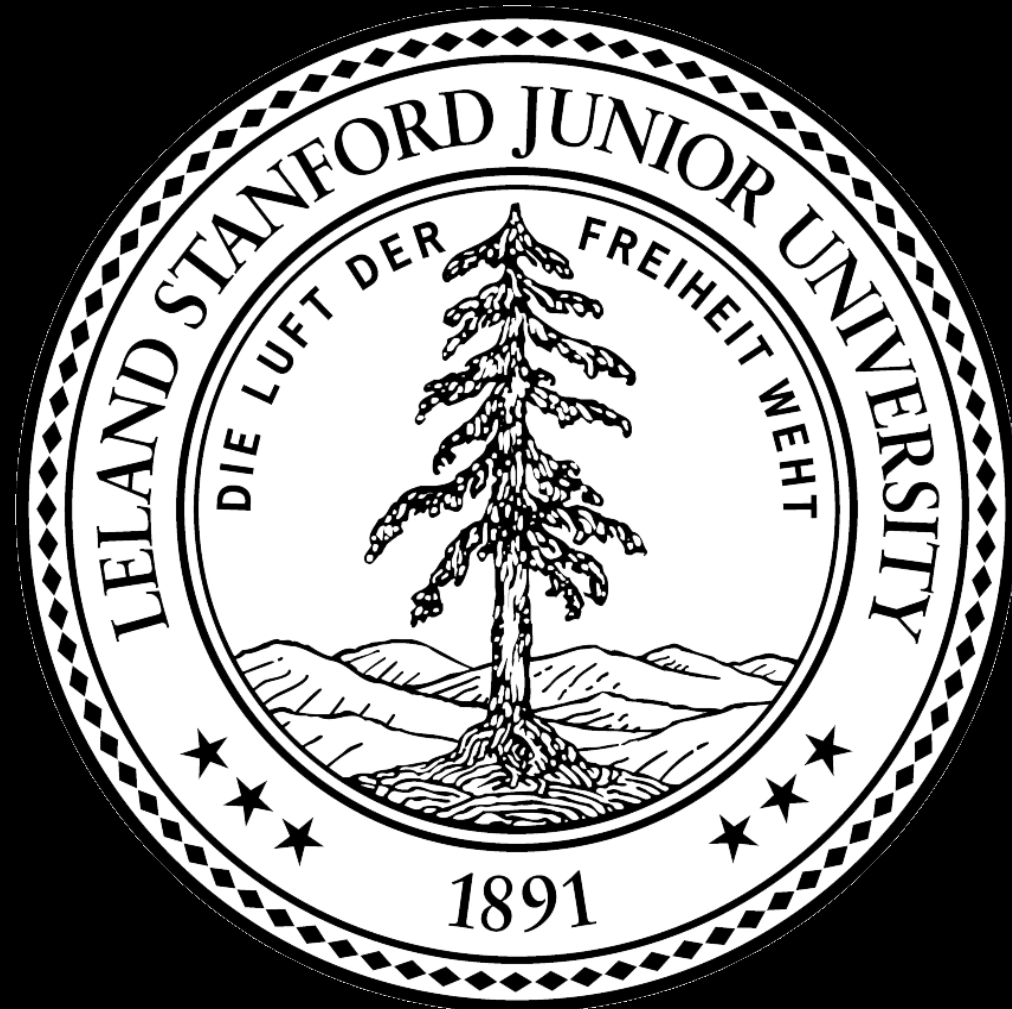


# Welcome to CS244 Spring 2020!

Class will start shortly



# CS244 Online for COVID-19

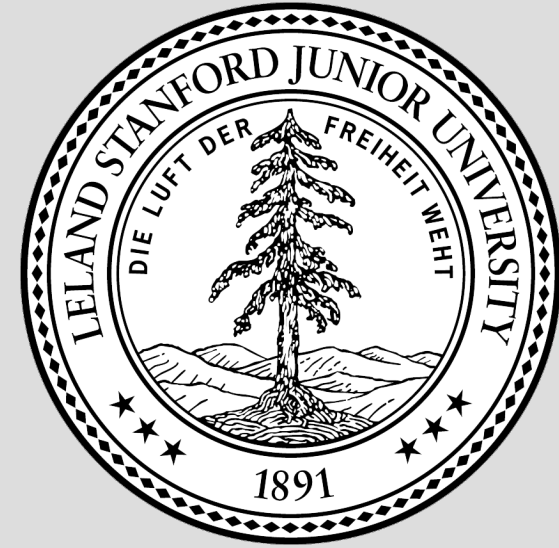
This is the first time for us too, so please email us if you have ideas for how we can improve the online version of the class.

- Please turn on your video! We want us all to get to know each other and interact online as best we can.
- We will occasionally use breakout rooms to foster smaller discussions to bring back to the whole class.
- Raise your hand in the chat window to ask questions or post your question in the chat window.
- We will then unmute you to speak.
- We may use polls to check in with you during class.
- We are all learning how to do this via Zoom.  
Let's see if we can have fun and learn as we go.

# CS244 Lecture 2

The Design Philosophy of the DARPA  
Internet Protocols [Clark 1988]

Sachin Katti



# Context: David D. Clark (MIT)

- Chief Protocol Architect for the Internet from 1981.
- Continues to be a network visionary today.
- At the time of writing (1987)...
  - (Almost) no commercial Internet
  - 1 yr after Cisco's 1<sup>st</sup> product, IETF started
  - Number of hosts reaches 10,000
  - NSFNET backbone 1 year old; 1.5Mb/s



# What you said

“I found this paper very interesting coming from someone who was so involved in the production of the early Internet. It was strong in being honest and straightforward. It felt much more like a formal blog post than a research paper, but that's really what it needed to be. It was full of facts, but it wasn't really presenting new ideas or trying to prove anything. It was just one man trying to update the general public about the Internet and how it came to be the way it was at the time..... A solid blog post for sure.”

- Wil Kautz

“I thought the paper was easy to read and interesting for its historical context. It focused more on the historical perspectives of the DARPA engineers creating the TCP/IP protocols rather than taking any serious deep dive into the technical details of their implementations.

- Isaac Westlund

# What you said

“As I was reading the paper, I was drawn to the analogy of parents raising their child. On the one hand, the parents want their child to be safe. On the other hand, they want their child to thrive in the real world, a decidedly unsafe (at times) place. In attempting to meet both goals, they have to put their feet down on some issues and let go of others. The design choices of the Internet feel the same way: the Internet needed (and needs to) provide a unified set of protocols and method of operation without forcing all of its constituent networks to comply to a set of rigid rules. (I suspect this is a poor analogy, but it was what came to mind while reading.)”

- Peter McEvoy

“What I found most striking about this paper was the software engineering attitude that pervaded it because the same attitude is shared by most modern engineers. David Clark mentions tradeoffs and choosing an easy or practical decision over more difficult or ambitious choices on almost every page. It feels in some way like a lesson in engineering and project management.”

- Amalee Wilson

# The Design Philosophy of the DARPA Internet Protocols [Clark 1988]

**Goal 0:** An “effective” technique for multiplexed utilization of existing interconnected networks.

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**Goal 1:** Internet communication must continue despite loss of networks or gateways.



# The Design Philosophy of the DARPA Internet Protocols [Clark 1988]

**Goal 0:** An “effective” technique for multiplexed utilization of existing interconnected networks.

**Goal 1:** Internet communication must continue despite loss of networks or gateways.

**Goal 2:** The Internet must support multiple types of communication service.

**Goal 3:** The Internet architecture must accommodate a variety of networks.

**Goal 4:** The Internet architecture must permit distributed management of its resources.

**Goal 5:** The Internet architecture must be cost effective.

**Goal 6:** The Internet architecture must permit host attachment with a low level of effort.

**Goal 7:** The resources used in the internet architecture must be accountable.

**Goal 0:** An effective technique for multiplexed utilization of existing interconnected networks

**Led to:** Different networks connected together by packet switched, store-and-forward routers/gateways

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Q. Why interconnect *existing* networks and not design a new overall network from scratch?

Q. Why was packet switching picked for multiplexing? What were the choices?

# Goal 1: Internet communication must continue despite loss of networks or gateways.

1. “Entities should be able to continue communicating without having to re-establish or reset the high level state of their conversation.”
2. “The architecture [should] mask completely any transient failure.”

## Leads to:

1. “Fate-sharing” model - only lose communication state if the end-host is lost.
2. Stateless packets switches => datagrams

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Q. What alternative design could there be?

Q. How does the Internet do this?

Q. Would a “dedicated” new network have been more reliable?

# Other goals

**Goal 4:** The Internet architecture must permit distributed management of its resources

Q. Does the Internet accomplish this?

**Goal 5:** The Internet architecture must be cost effective.

Q. Is it cost effective?

**Goal 7:** The resources... must be accountable

Q. What does this mean?

Q. What would such a network look like?

# Minimum Assumptions of interconnected networks

1. Can transport a datagram
2. ...of reasonable size
3. ...with reasonable chance of delivery

## Interesting comments:

- Reliability and qualities of service were not built in because they would require too much change.
- Datagram as a building block, not as a service.

# More discussion questions

1. Originally TCP+IP were joined, but were later split.

Q: Why?

2. “It proved more difficult than first hoped to provide multiple types of service without explicit support from the underlying network”

Q. Why? What has happened since?

# More discussion questions

**Interesting comment:** “The most important change in the Internet...will probably be the development of a new generation of tools for management of resources...”

Q. Has this happened?

# Author's conclusion

- “Datagram” good for most important goals, but poor for the rest of the goals.
- Processing packets in isolation, resource management, accountability all hard.
- Anticipates flows and “soft-state” for the future.