OFC: An Opportunistic Caching System for FaaS Platforms

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Context: Function-as-a-Service

- Cloud-native applications
  - Built as collections of (chains of) functions
  - Rely on platform-provided back-end servers (serverless)
  - Mostly stateless by design

Function-as-a-Service architecture in a serverless cloud.
Extract-Transform-Load pattern\textsuperscript{a}

1. Extract (E) data from remote persistent storage (object store...)
2. Transform (T) by performing some computation (blur image...)
3. Load (L) result to remote persistent storage

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Function-as-a-Service architecture in a serverless cloud.

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EuroSys’21, April 26–28, 2021

Opportunistic FaaS Cache — Mvondo, Bacou et al.
Performance issue: latency

- **Storage access** is a big issue with ETL
- **Problem of data locality**
  - Out-of-infrastructure **remote** storage
  - Even worse for pipelines

FaaS performance issues in latency of function invocation, and concerns of our work.
Related work

Caching, caching, and caching ...

- Cloudburst$^a$
- Infinicache$^b$
- Pocket$^c$
- ....

Existing works either require function modification or extra-resources (memory) to provision the cache layer

Solution: caching in the FaaS age

- Avoid remote storage with in-memory caching
- FaaS characteristics: very short latency, very elastic
- New challenges in the FaaS context:
  - How to provision memory for the cache?
  - How to make caching scale?
  - How to provide caching to functions?
OFC: Opportunistic FaaS Cache

Opportunistic

Function-as-a-Service

Cache

The three pillars of OFC.

Opportunistic FaaS Cache — Mvondo, Bacou et al.
OFC: Opportunistic FaaS Cache

Model Trainer -> Controller

Controller -> predictor

predictor -> RC Coor

RC Coor -> proxy

proxy -> rcLib

rcLib -> RC M

RC M -> Invoker

Invoker -> Sizer

Sizer -> cacheAgent

cacheAgent -> func-monitor

func-monitor -> Model Trainer
Unused reserved memory

1. **Over-provisioning** by tenants to absorb workload variation:
   - 50% of functions reserve ≥512MB
   - 50% of functions use ≤29MB

2. **Keep-alive policy**: keep functions warm to reduce latency:
   - 81% invoked once per min. or less
   - Functions kept warm 10~20min (OpenWhisk, AWS Lambda)

Timeline of a function sandbox illustrating wasted memory.

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Predicting wasted memory

- How much memory is available to the cache?
  - Complex relation with data, parameters
- Use machine learning!
  - White-box functions
    - Parameters, inputs...
  - High invocation rate
    - Quick dataset gathering

Memory usage of an image blurring function

Relation between memory usage and function invocation parameters and input.
Learning memory usage, and more

- **Constraints of the FaaS:**
  - Learn and update models
    - Maintain training dataset
  - Learn from unknown features: bounds, sets of values?
    - Cannot compute from features
  - **Prediction speed:** on the critical path of the invocation
    - Predict in less than 1ms
- **Classification instead of regression**
  - Predict among 16MB intervals
- **Decision trees:** J48 (C4.5)
  - 92.7% accuracy for exact-or-over predictions
  - Model accurate enough for 95% of functions in less than 8h of lifetime
  - 13x faster at 99% than RandomForest
    - While being just as accurate
- ML also used to predict caching benefits
  - Keep only useful data in cache
OFC: Opportunistic FaaS Cache

Opportunistic

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Cache

The three pillars of OFC.
OFC caching mechanisms overview

- OFC leverages RAMCloud\(^a\)
  - Distributed
  - In-memory
  - Fault tolerant

- RAMCloud can store objects up to 8MB. We updated this to 10MB.

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OFC caching mechanisms overview

- On each invoker node:
  - **RC M**: RAMCloud cache master
  - **CacheAgent**: cache autoscaling
    - Scale the cache memory up/down
    - Monitor the cache pressure
    - Perform Garbage Collection

![Diagram showing components and their connections](image)
OFC: Opportunistic FaaS Cache

**Opportunistic**

**Function-as-a-Service**

**Cache**

The three pillars of OFC.
OFC caching mechanisms overview

- A *proxy* transparently intercepts function calls to storage nodes.
  - Runtime interception
  - Routes request to cache API (*rcLib*)
OFC caching mechanisms overview

- RAMCloud library *rcLib*:
  - Persist data on the local cache
  - Ensure consistency with *remote storage*

- To ensure consistency with OFC, on storage node, a webhook checks for queries the cache for incoming read requests
OFC evaluation results

- Does OFC improve serverless functions latencies?
  - Single functions
  - Multi-stage functions

- Five scenarios
  1) Redis
  2) OFC Local Hit (LH)
  3) OFC Remote Hit
  4) Miss (M)
  5) Default (Swift)

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>Memory</strong></td>
<td>512 GB</td>
</tr>
<tr>
<td><strong>OS</strong></td>
<td>Ubuntu 16.04.7 LTS</td>
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<tr>
<td><strong>CPUs</strong></td>
<td>2 Intel Xeon E5-2698v4 CPUs (20 cores/CPU)</td>
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<tr>
<td><strong>Disk</strong></td>
<td>480 GB SSD</td>
</tr>
<tr>
<td><strong>Network</strong></td>
<td>Intel Ethernet 10G 2P X520 Adapter</td>
</tr>
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OFC evaluation results

- Single functions: OFC overcomes Swift by up to 82%
OFC evaluation results

- Multi-stage functions

OFC overcomes Swift by up to 60%
OFC: Conclusion

- OFC leverages ML and RAMCloud
  - Opportunistic caching layer for serverless functions
- OFC does not require function modification
  - Direct benefit for existing functions
- OFC ensures consistency between the platform’s cache and the remote storage
- OFC achieves major latency improvements
  - Up to 82% for single functions
  - Up to 60% for multi-stage functions

Checkout OFC source code at https://gitlab.com/lenapster/faascache/