SoCC’22 serverless session notes

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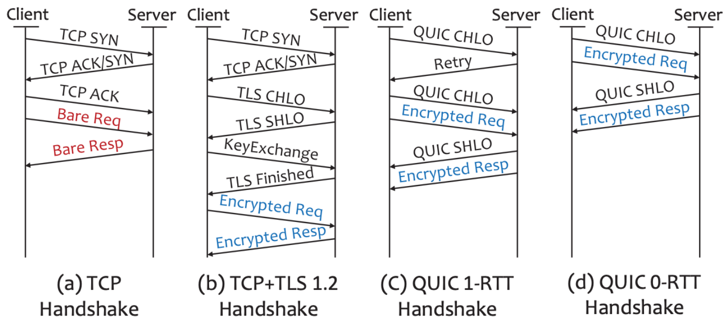
Serverless session in SoCC'22

1. QFaaS: Accelerating and Securing Serverless Cloud Networks with QUIC(*network acceleration*)
2. Cypress : Input size–Sensitive Container Provisioning and Request Scheduling for Serverless Platforms(*resource management*)
3. Method Overloading the Circuit (*service reliability study*)
4. Hermod: Principled and Practical Scheduling for Serverless Functions(*resource management*)
5. SIMPPO: A Scalable and Incremental Online Learning Framework for Serverless Resource Management(*ML for resource management*)
6. SimLess: Simulate Serverless Workflows and Their Twins and Siblings in Federated FaaS(*Simulation*)

Note: there is also a session specifically for *resource management* in SoCC'22

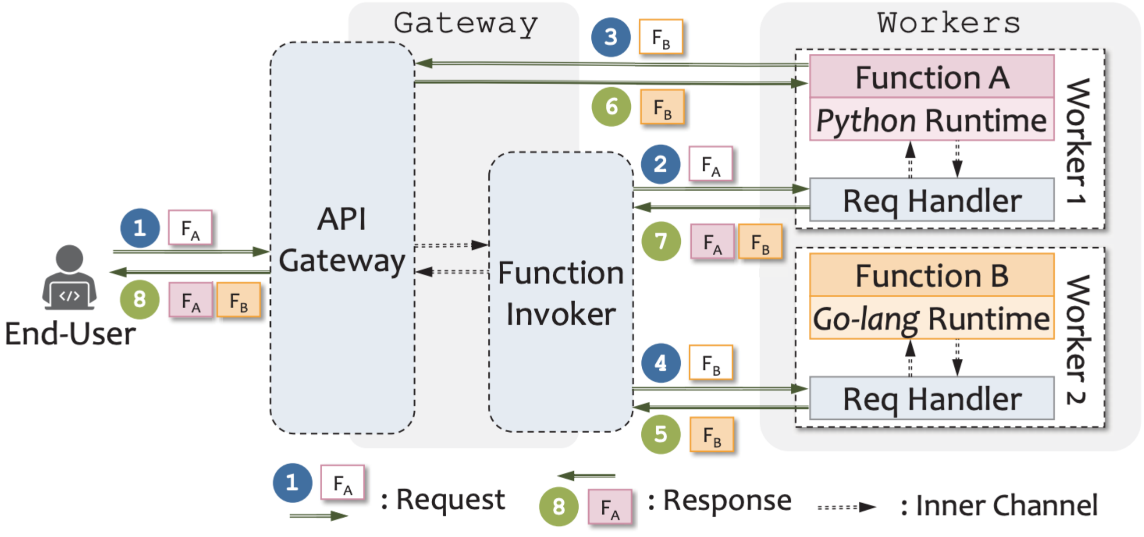
QFaaS: Accelerating and Securing Serverless Cloud Networks with QUIC

- QUIC-based FaaS framework on top of **OpenFaaS** platform
- **Problem they claim**
  - huge internal network communications between latency sensitive serverless features such as agile autoscaling and function chains;
  - Currently serverless providers sacrifice security for performance by keeping those communications unencrypted
- **Proposed solution**
  - Using QUIC instead of TCP for internal communication
  - Define Serverless Architecture in Network-centric View
  - Optimize Internal communication on top of QUIC(QUIC Server, QUIC Client)
- Their tests show QFaaS can reduce communication latency for single function and function chains by 28% and 40%, respectively, and save up to 50 ms in end-user response time.



Scheme	TCP	TCP + TLS 1.2	QUIC 1-RTT	QUIC 0-RTT
New Session	1	3	1	-
Recover Session	1	2	1	0

Figure 1: Round-trips in different transport protocols: (a) insecure TCP incurs 1 extra RTT; **(b)** in TCP+TLS 1.2 scheme, the encrypted request is sent after 3 RTTs; **(c)** in QUIC 1-RTT mode (new session establishment), the encrypted request is sent after 1 RTT; **(d)** in QUIC 0-RTT (session resumption), the encrypted request is sent immediately.



(b) Serverless Architecture in Network-centric View

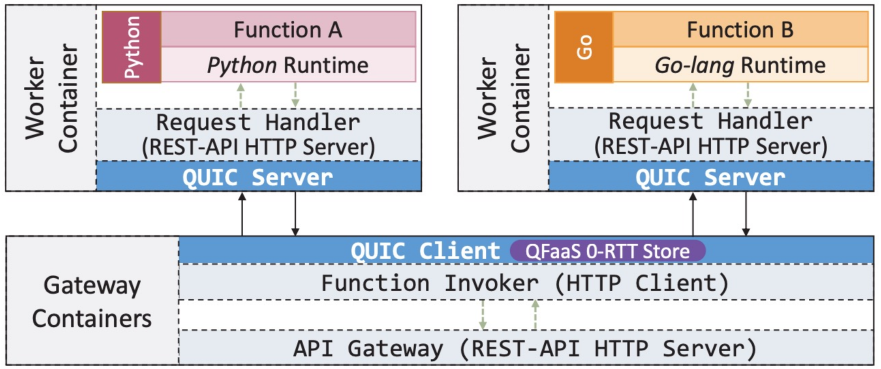


Figure 3: System Design of QFaaS. QUIC client and QUIC servers are integrated into Function Invoker and worker request handlers to replace the TCP/TLS client and servers. This modification is transparent to cloud tenants and ensures the activation of the QUIC 0-RTT feature.

Cypress : Input size–Sensitive Container Provisioning and Request Scheduling for Serverless Platforms

- **Problem**

  Existing serverless **resource management** frameworks are agnostic to the input size–sensitive nature of these apps

- Cypress propose an *input size-sensitive* ***resource management*** *framework* (OpenFaaS + K8s)
  - Minimizes containers provisioned for apps
  - Ensuring high degree of SLO compliance

- Their experimental results show up to 66% less container spawns, improving container utilization and saving cluster-wide energy by up to 2.95X and 23%

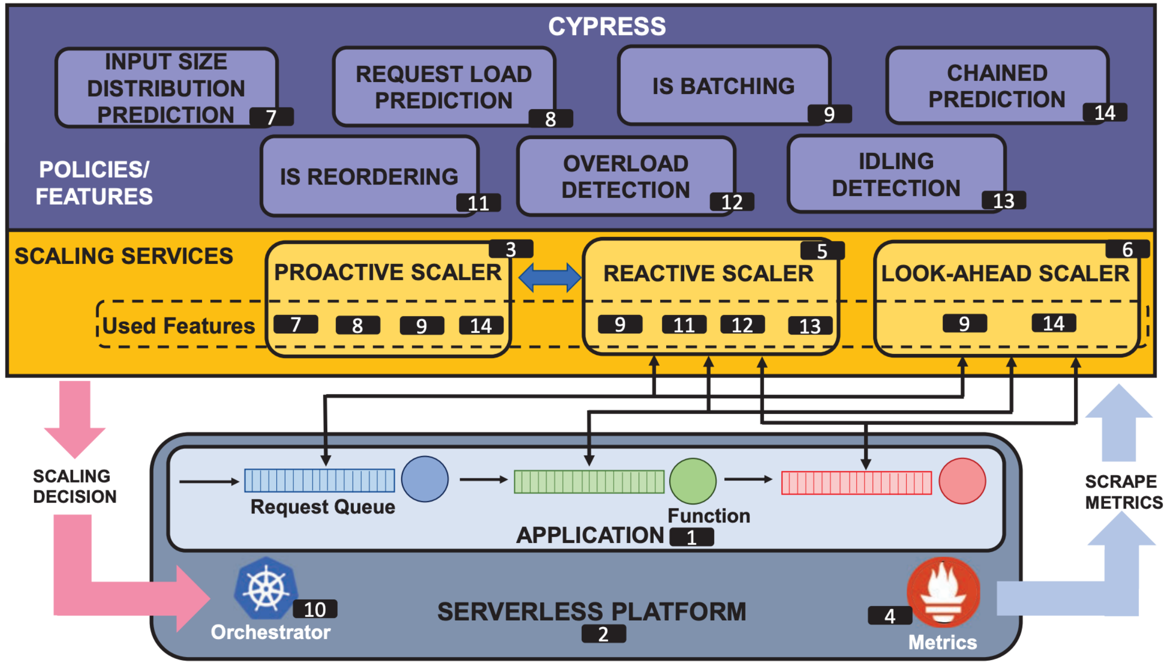
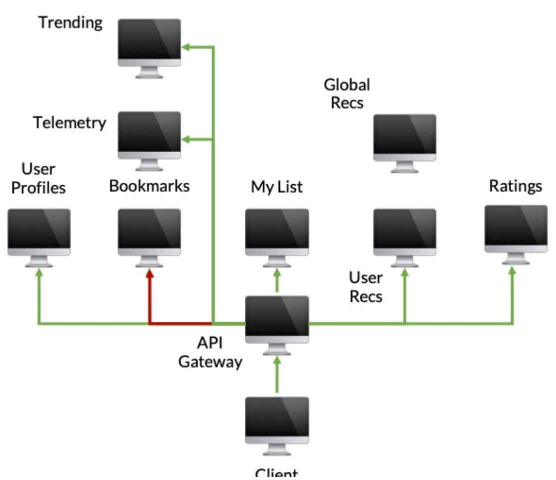


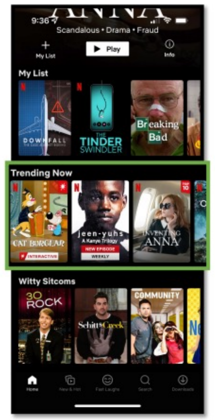
Figure 7: High-level view of *Cypress*'s design.

Method Overloading the Circuit(*Service Reliability study*)

Case study of DoorDash's ***Circuit breaker*** behavior in its microservice architecture, which composes of 500+ services.

What *should*, and what *does*, happen?





Fallbacks
Developers specify **alternative application logic** in the event of dependency failure.

Other resilience techniques:

1	**Retries**
2	**Timeout**
3	**Load shedding**
4	**Circuit breakers**

Fault injection and chaos engineering used to **verify what *should* happen *does* happen.**
[Meiklejohn et al. 2021, SoCC '21]

Reliability at DoorDash

1. **Fallbacks**
When dependencies are unavailable, load alternative content from different services or use default responses to allow application to degrade gracefully.
(e.g., personalized recommendations become generic recommendations.)

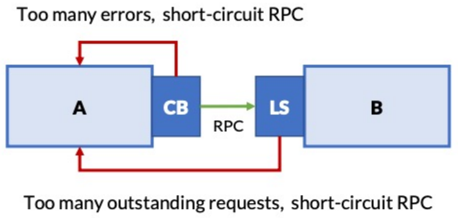
2. **Cluster Orchestration**
Support for rolling deploys with replicas of services supported by load balancing.
Combined with single retries *(not timeout)*, lets nodes to hit non-failed replica on retry.
Automatic readiness and liveness checks with auto-scaling and restart policies.

3. **Load Shedding**
Short-circuit request at the **callee** using a predefined error indicating overload.
Typically performed based on the number of outstanding concurrent requests.

4. **Circuit Breakers**
Short-circuit request at the **caller** using a predefined error indicating failure condition.
Typically performed based on the number of observed errors within a specific period.

Circuit Breakers: Overview

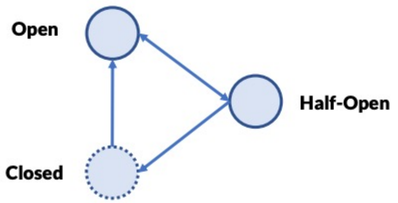
Circuit Breakers
Interpose on RPCs between services and record successes/errors to determine if RPC should be allowed.
With on a min threshold of requests and a sliding window, determine if the num of errors have exceeded a threshold.



Load Shedding
Special case of circuit breakers that use number of outstanding requests at a given service.

Transitions

1. Circuits begin in the **closed** state.
When the threshold is exceeded move to the **open** state where all RPCs are refused.
2. *Circuits move to the **half-open** state to determine if they should move to **open** if a subset of RPCs succeed.*



- Their claim
  - *Existing circuit breaker designs are insufficient for fault tolerance;*
  - *Even a small common abstraction changes in application code can drastically alter how circuit breakers work.*
- Propose two new designs for circuit breaker: *path-sensitivity* and *context-sensitivity.*
- They prefer path-sensitivity approach for minimal developer overhead with proper sensitivity.
- Introduce **DEI**(*distributed execution Indexing*), *an algorithm used in fault injection testing in DoorDash*, to be used in circuit break implementation to provide path-sensitivity.

Hermod: Principled and Practical Scheduling for Serverless Functions

A **Scheduler for Serverless Functions** with two key characteristics

- a combination of early binding and processor sharing for scheduling at individual worker machines to avoid head-of-line blocking due to high function execution time variability.
- Cost, load, and locality-aware. It improves consolidation at low load, it employs least-loaded balancing at high load to retain high performance, and it reduces the number of ***cold starts*** compared to pure load-based policies.
- Build on open-source serverless platforms, Apache ***OpenWhisk***(it powers IBM's commercial serverless offering).

Claims to achieve up to 85% lower function slowdown and 60% higher throughput compared to existing production and state-of-the-art research schedulers for the case of the function patterns observed in real-world traces.

Existing Approaches

Serverless Scheduling Taxonomy

T / LB / S

T: Type of binding used (early E vs. late L)

LB:
- LOC – locality-based
- LL – least-loaded
- R – random

S: intra-Worker policy
- FCFS – First-Come-First-Serve
- PS – Processor Sharing

System	Policy	Load-aware	Cost-aware	Locality-aware
OpenWhisk	E/LOC/PS	✗	✗	✓
kNative	E/R/PS	✗	✗	✓
Sparrow	Late Binding	✓	✗	✗
Hermod	E/Hybrid/PS	✓	✓	✓

SIMPPO: A Scalable and Incremental Online Learning Framework for Serverless Resource Management

What do they do?

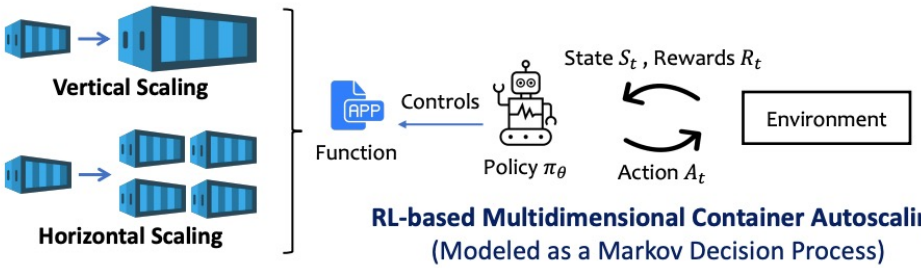
- Apply ML to cloud computing/cloud network
- Automate the management for diverse workloads with reinforcement learning (RL)
- Trying to achieve *per-function performance-wise SLOs*, which are not supported yet in Serverless (FaaS).

Benchmark Serverless Function

- SIMPPO provides online policy-serving performance comparable to single-agent RL in isolation (the baseline), with the performance degradation <9.2%
- • In multi-tenant/agent environments:
  - SIMPPO achieves 2x-4.4x improvement compared to single-agent RL
  - SIMPPO has 21.4x less performance degradation compared to a threshold-based approach ENSURE (ACSOS 2020)

ML-managed SLO-driven Cloud Services

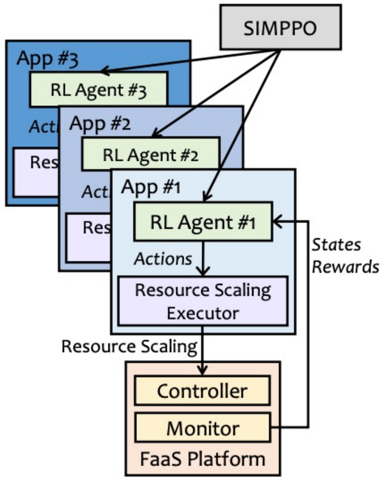
- **Why ML?:** Heuristics-based resource management are inefficient and not tenable
  - Providers dynamically manage orchestration platforms to achieve efficiency as cloud evolves
- **Contributions:**
  - **SIMPPO**: Automate the management for diverse workloads with **reinforcement learning (RL)**
  - Quantitative characterization study of existing RL approaches
  - A system that orchestrates multiple learning-based agents to achieve optimal resource allocation in the task of **multidimensional container autoscaling**
  - **Key Idea**: “Virtual Agent” and mean-field theory



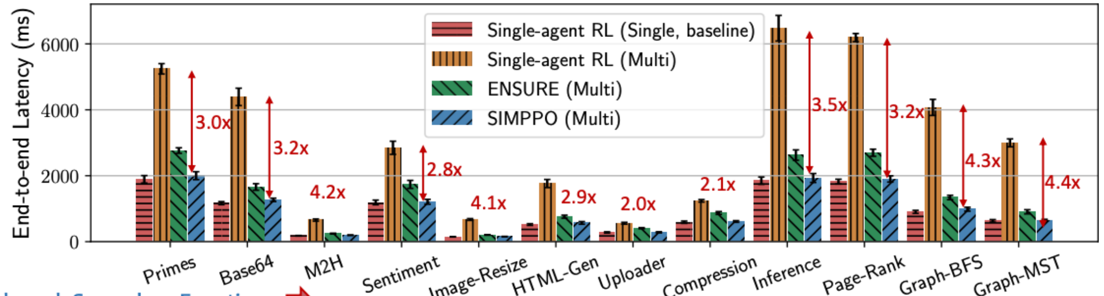
RL-based Multidimensional Container Autoscaling
(Modeled as a Markov Decision Process)

SIMPPO: Scalable and Incremental MARL

- Two building blocks of SIMPPO
  - Virtual agent
  - Auxiliary global system states
- Applied SIMPPO to multi-dimensional autoscaling of serverless platforms
  - Based on the state-of-the-art RL algorithm – PPO (Proximal Policy Optimization)
  - Serverless platform: OpenWhisk
- Evaluated SIMPPO on 12 open-source serverless benchmarks
  - Function invocation patterns from Azure Functions traces
- **RQ1: Incremental training?**
- **RQ2: Online policy-serving performance?**



SIMPPO Online Performance



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SimLess: Simulate Serverless Workflows and Their Twins and Siblings in Federated FaaS

An FC(function choreographies) simulation framework for accurate FC simulations across multiple FaaS providers with a simple and lightweight parameter setup with two light concepts:

- ***Twins***, representing the same function deployed with the same computing, communication, and storage resources, but in other regions of the same FaaS provider,
- ***Siblings***, representing the same function deployed in the same region with different computing resources.

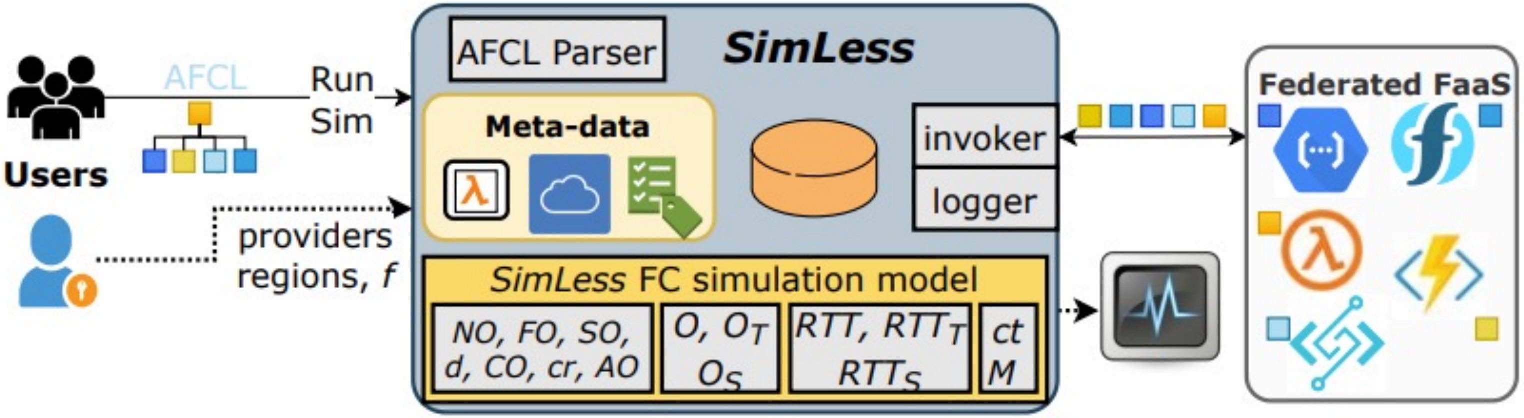

Figure 4: *SimLess* system architecture.

Current Serverless Limitation and how XDP/eBPF may help?

- **Existing framework limitations**
  - Still in the early stage, mostly suitable for simple workload of independent tasks and/or well tailored proprietary service offerings from the vendors
  - Limitation in AWS Lambda infrastructure:
    - Limited Lifetimes – 15 mins
    - I/O Bottlenecks -- 538Mbps network bandwidth, an order of magnitude slower than a single modern SSD
    - Communication Through Slow Storage
    - No Specialized Hardware
  - Academia think existing serverless offering is "***one step forward, two steps back***", more to be studied.

- **Use Case deep dive**
  - QFaaS as an example, tries to address both security and latency issues in serverless framework

- **Which serverless frameworks to start?**
  - Opensource frameworks:
    OpenFaaS, OpenWhisk, Knative
  - Cloud provider solutions:
    AWS Fargate, AWS Lamba, Azure Functions, Google Cloud Functions, etc.

- **Potential approach**
  - ***Target desirable application(s) in a particular serverless framework, analyze it and try further optimize overall performance with XDP/eBPF and/or other technologies***