15-441 Computer Networking

Lecture 1 – Introduction

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
  - An HTTP server
  - A peer-to-peer file sharing system
- Understanding about network internals in a hands-on way – you'll implement:
  - Routing protocols
  - TCP-style congestion control/reliability

Course Goals

- At the end of the class you should be able to…

1. Explain all the events that occur to deliver a Web page to your browser
2. Design/build complex messaging protocols between nodes of a networked system
    - Address security, economic, scalability, fault-tolerance, performance, etc.
1. Build/manage/diagnose networks

Today's Lecture

- Administrivia
- Whirlwind tour of networking

Instructors

- Instructors.
  - Srini Seshan
    - srini@cs.cmu.edu, Gates Hall 8123
  - Roger Dannenberg
    - rbd@cs.cmu.edu, Gates Hall 7003
- Teaching assistants.
  - Athula Balachandran
  - Wolfgang Ricther
  - TBD
- staff-441@cs.cmu.edu → course staff
  - Please use this instead of emailing just one of us!

Course Format

- ~30 lectures
  - Cover the "principles and practice"
  - Complete readings before lecture
- 4 homework assignments
  - "Paper": Do you understand and can you apply the material?
  - "Lab": Illustrate networking concepts
  - Loosely tied to lecture materials
  - Teach networking concepts/tools
- 3 programming projects
  - How to use and build networks / networked applications
  - Application-layer programming; include key ideas from kernel
  - Larger, open-ended group projects. **Start early!**
- Midterm and final
  - Covers each of the above 3 parts of class

Recitation Sections

- Key 441 objective: system programming
- Different from what you've done before!
  - Low level (C)
  - Often designed to run indefinitely. Handle all errors!
  - Must be secure
  - Interfaces specified by documented protocols
  - Concurrency involved (inter and intra-machine)
  - Must have good test methods
- Recitations address this
  - "A system hackers' view of software engineering"
  - *Practical* techniques designed to save you time & pain!

Administrative Stuff

- Watch the course web page
  - http://www.cs.cmu.edu/~srini/15-441/F11/index.html
  - Handouts, readings, ..
- Read bboards
  - **academic.cs.15-441[.announce]** for official announcements
  - **cyrus.academic.cs.15-441.discuss** for questions/answers
- Office hours posted on web page
  - By appointment this week
- Course secretary
  - Angela Miller, Gates 9118

Grading

- Roughly equal weight in projects and testing
  - 45% for Project I, II and III
  - 15% for Midterm exam
  - 25% for Final exam
  - 15% for Homework
- You **MUST** demonstrate competence in both projects and tests to pass the course
  - Fail either and you fail the class!

Policy on Collaboration

- Working together is important
  - Discuss course material in general terms
  - Work together on program debugging, ..
  - Final submission must be your own work
    - Homeworks, midterm, final

- Projects: Solo (P1) + Teams of two (P2,P3)
  - Collaboration, group project skills
  - Both students should understand the entire project

- Web page has details

- Things we don't want to have to say: We run projects through several cheat-checkers against all previously and concurrently handed in versions…

Late Work and Regrading

- Late work will receive a 15% penalty/day
  - No assignment can be more than 2 days late
  - No penalty for a limited number of handins - see web page
  - Only exception is documented illness and family emergencies
- Requests for regrading must be submitted in writing to course secretary within 2 weeks.
  - Regrading will be done by original grader
- No assignments with a “short fuse”
  - Homeworks: ~1-2 weeks
  - Projects: ~5 weeks
  - Start on time!
  - Every year some students discover that a 5 week project cannot be completed in a week

This Week

- Intro – what's this all about?
- Protocol stacks and layering
- Recitations start this week: Socket programming (213 review++)

- On to the good stuff…Whirlwind tour of networking
  - Low-level (physical, link, circuits, etc.)
  - Internet core concepts (addressing, routing, TCP, DNS)
  - Advanced topics

What is the Objective of Networking?

- Enable communication between applications on different computers
  - Web (Lecture 22)
  - Peer to Peer (Lecture 23)
  - Audio/Video (Lecture 20)
  - Funky research stuff (Lecture 27)

- Must understand application needs/demands (Lecture 3)
  - Traffic data rate
  - Traffic pattern (bursty or constant bit rate)
  - Traffic target (multipoint or single destination, mobile or fixed)
  - Delay sensitivity
  - Loss sensitivity

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, …
- Class focuses on Internet, but explores important common issues and challenges

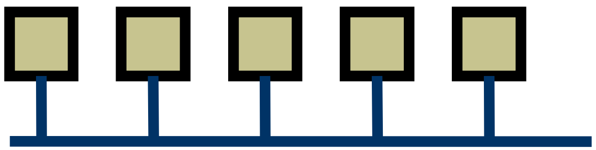
How to Draw a Network

Basic Building Block: Links

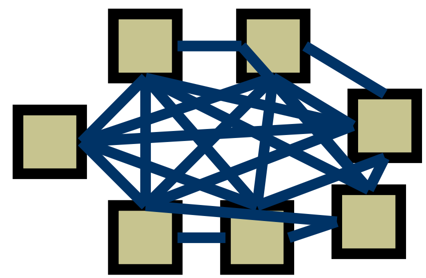
- Electrical questions
  - Voltage, frequency, …
  - Wired or wireless?
- Link-layer issues: How to send data?
  - When to talk – can either side talk at once?
  - What to say – low-level format?
  - Lecture 5
- Okay… what about more nodes?

Basic Building Block: Links

- … But what if we want more hosts? (Lectures 6 & 7)



One wire



Wires for everybody!

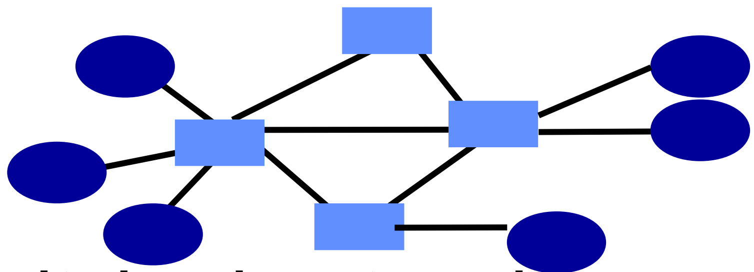
- Scalability?!

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 6)
  - Token ring, FDDI
  - 802.11 wireless (Lecture 25)

Multiplexing

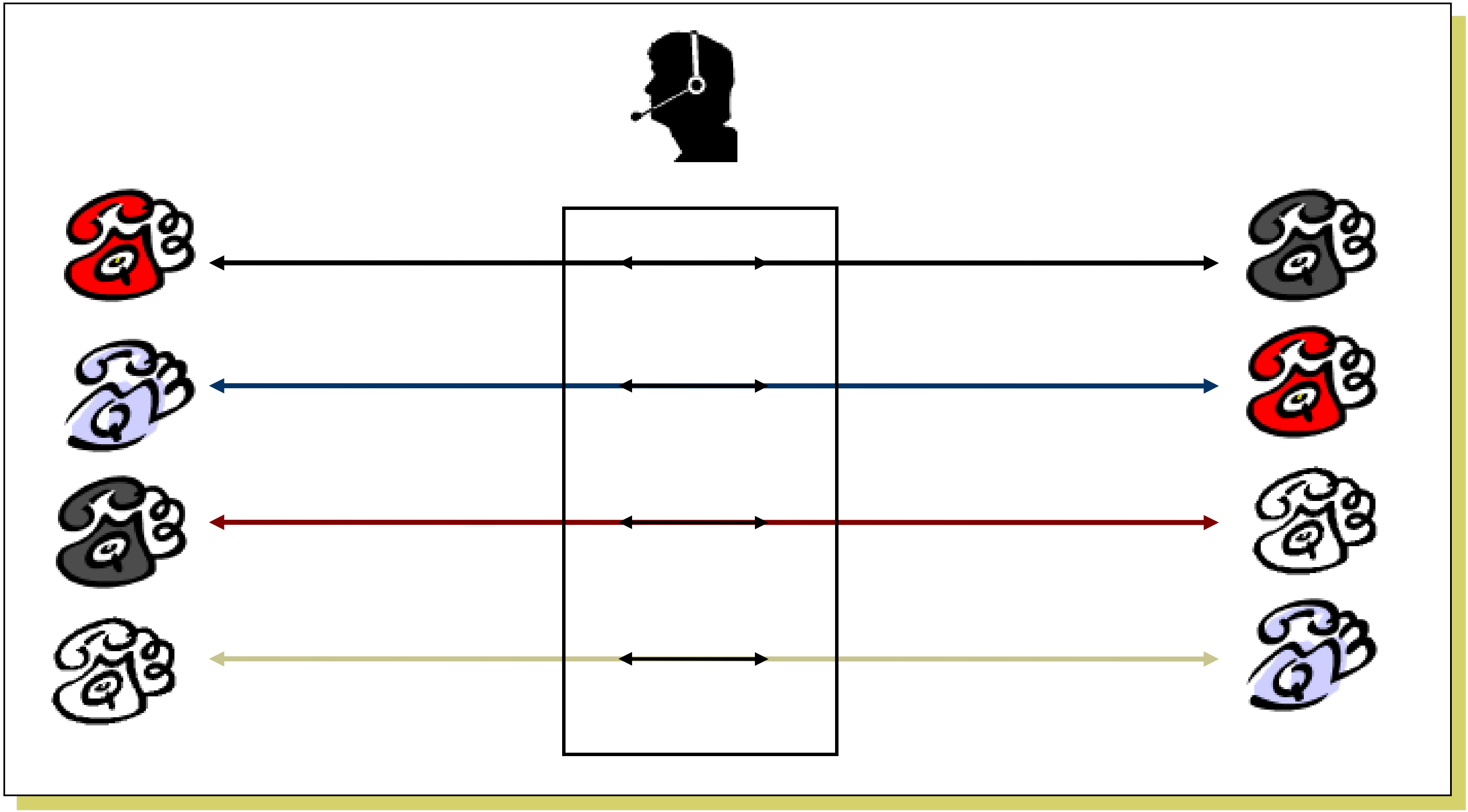
- Need to share network resources



- How? Switched network
  - Party “A” gets resources sometimes
  - Party “B” gets them sometimes
- Interior nodes act as “Switches”

- What mechanisms to share resources?

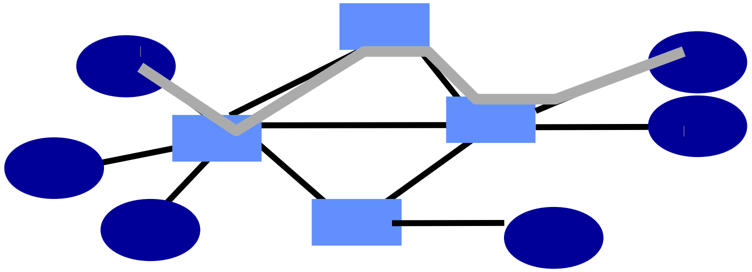
Back in the Old Days…



Circuit Switching

- Source first establishes a connection (circuit) to the destination
  - Each switch along the way stores info about connection (and possibly allocates resources)
- Source sends the data over the circuit
  - No need to include the destination address with the data since the switches know the path
- The connection is explicitly torn down

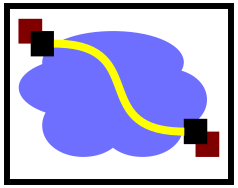
- Example: telephone network (analog)



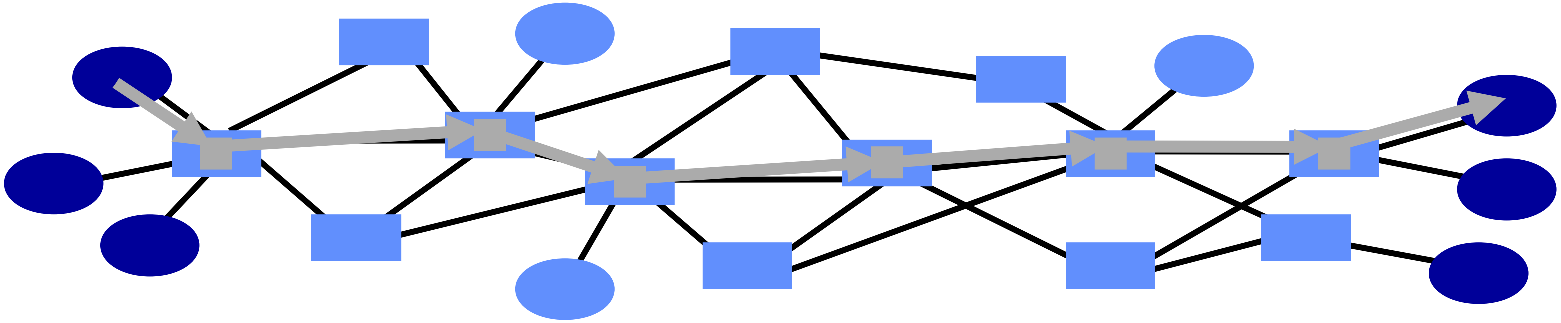
Circuit Switching Discussion

- 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.

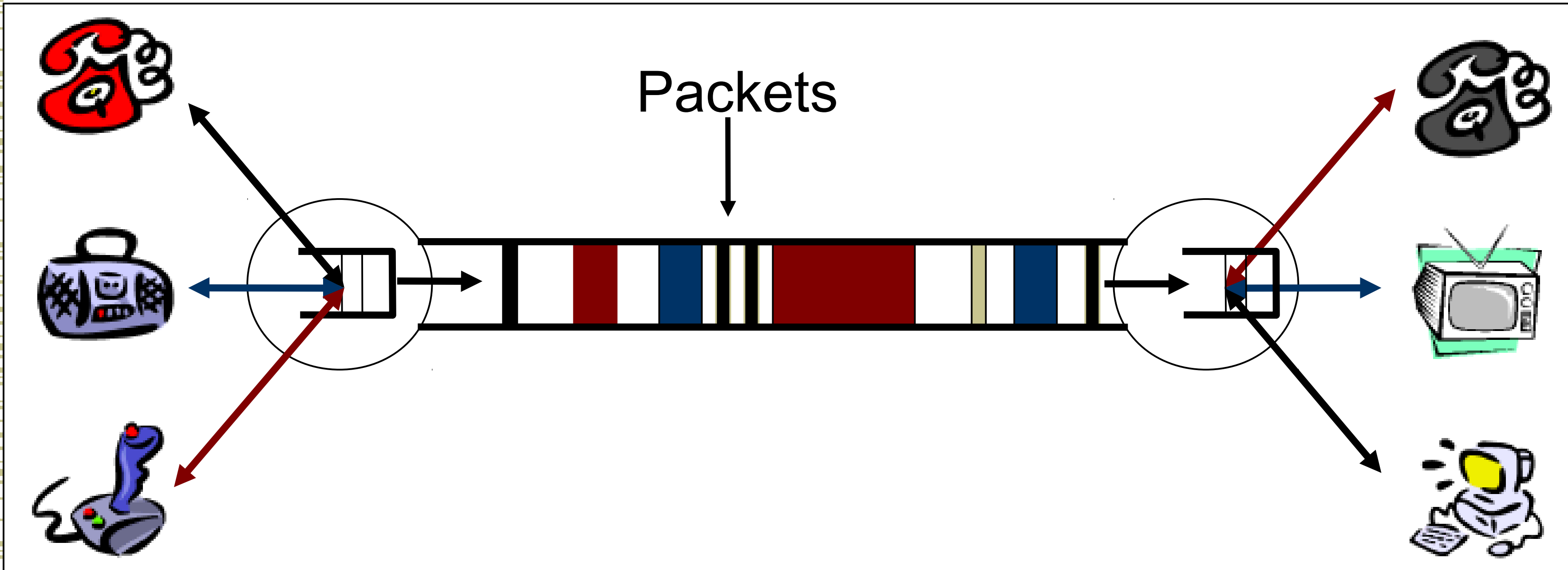
Packet Switching (our emphasis)



- 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.
  - Switches use the address in the packet to determine how to forward the packets
  - Store and forward
- Analogy: a letter in surface mail.



Packet Switching – Statistical Multiplexing



- Switches arbitrate between inputs
- Can send from *any* input that's ready
  - Links never idle when traffic to send
  - (Efficiency!)

Packet Switching Discussion

- Efficient
  - Can send from any input that is ready
- General
  - Multiple types of applications
- Accommodates bursty traffic
  - Addition of queues
- Store and forward
  - Packets are self contained units
  - Can use alternate paths – reordering
- Contention (i.e. no isolation)
  - Congestion
  - Delay

Networks Juggle Many Goals

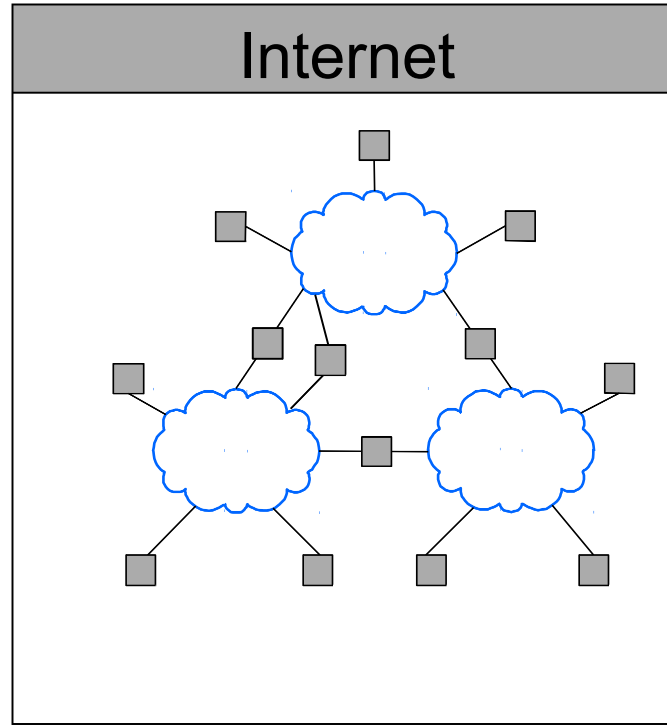
- Efficiency – resource use; cost
- The "ilities":
  - Evolvability
  - Managability
  - Security (securability, if you must)
  - Ease of:
    - Creation
    - Deployment
    - Creating useful applications
  - Scalability

Challenges for Networks

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

Internet

- An inter-net: a network of networks.
  - 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)
  - About 17,000 different networks make up the Internet



Challenges of the Internet

- Heterogeneity
  - Address formats
  - Performance – bandwidth/latency
  - Packet size
  - Loss rate/pattern/handling
  - Routing
  - Diverse network technologies → satellite links, cellular links, carrier pigeons

Challenges of the Internet

- Scale
  - 100,000,000s of hosts
  - 17,000+ administrative domains,
  - Thousands of applications
- Adversarial environment
- Oh, and let's make it easy to use…

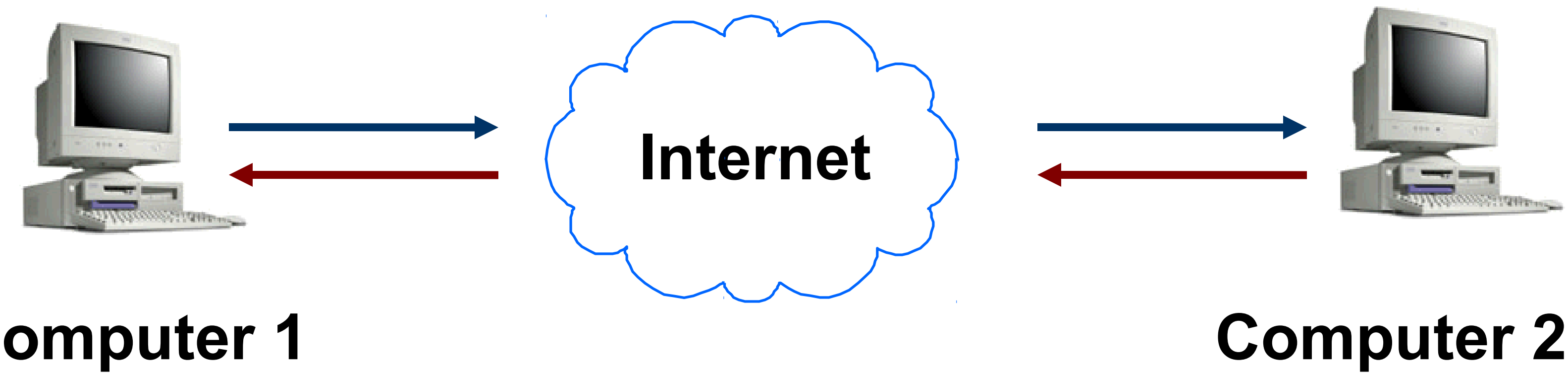
- How to translate between various network technologies?

Internet Design

- In order to inter-operate, all participating networks have to follow a common set of rules

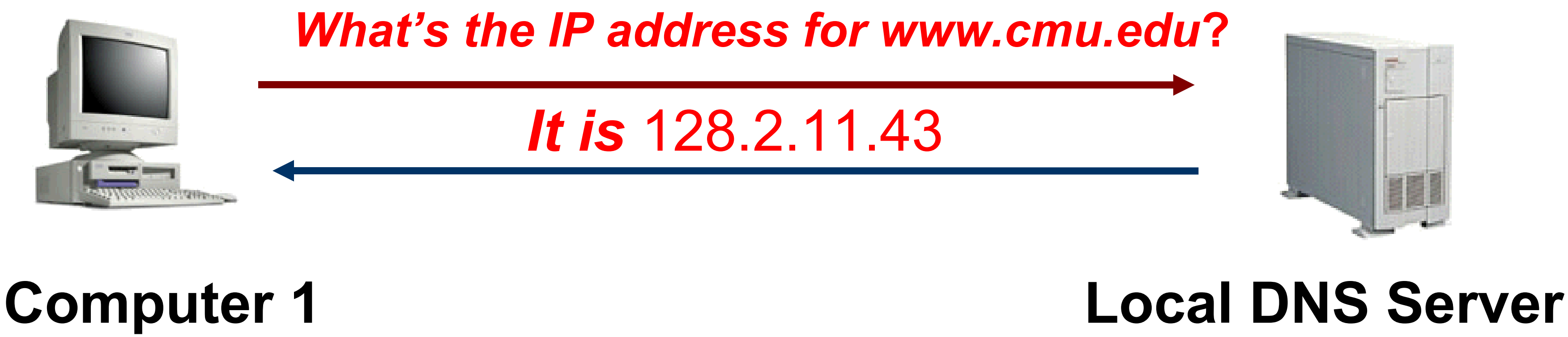
- E.g., requirements for packets:
  - Header information: Addresses, etc. (Lecture 9)
  - Data. What is packet size limit? (Lectures 5—9)

How To Find Nodes?



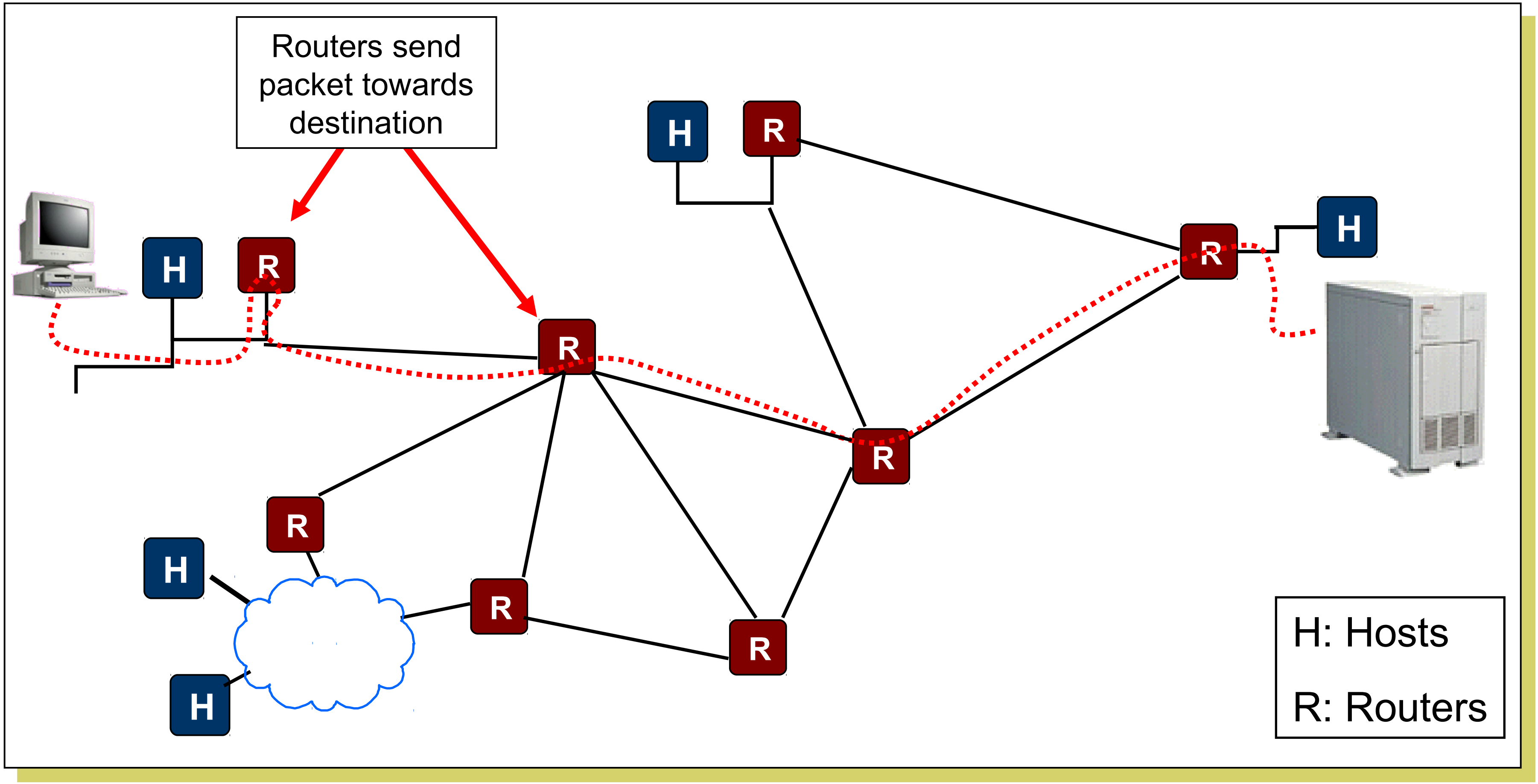
Need naming and routing
Lectures 8-13

Naming



Translates human readable names to logical endpoints

Routing


Routers send packet towards destination
H
R
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R
H
H: Hosts
R: Routers

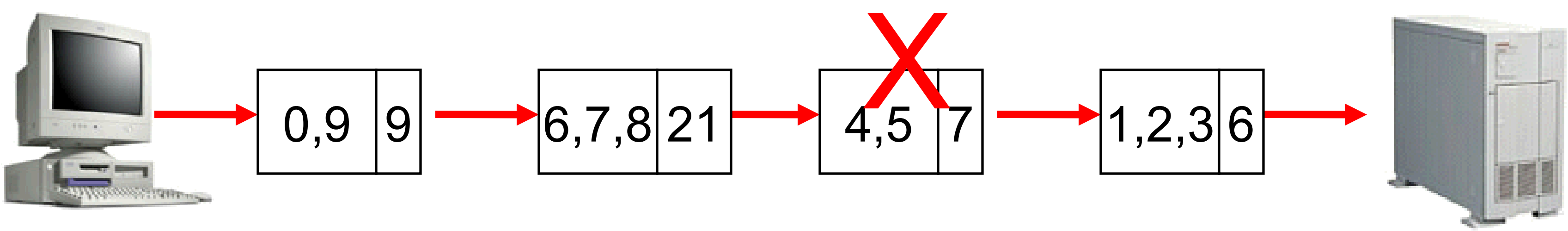
Network Service Model

- What is the *service model?*
  - Ethernet/Internet: *best-effort* – packets can get lost, etc.
- What if you want more?
  - Performance guarantees (QoS)
  - Reliability
    - Corruption
    - Lost packets
  - Flow and congestion control
  - Fragmentation
  - In-order delivery
  - Etc…

What if the Data gets Corrupted?

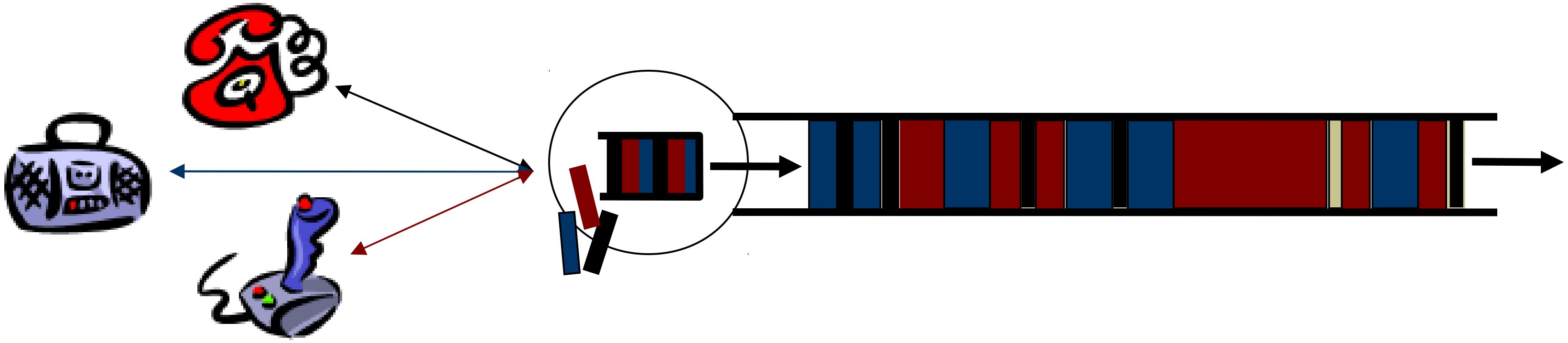
Problem: Data Corruption

Solution: Add a *checksum*



What if Network is Overloaded?

Problem: Network Overload



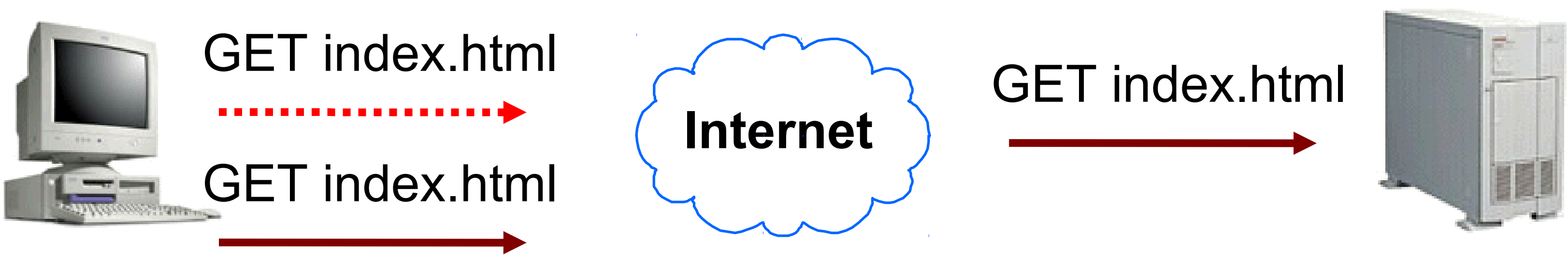
Solution: Buffering and Congestion Control

- Short bursts: buffer
- What if buffer overflows?
  - Packets dropped
  - Sender adjusts rate until load = resources → "congestion control"

What if the Data gets Lost?

Problem: Lost Data

Solution: Timeout and Retransmit

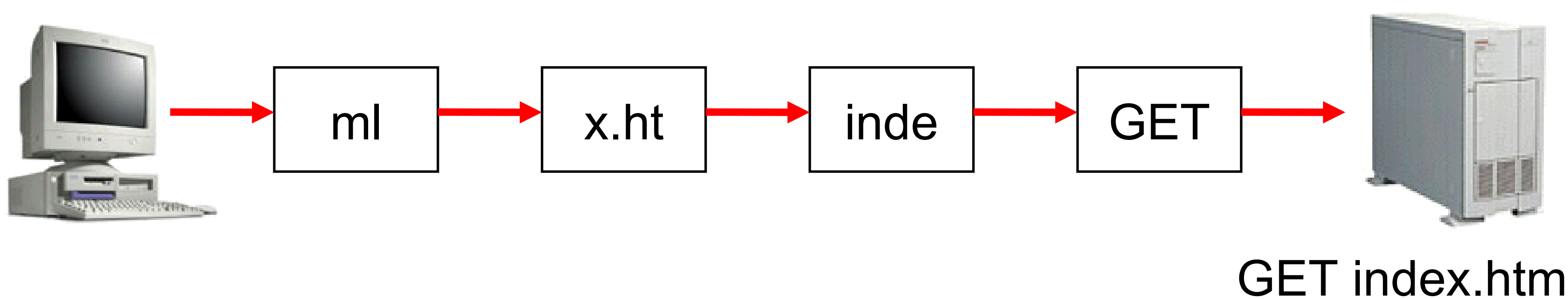


What if the Data Doesn't Fit?

Problem: Packet size

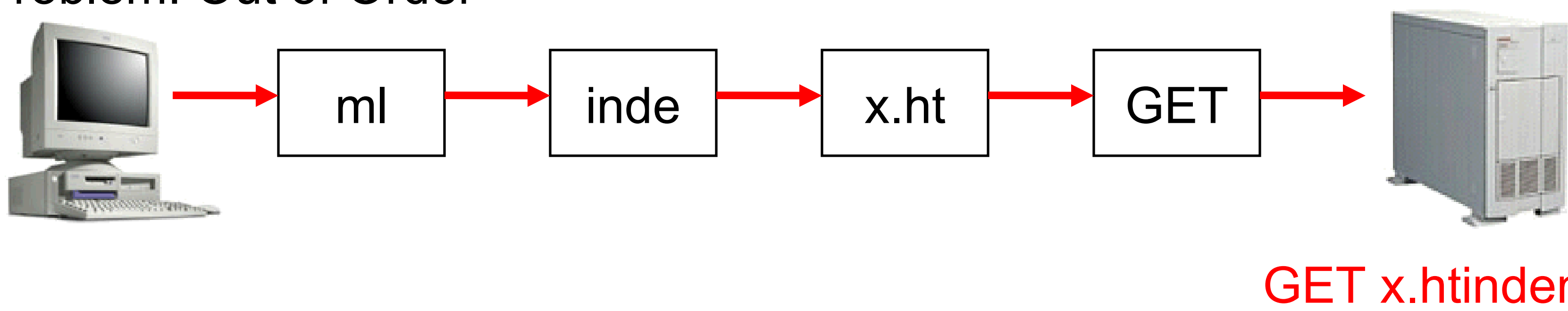
- On Ethernet, max IP packet is 1.5kbytes
- Typical web page is 10kbytes

Solution: Fragment data across packets

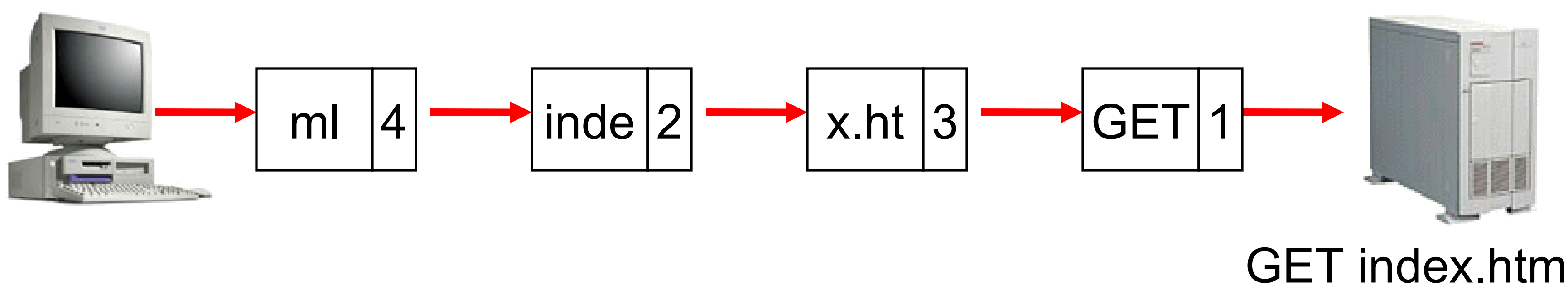


What if the Data is Out of Order?

Problem: Out of Order



Solution: Add Sequence Numbers



Networks [including end points] Implement Many Functions

- Link
- Multiplexing
- Routing
- Addressing/naming (locating peers)
- Reliability
- Flow control
- Fragmentation
- Etc….

Meeting Application Demands

- Sometimes interior of the network can do it
  - E.g., Quality of Service
    - Benefits of circuit switching in packet-switched net
    - Hard in the Internet, easy in restricted contexts
    - Lecture 21
- OR hosts can do it
  - E.g., 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

Next Lecture

- How to determine split of functionality
  - Across protocol layers
  - Across network nodes
- Read two papers on the motivations for the Internet architecture:
  - “The design philosophy of the DARPA Internet Protocols”, Dave Clark, SIGCOMM 88
  - “End-to-end arguments in system design”, Saltzer, Reed, and Clark, ACM Transactions on Computer Systems, November 1984