18-441/741: Computer Networks

Lecture 1: Course Overview

Swarun Kumar

Course Overview

- **Administrivia**
  - Objective
  - People, course communications
  - Grading, course policies
- Why are networks important?
- A whirlwind tour of the course

Instructors

- Instructor
  - Swarun Kumar
  - swarun@cmu.edu
  - Office hours: 5-6 pm Mondays (Over zoom)
- Teaching Assistants
  - Atul Bansal, Joel Miller and Junbo Zhang
  - [atulb, jgmiller, junboz2]@andrew.cmu.edu
  - Office hours: Atul: 5-6 pm Fridays, Joel: 7-8 pm Tuesdays, Junbo: 4:30-5:30 pm Thursdays (Over zoom)
- Check canvas for zoom links

Hybrid Mode

- All lectures, office hours will be remote over zoom
- All recitations will be hybrid (schedule on canvas)
  - Recitations will be offered both over zoom & in-person at WEH7500
  - Room capacity of WEH7500 is 38
  - Last names starting between A-L can attend odd numbered recitations, others even numbered recitations
  - You are permitted to attend any/all recitations remotely
- Zoom links available on canvas

Course Goals

- Become familiar with the principles and practice of data networking
  - Routing, transport protocols, naming, …
- Learn how to write applications that use network
  - Use web and peer-to-peer style applications
- Get hands-on understanding of network internals
  - Implementing different types of protocol, error recovery, conformance with standards, etc.

Course Materials

- Textbook: Computer Networks – A Systems Approach, L. Peterson and B. Davie, Morgan Kaufmann
- References
  - Computer Networking – A Top-Down Approach, by J. Kurose and K. Ross, Addison Wesley
  - Computer Networks, Wetherall and Tanenbaum
  - Communication Networks, by A. Leon-Garcia and I. Widjaja, , Second edition, McGraw-Hill.
  - Data and Computer Communications, W. Stalling, MacMillan Publishing Company, New York.

Course Format

- ~24 lectures, 1.5 hrs each
  - Cover the "principles and practice"
- 3 programming projects
  - How to use and build networks / networked applications
  - Open-ended individual projects. *Start early!*
- 5 online quizzes (canvas)
  - Not timed + open book & Internet (no collaboration)
- Midterm and final
  - Two 110-min quizzes on canvas
  - Will be timed and open book & Internet (no collaboration)

Getting Questions Answered

- Administrative: start with canvas
  - If the answer is not there, please send us e-mail
- Course material: class, office hours, piazza
  - Typically requires a discussion – e-mail often does not work well
- Projects: piazza, office hours
  - Piazza: others might have the same question
  - Office hours for more complicated issues

Projects and Recitation Sections

- Key objective: system programming
- Different from what you've done before!
  - Project 1 – MATLAB (recommended)
  - Project 2/3 – Can use C/C++ or Java
  - May run indefinitely – must handle all errors!
  - Interfaces specified by documented protocols
  - Concurrency involved (inter and intra-machine)
  - Must have good test methods
- Recitations to provide project background, discuss programming tools and skills
  - First recitation: Feb 12

Administrative Stuff

- Watch the course canvas website
  - **All** handouts, readings, project information, ..
  - If something is missing, please let us know ASAP
- Post questions about lectures/project on piazza.
- Email instructor / TA with questions about grades, etc.

Grading

- Grading:
  - 20% for quizzes
  - 30% for projects (bonus problems – 18-741)
  - 50% for two exams
- Cutoff:
  - >90% or > mean + std - A
  - 70-90% or > mean – std - B
  - 50-70% or > mean – 2*std - C
  - 40-50% - D
  - Else fail
- 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
  - Final submission must be your own work
- What we don't want to have to say: we run all projects through cheat-checkers
- All cases of cheating will be reported

Policy on Late Work, Re-grading

- Submit assignments on time
  - Only exception is **documented** illness and family emergencies
- Re-grading requests must be submitted in writing with secretary within 1 week
  - Entire exam or quiz will be re-graded
- Exam and Quiz coverage:
  - All materials right before the exam/quiz
  - Details will be on canvas

The Slides

- The slides are a resource that is shared by many instructors
  - Also some sharing with 15-441

- They include contributions from Peter Steenkiste, Hyong Kim, Srini Seshan, Dave Andersen, Hui Zhang, and others

Why take this course?

- If you need to build foundations on computer networks (for industry / gradschool / capstone project)
- If your interviewer asks: “How does TCP work?” or explain “What an IP address is?”
- Cool (individual) project: Build your own Netflix (-ish) from scratch.. Doable remotely + Get something you can show off to potential employers (academia/industry) later ☺
- 12 units means 12 units
- It’s a popular course (long waitlist even with ~ 2x capacity)

Course Overview

- Administrivia

- **Why are networks important?**

  - What is a network?

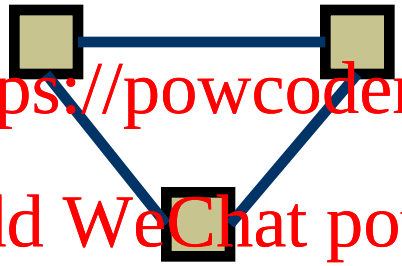
  - What is the Internet
  - Internet design

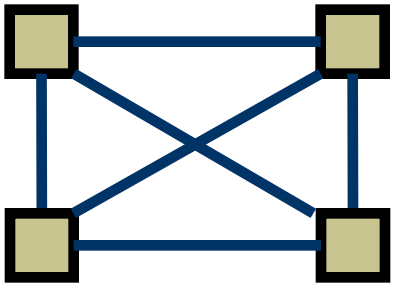
- A whirlwind tour of the course

What is a Network?

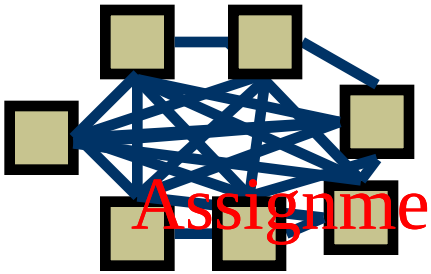
- An infrastructure that allows (distributed) "users" to communicate with each other
  - People, devices, …
  - By means of voice, video, text, …
- It is assumed that the infrastructure is shared by many users

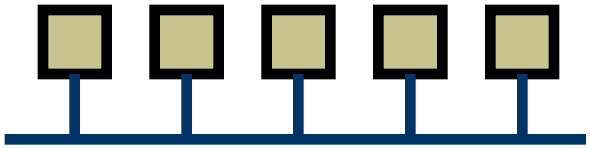
Basic Building Block: Links





Scaling the Network



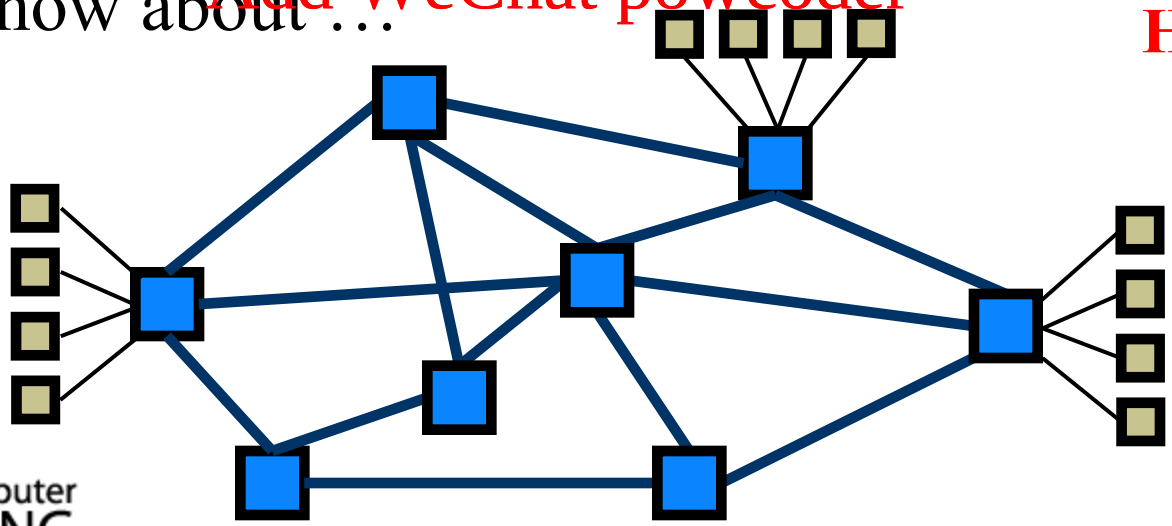


Or one wire

(N^2) Wires for everybody!

But First a bit of History

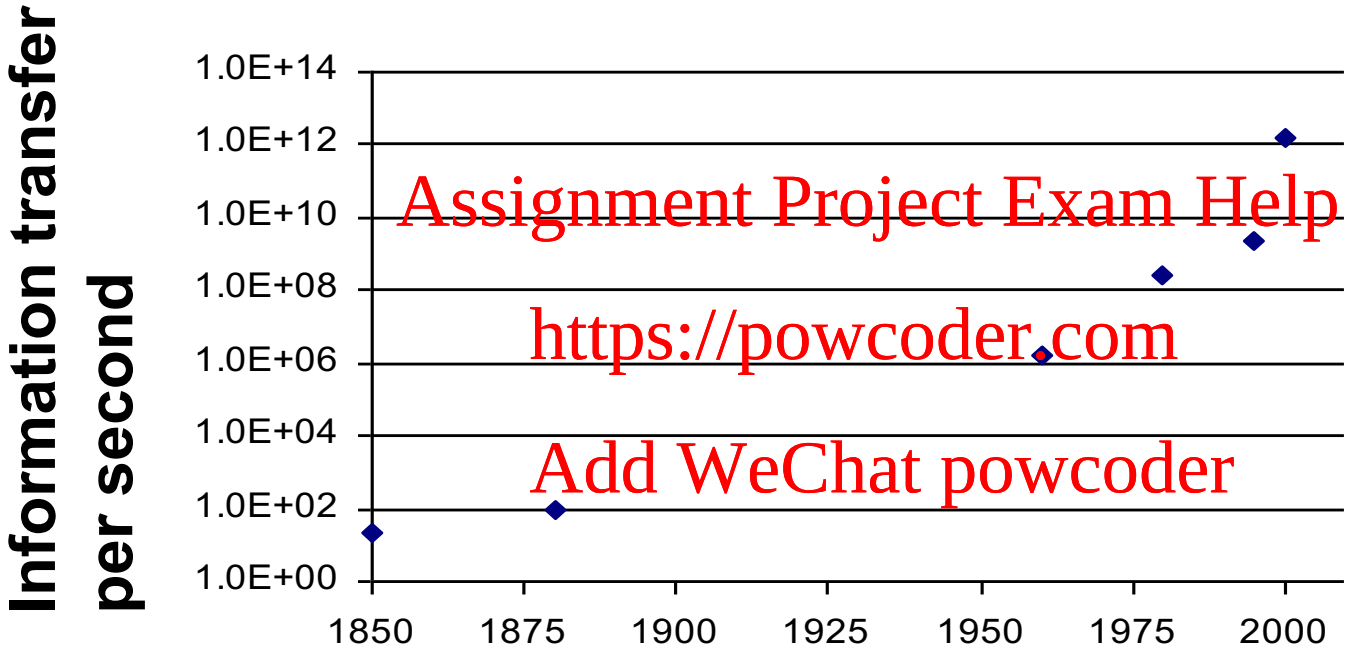
Or how about …



Network Architecture

Network architecture: the plan that specifies how the network is built and operated

Network Architecture Trends



?

Telegraph networks

Telephone networks

Internet, Optical & Wireless networks

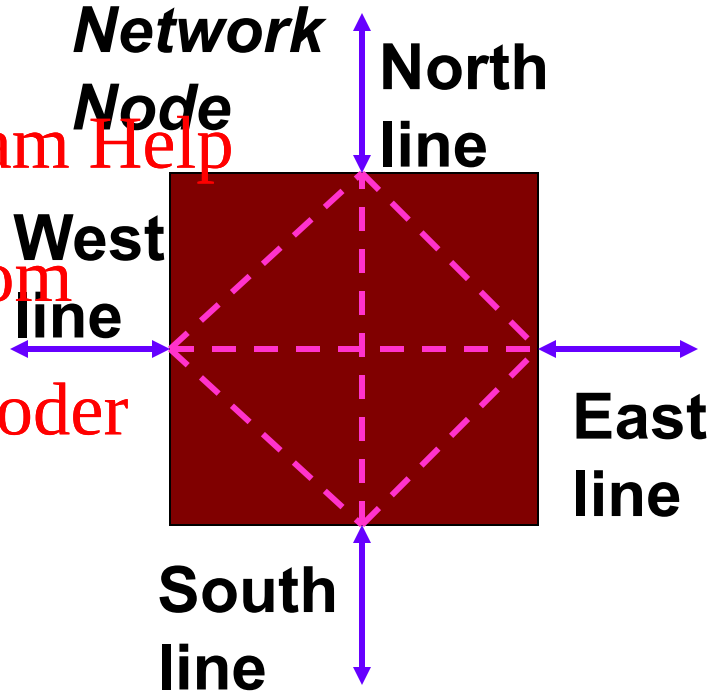
Next Generation Internet

Telegraphs & Long-Distance Message Communications

- Drumbeats … Courier … Telegraphs

Message Switching Architecture

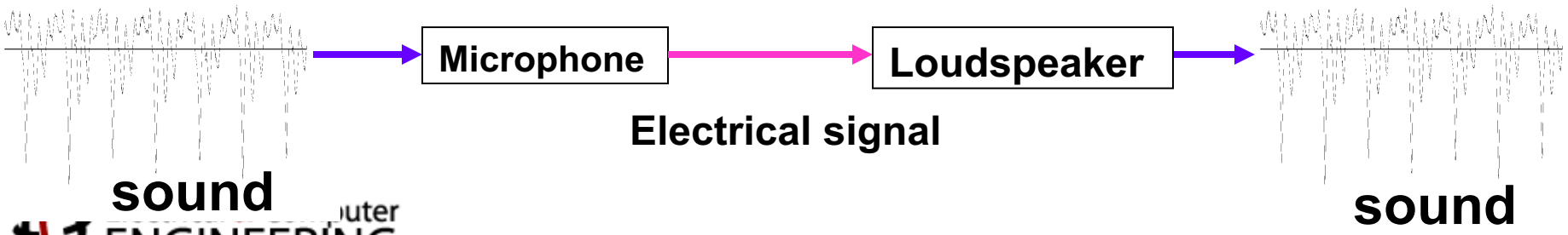
- Network nodes were created where several telegraph lines met (Paris and other sites)
- *Store-and-Forward Operation:*
  - Messages were decoded
  - Next-hop in ***route*** determined by destination ***address*** of a message
  - Each message was carried by hand to next line



Bell's Telephone

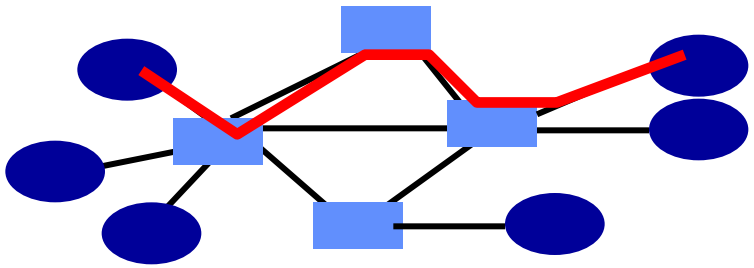
- Alexander Graham Bell (1875) working on harmonic telegraph to multiplex telegraph signals
- Discovered voice signals can be transmitted directly
  - Microphone converts voice pressure variation (sound) into *analogous* electrical signal
  - Loudspeaker converts electrical signal back into sound
- Bell Telephone Company founded in 1877

Signal for "ae" as in cat

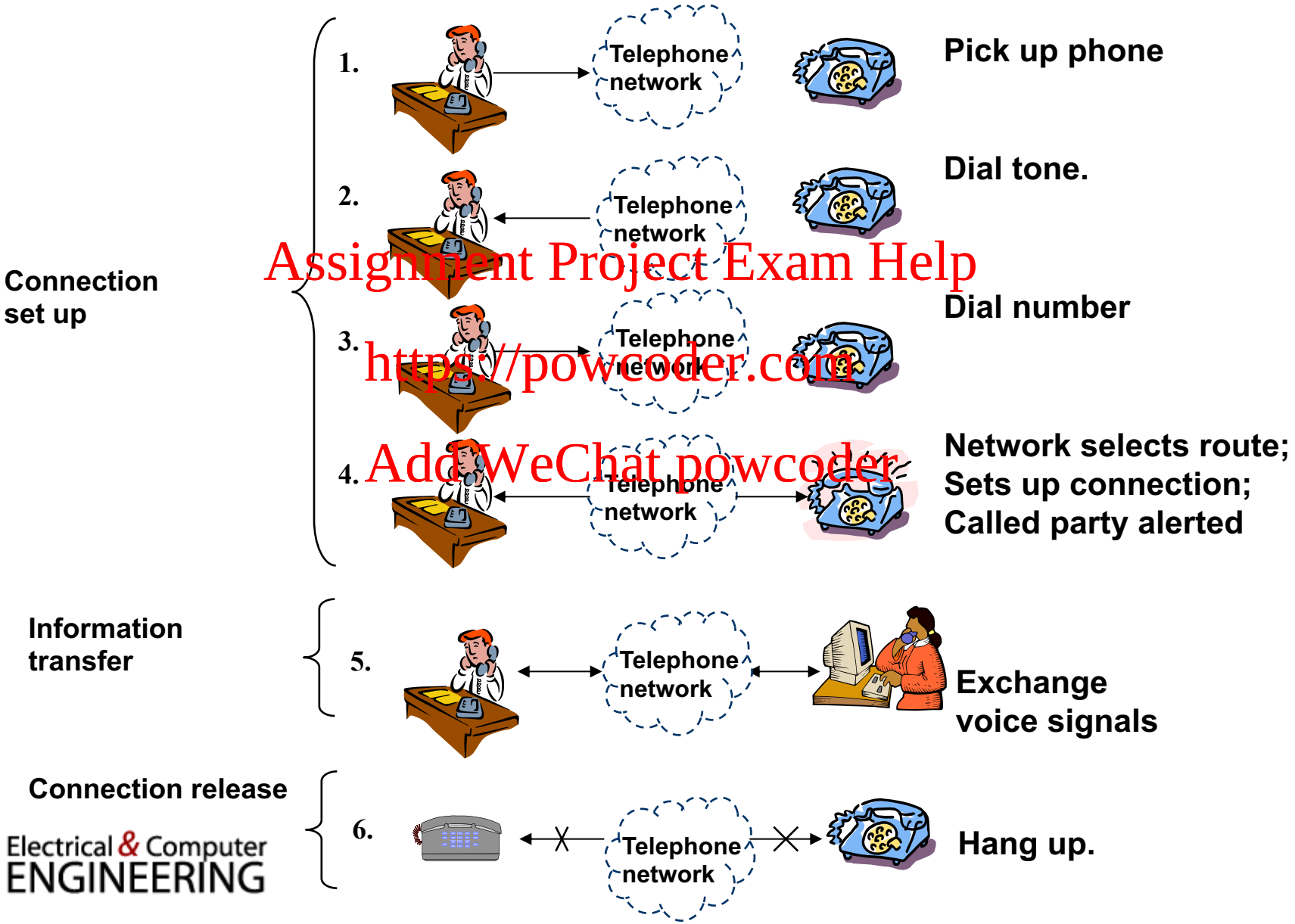


Circuit Switching (analog telephones)

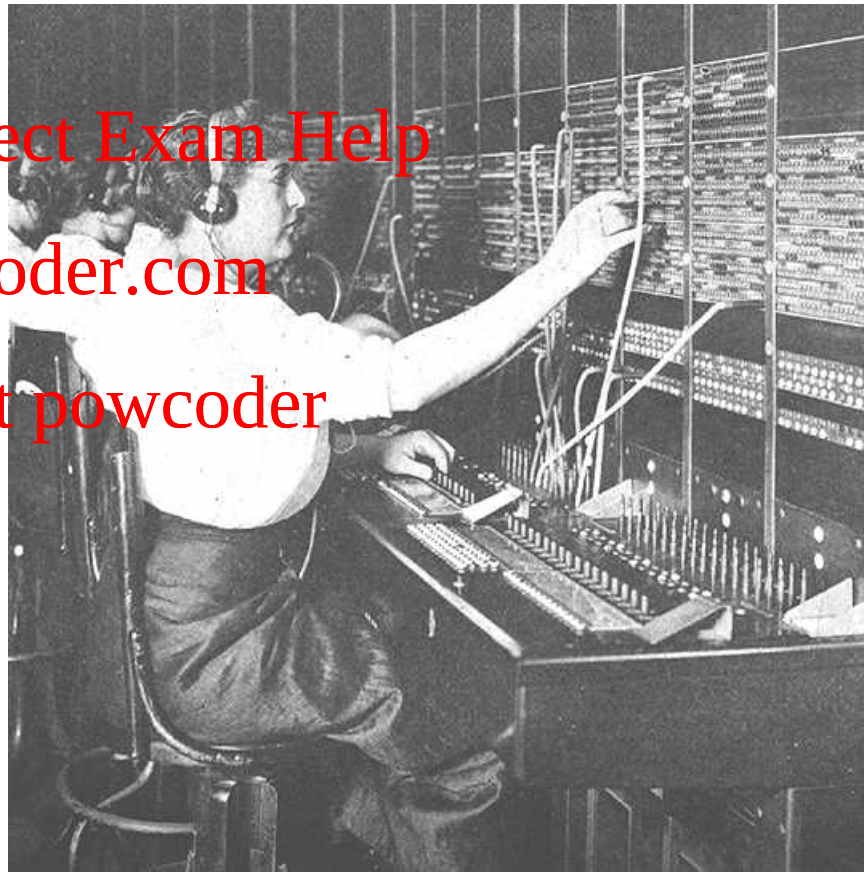
- Source first establishes a connection (circuit) to destination
  - Each switch along the way stores info about connection (and possibly allocates resources)
- Source sends the data over the circuit
  - No need to include the destination address with the data since the switches know the path
- The connection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



Three Phases of a Connection



Links and Switches in Early Telephone Networks

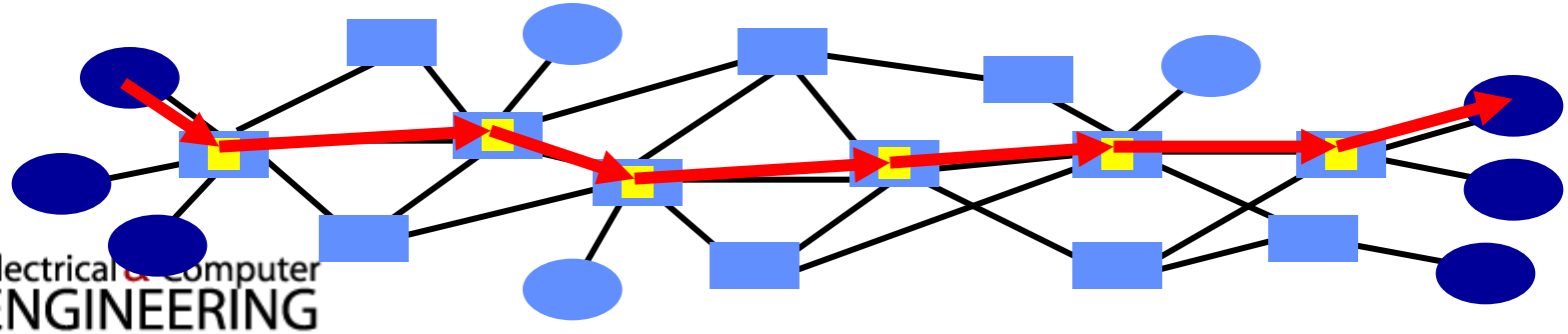


Circuit Switching Discussion

- Circuits have some very attractive properties.
  - Fast and simple data transfer, once the circuit is established
  - Predictable performance, i.e. guaranteed bandwidth
- But it also has some shortcomings.
  - How about bursty traffic?
    - Do you need a permanent circuit to Facebook?
    - Circuit will be idle for significant periods of time
  - How about users with different bandwidth needs?

Contrast this with the Internet, i.e. (Packet) Switching (our emphasis)

- Source sends information as self-contained messages that have an address.
  - Source may have to break up single message in multiple packets
- 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.



Sample Quiz Question!

- **Question:** "Now that VOIP (e.g. Skype audio, Whatsapp calls) is here, circuit-switched landline phones are obsolete and can be phased out". Do you agree or disagree with this statement? Justify.

React on Zoom:

- **Solution:** Not necessarily. Circuit switched networks do have reliable bandwidth – something that Skype, Whatsapp do not. It is debatable whether these networks will reach the kind of reliability that (say) 911 requires. As of today, they do not, although there are exceptions.

Today's Lecture

- Administrivia

- Why are networks important?

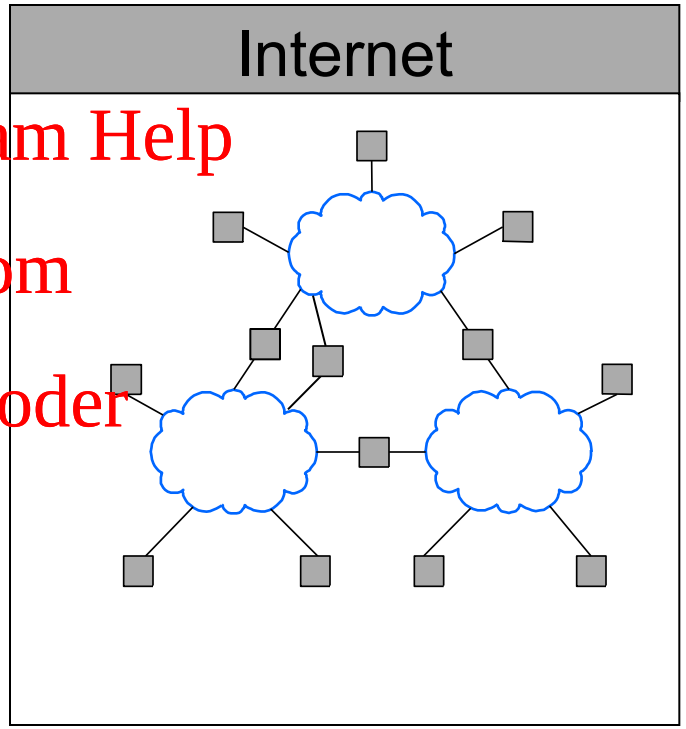
  - What is a network?
  - What is the Internet

  - Internet design

- A whirlwind tour of the course

What about the Internet

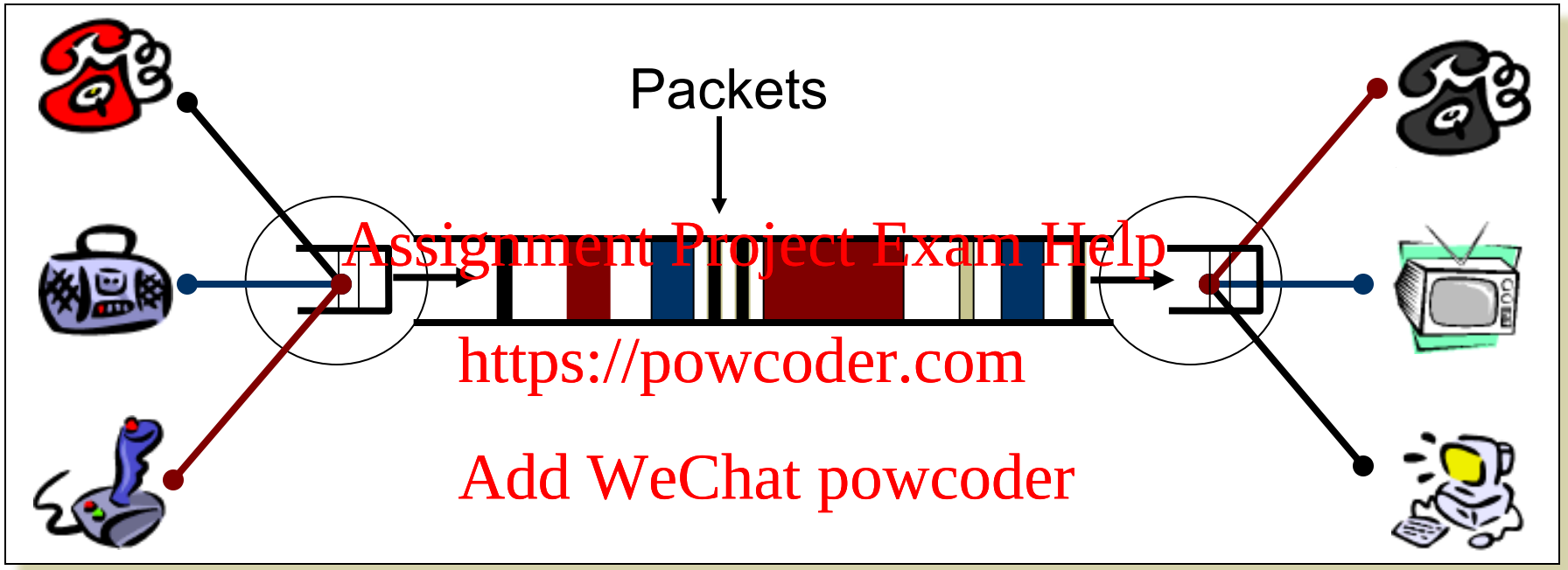
- inter-net: network of networks.
  - Networks are connected using routers and other devices, e.g., for security, accounting, …
  - Use diverse technologies
  - Managed by different cos.
- The Internet: the interconnected set of networks of the Internet Service Providers (ISPs)
  - About ~23,000 “transit” ISPs make up the Internet
  - Many more “edge” networks



What is the Objective of the Internet?

- Enable communication between diverse applications on diverse devices ("computers")
  - Web, peer-to-peer, video streaming, audio conferencing, …
- Over very diverse infrastructures: WiFi, cellular, data center networks, corporate networks, …
- In contrast: previous networks were special purpose and fairly homogeneous in terms of technology
- Must understand application needs/demands
  - Traffic data rate and loss sensitivity
  - Traffic pattern (bursty or constant bit rate)
  - Traffic target (multipoint or single destination, mobile or fixed)

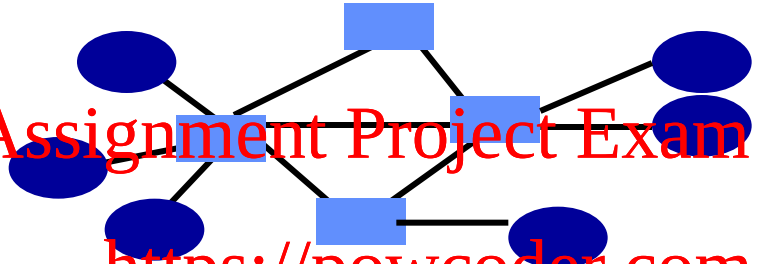
Packet Switching – Statistical Multiplexing



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

Multiplexing

- Need to share network resources



- How? Switched network
  - Party “A” gets resources sometimes
  - Party “B” gets them sometimes
- Interior nodes act as “Switches”
- Many challenges: fairness, efficiency, …

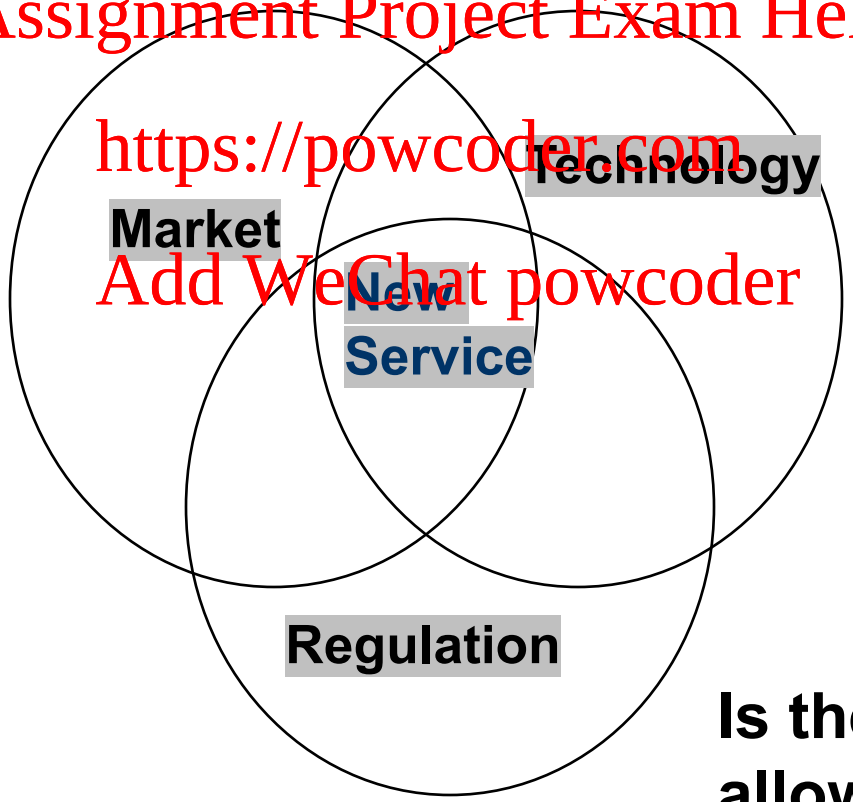
Internet Design

- In order to inter-operate, all participating networks must follow a common set of rules
- Example requirements for packets:
  - Address format, header information, packet size limit, ..
- Also: what is the "service model", i.e., the commitment made to applications
  - Internet: *best-effort* – packets can get lost, etc.
  - But some applications need reliable data delivery, a minimal bandwidth guarantee, low latency, …

Success Factors for New Services

- Technology not only factor in success of a new service
- Three factors considered in new telecom services

Can there be demand for the service?



Can it be implemented cost-effectively?

Is the service allowed?

Standards

- New technologies very costly and risky
- Standards allow players to share risk and benefits of a new market
  - Reduced cost of entry
  - Interoperability and network effect
  - Compete on innovation
  - Completing the value chain
    - Chips, systems, equipment vendors, service providers
- Example:
  - 802.11 LAN, IP, HTTP/SMTP/…

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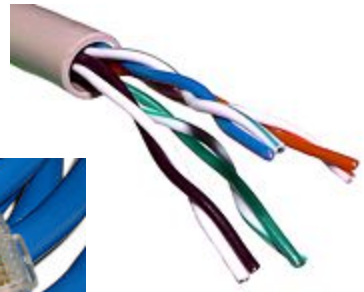
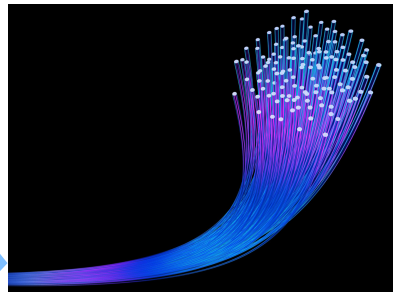
Whirlwind Tour of the Course

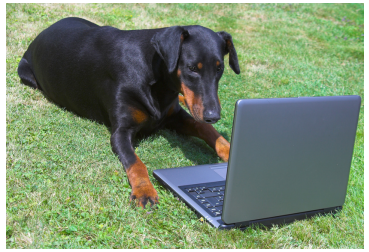
- Infrastructure: hardware (or close to it)
- Core networking protocols: IP, dealing with errors and congestion, routing, …
- Tools: caching, CDNs, SDNs, middleboxes, …
- Making it work well: security, management, …
- IP everywhere: the Internet, last mile, wireless, mobility, data center, video, IP-TV, skype, …
- Focus is on today's Internet but also trends
  - What will the Internet look like in 10, 20, 30 years?

Infrastructure

- Ethernet is very old, so why is it so fast?
  - Can't they find something better?
- Wireless: 2G, 3G, 4G and (now) 5G.. How's the speedup achieved?
- What are the limits of some of the technologies?
  - Both physical and protocol limits



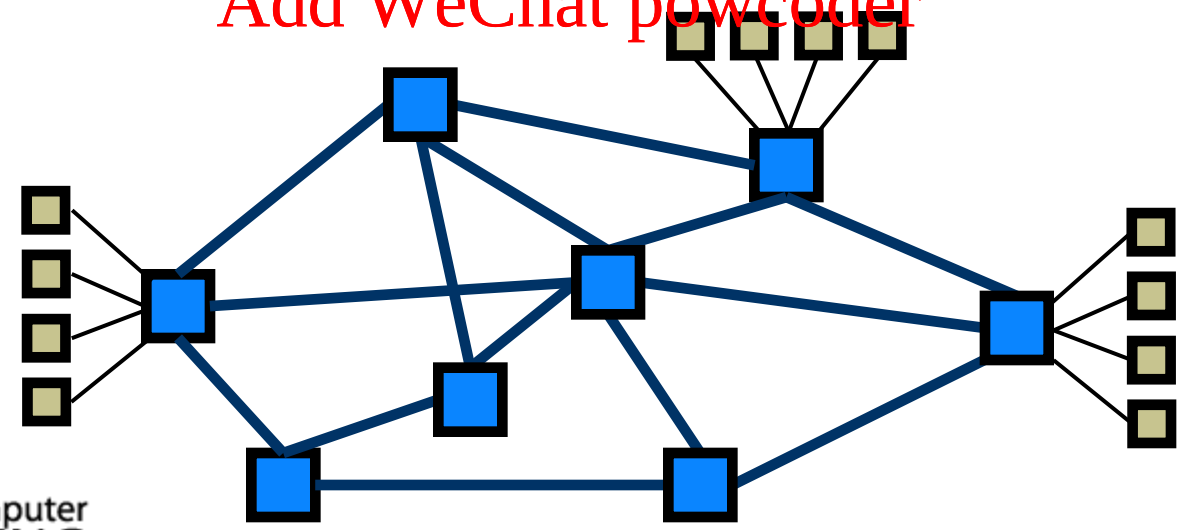




Core Networking Protocols

Think: traffic on the roads

- How do I found a path to my destination
- How do I specify addresses
- What if my car breaks down?
- How do I deal with traffic jams
- …



Optimizing Performance

- Intuitively: lots of bandwidth!
- But there is more to it:
  - Latency is often more critical!
  - How voice and video – can I offer guarantees?
  - Can I beat the speed of light?
    - Hint: this can make you rich
  - Why did we use peer to peer networks?
  - And why did they (mostly) go away?

Making the Network Work Well

- Good technology is only a small part of the puzzle – deployment and management issues are equally (or more) critical
  - Involves many people, high cost
- How do I secure my network?
  - Lots of bad guys: DOS, compromised hosts, privacy leaks, botnets, …
- How I manage resources, reduce operator errors, deal with failures, …
  - And how does it differ in LAN, WAN, wireless, …

IP Everywhere

- Using IP technology has become attractive
  - Cheap commodity hardware, lots of tools, people trained in the technology, end-to-end support, …
- The (public) Internet: our focus
  - How do you optimize "the web": CDNs, caching, …
- Data centers: very special requirements
  - Map-reduce, 3-tier business apps, load balancing, …
- IP TV, voice/video conferencing:
  - Very high QoE expectations
- Wireless and mobile apps
  - For many users, primary way of accessing Internet

Course Schedule (Bird's eye view)

- Feb-Mar: "The hardware", "The protocols"
  - Physical Layer
  - Data Link
  - Network
  - Transport
- April: "Making it work", "The use cases"
  - Software Defined Networking
  - Security
  - Future Internet

Next Lecture

Protocol Stack: an overview