CSC 525:
Computer Networks

Logistics

- Lectures:
  - Mon & Wed, 2-3:15pm, GS 701
  - Instructor: Beichuan Zhang
  - Email: bzhang@cs.arizona.edu, Office: GS 723
  - Office Hour:
    - Tue 1-2 PM in office
    - Other times by appointment

- Online resources
  - D2L: course material
  - Piazza: online discussions
  - Gradescope: exam grading

What this course is about …

- The Internet: the past, the present, and the future
- Learn the core Internet protocols
  - only have time to cover a small subset
  - open to suggestions
- Understand network protocol design
  - Principles ➔Practice ➔Principles
- Hands-on network programming experience

What we cover

- Basic design principles behind Internet architecture
- Network Layer
  - Intra-domain Routing: RIP, OSPF
  - Inter-domain Routing: BGP
  - Multicast Routing: DVMRP, CBT, etc.
- Transport Layer
  - Congestion control: TCP, XCP
- Application Layer
  - service: DNS, HTTP
  - Peer-to-Peer and Overlay
- Emerging areas and new directions
  - Data centers, IPv6, software-defined networks, information-centric network, etc.

What we don't cover

- Wireless networks
- Network security
- Data Link layer and Physical Layer
- Cisco certificates, etc.
- …

Prerequisites

- CSc 425 or equivalent
  - Understanding of packet switched networks and TCP/IP protocol suite

- C programming on Linux, basic data structures, debugging, etc.

What we aim by the semester end

- A solid understanding of how the Internet works today, why the protocols were designed the way they are, and what potential challenges lie ahead.
- A better understanding of how to approach and solve protocol design problems
- The benefits
  - Open the door to network research
  - Prepare you for industry jobs.

Course Workload

- Reading: usually about 2 papers per week
- Report: a one-page report per week

- Midterm Exam: cover first half
- Final Exam: comprehensive, but focus on second half

- Project
  - First: implement a software router.
  - Second: implement a routing protocol.

Papers

- Posted on D2L.
- Read before lectures
- Pick one paper from the week to write a reading report
  - Submission on D2L, due on the following Monday before class.

Reading Reports

- Format
  - 11pt Times font, single column, single space.
  - At least 300 words.
  - At most one page, including the paper title and your name.
  - Use your own words
- Focus on a single technical point.
  - E.g., discuss what you would do to follow up the work, or what you would do differently from the paper.
- The most important thing is to put your own thoughts here, try to be ***different, critical,*** and ***creative***.

Projects

- First project: implement a software router
  - Be able to forward IP packets
  - Will use your router to download files.
- Second project: add a routing protocol to the router
  - Be able to route packets around link failures.
- You’ll be given a code skeleton to start with.
- You’ll test it with real traffic.

Projects

- Start from the second week of class.
- Program in C on department Linux machines.
- Can work in a group of up to 2 people.

Textbooks

- No required books
- Optional Reference:
  - **Computer Networks, A Systems Approach** by Peterson and Davie.
  - **Routing in the Internet** by Huitema

Grading

- Final numeric grade is a weighted sum of
  - Project 1: 20%, Project 2: 25%, Midterm: 20%, Final: 20%, Reading reports 15%
- The final letter grade may be curved:
  - *>= 90% A, >= 75% at least B, >= 60% at least C, >= 50% at least D, < 50% E*
- No late turn-in will be accepted.
- Partial credit for incomplete but on-time submissions.

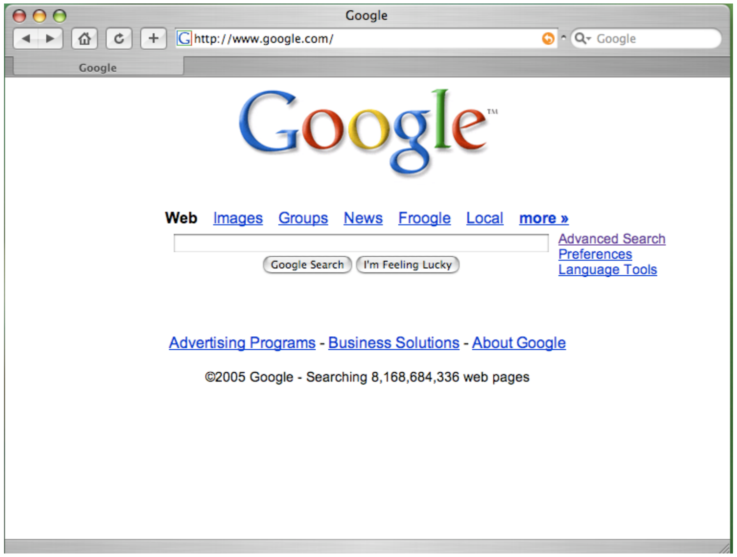
Academic Integrity

- Familiarize yourself with the code of academic integrity on the syllabus.
  - Especially don’t share your code and exams with others nor upload them to other websites; and don’t access those from other websites either.

Review on Internet Layering

Example

"On the Internet, nobody knows you're a dog."


Google
http://www.google.com/
Google
Web Images Groups News Froogle Local more »
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Language Tools
Google Search
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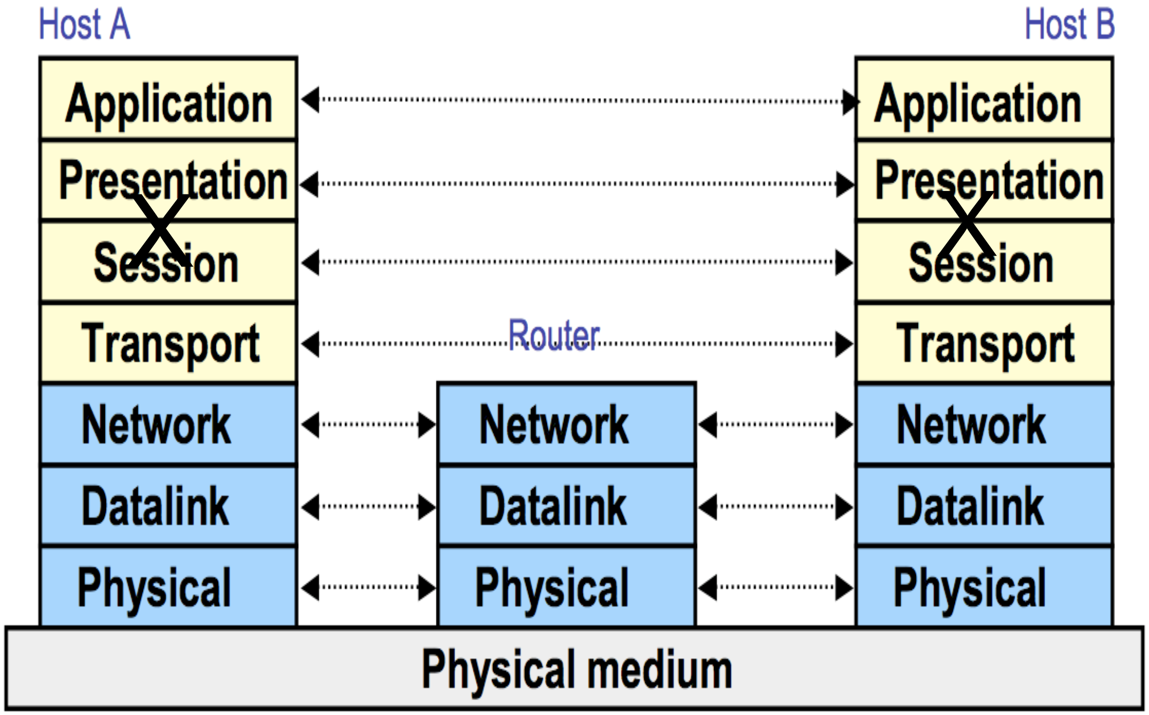
Advertising Programs - Business Solutions - About Google
©2005 Google - Searching 8,168,684,336 web pages

- How to express what we're looking for
- How to find the content?
- How to direct bits towards the destination?
- How to transmit the bits?
- How to recover from loss, error etc. ?
- Many more …

Solution

- Divide and Conquer
- Layering, protocol stack, logical communication, encapsulation.
- Naming
- APIs
- Internet vs. OSI



How to retrieve a web page?

- Get http://www.google.com/index.htm
- DNS name lookup
  - www.google.com ➔ 64.233.167.104
- Establish TCP connection with 64.233.167.104
- Send IP packets to the destination
- Routers figure out how to forward packets.
- Translate IP address to Ethernet address via ARP
  - 192.12.69.2 ➔ 0:f:8f:f7:13:7f
- Send/receive Ethernet frames on the wire.

Application Layer

- Application-specific functionality
  - Client-server: HTTP, DNS, SMTP, NTP …
  - Peer-to-peer: Gnutella, Bittorrent, DHT, ALM

HTTP Request:

protocol header

```
POST /index.html HTTP/1.1
Host: map.google.com
User-Agent: Mozilla/4.0
Content-Length: 22
Accept-language: fr
```

Application data

```
City=Tucson&State=AZ
```

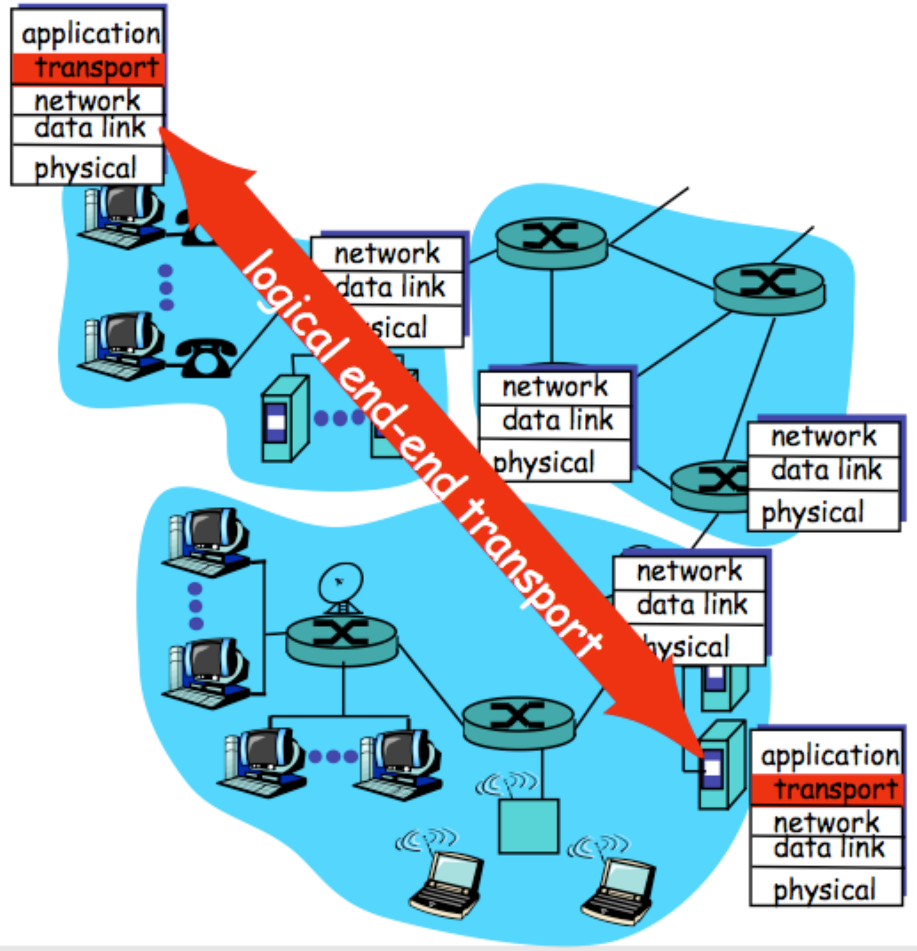
HTTP Response:

```
HTTP/1.1 200 OK
Date: Tue, 04 Mar 2003 08:01:01 GMT
Server: GWS/2.0
Content-Length: 2824
Content-Type: text/html


<HTML> … </HTML>
```

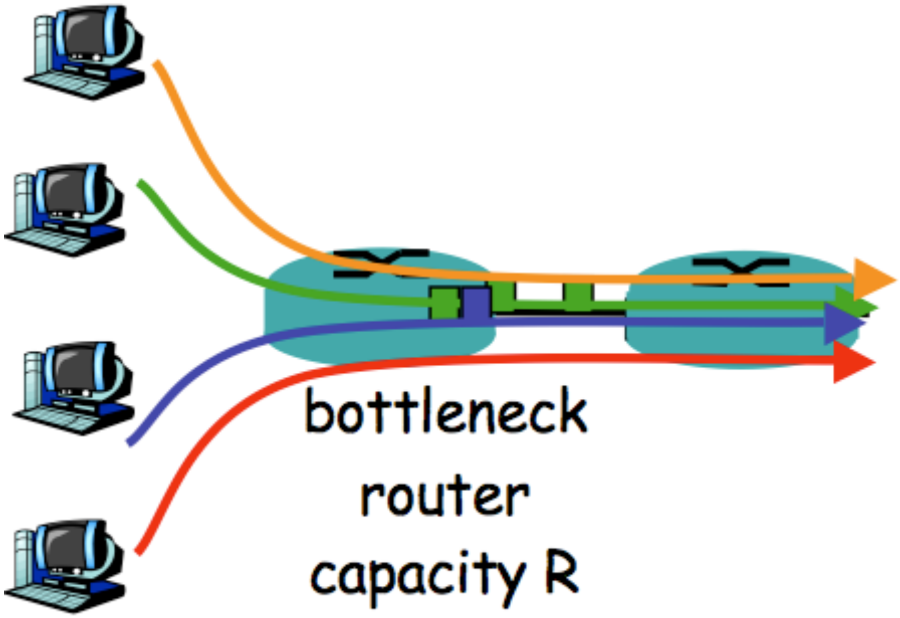
Transport Layer

- Data can get lost in communication
  - Transmission error
  - Equipment failure
  - Congestion
- Transport Layer: end-to-end data delivery service
  - TCP: reliable byte stream
  - UDP: unreliable datagram
  - DCCP, SCTP etc.



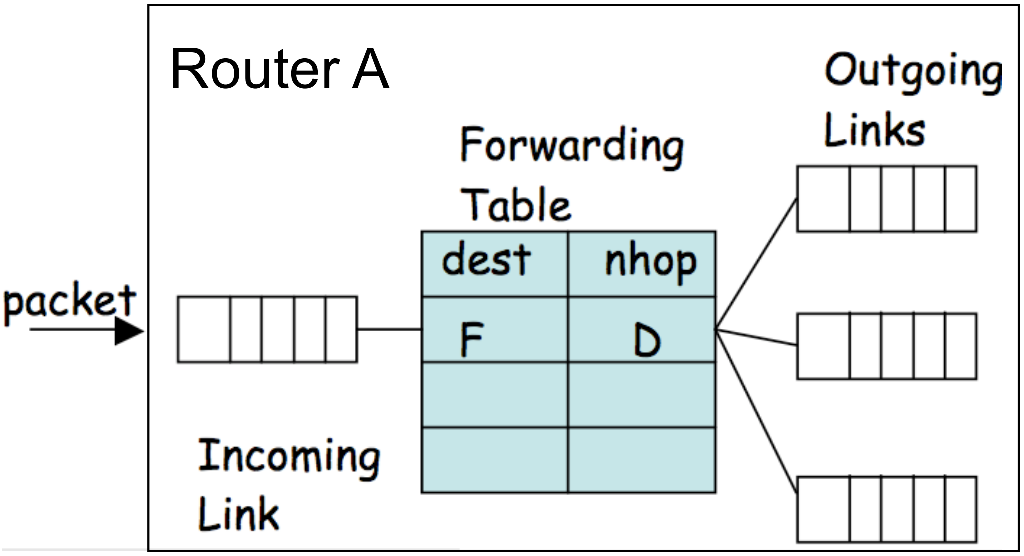
Congestion Control

- Congestion
  - Too many sources sending too much data and too fast for network to handle
  - Throughput plunges, lost packets and long delay
- Solution: rate control
  - By how much? When to increase sending rate back?
  - End-to-end
  - Network assisted



Network Layer

- Forwarding packets from source host to the destination host
- Forwarding: send packets to the next hop router.
- Routing: compute the next hop for each destination.
- Routing Algorithms and protocols
  - Distance Vector (RIP)
  - Path Vector (BGP)
  - Link State (OSPF)
- Best effort and QoS



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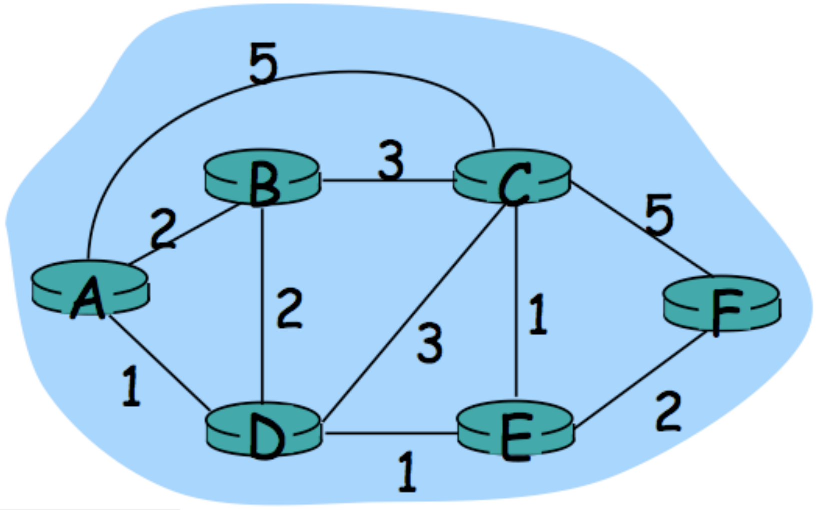
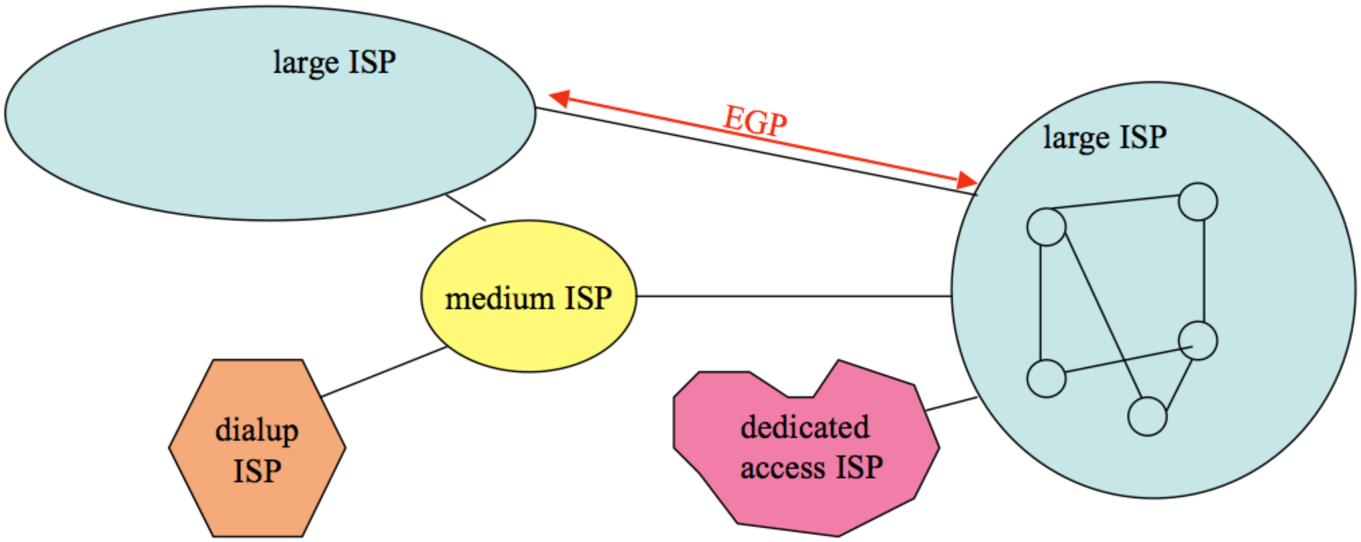
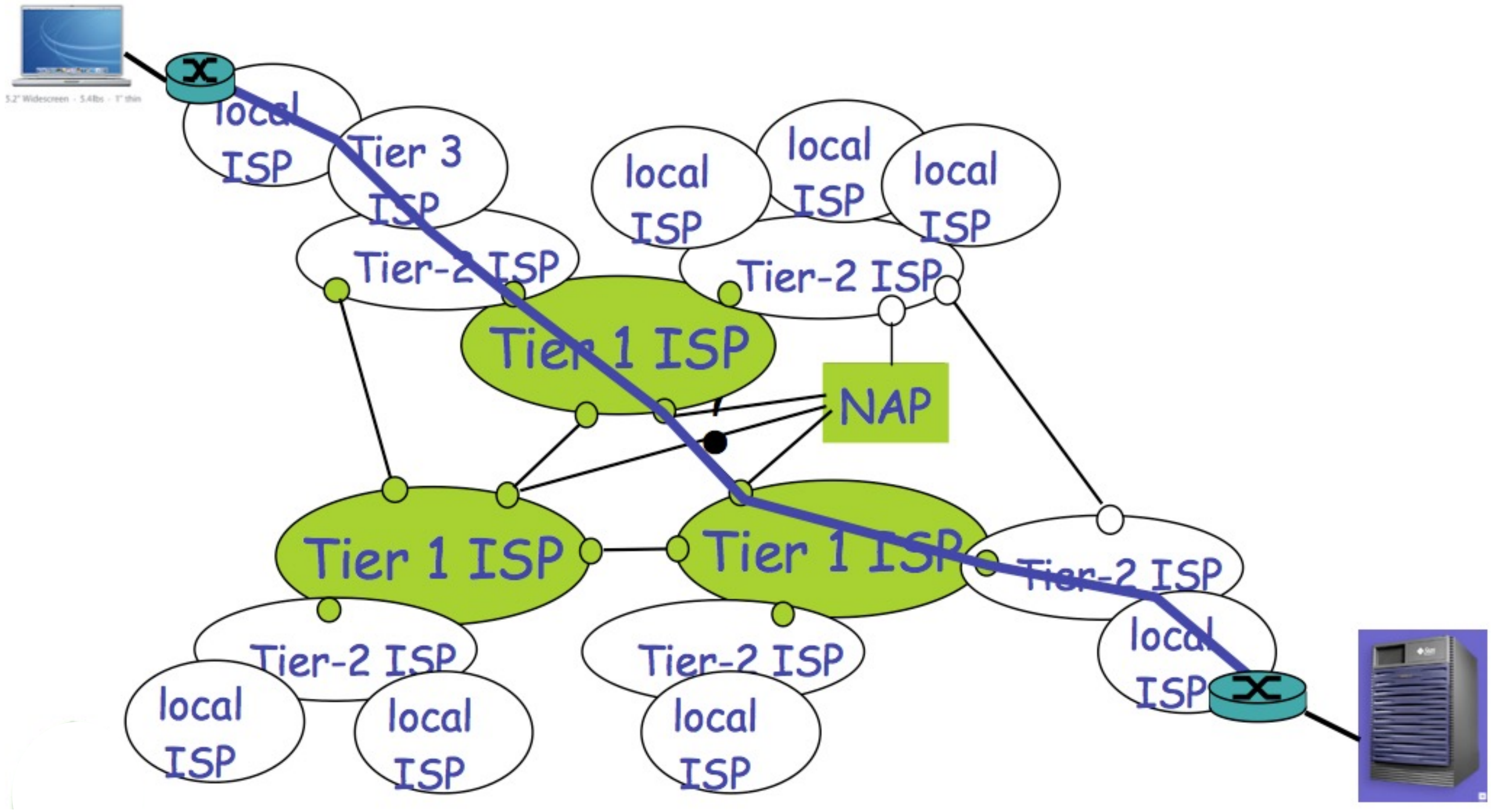


Internet Routing Hierarchy



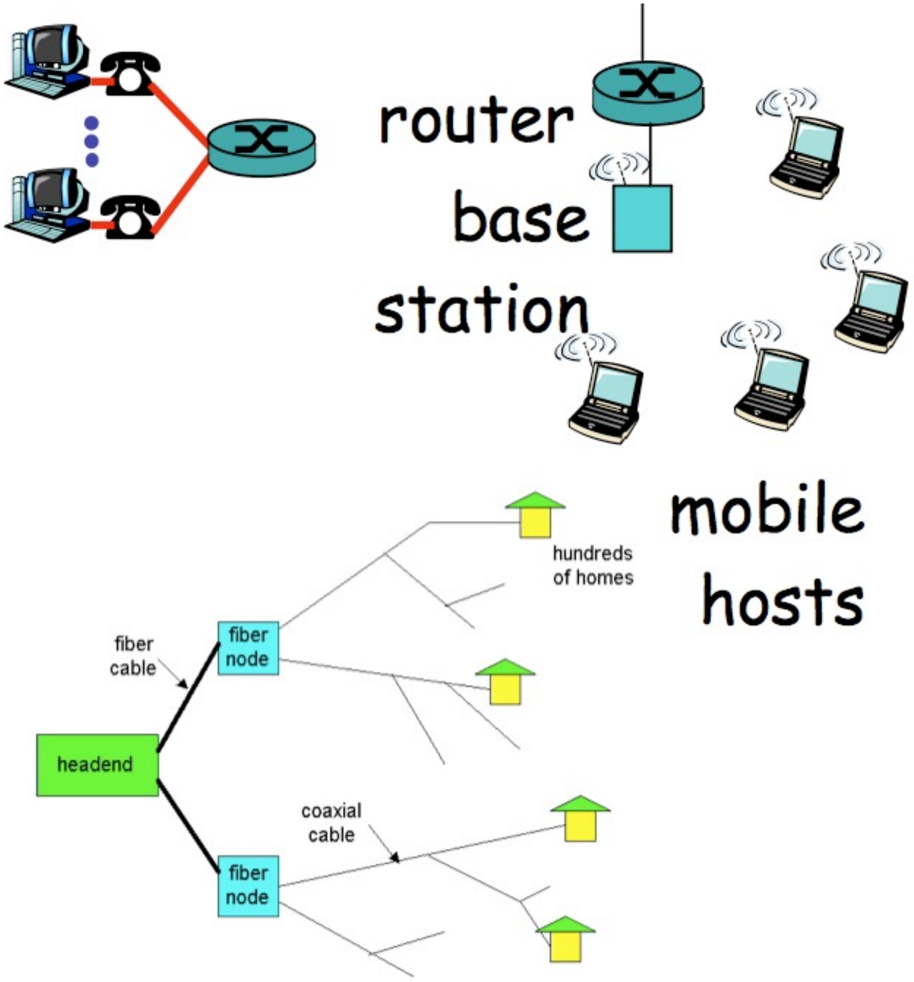
- AS (Autonomous System): a collection of routers under the same technical and administrative control.
- EGP (External Gateway Protocol): for inter-domain routing, e.g. BGP
- IGP (Internal Gateway Protocol): for intra-domain routing, e.g. RIP, OSPF

Internet: Network of Networks



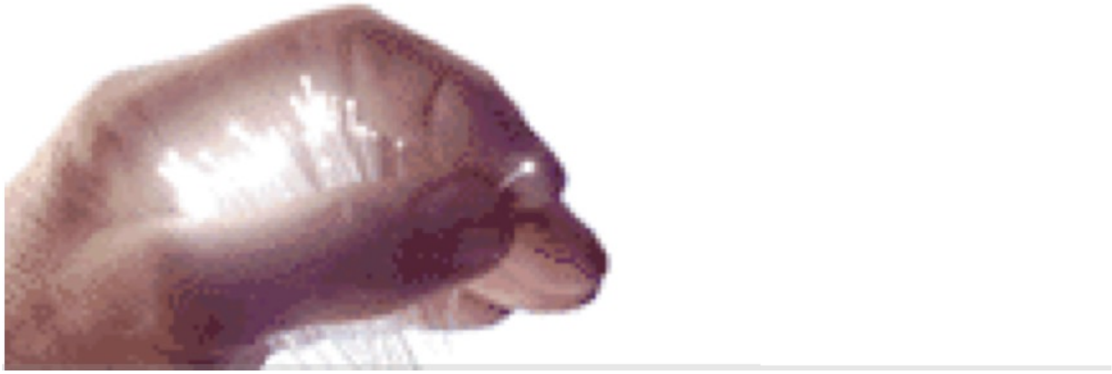
Data Link Layer

- Functions
  - Framing
  - Error detection & correction
  - Access sharing
- Example
  - Dialup, DSL
  - Cable Modem
  - WiFi, CDMA, 5G

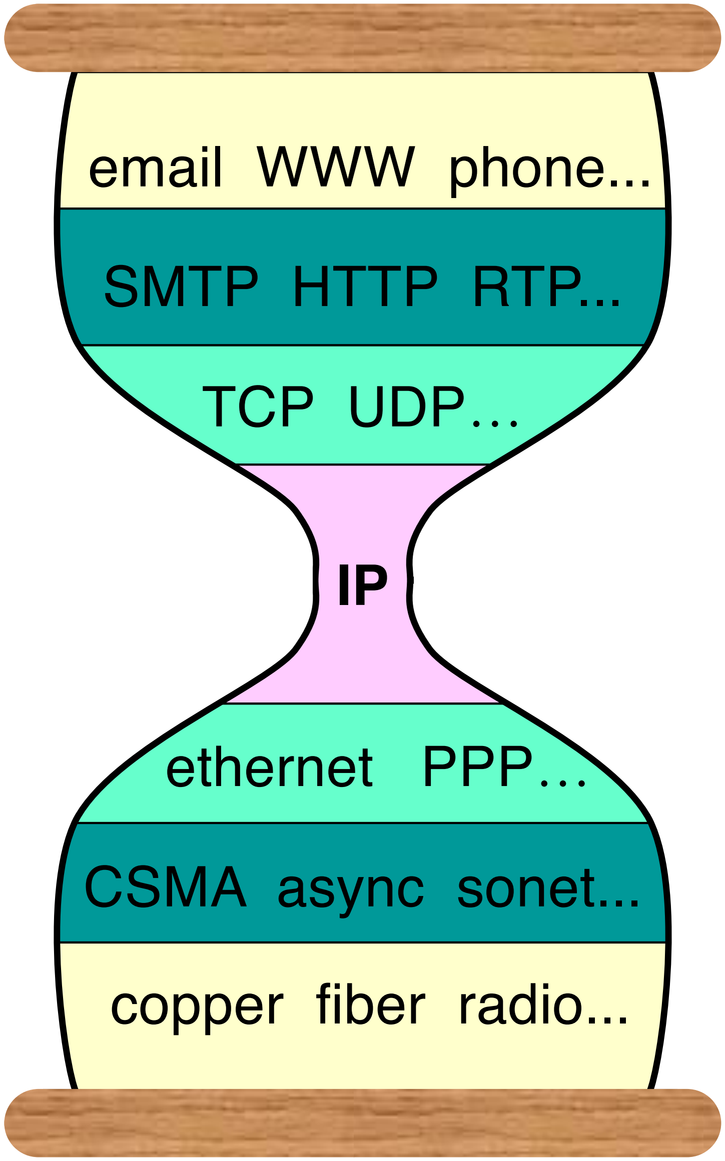


Physical Layer

- Transmit bits on physical media
  - Twisted pair
  - Coaxial cable
  - Fiber optics
  - Radio link
- Bandwidth
- Dedicated vs. shared



The Hourglass Architecture of the Internet



Challenges

- Changing environment
  - Large-scale, dynamic content publishing and distribution
  - Mobile ad-hoc connectivity
  - E.g., Internet of Things, vehicular networks, cloud computing, etc.
- Scalability
- Security and privacy
- Architectural evolution

Assignments

- Read the first paper
  - "On Distributed Communications Networks"
- Decide on project team
  - You can either work by yourself or with another student.