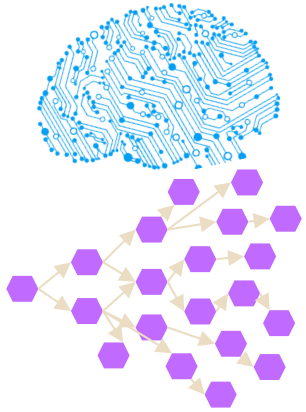


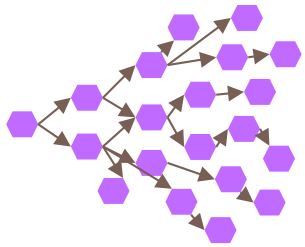
Seer: Leveraging Big Data to Navigate The Increasing Complexity of Cloud Debugging

Yu Gan, Meghna Pancholi, Dailun Cheng,
Siyuan Hu, Yuan He and Christina Delimitrou

Cornell University

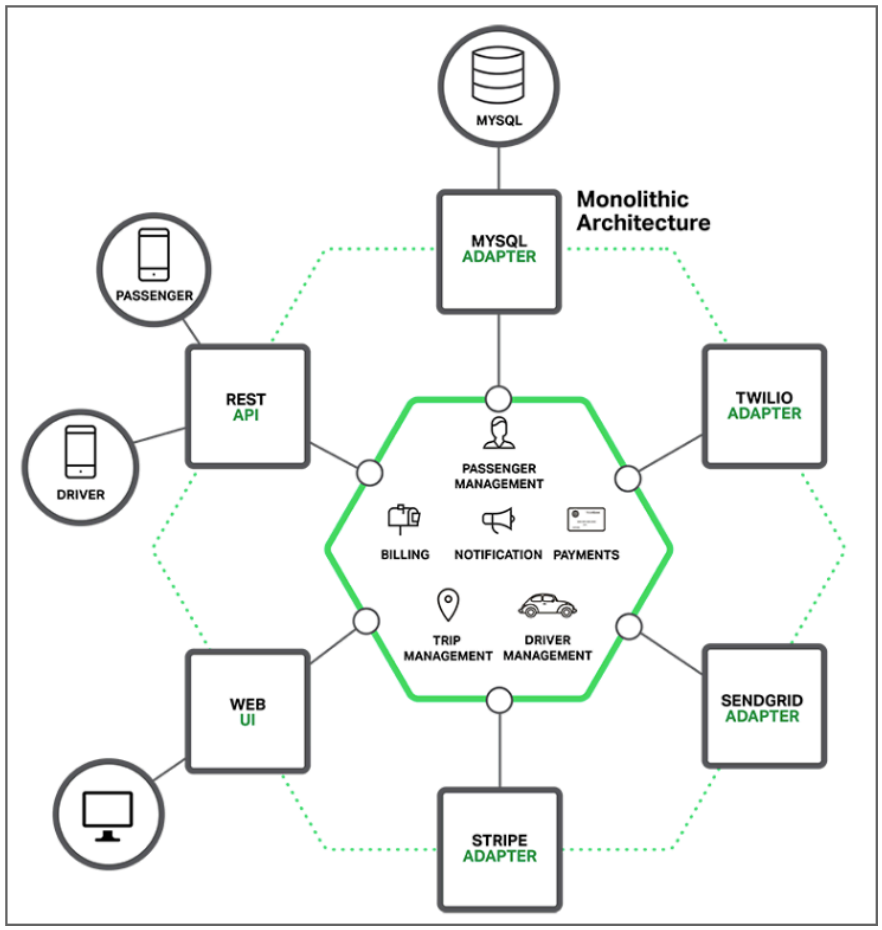
HotCloud– July 9th 2018

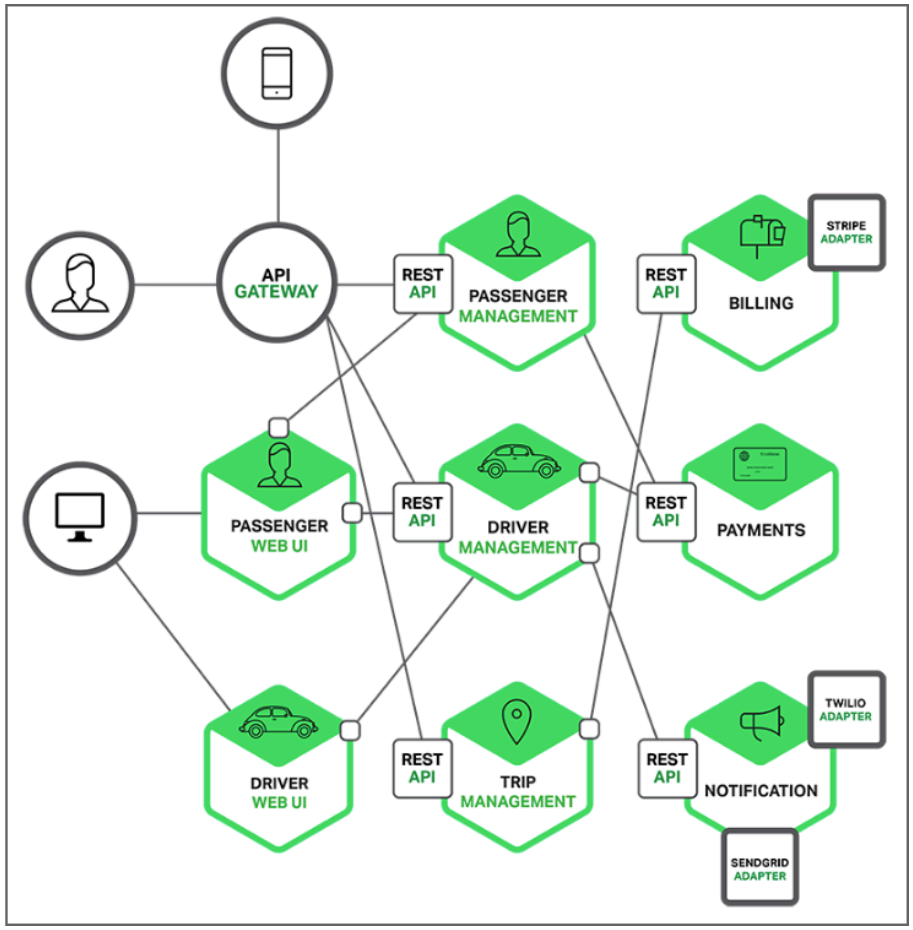
Executive Summary



- Microservices puts more pressure on performance predictability
  - Microservices dependencies → propagate & amplify QoS violations
  - Finding the culprit of a QoS violation is difficult
  - Post-QoS violation, returning to nominal operation is hard
- Anticipating QoS violations & identifying culprits
- Seer: Data-driven Performance Debugging for Microservices
  - Combines lightweight RPC-level distributed tracing with hardware monitoring
  - Leverages scalable deep learning to signal QoS violations with enough slack to apply corrective action

From Monoliths to Microservices





Motivation

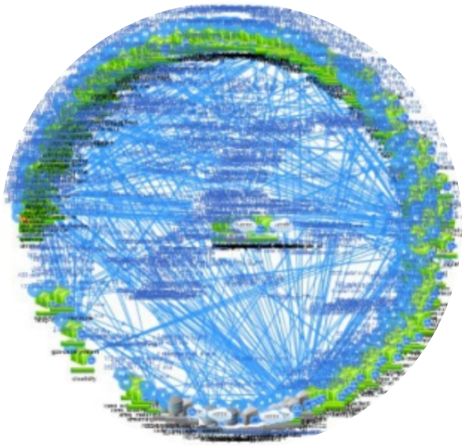
- Advantages of microservices:
  - Ease & speed of code development & deployment
  - Security, error isolation
  - PL/framework heterogeneity
- Challenges of microservices:
  - Change server design assumptions
  - Complicate resource management → dependencies
  - Amplify tail-at-scale effects
  - More sensitive to performance unpredictability
  - No representative end-to-end apps with microservices

An End-to-End Suite for Cloud & IoT Microservices

- 4 end-to-end applications using popular open-source microservices → ~30-40 microservices per app
  - Social Network
  - Movie Reviewing/Renting/Streaming
  - E-commerce
  - Drone control service

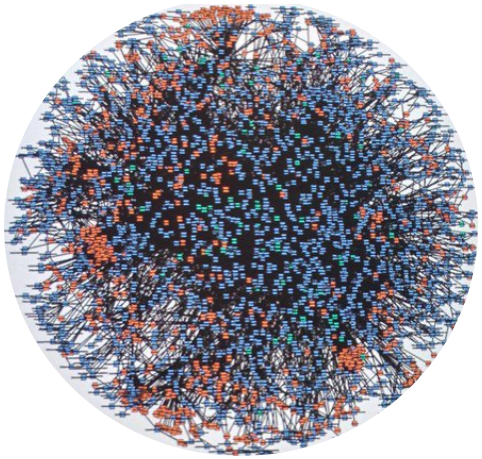
- Programming languages and frameworks:
  - node.js, Python, C/C++, Java/Javascript, Scala, PHP, and Go
  - Nginx, memcached, MongoDB, CockroachDB, Mahout, Xapian
  - Apache Thrift RPC, RESTful APIs
  - Docker containers
  - Lightweight RPC-level distributed tracing

Resource Management Implications

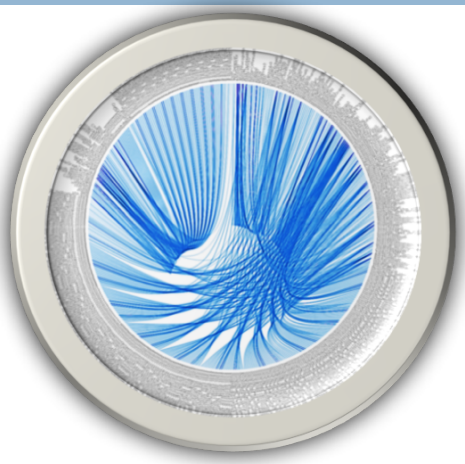


Netflix

Twitter



Amazon



Movie Streaming

- Challenges of microservices:
  - Dependencies complicate resource management
  - Dependencies change over time → difficult for users to express
  - Amplify tail@scale effects

The Need for Proactive Performance Debugging

- Detecting QoS violations after they occur:
  - Unpredictable performance propagates through system
  - Long time until return to nominal operation
  - Does not scale

Queue CPU Mem Net Disk

Performance Implications

Queue CPU Mem Net Disk

Performance Implications

Seer: Data-Driven Performance Debugging

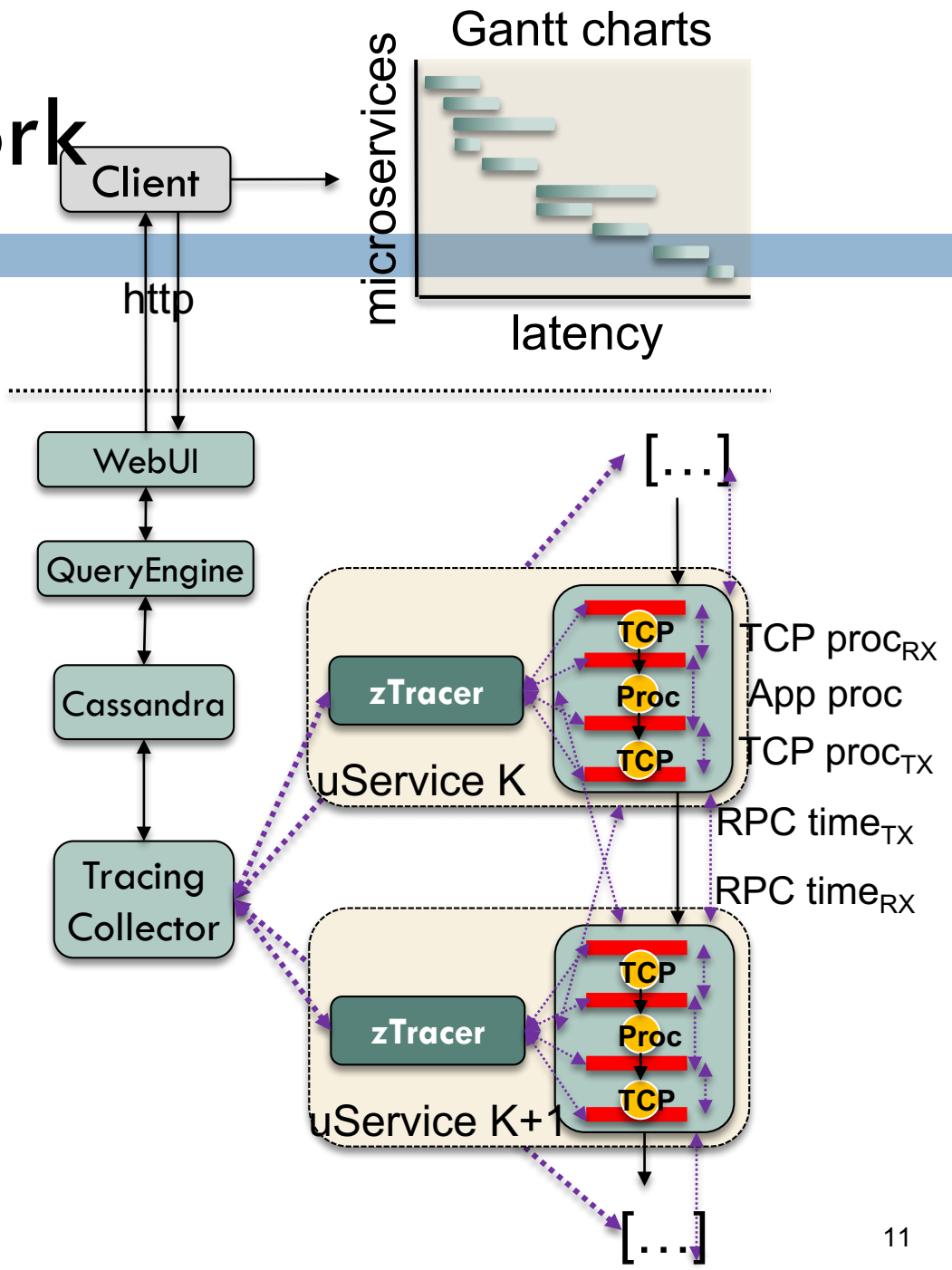
- Leverage the massive amount of traces collected over time

1. Apply online, practical data mining techniques that identify the culprit of an *upcoming* QoS violation
2. Use per-server hardware monitoring to determine the cause of the QoS violation
3. Take corrective action to prevent the QoS violation from occurring

- Need to predict 100s of msec – a few sec in the future

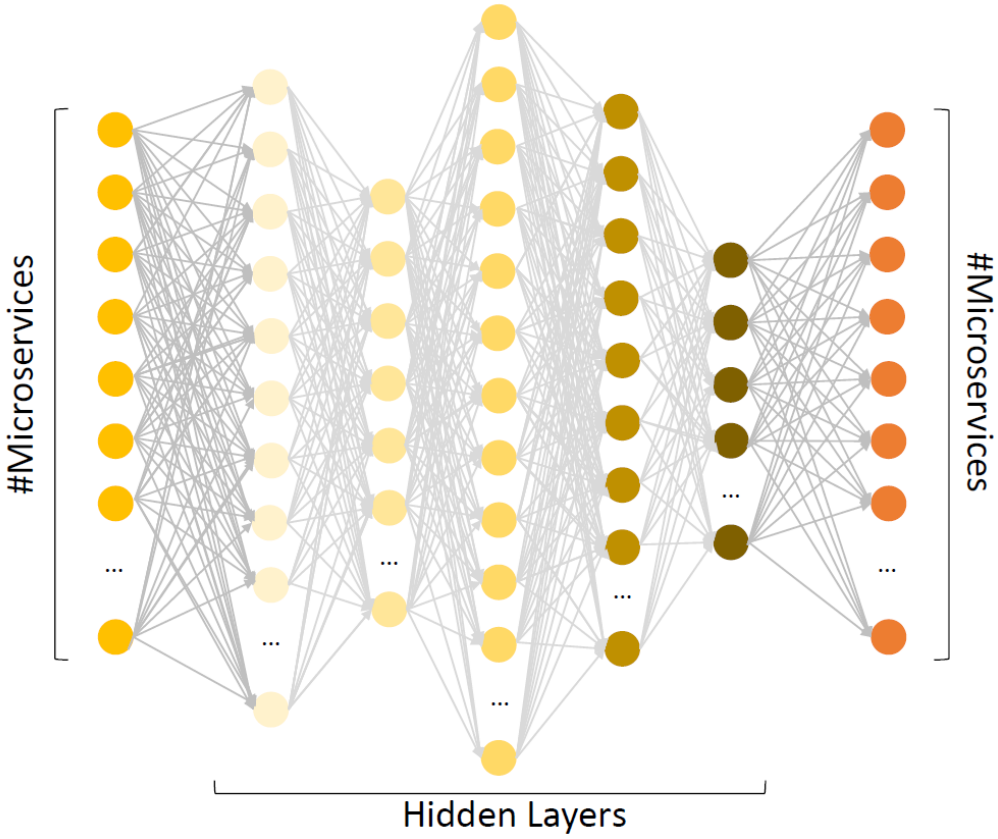
Tracing Framework

- RPC level tracing
- Based on Apache Thrift
- Timestamp start-end for each microservice
- Store in centralized DB (Cassandra)
- Record all requests → No sampling
- Overhead: <0.1% in throughput and <0.2% in tail latency



Deep Learning to the Rescue

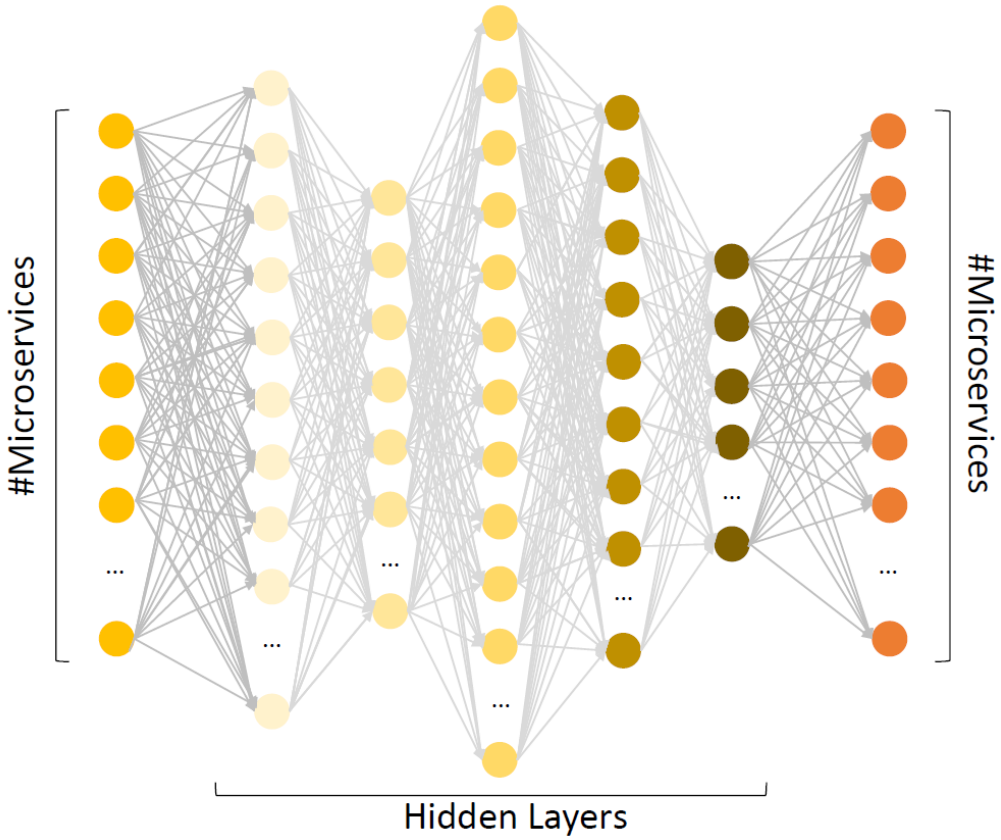
- Why?
  - Architecture-agnostic
  - Adjusts to changes in dependencies over time
  - High accuracy, good scalability
  - Inference within the required window



DNN Configuration

Input signal

- Container utilization
- Latency
- Queue depth



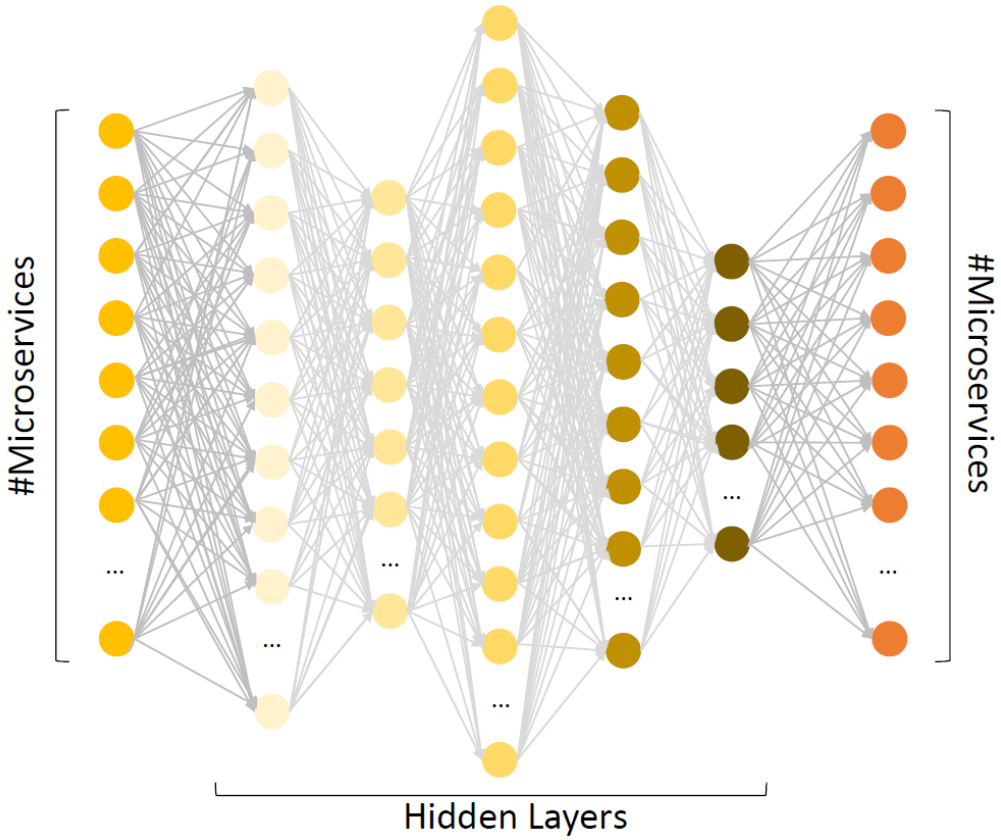
Output signal

Which microservice will cause a QoS violation in the near future?

DNN Configuration

Input signal

- Container utilization
- Latency
- Queue depth



Output signal

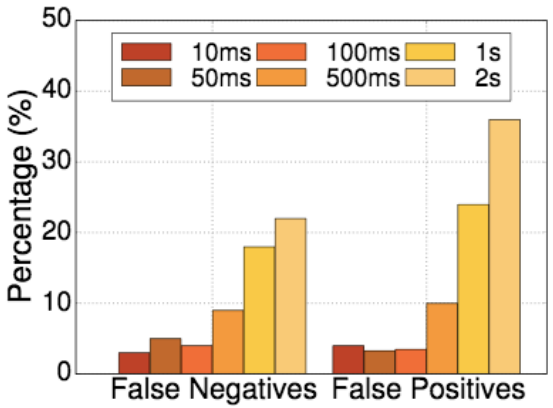
Which microservice will cause a QoS violation in the near future?

DNN Configuration

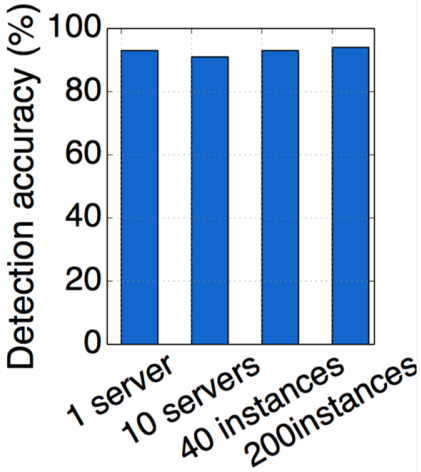
- Training once: slow (hours - days)
  - Across load levels, load distributions, request types
  - Distributed queue traces, annotated with QoS violations
  - Weight/bias inference with SGD
  - Retraining in the background
- Inference continuously: streaming trace data

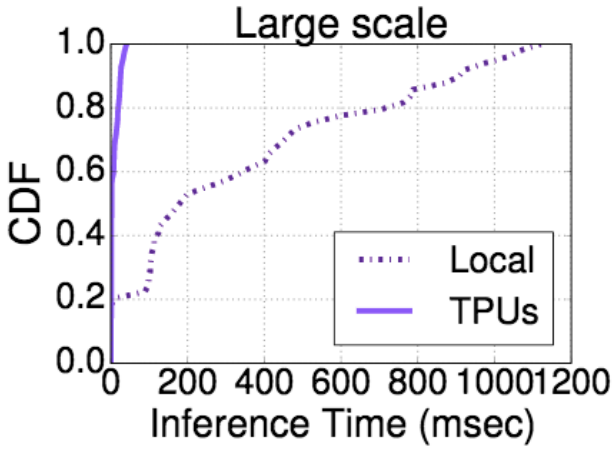
93% accuracy in signaling upcoming QoS violations

91% accuracy in attributing QoS violation to correct microservice



DNN Configuration



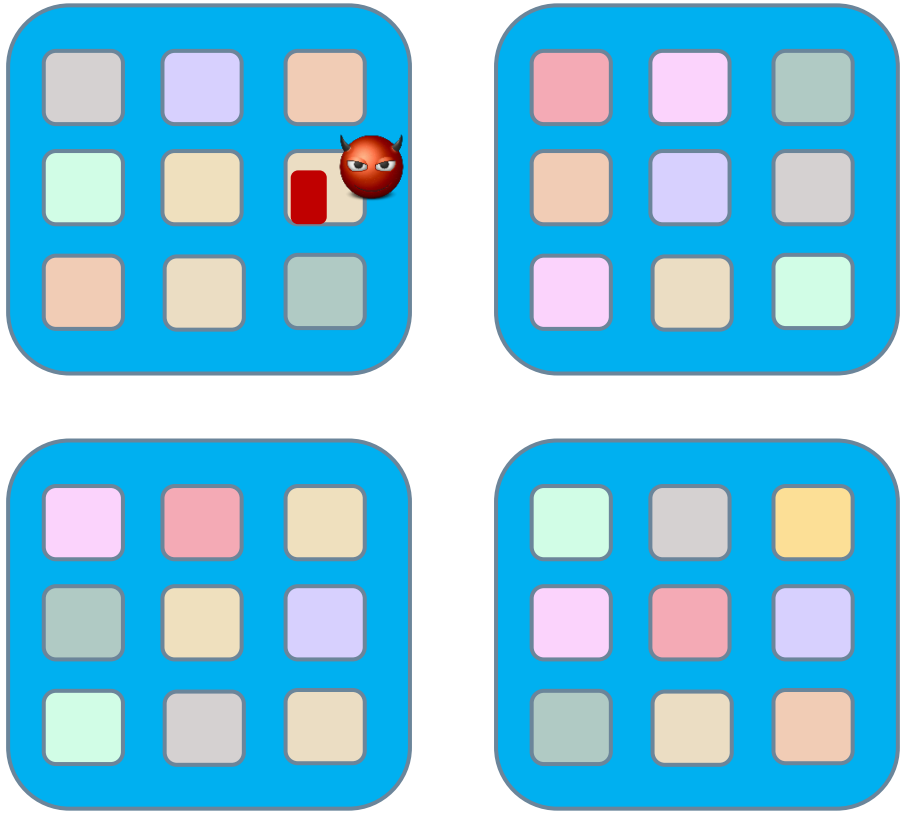


Accuracy stable or increasing with cluster size

- Challenges:
  - In large clusters inference too slow to prevent QoS violations
  - Offload on TPUs, 10-100x improvement; 10ms for 90th %ile inference
  - Fast enough for most corrective actions to take effect (net bw partitioning, RAPL, cache partitioning, scale-up/out, etc.)

Experimental Setup

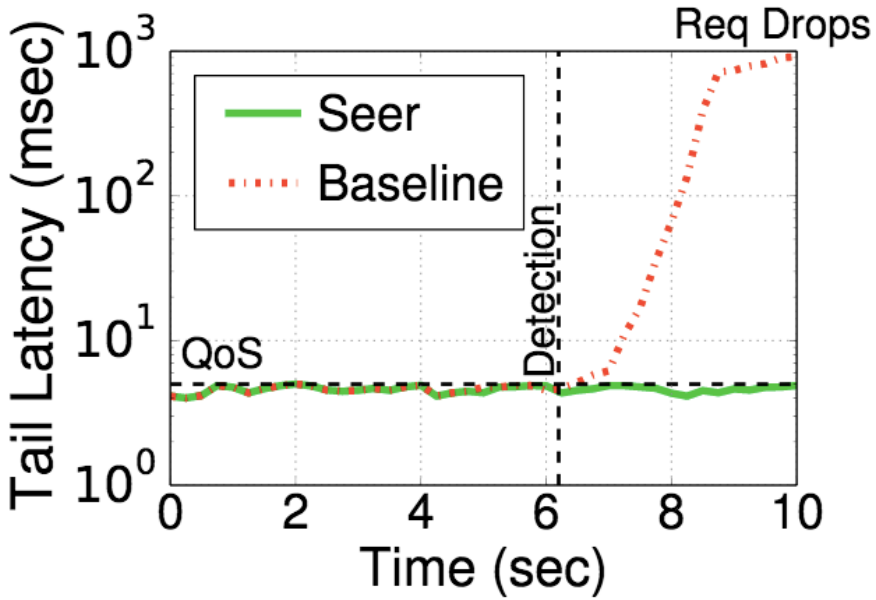
- 40 dedicated servers
- ~1000 single-concerned containers
- Machine utilization 80-85%
- Inject interference to cause QoS violation
  - Using microbenchmarks (CPU, cache, memory, network, disk I/O)



Restoring QoS

- Identify cause of QoS violation
  - Private cluster: performance counters & utilization monitors
  - Public cluster: contentious microbenchmarks
- Adjust resource allocation
  - RAPL (fine-grain DVFS) & scale-up for CPU contention
  - Cache partitioning (CAT) for cache contention
  - Memory capacity partitioning for memory contention
  - Network bandwidth partitioning (HTB) for net contention
  - Storage bandwidth partitioning for I/O contention

Restoring QoS

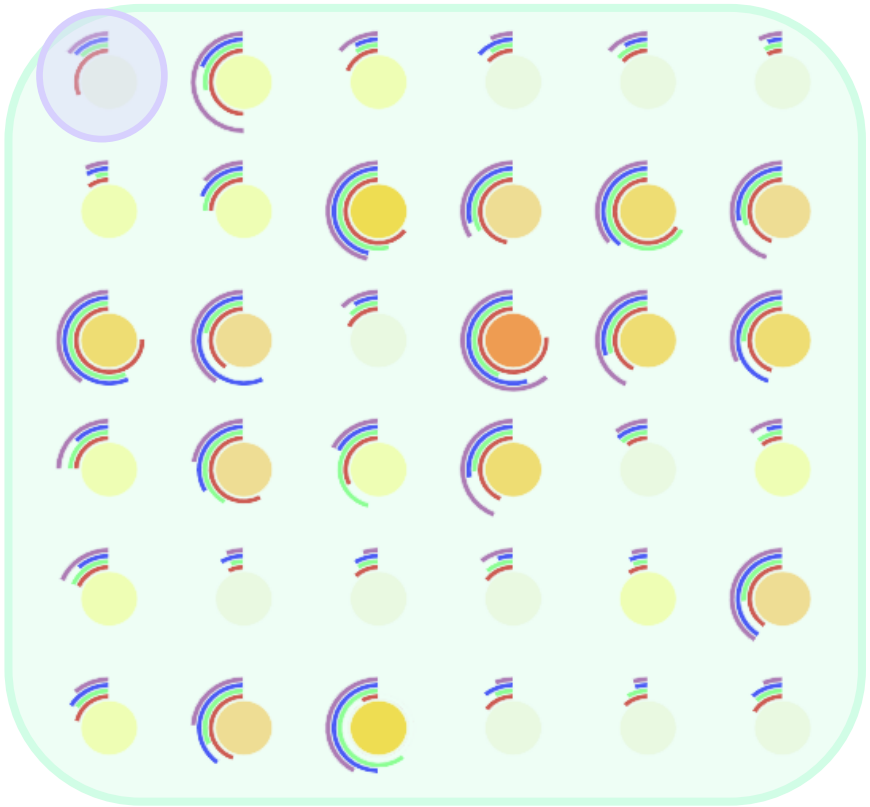


- Post-detection, baseline system → dropped requests
- Post-detection, Seer → maintain nominal performance

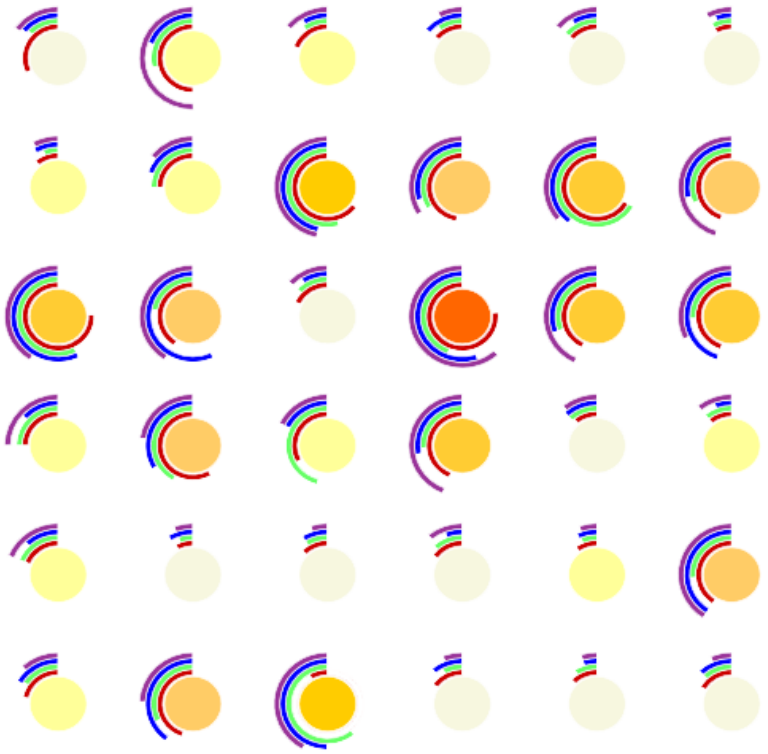
Demo

Queue CPU Mem Net Disk

Seer

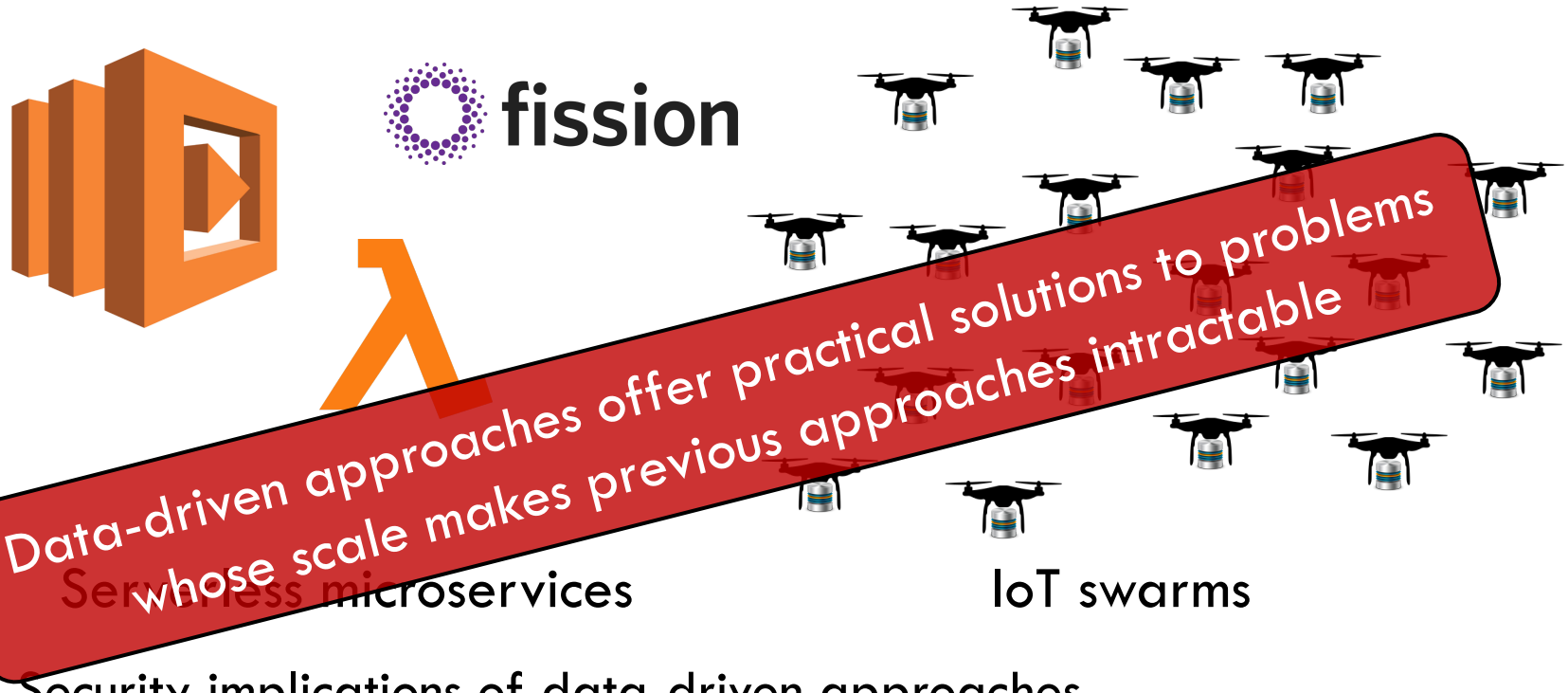


Default



Demo

Challenges Ahead



- Security implications of data-driven approaches
- Fall-back mechanisms when ML goes wrong
- Not a single-layer solution → Predictability needs vertical approaches

Thank you!