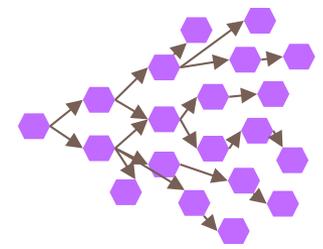


Seer: Leveraging Big Data to Navigate The Increasing Complexity of Cloud Debugging

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Siyuan Hu, Yuan He and Christina Delimitrou

Cornell University

Executive Summary

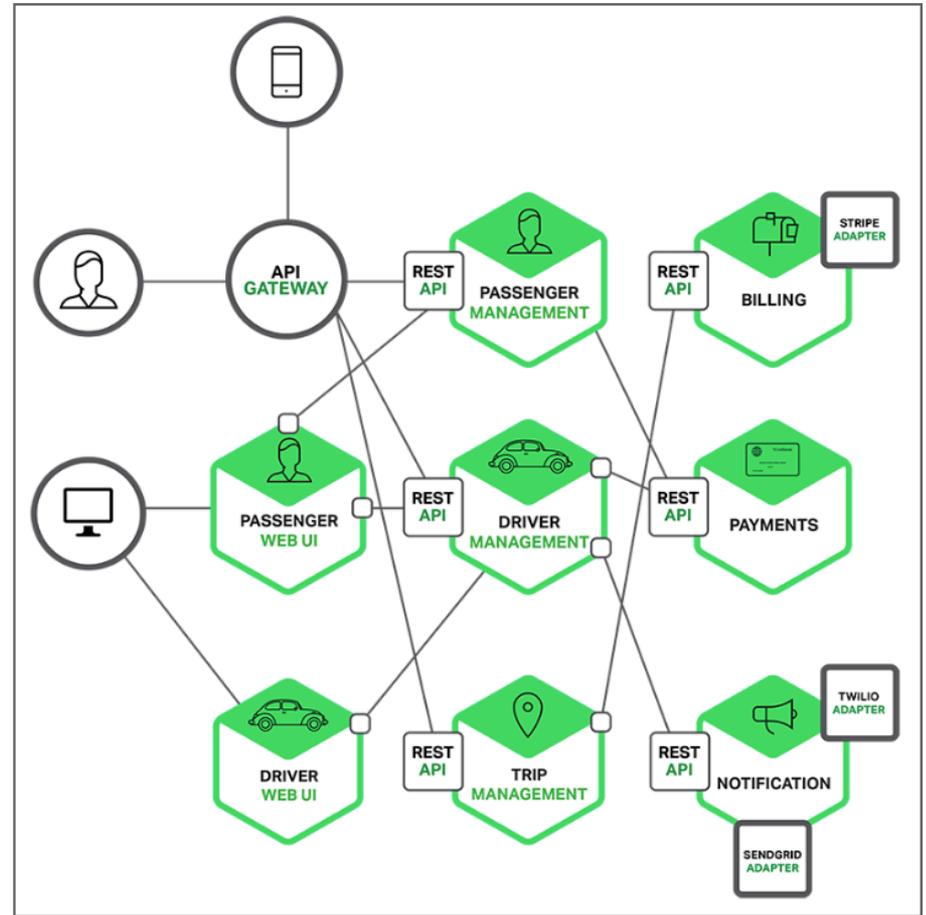
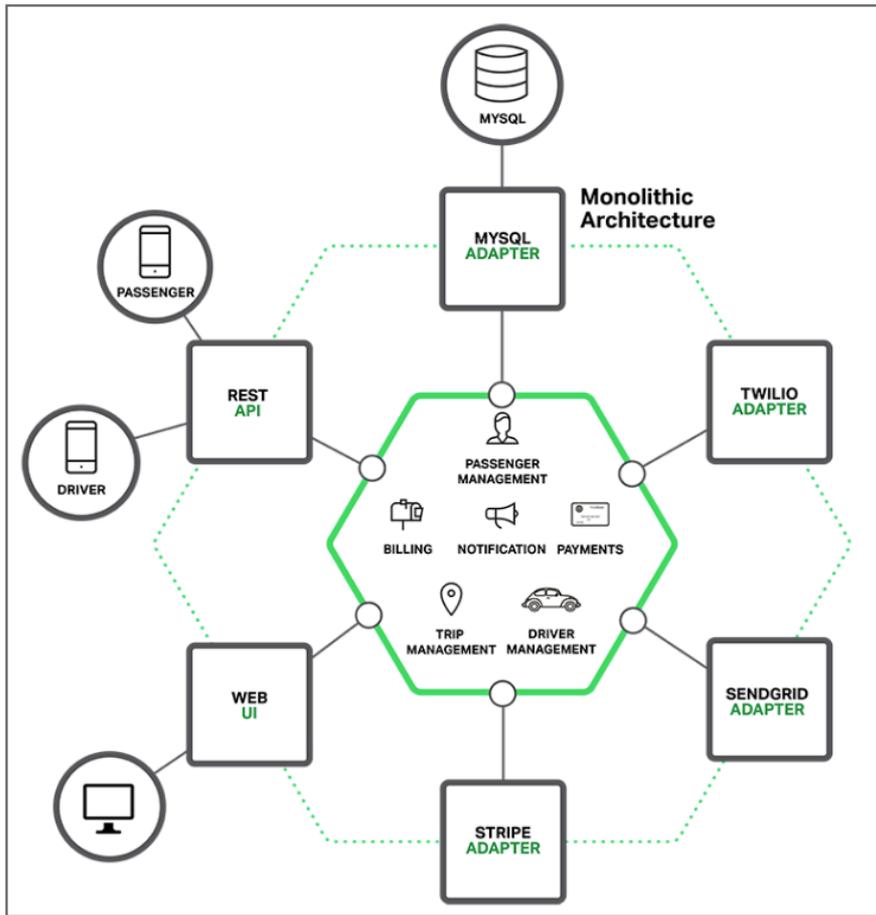


- **Microservices puts more pressure on performance predictability**
 - ▣ Microservices dependencies → propagate & amplify QoS violations
 - ▣ Finding the culprit of a QoS violation is difficult
 - ▣ Post-QoS violation, returning to nominal operation is hard

- 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



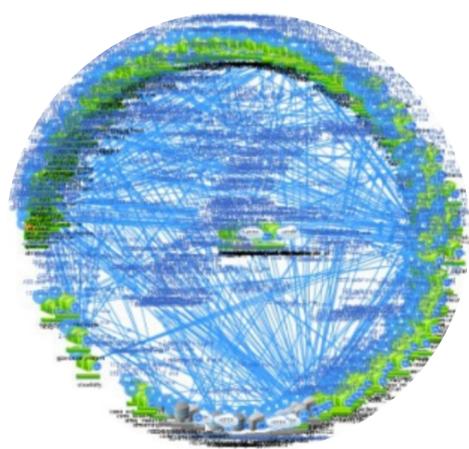
Motivation

- **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

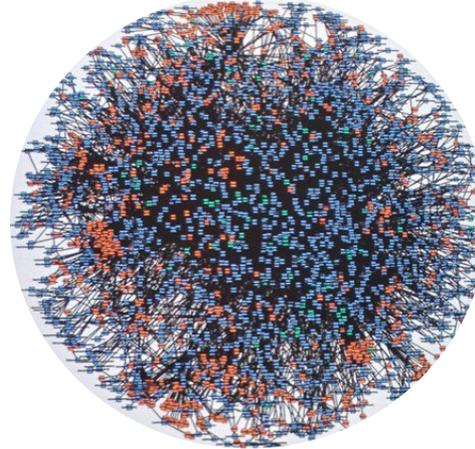
Resource Management Implications



Netflix



Twitter



Amazon



Movie Streaming

□ Challenges of microservices:

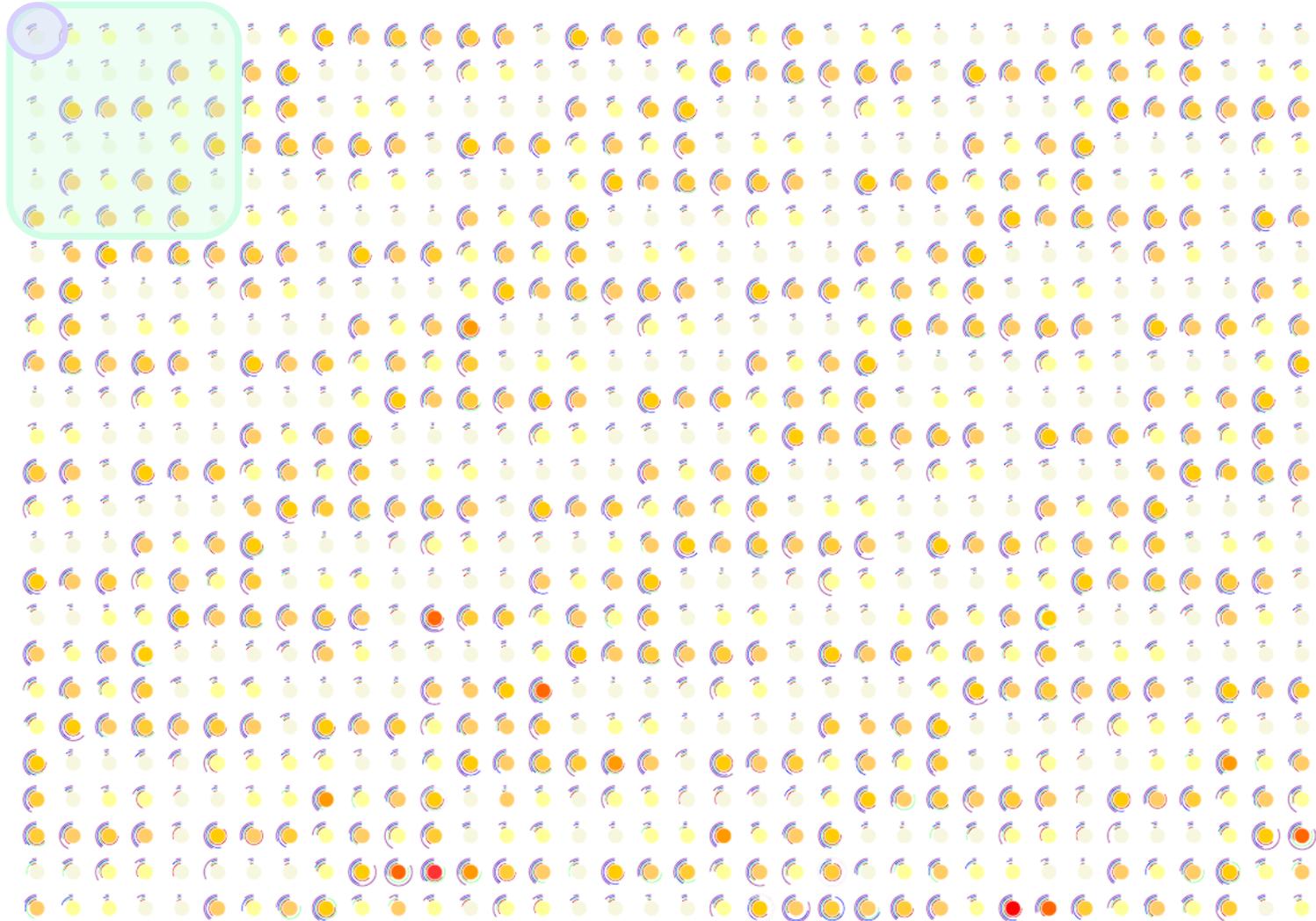
- Dependencies complicate resource management
- Dependencies change over time → difficult for users to express
- Amplify tail@scale effects

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

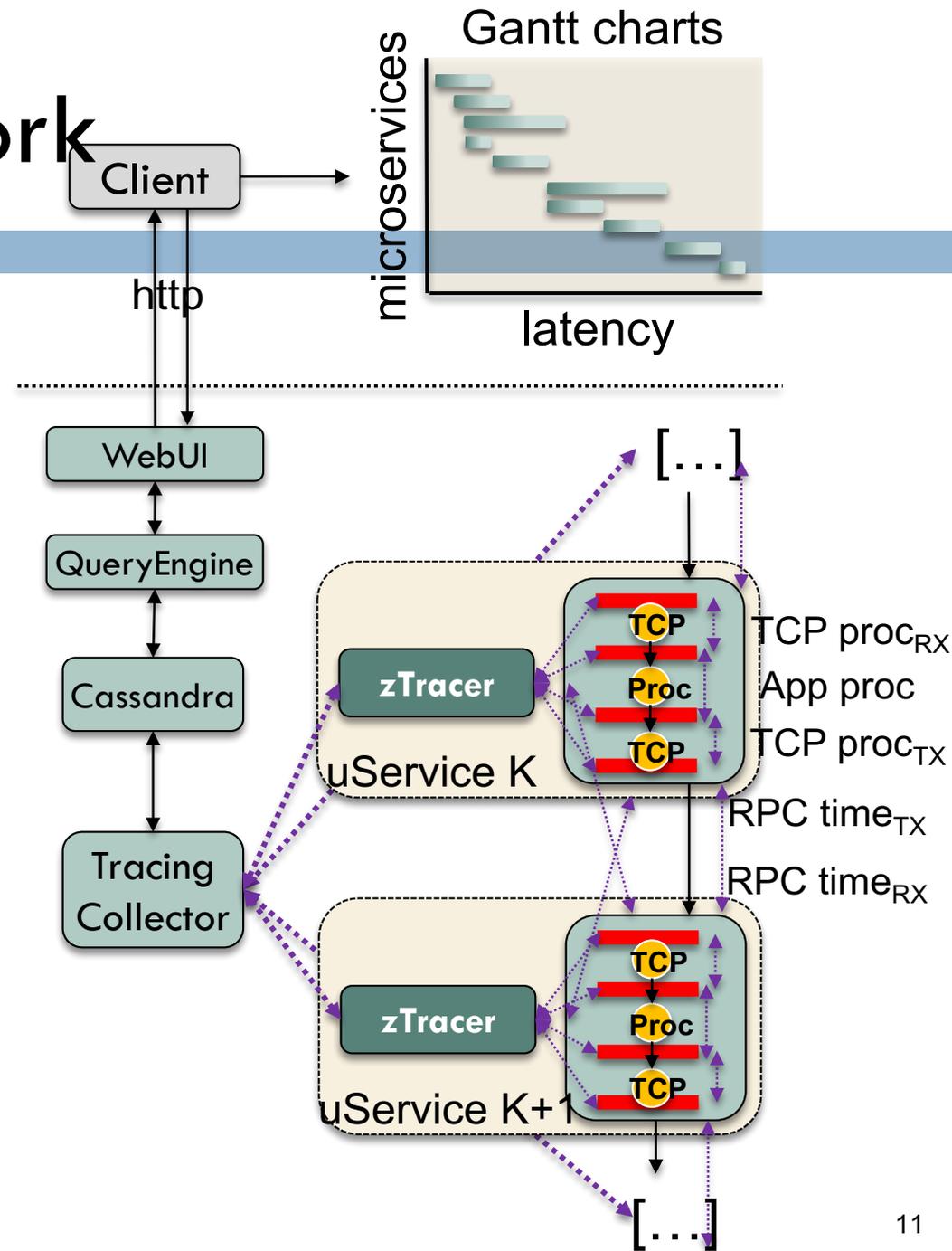


Seer: Data-Driven Performance Debugging

- 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

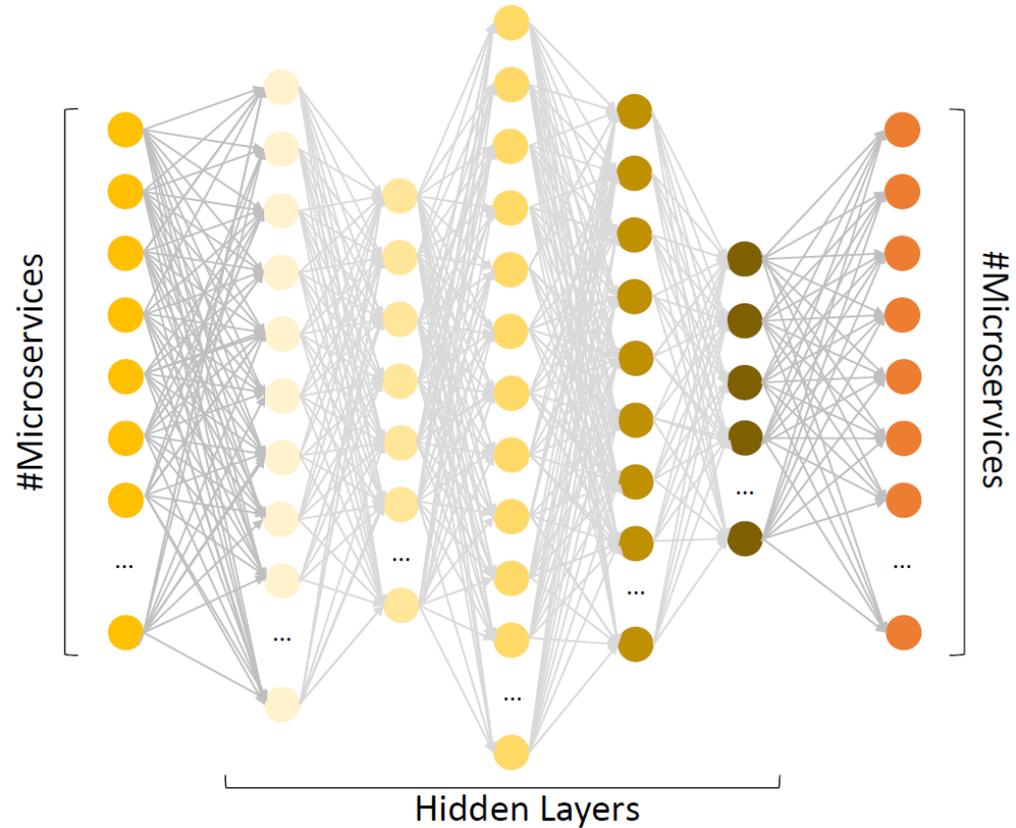
- RPC level tracing
- Based on Apache Thrift
- Timestamp start-end for each microservice
- Store in centralized DB (Cassandra)
- Record all requests → No sampling
- Overhead: <0.1% in throughput and <0.2% in tail latency



Deep Learning to the Rescue

□ Why?

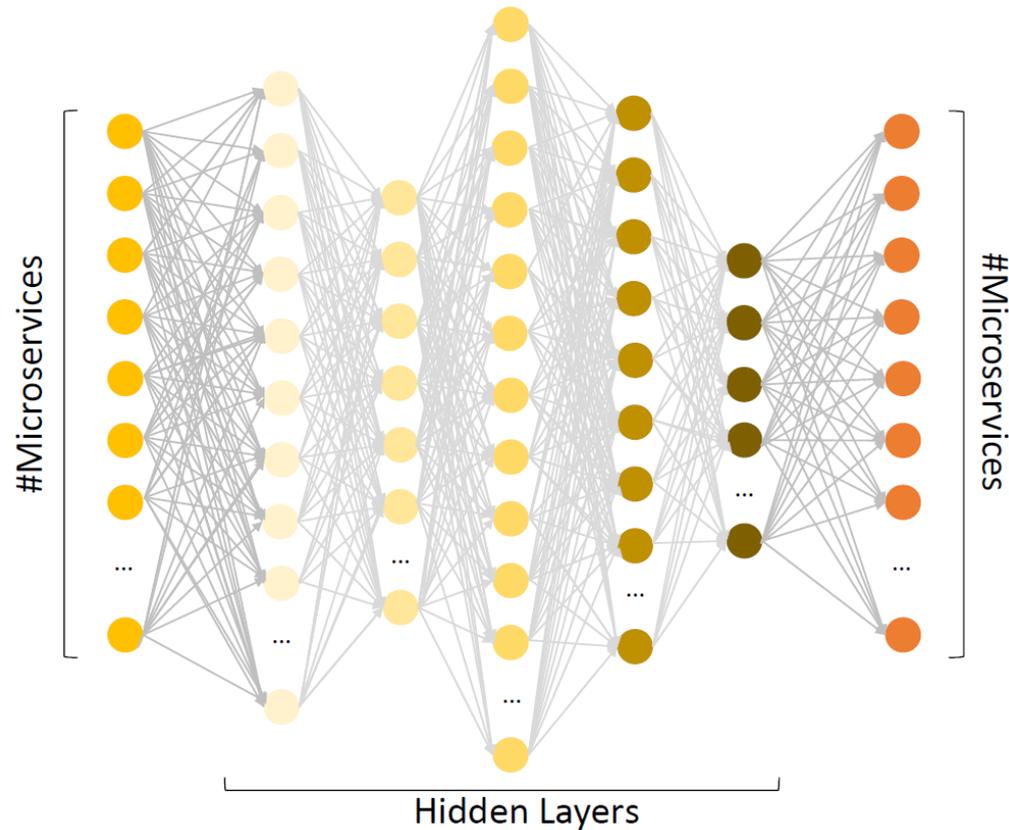
- Architecture-agnostic
- Adjusts to changes in dependencies over time
- High accuracy, good scalability
- Inference within the required window



DNN Configuration

Input signal

- Container utilization
- Latency
- Queue depth



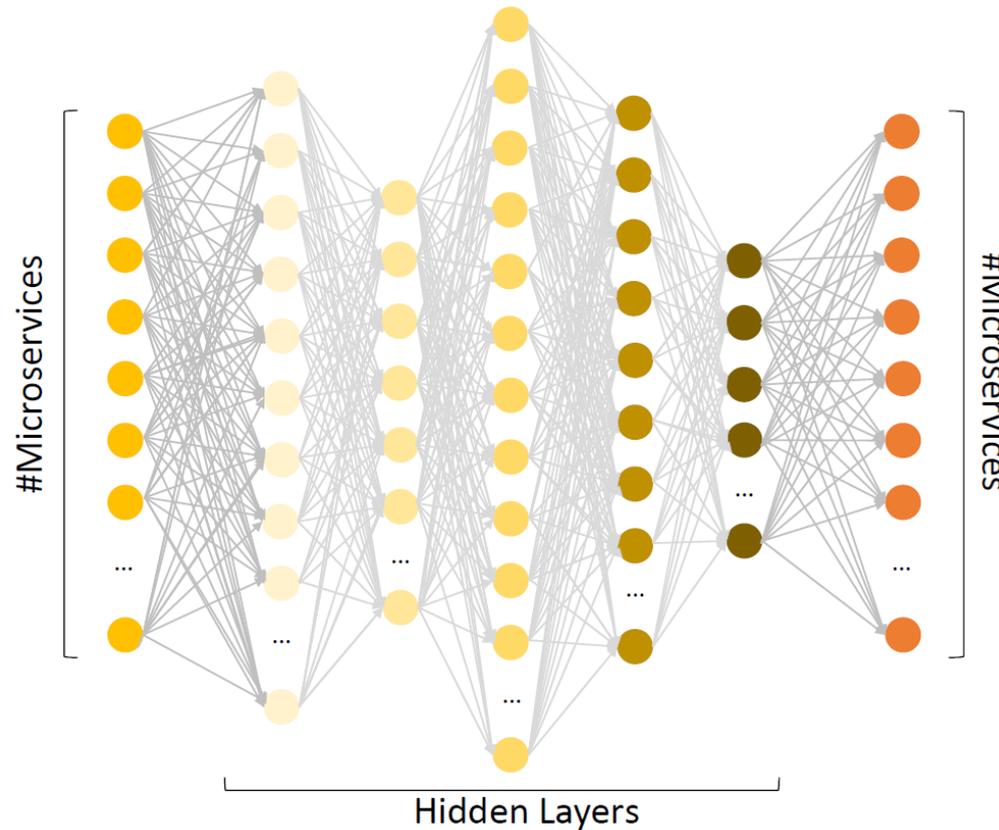
Output signal

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

DNN Configuration

Input signal

- Container utilization
- Latency
- Queue depth



Output signal

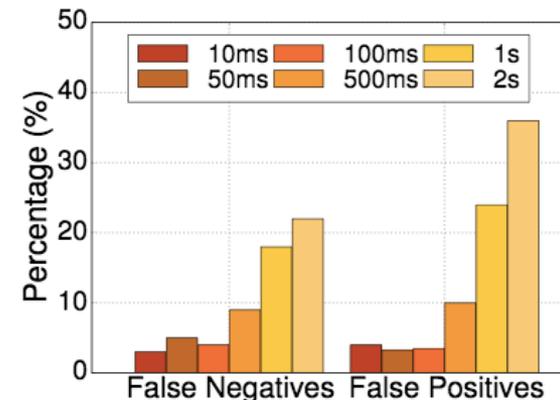
Which microservice will cause a QoS violation in the near future?

DNN Configuration

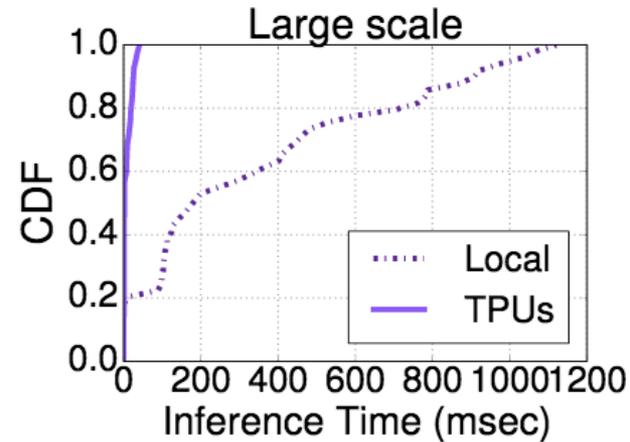
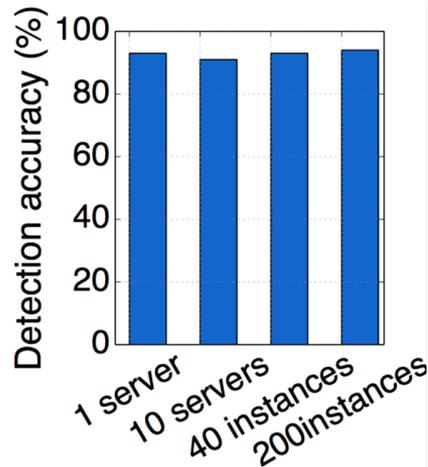
- **Training** once: slow (hours - days)
 - Across load levels, load distributions, request types
 - Distributed queue traces, annotated with QoS violations
 - Weight/bias inference with SGD
 - Retraining in the background
- **Inference** continuously: streaming trace data

93% accuracy in signaling upcoming
QoS violations

91% accuracy in attributing QoS
violation to correct microservice



DNN Configuration



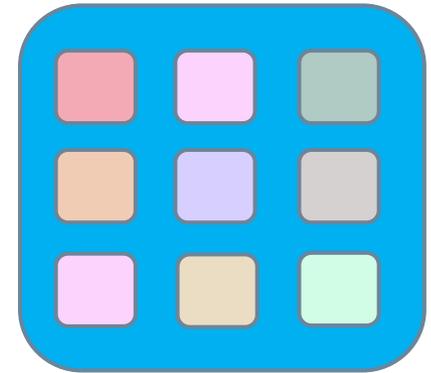
Accuracy stable or increasing with cluster size

□ 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

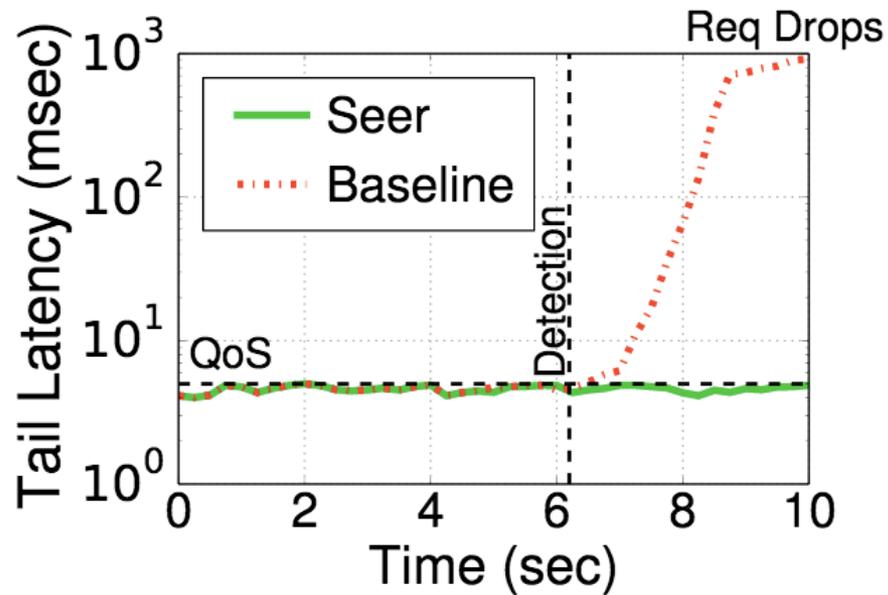
- 40 dedicated servers
- ~1000 single-concerned containers
- Machine utilization 80-85%
- Inject interference to cause QoS violation
 - ▣ Using microbenchmarks (CPU, cache, memory, network, disk I/O)



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

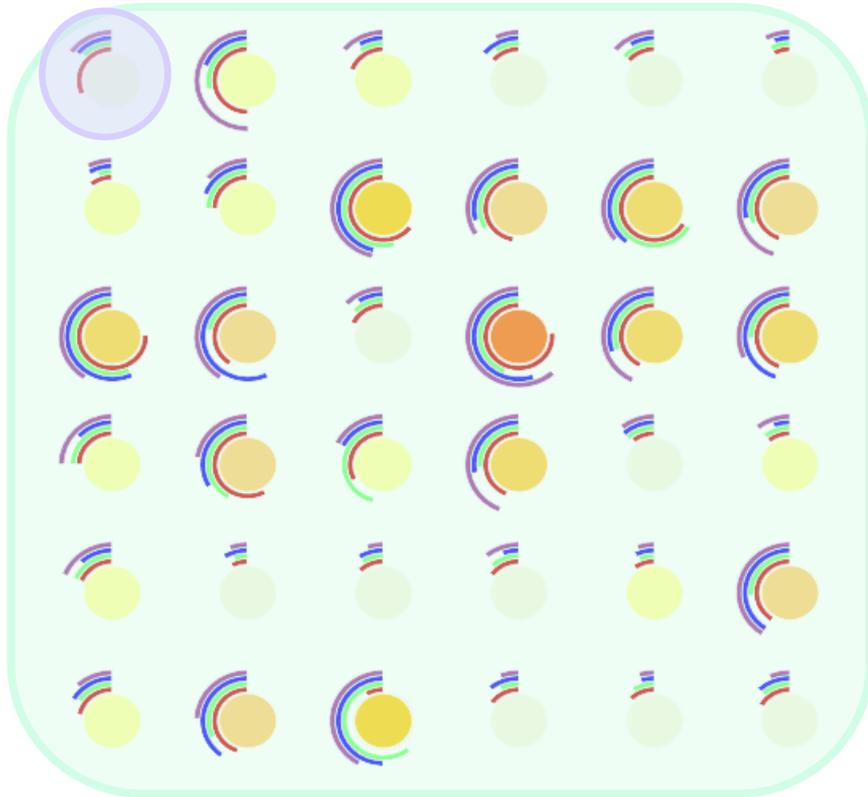


- Post-detection, baseline system → dropped requests
- Post-detection, Seer → maintain nominal performance

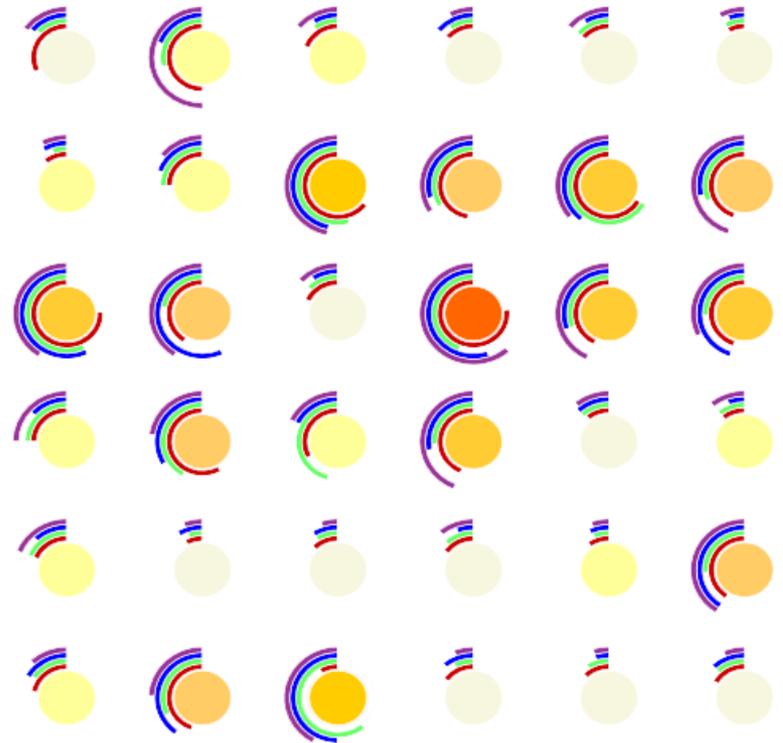
Demo



Seer

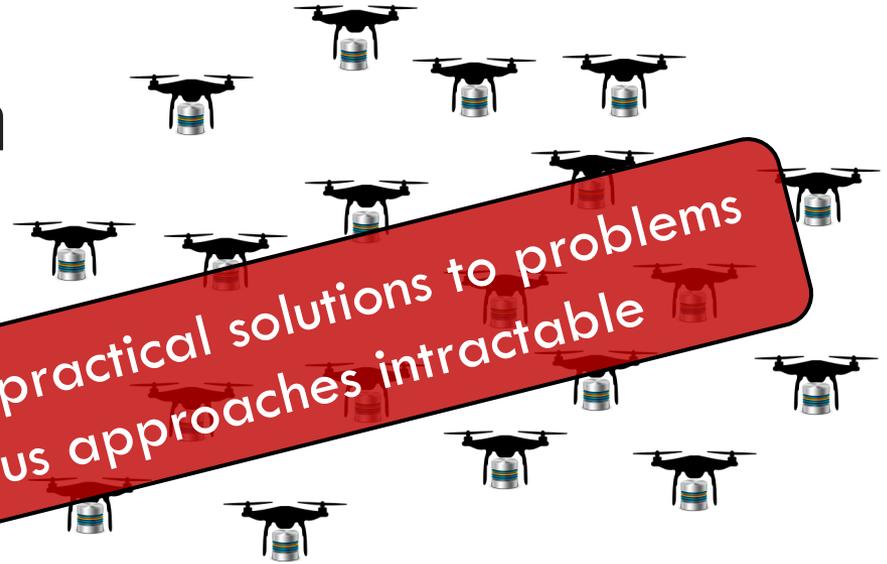


Default



Demo

Challenges Ahead



Data-driven approaches offer practical solutions to problems whose scale makes previous approaches intractable

Service microservices

IoT swarms

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

Thank you!