

Welcome to
ECE509/CS598HPN!

High-speed and
Programmable Networks

Instructor: Radhika Mittal

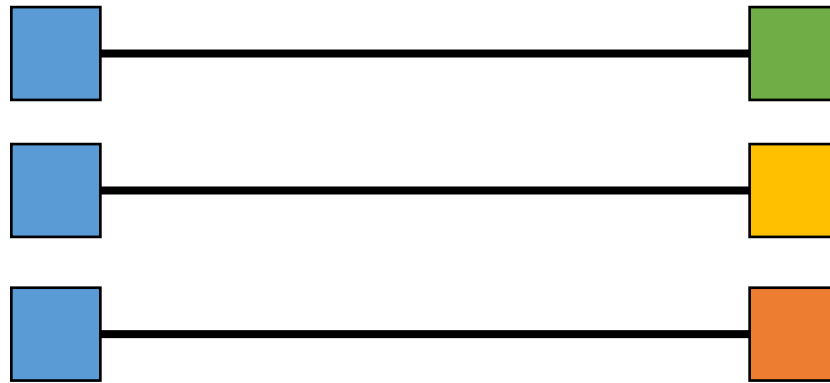
Evolution of Computer Networks

1876: Alexander Graham Bell invented telephone.



Evolution of Computer Networks

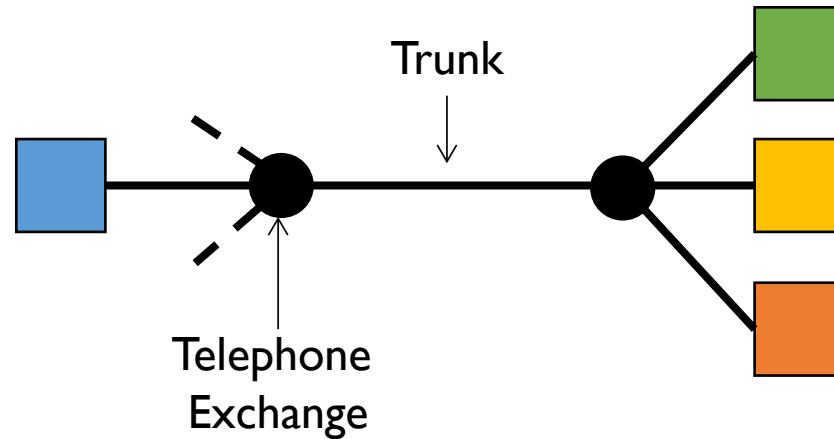
1876: Alexander Graham Bell invented telephone.



Such a design cannot scale!

Evolution of Computer Networks

Soon evolved to Public Switched Telephone Network.



Evolution of Computer Networks

Manually operated!



Earliest circuit-switched network

Evolution of Computer Networks

Manually operated!

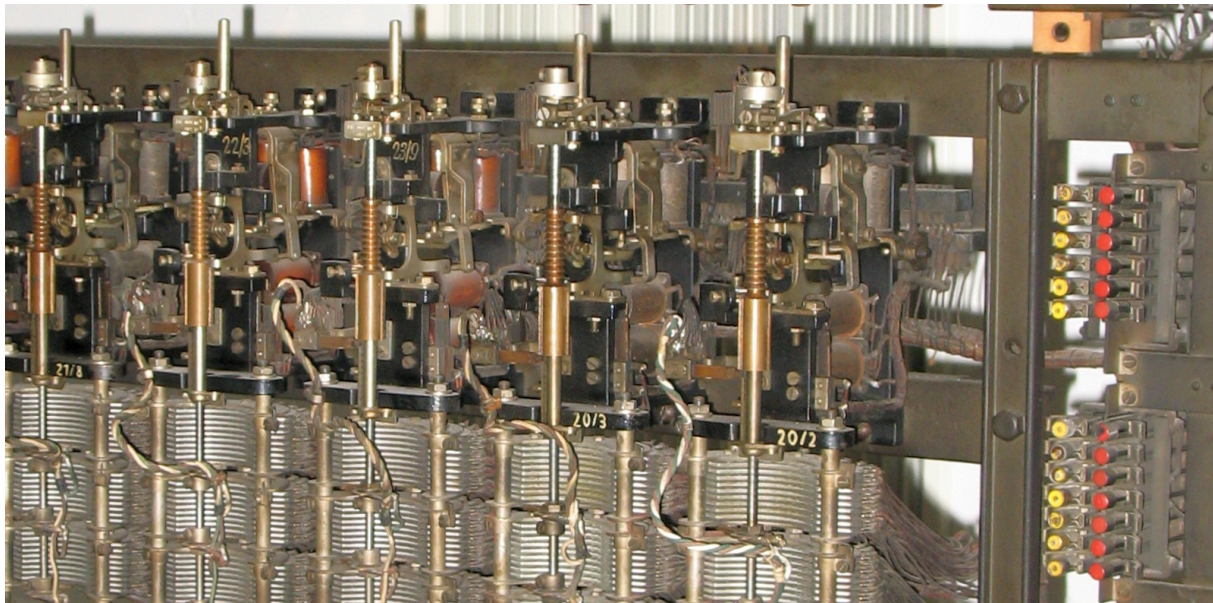


A.B. Strowger's
competitor's
wife

Earliest circuit-switched network

Evolution of Computer Networks

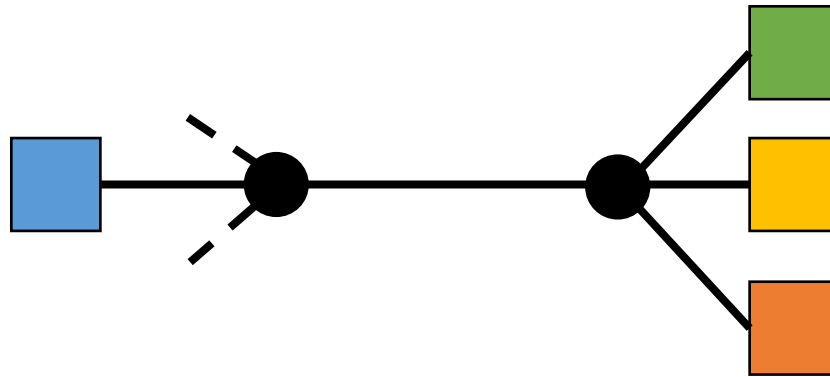
1889: AB Strowger invents first mechanical circuit switch.



Earliest mechanical circuit-switched network!

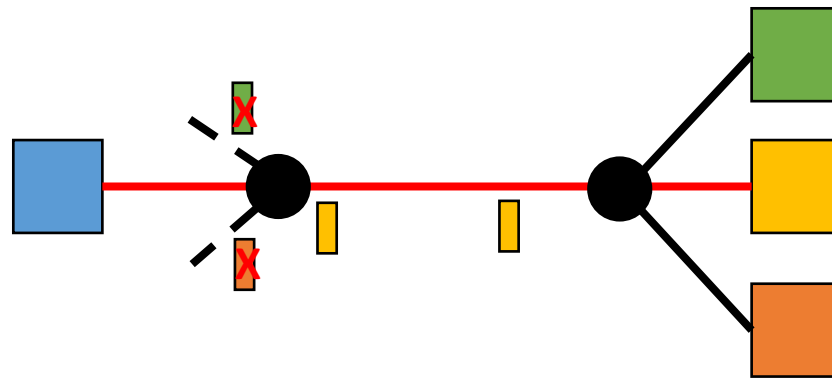
Evolution of Computer Networks

1960s: mechanical switches replaced with electronic switches



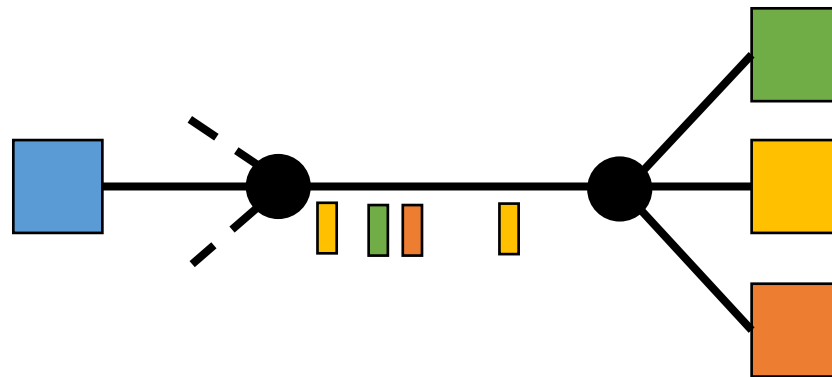
Evolution of Computer Networks

Circuit switching is wasteful!



Evolution of Computer Networks

Packet switching is designed:
1959(Paul Baran), 1961(Leonard Kleinrock), 1965 (Donald Davies).

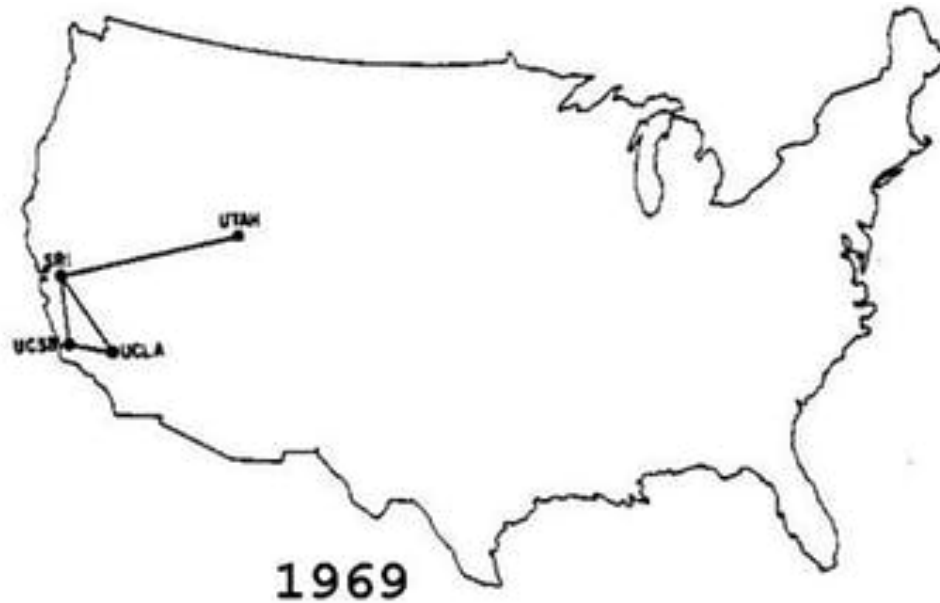


Evolution of Computer Networks

- Simultaneously, growing interest in connecting computers.
- Lawrence Roberts meets Davies' teammate at 1967 SOSP, and decides to use packet-switching for a network to connect computers.
- Roberts, Davies, Kleinrock, and Baran get together to design ARPANET.

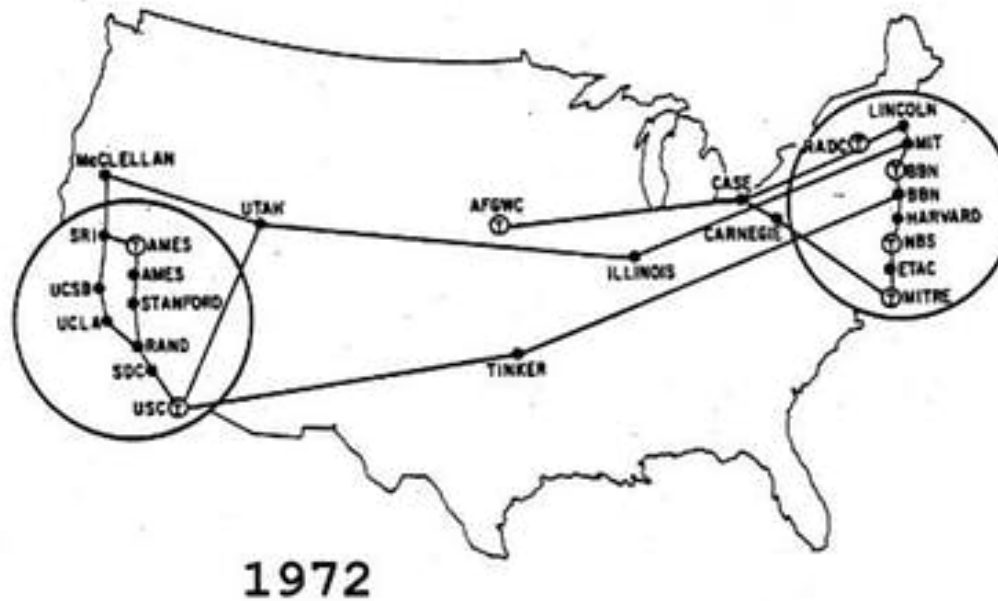
Evolution of Computer Networks

1969: ARPANET is developed.



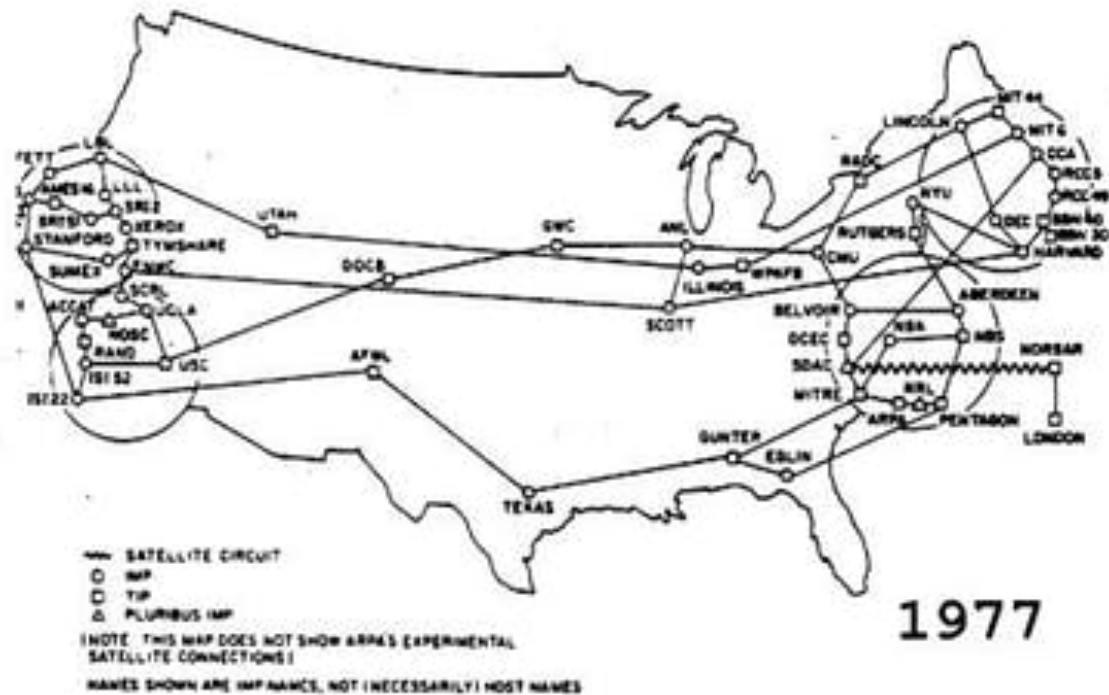
Evolution of Computer Networks

Early 1970's: Vint Cerf develops NCP for transport and addressing.



Evolution of Computer Networks

1973: European nodes added to ARPANET. The term Internet is born.



Evolution of Computer Networks

- mid-1970's: Vint Cerf and Bob Kahn develop TCP/IP, separating reliability from addressing.
- 1983: NCP becomes obsolete; all nodes switch to TCP/IP (*flag day*).
- Late 1970's: More scalable routing protocols was developed.
 - 1980: Link-state routing protocol was proposed.
- 1986: Series of congestion collapse; congestion control added to TCP.
- More interconnected networks emerge (Internet grows).
 - Early 1990's: BGP introduced for inter-domain routing.

Since then, for many years....

- No fundamental change in how we operate and use networks.
 - Distributed management of hardware switches.
 - Packet switching with store-and-forward design.
 - Endhost implements a TCP/IP stack in the kernel.
- Innovations in:
 - Transmission technology: wireless, cellular, more bandwidth.
 - Applications: HTTP, TLS, SSL, DNS.
 - Specific details: Congestion control algorithms, hierarchical addressing, etc.

But, changes emerged in the last decade...

This course tells the story of these changes.

Key enablers of the changes

- Increasing scale:
 - greater need to make networks *easier to manage*.
- More functionality:
 - greater need to make networks *more evolvable*.
- Commercialization:
 - greater emphasis on *performance*.

Key enablers of the changes

Emergence of large private networks (datacenters).



Key enablers of the changes

New and demanding workloads:

- multi-tenant clouds.
- large scale distributed training.

In this course...

- What changes have been made to the networking infrastructure in the last decade?
- Why were the changes introduced?
- What do these changes enable?

In this course...

- Week 1: Review relevant concepts.
- Week 2: Historical perspective.
- Week 3-6: Switching infrastructure.
- Week 6-13: Endhost infrastructure.
- Week 13: Cellular infrastructure.

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Classical Papers

- End-to-end arguments in system design.
- The Design Philosophy of the DARPA Internet Protocols.
- Active networking.

In this course...

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Switching Infrastructure

- Software-Defined Networking
 - Philosophy, enabling technologies, usecases.
- Programmable data plane
 - Software switches, reconfigurable match-action tables, usecases.

In this course...

- Week 1: Review relevant concepts.
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Host Network Stack

- Standard kernel-based TCP stack is inefficient.
- User-space network stack (e.g. over DPDK).
- Accelerating kernel packet processing through eBPF.
- Offload network stack to hardware NIC (RDMA)

Smart NICs

- Software NIC to augment hardware.
- Custom NIC hardware.
- NICs equipped with FPGAs.
- NICs with multi-core SoC.

Systems built and used in industry

- Google:
 - SNAP: software solution for host networking
 - Falcon: custom hardware transport.
- Microsoft:
 - Azure's RDMA network,
 - AccelNet using FPGA based smartNIC
- NVIDIA's Spectrum-X for large scale AI workloads.
- Alibaba's cloud gateway platform.

In this course...

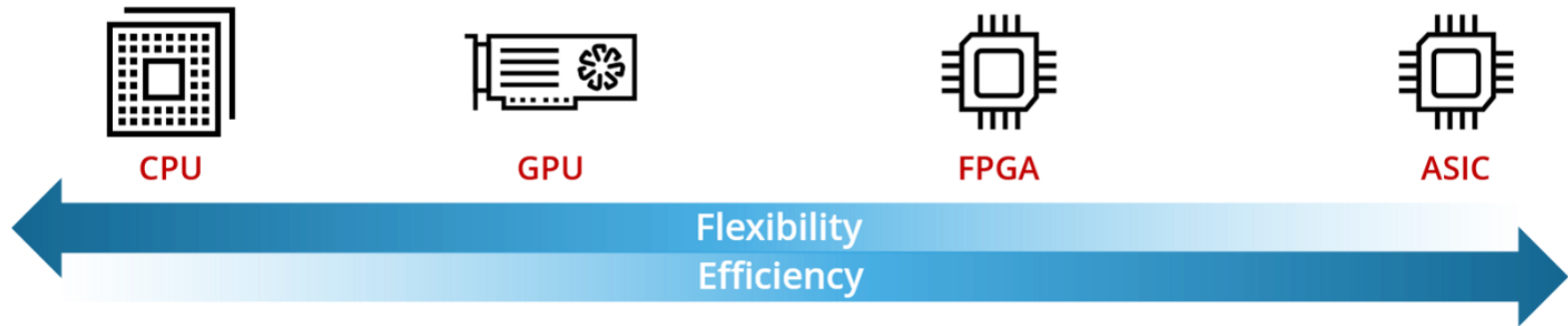
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Innovation in cellular architecture

- How software-defined networking principles are being applied to cellular networks.

A recurring theme

Tussle between performance (high-speed) and programmability.



Logistics

Course Website

<https://courses.grainger.illinois.edu/ece509/fa2026/index.html>

Office Hours

- Fridays 1pm-2pm, CSL 257.
- Meet by appointment: radhikam@illinois.edu

Online Class Forum

- Campuswire
- Invitation link sent via email.
- Student led discussions
 - e.g. finding project partners, asking clarifying questions as you read papers, etc.
- Might not be monitored by course staff (i.e. me).
 - *Please feel free to reach out to me over email, or come to my office hours.*

Reading assignments (25%)

- Each class: one full-length paper or two half-length papers.
- **Submit by 11:59pm the day before:**
 - 3-4 lines of summary.
 - 2 reasons why you would accept the paper.
 - 2 reasons why you would reject the paper.
 - One follow-up idea
 - Extension, weaker assumption, usecase.
- Submit via Google Forms (link on course website).
- 3 skips allowed (partial submission will be counted as a skip).
 - A submission that is late by more than 9hrs is counted as a skip.
 - Three late submissions (within 9hrs of deadline) counted as a skip.

Class Participation (25%)

- Actively engage in class discussions.
- A chance to present a paper of your choice towards the end of the course.
- Only in person class participation will count towards participation points. (*Campuswire discussions will not count towards class participation points.*)

Course Project (50%)

- Research style project in groups of up to three.
- Sept 8: I'll setup meeting slots to discuss project proposals.
- Sept 24: Last date to discuss project proposal
- Oct 9: First progress report.
- Nov 6: Second progress report due.
- Dec 4: Final project report due.
- Last week of class: Final project presentation.

AI use policy

- Varies across assignments.
- Detailed in the course website (assignments tab).
 - <https://courses.grainger.illinois.edu/ece509/fa2026/assignments.html>

Questions?