To edge, or not to edge, that's the question – *an outsider's view*

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Caveats

Really, an outsider when it comes to edge

Intentionally, this is a controversial talk

Cloud outposts (i.e., “edge” **managed by cloud** providers), not edge in this talk

Why “not to edge”?

Huge heterogeneity:

- Hard to develop
- Hard to test

Deployment nightmare:

- Cannot deploy when you want unless you own devices
- Can take weeks, even months to upgrade!

Edge

Huge heterogeneity:

- Hard to develop
- Hard to test

Deployment nightmare:

- Cannot deploy when you want unless you own devices
- Can take weeks, even months to upgrade!

Cloud

Homogeneous:

- Same hardware, same infrastructure, same tools
- Test on same infrastructure

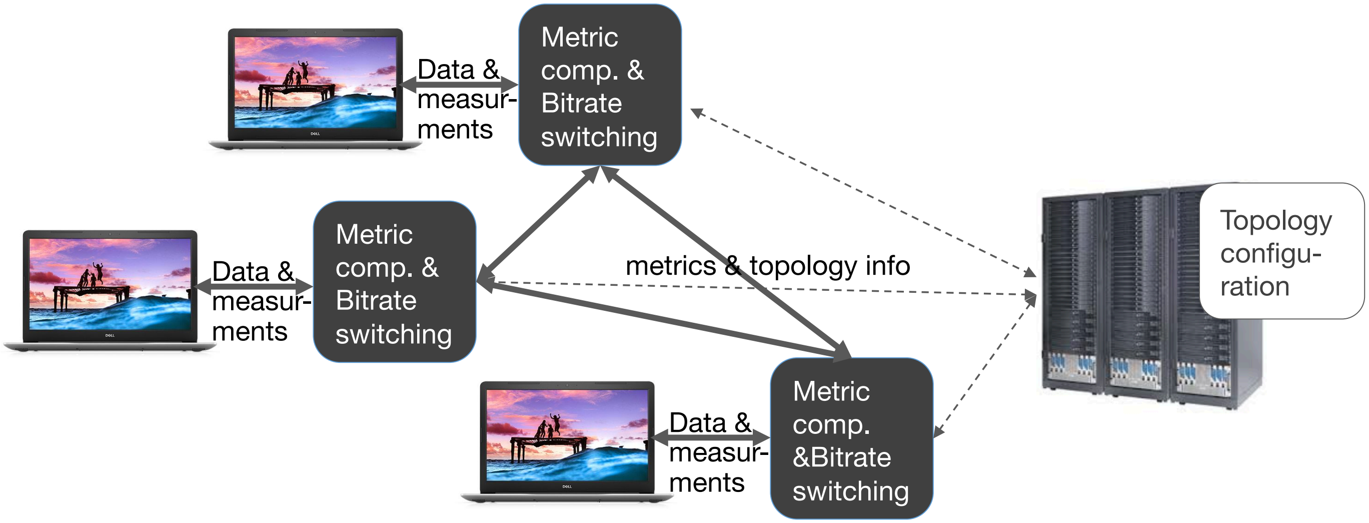
Anytime deployment:

- Can deploy daily
- No need to handle multiple versions

Conviva's story

Phase 1: peer-to-peer video distribution

- Most functionality at edge



Data & measurements

Metric comp. & Bitrate switching

Data & measurements

Metric comp. & Bitrate switching

metrics & topology info

Topology configuration

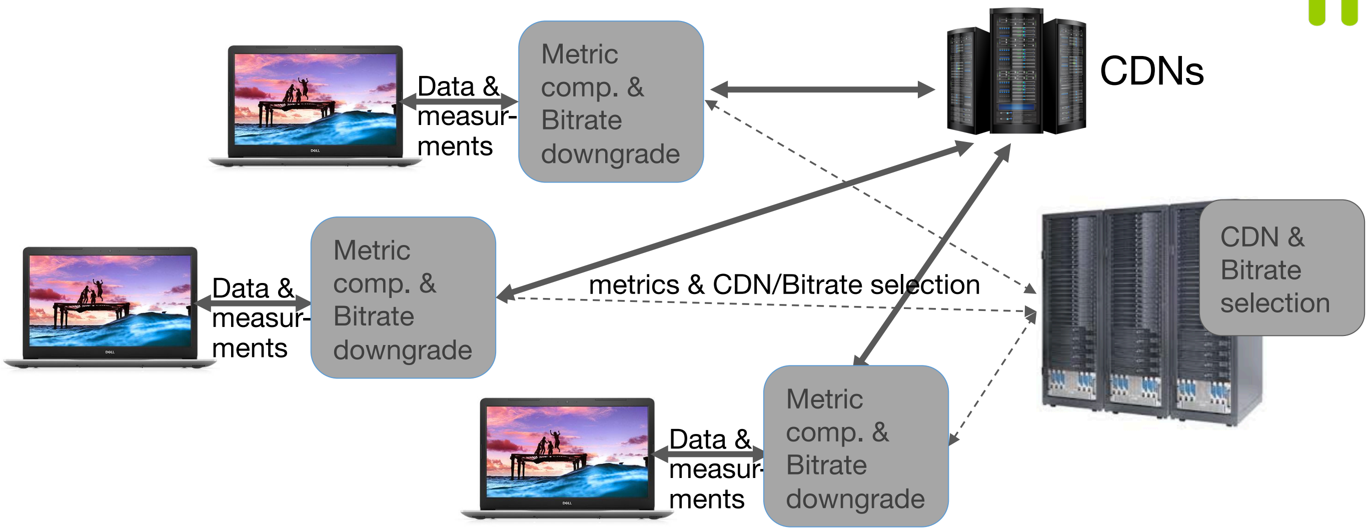
Data & measurements

Metric comp. &Bitrate switching

Conviva’s story

Phase 2: Split functionality; multi-CDN delivery

- Backend: select CDN and bitrate
- Peer: metrics computation, downgrade bitrate



Data & measur- ments

Metric comp. & Bitrate downgrade

CDNs

Data & measur- ments

Metric comp. & Bitrate downgrade

metrics & CDN/Bitrate selection

CDN & Bitrate selection

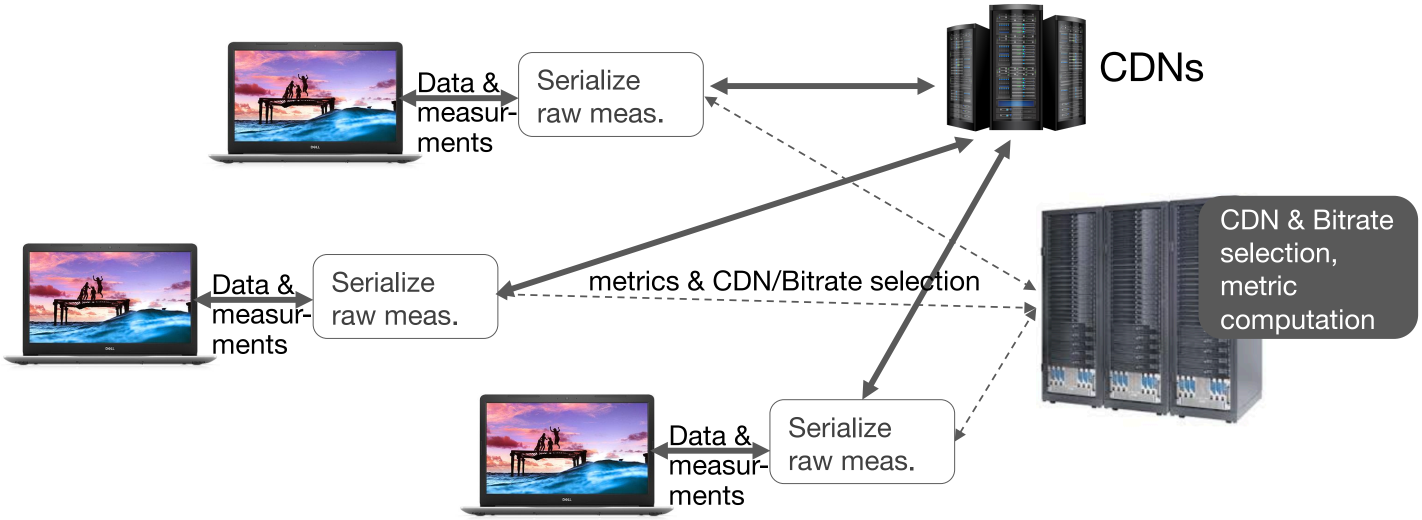
Data & measur- ments

Metric comp. & Bitrate downgrade

Conviva’s story

Phase 3: dumb edge

- Backend: chose CDN and bitrate; compute metrics
- Edge: collect raw measurements & execute commands



Conviva’s story

Phase 3: dumb edge

- Backend: chose CDN and bitrate; compute metrics
- Edge: collect raw measurements & execute commands

Use JavaScript whenever possible to simplify upgrade

Tradeoff: trade performance for simplicity and flexibility

Side benefit: can compute new metrics, not available at the collection time as we have raw data!

Another example: Video on Demand

Download & watch (2000-2010):
Limited bitrate couldn't sustain playing rate

- Complex DRM software

Netflix (2007-): advances in bitrate and network infrastructure allowed streaming

Another example: CDNs

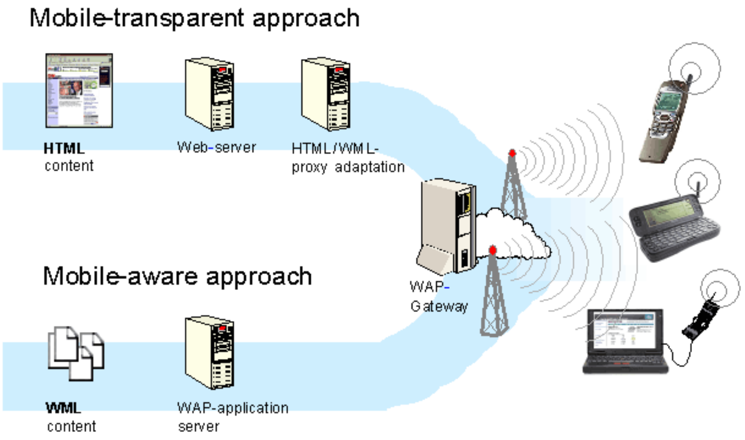
Akamai (2000s): deployed servers at hundreds of sites collocated with ISPs to minimize latency and maximize aggregate bandwidth

- Hard to manage, upgrade

CDN dominant design today: relatively few datacenters peering with many ISPs

Yet another example: Wireless App Protocol (WAP)

WAP (1999): Make it possible for a mobile (bwdth constrained) device to display HTML content



Fully featured HTML mobile clients (2007-)

Why “to edge”?

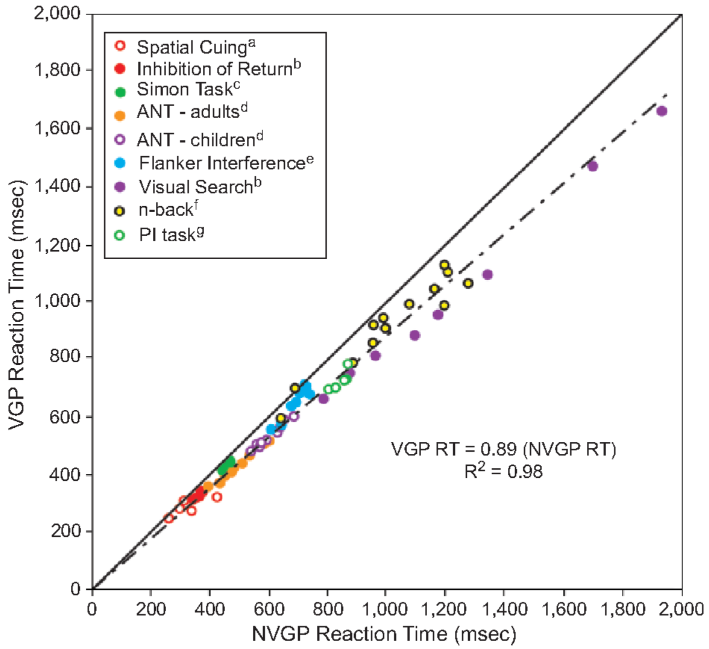
Performance (latency, bandwidth)

Availability

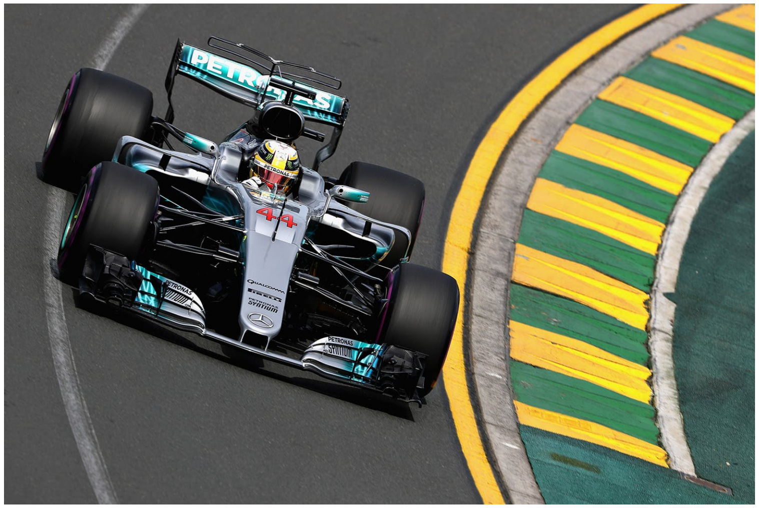
Security

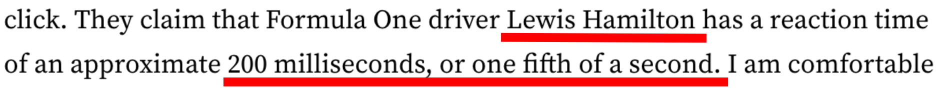
Latency

If human interaction, we are talking about 100s ms



Increasing Speed of Processing With Action Video Games, Matthew W. G. Dye, C. Shawn Green, Daphné Bavelier, Current directions in psychological science 2009





click. They claim that Formula One driver Lewis Hamilton has a reaction time of an approximate 200 milliseconds, or one fifth of a second. I am comfortable

https://www.thedrive.com/accelerator/8916/is-your-reaction-time-faster-than-lewis-hamiltons

Latency

If wearable cognitive assistance, we are talking about ~33ms (assuming 30 fps)

Latency

If humans involved, we are talking about at least ~33ms

But: 5G + close by datacenter < 10ms RTT

So, even for most interactive tasks, cloud probably ok

If not latency, then what?

Bandwidth

Too much data to send to the backend, e.g., video, sensor measurements → too **expensive**

But…

Saying it’s too expensive to push data to cloud/cluster…

… is “equivalent” with saying **much of data is not valuable**!

True in some cases (e.g., traffic video monitoring)…

… but not others (e.g., video surveillance)

If not latency and bandwidth, then what?

Availability

For mission critical apps where human life is at stake cannot get disconnected!

But…

… both bandwidth and availability might grow rapidly

Could be good enough for **almost all apps**

Security

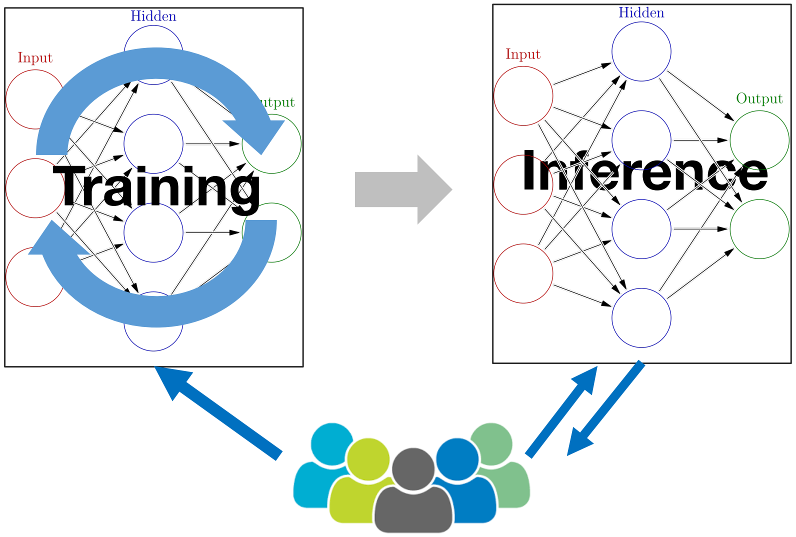
Process personal identifiable information locally → strong privacy guarantees

Lots of resources going into this at Apple, Google, Microsoft, etc!

The challenge

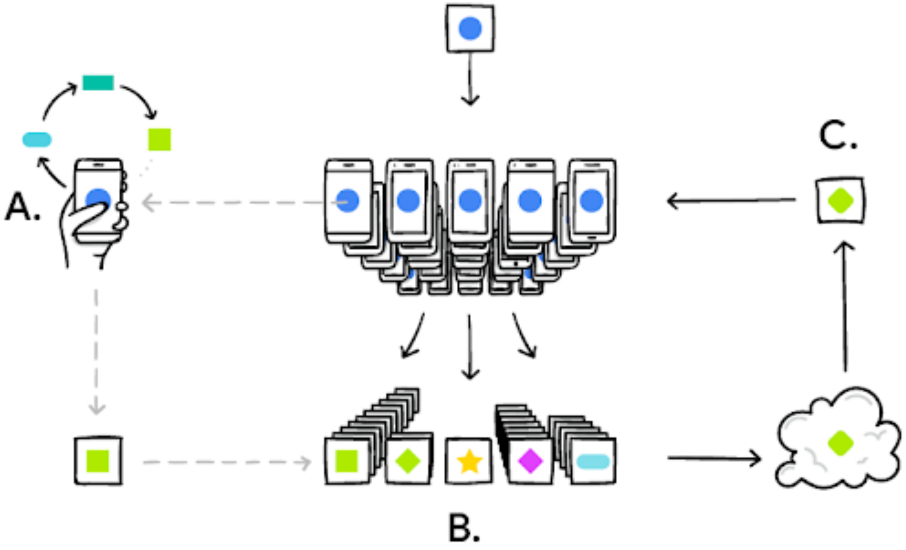
Train models preserving user privacy

Serve models preserving user privacy



Federated training

Learn without revealing data user's data



https://ai.googleblog.com/2017/04/federated-learning-collaborative.html

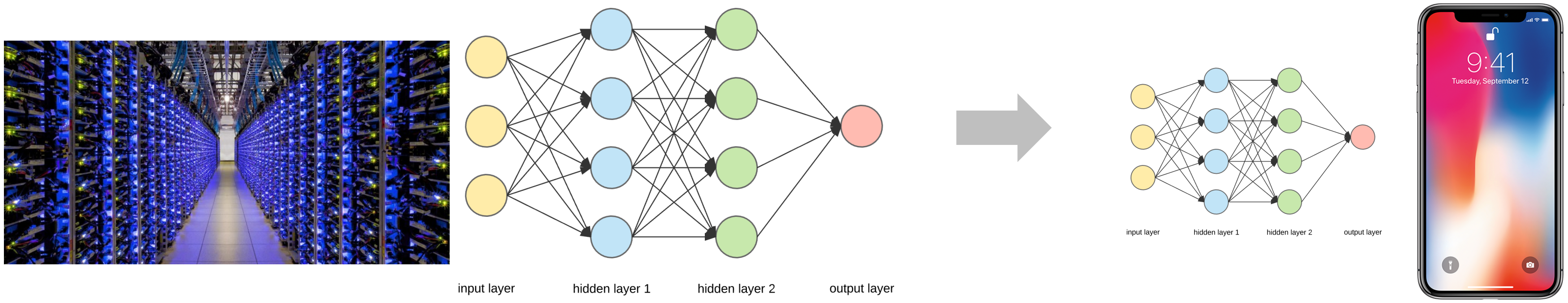
Transfer learning

Train model on lots of public data

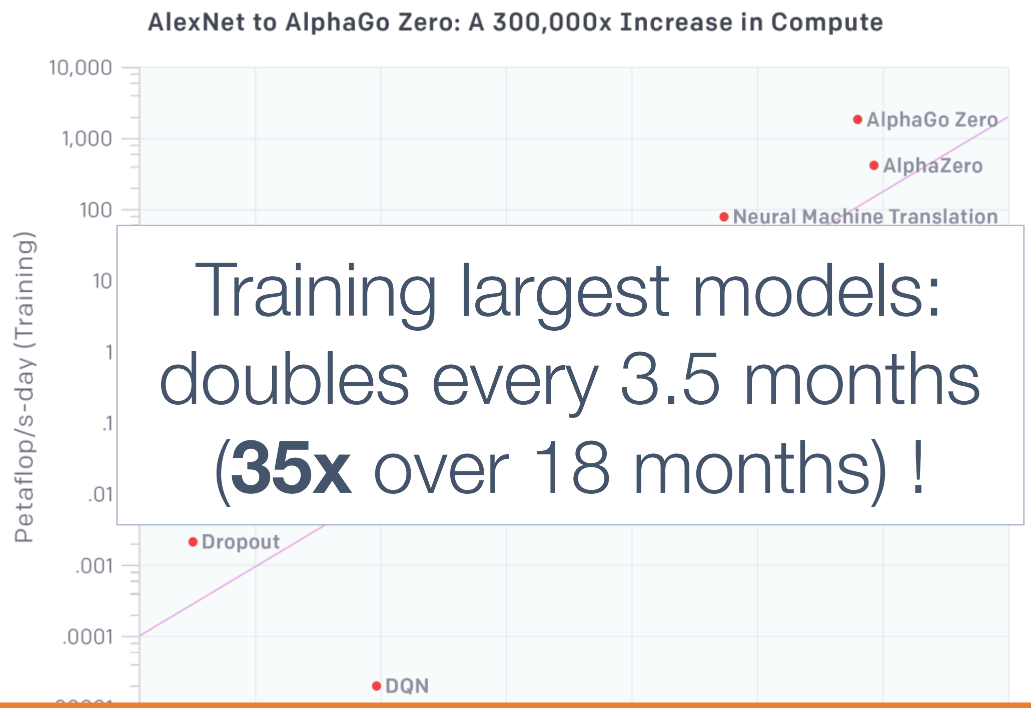
Refine it on each edge device

Cloud

Edge



One Challenge

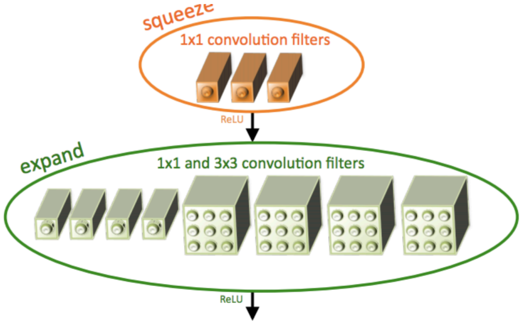

AlexNet to AlphaGo Zero: A 300,000x Increase in Compute

Training largest models:
doubles every 3.5 months
(**35x** over 18 months) !

Need specialized hardware and algorithms

Promising directions

DEEPSCALE



SqueezeNet[1]: 100x smaller

New network architectures

Use sketching to reduce communication[2]

[1] “SqueezeNet: AlexNet-level Accuracy with 50X Fewer Parameters and < 0.5MB Model Size”, Forrest N. Iandola, Song Han, Matthew W. Moskewicz , Khalid Ashraf , William J. Dally , Kurt Keutzer (https://arxiv.org/pdf/1602.07360.pdf)

[2] ”Communication-efficient distributed SGD with Sketching”, Nikita Ivkin, Daniel Rothchild, Enayat Ullah, Vladimir Braverman, Ion Stoica, Raman Arora, NeurIPS 2019

What about development?

Automatic optimization for given platform

- E.g., Auophase[1], NeuroVectorizer[2]

Program synthesis: generate programs from high level specifications or input-output examples:

- E.g., Autopandas[3]

"AutoPhase: Compiler Phase-Ordering for High Level Synthesis with Deep Reinforcement Learning", Ameer Haj-Ali, Qijing Huang, William Moses, John Xiang, Ion Stoica, Krste Asanovic, John Wawrzynek (https://arxiv.org/abs/1901.04615)

[2] "NeuroVectorizer: End-to-End Vectorization with Deep Reinforcement Learning", Ameer Haj-Ali, Nesreen K. Ahmed, Ted Willke, Sophia Shao, Krste Asanovic, Ion Stoica (https://arxiv.org/abs/1909.13639)

[3] "AutoPandas: Neural-Backed Generators for Program Synthesis", Rohan Bavishi, Caroline Lemieux, Roy Fox, Koushik Sen, Ion Stoica, OOPSLA 2019

Summary

The edge is more exciting than ever: key drivers

- Security and availability for mission-critical apps
- Bandwidth cost prohibitive in some situations
- Latency (not sure)

However:

- Keep in mind technology trends (e.g., 5G, satellites)

Put functionality at the edge,
only if you cannot put it in the cloud