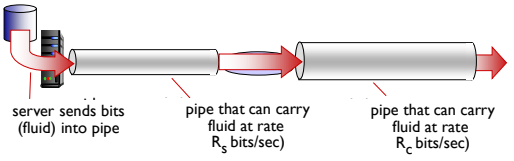
Computer Networks

Notes 4

KOÇ UNIVERSITY

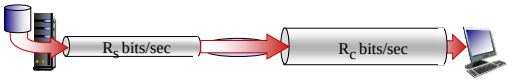
Throughput

- throughput: rate (bits/time unit) at which bits transferred between sender/receiver
  - instantaneous: rate at given point in time
  - average: rate over longer period of time

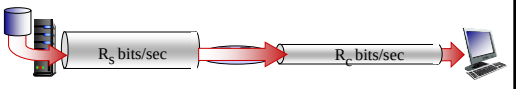


Throughput (more)

- $R_s < R_c$ What is average end-end throughput?



- $Rs > Rc$ What is average end-end throughput?

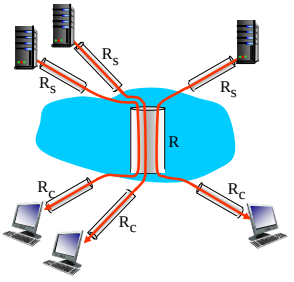


bottleneck link

link on end-end path that constrains end-end throughput

Throughput: Internet scenario

- per-connection end-end throughput: $\min(R_c,R_s,R/10)$
- in practice: R_c or R_s is often bottleneck



10 connections (fairly) share backbone bottleneck link R bits/sec

Protocol "Layers"

Networks are complex!

- many "pieces":
  - hosts
  - routers
  - links of various media
  - applications
  - protocols
  - hardware, software

Question:

- Is there any hope of *organizing* the structure of a network?
- Or at least our discussion of networks?

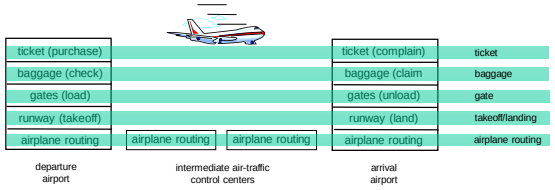
Organization of air travel

ticket (purchase)	ticket (complain)
baggage (check)	baggage (claim)
gates (load)	gates (unload)
runway takeoff	runway landing
airplane routing	airplane routing

airplane routing

as a series of steps

Layering of airline functionality



Layers: each layer implements a service
- via its own internal-layer actions
- relying on services provided by layer below

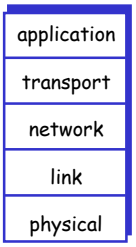
Distributed implementation of layer functionality

Why layering?

Dealing with complex systems:
- explicit structure allows identification of a complex system's pieces and their relations with each other
  - *A layered reference model is useful for discussions*
- modularization eases system maintenance and update
  - changing implementation of a layer's service is transparent to the rest of the system
    - *e.g., a change in the baggage handling procedures doesn't affect the rest of the air travel system..*
- *can layering be considered harmful?*

Internet protocol stack

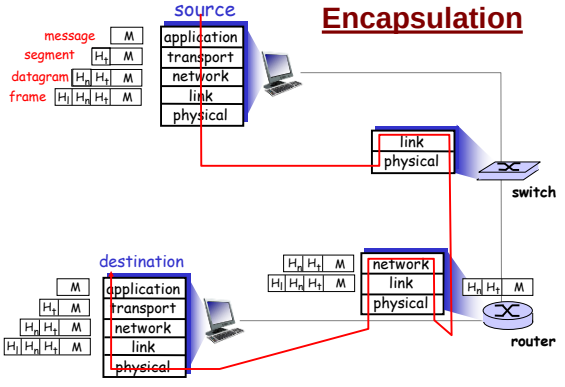
- application: supporting network applications
  - FTP, SMTP, HTTP
- transport: process-process data transfer
  - TCP, UDP
- network: routing of datagrams from source to destination
  - IP, routing protocols
- link: data transfer between neighboring network elements
  - Ethernet, 802.11 (WiFi), PPP
- physical: bits "on the wire"



ISO/OSI reference model

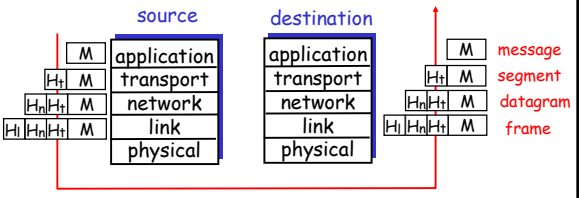
- presentation: allow applications to interpret meaning of data, e.g., encryption, compression, machine-specific conventions
- session: synchronization, checkpointing, recovery of data exchange
- Internet stack "missing" these layers!
  - these services, *if needed,* must be implemented in application
  - needed?

Encapsulation



Protocol layering and data

Each layer takes data from its upper layer
- adds header information to create a new data unit
- passes the new data unit to the layer below



Internet History

1961-1972: Early packet-switching principles

- 1961: Kleinrock - queueing theory shows effectiveness of packet-switching
- 1964: Baran - packet-switching in military nets
- 1967: ARPAnet conceived by Advanced Research Projects Agency
- 1969: first ARPAnet node operational

- 1972:
  - ARPAnet public demonstration
  - NCP (Network Control Protocol) first host-host protocol
  - first e-mail program
  - ARPAnet has 15 nodes

Internet History

1972-1980: Internetworking, new and proprietary nets

- 1970: ALOHAnet satellite network in Hawaii
- 1973: Metcalfe's PhD thesis proposes Ethernet
- 1974: Cerf and Kahn - architecture for interconnecting networks
- late70's: proprietary architectures: DECnet, SNA, XNA
- late 70's: switching fixed length packets (ATM precursor)
- 1979: ARPAnet has 200 nodes

Cerf and Kahn's internetworking principles:

- minimalism, autonomy - no internal changes required to interconnect networks
- best effort service model
- stateless routers
- decentralized control

define today's Internet architecture

Internet History

1980-1990: new protocols, a proliferation of networks

- 1983: deployment of TCP/IP
- 1982: smtp e-mail protocol defined
- 1983: DNS defined for name-to-IP-address translation
- 1985: ftp protocol defined
- 1988: TCP congestion control

- new national networks: Csnet, BITnet, NSFnet, Minitel
- 100,000 hosts connected to confederation of networks

Internet History

1990, 2000's: commercialization, the Web, new apps

- Early 1990's: ARPAnet decommissioned
- 1991: NSF lifts restrictions on commercial use of NSFnet (decommissioned, 1995)
- early 1990s: Web
  - hypertext [Bush 1945, Nelson 1960's]
  - HTML, HTTP: Berners-Lee
  - 1994: Mosaic, later Netscape
  - late 1990's: commercialization of the Web

late 1990's – 2000's:

- more killer apps: instant messaging, P2P applications: BitTorrent (file sharing) Skype (VoIP), PPLive (video)
- network security to forefront
- est. 50 million host, 100 million+ users
- backbone links running at Gbps
- more applications: YouTube, gaming
- wireless, mobility

Internet history

2005-present

- ~750 million hosts
  - Smartphones and tablets
- Aggressive deployment of broadband access
- Increasing ubiquity of high-speed wireless access
- Emergence of online social networks:
  - Facebook: soon one billion users
- Service providers (Google, Microsoft) create their own networks
  - Bypass Internet, providing "instantaneous" access to search, email, etc.
- E-commerce, universities, enterprises running their services in "cloud" (eg, Amazon EC2)

Introduction: Summary

Covered a "ton" of material!

- Internet overview
- what's a protocol?
- network edge, core, access network
  - packet-switching versus circuit-switching
- Internet/ISP structure
- performance: loss, delay, throughput
- Layering and service models
- history

You now have:

- context, overview, "feel" of networking
- more depth and details *to follow!*