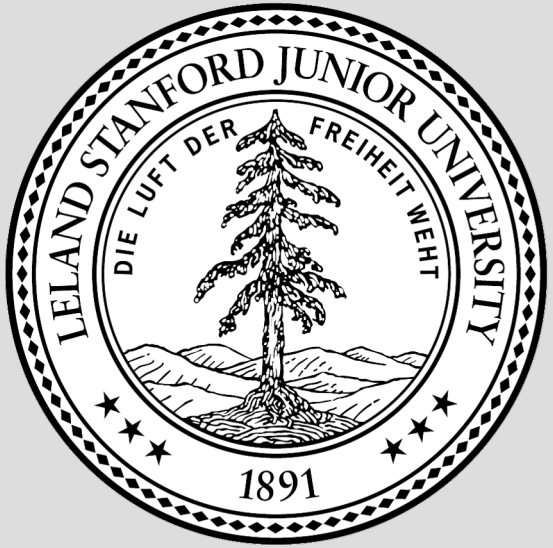
CS244 Lecture 2

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

Chang Kim



Contact

Whenever possible: ~~Piazza~~ → Ed

- Official Q&A channel
- Someone else probably has the same question
- Please don't send questions to class email list
- If private: Post a private ~~Piazza~~ Ed post

Quick and pseudo-real-time conversation (best effort): Slack

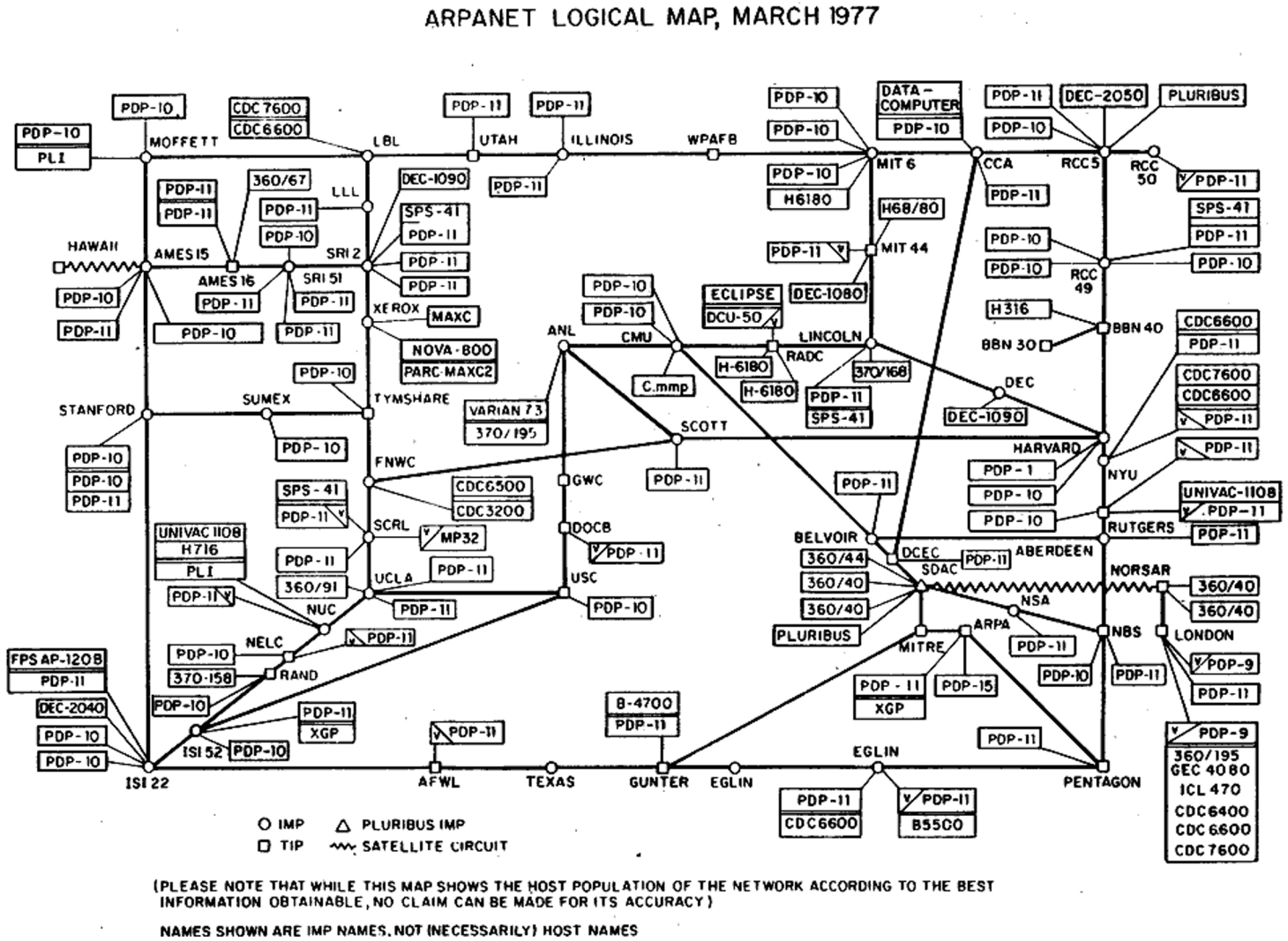
- Please send email to me and the TAs right after the first class, and we'll invite you to the Slack channel

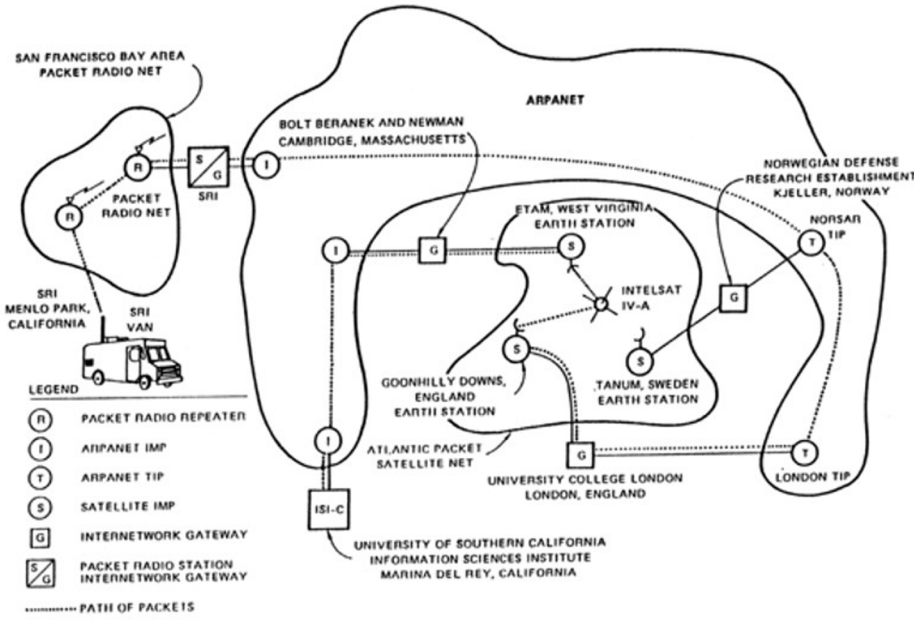
All extension requests should go to Chang.

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 1st product, IETF started
  - Number of hosts reaches 10,000
  - NSFNET backbone 1 year old; 1.5Mb/s

The Origin: ARPANET + PRNET





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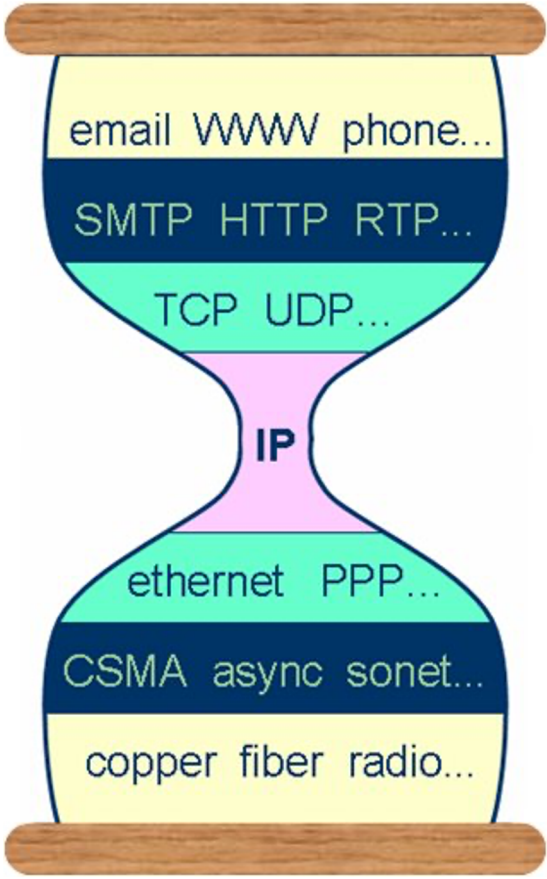
Goal 0: An "effective" technique for multiplexed utilization of existing interconnected networks.



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

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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

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?

3. “Multiple types of service could be constructed out of the basic datagram service using algorithms within hosts and gateways”
   Q. What kinds of additional services? Did this really happen?

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?

What you said

“It's an interesting thought experiment to consider how the world would rely on the Internet differently if the author's "Second-Level Goals" were shuffled in order; for instance, if accountability was more important than persistence. In such a case, we might have more secure or robust Internet.”

“the list of goals is the missing of security of Internet architecture, like the integrity and confidentiality of the data being transmitted. Especially the Internet was widely used by military, I am surprised to see security is not considered as one key factor in communication.”

“... was curious that security/cybersecurity protecting packet transfers wasn't a higher priority in the list of goals for the Internet. …. I wonder if this is because the Internet's early architects didn't realize the scope of what the Internet would become, or anticipate that international-level cybersecurity would be vital.”

“The fact that the paper was written in 1988 makes some parts quite humorous, such as the prediction that "tools for management of resources in the context of multiple administrations" is the most important axis of development for the Internet at the time; BGP was introduced in 1989.”

What you said

“If I wrote this paper, I would have focused on a timeline of events in the development of networking, and with each event, explained what decisions were made for technical reasons, and what political/social motivations had a role in the development of the technology.”

“If networking were to be invented today, what social needs would affect the primary goals we would have for the internet? “

“The paper mentions that one of the struggles with the Internet architecture is how to give guidance to the designer of some realization of the Internet. It seems that thousands of RFCs and IEEE specifications is how we do it today. Is there anyway this guidance can be simplified, or is there no way back?”

What you said

“How common is this type of paper (which combines the exploration of technical and organizational aspects of systems) in networks venues nowadays?”

“Could different design priorities have led to the creation of an architecture that avoids this centralization of power in our current internet and web access?”

“And, on the other end of the abstraction, how have implementations and applications adapted to the quirks of TCP, and how did that influence / may influence its further development? “

What other goals would you like to add?

- Privacy
- Attributability
- Predictability
- Extreme performance (super-low latency, very high throughput)
- …?

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.

Architecture and Implementation

- The idea is deliberately simple and liberal; what really matters is the realization
  - Many serious problems occur owing to differences in implementation
  - Proving anything practically useful (beyond some trivial things) turns out to be impossible
  - Analyzing reachability (logical correctness) may be doable, analyzing performance is close to impossible
- "It is a comment on the goal structure of the Internet architecture that a back of the envelope analysis, if done by a sufficiently knowledgeable person, is usually sufficient."

Common Themes We Find In Successful Things

- **Extremely pragmatic**
  - Sought a working (i.e., effective), not optimal or ideal, solution
  - The Tao of IETF: "*We reject kings, presidents and voting. We believe in rough consensus and running code.*" – Dave Clark (again)

- **Deliberately simplistic and minimalistic; less is more**
  - Design for simplicity; add complexity only where you must.
  - "*You know it's done not when there's nothing more to add, but when there's nothing more to remove.*"

- **Commercial requirements were largely ignored, which made it commercially viable**