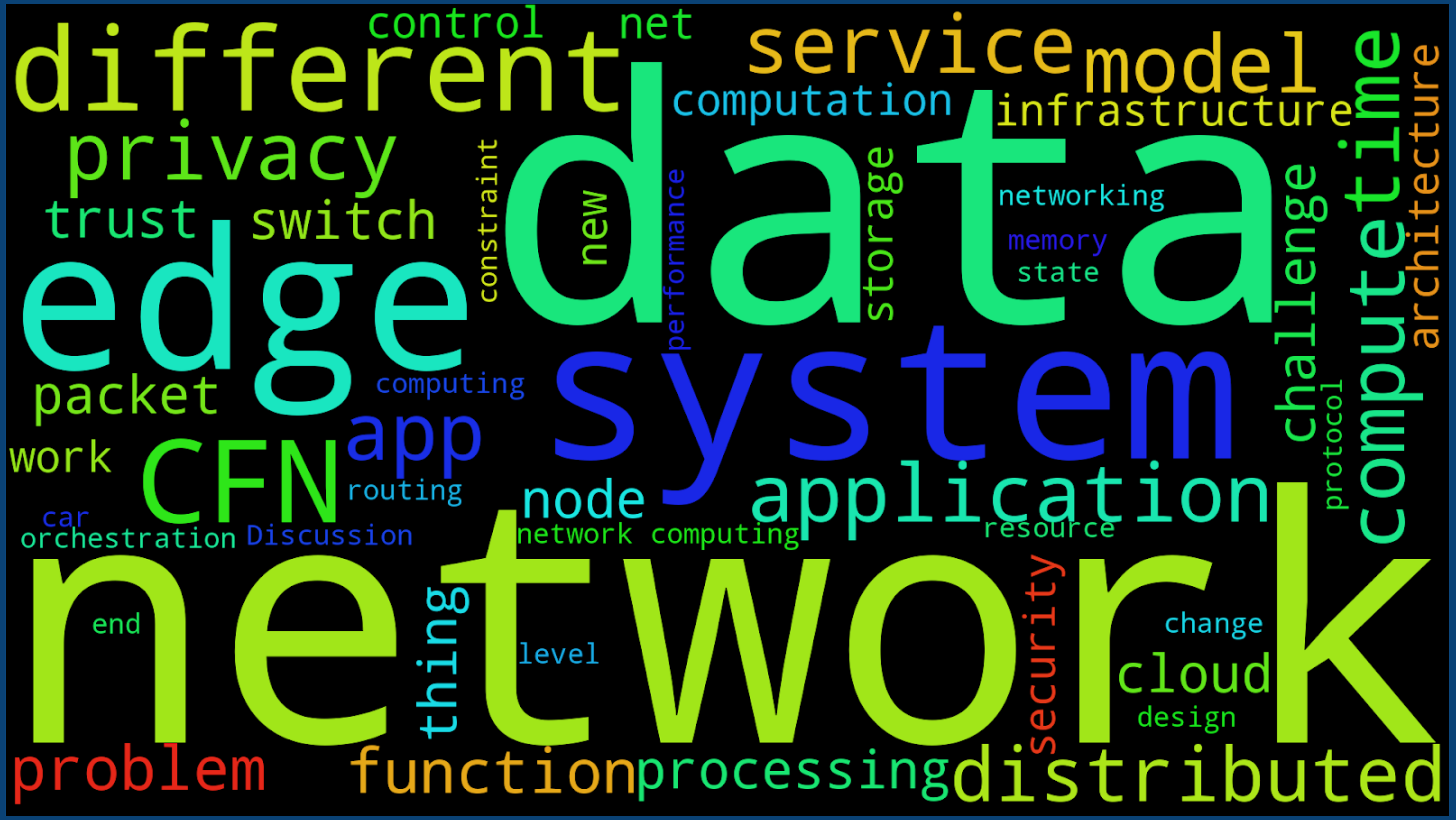
Dagstuhl Seminar: Compute-First Networking

Report for IRTF COINRG

Teaser



Organizers: Jon Crowcroft, Phil Eardley, Dirk Kutscher, Eve Schooler

2021-07-26

https://www.dagstuhl.de/en/program/calendar/semhp/?semnr=21243

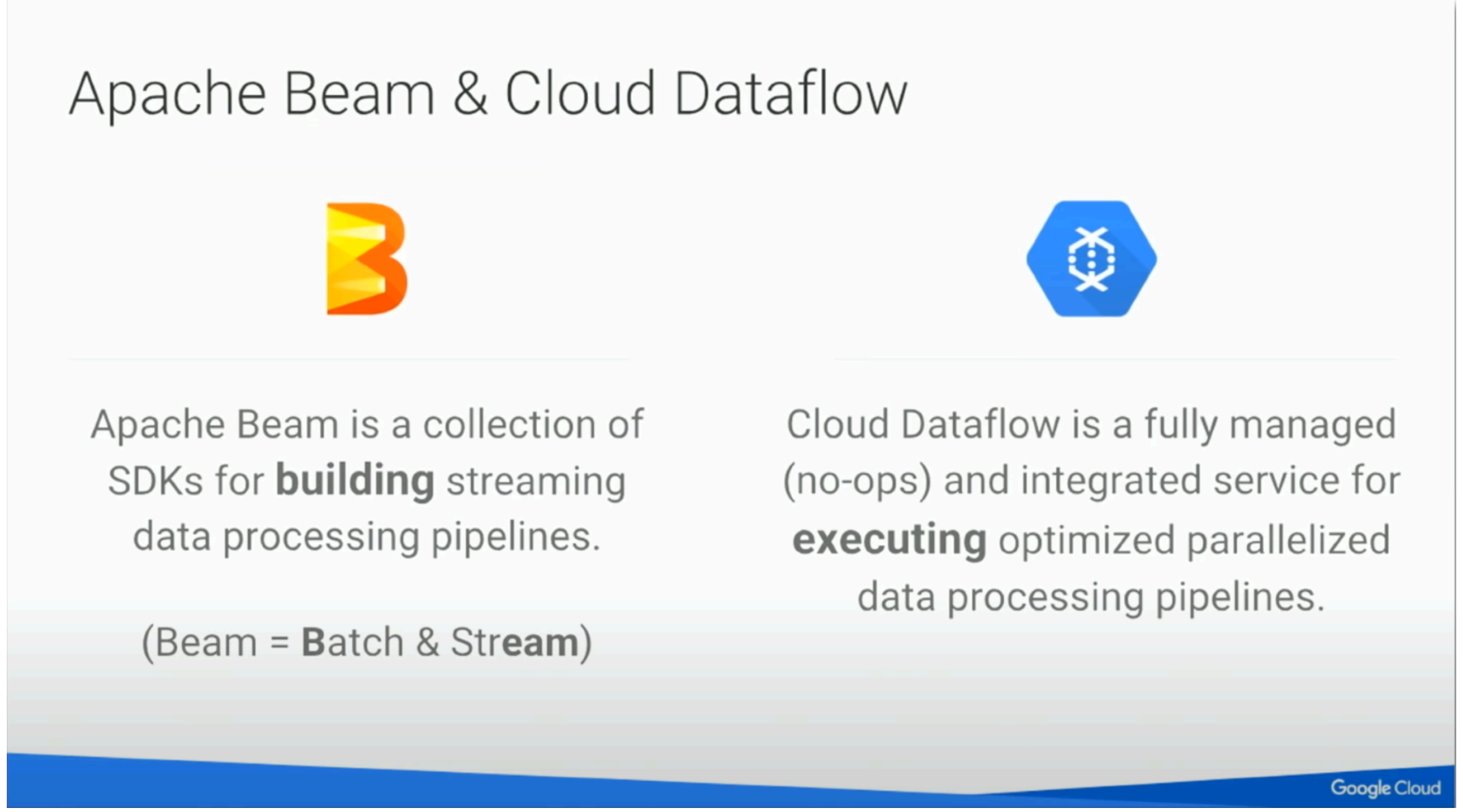
Objectives for this Seminar

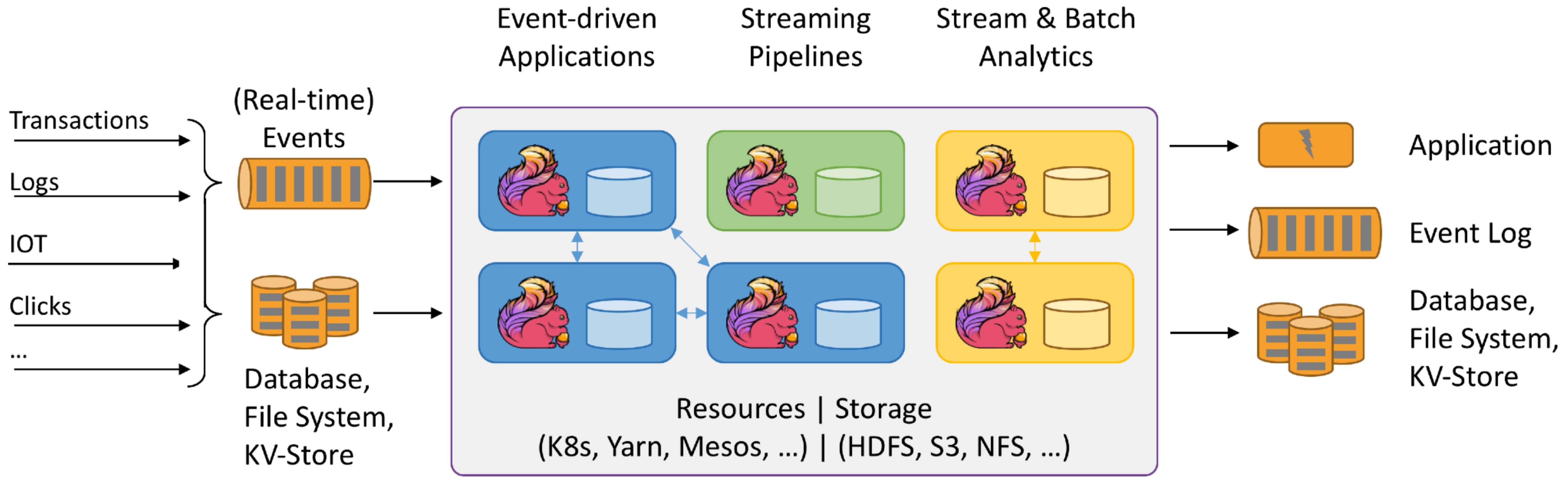
Definition and Research Agenda for "Compute-First Networking"

- Is there a space for a new approach of integrating computing and networking?
  - Beyond packet flow processing
  - Beyond microservice overlays
  - Learning from distributed computing systems (and taxonomy of those)
- What are hard problems todays?
- What are promising new approaches?
- Is there a critical mass of research?
- What are the research challenges?

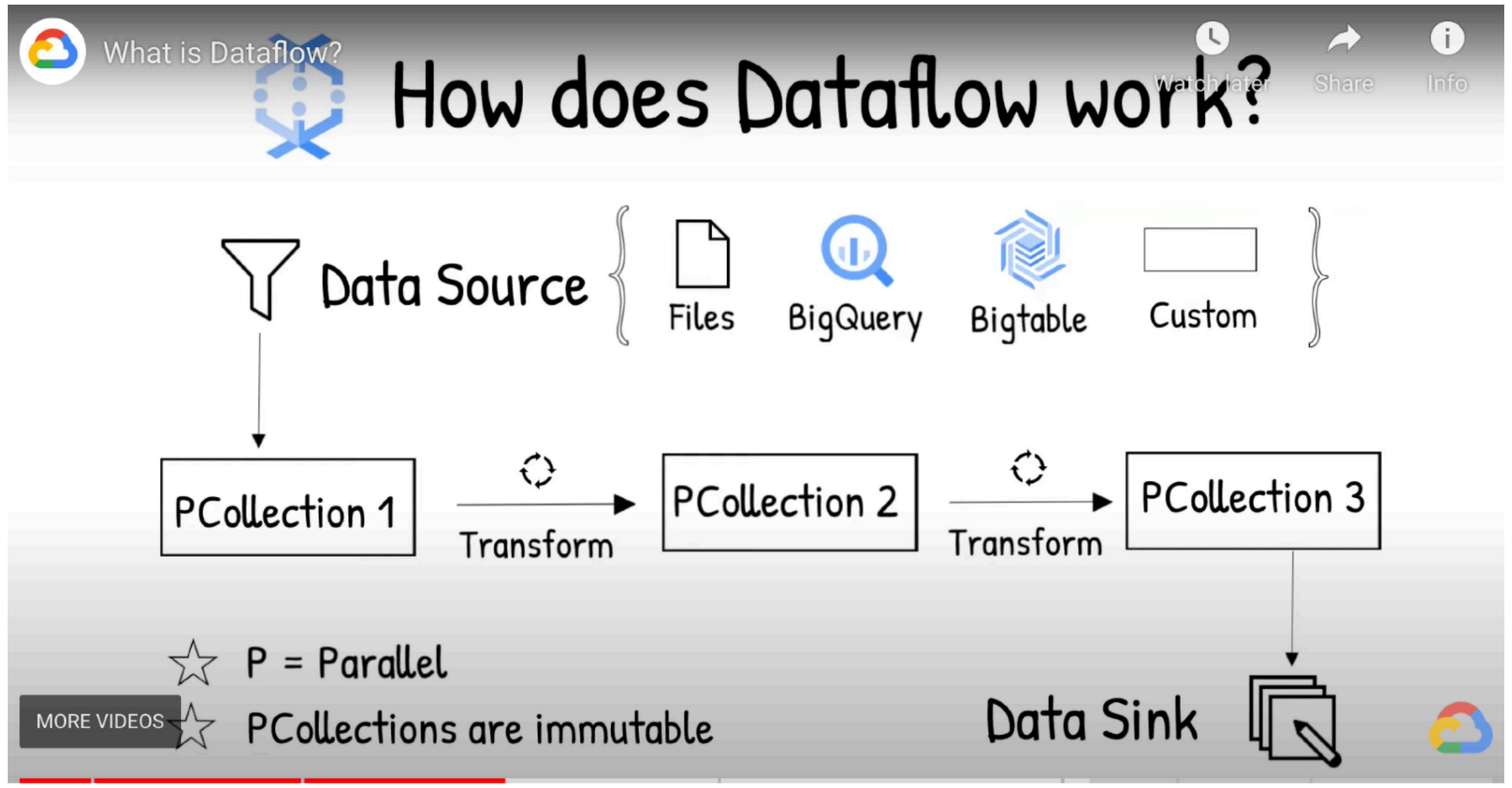
Succesful Example in Distributed Computing

Dataflow





Apache Flink



Google Dataflow

Example

Packet Interception vs. Dataflow

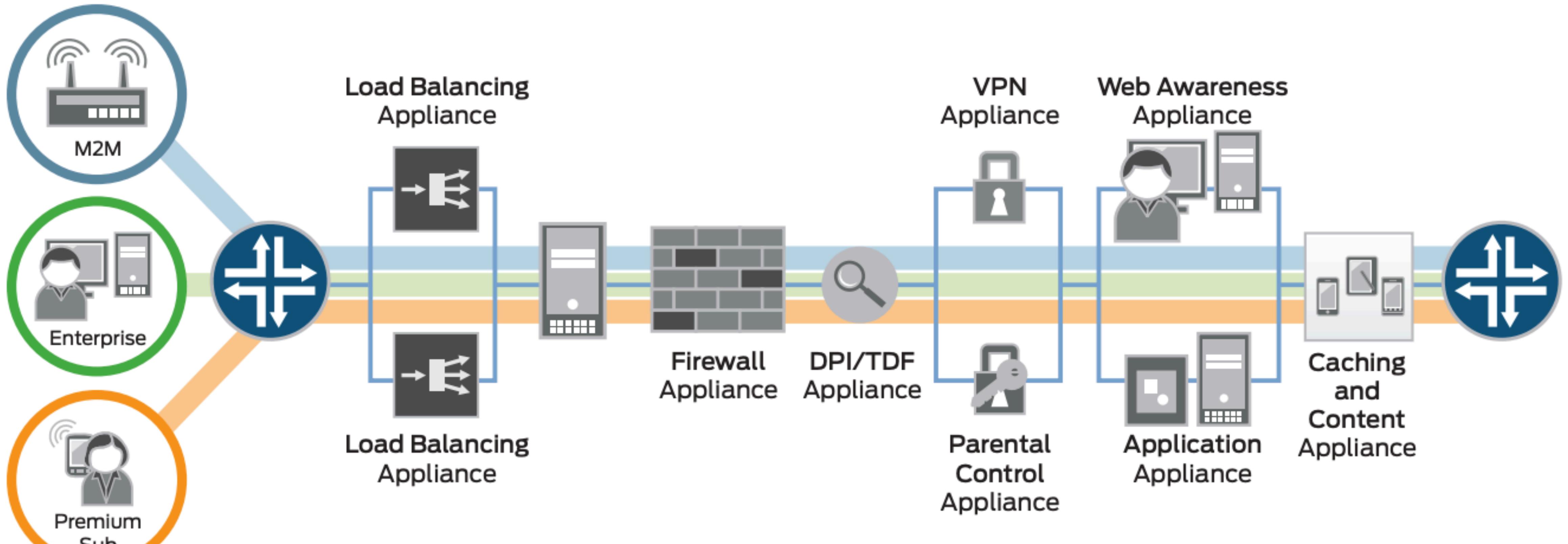
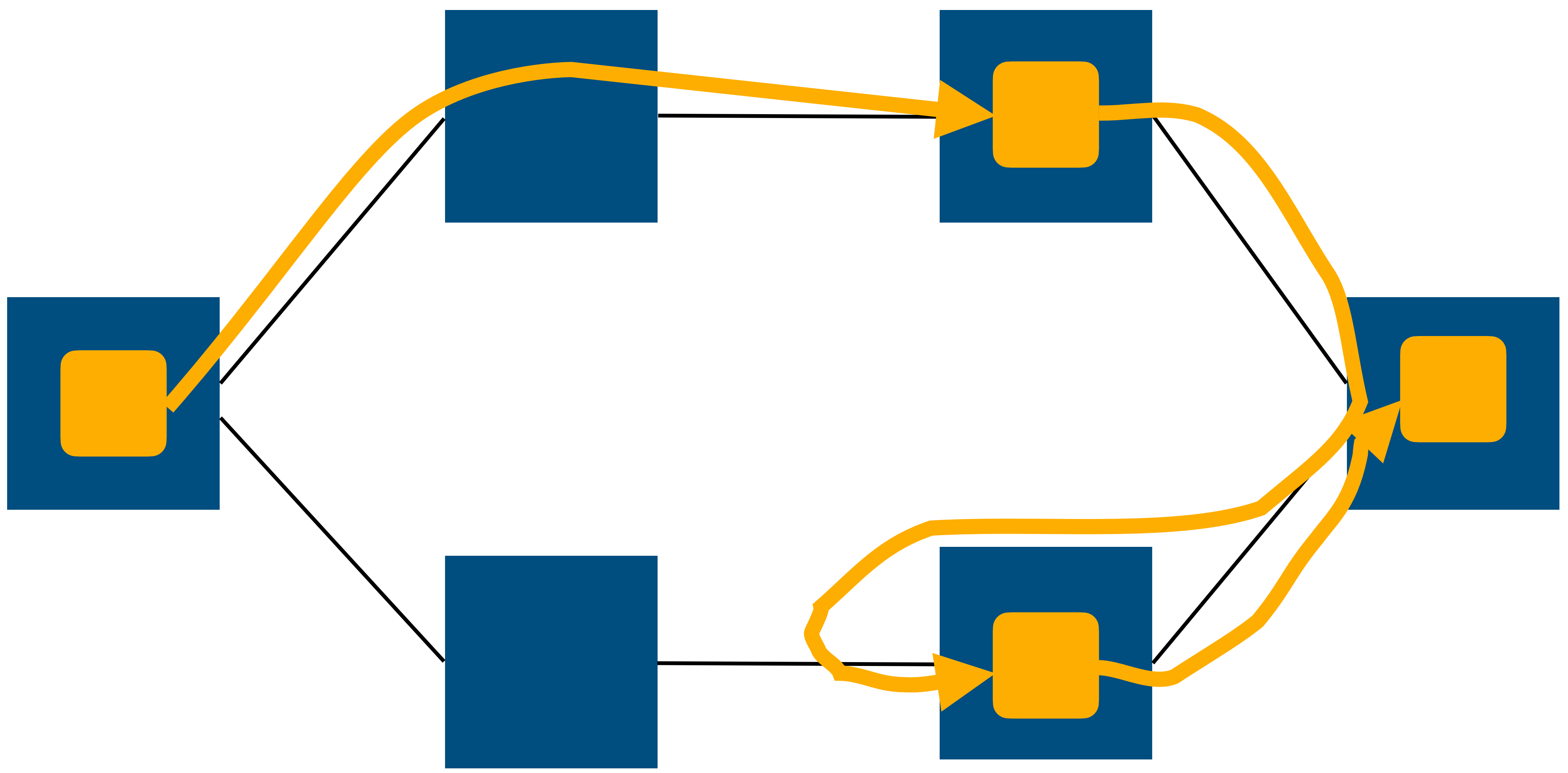


Figure 1. The single, static service chain



- Transparent middleboxes
- Transformations on packet flow
- Side effects

- Explicit transformations on input data
- Can have side effects
- But principally, focus is on result data

Dagstuhl: Compute-First Networking

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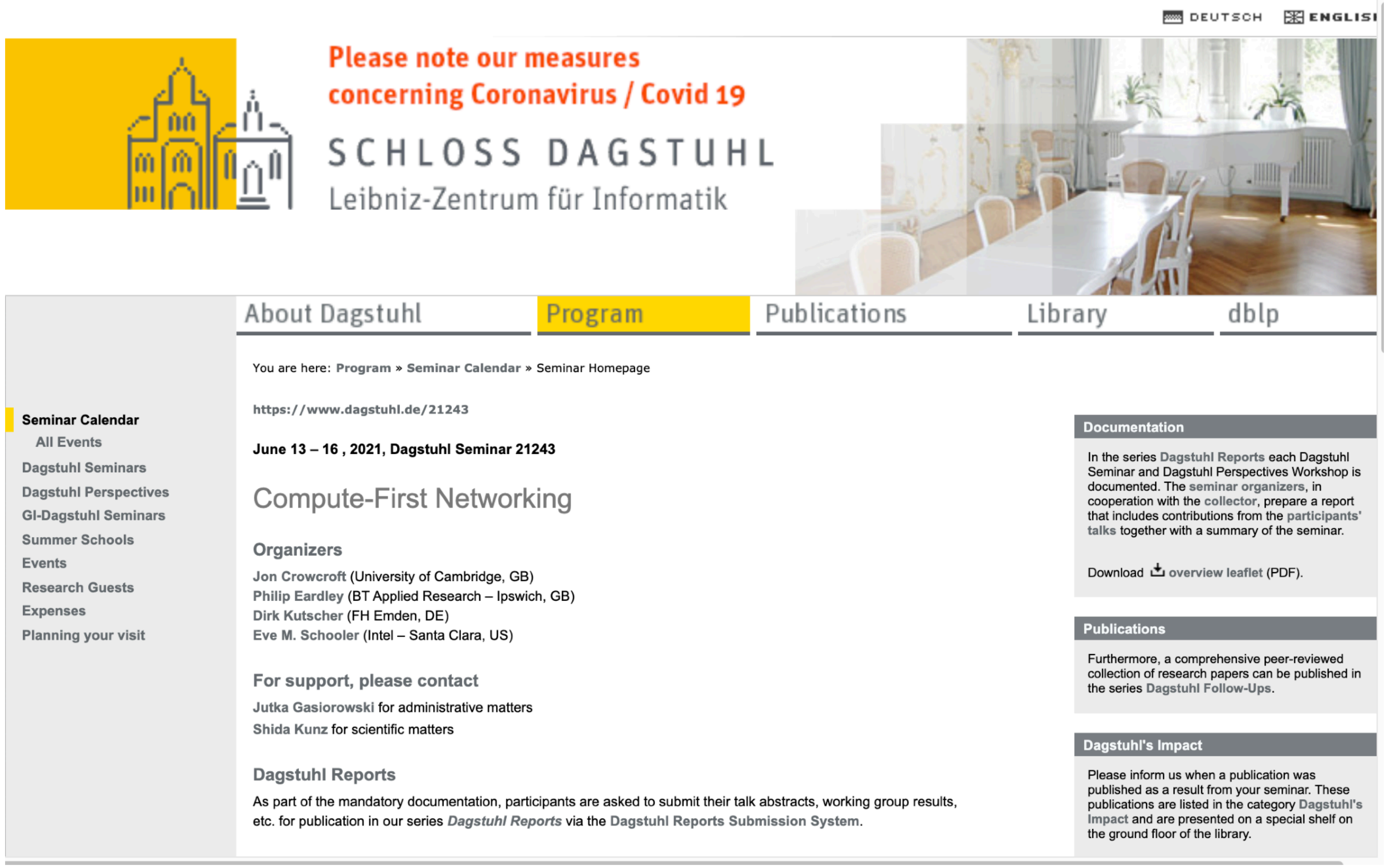
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June 13 – 16 , 2021, Dagstuhl Seminar 21243

Compute-First Networking

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As part of the mandatory documentation, participants are asked to submit their talk abstracts, working group results, etc. for publication in our series *Dagstuhl Reports* via the Dagstuhl Reports Submission System.

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Program at a Glance

- **Use Cases**
  - Jag Minhas: Privacy Preservation in Edge Video Processing
  - Jon Crowcroft: CFN for Health
  - Naresh Nayak: Compute Centric Networking for Connected and Automated Driving
- **Research Challenges**
  - Dave Oran: Networking and Computing - the great confluence
  - Erik Nordmark: EVEn Harder Challenges
- **Other topics**
  - PhD topics for CFN
  - AI & ML opportunities and challenges
- **Research Topics**
  - Christian Tschudin: After the Fun the Hard Stuff
  - Gianni Antichi: In-network telemetry
  - Noa Zilbermann: In network computing challenges and opportunities
  - Andy Reid: Deconstructing and reimagining orchestration
  - Michio Honda: Networking matters for storage systems
  - Peer Stritzinger: Heterogenous Networks and Laying out the Compute Graph
  - Jörg Ott: In-Network Compute Architecture
  - Jianfei He: New Network for Distributed Systems

Motivation

Dave Oran

So, why should we care about this?

- Applications are becoming more multi-party and distributed
  - Difficult (and possibly undesirable) to make the network “transparent” to the application programmer
    - Performance inhomogeneities in both throughput and delay
    - Complex partial failures
  - Programming model only easily exploits localized parallelism
  - Isolation against competing workloads and resilience against attack requires sophisticated features “in” the network
- DevOps requires incremental partial deployment
  - Coordination with network underlays tricky and slows things down
  - Responsibilities for various security and disaster protection divided organizationally – partially due to expertise gap and technology differences
- Computing and Communications are on different cost/performance trajectories

Use Case: Health

Jon Crowcroft

Health Sensing

- On phones
  - Accelerometer, camera, mike, or addon
- or on bespoke devices
  - (pacemakers, insulin pumps, defibr etc)

Federation of Planet Health Data

- But cost of upload data
  - Battery, network charges etc
  - Privacy (blah blah:-)
- So learn model, and upload model params
  - Federated PCA, or SGD
  - Or even federated Bayes inference

Federation of Planet Contacts

- GAEN is a cryptic digital twin
  - phones load (BLE) contacts into the "net"
  - If/when a phone's owner test +ve
    - contacted phones "notified"

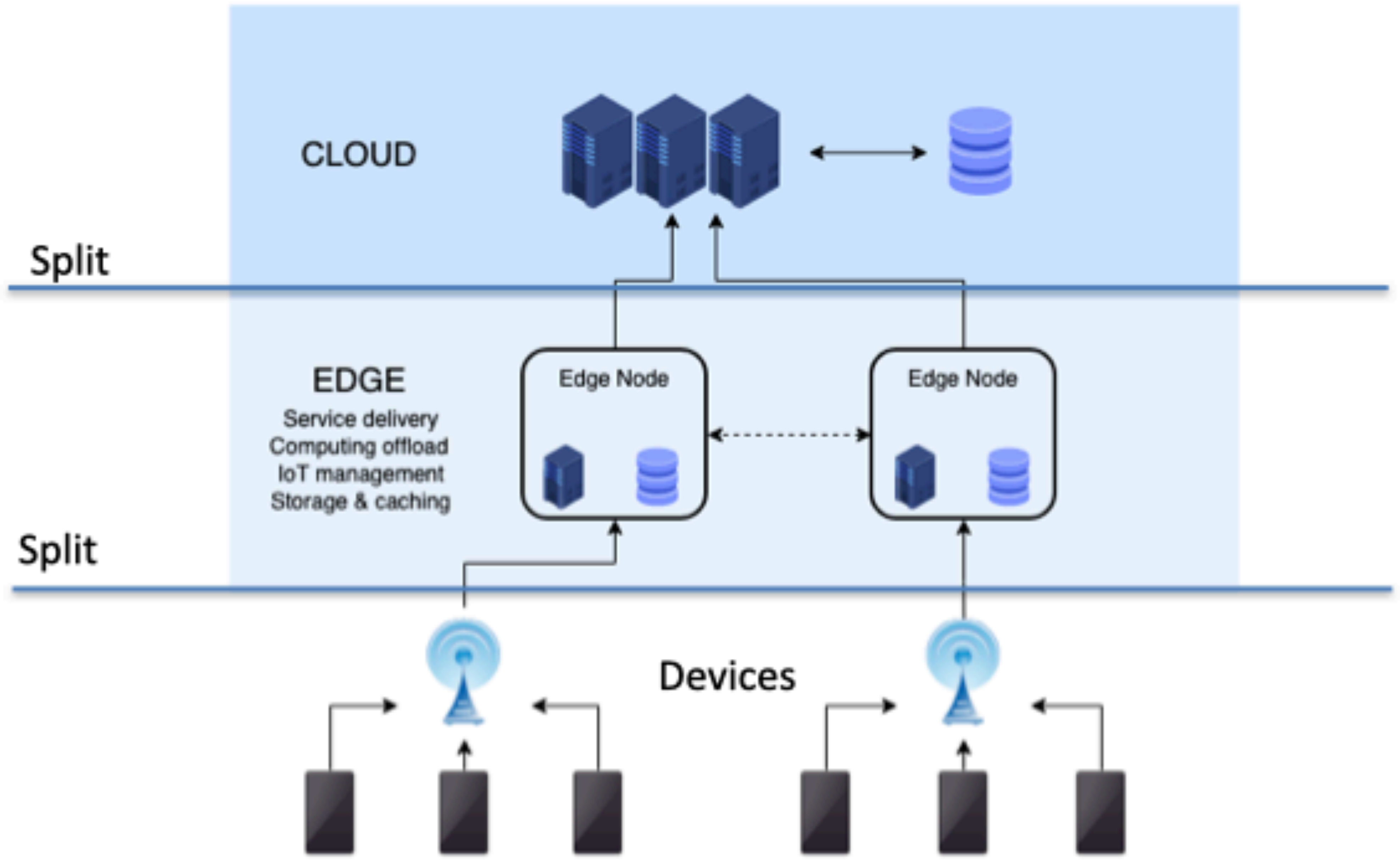
Federation of Planet Health Risk

- Risk - #people not tested of vaccinated
- Prevalance in an area
- Variants
- Location of test/vaccination centre
- etc

Use Case: Split Learning

Dave Oran

Simplified Edge computing model



Potential advantages of CFN to Split Learning

- Privacy
  - Confine raw data to device only, or
  - Store/process raw data in secure enclave on edge computing complex
    - Rely on channel security or ICN-style secure objects to hide raw data from eavesdroppers
      - If using channel security, separate encryption needed for local storage media
    - Process in security context of data owner/generator
- Resource tiers
  - Simple sensing on device
  - Feature extraction at edge (or on more capable device)
  - Full model execution in the cloud
- Flexible processing options
  - Limited model locally to solve latency issues
  - Bandwidth savings by only invoking full model when needed
- Failure resiliency
  - Degraded operation feasible when cloud unreachable
  - Local storage for time-series data – decouple from real time constraints when learning

Facts

Dave Oran

Summing up – Servers versus Switches

Servers

- Many cycles/bit
- Memory intensive
  - Either lots of state or high creation/destruction rate
- Scalable load
- Rapid feature evolution
- Need isolation / multi-tenant

Switches

- Few cycles/bit
- Small/moderate memory
  - But run at clock rate w/o caches
- Need to process input at wire rate
- Simple, "inner loops"
- Works if crypto not an issue

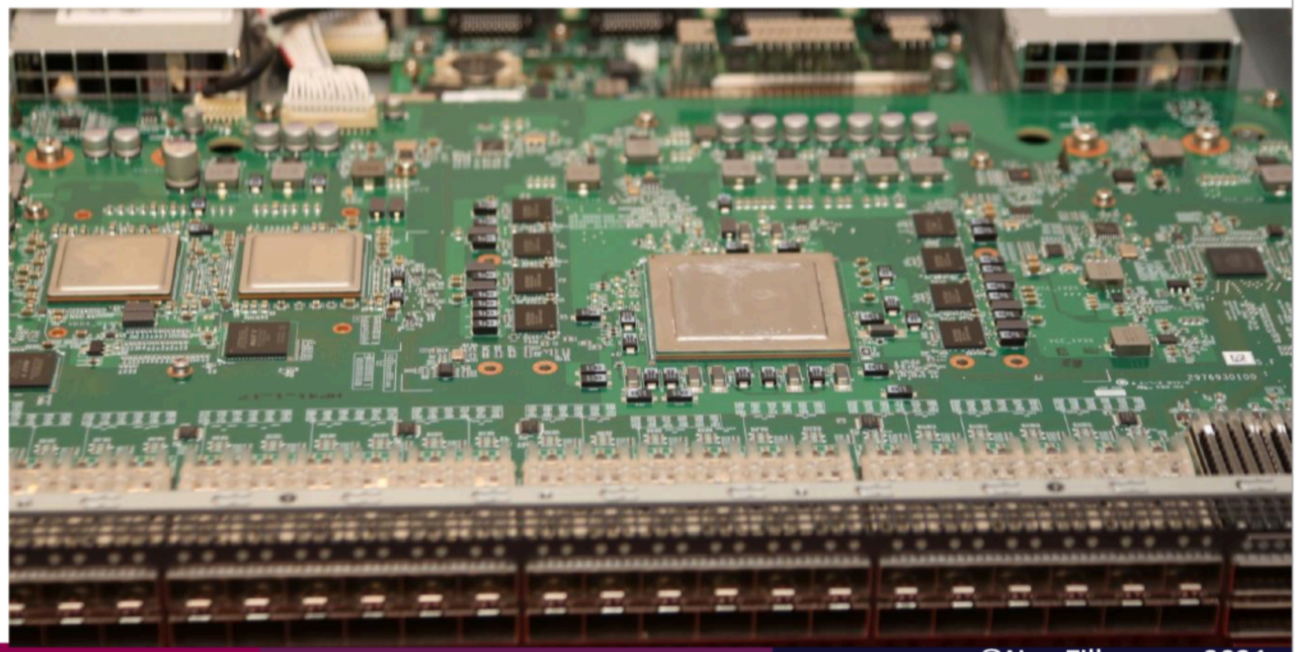
Facts

Noa Zilberman

Programmable Dataplane as a Platform

Summary: Opportunities

- Open end-to-end switch architecture
- A good model for resource-constrained programming
- Multi-target compiler
- State saving and state sharing
- Programmable externs
- Data plane debuggers
- End-to-end performance
- Failure recovery
- Multi-tenancy



Micro-Architecture

- You can save state.
  - Once.
- You can access state.
  - Once.
  - In the same stage.
- And we won't make it easy.

- Sharing state between pipelines?
- Pipelines????

Challenges

Dave Oran

What do we need to make this work?

- Intelligent placement of computing
  - Joint optimization of network resources and computing resources
  - Visibility into network state/metrics by the application programmer (or at least in the framework)
- Lay out processing graphs flexibly – react to medium-timescale changes
  - Conditions may change dynamically and constantly: network to adapt to application requirements, network conditions etc.
- Sometimes we can move functions instead of data (close to big data assets)
- At other times we *gradually* move data where it is needed (e.g., where specific computations run)
- **Optimization based on application requirements & view of all relevant resources**

Challenges

Dave Oran

Some interesting outstanding questions

- Smart NICs have FPGAs – what's the best way to use them?
- Figure out how to use P4 on switches for general computing?
- How to bridge the gap in the programming model?
  - What is imperative/functional versus what is done data-flow
- What do the platforms look like?
  - Heterogenous elements closely coupled internally, with conventional network externally, or
  - Heterogenous elements with custom "internal" network built scale-out, with conventional network connecting the complexes, or
  - Some hybrid with multiple parallel interconnects
    - Note: Microsoft tried this with FPGA's to scale Bing search

Re-Imagining Orchestration

Andy Reid

Cycles of deconstruction and reimagining

Dedicated boxes

Replaced by

Cloud technology

Reimagine ‘automobile’ afresh

Replace horse with internal combustion engine

Traditional network with dedicated boxes

NFV and SDN orchestration

Automation without the legacy familiarity

Retains many features of horse-drawn carriage

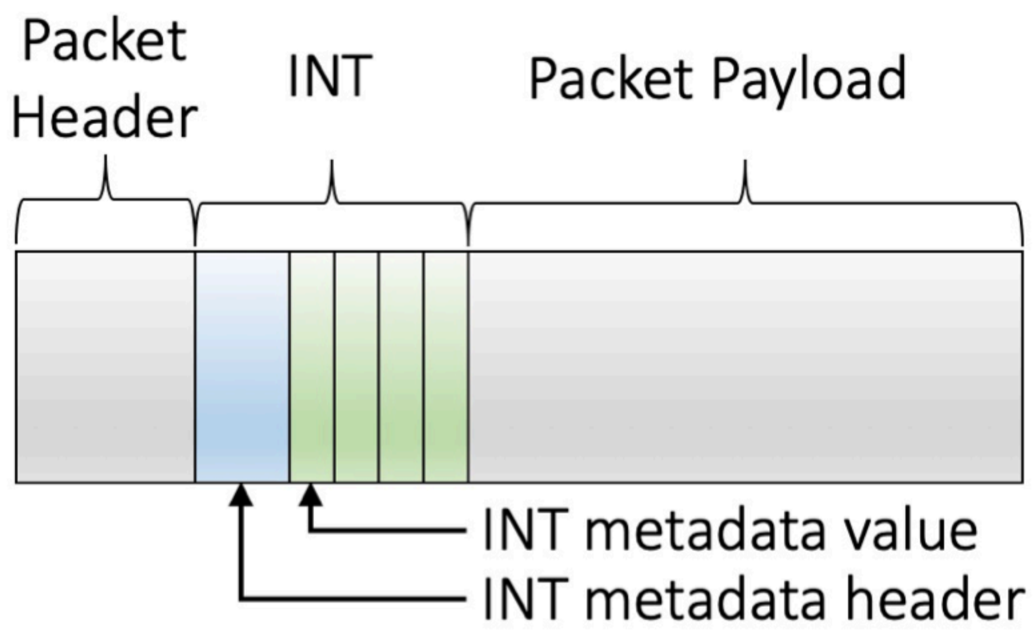
- Chauffeur = carriage driver/footman
- Arrangement of chauffeur and passengers
- NFVO+VNFM etc = Management plane
Load balancer+firewall+NAT = Data plane

Control plane

Leveraging In-Network Telemetry

Gianni Antichi

This is INT (In-band Network Telemetry)



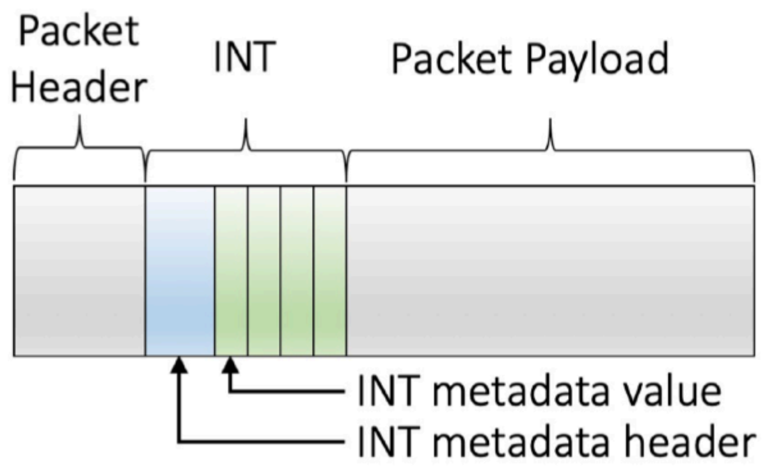
Metadata value	Description
Switch ID	ID associated with the switch
Ingress Port ID	Packet input port
Ingress Timestamp	Time when packet is received
Egress Port ID	Packet output port
Hop Latency	Time spent within the device
Egress Port TX utilization	Current utilization of output port
Queue Occupancy	The observed queue build up
Queue Congestion Status	Percentage of queue being used

Tell me more about my packets

- Is there a congestion/queue buildup?
- Do routing paths agree with the policy?
- Does my network experience load imbalance?

INT as building block for many network functionalities

- INT is deployed in major companies such as Alibaba
- Used in a number of contexts:
  - Congestion Control (HPCC – SIGCOMM 2019)
  - Load Balancing (Clove – CoNEXT 2017)
  - Path Tracing



Rethinking Communication and Computation Abstractions

Christian Tschudin

Wished it was a Broadcast-Only World

"Receivers are an afterthought - it all starts with the event source"

- Source = secure single-author event stream
  (e.g. signed hash chain)
- then replication kicks in
  (any "ether" works)
- eventually and potentially, all parties*) can see all events
  (observers react to events, become a source themselves)

Computer Networking = coping with "ether" scarcity (BW and mem limitations)

"Distributed Memory Side Effects"

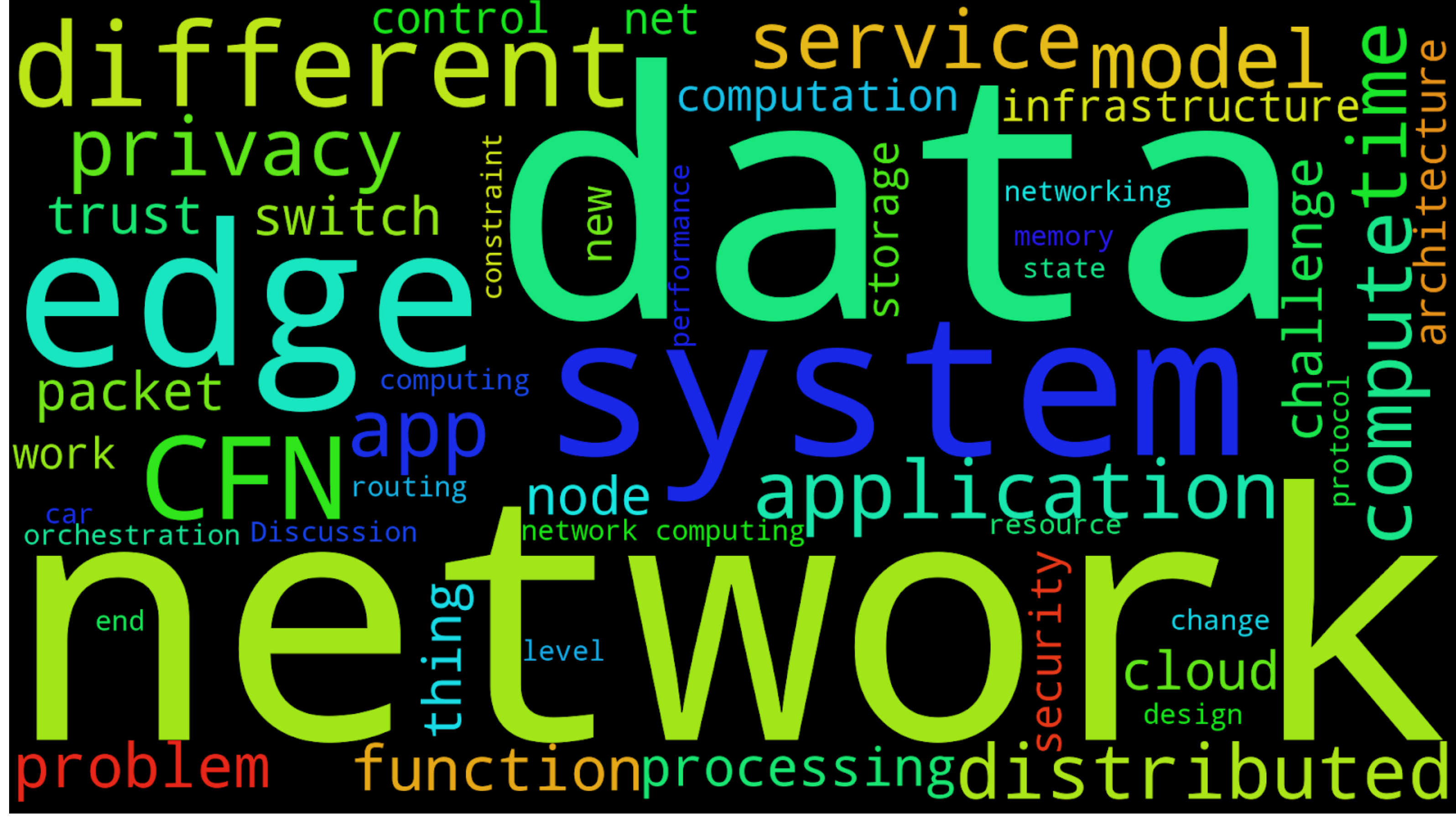
I suggest an architecture based on:
- enabling explicit (programmable) storage side effects for in-network memory
- scheduling of side effects (not covered here, see chem-based protocols)

Some first principles why the **effect** on mem is important:

- Persisted state is the ***only valid anchor*** in distr systems (also think WAL)
- Abstraction: ***All*** ways of doing storage side effects are valid:
  - kick remote state with packets - but don't stop there
  - sneaker nets (USB sticks), DNA phial, "a van full of tapes", opportunistic

Local (!) operations: running code has to read scent marks, leaves scent marks

Provisional Summary



- **Trends in hardware development**
  - limitations of multi-core
  - evolution of specialized hardware-support
  - programmable data plane
- **Trends in distributed application design**
  - Distributed ML (federated ML, split learning)
  - Applications increasingly distributed multi-party and distributed

- **Successful distributed overlay systems**
  - Ray (Berkeley RISE)
  - Dataflow-inspired (Beam, Flink)
- **Opportunities**
  - Programming abstractions and platforms that do not treat network as black box
  - Leveraging different types of hardware platforms optimally
  - Exploring optimization potential: joint optimization, less centralized designs
  - Rethinking role of management and orchestration