Lecture 1
Introduction

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15-441 Networking, Spring 2005
http://www.cs.cmu.edu/~srini/15-441/S05/

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Today's Lecture

- **Course outline and goals.**
- **Whirlwind Tour of Networking ™**

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Instructors

- **Two instructors.**
  - » **David Andersen**
    - – **<dga@cs.cmu.edu> , Wean Hall 8206**
  - » **Srini Seshan**
    - – **<srini+@cs.cmu.edu>, Wean Hall 8113**
- ***N* teaching assistants.**
  - » **Ed Bardsley ebardsle@andrew.cmu.edu - WeH 5201 cluster**
  - » **Eric Burns - latinum@cs.cmu.edu – NSH 4511**
  - » **David Craft dcraft@andrew.cmu.edu – WeH 7th whiteboard**
  - » **2 more TBA**

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Course Goals

- **Become familiar with the principles and practice of data networking.**
  - » **Routing, transport protocols, naming, ...**
- **Learn how to write applications that use the network.**
  - » **How does a web server work?**
- **Get some understanding about network internals in a hands on way.**
  - » **By building a simple network in software**

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Course Format

- ~30 lectures.
  - Cover the "principles and practice"
  - Readings are posted beforehand
- 3 "paper" homeworks.
  - Do you understand and can you apply the material?
  - Feedback to students and instructors
- 2 "lab" homeworks.
  - Illustrate networking concepts
- Mid-term and final.
- 2 programming projects.
  - How to use and build networks / networked applications
  - Application layer; include key ideas from kernel
  - Larger, open-ended group projects. *Start early!*

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Sounds Great! How Do I Get In?

- Currently 99 people are enrolled, and 9+ people are on the waiting list.
  - There is room for 107 students
  - In other words: your chances of getting in are very good
- We give preference to students attending class.
  - Look me up after class
  - All else being equal, we go FCFS.
- If you do not plan to take the course, please drop it ASAP so somebody else can take your place!

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Administrative Stuff

- Watch the course web page.
  - Handouts, readings, ..
- Read courses bboards.
  - "Announce" for official announcements
  - "General" for questions/answers
- Office hours posted on web page.
- Course secretary
  - Barbara Grandillo, Wean Hall 8018
- Srini – no office hours this week
  - Office hours start Thursday
- Books – have people gone to the bookstore? How many copies? *Should* be there…

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Grading

- Roughly equal weight in projects and testing on course contents.
- 20% for Project I
- 25% for Project II
- 15% for Midterm
- 25% for Final exam
- 15% for Homeworks
- You need to demonstrate competence in both projects and tests to pass the course.

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Policy on Collaboration

- **Working together is important.**
  - » **Discuss course material in general terms**
  - » **Work together on program debugging, ..**
- **Parts *must* be your own work**
  - » **Homeworks, midterm, final**
- **Projects: Teams of two**
  - » **Collaboration, group project skills**
  - » **Both students should understand the entire project**
- **Web page has details.**

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Policy on Late Work and Regrading

- **No assignments with a "short fuse".**
  - » **Homeworks: ~1 week**
  - » **Projects: ~5 weeks**
- **Late work will receive a 10% penalty/day.**
  - » **No penalty for a limited number of handins - see web page**
  - » **No assignment can be more than 2 days late**
- **Only exception is documented illness and family emergencies**
- **Start on time!**
  - » **Every year some students discover that a 4 week project cannot be completed in a week**
- **Requests for regrading must be submitted in writing with course secretary within 2 weeks.**
  - » **Regrading will be done by original grader**

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This Week

- Intro – what's this all about?
- Network programming review.
  - » Socket programming (213 review++)
  - » Project management (RCS, etc.)
- Outline
  - » Low-level (physical, link, circuits, etc.)
  - » Internet core concepts (addressing, routing, DNS)
  - » Advanced topics
- On to the good stuff…

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What Is a Network?

- Collection of nodes and links that connect them
- This is vague. Why? Consider different networks:
  - » Internet
  - » Andrew
  - » Telephone
  - » Your house
  - » Others – sensor nets, cell phones, …
- Focus on Internet, but understand important common issues and challenges

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Networks Juggle Many Goals

- **Efficiency – resource use; cost**
- **The "ilities":**
  - **Evolvability**
  - **Managability**
  - **Security (securability, if you must)**
  - **Ease of:**
    - **Creation**
    - **Deployment**
    - **Management**
    - ***Creating useful applications***
  - **Scalability**

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Challenges for Networks

- **Geographic scope**
  - **The Internet vs. Andrew, etc.**
- **Scale**
  - **The Internet vs. your home network**
- **Application types**
  - **Email vs. Videoconferencing**
- **Trust and Administration**
  - **Corporate network – one network "provider"**
  - **Internet – 17,000 network providers**

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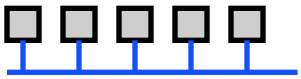
How to Draw a Network

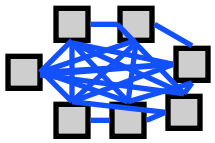
Building block: The Links

- **Electrical questions**
  - Voltage, frequency, …
  - Wired or wireless?
- **Link-layer issues: How to send data?**
  - When to talk – can everyone talk at once?
  - What to say – low-level format?
  - Stay tuned for lecture 5
- **Okay… what about more nodes?**

- … But what if we want more hosts?



One wire



Wires for everybody!

- Scalability?!

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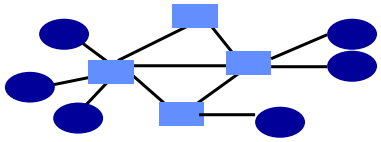
Multiplexing!

- Need to share network resources



- How? Switched network
  - Party “A” gets resources sometimes
  - Party “B” gets them sometimes
- Interior nodes act as “Routers” or “Switches”
- What mechanisms can share resources?

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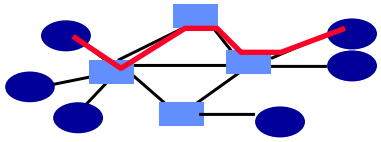
Circuit Switching

- Source first establishes a connection (circuit) to the destination.
  - » Each router or switch along the way may reserve some bandwidth for the data flow
- Source sends the data over the circuit.
  - » No need to include the destination address with the data since the routers know the path
- The connection is torn down.
- Example: telephone network (analog).



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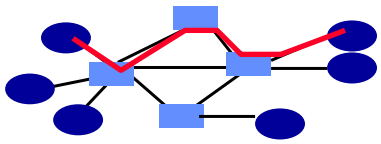
Circuit Switching

- Source first establishes a connection (circuit) to the destination.
- Source sends the data over the circuit.
  - » e connection is torn down.
- Example: telephone network
  - » Early early versions: Human-mediated switches.
  - » Early versions: End-to-end electrical connection!
  - » Today: Virtual circuits or lambda switching



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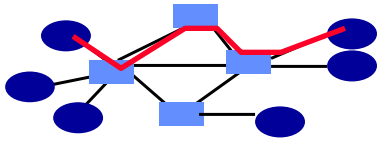
Circuit Switching 2

- What about many connections?
  - Many wires (e.g., those big 200-pair cables you sometimes see)
- A more practical approach is to multiplex multiple circuits over a single "fast" wire.
  - Can benefit from improvements in technology
  - Fewer wires
  - Multiplexing is discussed in more detail in Lecture 5



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Circuit Switching Discussion

- Circuits have some very attractive properties.
  - Fast and simple data transfer, once the circuit has been established
  - Predictable performance since the circuit provides isolation from other users
  - E.g. guaranteed bandwidth
- But it also has some shortcomings.
  - How about bursty traffic
    - circuit will be idle for significant periods of time
  - How about users with different bandwidth needs
    - do they have to use multiple circuits
- Alternative: packet switching.

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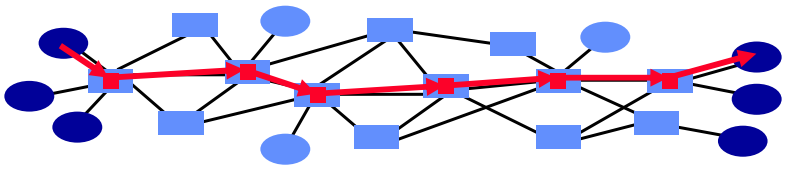
Packet Switching (our emphasis)

- Source sends information as self-contained packets that have an address.
  - » Source may have to break up single message in multiple
- Each packet travels independently to the destination host.
  - » Routers and switches use the address in the packet to determine how to forward the packets
- Analogy: a letter in surface mail.



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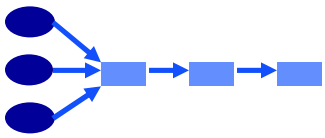
Statistical Multiplexing

- Switches arbitrate between inputs



- Can send from *any* input that's ready
  - » Links never idle when traffic to send
  - » (Efficiency!)
- What networks can we build with these tools?

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Local Area Networks (LANs)

- **Benefits of being "local":**
  - » **Lower cost**
  - » **Short distance = faster links, low latency**
    - – **Efficiency less pressing**
  - » **One management domain**
  - » **More homogenous**
- **Examples:**
  - » **Ethernet (Lecture 7)**
  - » **Token ring, FDDI**
  - » **802.11 wireless (Lecture 21)**

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Wide Area Networks

Distance makes things harder:

- **High(er) delays and cost → Need efficiency**
- **Larger size → Need scalability**
- **Heterogeneity:**
  - » **Traffic types**
  - » **Host needs**
- **Administrative diversity → Management harder**

Let's look at one prominent example:

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"The Internet"

- An inter-net: a network of networks.
  - A set of networks that are connected with each other
  - Networks are connected using routers that support communication in a hierarchical fashion
  - Often need other special devices at the boundaries for security, accounting, ..
- The Internet: the interconnected set of networks of the Internet Service Providers (ISPs) providing data communications services.
  - About 17,000 different networks make up the Internet
- In order to inter-operate, all participating networks have to follow a common set of rules.

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Challenges of the Internet

- Scale: 100,000,000s of hosts
- Heterogeneity:
  - 18,000+ administrative domains
  - Thousands of applications
  - Lots of users
  - Fast links, slow links, satellite links, cellular links, carrier pigeons
- Diversity of network technologies
- Adversarial environment
- Oh, and let's make it easy to use…

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Implementing Packet-Switched Networks

- **Requirements for packets:**
  - » Header information: Addresses, etc. (Lecture 9)
  - » Data. What is packet size limit? (Lectures 5—9)
  - » Everybody has to agree on these for interoperability
- **How do packets reach destination? Routing**
  - » Nodes in network forward packets towards destination
  - » Routing tells nodes where to send the packets they receive
    - – Design questions: What criteria to decide?
      - Destination is a must
      - Source?
      - "Type"?

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Routing

- **Who chooses the routes?**
  - » A human: Static routing
  - » Centralized routing (telenet, c.a. 1980s)
  - » Distributed routing (Internet, …)
- **Distributed routing uses a *Routing Protocol***
  - » Many different protocols are in use.
  - » Inside an organization: RIP, OSPF, etc (Lecture 11)
  - » Between organizations: BGP (Lecture 12)

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Network Service Model

- What is the *service model?*
  - » Ethernet/Internet: *best-effort* – packets can get lost, etc.
- What if you want more?
  - » Network can do it – Quality of Service
    - – Benefits of circuit switching in packet-switched net
    - – Hard in the Internet, easy in restricted contexts
    - – Lecture 20
  - » Hosts can do it – end-to-end *Transport protocols*
    - – TCP performs end-to-end retransmission of lost packets to give the illusion of a reliable underlying network.

  (Lectures 16—19)

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Using Networks

- Layering and abstraction
  - » Protocol stacks failicate re-use
  - » Hide underlying complexity from the programmer
  - » (Lecture 3)
  - » Protocol reuse *and* code/library reuse
- Tomorrow's lecture: Programmer API
- Many "human-friendly" abstractions:
  - » Higher-level protocols (e.g., reuse the Web's HTTP instead of writing your own!).
  - » Naming (www.google.com vs. 64.233.161.99)
    - – The Domain Name System, or DNS (Lecture 13)

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Using Networks *Securely*

- The Internet is an unfriendly place
  - » Hacking, viruses, denial-of-service, etc.
- Cryptography to the rescue:
  - » Secure Sockets Layer (SSL) – https://www.foo.com/
  - » Key management, etc.
  - » Lecture 25
- Policy control to the rescue:
  - » Firewalls / Denial of Service (Lecture 26)
  - » Network address translation / virtual private networks (NAT, VPN) – Lecture 14

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Applications

- All well and good to have networks that deliver packets, but what do we actually *do* with them?
- The Web (Lecture 23)
- Peer to Peer (Lecture 24)
- Funky research stuff (Lecture 27)
- Class Projects (…)
  - » Remember, get started early. ☺

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