

EN.601.414/614

Computer Networks

Misc

Xin Jin

Spring 2019 (MW 3:00-4:15pm in Shaffer 301)



<https://github.com/xinjin/course-net>

Assignments

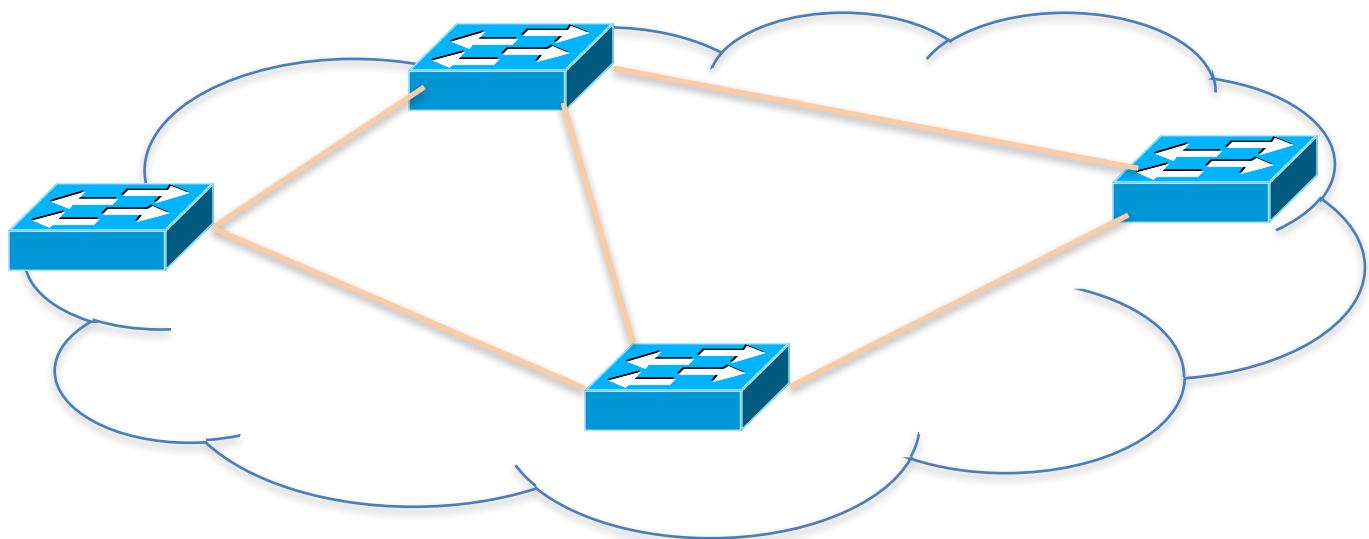
- **The grades for assignment 3 are out**
 - Average: 10.28, median: 10.0, std dev: 1.9
 - Great job!
- **Assignment 4 is due this Wednesday**
 - Keep going

Agenda

- **Software-Defined Networking**
- **Cloud Computing**
- **Network Virtualization**
- **Network Testing and Verification**
- **Big Network Data Processing**
- **AI and Networking**
- **Internet of Things**
- **Bitcoin and Blockchain**

Traditional Computer Networks

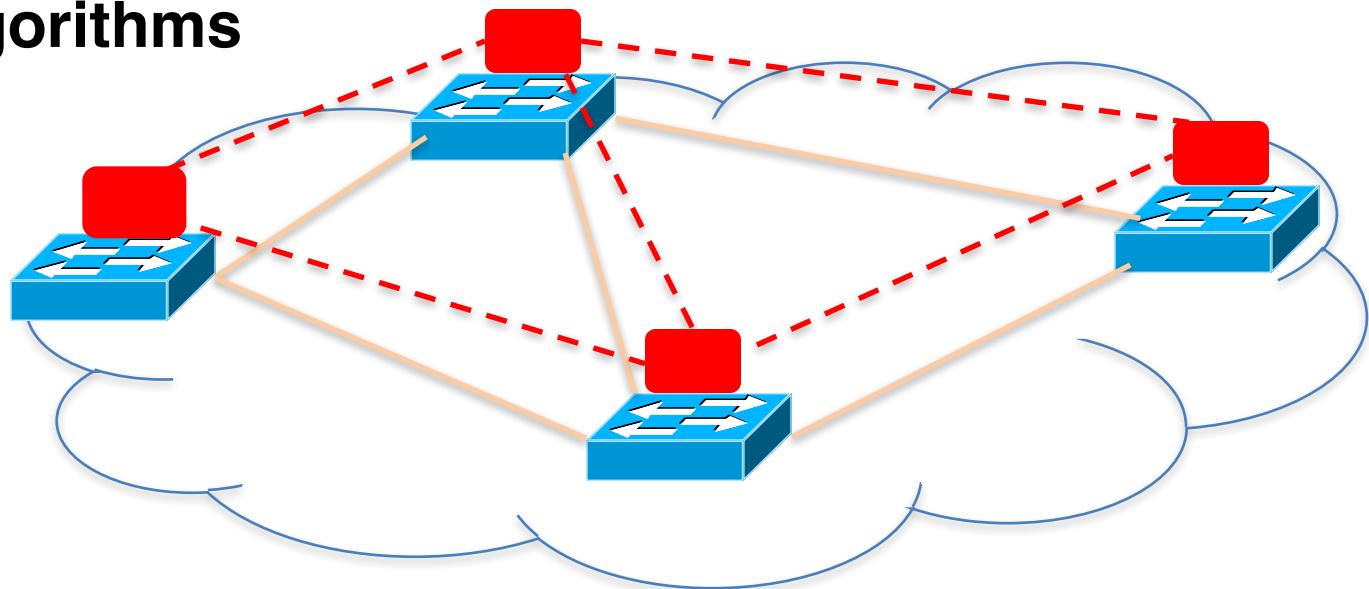
Data plane:
Packet
processing



**Forward, filter, buffer, mark,
rate-limit, and measure packets**

Traditional Computer Networks

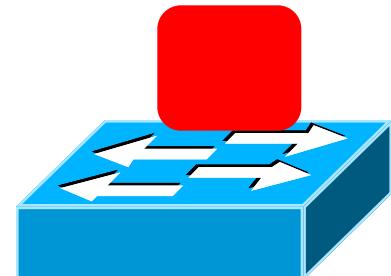
Control plane:
Distributed algorithms



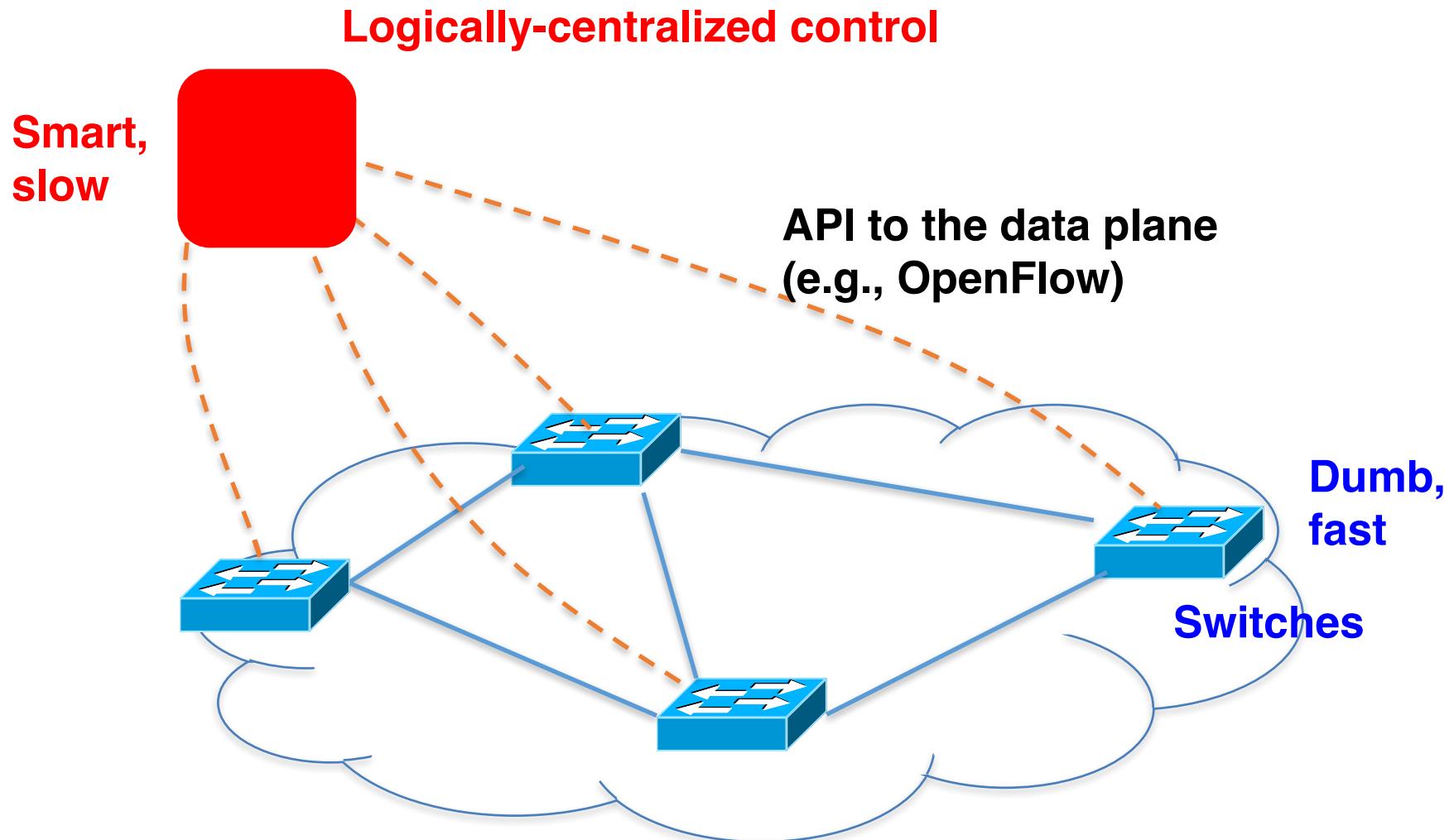
**Track topology changes, compute
routes, install forwarding rules**

The Call for a Change

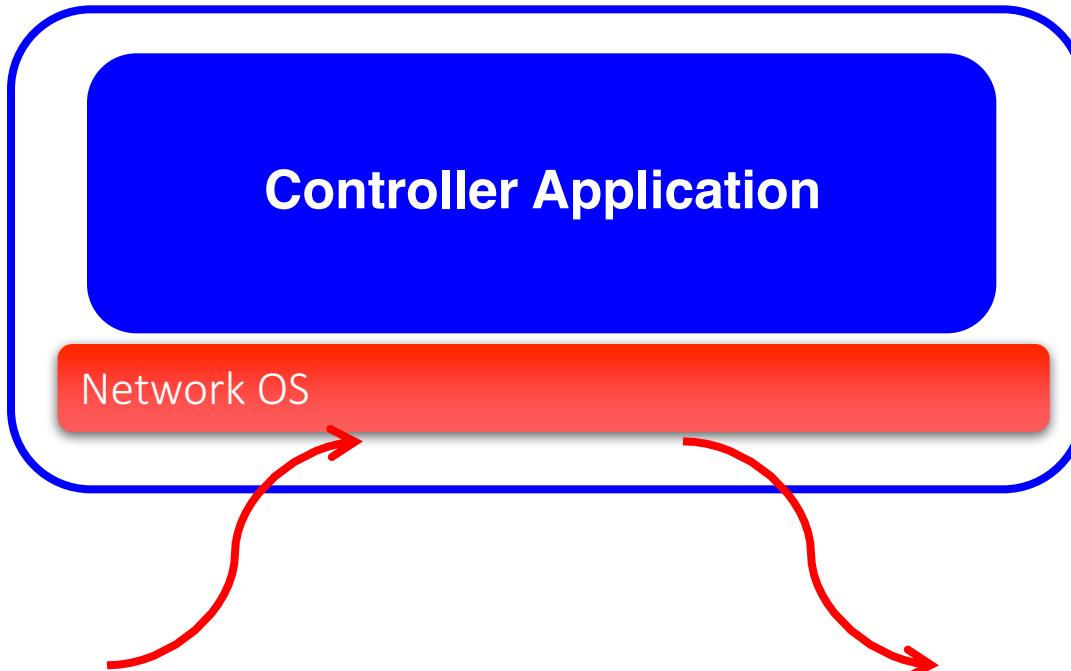
- **Simpler management**
 - No need to “invert” control-plane operations
- **Faster pace of innovation**
 - Less dependence on vendors and standards
- **Easier interoperability**
 - Compatibility only in “wire” protocols
- **Simpler, cheaper equipment**
 - Minimal software



Software Defined Networking (SDN)



Controller: Programmability



Events from switches

**Topology changes,
Traffic statistics,
Arriving packets**

Commands to switches

**(Un)install rules,
Query statistics,
Send packets**

A Helpful Analogy

From Nick McKeown's talk “Making SDN Work” at
the Open Networking Summit, April 2012

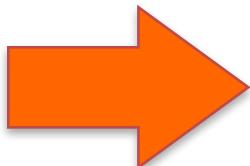
Mainframes

Specialized Applications

Specialized Operating System

Specialized Hardware

Vertically integrated
Closed, proprietary
Slow innovation
Small industry



— Open Interface —

Windows (OS)

or

Linux

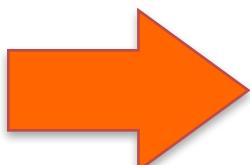
or

Mac OS

— Open Interface —



Microprocessor

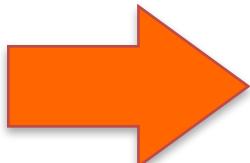


Horizontal
Open interfaces
Rapid innovation
Huge industry

Routers/Switches



**Vertically integrated
Closed, proprietary
Slow innovation**



— Open Interface —

Control
Plane

or

Control
Plane

or

Control
Plane

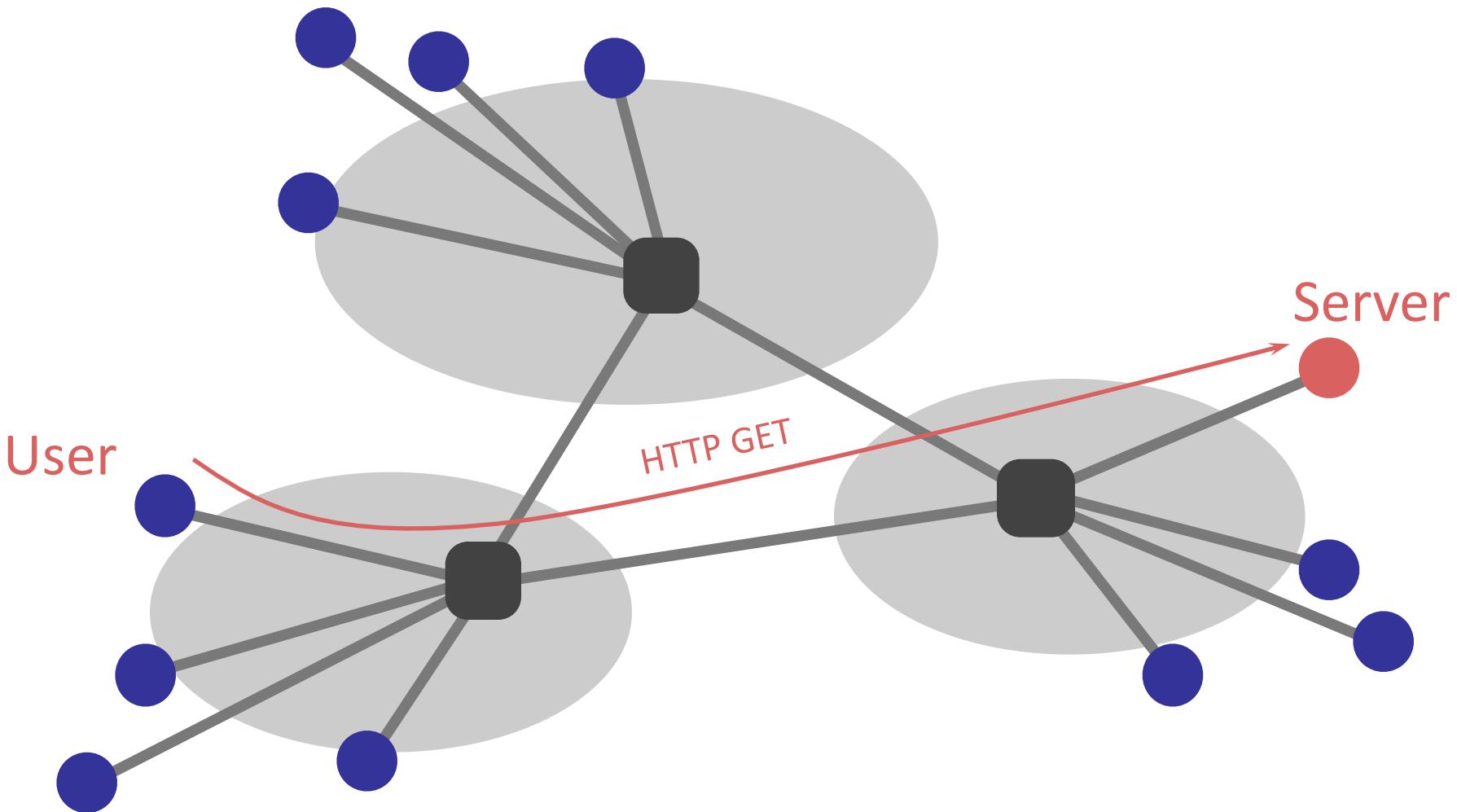
— Open Interface —

Merchant
Switching Chips

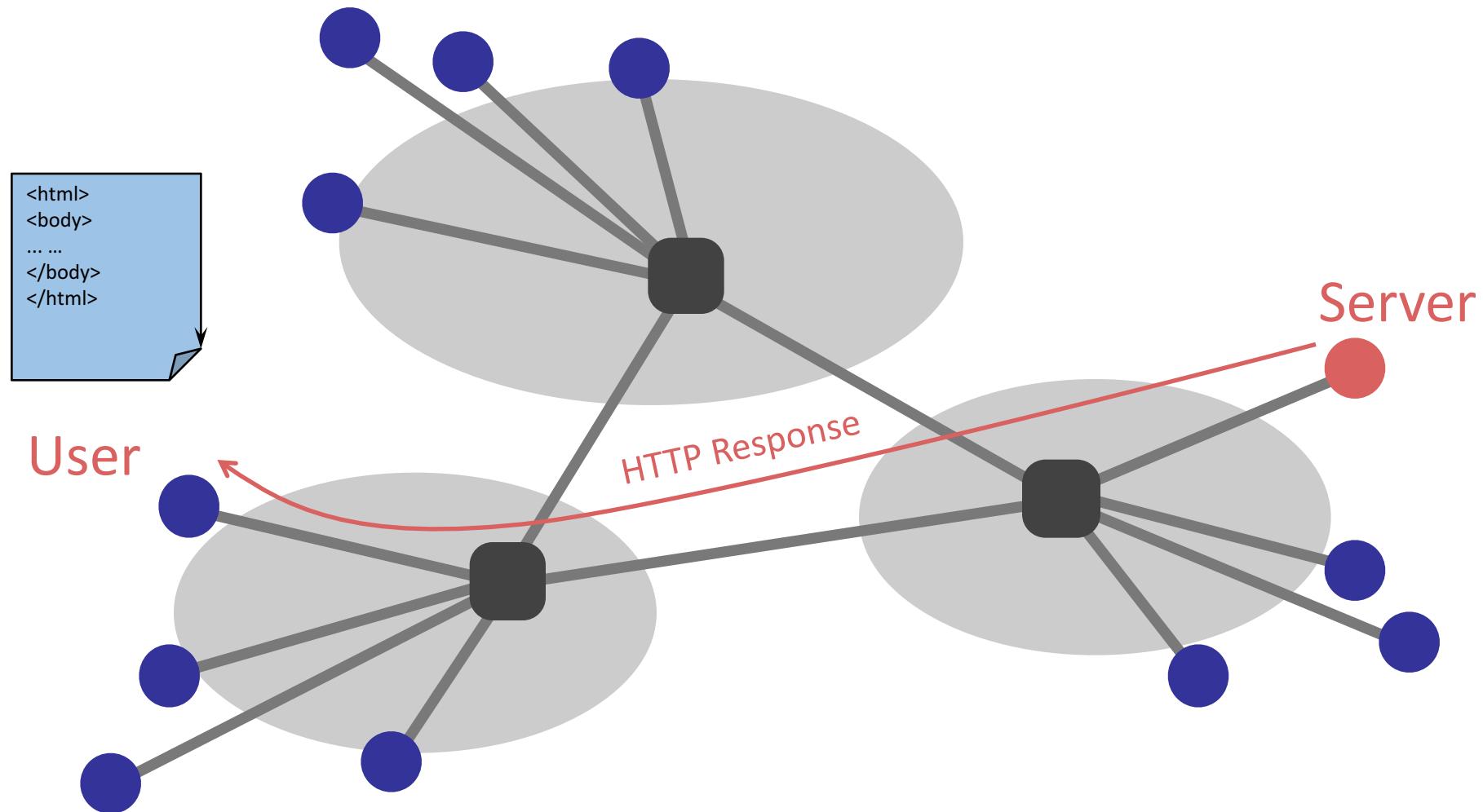
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Who's serving Web services?



Who's serving Web services?



Who's serving Web services?

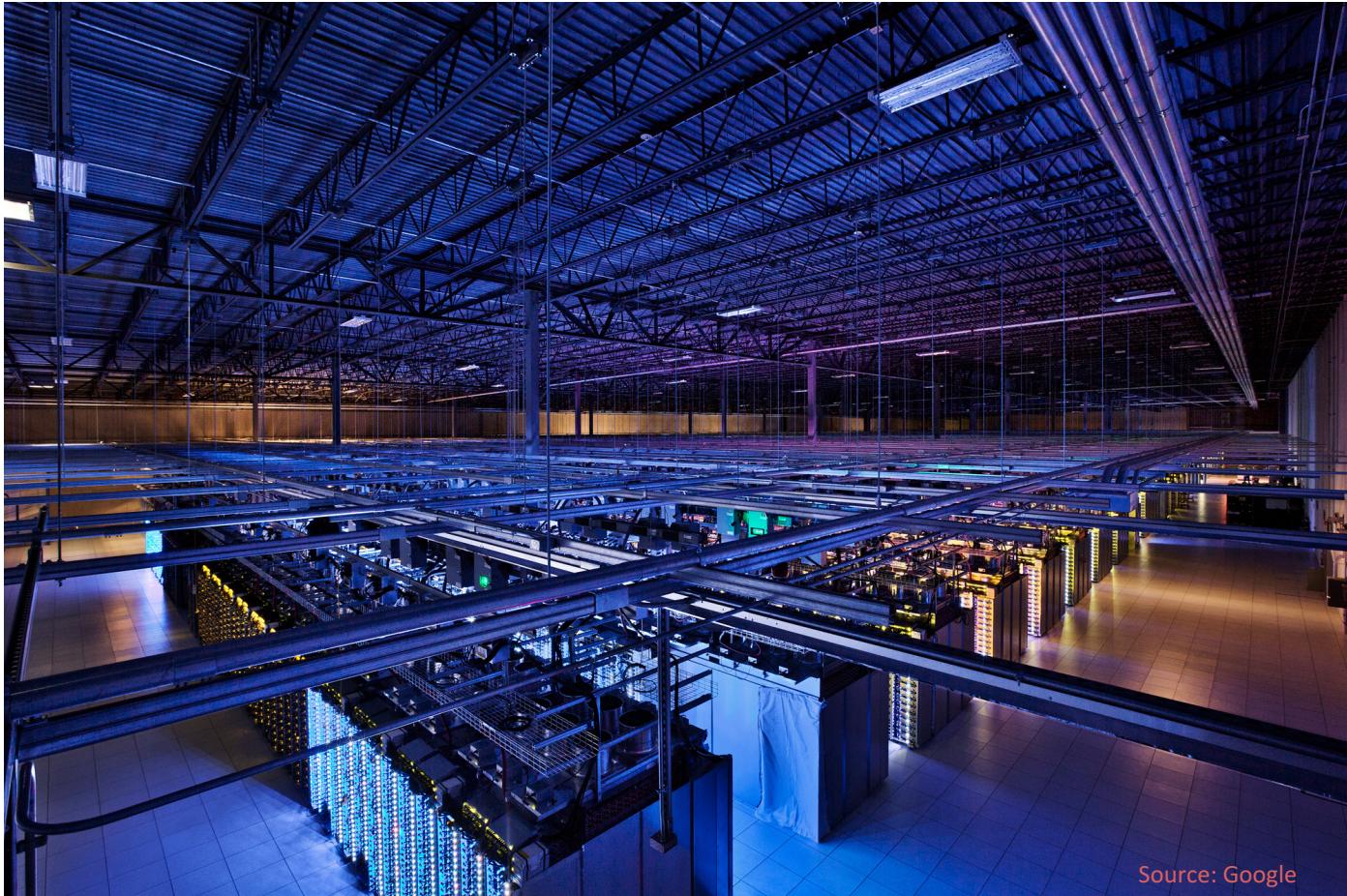
Datacenters



Source: Google

Who's serving Web services?

Datacenters



Source: Google

Who's serving Web services?

Datacenters



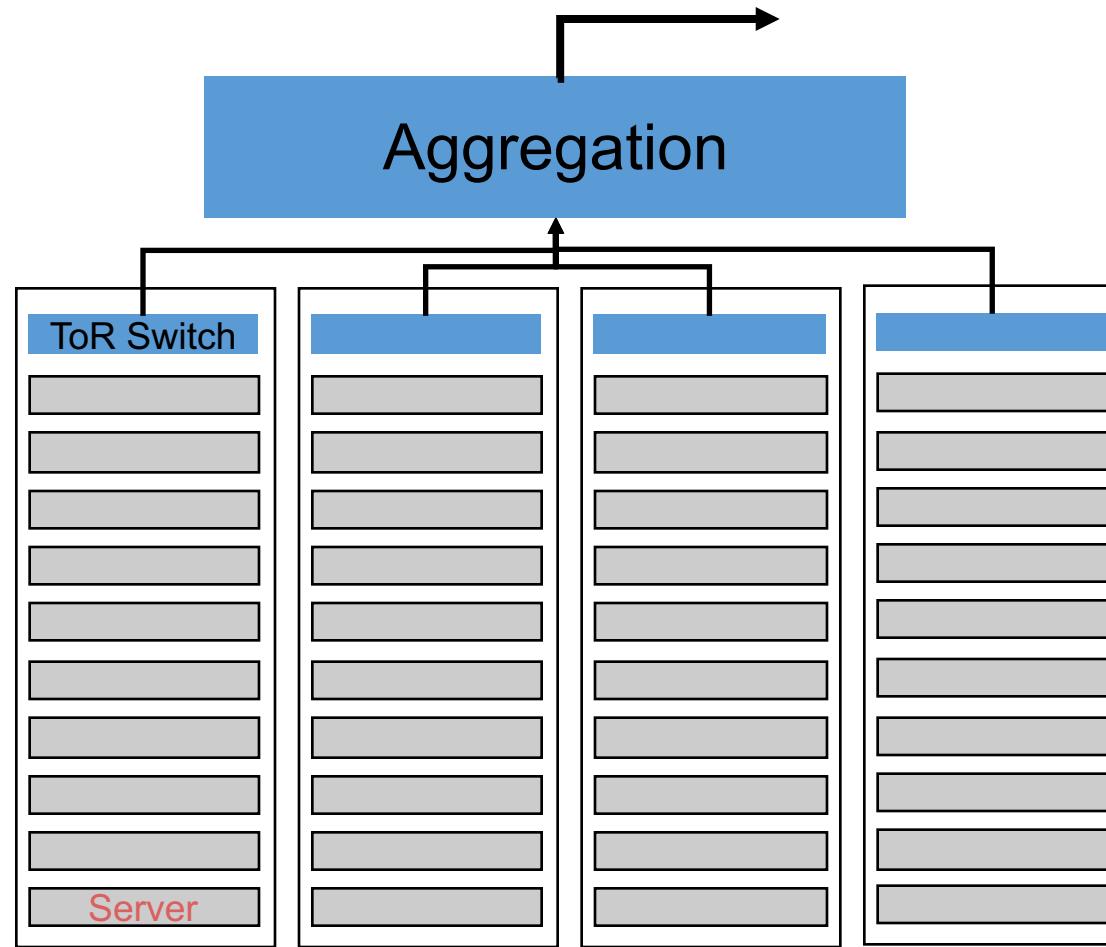
Datacenter networks

- **Tens to hundreds of thousands of hosts, often closely coupled, in close proximity:**
 - E-commerce (e.g., Amazon)
 - Content servers (e.g., Netflix, YouTube, Apple, Microsoft)
 - Search engines, data mining (e.g., Google)
 - Social networks (e.g., Facebook, Twitter, Instagram)
- **Challenges:**
 - Multiple applications, each serving massive numbers of clients

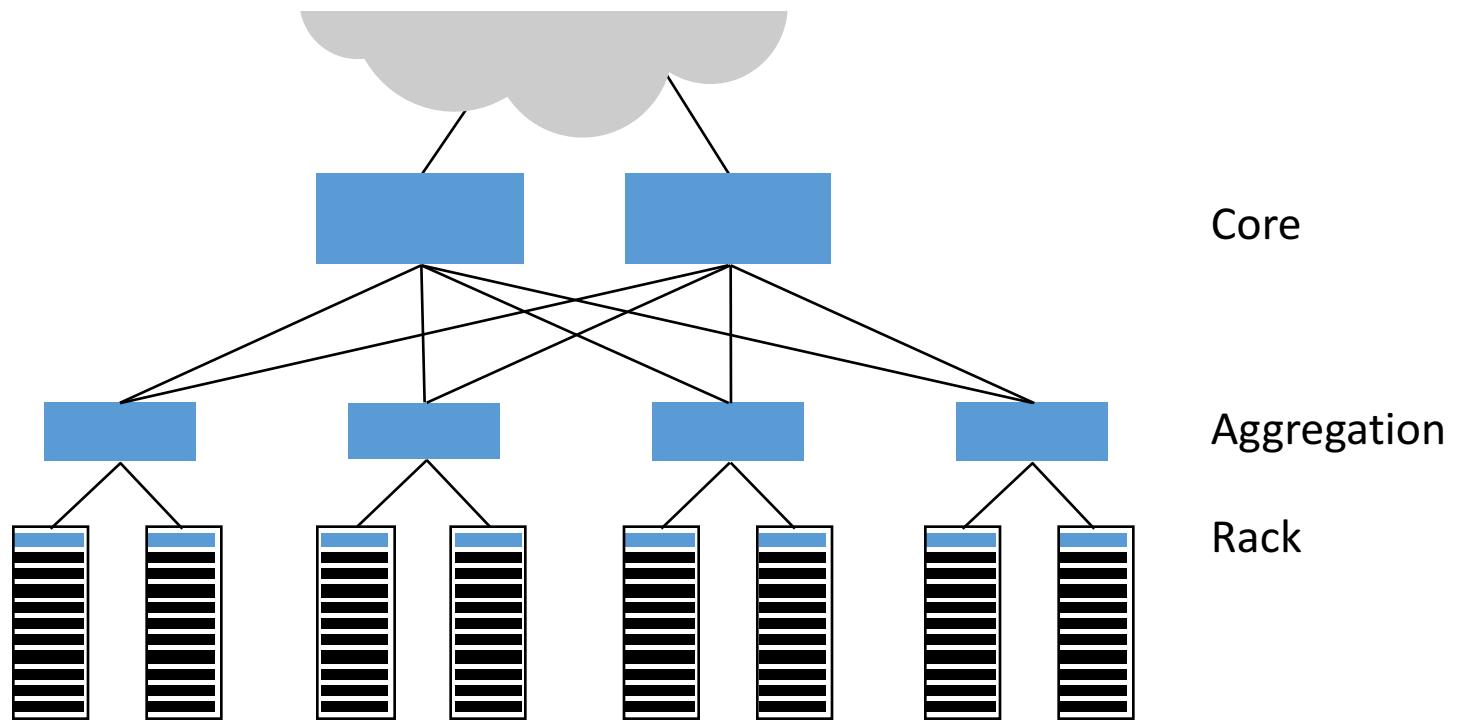
How big exactly?

- 1M servers/site [Microsoft/Amazon/Google]
- > \$1B to build one site [Facebook]
- >\$20M/month/site operational costs [MS'09]
- Data center systems spending will grow to **\$195 billion** in 2019. [Gartner report]
- But only O(10-100) sites

Datacenter networks



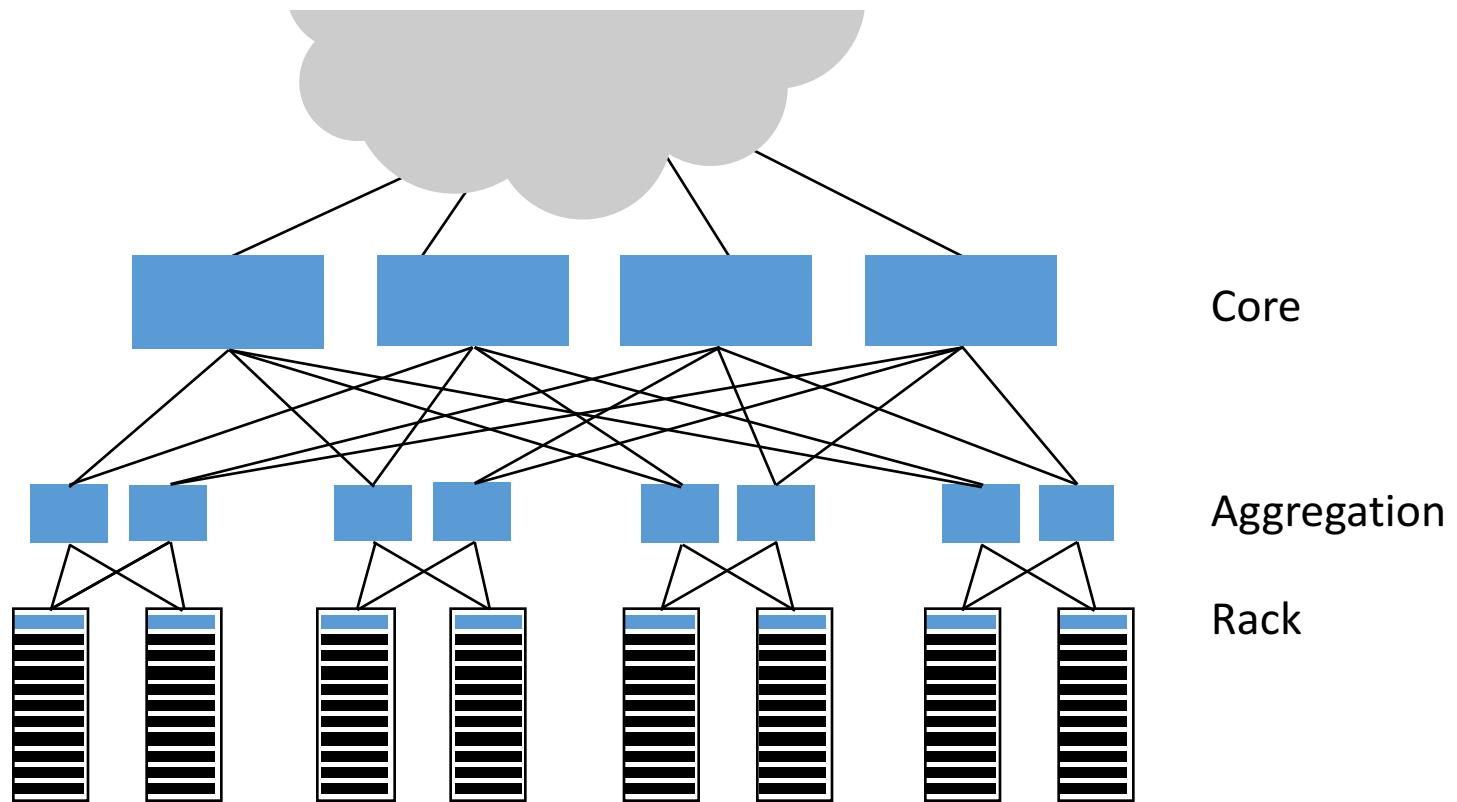
Datacenter networks (Cont.)



Challenges

- **Not enough bandwidth**
 - **Oversubscription**: Less bandwidth in the ToR-Agg links than all the servers bandwidth in the rack
 - **Oversubscription ratio**: Ratio between bandwidth underneath and bandwidth above
- **Not enough paths between server pairs**
 - Load balancing issues
 - Failure recovery issues

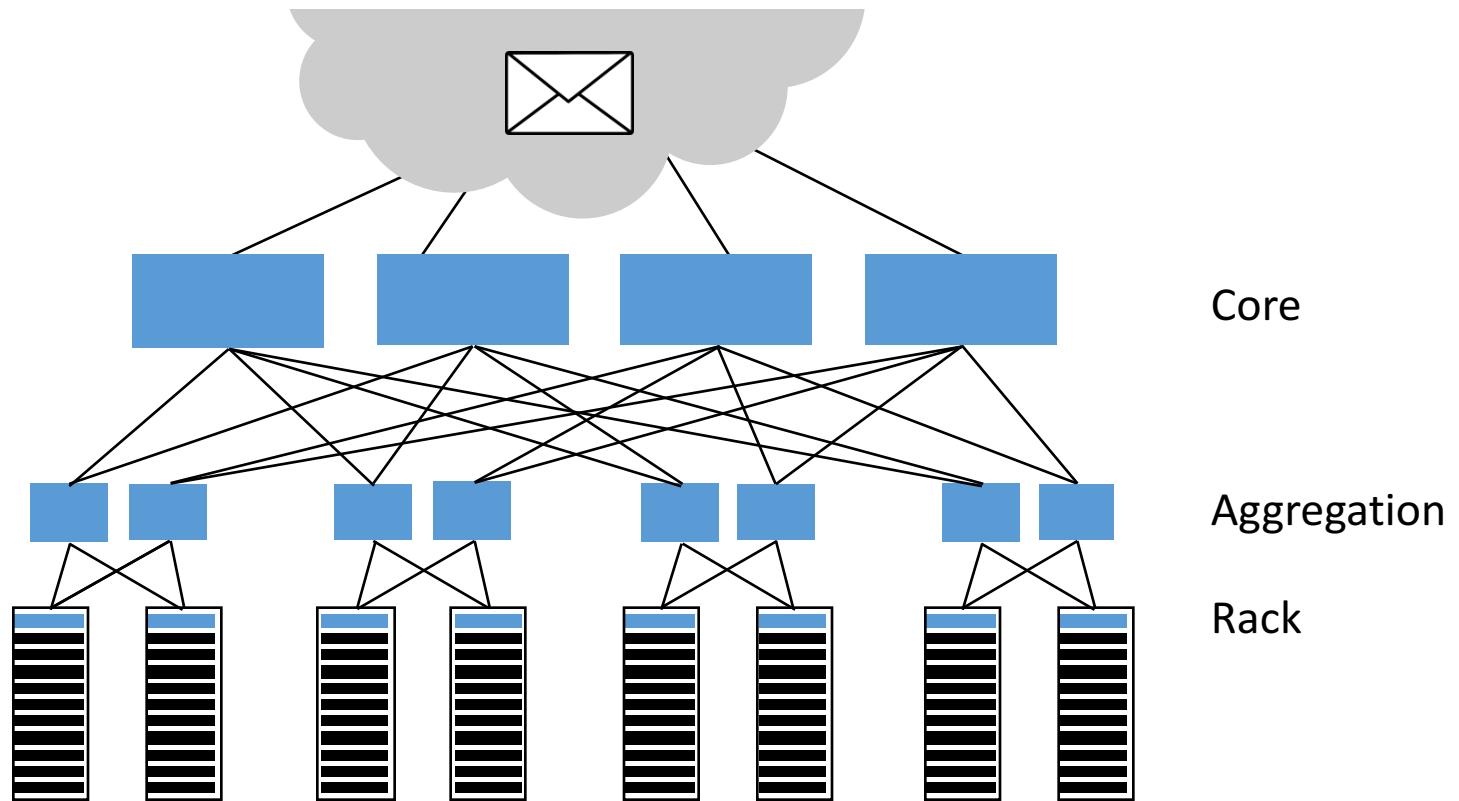
Modern datacenter networks: More bandwidth, more paths



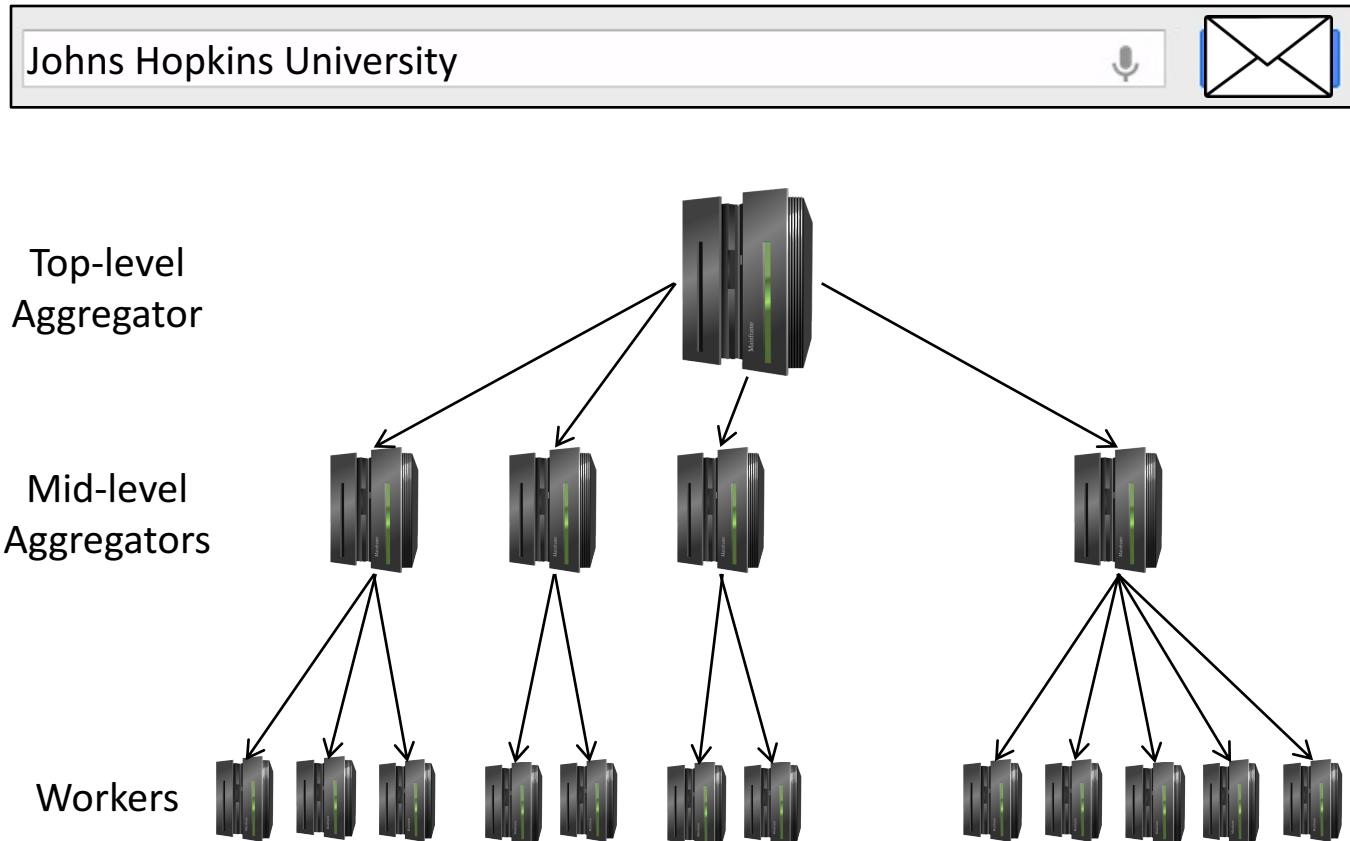
Let's take a Web service



Who's serving Web services?



What happens inside?



Partition-Aggregate traffic

Johns Hopkins University

About 45,200,000 results (0.66 seconds)

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[https://www.jhu.edu/ ▾](https://www.jhu.edu/)
We're America's first research university. Johns Hopkins was founded on the principle that by pursuing big ideas and sharing what we learn, we make the world a better place. For more than 140 years, we haven't strayed from that vision. Human brain icon. Intellectually diverse. More than 24,000 undergraduate and ...

Results from jhu.edu

Admissions & Aid
Undergraduate Admissions. We accept applications for the fall ...

Academics
Undergraduate Studies - Graduate Studies - Online Studies - ...

Graduate Studies
That spirit of inquiry, of challenging the way things are done, lives ...

Alerts
There are no emergency notices at this time. Emergency Contact ...

[Johns Hopkins University - Wikipedia](#)
https://en.wikipedia.org/wiki/Johns_Hopkins_University ▾
Johns Hopkins University is an American private research university in Baltimore, Maryland. Founded in 1876, the university was named for its first benefactor, the American entrepreneur, abolitionist, and philanthropist Johns Hopkins. His \$7 million bequest (~\$150 million in 2017 dollars)—of which half financed the ...
History · Campuses · Academics · Student life



See photos See outside

Johns Hopkins University

Private university in Baltimore, Maryland

[Website](#) [Directions](#)

Johns Hopkins University is an American private research university in Baltimore, Maryland. Founded in 1876, the university was named for its first benefactor, the American entrepreneur, abolitionist, and philanthropist Johns Hopkins. [Wikipedia](#)

Address: Baltimore, MD 21218

Acceptance rate: 11.4% (2016)

Undergraduate tuition and fees: 52,170 USD (2017)

Typical ACT scores: 31-34 (2014)

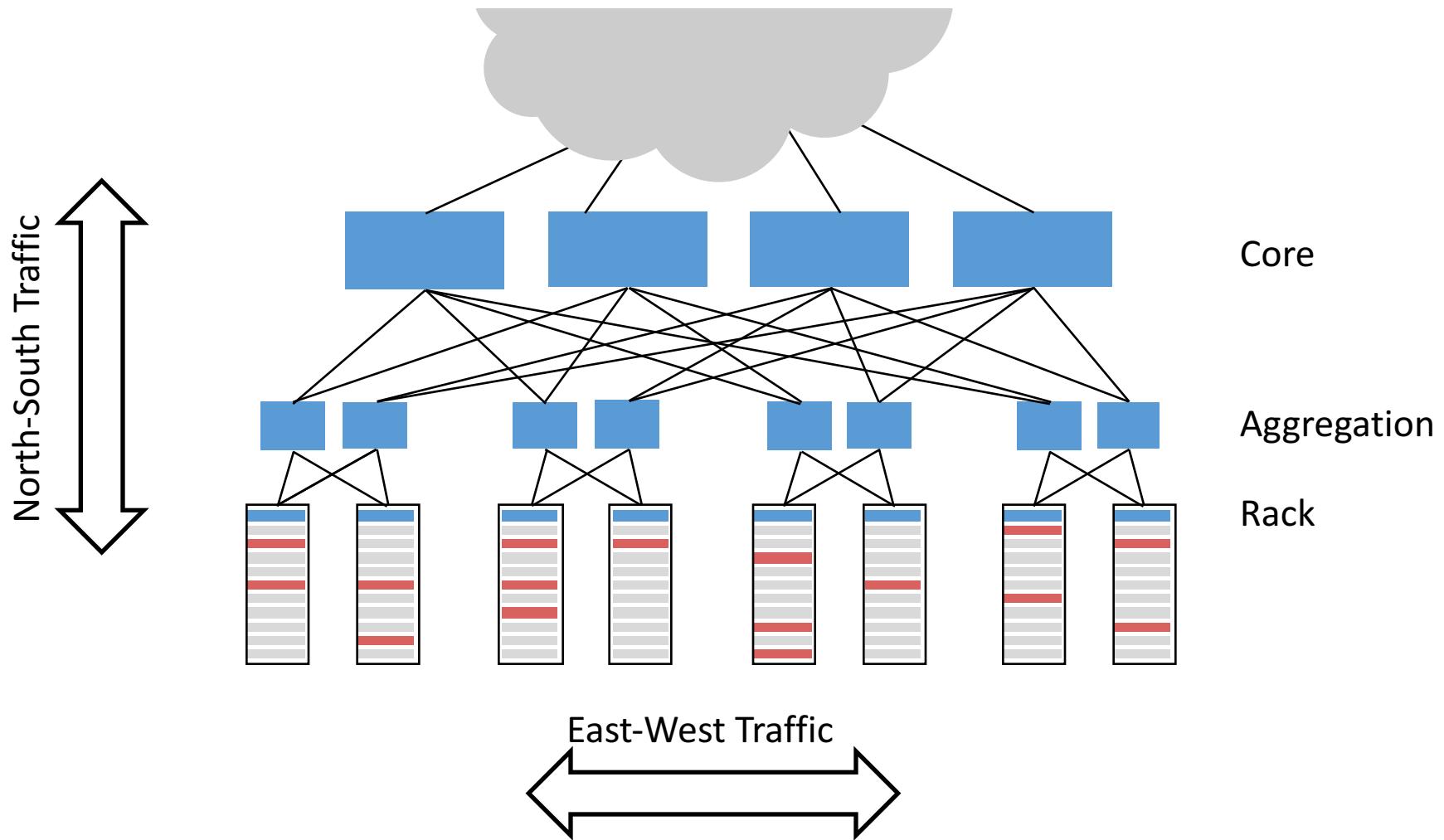
Typical SAT scores: Writing 670-760 (2014), Math 690-770 (2014), Reading 670-740 (2014)

[Suggest an edit](#)

Reviews from the web

4.2/5 [Facebook](#) · 766 votes

Partition-Aggregate traffic



End-to-end response time

- **Less than 200 milliseconds between receiving user query in the browser and displaying the results**
 - RTT = O(10) to 100 milliseconds
 - What remains?
- **Next time, when the page is not loading fast enough, think about the poor servers working for you 😊**

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What are we talking about when we talk about network virtualization?

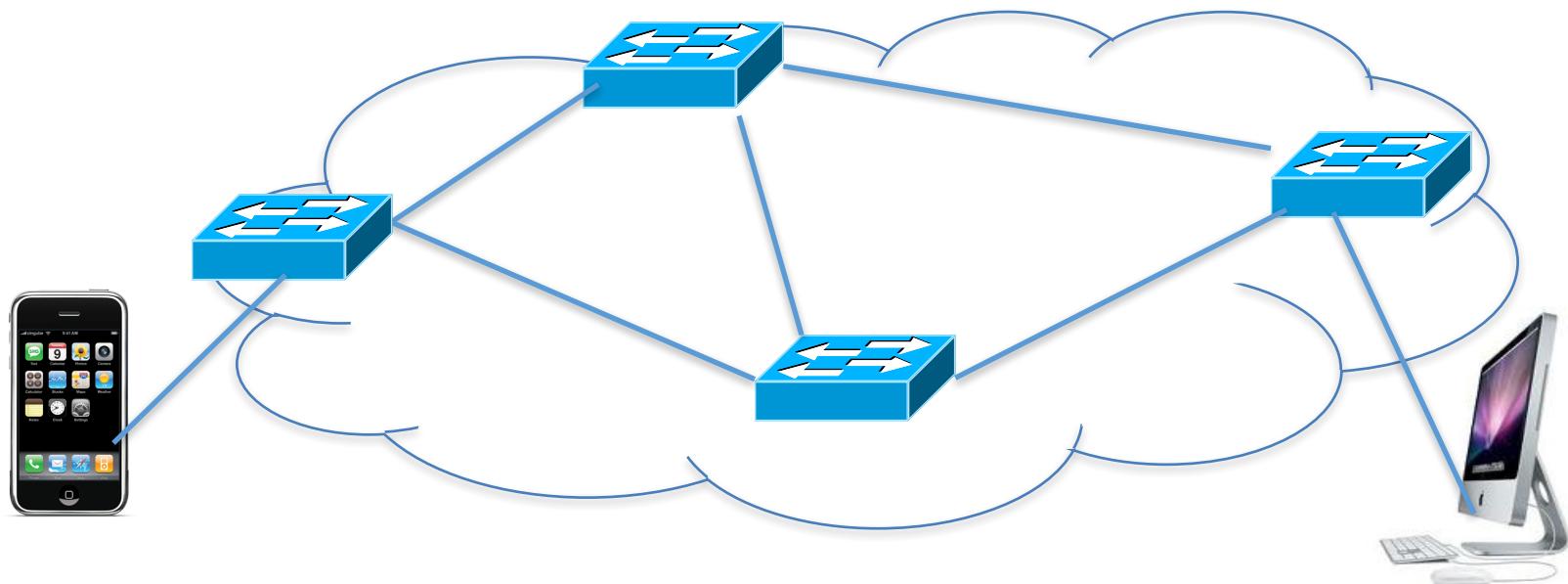
Network Virtualization of the “Network”

Controller #1

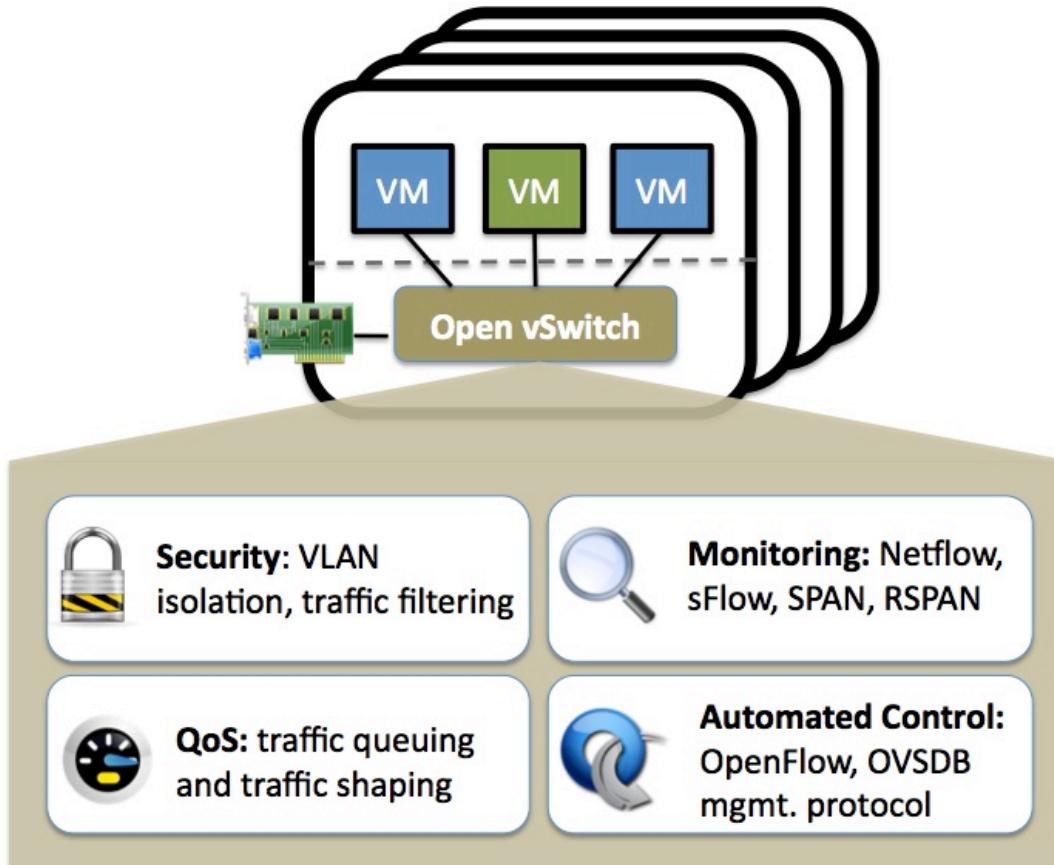
Controller #2

Controller #3

Partition the space of packet headers



Network Virtualization of the “Host”



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Network Testing and Verification

- **What problems to test and verify?**

- Reachability
- Loop
- Blockhole
- Policy: access control, isolation for multi-tenancy

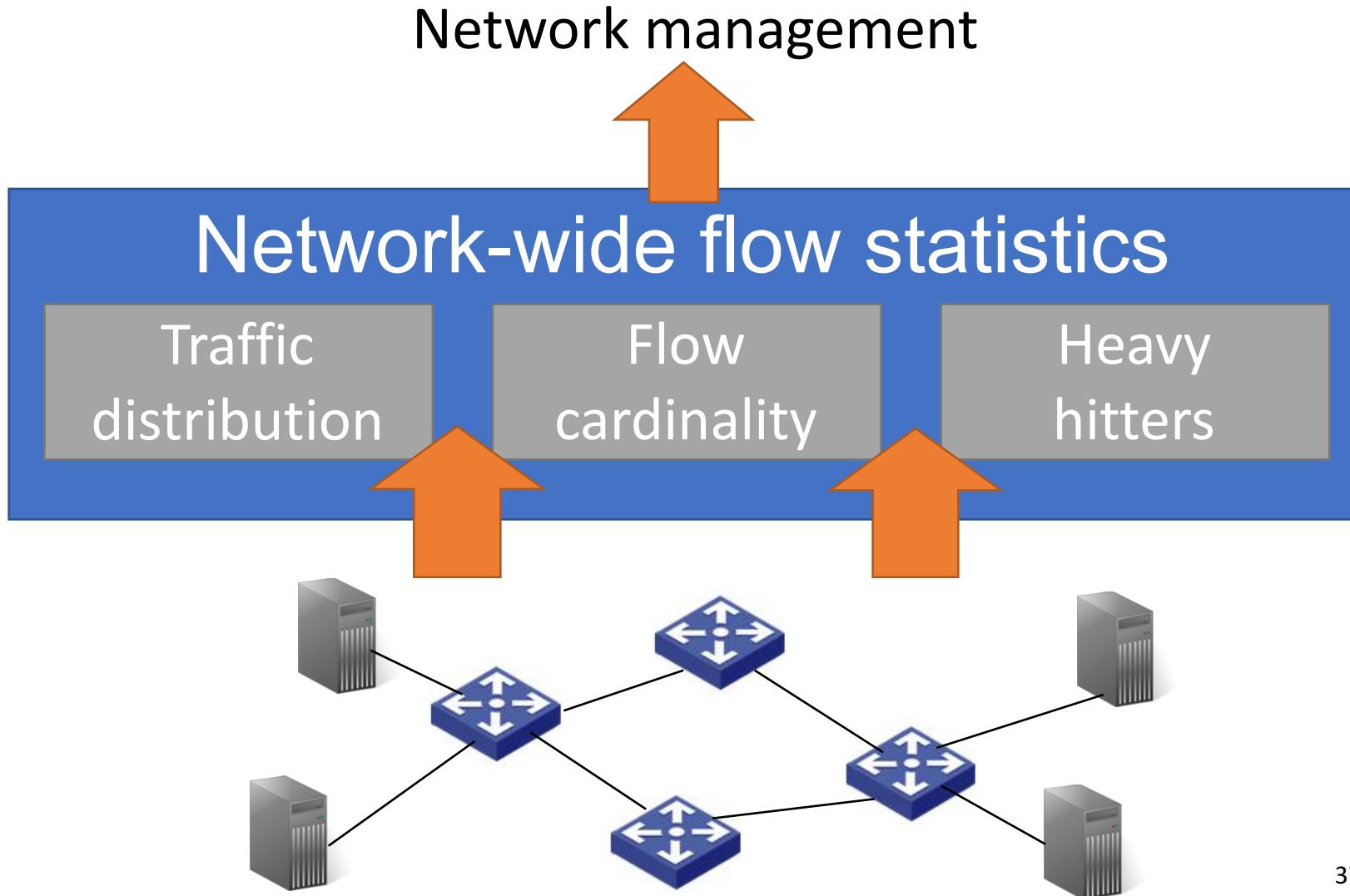
- **How to test and verify?**

- Control plane
 - Analyze switch configuration files
- Data plane
 - Analyze flow tables in switches
 - Passively collect network measurements
 - Actively inject test packets

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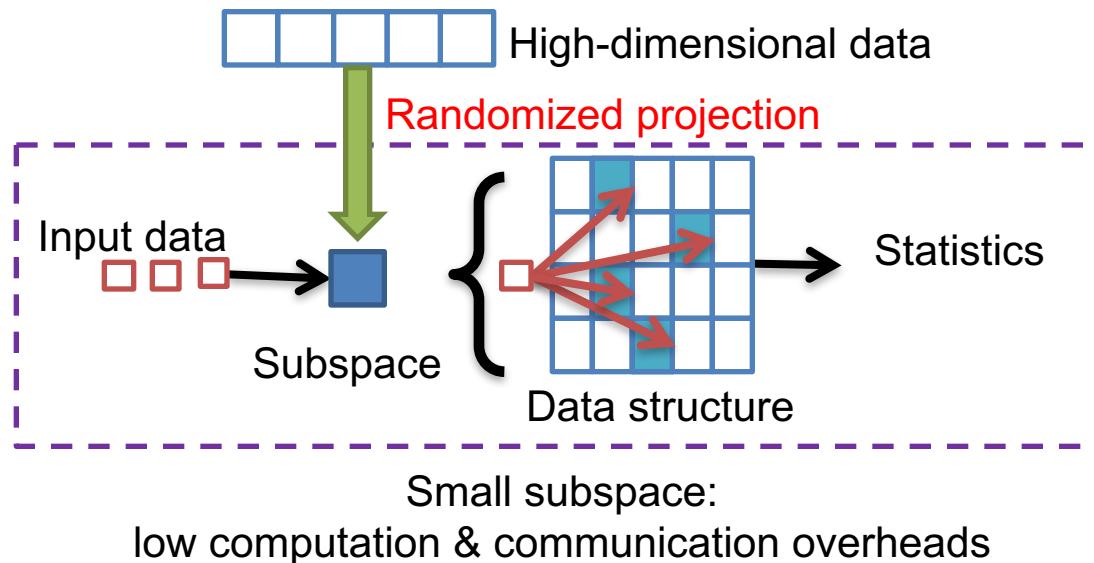
Big Network Data Processing



Big Network Data Processing

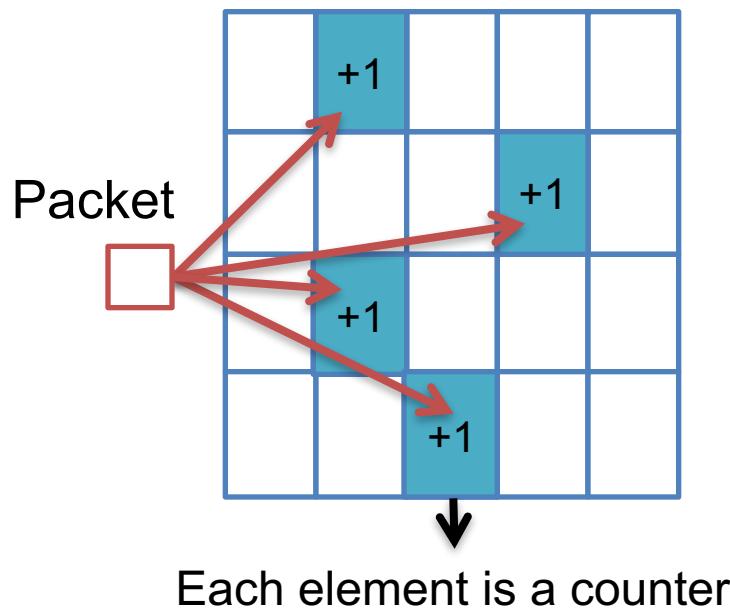
- **Sketch: a promising solution**

- A family of randomized algorithms
- Key idea: project high-dimensional data into small subspace
- Subspace reflects mathematical properties
 - Strong theoretical error bounds when querying for statistics



Big Network Data Processing

- Example: count flow packets with Count-Min sketch



➤ Update with a packet

- Hash flow id to one counter per row
- Increment each selected counter

➤ Query a flow

- Hash the flow to multiple counters
- Take the minimum counter as estimated packet count

➤ Theoretical guarantees

- Allocate $\lceil \log_2 \frac{1}{\delta} \rceil$ rows and $\lceil \frac{U}{\epsilon} \rceil$ counters each row
- The error for a flow is at most ϵ with probability at least $1 - \delta$

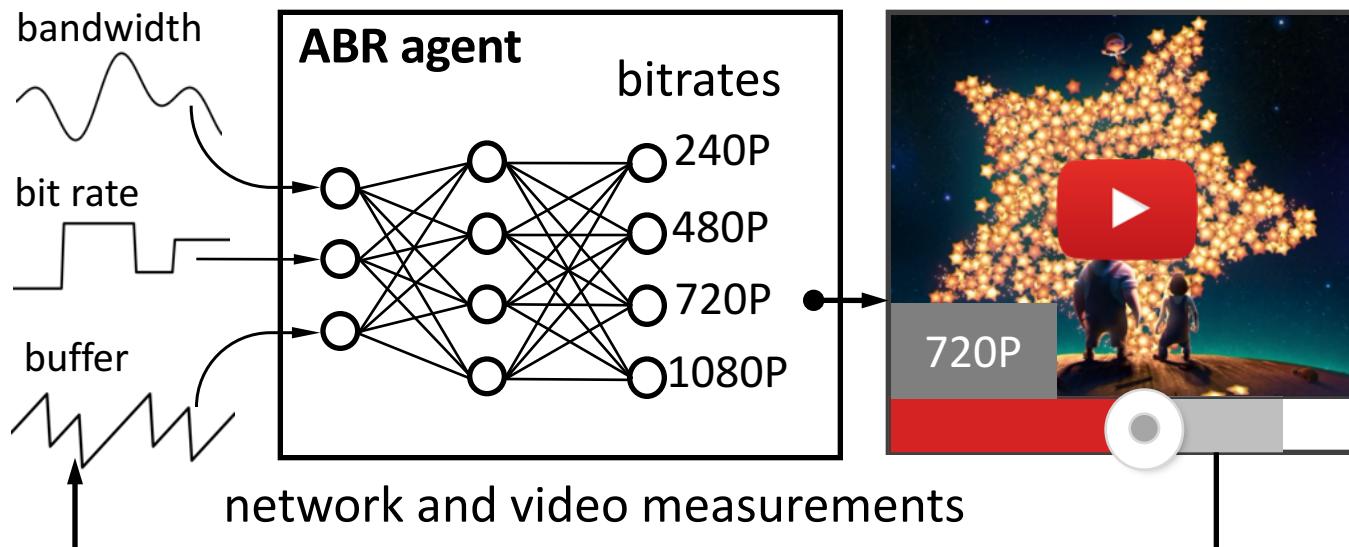
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AI and Networking

- **AI for networking**

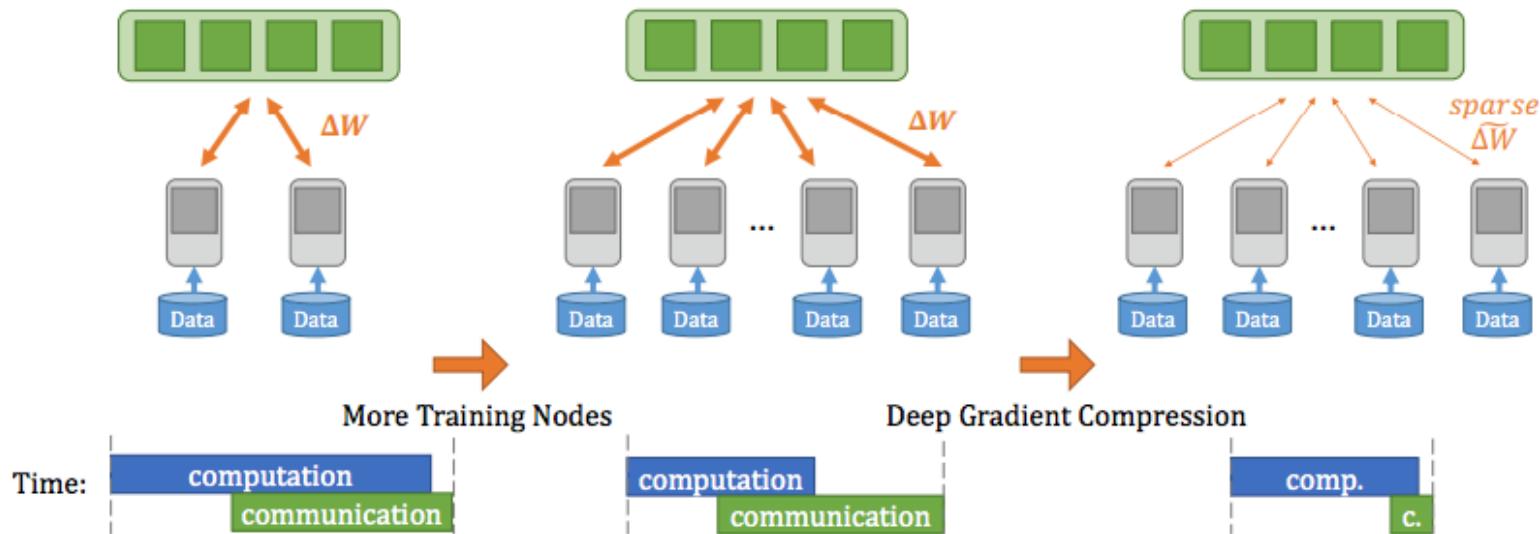
- Apply AI to solve networking problems, e.g., video streaming, routing, congestion control
- Example: apply deep reinforcement learning to bitrate adaptation for better Quality of Experience (QoE) [SIGCOMM'17 Pensieve]



AI and Networking

- **Networking for AI**

- Apply networking to solve AI problems, e.g., improve communication efficiency for training and serving
- Example: compress gradients to reduce communication to speed up distributed training of DNNs [ICLR'18 DGC]



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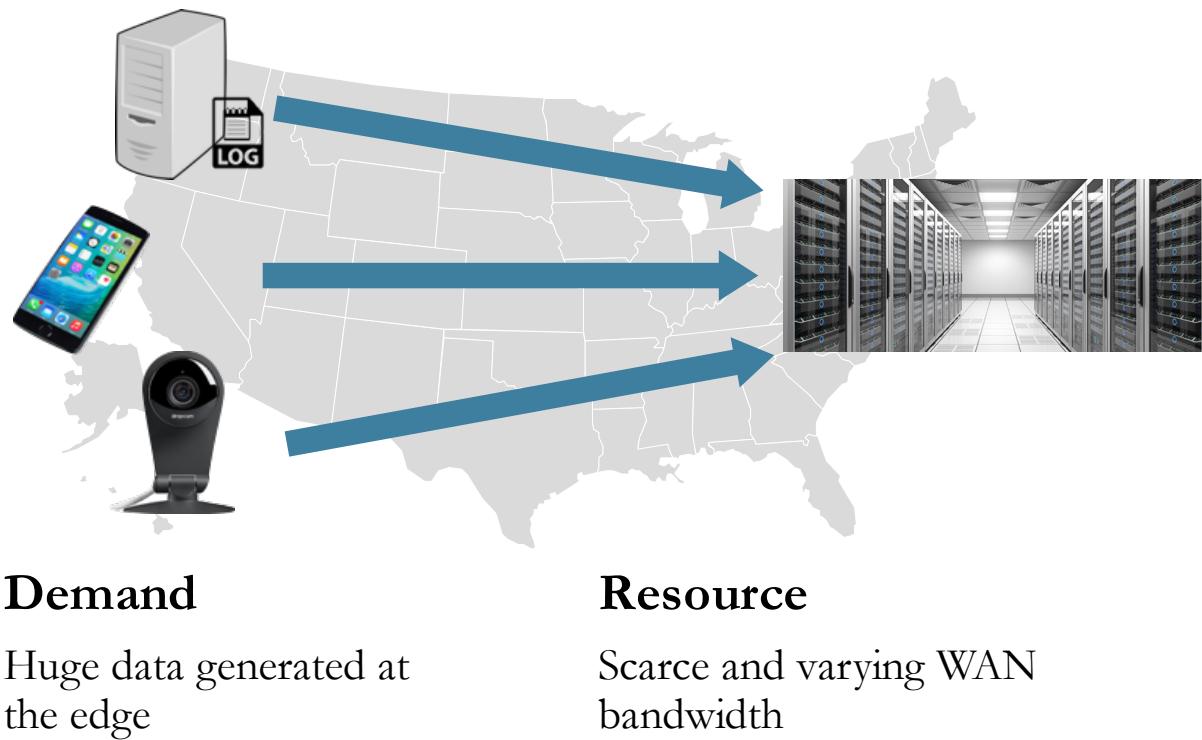
Internet of Things

- Internet-connected things are everywhere
[MobiCom'19 Living IoT]



Internet of Things

- And, we need to collect and analyze the data collected from all of them [SIGCOMM'18 AWStream]



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What is bitcoin?

Bitcoin is money.

What is money?

Types of Money

- Paper



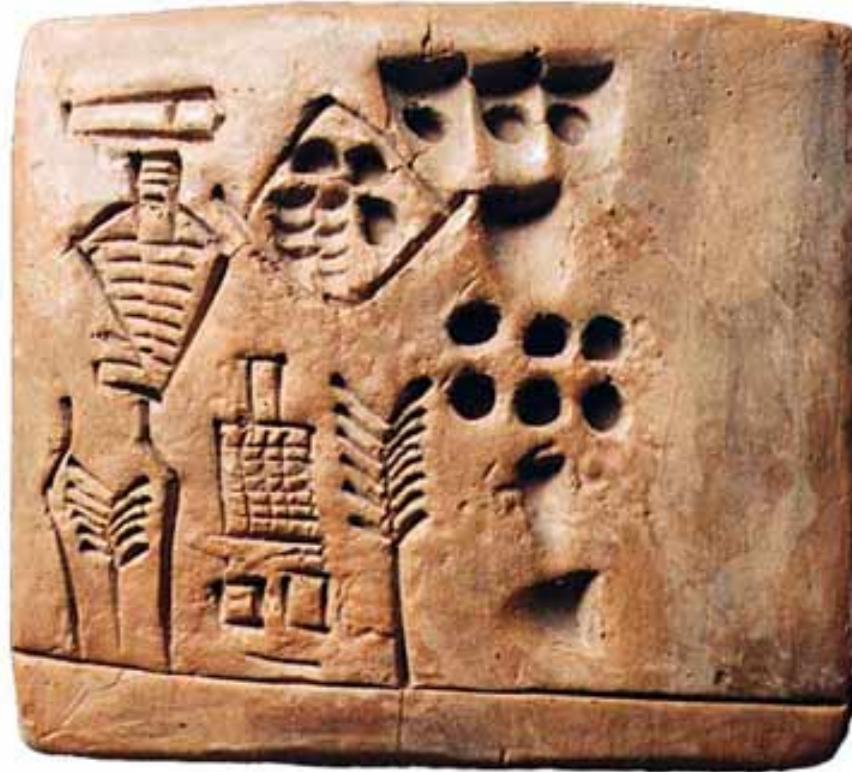
Types of Money

- **Gold, silver, and precious metals**



Types of Money

- **Grains and other crops**



Types of Money

- Shells (e.g. wampum)



Types of Money

- Ramen noodles



EurekAlert! | AAAS

HOME NEWS MULTIMEDIA MEETINGS PORTALS ABOUT

PUBLIC RELEASE: 22-AUG-2016

Ramen noodles supplanting cigarettes as currency among prisoners

AMERICAN SOCIOLOGICAL ASSOCIATION



PRINT E-MAIL

Types of Money

- Digital currencies: a number on your digital (banking) account

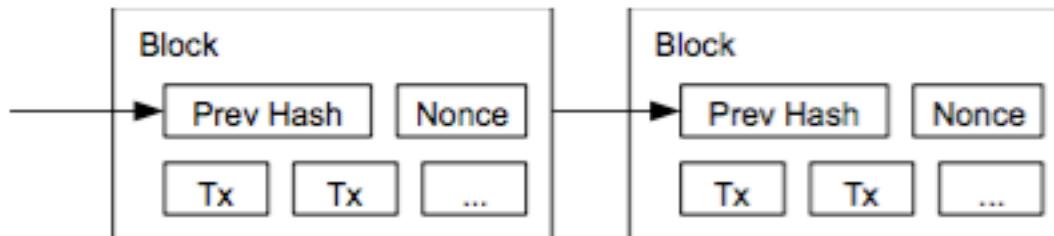


Bitcoin and Digital Currencies

- **Advantages of digital currencies**
 - Easy to produce
 - Easy to use
 - Easy to store
- **Bitcoin is a decentralized digital currency without a central bank or single administrator that can be sent from user to user on the peer-to-peer bitcoin network without the need for intermediaries.**
 - Bitcoin, and Cryptocurrencies in general, are just one type of digital currencies
 - Key feature: decentralization, no central bank or single administrator

Bitcoin and Blockchain

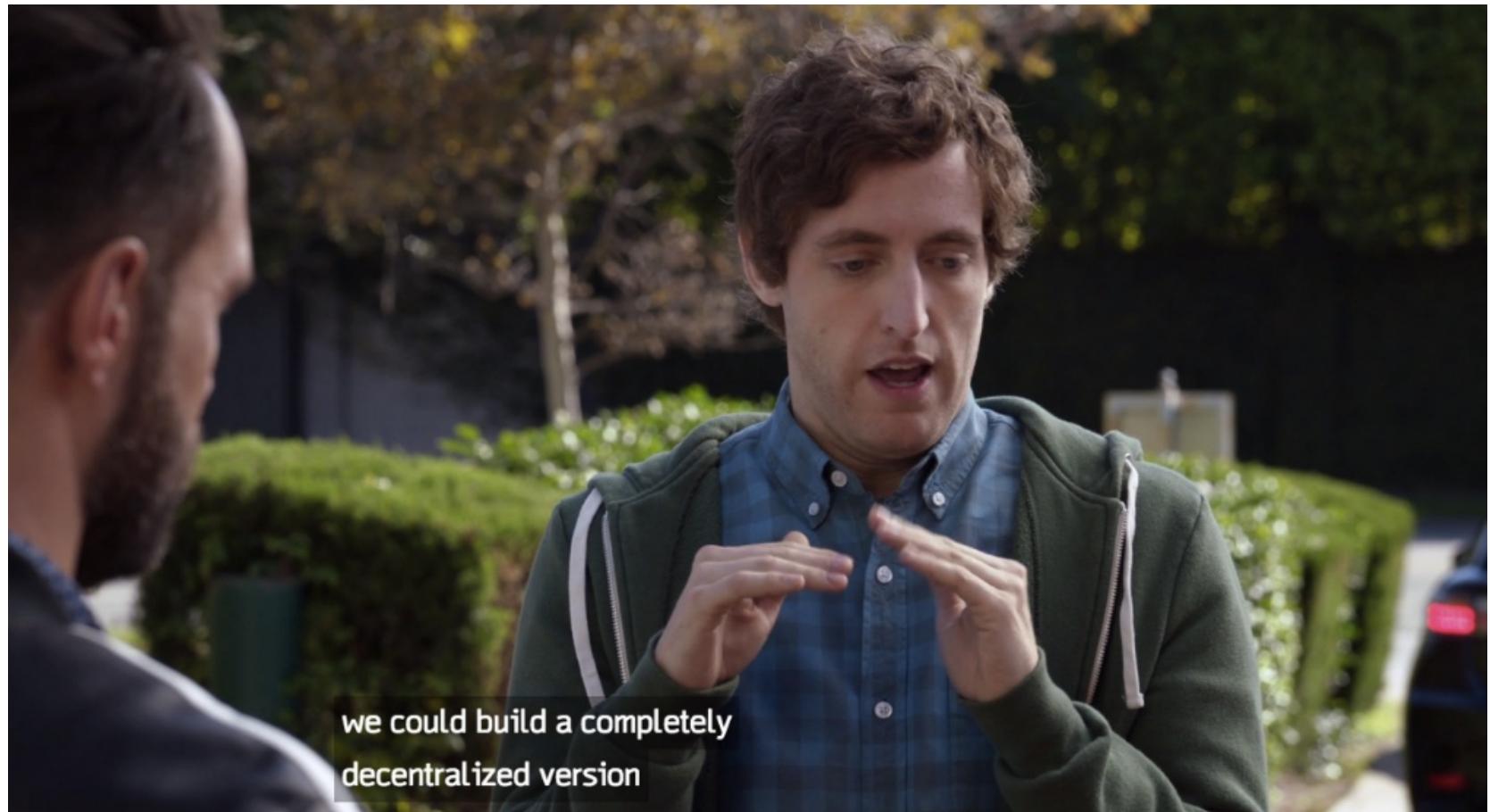
- Bitcoin is realized by the blockchain technology
- A blockchain is a linked list of blocks
- Each block contains a set of transactions
 - The blockchain stores the entire transaction history
- The blockchain is replicated in all participants
 - No need to trust any single entity
 - It works as long as more than half of the participants are honest



And then, the new Internet...



And then, the new Internet...



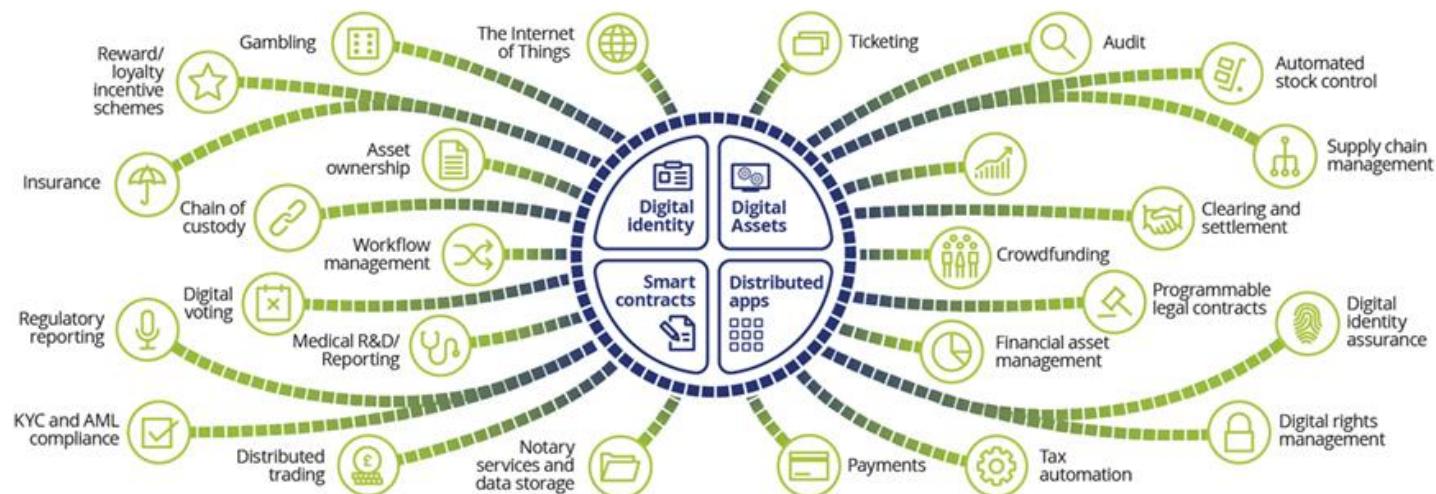
we could build a completely
decentralized version

And then, the new Internet...

- **Blockchain enables a new generation of decentralized Internet applications**
 - Bitcoin is only one of them
 - Still a hype...

What can you do with a blockchain?

KYC – Know Your Customer
AML – Anti-Money Laundering



Summary

- Computer networks is a fast growing area
- Take 601.714 Advanced Computer Networks if you are interested

Thanks!
Q&A