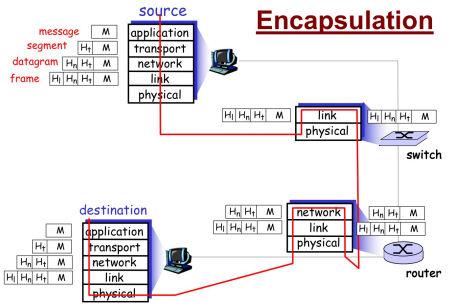
Chapter 2: Application layer

- 2.1 Principles of network applications
- 2.2 Web and HTTP
- 2.3 FTP
- 2.4 Electronic Mail
  - SMTP, POP3, IMAP
- 2.5 DNS
- 2.6 P2P file sharing
- 2.7 Socket programming with TCP
- 2.8 Socket programming with UDP
- 2.9 Building a Web server



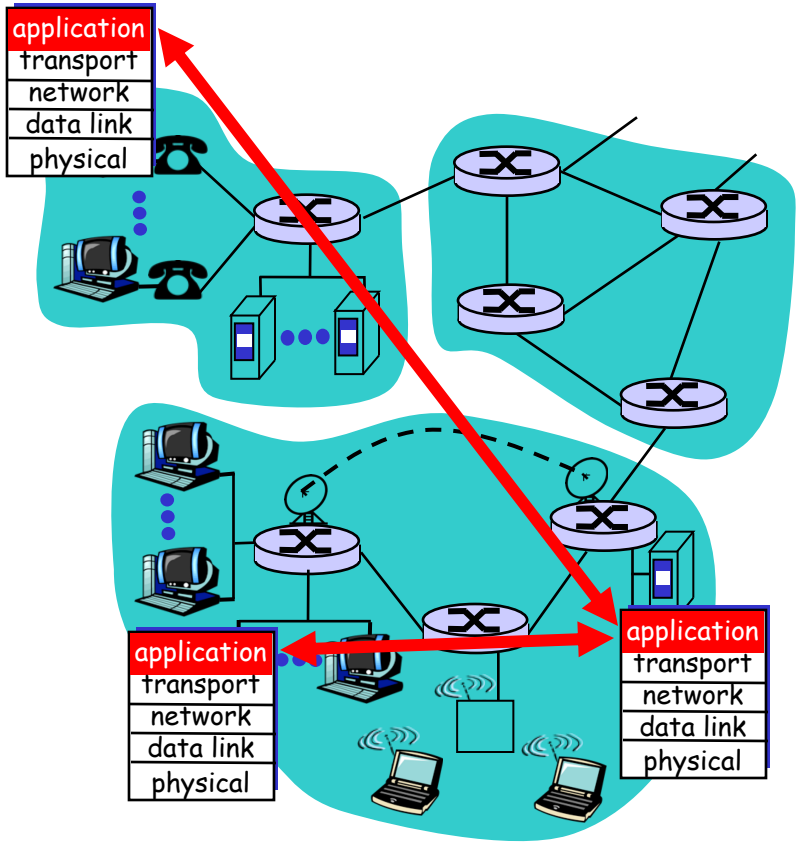
Creating a network app

Write programs that

- run on different end systems and
- communicate over a network.
- e.g., Web: Web server software communicates with browser software

little software written for devices in network core

- network core devices do not run user application code
- application on end systems allows for rapid app development, propagation



Some network apps

- E-mail
- Web
- Instant messaging
- Remote login
- P2P file sharing
- Multi-user network games
- Streaming stored video clips
- Internet telephone
- Real-time video conference
- Massive parallel computing
-
-
-

Edge Computing

Next generation: The network will be the computer. Most Applications will run over the network. Local PC minimaly required
Example: Google spread sheet

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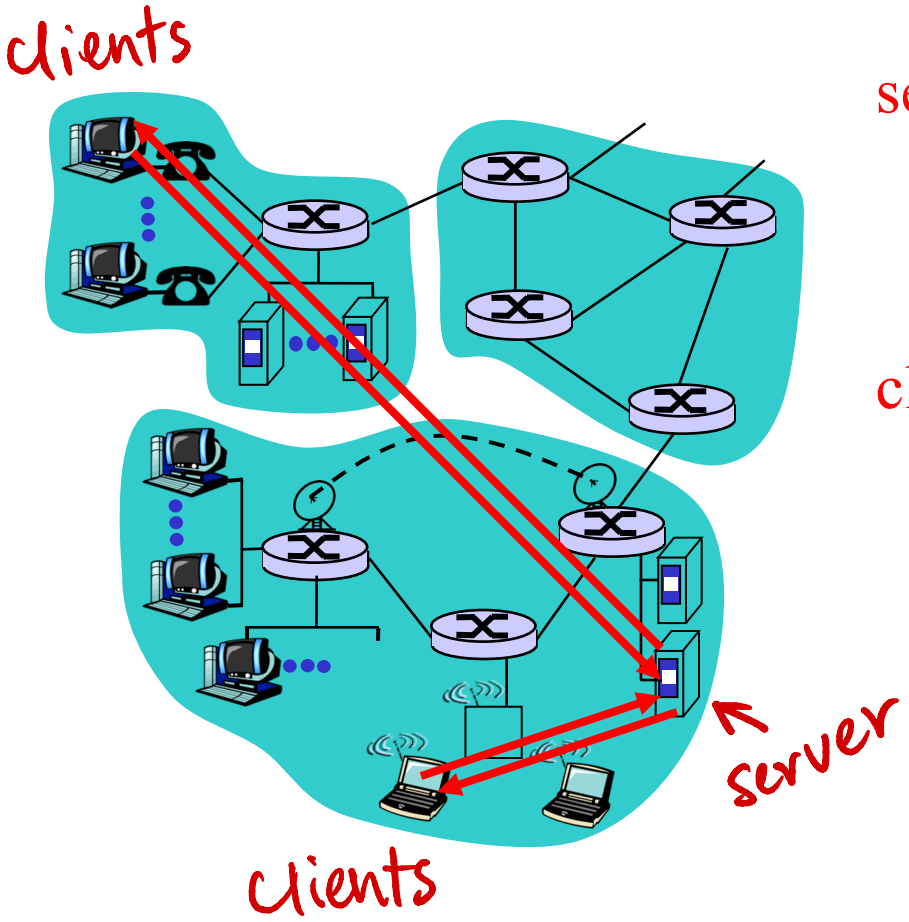
Application architectures

- Client-server
- Peer-to-peer (P2P)
- Hybrid of client-server and P2P

Client-server architecture



server:

- always-on host
- permanent IP address
- server farms for scaling

clients:

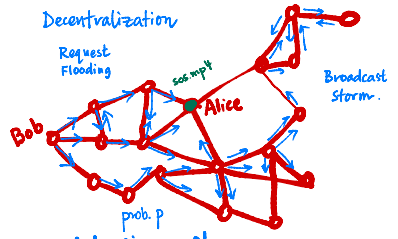
- communicate with server on demand
- may be intermittently connected
- may have dynamic IP addresses
- do not communicate directly with each other

Romit → sos.mp4, Hc.mp4, Vm.mp4 ....
<IP address>

1. Leader Election
→ Store index

Pure P2P architecture

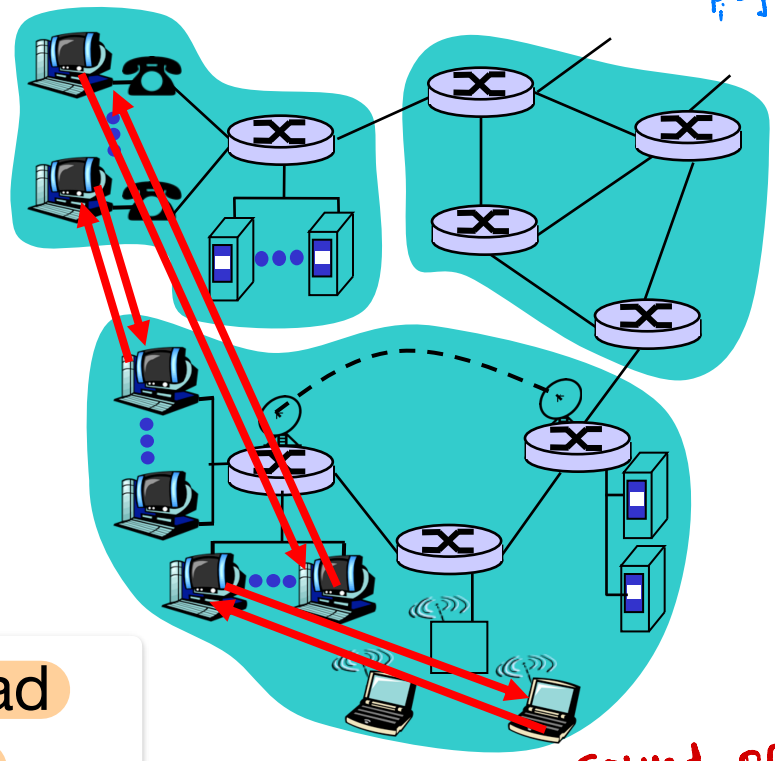
2. Gossip



$p_i = f(\#\text{ of neighbors of that node } i)$

- no always-on server
- arbitrary end systems directly communicate
- peers are intermittently connected and change IP addresses
- example: Gnutella

hotel_california.mp4



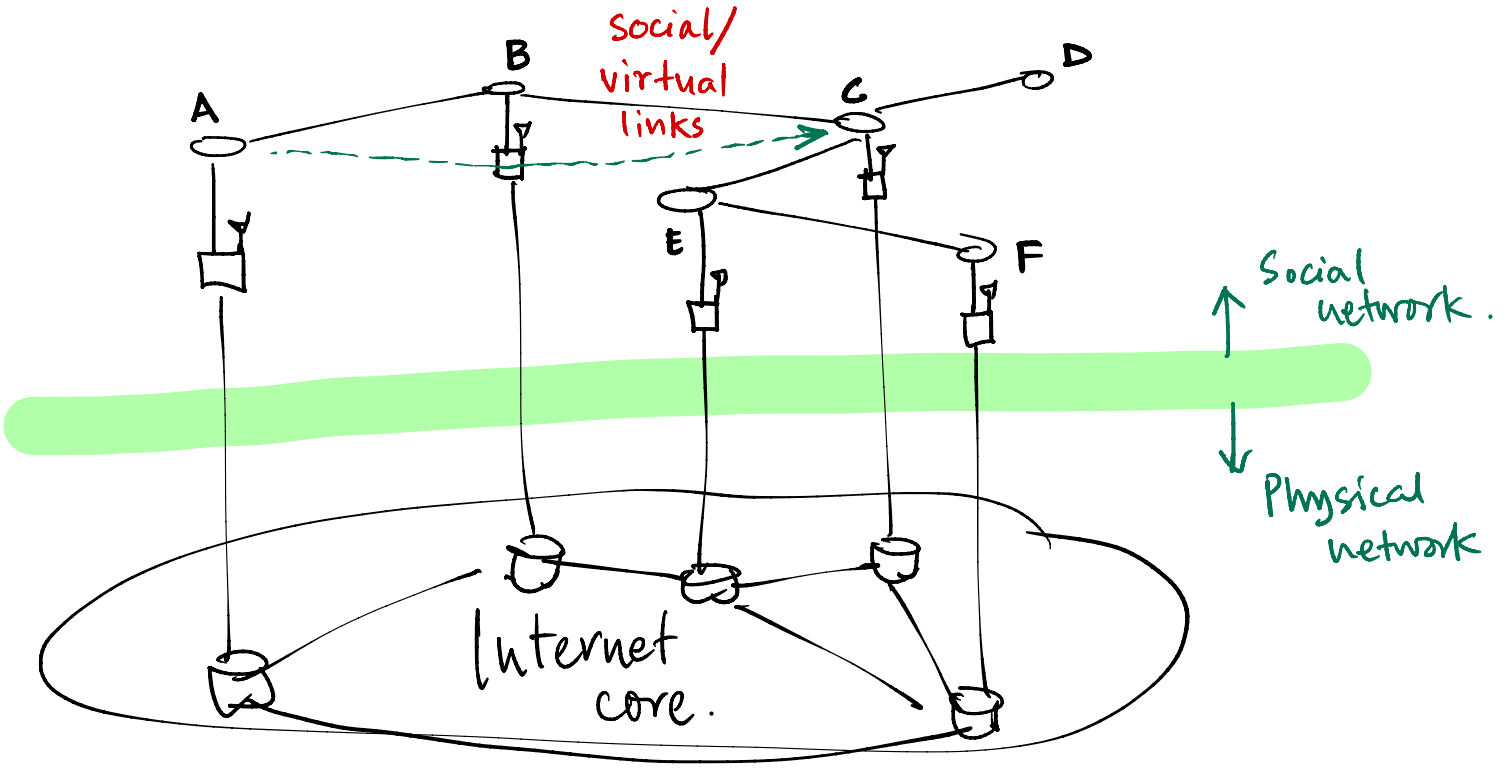
3. Replication
Share union of content w/ everyone.
- Huge network traffic
- New mp4 has to be propagated

sound_of_silence.mp4

How will you search and download songs over a pure P2P network?

4. Distributed hash tables.

Social networks, Overlay networks, Topology, Graph



Hybrid of client-server and P2P

Skype

- Internet telephony app
- Finding address of remote party: centralized server(s)
- Client-client connection is direct (not through server)

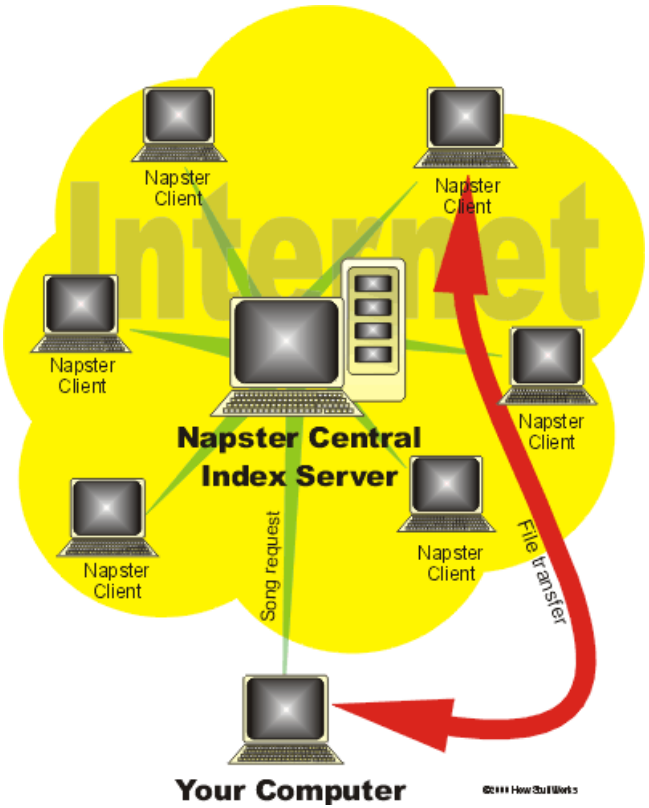
Instant messaging

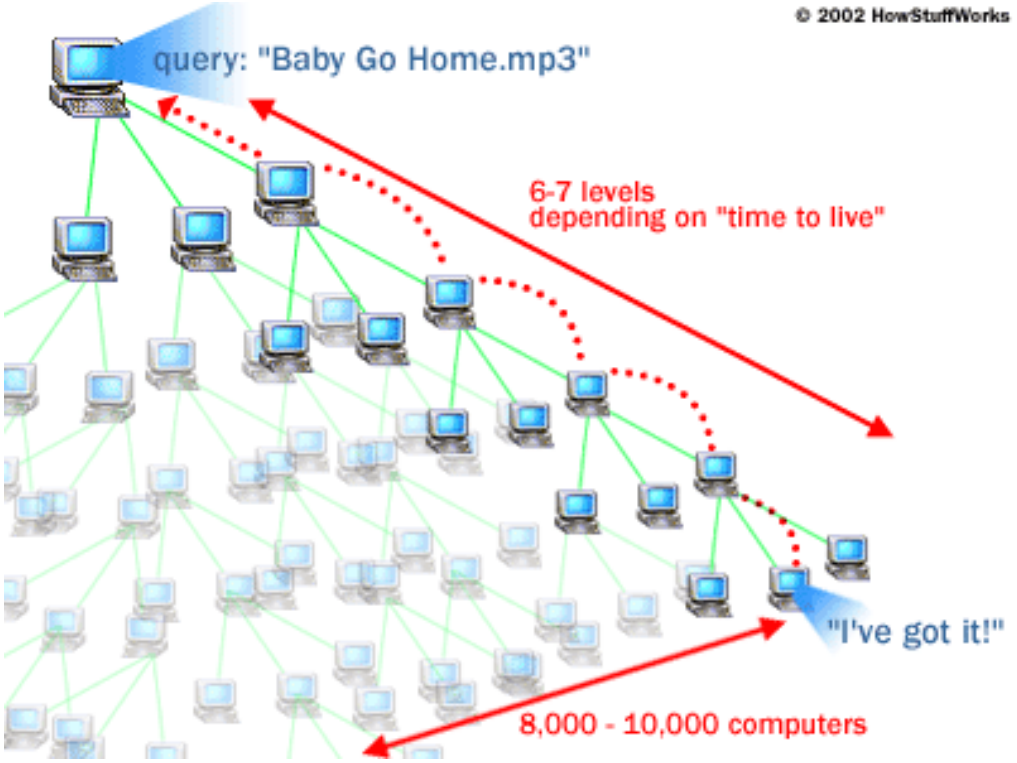
- Chatting between two users is P2P
- Presence detection/location centralized:
  - User registers its IP address with central server when it comes online
  - User contacts central server to find IP addresses of buddies

Case Study: Napster Vs Gnutella

Hybrid

Pure



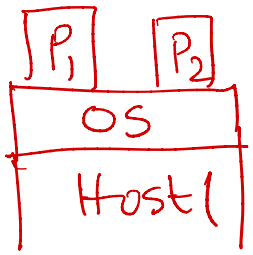


Any problem with this architecture?

Processes communicating

Process: program running within a host.

- within same host, two processes communicate using inter-process communication (defined by OS).

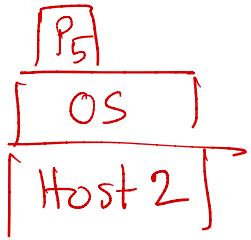


- processes in different hosts communicate by exchanging messages

Client process: process that initiates communication

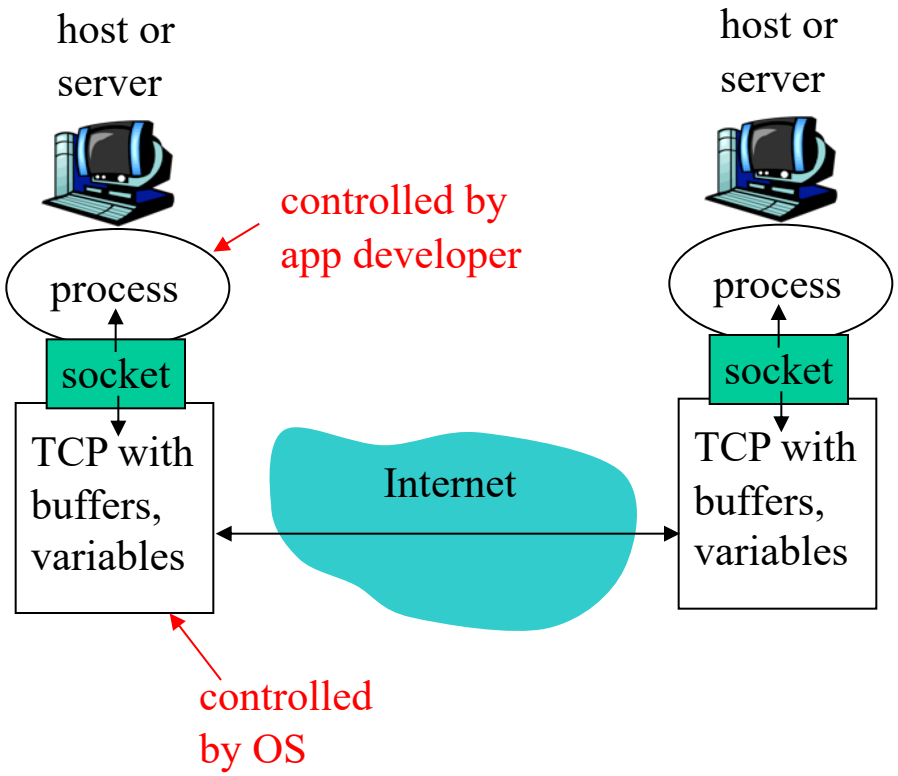
Server process: process that waits to be contacted

- Note: applications with P2P architectures have client processes & server processes



Sockets

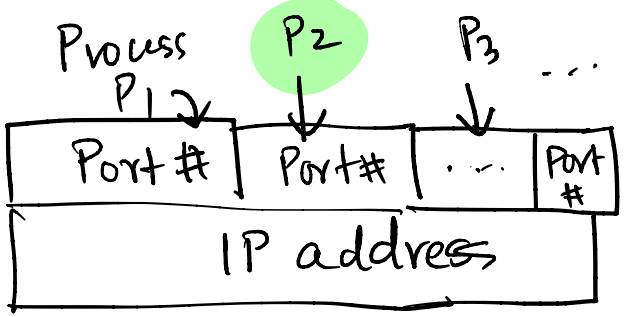
- process sends/receives messages to/from its socket
- socket analogous to door
  - sending process shoves message out door
  - sending process relies on transport infrastructure on other side of door which brings message to socket at receiving process



- API: (1) choice of transport protocol; (2) ability to fix a few parameters (lots more on this later)

Addressing processes

- to receive messages, process must have *identifier*
- host device has unique32-bit IP address
- Q: does IP address of host on which process runs suffice for identifying the process?



Addressing processes

- to receive messages, process must have *identifier*
- host device has unique32-bit IP address
- Q: does IP address of host on which process runs suffice for identifying the process?
  - Answer: NO, many processes can be running on same host

Client Process

- *identifier* includes both IP address and port numbers associated with process on host.
- Example port numbers:
  - HTTP server: 80
  - Mail server: 25
- to send HTTP message to gaia.cs.umass.edu web server:
  - IP address: 128.119.245.12
  - Port number: 80
- more shortly…

Message Format:

App-layer protocol defines

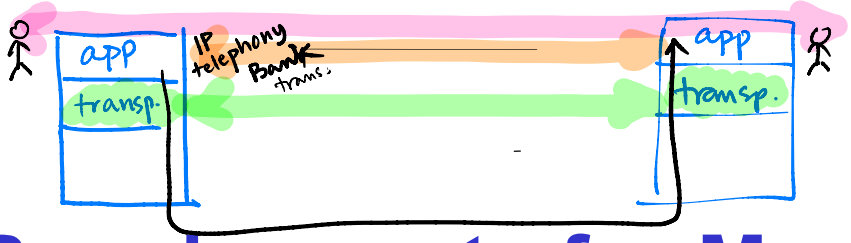
- Types of messages exchanged,
  - e.g., request, response
- Message syntax:
  - what fields in messages & how fields are delineated
- Message semantics
  - meaning of information in fields
- Rules for when and how processes send & respond to messages

Public-domain protocols:

- defined in RFCs
- allows for interoperability
- e.g., HTTP, SMTP

Proprietary protocols:

- e.g., KaZaA



Requirements for Message Transport:

Data loss

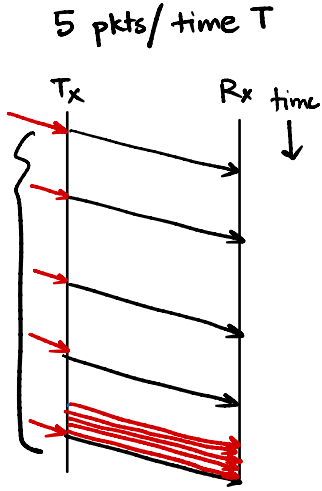
- some apps (e.g., audio) can tolerate some loss
- other apps (e.g., file transfer, telnet) require 100% reliable data transfer

Timing

Buffered or not

- some apps (e.g., Internet telephony, interactive games) require low delay to be "effective"

Bandwidth



- some apps (e.g., multimedia) require minimum amount of bandwidth to be "effective"
- other apps ("elastic apps") make use of whatever bandwidth they get

bitrate / throughput

Why is ~~bandwidth~~ different from timing constraints?

Transport service requirements of common apps

Application	Data loss	Bandwidth (Bitrate)	Time Sensitive
file transfer	no loss	elastic	no
e-mail	no loss	elastic	no
Web documents	no loss	elastic	no
real-time audio/video	loss-tolerant	audio: 5kbps-1Mbps video:10kbps-5Mbps	yes, 100's msec
stored audio/video (Netflix)	loss-tolerant	same as above	yes, few secs
interactive games	loss-tolerant	few kbps up	yes, 100's msec
instant messaging	no loss	elastic	yes and no

Internet transport protocols services

Reliable

TCP service:

- *connection-oriented:* setup required between client and server processes
- *reliable transport* between sending and receiving process
- *flow control:* sender won't overwhelm receiver
- *congestion control:* throttle sender when network overloaded
- *does not provide:* timing, minimum bandwidth guarantees

Best effort / unreliable

UDP service:

- unreliable data transfer between sending and receiving process
- does not provide: connection setup, reliability, flow control, congestion control, timing, or bandwidth guarantee

Q: why bother? Why is there a UDP?

Internet apps: application, transport protocols

Application	Application layer protocol	Underlying transport protocol
e-mail	SMTP [RFC 2821]	TCP
remote terminal access	Telnet [RFC 854]	TCP
Web	HTTP [RFC 2616]	TCP
file transfer	FTP [RFC 959]	TCP
streaming multimedia	proprietary (e.g. RealNetworks)	TCP or UDP
Internet telephony	proprietary (e.g., Vonage, Dialpad)	typically UDP

Google trying to improve:
Quic for TCP
SPDY for HTTP

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