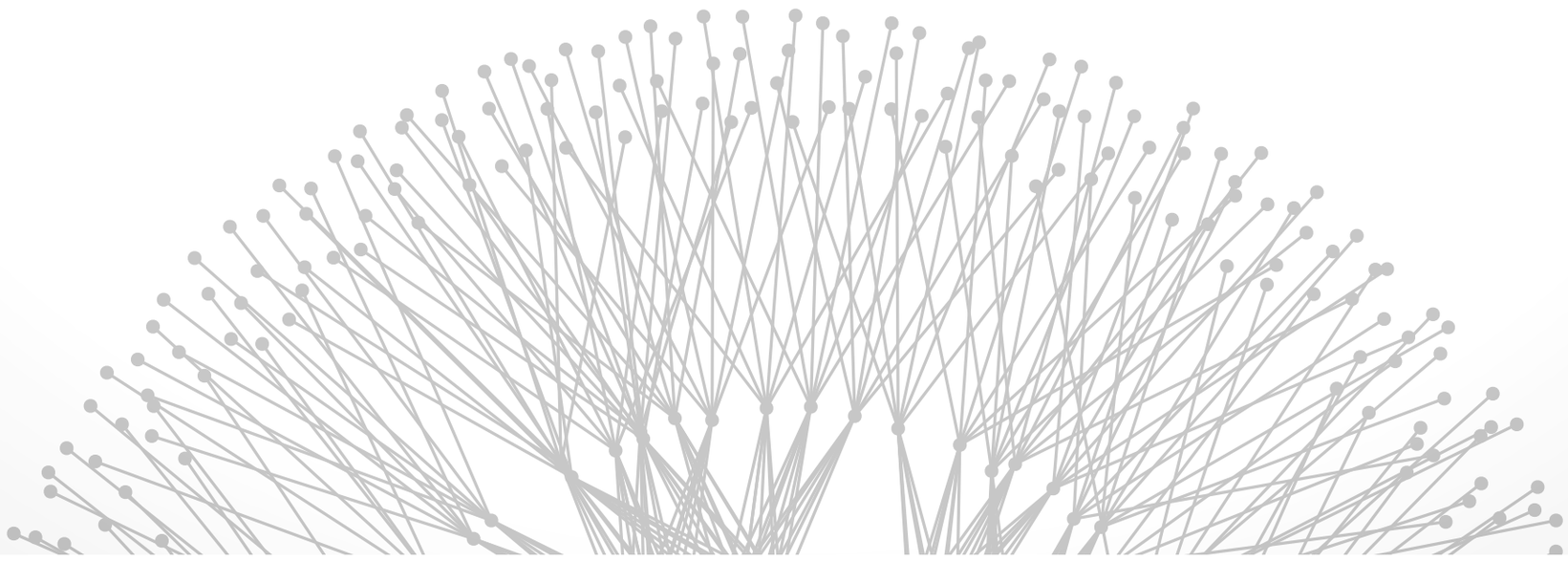
# The Last Word

Brighten Godfrey
CS 538 May 2 2018



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# What we learned

The classics: how the Internet works

The problems: how networks fail to work

The latest: how networks could work

so you now can go forth and do research...

...but why would you want to?

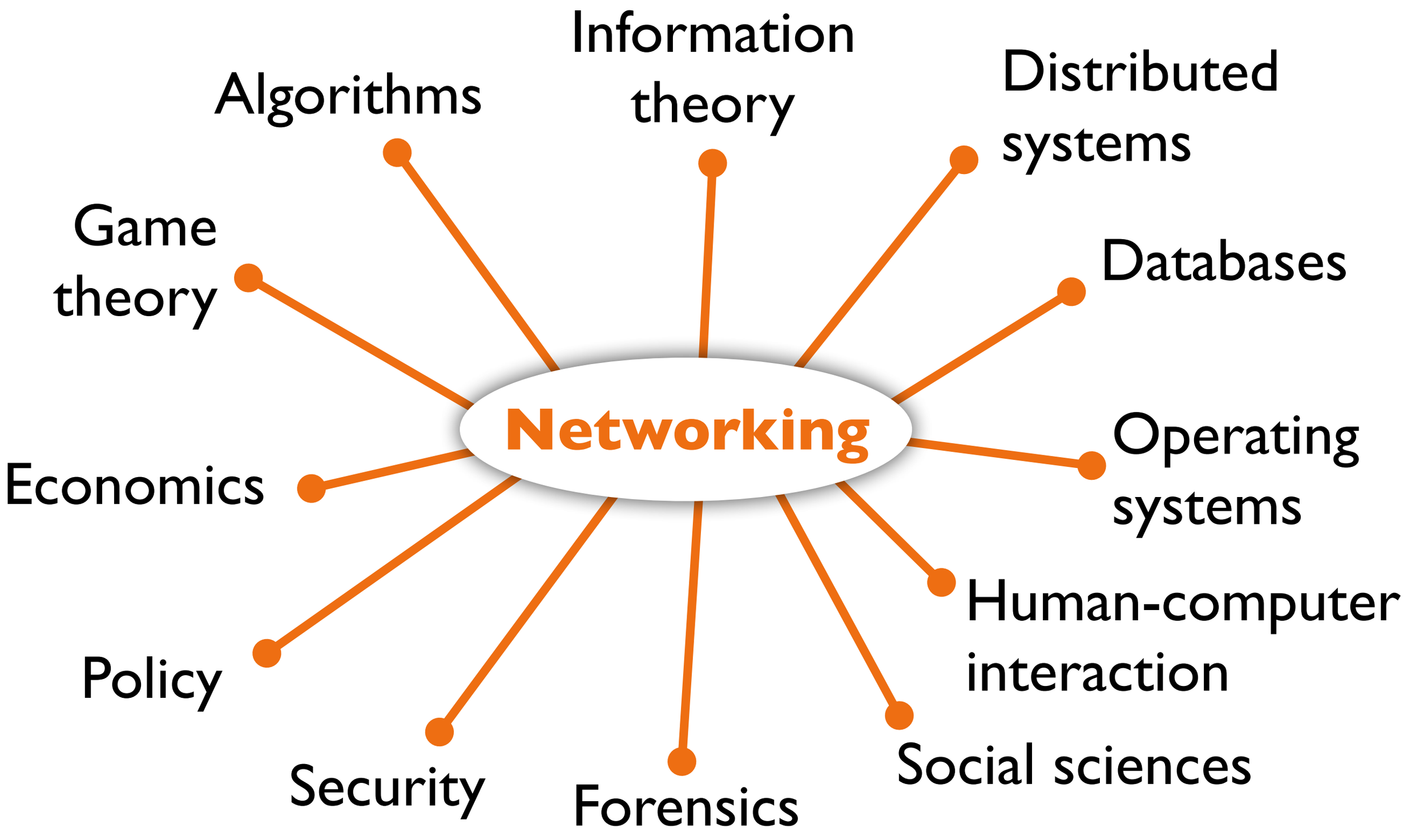
# Why I’m excited about networking

# 1. It's relevant

Majority of new developments in computer systems are dependent on networking

Far-reaching impacts beyond systems & networking

# 1. It's relevant



# 2. It's new

~40 years since the birth of the field

But only ~20 years since networks in widespread use

- tussles between businesses, P2P, malware, DDoS, government Internet censorship, CDNs all fundamental but relatively new!

Operating systems: ~40 years in widespread use

Physics: ~13.75 billion years in widespread use

# 3. It's changing

Network new people, new technologies, connect disciplines, "make order out of chaos" (– Jen Rexford)

Start a new area!

- In the last decade: Internet architecture, data centers, cloud, energy, big data, next-gen cell networks, software-defined networking, NFV, IoT, network verification, programmable hardware, containers and lambdas…
- A new subfield about every year!

**You can change not just the technology, but the field!**

# Emerging area: Networking + ML

Already work in

- Video delivery optimization
- Transport-layer congestion control
- Cluster scheduling

My guess: *much* more we can do!

- Networks gather widely distributed data that is the input to many applications' use of machine learning
- Networks contain numerous elements whose behavior can't be cleanly modeled (hence, ML may assist)

# Emerging area: Self-driving Networks

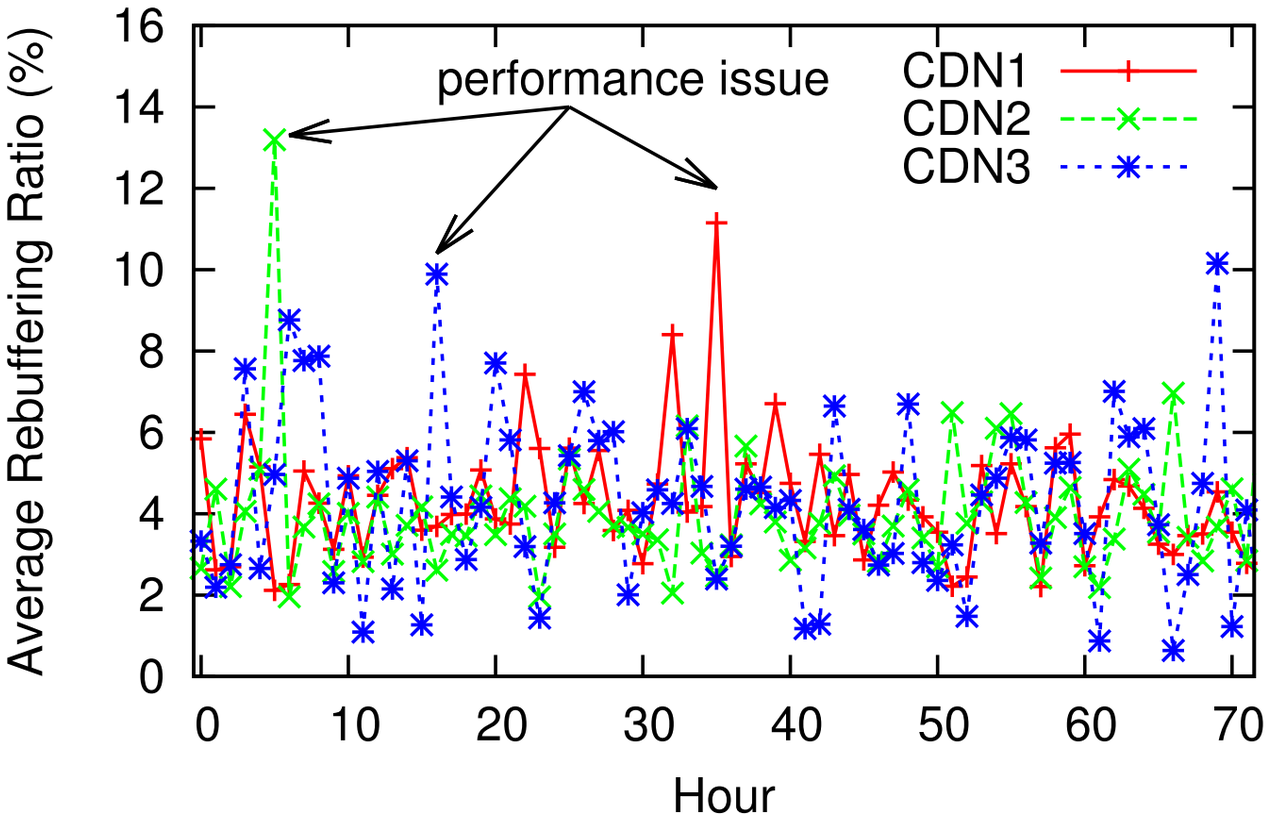
Attempted definition of self-driving networks

- Intent-based: Driven by the high-level goal
  - Network wide or end-to-end; not device-by-device
  - Objective is explicitly represented in the system
- Understands the reality of network conditions
- Implements closed-loop decisions to automagically steer the network towards meeting the intent

Self-driving networks are already happening!

- Network layer?
- Transport layer?
- Application layer?

# Conviva's C3 control plane




From the paper we read:
X. Liu et al., "A Case for a Coordinated Internet Video Control Plane", ACM SIGCOMM 2012

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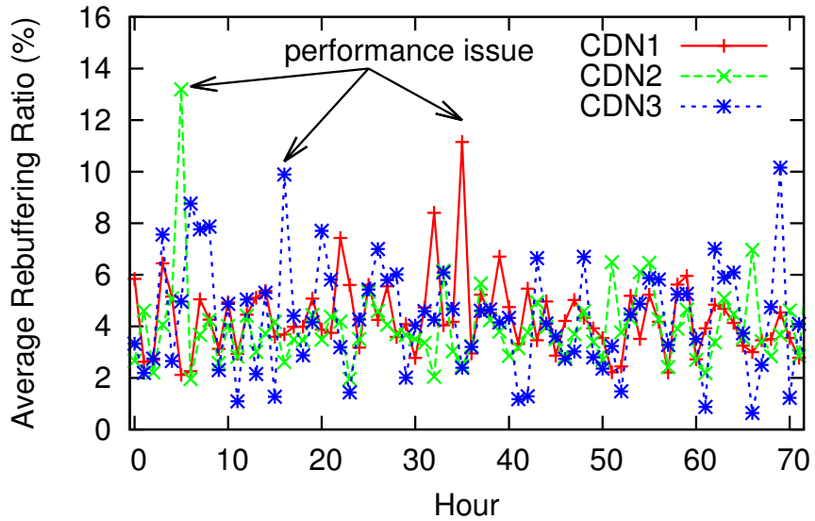


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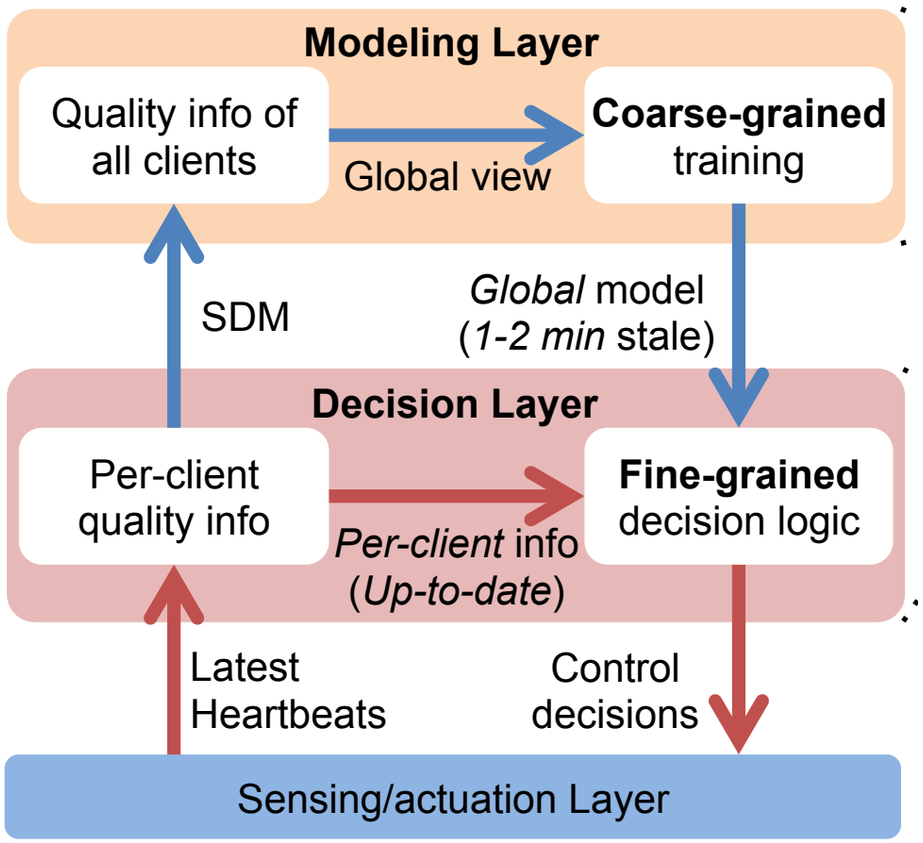


**(a) Logical view of split control plane**

From: Ganjam, Jiang, Liu, Sekar, Siddiqui, Stoica, Zhan, Zhang, "C3: Internet-Scale Control Plane for Video Quality Optimization", USENIX NSDI 2015

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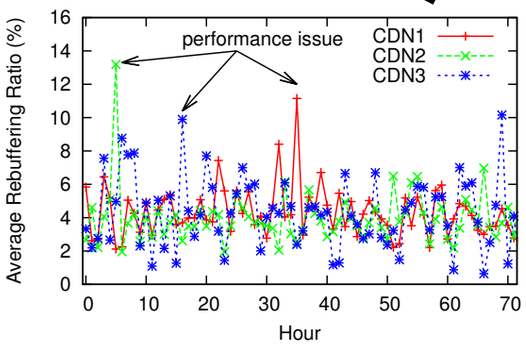


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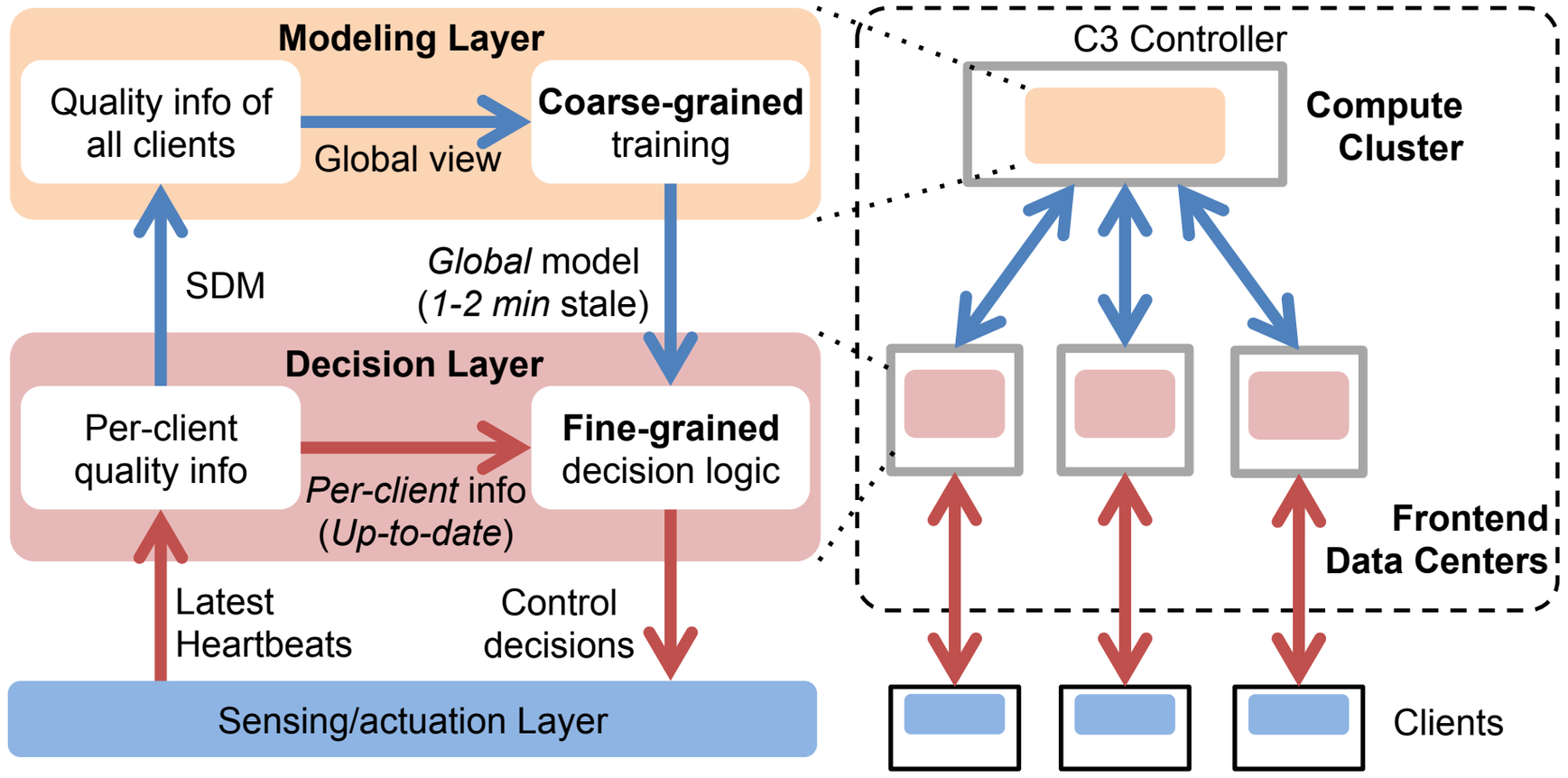



**(a) Logical view of split control plane**

**(b) Design and workflow of the C3 controller**

From: Ganjam, Jiang, Liu, Sekar, Siddiqui, Stoica, Zhan, Zhang, "C3: Internet-Scale Control Plane for Video Quality Optimization", USENIX NSDI 2015

# Emerging area: Self-driving Networks

Challenges in every aspect of self-driving networks

- Intent-based: Driven by the high-level goal
  - How do you express the intent?
  - Can you figure it out without being told?

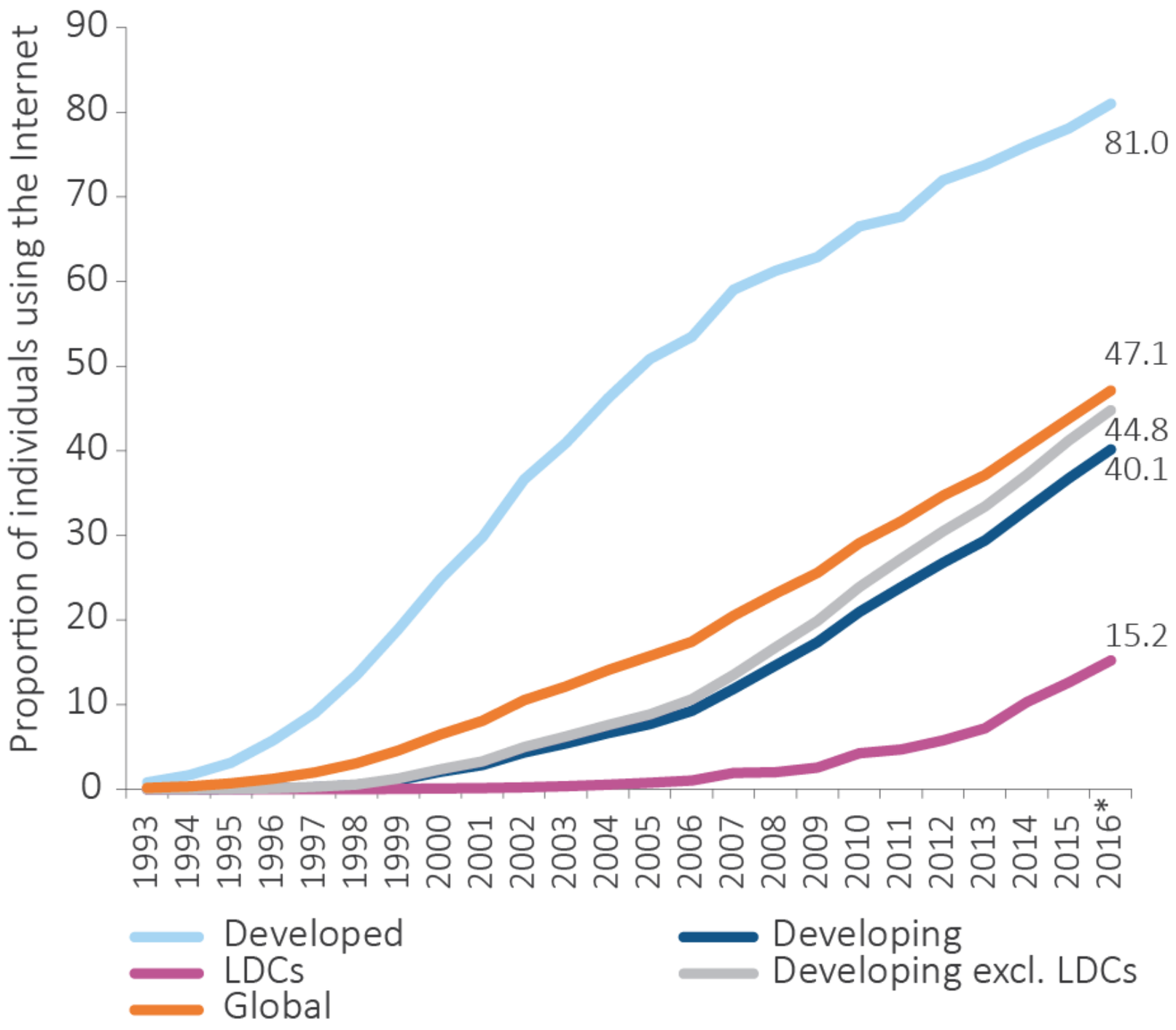
- Understands the reality of network conditions
  - Real-time telemetry, monitoring, verification

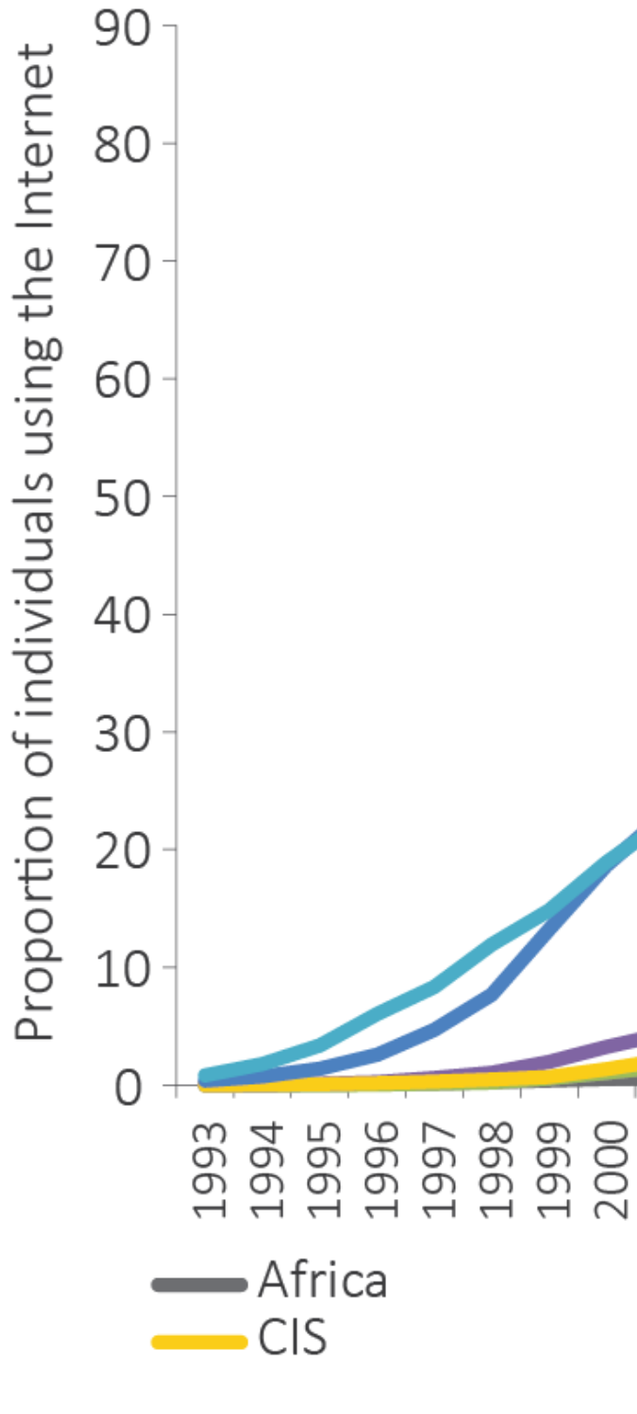
- Implements closed-loop decisions to steer the network towards meeting the intent
  - Learning algorithms? Algorithmic derivations?
  - What happens if you have multiple closed-loop controllers that don't know about each other?

# 3. It's changing

Over half the world not yet online!

# 3. It's changing




Note: * Estimate.
Source: ITU.

LDCs = Least Developed Countries
CIS = Commonwealth of Independent States

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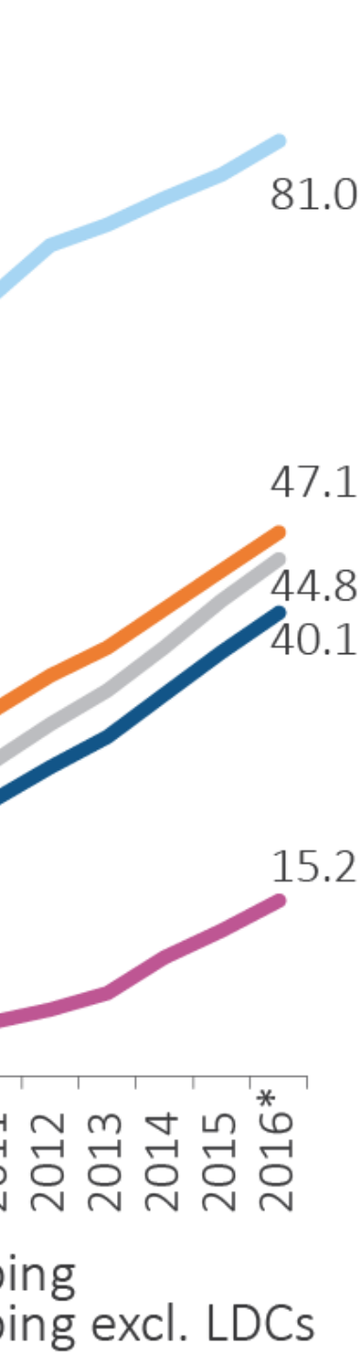


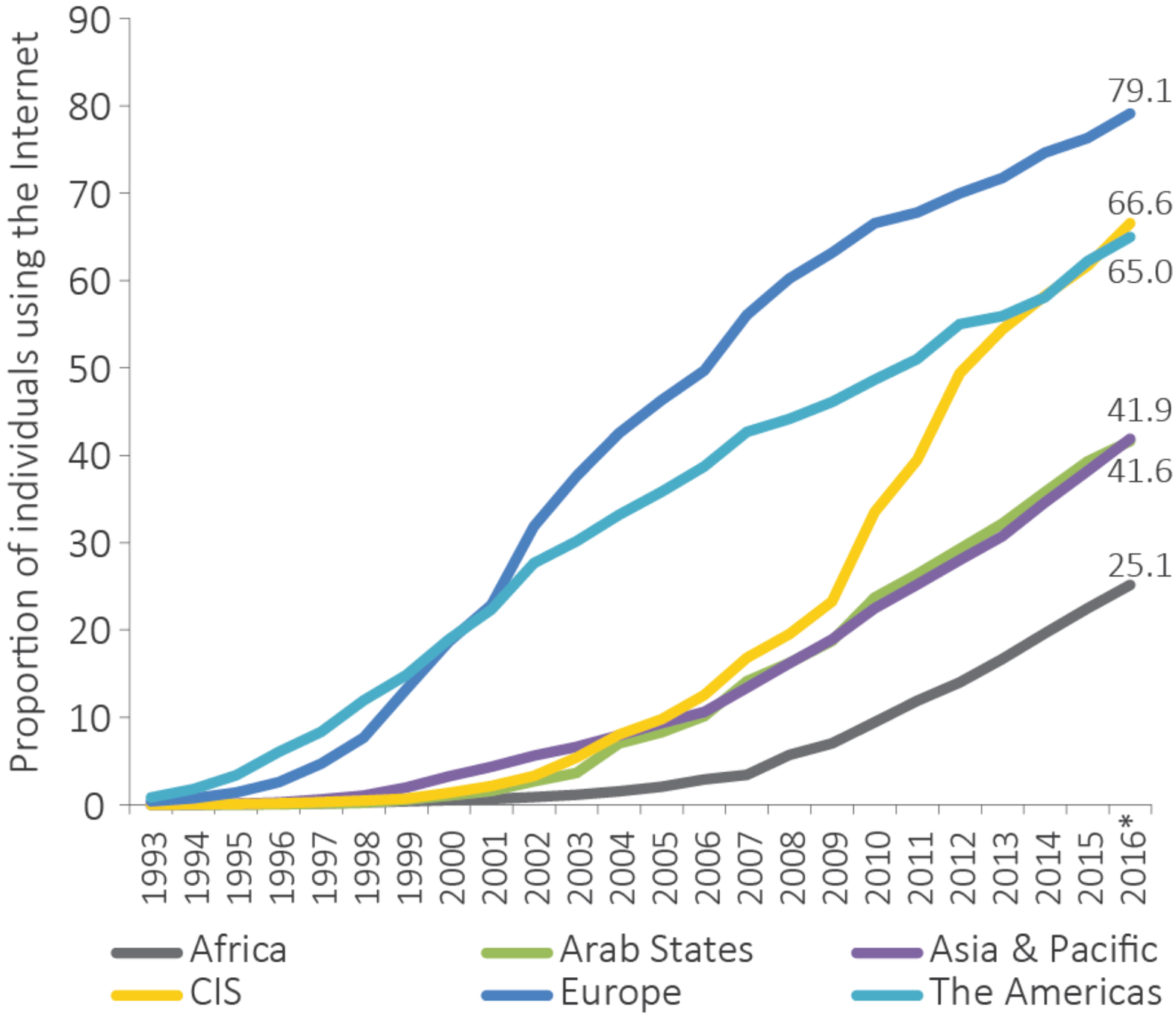


LDCs = Least Developed Countries
CIS = Commonwealth of Independent States (former Soviet republics)

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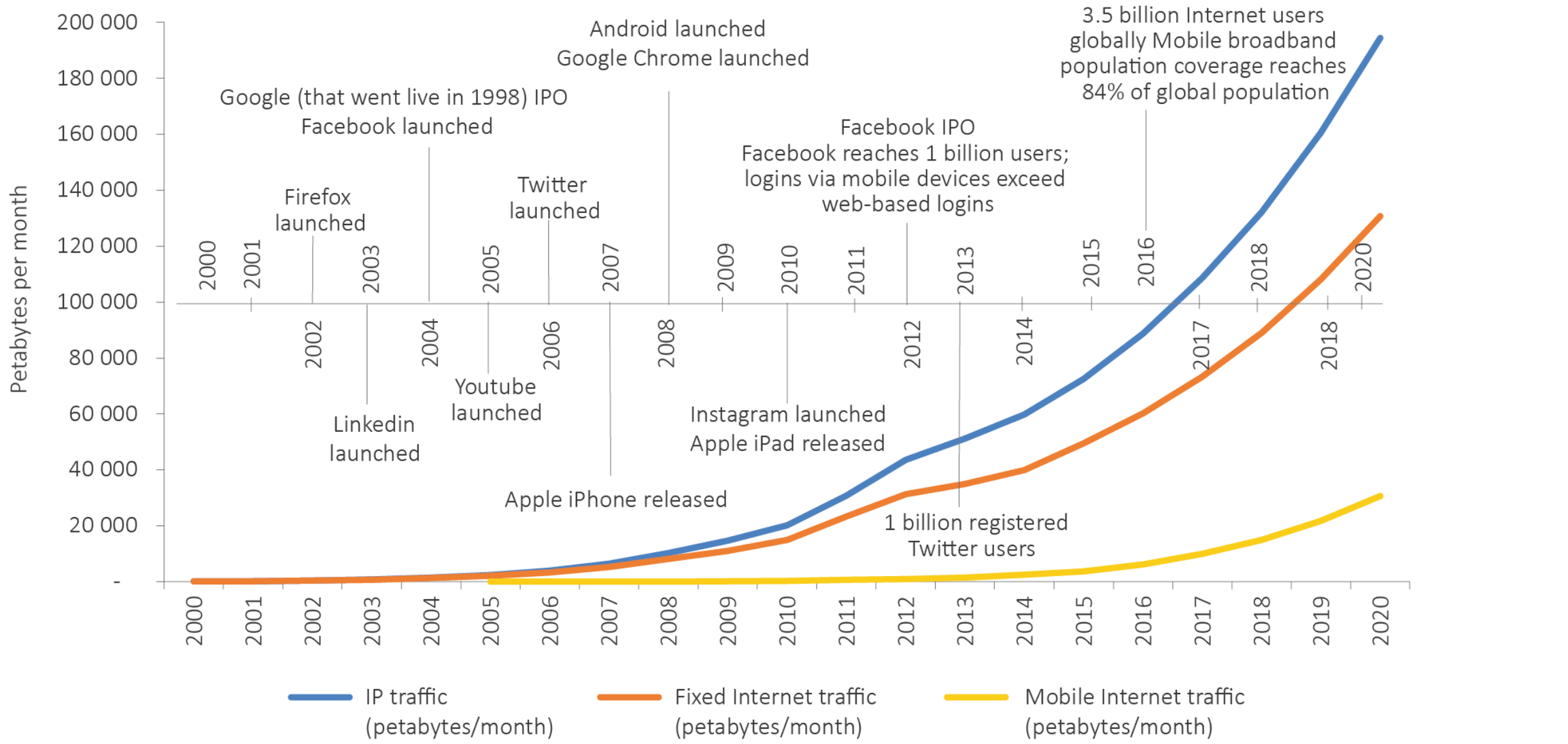


Note: Fixed Internet traffic refers to traffic through fixed network providers on different platforms. Mobile Internet traffic refers to traffic through mobile-cellular networks. IP traffic refers to the sum of fixed and mobile Internet traffic (denoting all IP traffic crossing an Internet backbone) as well as non-Internet IP traffic (e.g. IP WAN, IP transport of TV and video-on-demand).
Source: ITU based on Cisco and company reports.

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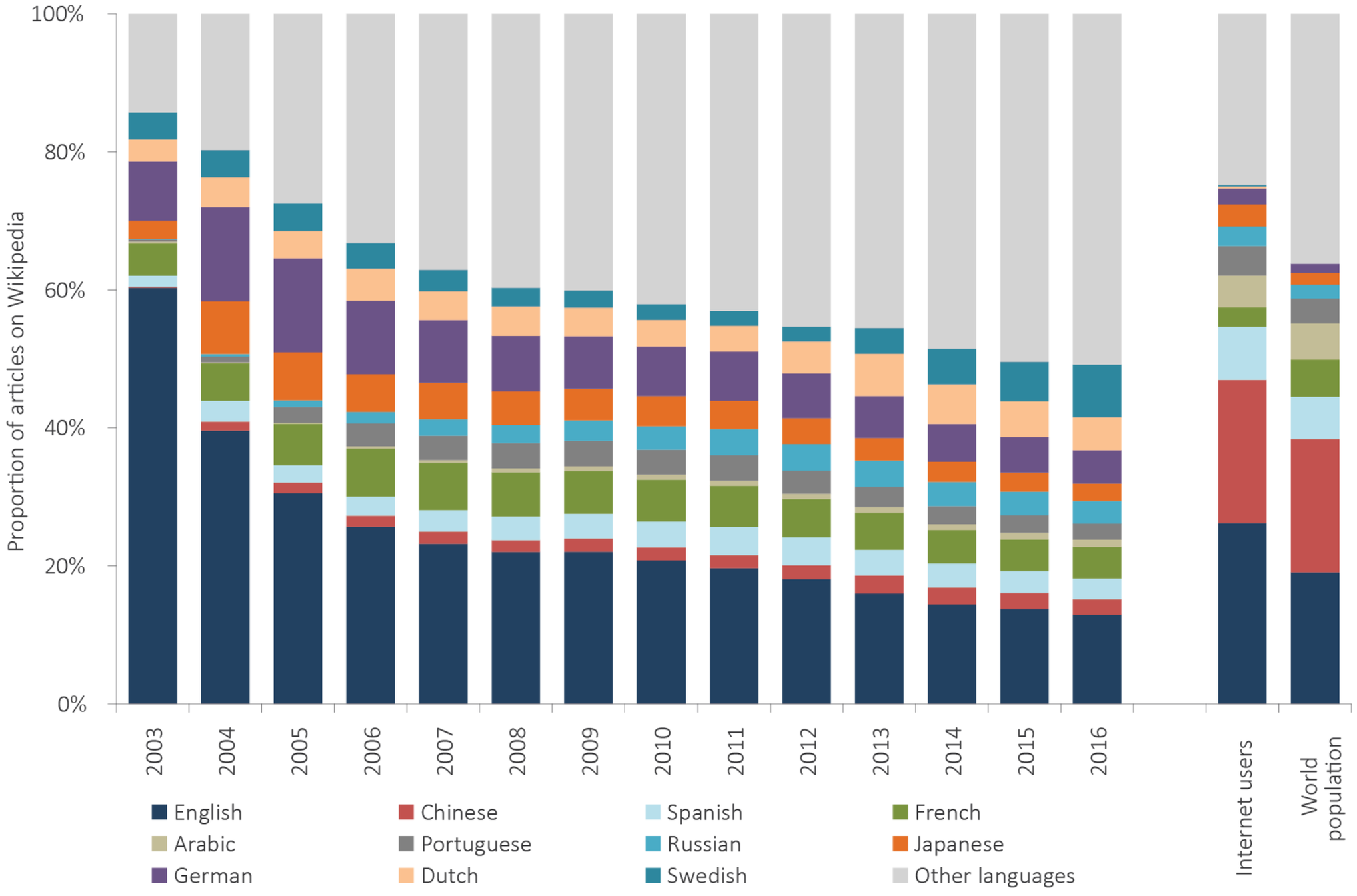


Note: The Internet users by language data are from Internet World Statistics, which assigns a single language to each individual in order to add up to the total world population; however, it is unclear how it assigns people's first language in countries where large proportions of the population are bilingual or multilingual.
Source: Wikipedia statistics at http://stats.wikimedia.org/EN/TablesArticlesTotal.htm, accessed 26 May 2016, and Internet World Statistics.

# 3. It's changing

Over half of the world not yet online!

Innovation more possible now than ever

- Clouds
- Global-scale testbeds
- Software-defined networking
- Programmable hardware

# What it all adds up to…

You have the opportunity for big impact!

# What's next

# Assignment 2

Returned by end of week

# Final Project Extravaganza

Fri May 4, 1:30pm - 4:30pm, 2nd floor atrium

- All team members should be prepared to present
- Remember to invite your friends!
- Remember to submit your poster PDF (see Piazza post)

## Content

- What problem are you solving?
- Why has past work not addressed the problem?
  - At least 3 academic paper citations
- What is your approach for solving it?
- What are the metrics to evaluate if the design works?
- What are the experimental results that provide answers?
- What are the unanswered questions?

# Where to go from here

Inspiration from conferences, "hot" workshops, classes

Chat with me anytime

Do great research

# Thank you!

# One more thing…

ICES forms!