18-441/741: Computer Networks

Lectu erview

Swarun Kumar

Course Overview

- **Administrivia**
  - Objective
  - People, course communications
  - Grading, c
- 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 A https://eduassistpro.github.io/
  - Atul Bansal, Joel Miller, Junbo Zhang
  - [atulb, jgmiller, junboz2]@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 wil & in-person at WEH7500
  - Room capacity of WEH7500 is
  - 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 use network
  - Use web and peer-to-peer cations
- 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 wn Approach, by J. Kurose an ley
  - Computer Networks, Wet 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 a rked applications
  - Open-ended
- 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 ma hours, piazza
  - Typically requires a di 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/ va
  - May run in all errors!
  - Interfaces specified by d protocols
  - Concurrency involved (in a-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 questi ject 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 > mea
  - 50-70% or > mea
  - 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 h y: we run all projects through cheat-c
- 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-gradin ubmitted in writing with secretary ek
  - Entire exam or quiz 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 contribution ter Steenkiste, Hyong Kim, Srini Seshan dersen, 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 ish) from scratch.. Doable remotely + Get something off to potential employers (academia/industry) late
- 12 units means 12 units
- It’s a popular course (long waitlist even with ~ 2x capacity)

Course Overview

- Administrivia

- **Why are ant?**

  - What is
  - What is the Internet

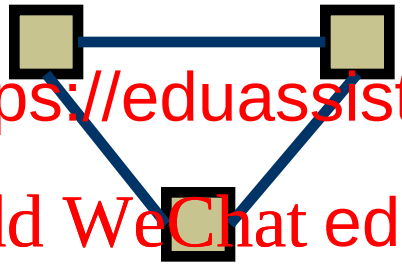
  - Internet design

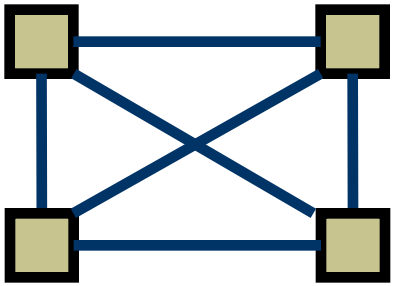
- A whirlwind tour of the course

What is a Network?

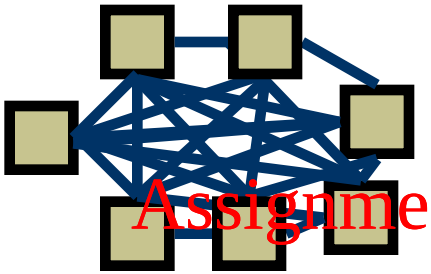
- An infrastructure that allows (distributed) "users" to communicate with each other
  - People, devices, …
  - By means , …
- It is assumed that the cture is shared by many users

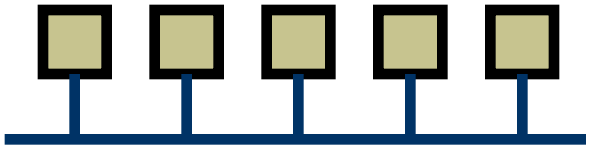
Basic Building Block: Links





Scaling the Network



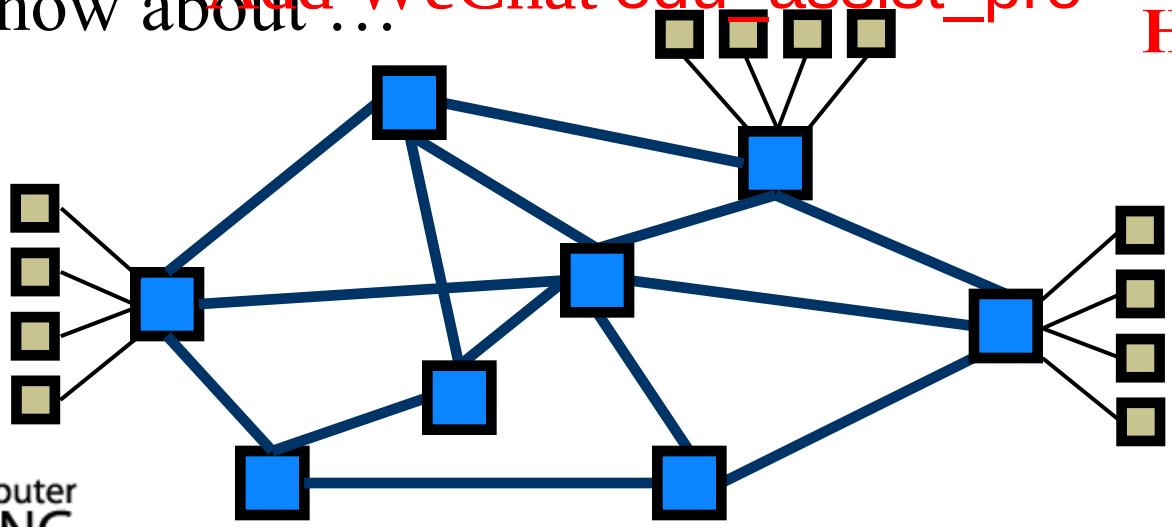


Or one wire

(N^2) Wires for

But First a bit of History

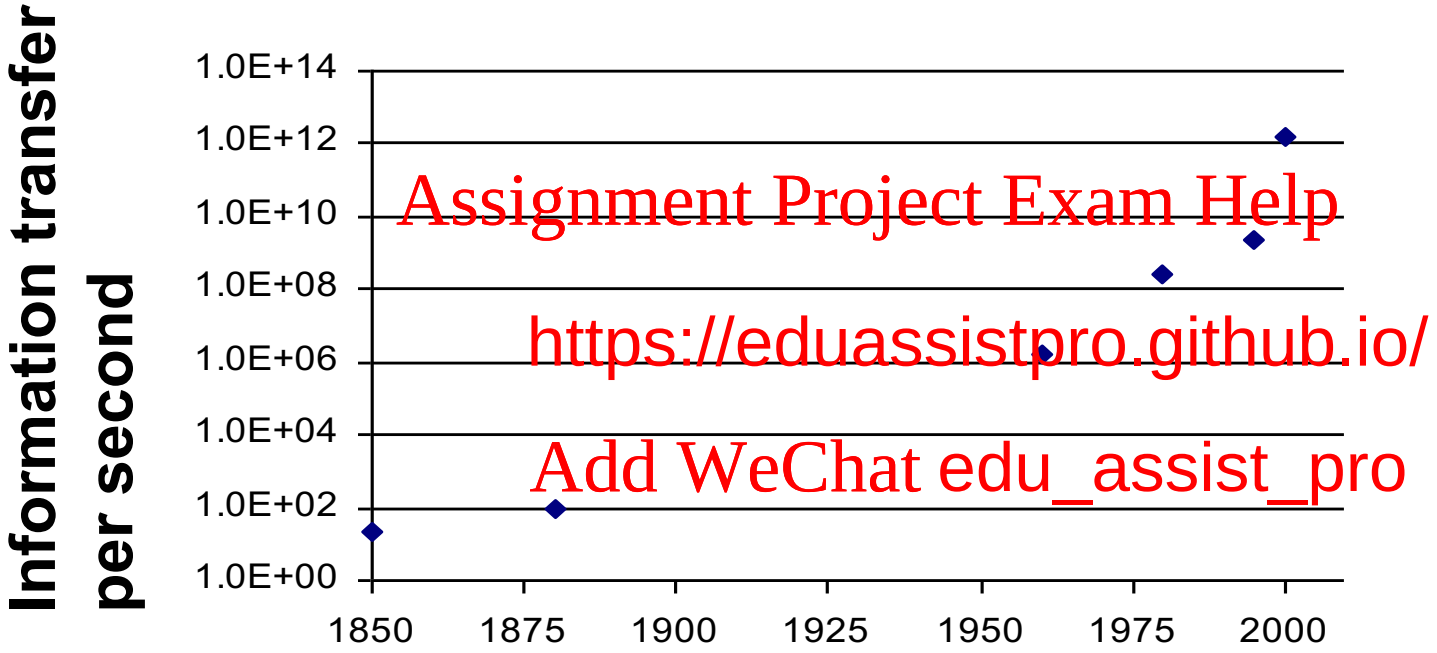
Or how about …



Network Architecture

Network archit specifies how the network is

Network Architecture Trends



?

Telegraph networks

Telephone networks

Internet, Optical & Wireless networks

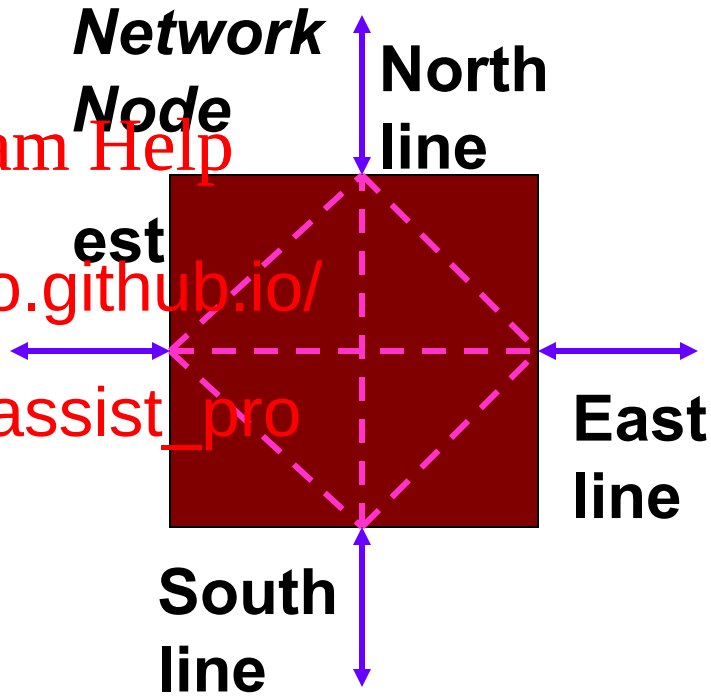
Next Generation Internet

Telegraphs & Long-Distance Message Communications

- Drumbeats … Courier … Telegraphs

Message Switching Architecture

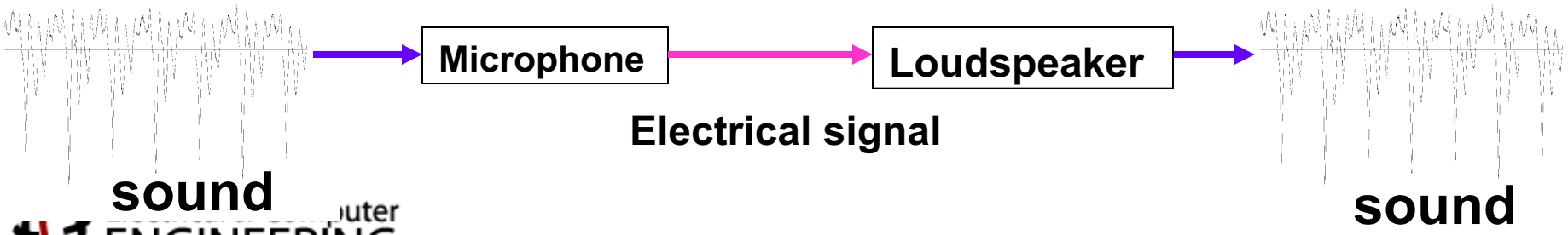
- Network nodes were created where several telegraph lines met (Paris and other sites)
- *Store-and-For*
  - Messages were decoded
  - Next-hop in ***route*** determine destination ***address*** of a message
  - Each message was carried by hand to next line



Bell's Telephone

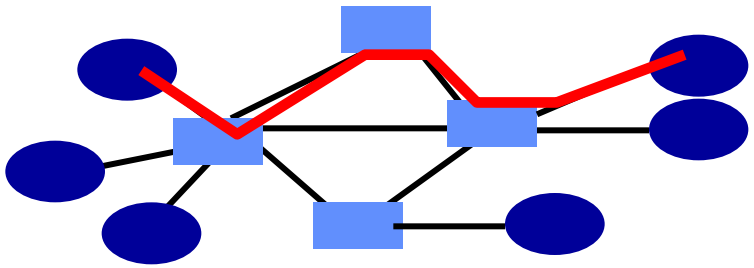
- Alexander Graham Bell (1875) working on harmonic telegraph to multiplex telegraph signals
- Discovered voice signals can be transmitted directly
  - Microphone converts voice pressure variation (sound) into *analog*
  - Loudspeaker converts analog signal back into sound
- Bell Telephone Company founded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

Signal for "ae" as in cat

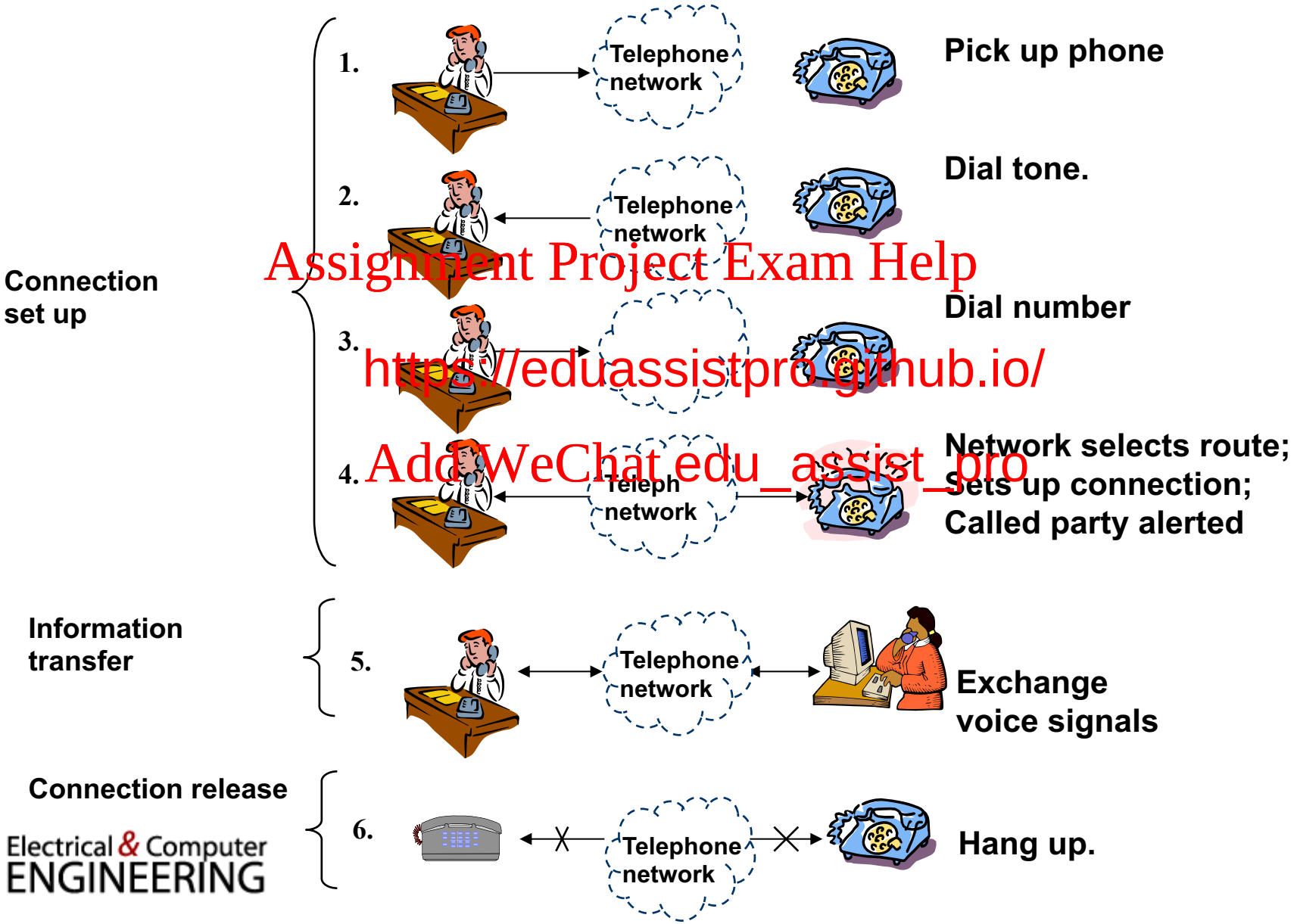


Circuit Switching (analog telephones)

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



Three Phases of a Connection



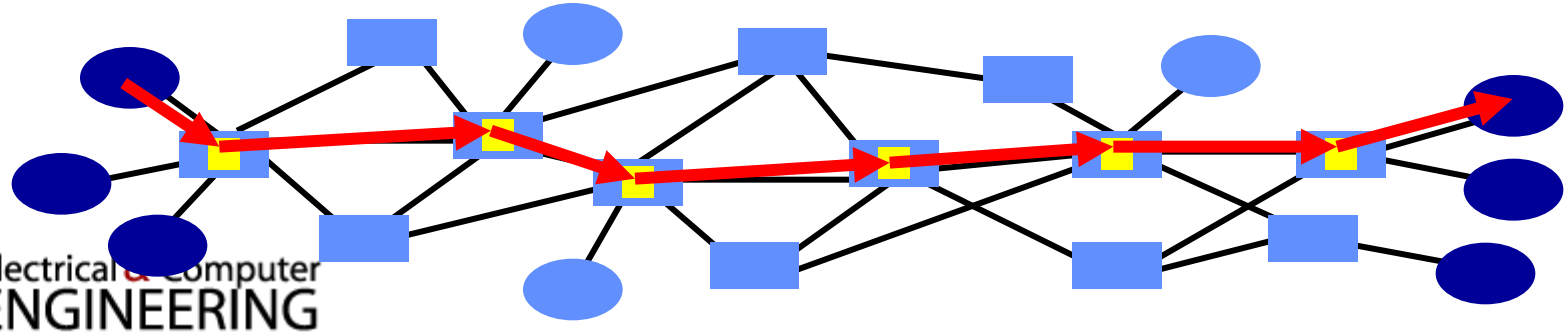
Links and Switches in Early Telephone Networks

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 shortco
  - 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 tr he destination host.
  - Switches use 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.

- **Solution:** Not necessarily. Ci ed 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 n

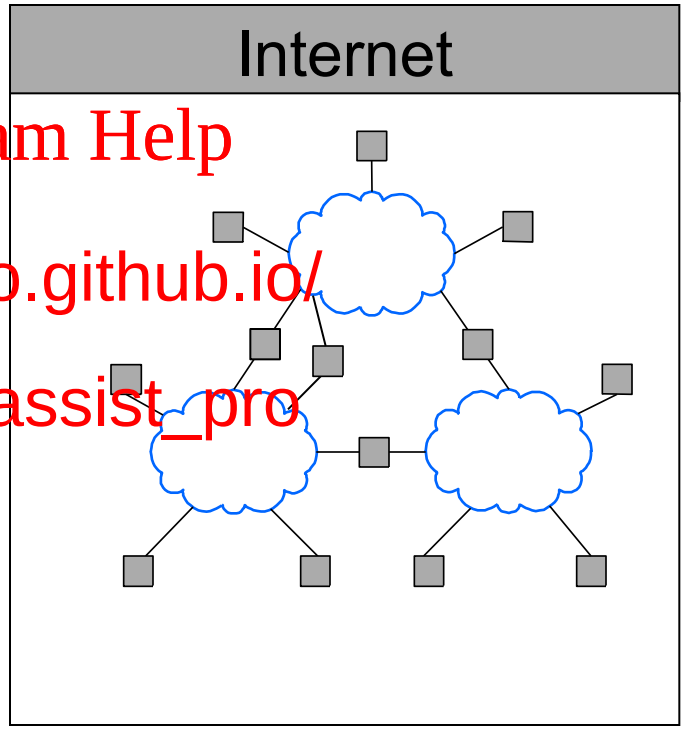
  - What is a
  - What is the Internet

  - Internet design

- A whirlwind tour of the course

What about the Internet

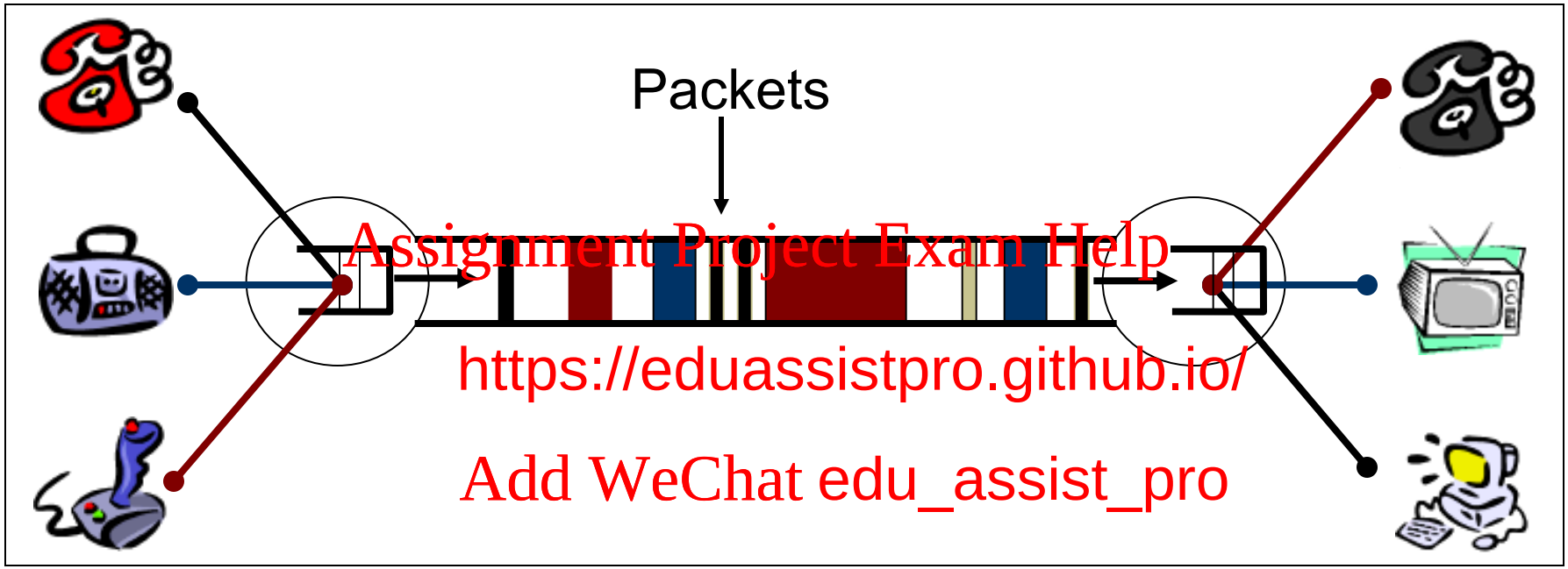
- inter-net: network of networks.
  - Networks are connected using routers and other devices, e.g., for security, accounting, …
  - Use diverse technologies
  - Managed by
- The Internet: t
  set of networks of the Internet Service Providers (ISPs)
  - About ~23,000 “transit” ISPs make up the Internet
  - 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, corpora
- In contrast: previous network ial purpose and fairly homogeneous in terms gy
- 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)

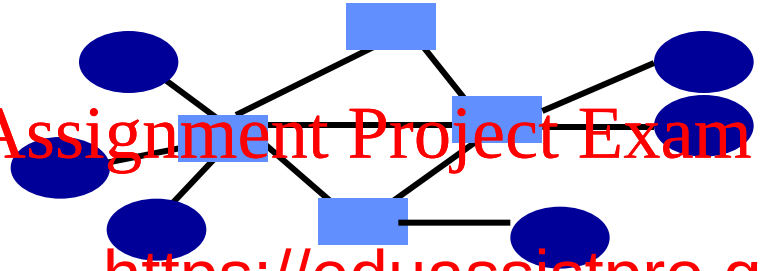
Packet Switching – Statistical Multiplexing



- 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? Swit
  - Party "A" gets resources
  - Party "B" gets them sometimes
- Interior nodes act as "Switches"
- Many challenges: fairness, efficiency, …

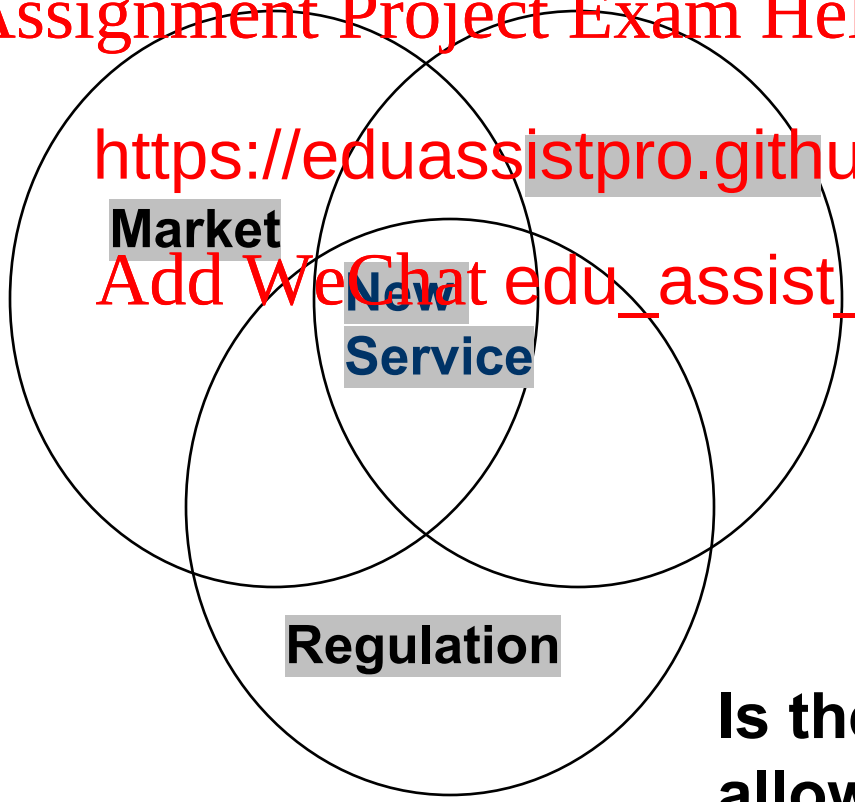
Internet Design

- In order to inter-operate, all participating networks must follow a common set of rules
- Example requirements for packets:
  - Address for , packet size limit, ..
- Also: what del", i.e., the commitment made to ons
  - 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
  - Interoper
  - Compete on innovatio
  - Completing the value
    - Chips, systems, equipment vendors, service providers
- Example:
  - 802.11 LAN, IP, HTTP/SMTP/…

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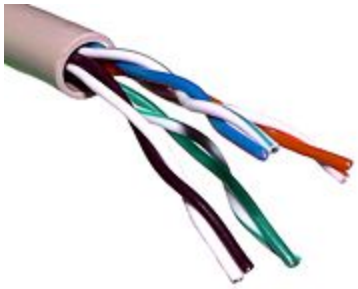
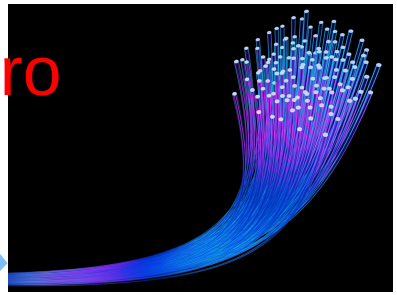
Whirlwind Tour of the Course

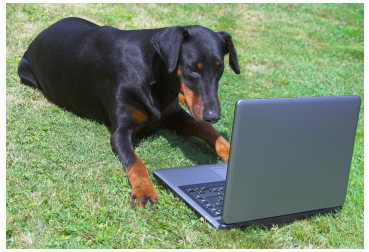
- Infrastructure: hardware (or close to it)
- Core networking protocols: IP, dealing with errors and congestion, routing, …
- Tools: cac middleboxes, …
- Making it anagement, …
- IP everywhere: the Int mile, wireless, mobility, data center, video, IP-TV, skype, …
- Focus is on today's Internet but also 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, (now) 5G.. Ho speedup achieved?
- What are the limits of some of the technologies?
  - Both physical and protocol limits



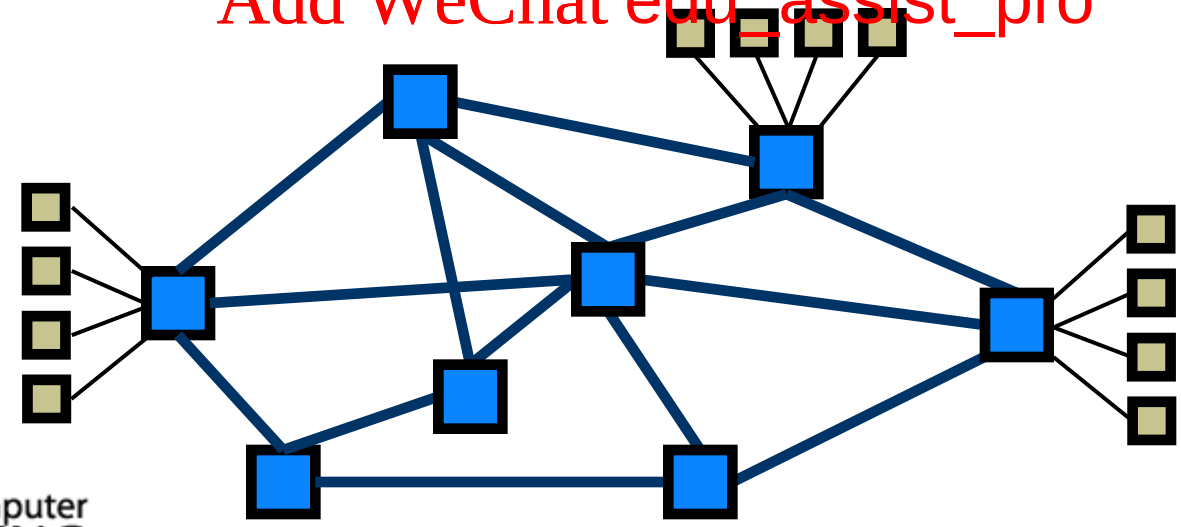




Core Networking Protocols

Think: traffic on the roads

- How do I found a path to my destination
- How do I specify addresses
- What if my car b
- How do I deal wi
- …



Optimizing Performance

- Intuitively: lots of bandwidth!
- But there is more to it:
  - Latency is
  - How voice ffer guarantees?
  - Can I beat the speed o
    - 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 ma
- How do I se
  - Lots of bad guys: DOS, co 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 o ching, …
- Data centers: ts
  - Map-reduce, 3-tier business ap cing, …
- 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 uses"
  - Software Defined Networking
  - Security
  - Future Internet

Next Lecture

Protocol Stack: an overview