Data Communications and Networks
IS 450/IS 650 – Fall 2015

Course Logistics

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Welcome to IS 450/IS 650

- Timings: Tuesday; 4:30pm to 7:00pm
- Location: Janet & Walter Sondheim 113
- Instructor: Nirmalya Roy

  Faculty in IS,

  MS in CSE: UT-Arlington, 2004

  PhD in CSE: UT-Arlington, 2008

  Postdoc in ECE: UT-Austin, 2010

  Faculty at Washington State University, 2013

  Research Interest: Mobile, Pervasive and Ubiquitous Computing http://mpsc.umbc.edu/

- Office hours: Thursday 1:30 – 3:00pm or by appointment

  Email: nroy@umbc.edu

  Office: ITE 421

Welcome to IS 450/IS 650

- Course website
  - http://mpsc.umbc.edu/is450dcn/
  - Course related information will be posted on the website
  - Please check the course website frequently

- Prerequisite:
  - MATH 215 or MATH 221

- Make up classes
  - Will be occasionally necessary due to travel

Welcome to IS 450/IS 650

- Grading:
  - Homework/Quizzes/Class Participation: 30%
  - Hands-on Data Communications
    Research & Development Project 20%
  - 1 mid-term exam: 20%
  - Final exam: 30%

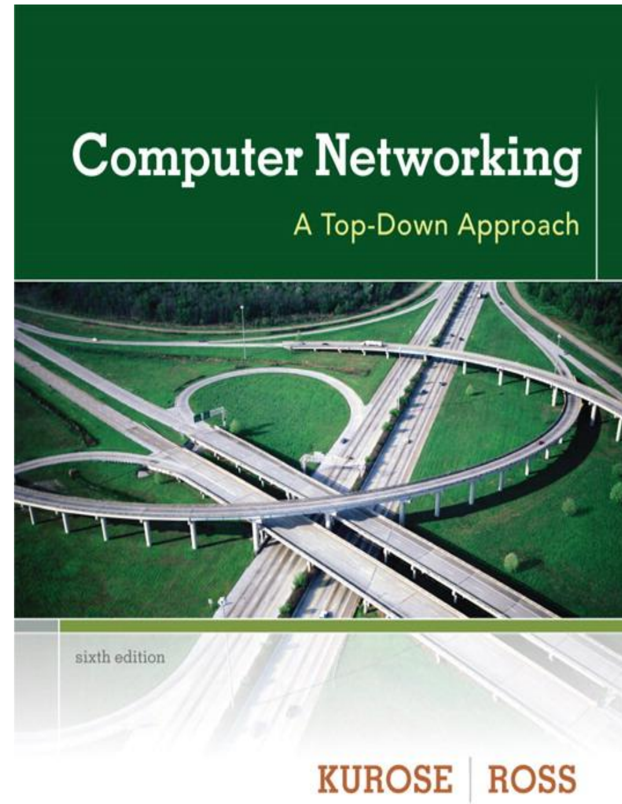
Course Expectations

- Attendance
  - You should attend class
  - Lecture notes will be made available, but they should not be considered a substitution for attending class

- Collaboration
  - Collaboration is good in general but do not copy from each other

Course Information

- Course materials:
  - Text:
    Computer Networking: A Top Down Approach, 6th Ed., by James F. Kurose and Keith W. Ross. Addison-Wesley, 2012
  - Class notes/slides
  - Some supplementary reading materials



What is this course about?

- First undergraduate and graduate level course in computer networking
  - BS and MS students

- Learn principles of computer networking
- Learn protocol modeling and analysis of computer networking
- Learn practice of computer networking
- Internet architecture/protocols as case study
- Real wireless networks and devices as case studies
- Introduction to next generation networking
- Learn how to find an interesting networking research and development problem

Course Information

- At the end of the course
  - You understand variety of concepts ……………
  - DSL , Cable, Aloha, CSMA, TDMA, Token, WiFi 802.11, …
  - Internet, HTTP, DNS, P2P, …
  - Sockets, Ports, …
  - Congestion Control, Flow Control, TCP, …
  - Routing, Basic Graphs, Djikstra’s Algorithm, IP, …
  - Sensor Networks
  - Tackling a research & development problem
  - …
  - Security, RSA, …
  - Cellular Networks, Mobile Networks, Satellite Networks, …
  - Wireless Multihop Networks (ad hoc, mesh, WLANs)

What this Course Does Not Cover?

- We will not discuss
  - Large-scale path loss, small scale fading and multipath
  - Modulation schemes; channel coding
  - Transmitter/Receiver design, signal processing, antenna design etc.

- This is a course on
  - Understanding, analyzing, and designing of protocols and algorithms in networking systems (wired Internet/Ethernet and wireless cell/WiFi)

Hands-on Data Communications Project

- Deploy, test, compare and if needed make changes to have access to real data on real devices commercially available in the market
  - Energy Education through Green Building
    - Constellation Energy
  - Smart Plugs
    - Enmetric, D-Link Wi-Fi Smart Plugs
    - Z-Wave, Belkin Wemo Insight Switch
    - iMeterSolo
    - SiteSage (previously was known as eMonitor)
  - Other devices:
    - Fitbit, iBeacon, Myo Armband, PIR Sensor, Nest Thermostat

Hands-on Data Communications Project

- Understand the working principle and pros & cons of different types of communication protocols
  - Wi-Fi (IEEE 802.11.x)
  - ZigBee (IEEE 802.15.4)
  - Bluetooth
  - X10
  - ANT
  - Bluetooth low energy (BLE) or Bluetooth Smart
  - Powerline communication protocol (PLC)
  - ……..

Hands-on Data Communications Project

- Device selection
  - Form a team (3 for undergrad and 2 for grad students)
  - Decide a team leader
  - Choose a device related to your tentative R&D project
  - Choose the most cost effective device
    - Our plan is to deploy the system ultimately at large scale in smart environments

- Email me the device specification with a purchase link, the tentative title of your project and research objective
  - Deadline for selecting the appropriate device is by the last class in September, 9/29

Selecting the Appropriate Device

- Select a device which is ubiquitous, easy to set up, easy to use and most importantly less expensive and has huge potential for the real deployment

- Discuss with me during office hours or through emails

- Let’s look at some potential choices

Potential Devices & Equipment

- Energy metering and communication
  - Z-Wave Smart Energy Power Strip
  - iMeter Solo - INSTEON Power Meter (quite a few in the lab)
  - PowerLinc Modem - INSTEON USB Interface
- Z-wave Smart Metering and Communication
  - Aeon Labs DSA02203-ZWUS Z-Stick Series 2
  - Aeon Labs DSC24-ZWUS Smart Switch Z-Wave Appliance Module
  - Aeon Labs DSC06106-ZWUS - Z-wave Smart Energy Switch
  - Aeon Labs Aeotec Z-Wave Smart Energy Power Strip

Potential Devices & Equipment

- Insteon Energy Metering and Communication
  - iMeter Solo - INSTEON Power Meter (Plug-In)
  - PowerLinc Modem - INSTEON USB Interface (Dual-Band)

- Enmetric System for Intelligent Plug load Management and Power Telemetry Communication
  - Enmetric PowerPort
  - Enmetric Wireless Bridge

Potential Devices & Equipment

- PeoplePower
  - Presence Pro Energy - for Android
- Nest Lab
  - Nest Thermostat
- Wattics: Innovative Energy Management
- Tendril: Changing the way the world uses energy

Potential Devices & Equipment

- EnergyHub: Powers positive relationships with millions of energy users every day

- Baltimore Energy Challenge

https://baltimoreenergychallenge.org/

Hands-on Data Communications Project

- Projects consist of 3 parts:
  - Choosing an interesting low-cost device
    - Identifying what you can do
    - Install the required SDK to make it work
  - Think about a novel application
    - Collect DATA for a period of at least 2-3 weeks or more
    - Based on the data build a dashboard or propose a novel application
  - Results
    - Identify the different communication protocols
    - Test with different settings based on the range, distance, interference, environment, user body positions etc.
    - Draw the important inferences or conclusions from the results
      - Is it good for what it’s meant for?
      - How does it make the environment more smarter, healthy and sustainable?

Hands-on Data Communications Project

- Mid semester progress update in mid October
- Final demonstration to the class and report submission in December
  - 3-page report (undergrad team)
  - 6-page report (grad team)

- Energy related projects and Course best project may get a chance to present their projects to *Constellation Energy Inc.*
- Bonus points will be given to the Best 3 projects in the class (up to 3 points)

Other Assignments

- Homework, Quizzes will be given appropriately as we make progress
- Attending class and participation in class discussion will be equivalent to the credit of an assignment

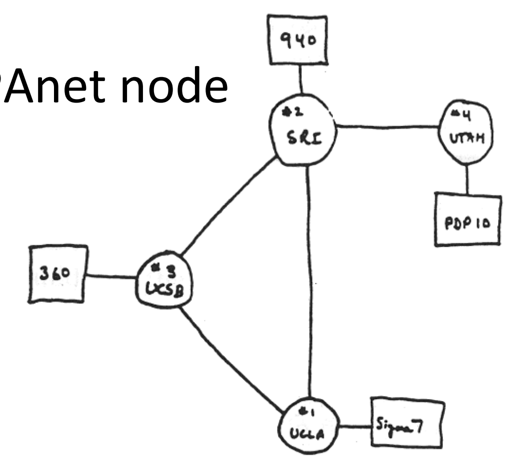
Data Communications and Networks

- Past
- Present
- Future

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



THE ARPA NETWORK

- 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
- 1974: Cerf and Kahn - architecture for interconnecting networks
- 1976: Ethernet at Xerox PARC
- 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]
  - 1989: HTML, HTTP: Berners-Lee
  - 1994: Mosaic, later Netscape
  - late 1990's: commercialization of the Web

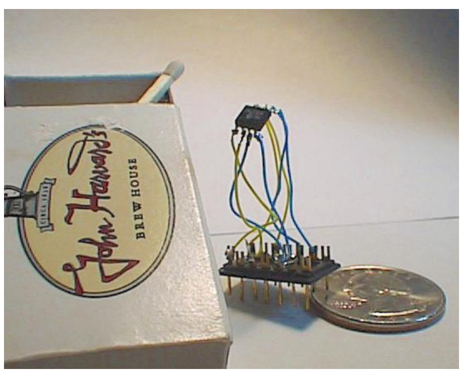
Late 1990's – 2000's:

- more killer apps: instant messaging, P2P file sharing
- network security to forefront
- est. 50 million host, 100 million+ users
- backbone links running at Gbps

The New Millennium: “Cool” Internet Applications

IP picture frame
http://www.ceiva.com/

Internet phones



World’s smallest web server
http://www-ccs.cs.umass.edu/~shri/iPic.html

Web-enabled toaster +
weather forecaster

Network Edge

- End points need not be devices

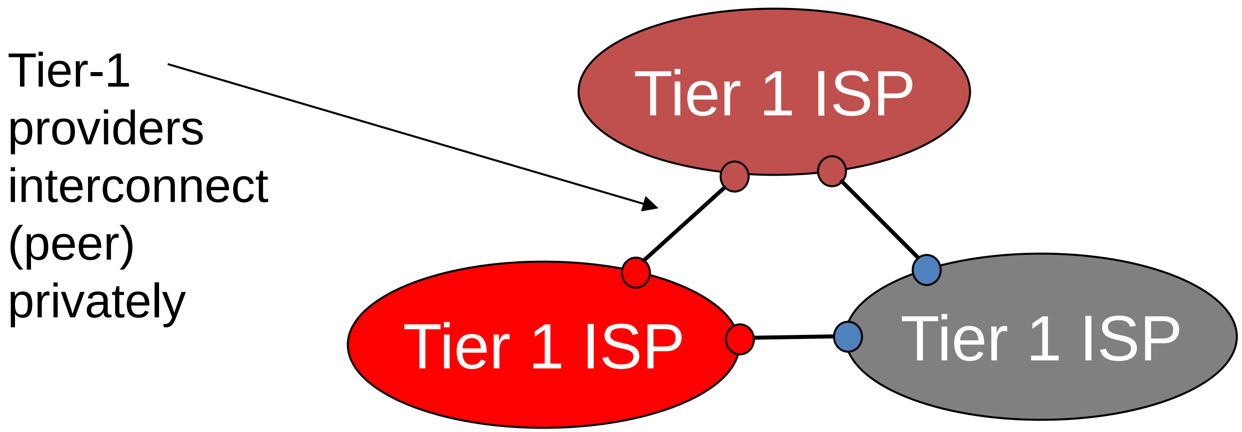
- Imagine locations as end points, and associated with email addresses in the future …
  - You could email your grocery list to aisle 3 in Safeway
  - I could email “running late” to whiteboard in the class

InterNetwork

- Millions of end points (you, me, and toasters) are connected over a network
  - Many end points can be addressed by numbers
  - Many others lie behind a virtual end point
- Many networks form a bigger network
- The overall structure called the Internet
  - Defined as *the network of networks*

Internet Structure: Network of Networks

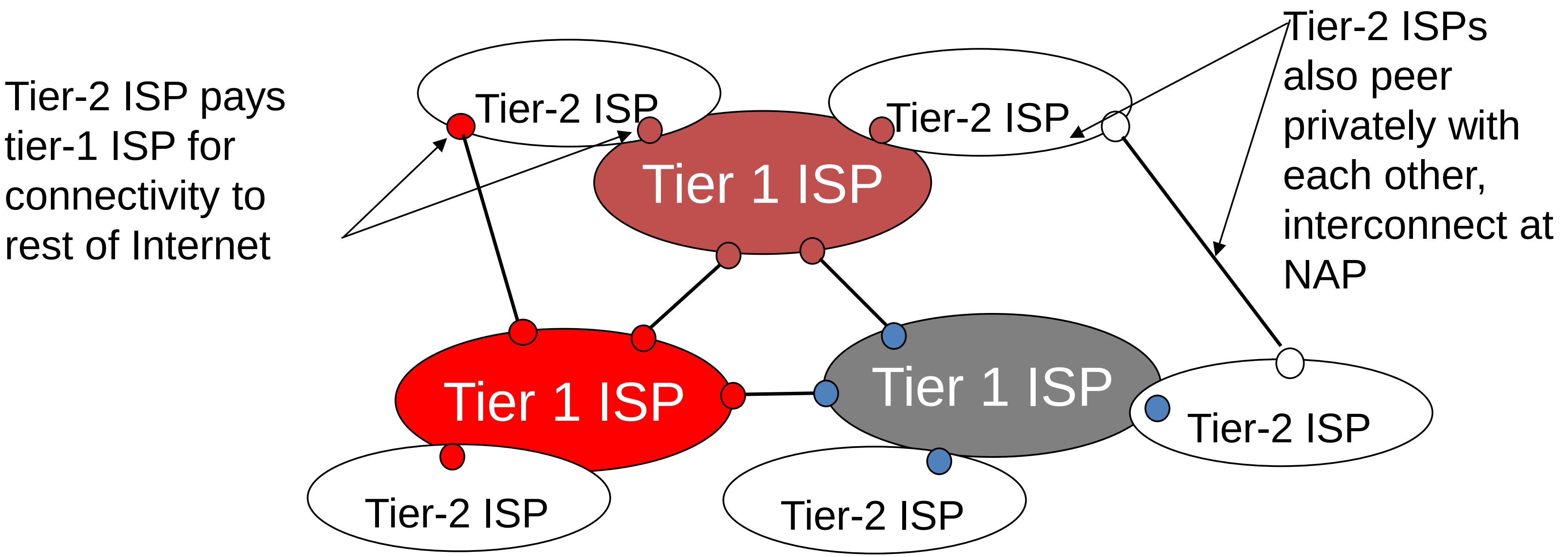
- roughly hierarchical
- at center: "tier-1" ISPs (e.g., MCI, Sprint, AT&T, Cable and Wireless), national/international coverage
  - treat each other as equals



Internet Structure: Network of Networks

- "Tier-2" ISPs: smaller (often regional) ISPs
  - Connect to one or more tier-1 ISPs, possibly other tier-2 ISPs

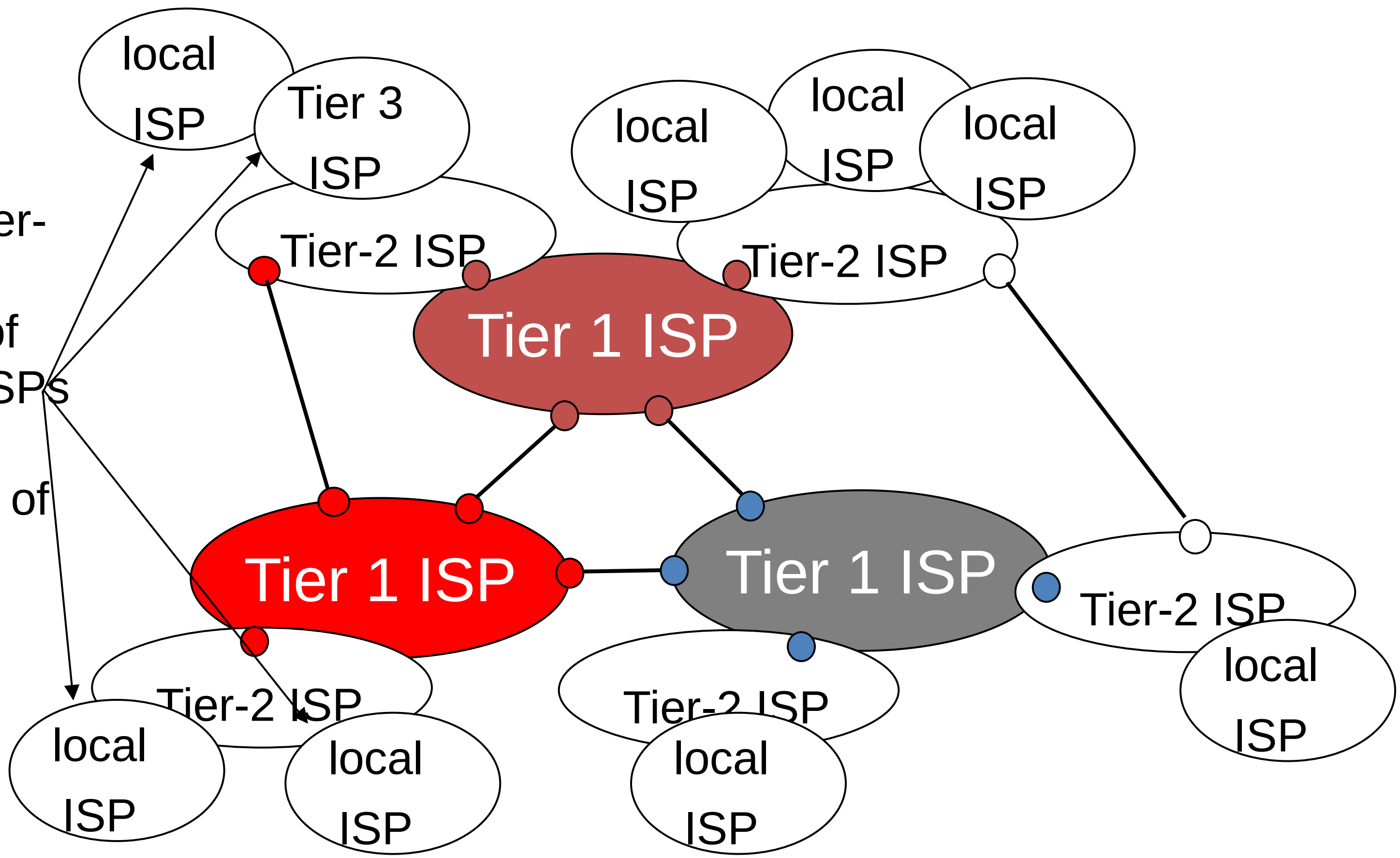
- France telecome, Tiscali, etc. buys from Sprint



Internet structure: Network of Networks

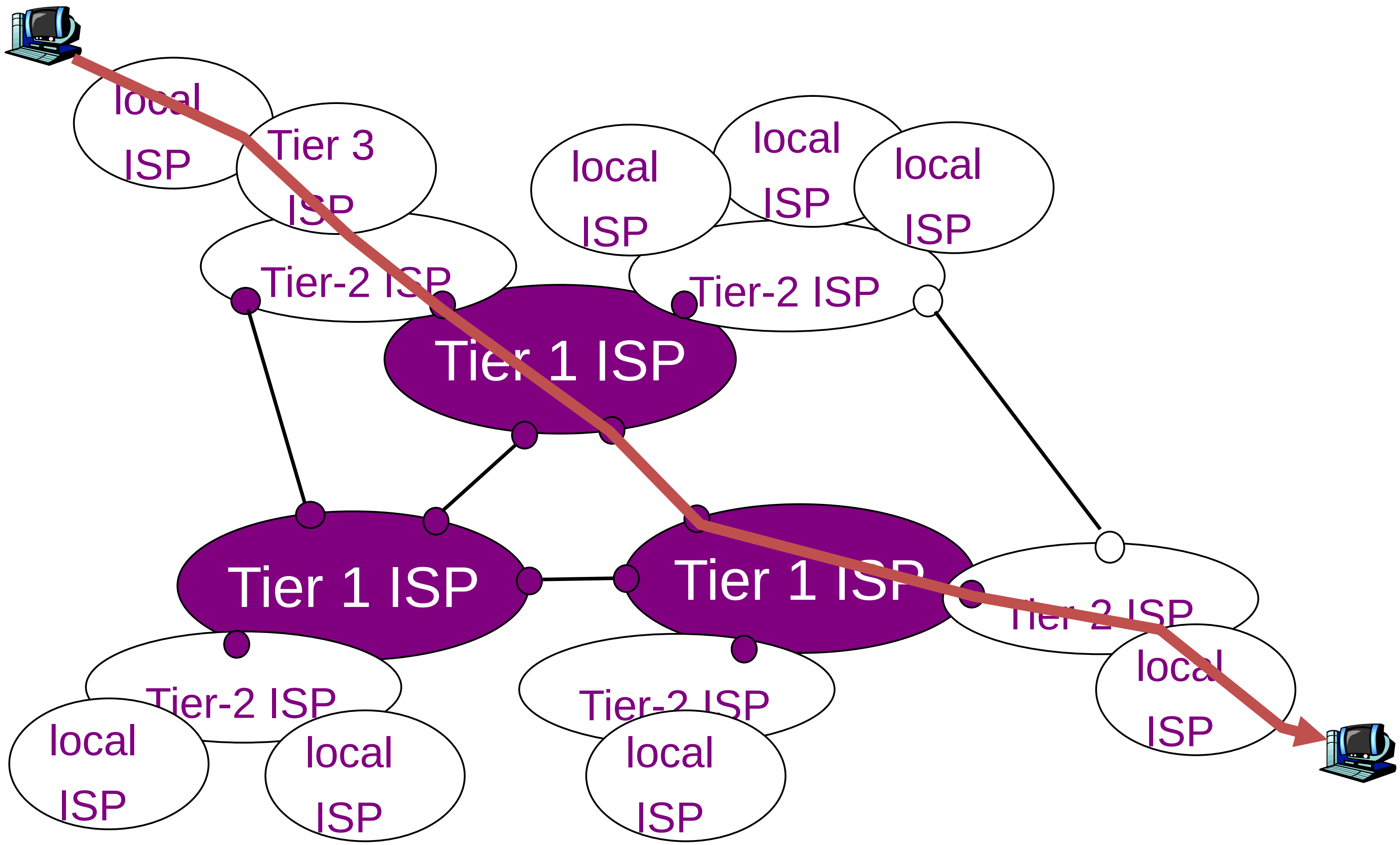
- “Tier-3” ISPs and local ISPs (Time Warner, Earthlink, etc.)
  - last hop (“access”) network (closest to end systems)

Local and tier-3 ISPs are *customers* of higher tier ISPs connecting them to rest of Internet



Internet Structure: Network of Networks

- a packet passes through many networks!
    - Local ISP (taxi) -> T3 (bus) -> T2 (domestic) -> T1 (international)



Organizing the giant structure

Networks are complex!

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

Question:

Is there any hope of *organizing* structure of network?

Or at least our discussion of networks?

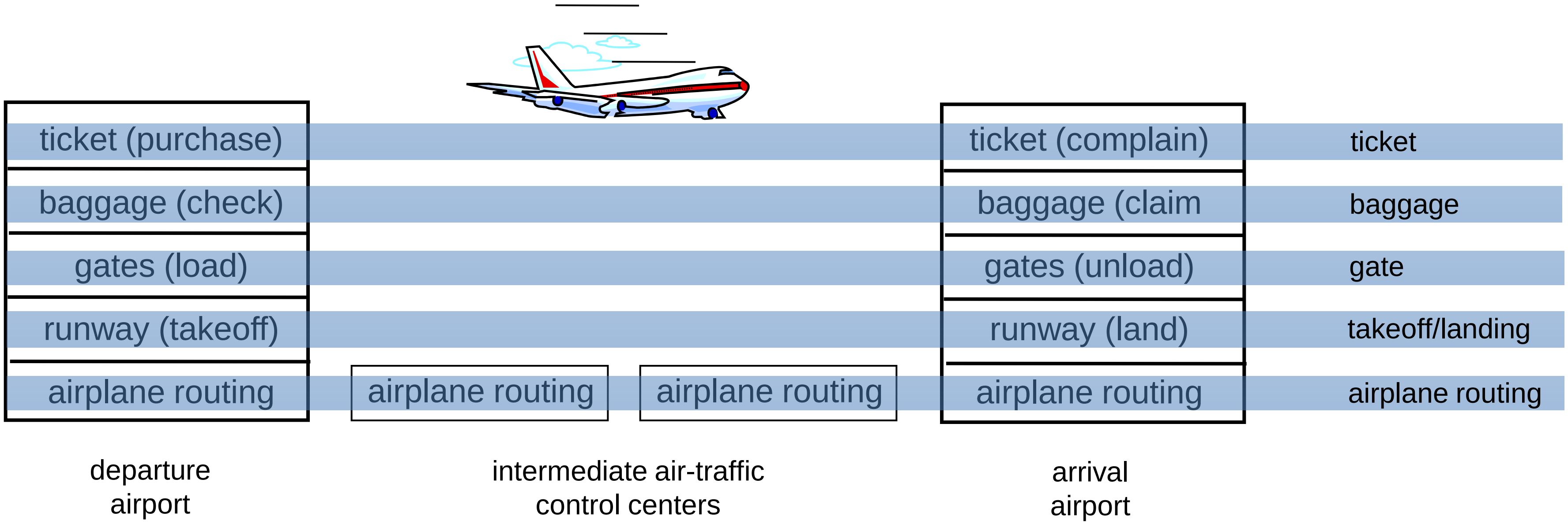
Turn to Analogies in Air Travel

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

airplane routing

- a series of steps

Layering of Airline Functionality



Layers: each layer implements a service

- layers communicate with peer layers
- rely on services provided by layer below

Why layering?

- Explicit structure allows identification, relationship of complex system's pieces

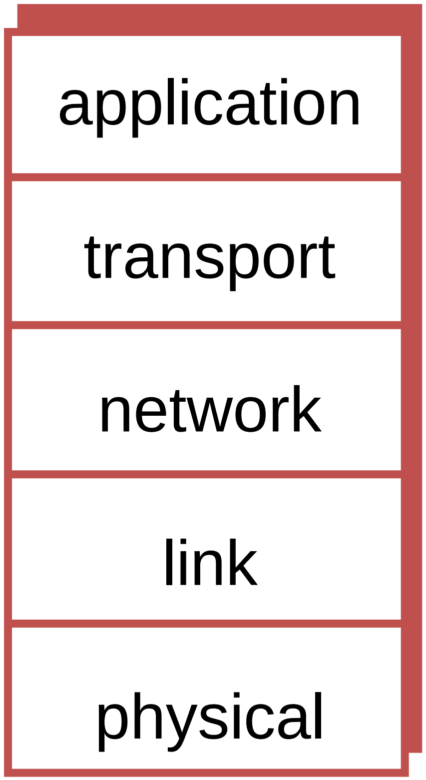
- Modularization eases maintenance, updating of system
  - change of implementation of layer's service transparent to rest of system
  - e.g., runway delay (wheels up time) depends on clearance of destination runway … doesn't affect rest of system

Protocol “Layers”

- Service of each layer encapsulated
- Universally agreed services called PROTOCOLS
- A large part of this course will focus on designing and analyzing protocols for networking systems

Internet protocol stack

- application: supporting network applications
  - FTP, SMTP, HTTP, DNS …
- transport: host-host data transfer
  - TCP, UDP …
- network: routing of datagrams from source to destination
  - IP, BGP, routing protocols …
- link: data transfer between neighboring network elements
  - PPP, Ethernet, WiFi, Bluetooth …
- physical: bits "on the wire"
  - OFDM, DSSS, CDMA, Coding …



Queueing Theory

- Waiting in lines
  - In the grocery store, on the telephone, at the airport, on the road
- Queueing theory is the mathematical study of lines
  - What are the stochastic characteristics of delay?
  - For example, what is the average delay?
  - What is the probability that delay exceeds some threshold?
  - What fraction of customers are turned away?
  - What system capacity (e.g., what number of servers) is needed to achieve a specified quality of service?
- Provide decision makers a way to efficiently allocate resources to reduce delay

Applications of Queueing Theory

- Applications to Networks
- Study of the performance of systems composed of
  - Waiting lines
  - Processing units
- Allows to estimate
  - Time spent in waiting
  - Expected number of waiting requests
  - Probability of being in certain states
- Useful for the design of systems such as networks
  - Delay, blocking probability, links, bandwidth, number of processors, buffers size

Questions

?