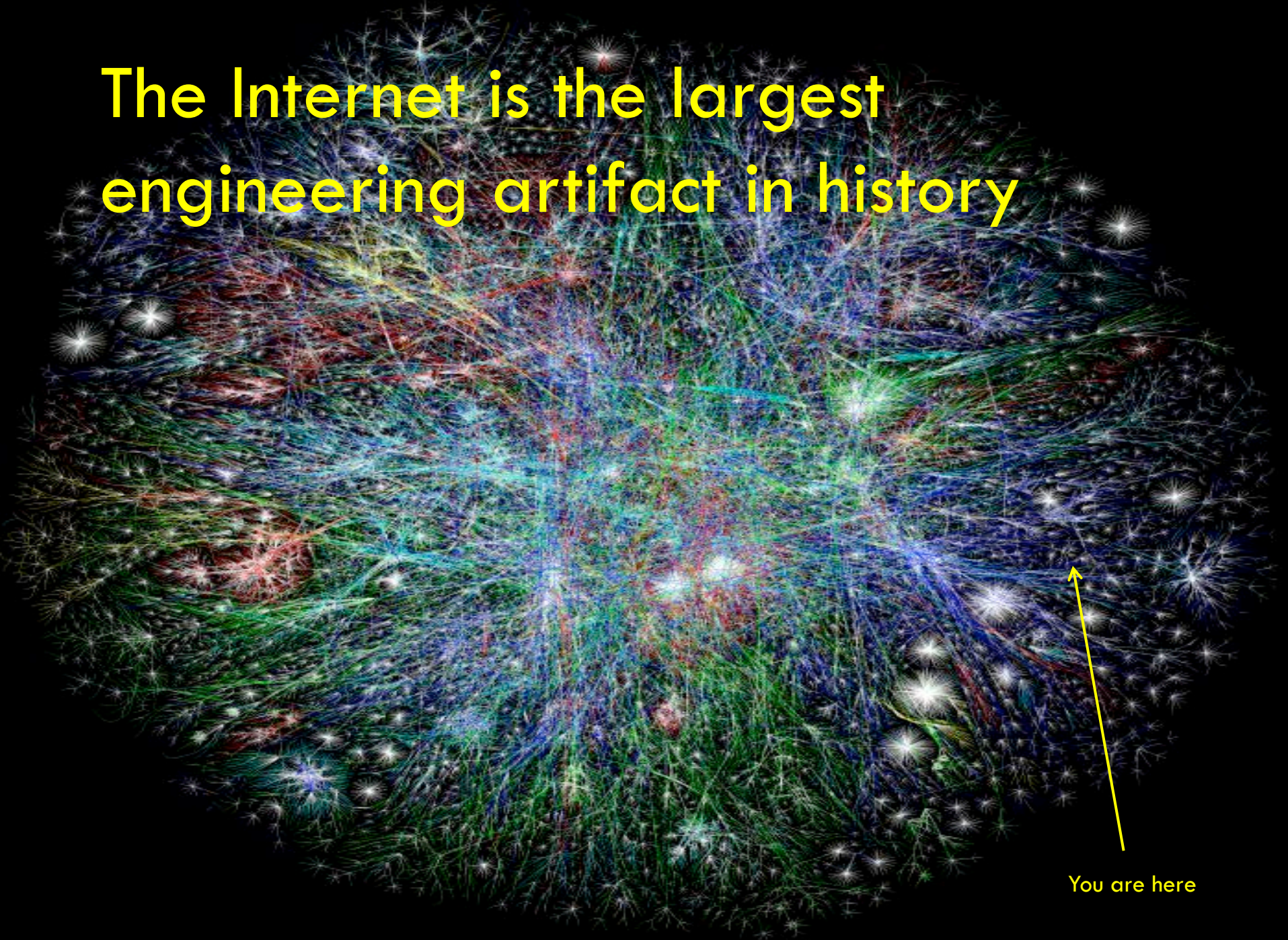


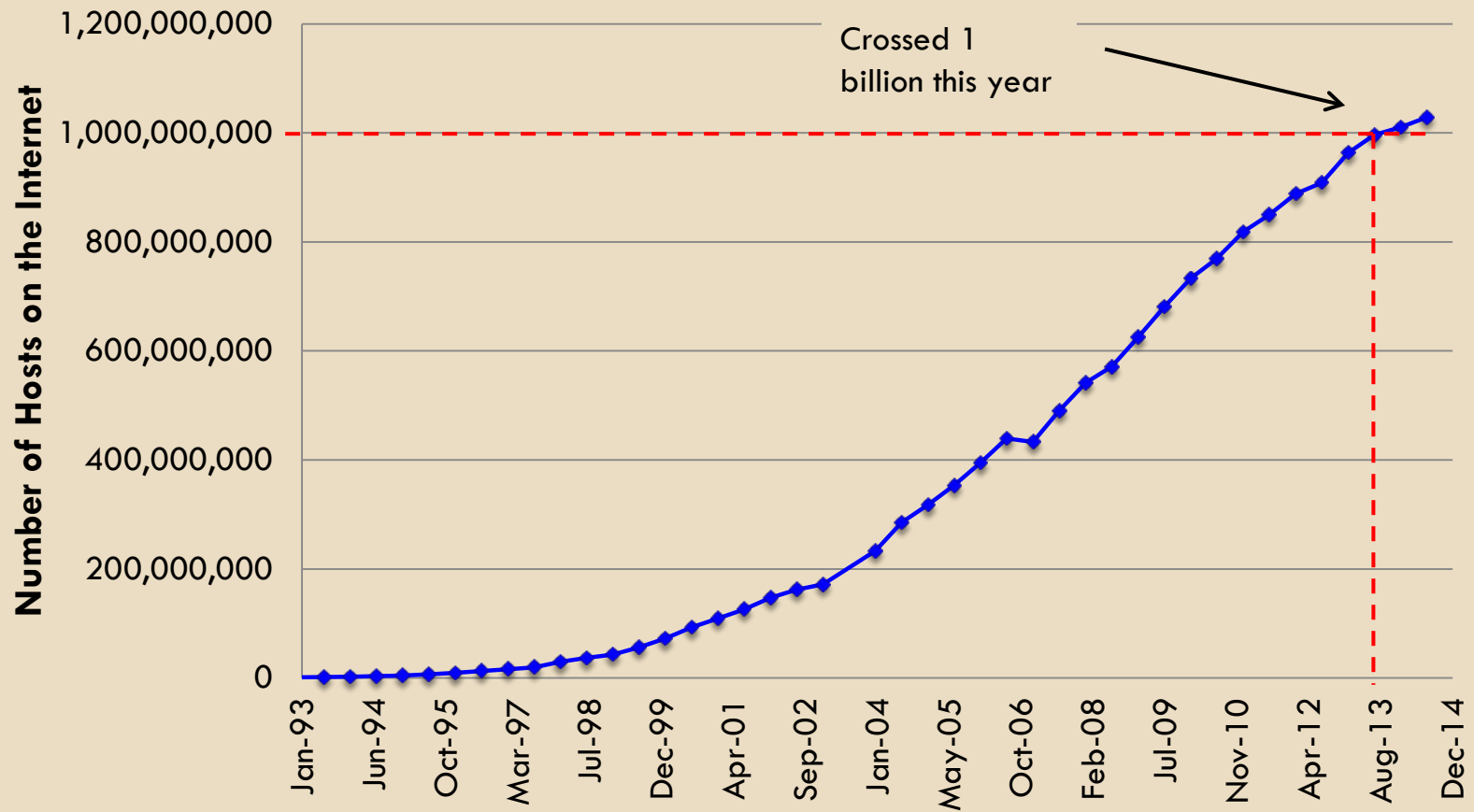
COMPUTER NETWORKS

AREA 5

The Internet is the largest
engineering artifact in history

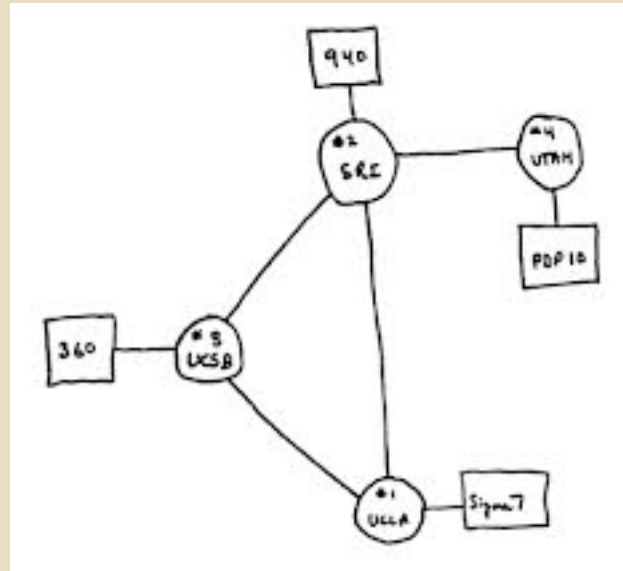


The number of hosts connected to the Internet continues to grow



Source: Internet Software Consortium

The Internet started small



The Internet started with four nodes in 1970 (as the ARPANET)

Evolution of Technology

- Routers are the switching devices of the Internet



1970

Interface Message Processor
Link rate: 50 kbits per seconds

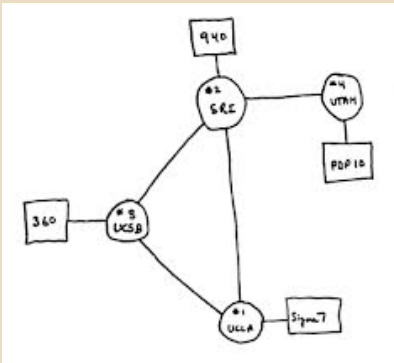


2012

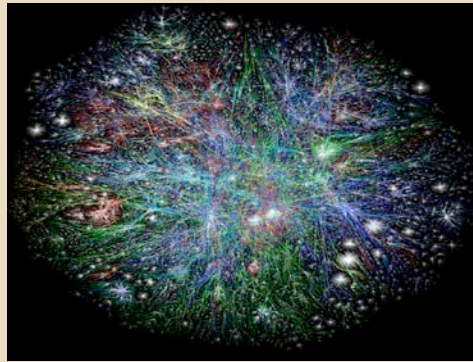
Cisco CSR-3 Router

- up to 1152 interfaces
- up to 322 Terabits per second

Shaping the future



1970



2010



2050

- Will the next 40 years bring as many changes as the previous 40 years?

Trends and Challenges in Computer Networks

- **Internet of Things:** Networks of sensors and devices connected to the Internet

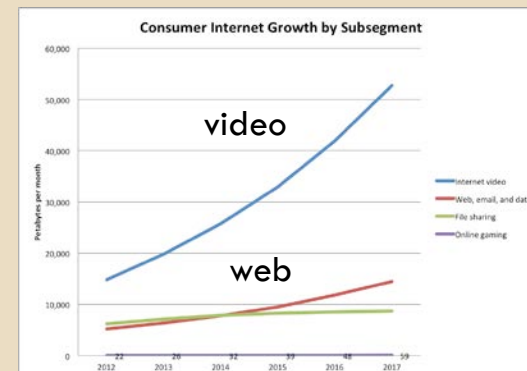
Cisco's Internet Business Solutions Group predicts some 25 billion devices will be connected by 2015, and 50 billion by 2020.



- **Mobility:** 5G networks will providing 1000 times higher wireless capacity compared to 2010.

- **Video:** By 2018, the fast majority (90%) of traffic will be Video

- **New Types of Networks:** Data center networks, software defined networks, Terabit Ethernet, Low latency networks,



Career Opportunities

- **Vendors:** Design and build networking hardware

Examples: Cisco, Huawei, Ericsson, Qualcomm



- **Operators:** Configure a network and keep it running

Examples: Bell, AT&T, British Telecom



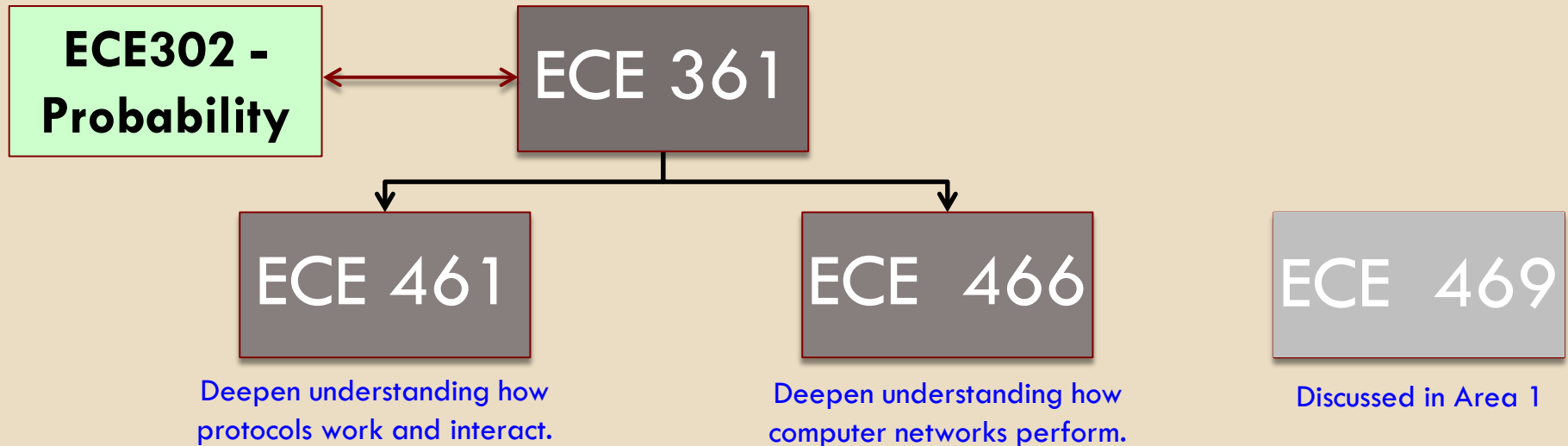
- **Content Providers:** Get data to users; Engineering of data centers and networks

Examples: Google, Facebook, Amazon, Netflix, Microsoft



- **Companies with critical infrastructures:** Financial sector, energy sector, health sector, defence, ...

Computer Networks courses in the ECE Department



- ECE361: Computer Networks (usually in Fall and Winter)
- ECE461: Internetworking (usually in Fall semester)
- ECE466: Computer Networks II (usually in Winter semester)
- ECE469: Optical Communication and Networks

ECE 361: Computer Networks

Main concepts of computer networking

- Web, Email, File Transfer

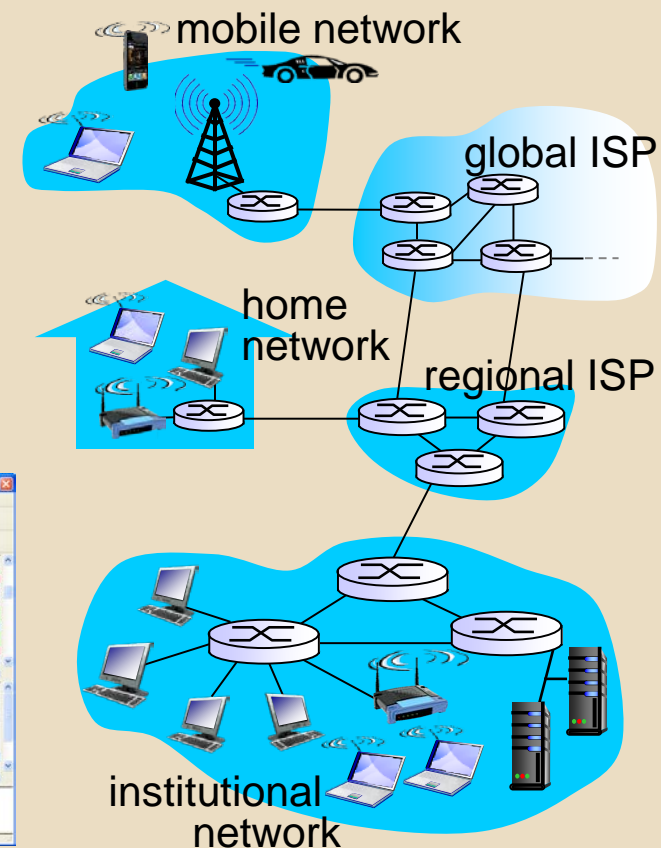
- TCP/UDP

- Internet Protocol

- Routing

- Ethernet and Wi-Fi

- Labs:** Client-server Socket Programming, File Transfer, Actual Traffic Measurement



The screenshot shows the Wireshark interface with a packet capture of network traffic. The packet list on the left shows several packets, with packet 32 selected. The packet details pane on the right shows the structure of the selected packet, including the Ethernet II header, Internet Protocol (IP) header, and Transmission Control Protocol (TCP) header. The packet bytes pane at the bottom shows the raw data of the packet.

| No. | Time | Source | Destination | Protocol | Info |
|-----|----------|-------------|-------------|----------|------------------------------------|
| 31 | 0.000000 | 192.168.0.1 | 192.168.0.2 | TCP | 8080 → 8080 [PSH, ACK] Seq=1 Ack=1 |
| 32 | 0.000019 | 192.168.0.2 | 192.168.0.1 | TCP | 8080 → 8080 [PSH, ACK] Seq=1 Ack=1 |
| 33 | 0.000038 | 192.168.0.1 | 192.168.0.2 | TCP | 8080 → 8080 [PSH, ACK] Seq=1 Ack=1 |
| 34 | 0.000057 | 192.168.0.1 | 192.168.0.2 | TCP | 8080 → 8080 [PSH, ACK] Seq=1 Ack=1 |
| 35 | 0.000076 | 192.168.0.1 | 192.168.0.2 | TCP | 8080 → 8080 [PSH, ACK] Seq=1 Ack=1 |
| 36 | 0.000095 | 192.168.0.1 | 192.168.0.2 | TCP | 8080 → 8080 [PSH, ACK] Seq=1 Ack=1 |
| 37 | 0.000114 | 192.168.0.1 | 192.168.0.2 | TCP | 8080 → 8080 [PSH, ACK] Seq=1 Ack=1 |
| 38 | 0.000133 | 192.168.0.1 | 192.168.0.2 | TCP | 8080 → 8080 [PSH, ACK] Seq=1 Ack=1 |
| 39 | 0.000152 | 192.168.0.1 | 192.168.0.2 | TCP | 8080 → 8080 [PSH, ACK] Seq=1 Ack=1 |
| 40 | 0.000171 | 192.168.0.1 | 192.168.0.2 | TCP | 8080 → 8080 [PSH, ACK] Seq=1 Ack=1 |

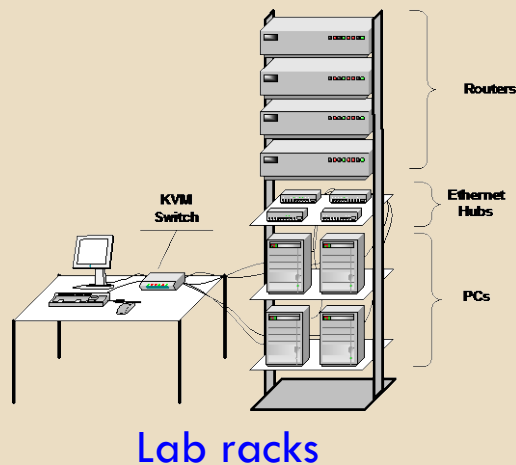
ECE 461: Internetworking

- Prerequisite: ECE 361

- In-depth study of Internet protocols:

Address translation (ARP), IP version 4 and version 6, Router architectures, Configuring routing protocols, TCP congestion control, dynamic assignment of IP addresses (DHCP) and IP address translation (NAT), Domain Name System (DNS)

- **Labs:** Sequence of labs to configure networks and perform network measurements



Working in the lab (SFB 520)

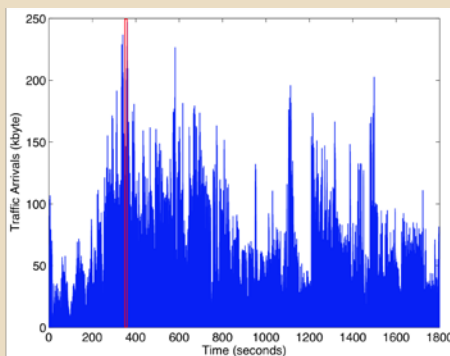
ECE 466: Internetworking

- Prerequisite: ECE 361

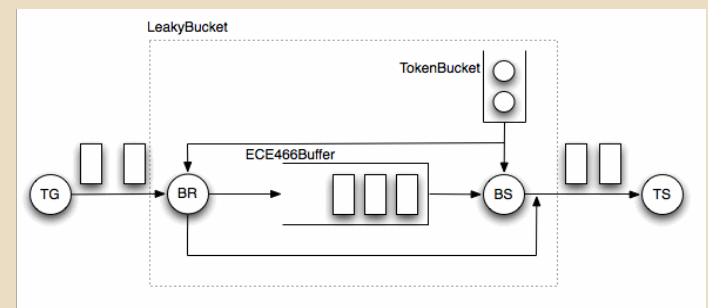
- Analysis of networks

Study of real network traffic, design of traffic shapers, packet scheduling algorithms, statistical multiplexing

- **Programming labs:** Design and evaluation of network components (traffic shaper, packet scheduler, bandwidth estimator)



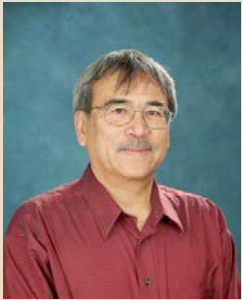
30 minutes of traffic from “Harry Potter”, encoded in H.264



“Token Bucket” traffic shaper
(Lab 2)

Professors

□ Courses in Computer Networks are taught by:



Professor Alberto
Leon-Garcia
alg@ece.utoronto.ca



Professor
Ben Liang
bliang@ece.utoronto.ca



Professor
Jorg Liebeherr
jorg@ece.utoronto.ca



Professor Shahrokh
Valaee
valaee@ece.utoronto.ca



Questions?