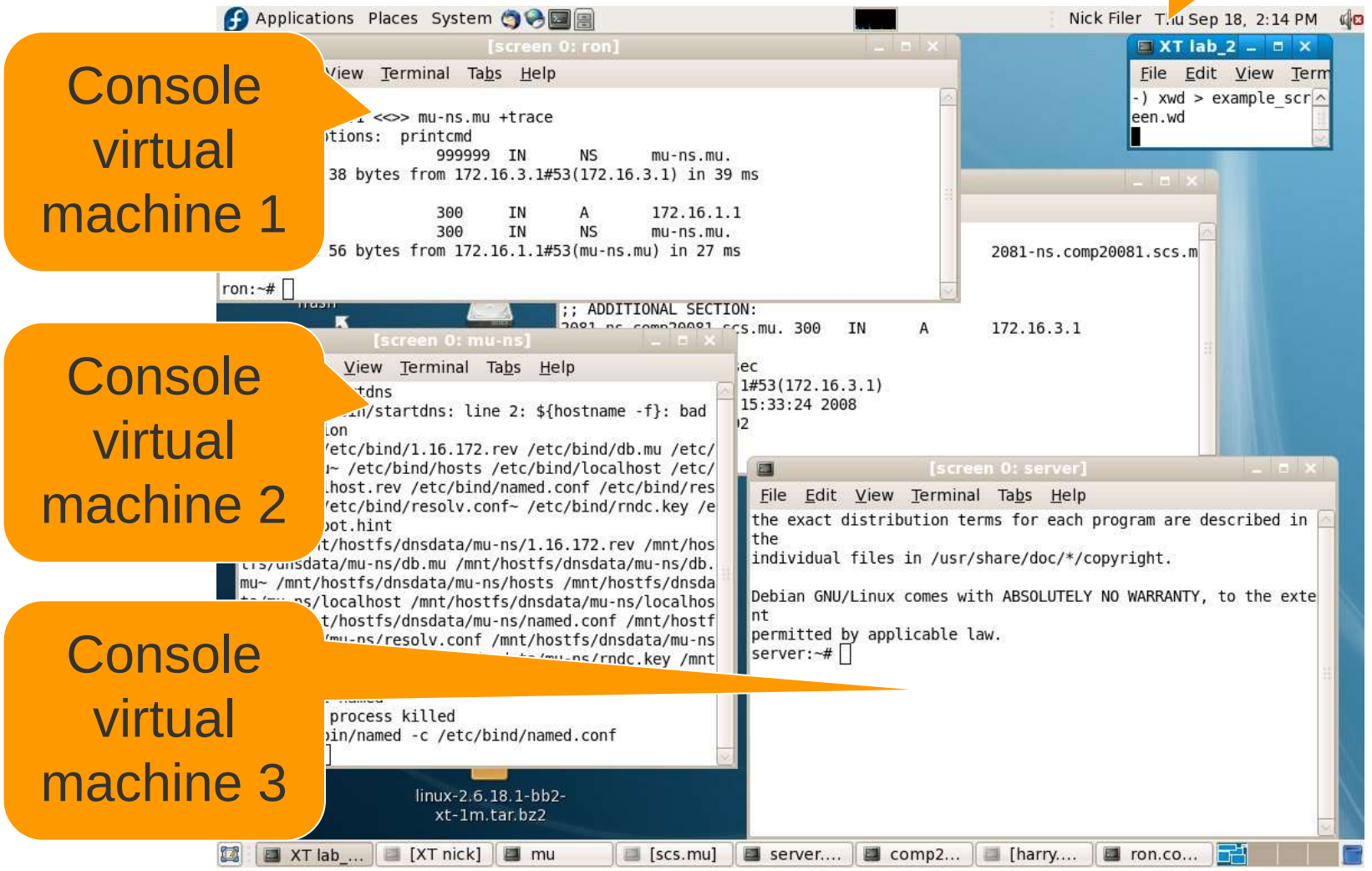


Laboratory: Core Tool (VNUML)

- 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: Example Screen



Laboratory: Deliverables

- Deadline end of your laboratory session
  - extended deadline 11pm on day of laboratory
- Unlike programming laboratories:
  - there is no program to submit and demo
- Instead:
  - configuration files, commands used
  - output from commands, your analysis
- We'll supply a Moodle quiz:
  - fill in the results as you go along
  - submit at end of laboratory session
  - record time when submit performed

Laboratory: Testing To See If It Works

- Virtual machines minimumally configured, available:
  - **ifconfig** shows configuration of network devices
  - **ping** sends “Are you there?” message, response:
    - Unknown Host – no address for given name
    - Network Unreachable – no path to machine
    - statistics – working
    - no output – not working
  - **arp** will show name/address of local machines
  - **netstat** shows statistics about the network
  - **traceroute** path through network (exercise 3…)
  - **dig** for information about names (exercise 4)

Reading

. Kurose & K. Ross, Computer Networking: A Top-Down Approach, 6th Ed, Pearson, ISBN: 0-273-76896-4

- L. Peterson & B. S. Davie, Computer Networks, 5th Ed, Morgan Kaufmann, ISBN:0123850592.

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