50.012 Networks

Lecture 1: Internet Overview

2020 Term 6

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Acknowledgements

- Some course materials based on / refer to the following:
  - Course materials from the reference book (Prof. James Kurose and Prof. Keith Ross)
  - Course materials from previous terms (Prof. Nils Tippenhauer and Dr. Jit Biswas)
  - Course materials from 50.005 CSE (Prof. David Yau and Dr. Natalie Agus)

What you have learnt about network

from 50.005 CSE

- *Sections from Textbook (K&R):*
  1.1 (Internet description, protocol)
  1.3 (packet switching vs. circuit switching)
  1.4 (performance: delay, loss, and throughput)
  1.5 (protocol, layered architecture, encapsulation)
  2.1 (principles of network applications)
  2.2 (Web and HTTP)
  2.4 (DNS)
  2.7 (Socket programming)
  8.1-8.5 (network security basics, securing E-Mail)
- *Tools you may have used:*

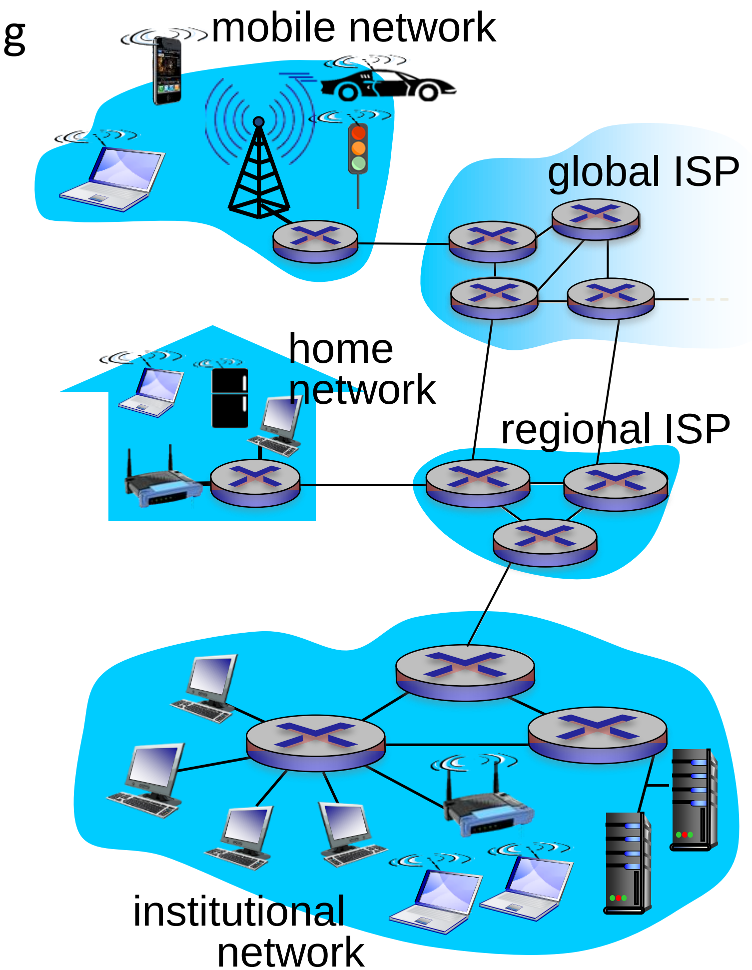
  Traceroute, ping, dig, wireshark, space-time diagram

Review: Internet -- a "nuts and bolts" view

- billions of connected computing devices:
  - *hosts* = *end systems*
  - running *network apps*

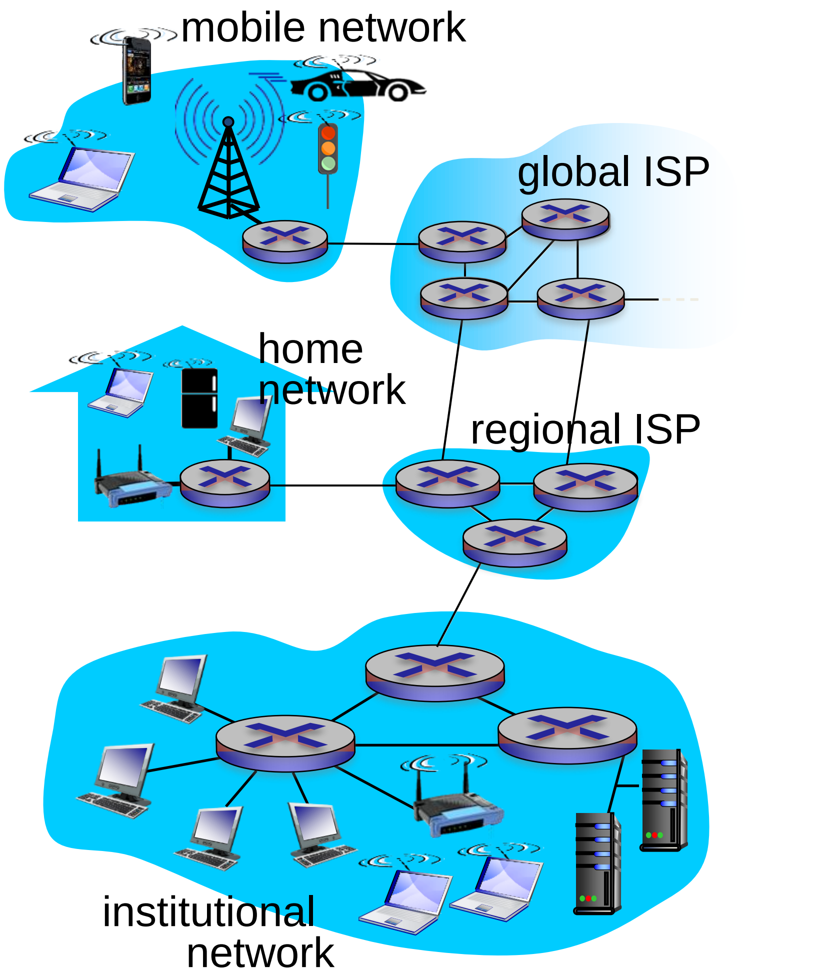
- *communication links*
  - fiber, copper, radio, satellite
  - transmission rate: *bandwidth*

- *packet switches:* forward packets (chunks of data)
  - *routers* and *switches*

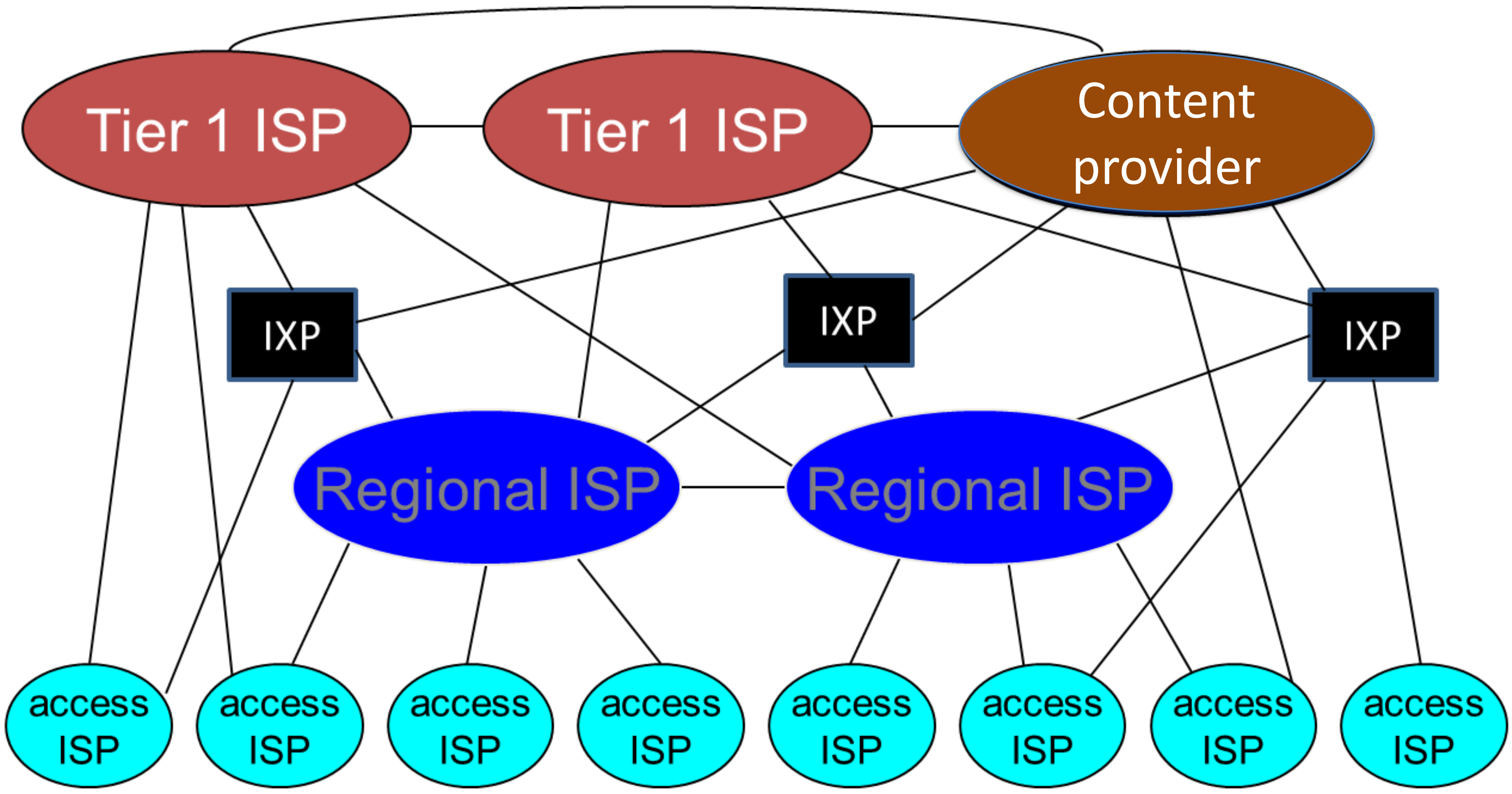


Review: Internet -- a "nuts and bolts" view

- *Internet:* "network of networks"
  - Interconnected ISPs
- *protocols* control sending, receiving of messages
  - e.g., HTTP, TCP, IP, 802.11
- *Internet standards*
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force



Internet structure: network of networks



Internet structure: network of networks

ASRank About Ranking Search Contact Data

AS 55919: neighbors

55919 search

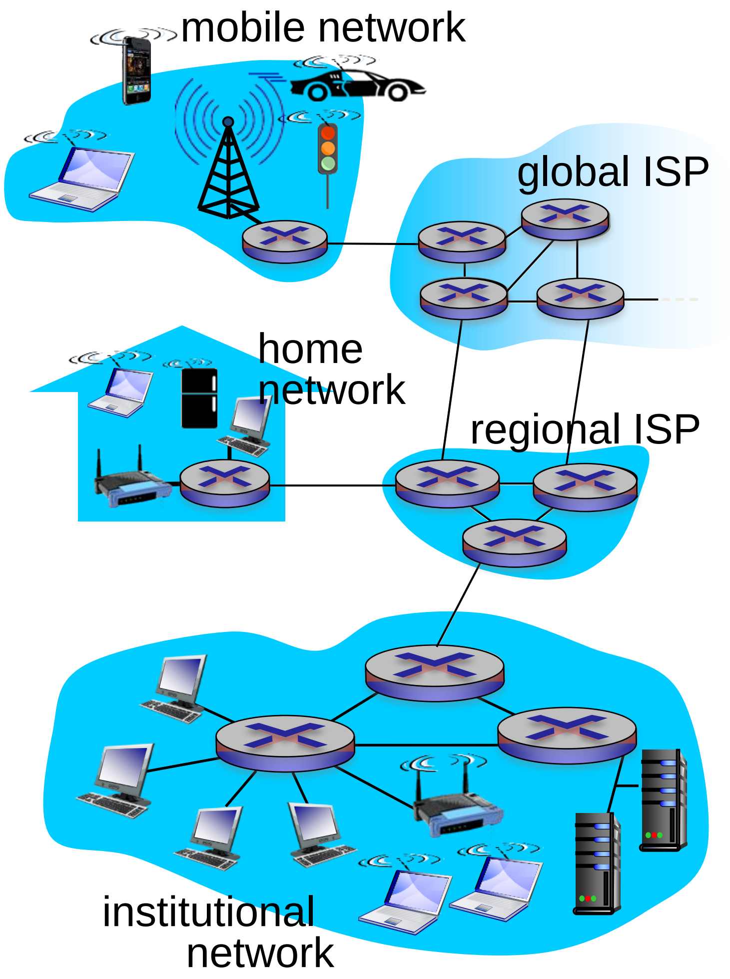
AS number	55919
AS name	SUTD-SG
organization	Singapore University of Technology and Design
country	Singapore
AS rank	48631
customer cone	1 asn, 2 prefix, 512 address
AS degree	2 global, 0 transit, 2 provider, 0 peer, 0 customer

AS Rank ▲	AS neighbors ▽	Organization		AS customer cone ▽	number of paths	relationship
118	4657	Starhub Internet Pte Ltd		365	234	provider
2956	139883	SPTEL PTE. LTD.		8	240	provider

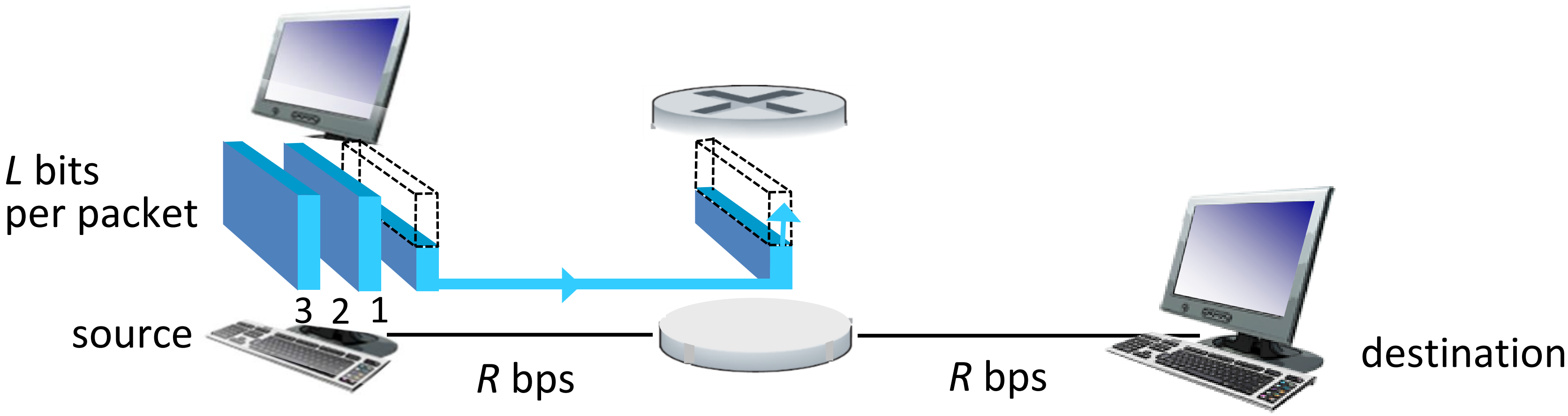
https://asrank.caida.org/asns/55919

Review: Internet -- a service view

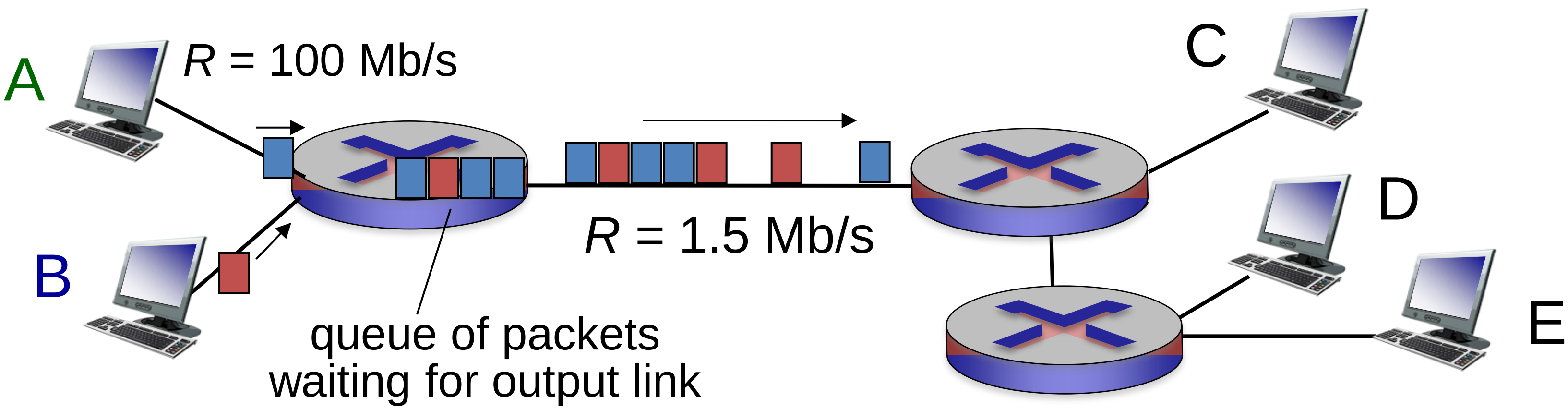
- *infrastructure that provides services to applications:*
  - Web, VoIP, email, games, e-commerce, social nets, …
- *provides programming interface to apps*
  - hooks that allow sending and receiving app programs to "connect" to Internet
  - provides service options, analogous to postal service



Review: Packet-switching



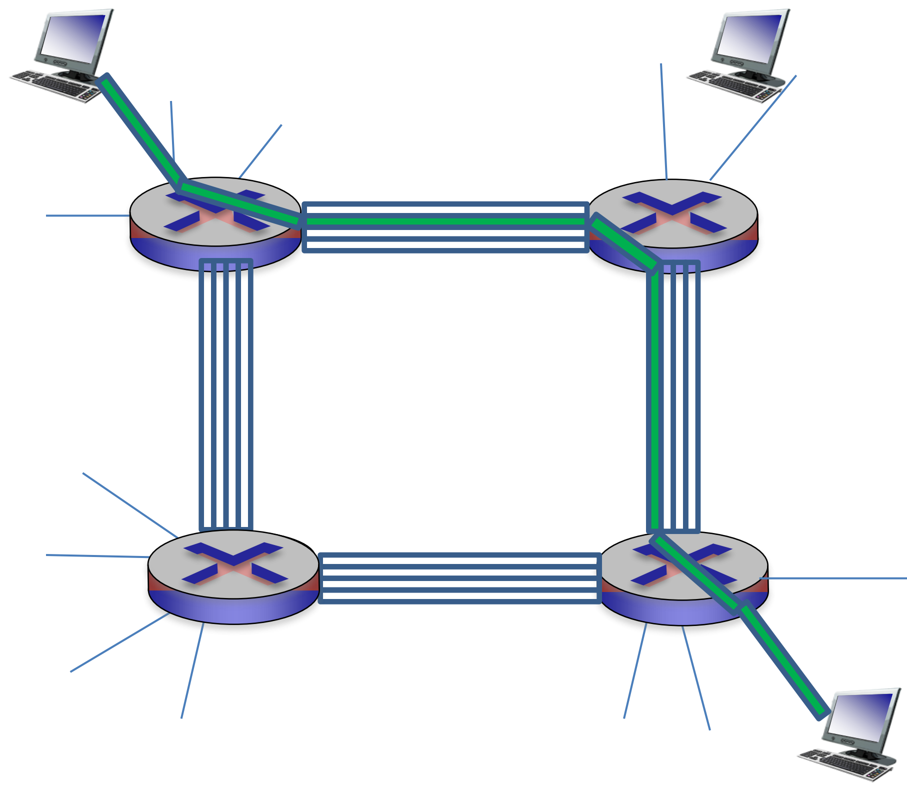
Review: Packet-switching



Alternative design: circuit switching

end-end resources allocated to, reserved for "call" between source & dest:

- in diagram, each link has four circuits.
  - call gets 2nd circuit in top link and 1st circuit in right link.
- dedicated resources: no sharing
  - circuit-like (guaranteed) performance
- circuit segment idle if not used by call *(no sharing)*
- commonly used in traditional telephone networks



In class activity:
Circuit switching vs. packet switching

Consider a number of users sharing a 100 Mbps link. Each user requires 2.5Mbps when transmitting, but transmits only 5 percent of the time (independently).

a) When circuit switching is used, how many users can be supported? What is the average link utilization when the maximum number of users are supported?

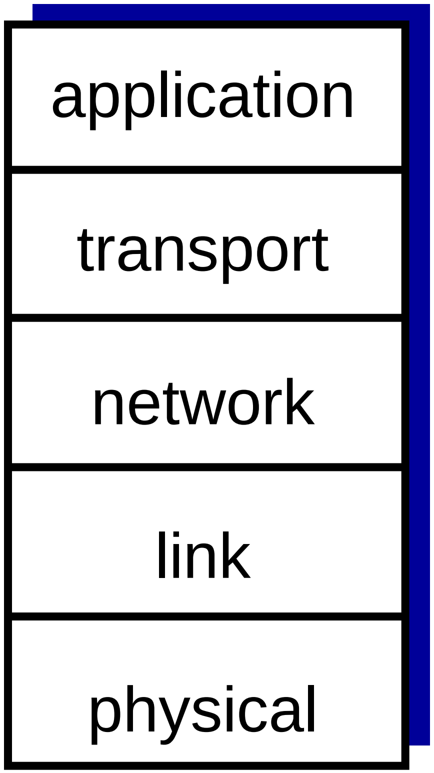
b) For the remainder of this problem, suppose packet switching is used. Suppose there are 500 users in total. Find the probability that at any given time, exactly x users are transmitting. Hint: use BinomialCoefficient(N, i) (or just (N,i) in short) to denote the "N choose i", i.e., the number of ways to choose an (unordered) subset of i items from N items.

c) Find the probability that there are more than 40 users transmitting. Compute your answer using https://homepage.divms.uiowa.edu/~mbognar/applets/bin.html

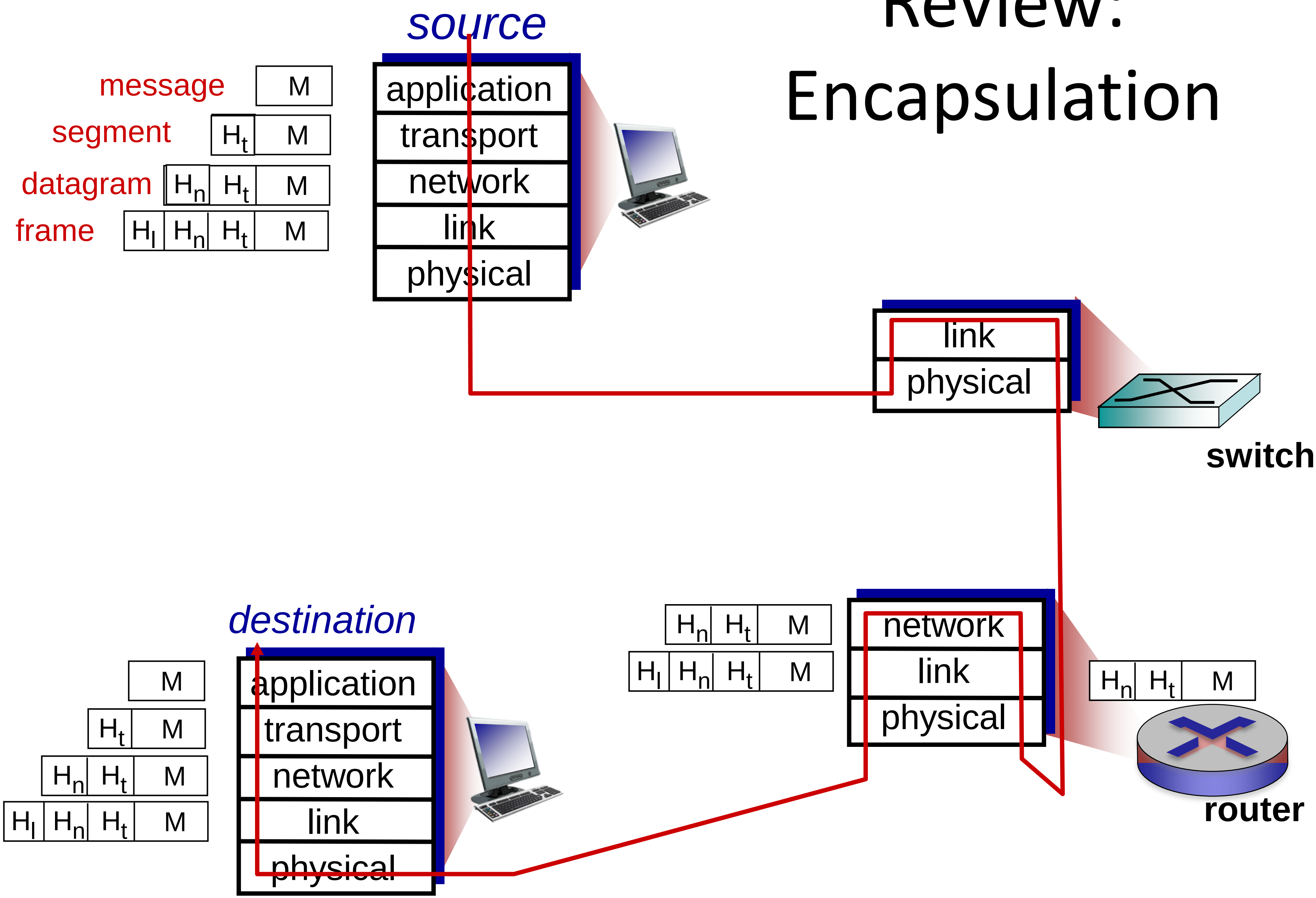
d) Estimate the average link utilization when 500 users are supported by packet switching

Review: Internet protocol stack

- *application:* supporting network applications
  - HTTP (web), SMTP (E-Mail), DNS
- *transport:* process-process data transfer
  - TCP, UDP
- *network:* routing of datagrams from source to destination
  - IP, routing protocols
- *link:* data transfer between neighboring network elements
  - Ethernet, 802.11 (Wi-Fi)
- *physical:* bits "on the wire"

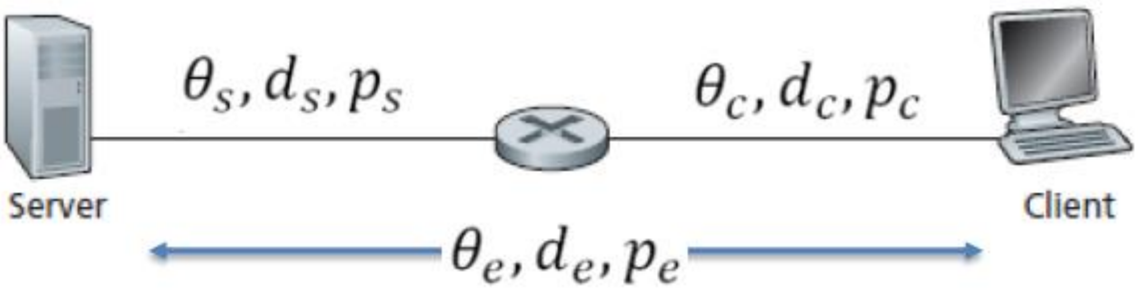


Review: Encapsulation

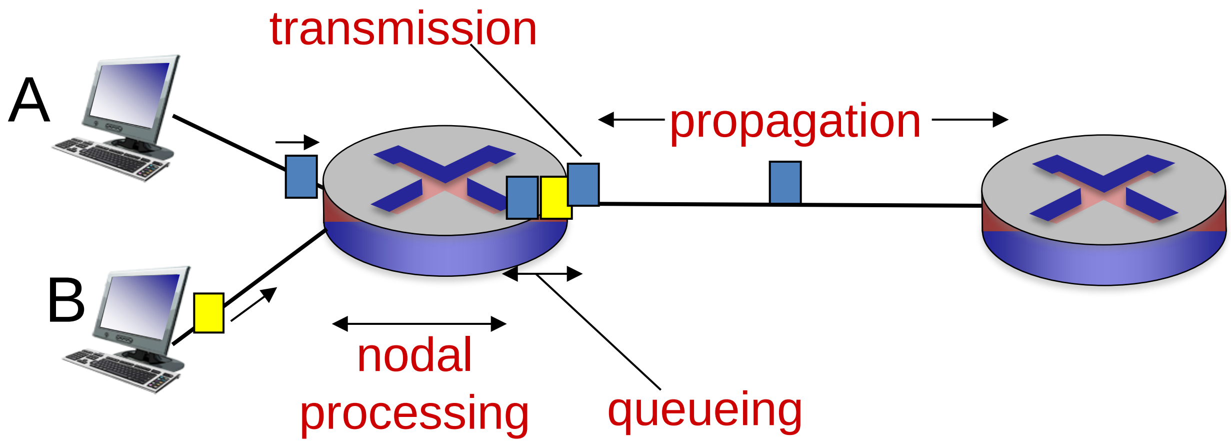


In class activity:
network performance measures

- Consider a server sends packets to a client in the network below. Denote the throughput, delay, and loss probability measured over the first link and over the end-to-end path by θ_s,d_s,p_s, and θ_e,d_e,p_e, respectively. Could you base on those to derive the throughput, delay, and loss probability over the second link (which is denoted as θ_c,d_c,p_c, below)?



Review: Four sources of packet delay



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

d_{trans}: transmission delay:

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

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

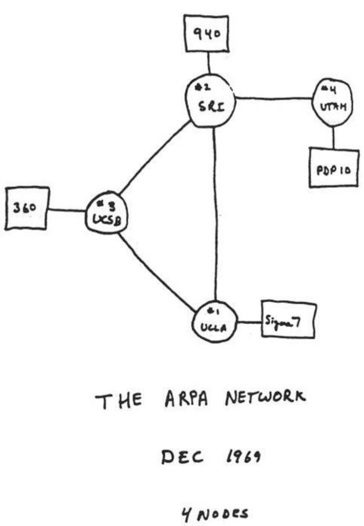
d_{prop}: propagation delay:

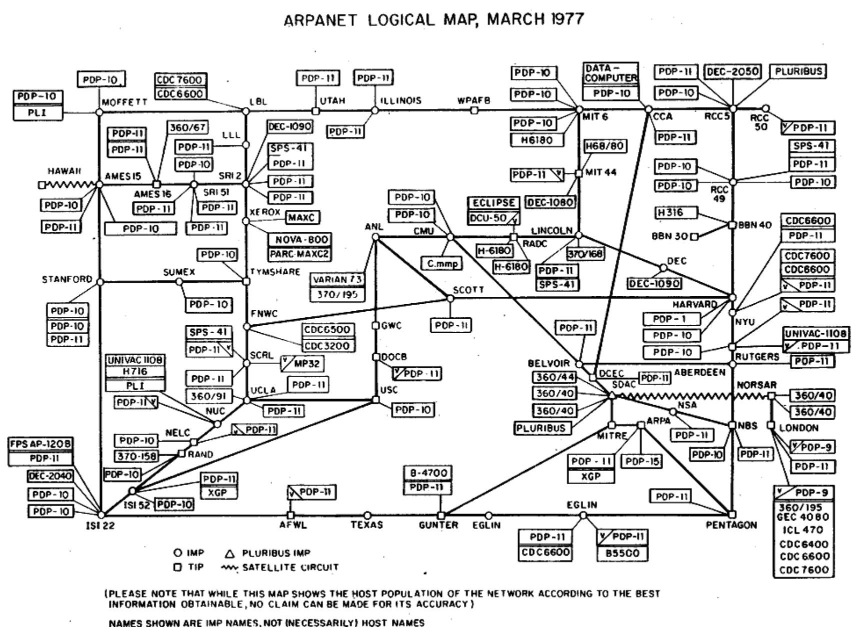
- *len*: length of physical link
- *s*: propagation speed (~$2x10^8$ m/sec)
- $d_{prop} = len/s$

- http://gaia.cs.umass.edu/kurose_ross/interactive/end-end-delay.php
- https://wps.pearsoned.com/ecs_kurose_compnetw_6/216/55463/14198700.cw/index.html

Internet: birth

- Half a century ago, Sep. 1969, the first IMP (Interface Message Processor) was installed and the first host computer was connected to ARPAnet at UCLA (Prof. Leonard Kleinrock's Network Measurement Center). With the second node at Stanford Research Institute (SRI) up, a first host-to-host message was sent “Lo”!



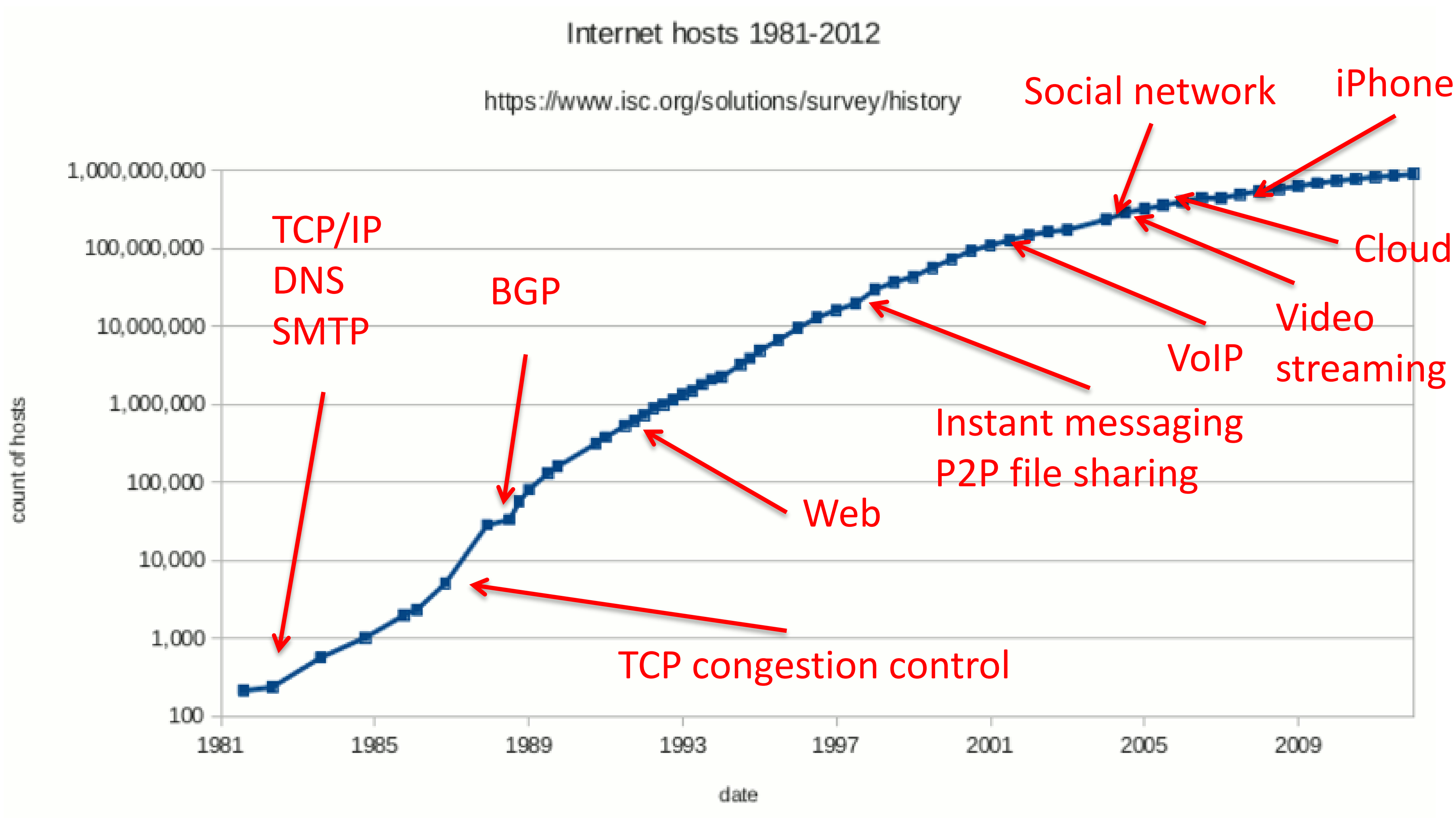


1970: ALOHAnet in Hawaii

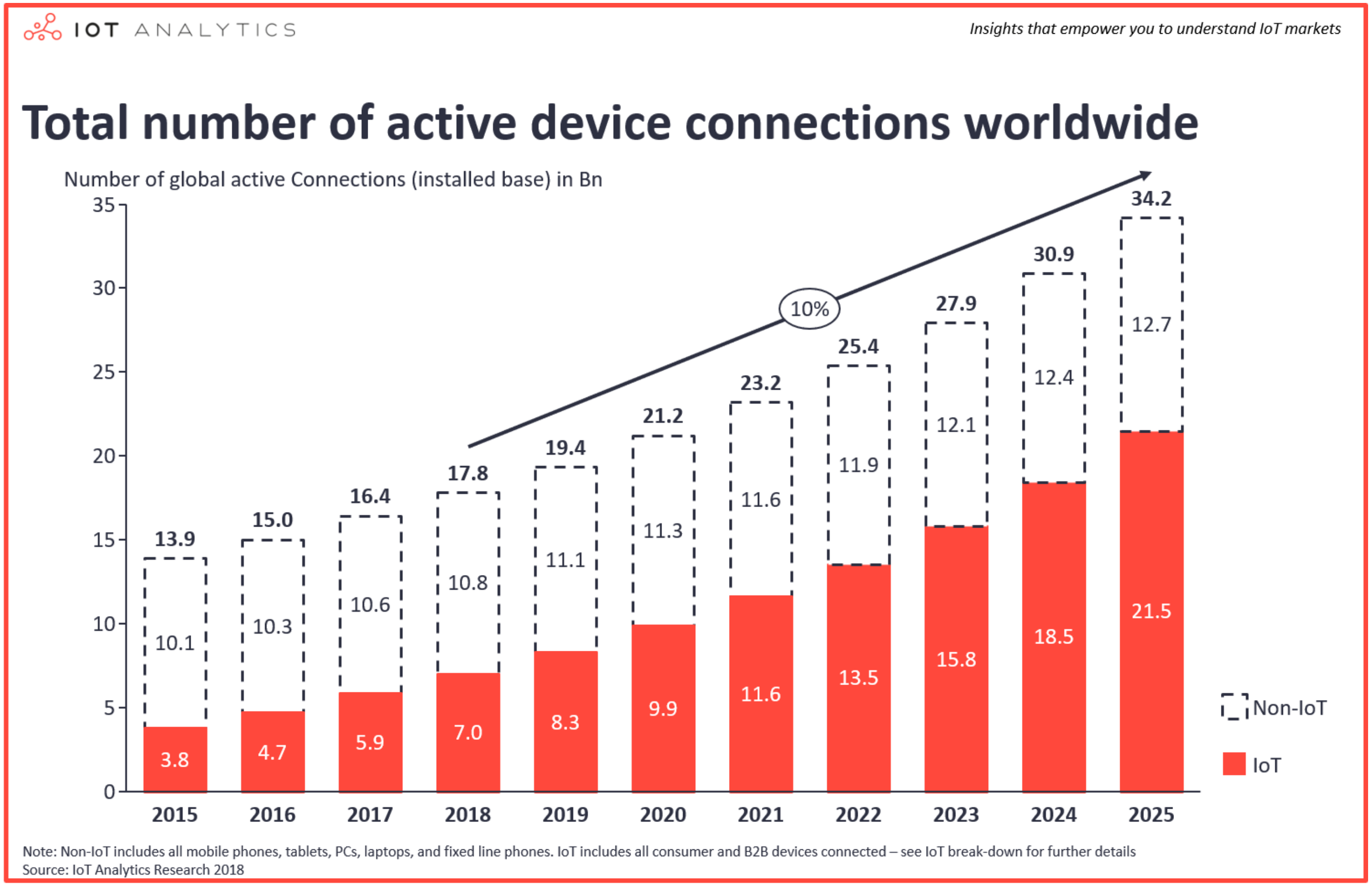
1974: Cerf and Kahn - architecture for interconnecting networks

1976: Ethernet at Xerox PARC

Internet: growth



Internet: some trends



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https://iot-analytics.com/state-of-the-iot-update-q1-q2-2018-number-of-iot-devices-now-7b/

Some pain points faced by Internet today

- Transport: how to support a diverse set of applications / types of networks with very different requirement?
- Routing: easily misconfigured, not reliable enough, not efficient enough, lack-of-control / lack of security assurance for users
- Connect the next billion of users
- Architecture: Internet / protocol ossification
  - Towards openness, programmability, virtualization
- Security: attacks & defence at all layers…
  - 50.020 network security in term 7 will be devoted to this

How this course may benefit you

- Learn how complex networking problems are defined and solved
- Learn from history what worked and what didn't
  - Appreciate the various design tradeoffs made in engineering the Internet
  - To tackle new challenges, it is important to understand the first principles
- Learn to tackle problems that have a distributed nature

Suggested approaches to study networks

- A top-down approach
  - Application is the raison d'être, technology is the enabler
- A problem-driven approach
  - How to share network resources?
  - How to scale up?
  - How to improve performance?
  - How to deal with packet loss?
  - How to avoid & control congestion?
  - How to determine route?
  - ….

Suggested approaches to study network

- Networking technologies evolve fast, but some fundamental issues and solution approaches withstand the test of time
- Focus on guiding principles:
  - Unified network vs. Internet
  - Packet switching vs. circuit switching
  - End-to-end argument

Suggested reading:

- David D. Clark: “The Design Philosophy of the DARPA Internet Protocols”

http://ccr.sigcomm.org/archive/1995/jan95/ccr-9501-clark.pdf

Suggested approaches to study network

- A comparative approach:
  - Moving data: circuit-switch vs. packet-switch
  - Application architecture: client-server vs. P2P
  - Application layer protocols, e.g.:
    - Stateful vs. stateless
  - CDN: enter-deep vs. bring-home
  - Congestion control: end-to-end vs. network-assisted
  - Routing: distributed vs. centralized
  - Multiple access: channel partitioning vs. random access vs. taking-turns

Reading assignment for week 1 & 2

- Chapter 1 and 2 of the textbook [K&R]