Serverledge: Decentralized Function-as-a-Service for the Edge-Cloud Continuum

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21st International Conference on Pervasive Computing and Communications (PerCom 2023)

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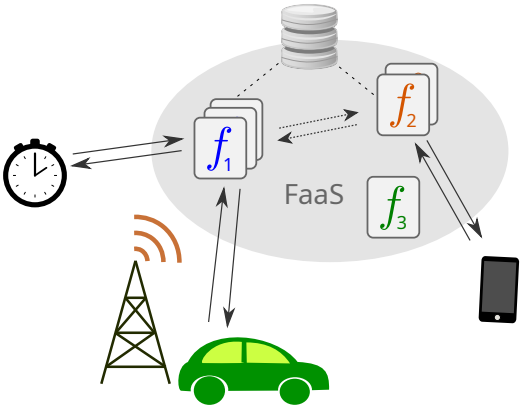
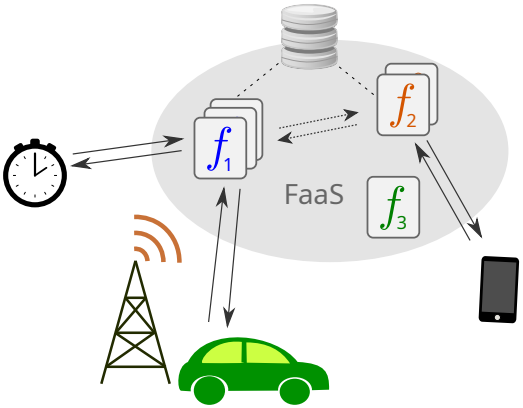
Function-as-a-Service

- Write functions, enjoy serverless execution
- Seamless scalability
- Fine-grained pricing
- Simplified app maintenance



Function-as-a-Service

- Write functions, enjoy serverless execution
- Seamless scalability
- Fine-grained pricing
- Simplified app maintenance
- Mostly Cloud-based!



FaaS Frameworks

- All the major Cloud providers have FaaS offerings, e.g.:
  - AWS Lambda
  - Google Cloud Functions
  - Azure Functions
  - IBM Functions
- Various open-source FaaS frameworks, usually deployed in Kubernetes clusters, e.g.:
  - OpenWhisk
  - OpenFaaS
  - KNative

Functions in the Edge-Cloud Continuum

- What about FaaS for pervasive services?
- Cloud execution not always acceptable
- Should we run functions across the Edge-Cloud Continuum?
  - Low-latency at the edge
  - Resource richness at higher layers, when needed
- But…methodologies, tools and platforms for FaaS in the Continuum still under development

Key Challenges

- Cloud-centric architecture
- Resource-constrained devices
- Mobility
- Performance unpredictability
- Privacy

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+ FaaS-specific issues:

- Cold start
- Container image caching
- Stateful functions

State of the Art

- Major frameworks not suited for Edge environments
  - Cloud-oriented, centralized design
  - No support for service differentiation among users
- Two main directions pursued so far
  - Federating existing FaaS frameworks (e.g., through overlay networks)
  - Designing novel frameworks for the Edge

Frameworks for FaaS at the Edge

Framework	Geo. Distribution	Offloading	Execution Env.
OpenWhisk	No	No	Container
faasm	No	Horizontal	WASM-based
Sledge	No	No	WASM-based
tinyFaaS	No	No	Container*

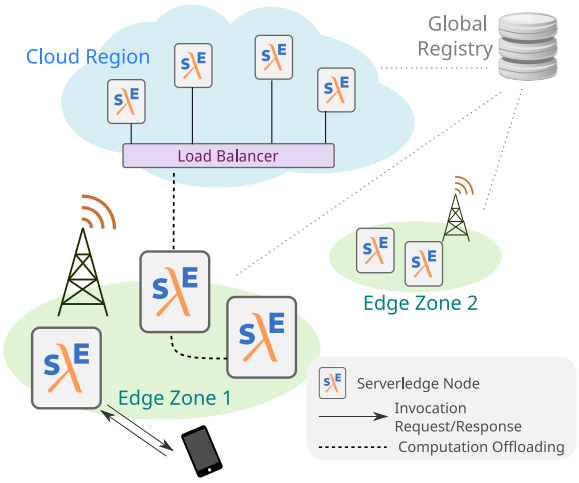
* = static pool

Goals

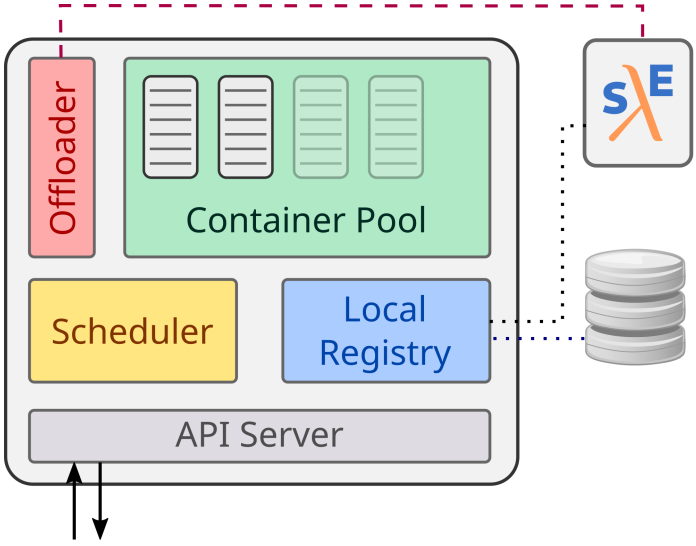
- Designing a FaaS framework with a decentralized architecture
- Horizontal and offloading mechanisms
- Support for QoS-aware scheduling
- Comparison against existing frameworks for FaaS at the Edge

Serverledge

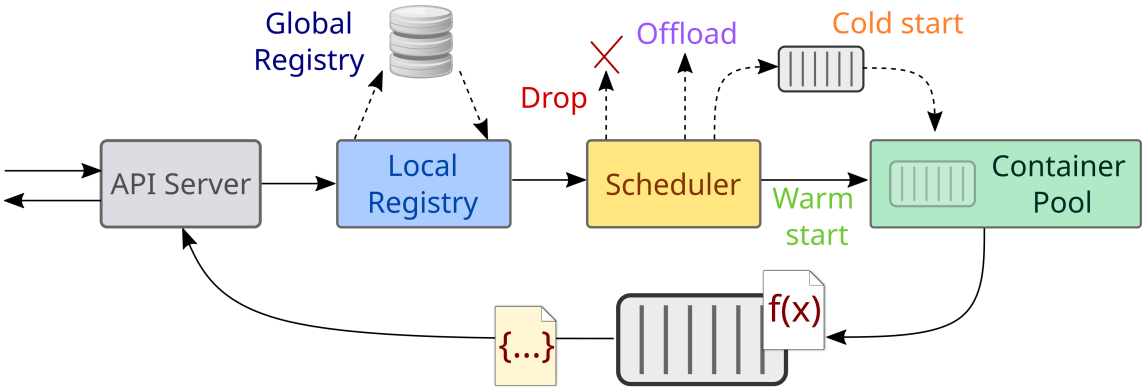
- A framework for the Continuum
- Nodes organized into Cloud regions and Edge zones
- (Replicated) Global Registry
- No centralized entry point!
- Vertical and horizontal offloading mechanisms



Node Architecture



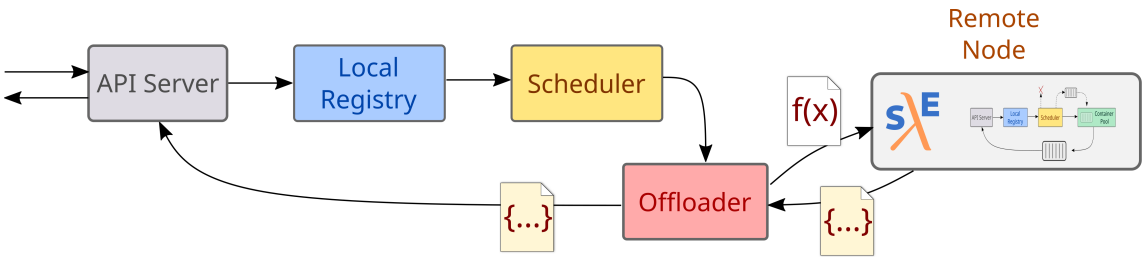
Journey of a Request



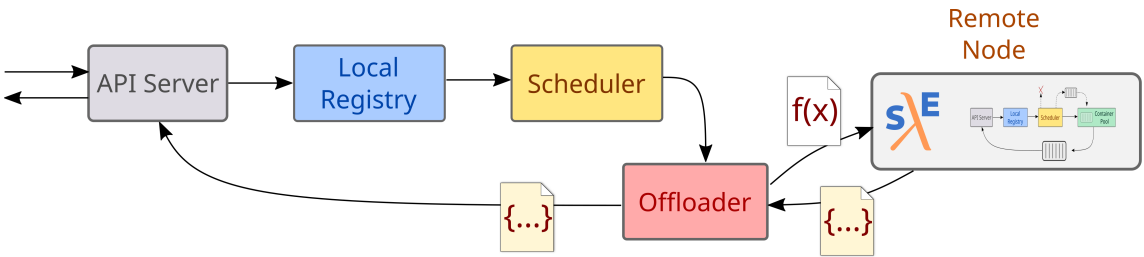
Offloading Mechanism

- Edge devices are likely to become overloaded (at least temporarily)
- Idea: offloading some requests
  - save local resources for “critical” invocations
  - exploit Cloud nodes when latency doesn’t matter
- Vertical/Horizontal offloading
- Each node acts as a reverse proxy in case of offloading

Journey of an Offloaded Request



Journey of an Offloaded Request



How to choose a destination node for offloading?

- Edge: send to a neighbor, based on proximity and current load
- Cloud: send to a load balancer

Implementation

- Implemented in Go
- Each node runs as a single process, which interacts with a Docker daemon for container management
- Global registry implemented on top of Etcd
- Additional components:
  - `serverledge-cli`: CLI interface
  - a load balancer for Cloud nodes

Evaluation

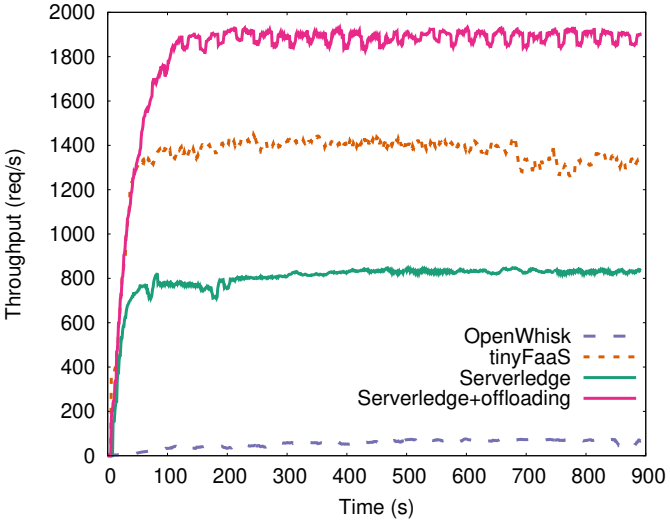
Goal 1: Performance comparison against SOTA alternatives

- Single-node deployment
- Load generated using Locust
- Comparison against faasm, tinyFaaS and OpenWhisk

Goal 2: Demonstrating advantages of QoS-aware offloading

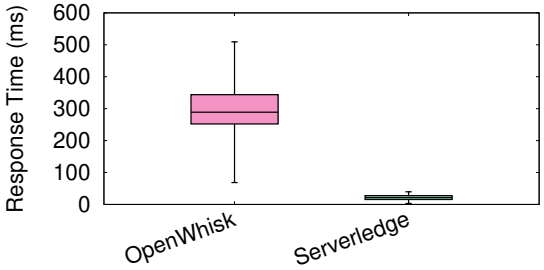
- 2 AWS Cloud regions act as “Cloud” and “Edge”
- 2 classes of users: best-effor and latency-sensitive

Results: Throughput

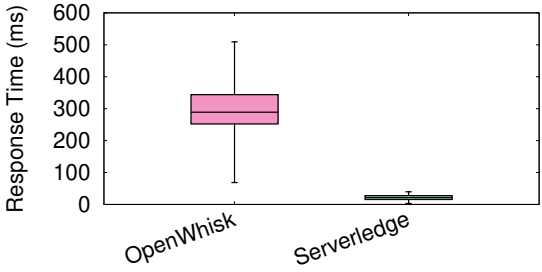


- tinyFaaS has the highest throughput (thanks to a static pool of containers!)
- OpenWhisk has the lowest one
- Serverledge can increase throughput via offloading

Results: Response Time

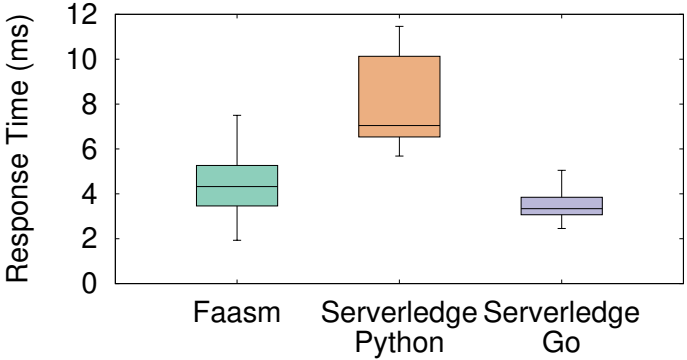


Results: Response Time



Results: Faasm Comparison

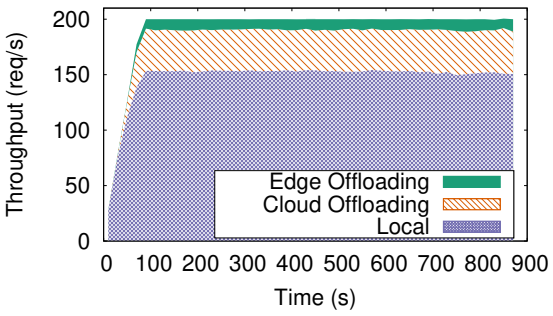
- We could not run faasm at high throughput because of a known issue causing crashes; focus on response time
- We use Python and Go implementations of *Fibonacci* computation



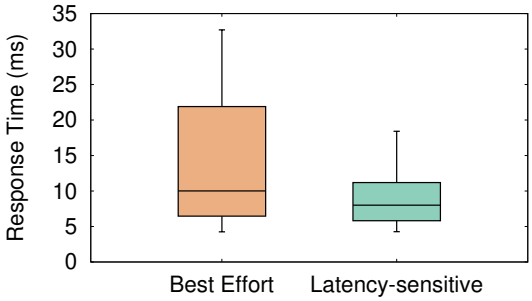
Results: Edge-Cloud Offloading

Proof-of-concept policy with 2 classes of users

Served requests



Response time



Conclusion

- A framework with a decentralized and easy-to-extend design
- Built-in support for offloading and service differentiation
- Open-source: `https://github.com/grussorusso/serverledge`
- …and “Artifact Evaluated”!

Already working on…

- Lightweight function execution environments
- Live function migration
- Adaptive offloading policies