

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

Advanced Topics in Networking

Lecture 1: Introduction

Nick McKeown and Sachin Katti



Spring 2020

About this class

Goals

1. To become familiar with the field of networking research:
Network architecture, systems and programming.
2. To practice the art of reading research papers.
3. To learn the art of reproducing research results.

It's a big field, so we have
to focus on just a few topics.

Basics

Online Class Time

- Each class we will discuss 1-2 papers
- You must read the papers before class
- You will write a critique before class
- Plan to read the papers carefully and in depth
- Most of the lecture will be spent on discussion
- (30% of your grade comes from critiques, and in-class participation)

So....read the papers, come to class,
and be ready to participate

How grading works in Spring 2020

This quarter: S/NS only, no letter grades

- Students taking CS244 for breadth requirements should contact Nick or Sachin
- We will decide if you satisfy breadth requirements, independently of the grade

How we normally grade (so you know what we think is important)

Reading and participation **35%**

- Critiques before class: 20%
- In-class participation: 15%

Programming assignments **45%**

- PA #1: 15% Reproducing a particular research result
- PA #2: 30% EITHER an original research project
OR reproducing a paper of your choice
(not previously reproduced in CS244)

Midterm exam **20%**

- Midterm: 20% (in-class, Tuesday, May 19)
- No final. Project Presentations in last two class slots

Please participate!

- Join online prepared to discuss the main ideas of the paper(s)
- We will all learn from each other
- Attendance and participation are vital parts of this class

Critiques

What to submit?

- Short critique for each paper before the class
(by midnight the night before the lecture)
- Submit online (see Canvas)

Questions to answer while writing your critique:

- What problem are the authors solving?
- What is the main idea and what do you think of it?
- What was the *status quo ante* before this paper, and what is the clearest way to explain this paper's contribution?
- How well is the paper written?

Grade: 0, 1, or 2 points

Two Assignments

Assignment 1: Reproduce the “Jellyfish” paper [NSDI ‘12]

- Will be posted on Friday, April 10
- Due Monday, Apr 27, 5 p.m.
- Plan to complete the project on your own.

Assignment 2: Either....

1. Reproduce the results from a networking research paper that has not been reproduced in CS244 before,
2. Or, complete an original project in networking.

Either way:

- Proposal due Friday, May 1 at 5pm.
- Intermediate report due Friday, May 22 at 5pm.
- Final Report due Saturday, June 6 at 5pm.
- Presentation Tuesday/Thursday, June 9 & 11 in-class.

Logistics

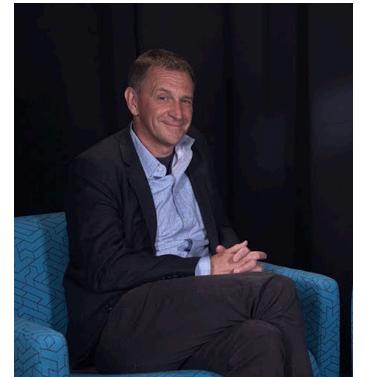
Who will lead the discussions

- Sachin Katti (skatti@cs.stanford.edu)
- Nick McKeown (nickm@stanford.edu)
- Some guest experts

TA: Bruce Spang (bspang@stanford.edu)



Sachin



Nick

Contact

Whenever possible: Piazza

- Quickest response
- Someone else probably has the same question
- Please don't send questions to class list

If private: Post a private Piazza post

All extension requests should go to Sachin and Nick

The Internet: An Exciting Time

One of the most influential inventions

- A research experiment that escaped from the lab
- ... to be the global communications infrastructure

Ever increasing reach

- Today: 3+ billion users
- Tomorrow: more users, smartphones, computers, sensors, content

Constant innovation

- Apps: Web, P2P, social networks, virtual worlds
- Links: optics, WiFi, cellular, 5G, ...

Transforming Everything

The ways we do business

- E-commerce, advertising, cloud computing, ...

The way we have relationships

- E-mail, IM, Facebook friends, virtual worlds

How we think about law

- Interstate commerce and sales tax, National boundaries, Wikileaks

The way we govern

- E-voting and E-government and fake news
- Censorship and wiretapping

The way we fight

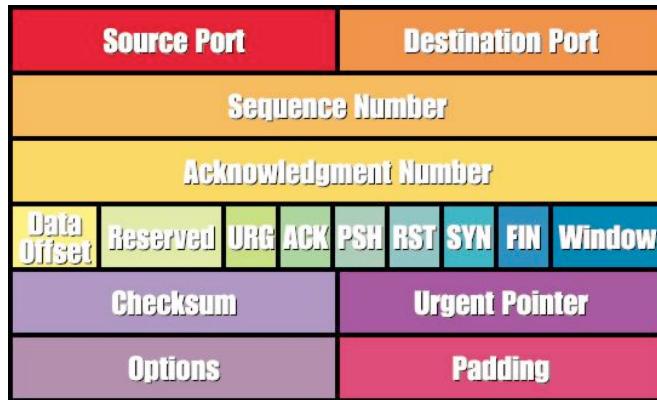
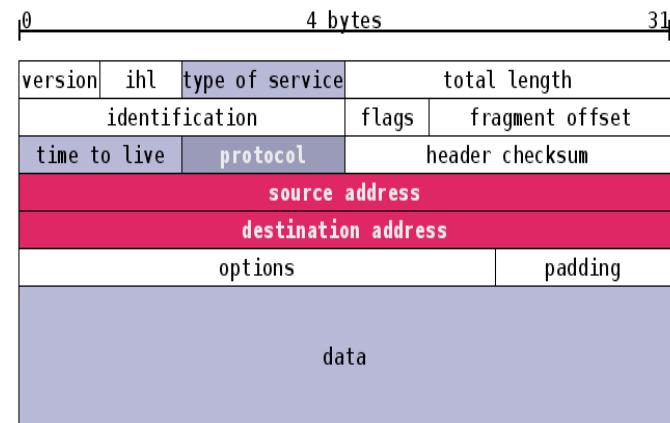
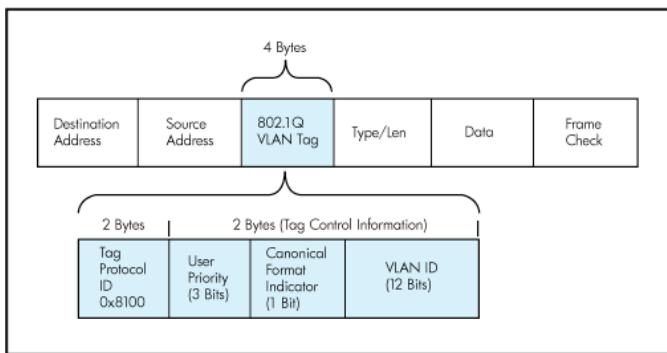
- Cyber-attacks, including nation-state attacks

But what *is* networking?

A Plethora of Protocol Acronyms?

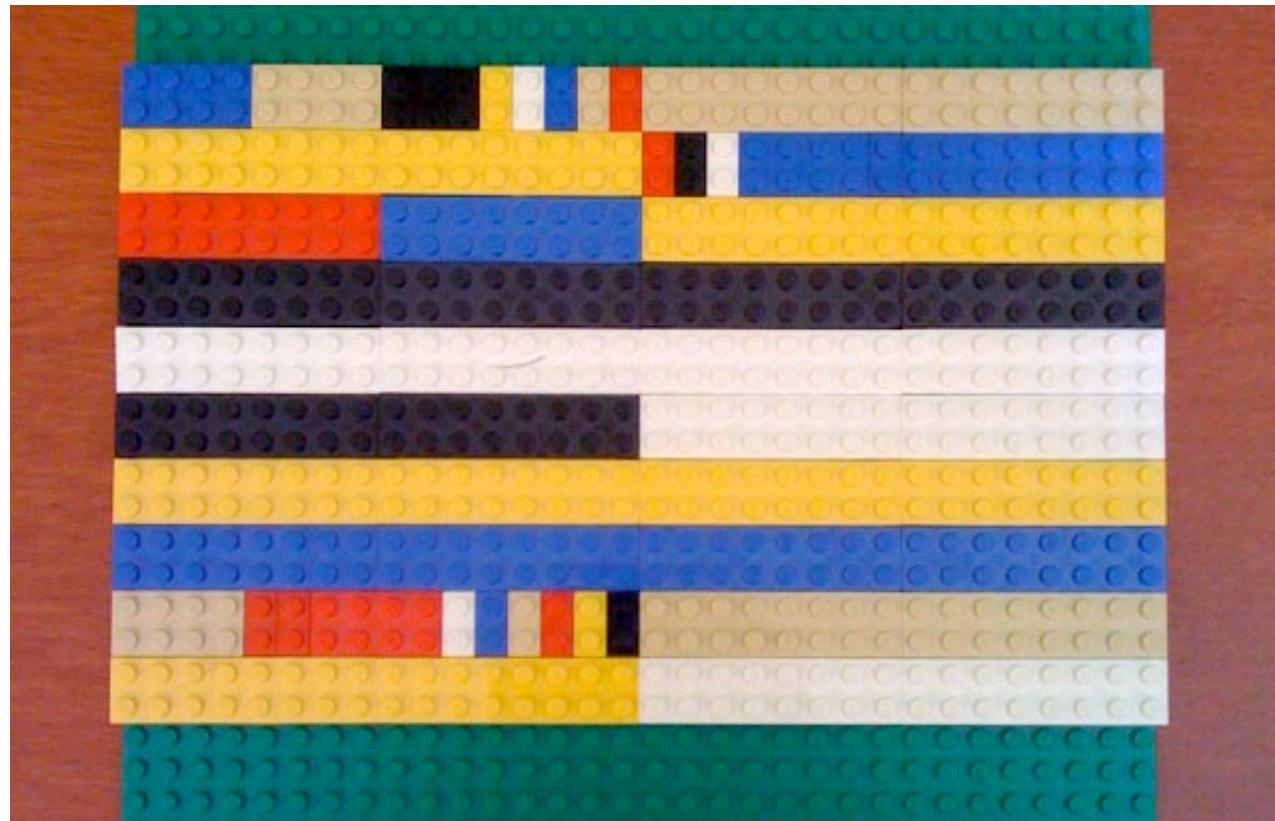
SNMP	WAP	SIP	PPP	IPX	MAC
LLDP	FTP	UDP			
OSPF	RTP		ICMP	IMAP	HIP
PIM	RED	BGP	IP	HTTP	IGMP
RIP		10BaseT		ARP	VXLAN
			MPLS	TCP	ECN
NNTP	SMTP	RTSP			RTCP
	SACK	LTE		BFD	CIDR
DNS			TLS	NAT	5G
POP	VLAN	SSH			STUN
		LISP	VTP	TFTP	DHCP
					LDP

A Heap of Header Formats?

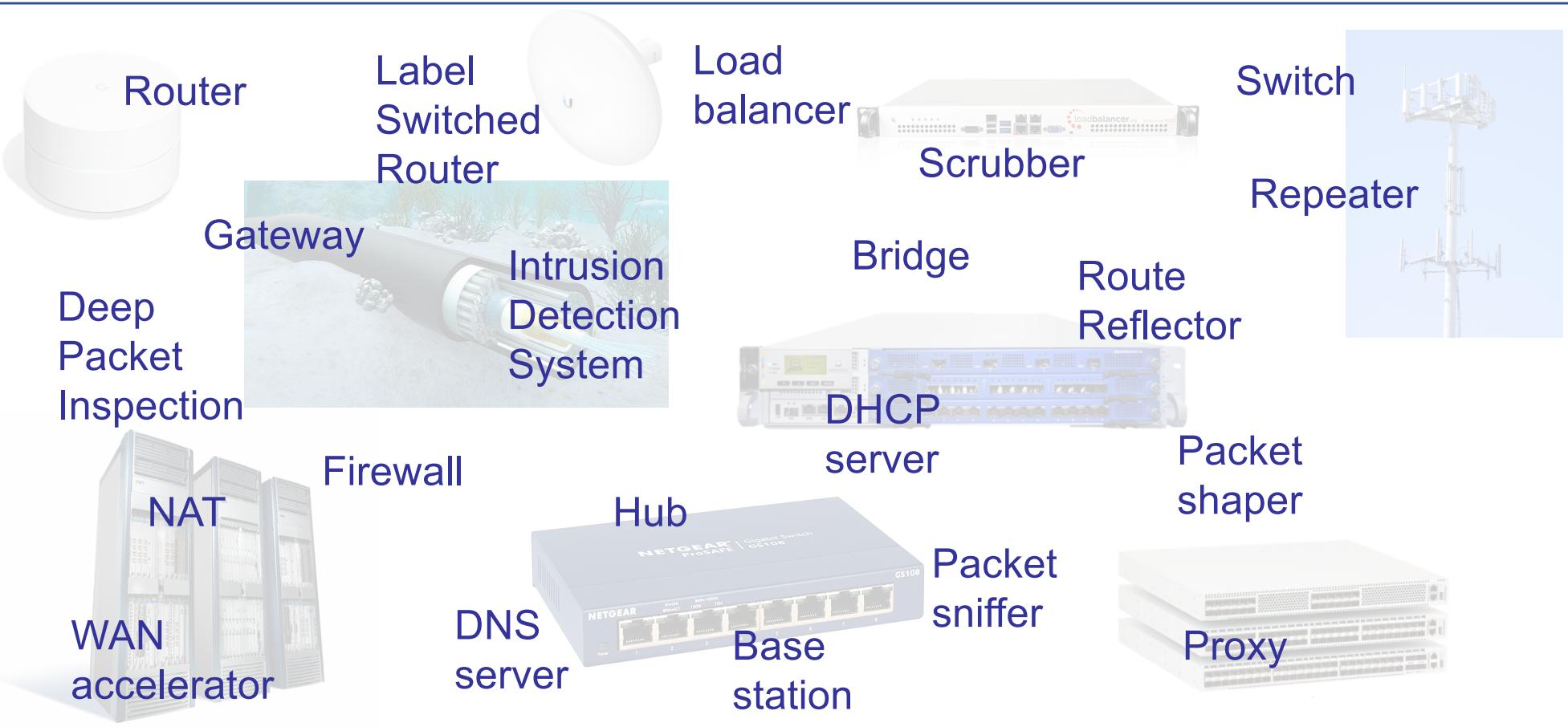


HTTP Response Header	
Name	Value
HTTP Status Code: HTTP/1.1 200 OK	
Date:	Thu, 27 Mar 2008 13:37:17 GMT
Server:	Apache/2.0.55 (Ubuntu) PHP/5.1.2
Last-Modified:	Fri, 21 Mar 2008 13:57:30 GMT
ETag:	"358a4e4-56000-ddf5c680"
Accept-Ranges:	bytes
Content-Length:	352256
Connection:	close
Content-Type:	application/x-msdos-program

TCP/IP Header Formats in Lego



Lots of Different Equipment?



A place to apply theory?

- Algorithms and data structures
- Control theory
- Queueing theory
- Optimization theory
- Game theory and mechanism design
- Formal methods
- Formal verification
- Information theory
- Cryptography
- Programming languages
- Graph theory
- AI/ML

A place to build systems?

- Distributed systems
- Operating systems
- Computer architecture
- Software engineering
- ...

What Peers in Other Fields Say

“What are the top ten classic problems in networking? I would like to solve one of them and submit a paper to SIGCOMM.” After hearing that we don't have such a list: “Then how do you consider networking a discipline?”

“So, these networking research people today aren't doing theory, and yet they aren't the people who brought us the Internet. What exactly are they doing?”

“Networking papers are strange. They have a lot of text.”

Is networking a problem domain or a scholarly discipline?

“There is a tendency in our field to believe that everything we currently use is a paragon of engineering, rather than a snapshot of our understanding at the time. We build great myths of spin about how what we have done is the only way to do it to the point that our universities now teach the flaws to students (and professors and textbook authors) who don't know better.”

John Day (Internet pioneer)

Before you all leave ...

Tell me: *Why is Networking Cool?*

Young, relatively immature field

- Tremendous intellectual progress is still needed
- You can help decide what the Internet really is

Widely-read papers

- Many of the most cited papers in CS are in networking

Interdisciplinary

- CS, EE, MS&E, Policy, Economics, Law, Ethics, Physics

Lots of platforms for building your ideas

- Simulation & Emulation:
[NS2](#), [NS3](#), [Mininet](#)
- Open source control software:
[ONOS](#), [SONiC](#), [ODL](#), [NOX](#), [POX](#)
- Programmability:
[Click](#), [NetFPGA](#), [P4 language](#)
- Routing software:
[Quagga](#), [XORP](#), and [Bird](#)
- Testbeds: Emulab, GENI
- Measurements:
[RouteViews](#), [traceroute](#), [Internet2](#)

Architectural questions tend
to dominate CS networking
research

Decomposition of Function

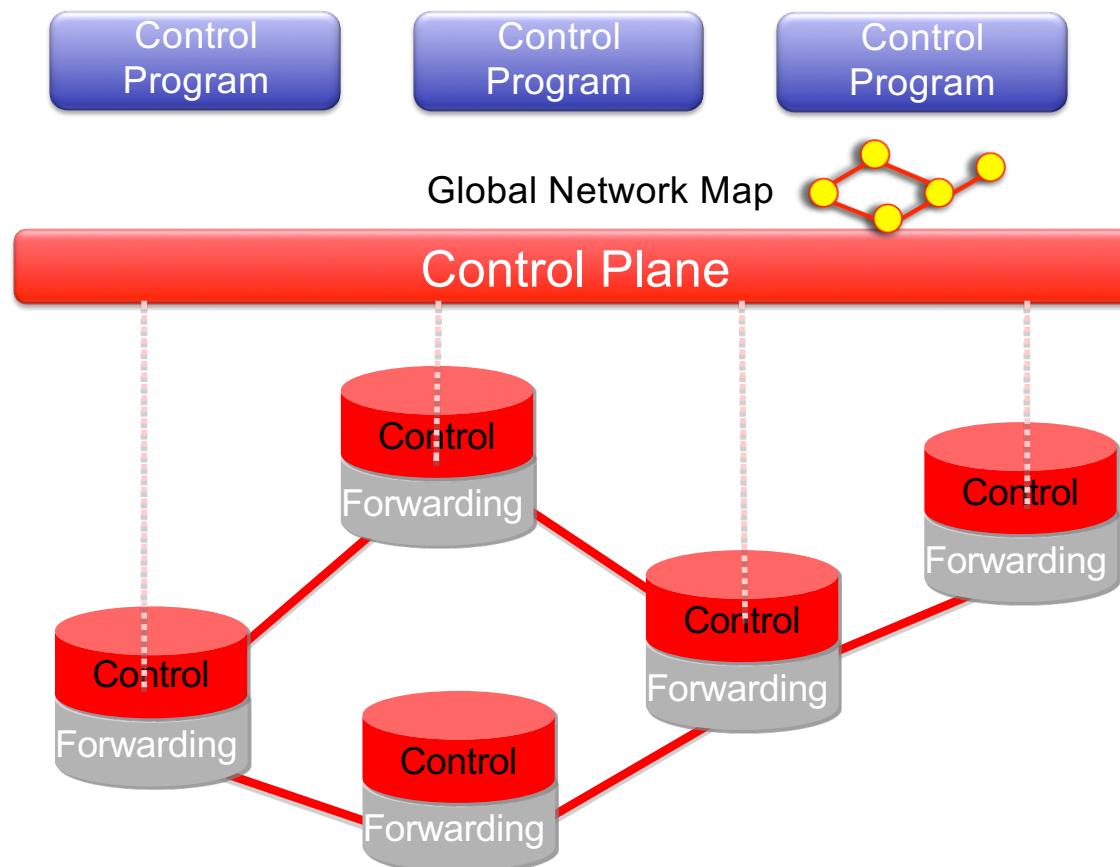
Definition and placement of function

- What to do, and where to do it

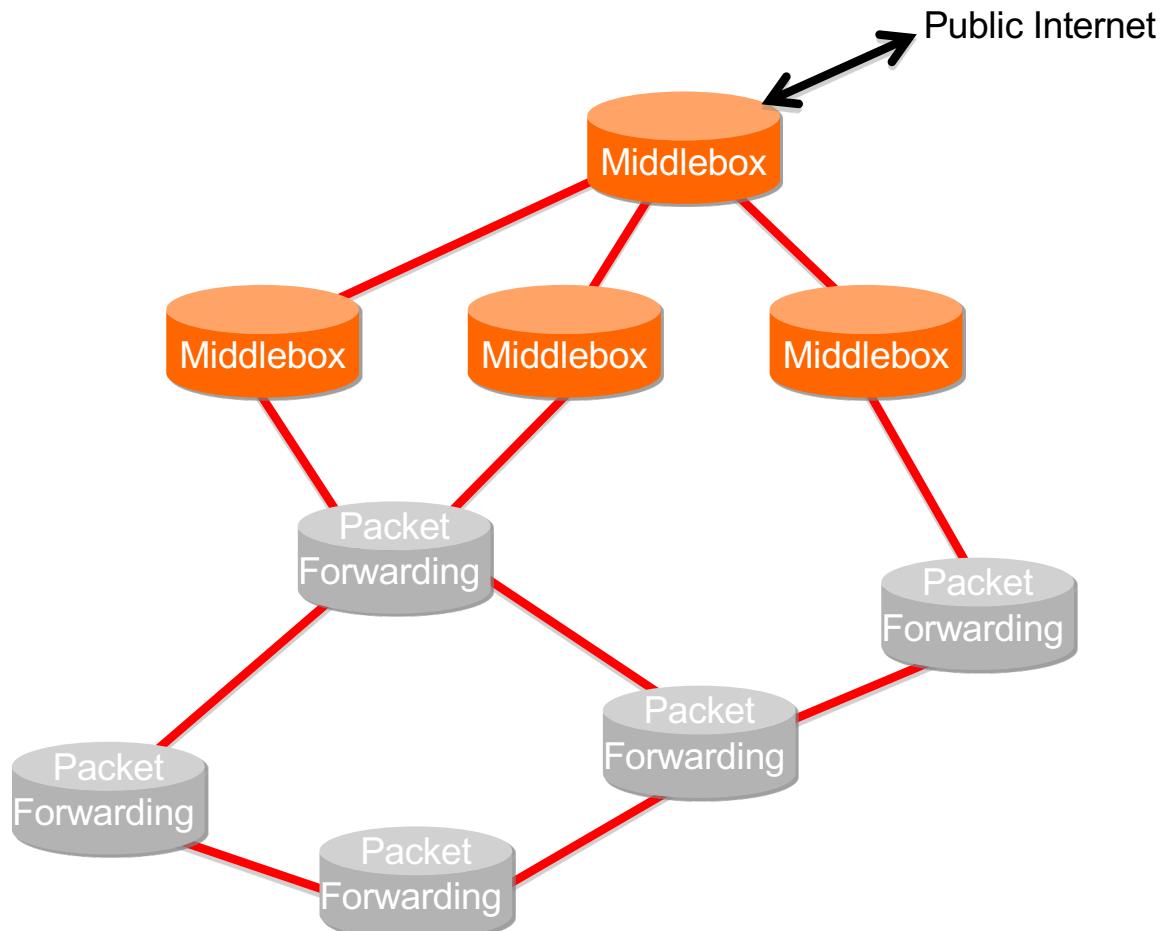
The “division of labor”

- Between the host, network, and management systems
- Across multiple concurrent protocols and mechanisms

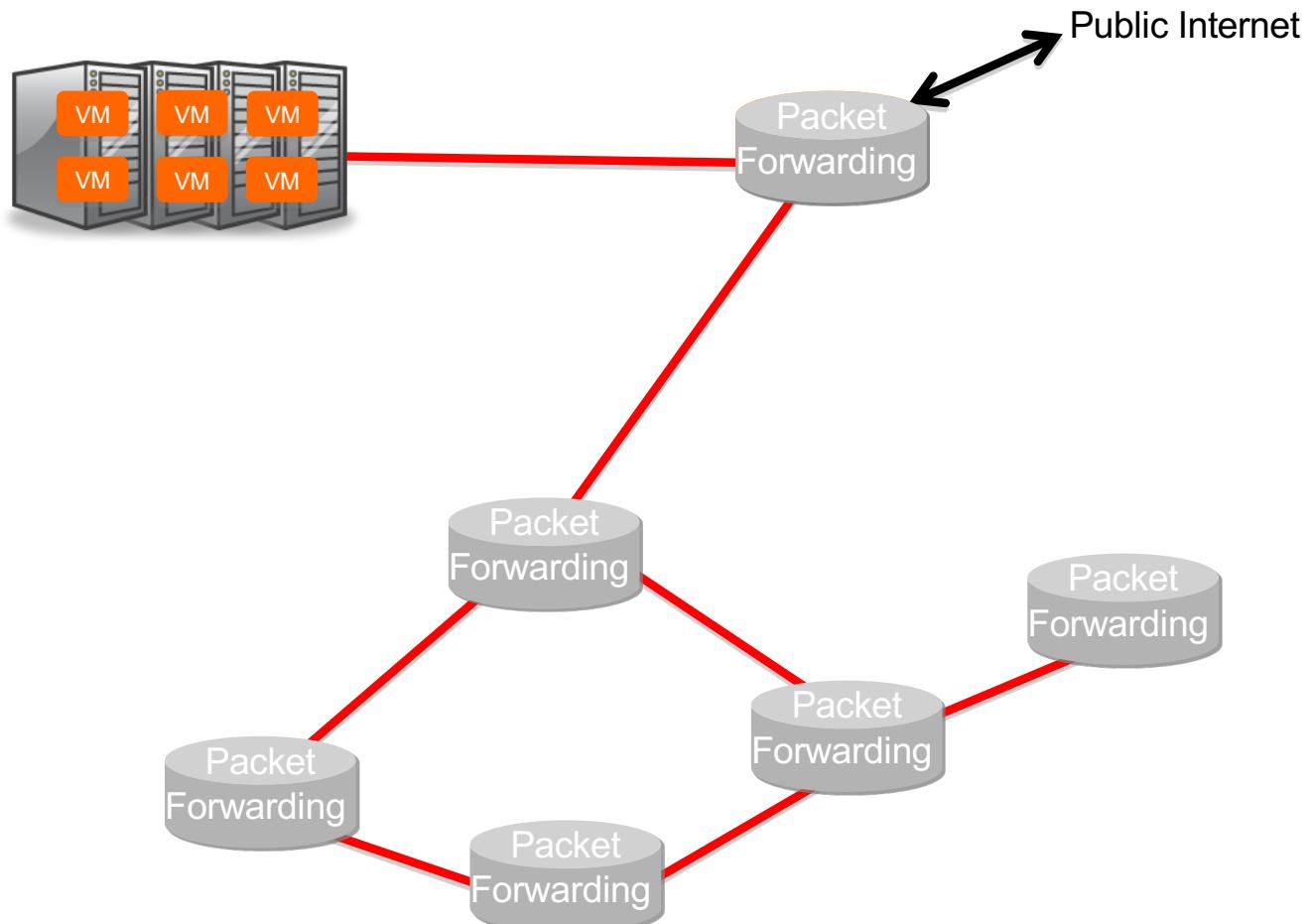
Software Defined Network (SDN)



Network Function Virtualization (NFV)



Network Function Virtualization (NFV)

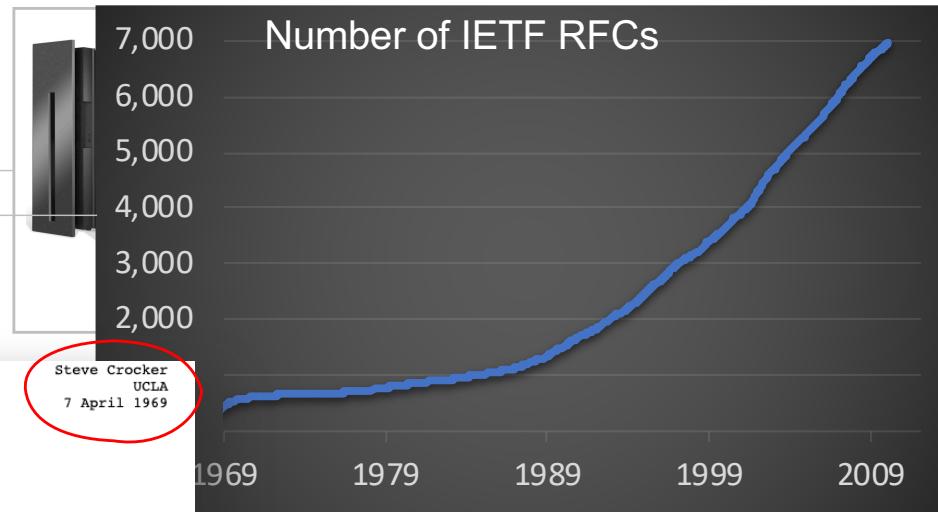


The Internet architecture is
evolving faster than ever

“closed and proprietary”
“proliferation of standards”
“barrier to entry”
“stranglehold by vendors”

Network Working Group
Request for Comments: 1

Title: Host Software
Author: Steve Crocker
Installation: UCLA
Date: 7 April 1969
Network Working Group Request for Comment: 1



2010

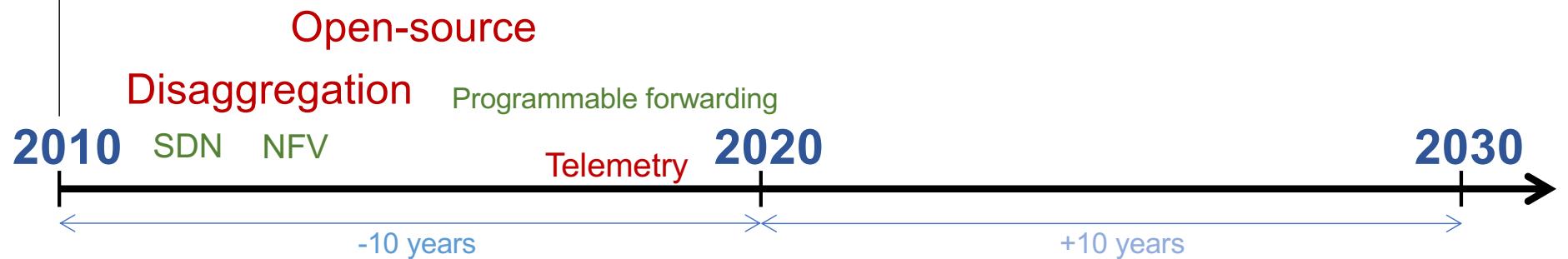
2020

2030

← -10 years +10 years →

Happy Birthday Internet!

“closed and proprietary”
“proliferation of standards”
“barrier to entry”
“stranglehold by vendors”



“closed and proprietary”
“proliferation of standards”
“barrier to entry”
“stranglehold by vendors”



Some possibilities for 2030

1. NICs, Switches, vSwitches, end host networking stacks will have been programmable for >7 years.
2. We will think of a network as a programmable platform. Behavior described at top; partitioned, compiled and run across elements.
3. Every network might work differently, programmed and tailored locally.
e.g **Routing**: Packets might be source-routed by topology-aware end-hosts.
e.g **Congestion control**: Will might use direct knowledge of precise queue occupancy, not heuristics based on loss and RTT.

Some possibilities for 2030

4. We will no longer think in terms of protocols. Instead, we will think in terms of software. All functions and “protocols” will have migrated up and out of hardware into software. Throughout the Internet.
5. Networking students will learn how to program a network top-down, as a distributed computing platform. Protocols will be described in historical terms. “Routing” and “Congestion control” will be programs, partitioned across the system by a compiler.

Some possibilities for 2030

6. Software engineering techniques will be used routinely: formal verification, on-the-fly checking of correctness, code generation (for control and forwarding).
7. Fine-grain per-packet measurement will monitor correct function and performance.
8. Computation will routinely be accelerated by the network.
9. Networks will be programmed by many, operated by few.

Q: What other consequences might there be?

We will briefly go to Breakout rooms with 4 people per room....
One person from your group should be prepared to report back.

I will call on 3-4 groups to speak when we return.

“Software will eat the world”
Marc Andreessen

Conclusion

Networking is extremely cool right now

- Real, important problems
- The Internet is evolving more rapidly
- You can influence its future
- There are real opportunities for impact
- Inherently interdisciplinary

But the field is immature

- More of a “domain” than a “discipline”

Hints on reading a paper

Keshav: "How to Read a paper", CCR 2007

Three stage approach

1. Read quickly in 5-10minutes
2. Read with greater care; ignore proofs
3. Deconstruct paper; question all assumptions

First papers

Read thoroughly, submit critiques

For Thursday April 9:

1. The Design Philosophy of the DARPA Internet Protocols
Clark, 1988

For next Tuesday April 14:

1. End-to-End Arguments in System Design
Saltzer, Reed and Clark, 1984
2. Flow Rate Fairness: Dismantling a Religion
Briscoe, 2007

First optional papers

Read through briefly

Optional (easy reads)

1. A Brief History of the Internet
Leiner et al., 2003
2. On Distributed Communication Networks
Paul Baran, 1963

Our first paper

The Design Philosophy of the DARPA Internet Protocols

David D. Clark*

Massachusetts Institute of Technology
Laboratory for Computer Science
Cambridge, MA. 02139

(Originally published in Proc. SIGCOMM '88, Computer Communication Review Vol. 18, No. 4,
August 1988, pp. 106–114)

Abstract

The Internet protocol suite, TCP/IP, was first proposed fifteen years ago. It was developed by the Defense Advanced Research Projects Agency (DARPA), and has been used widely in military and commercial systems. While there have been papers and specifications that describe how the protocols work, it is sometimes difficult to deduce from these why the protocol is as it is. For example, the Internet protocol is based on a connectionless or datagram mode of service. The motivation for this has been greatly misunderstood. This paper attempts to capture some of the early reasoning which shaped the Internet protocols.

1. Introduction

For the last 15 years¹ the Internet

architecture into the IP and TCP layers. This seems basic to the design, but was also not a part of the original proposal. These changes in the Internet design arose through the repeated pattern of implementation and testing that occurred before the standards were set.

The Internet architecture is still evolving. Sometimes a new extension challenges one of the design principles, but in any case an understanding of the history of the design provides a necessary context for current design extensions. The connectionless configuration of ISO protocols has also been colored by the history of the Internet suite, so an understanding of the Internet design philosophy may be helpful to those working with ISO.

This paper catalogs one view of the

David D. Clark (MIT)

Happy Birthday David!



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

The Design Philosophy of the DARPA Internet Protocols

- 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 [underneath].
- 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.