Fast and Flexible Containerization with Pipsqueak

Edward Oakes, Leon Yang, Kevin Houck, Tyler Harter*, Andrea C. Arpaci-Dusseau, Remzi H. Arpaci-Dusseau

* Microsoft Gray Systems Lab

OpenLambda

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Containers in the Cloud

(1) Traditional Server Containers

- Runtime & server deployed as a container
- Flexible runtime, but slow startup

(2) Serverless Computing

- Containers/customers **share** a host server
- Fast startup, but inflexible runtime

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- Secure, built-in package support
- 9-2000x speedups for single-package workloads

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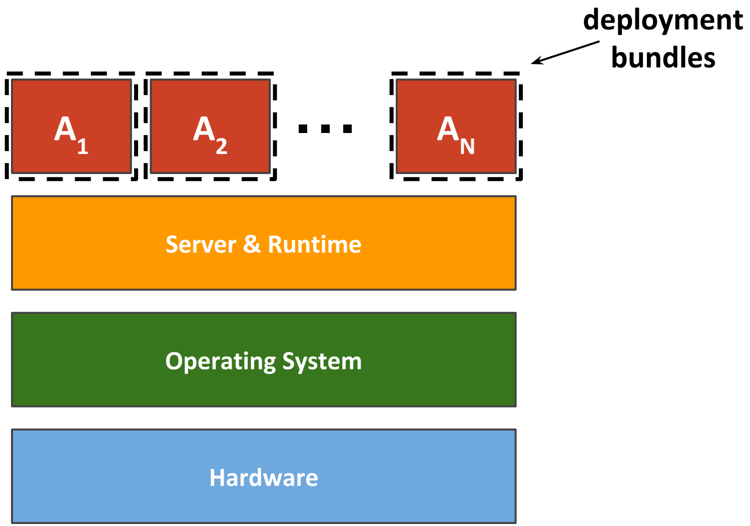
Microservices

- Applications are decoupled into modular pieces, or “services”
- Services are lightweight, making deployment and scaling less painful



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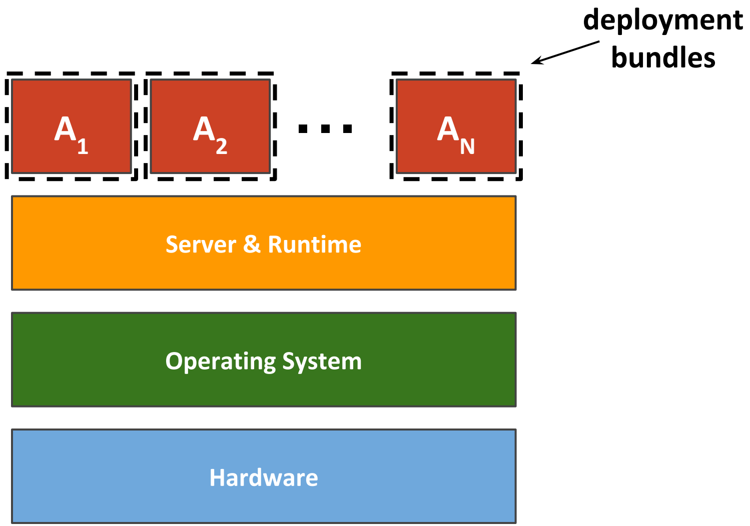

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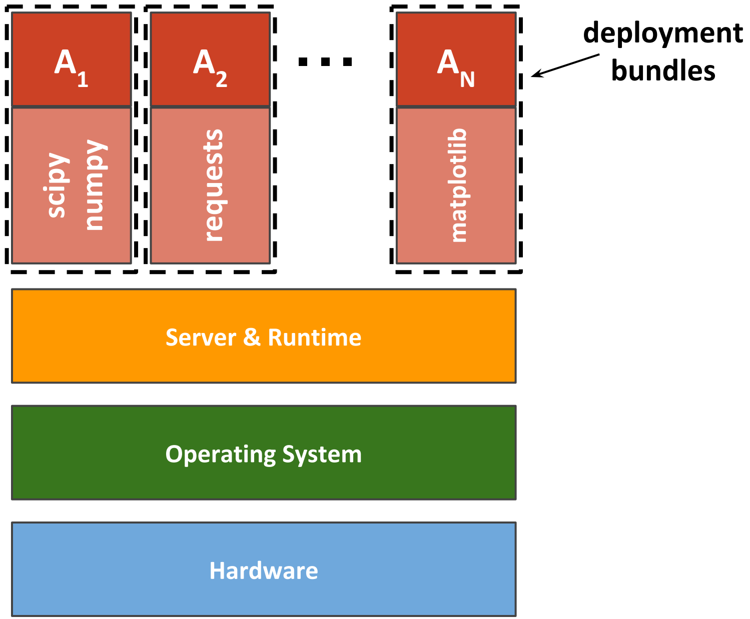

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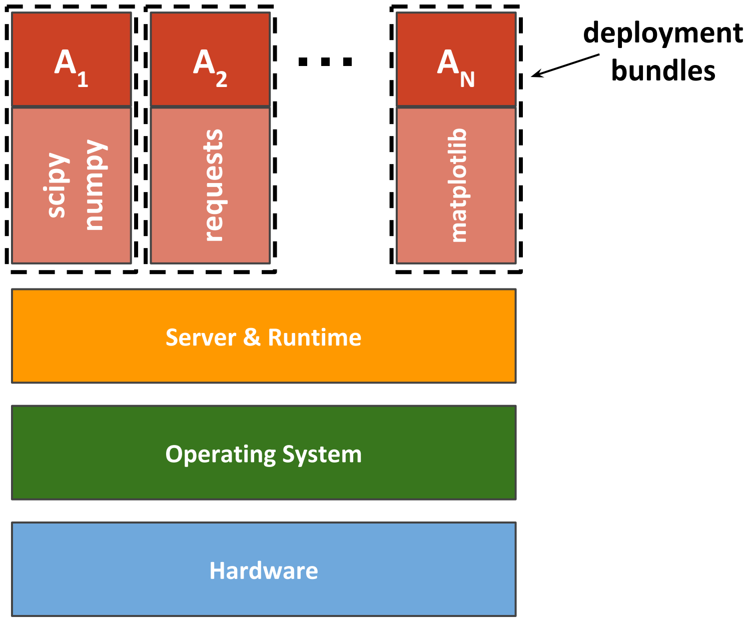

Matplotlib installation:

- 4.37s to download
- 5.24s to install
- 0.21s to import

~~Microservices~~ MicroMonoliths

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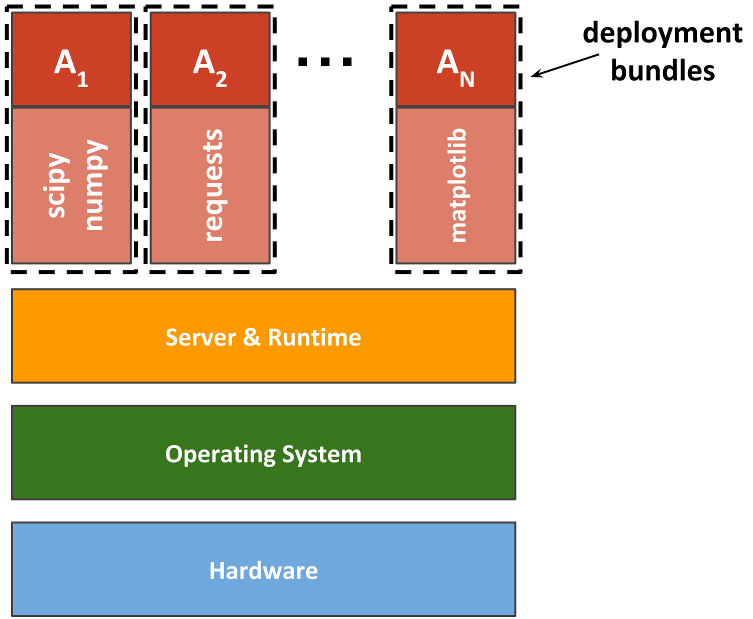
MicroMonolith - a conceptually small service that is inflated by large userspace libraries



Outline

Motivation

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- Anatomy
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Installation Workflow

Download

numpy.tar.gz
requests.tar.gz
matplotlib.tar.gz
...

pip mirror

→

Install

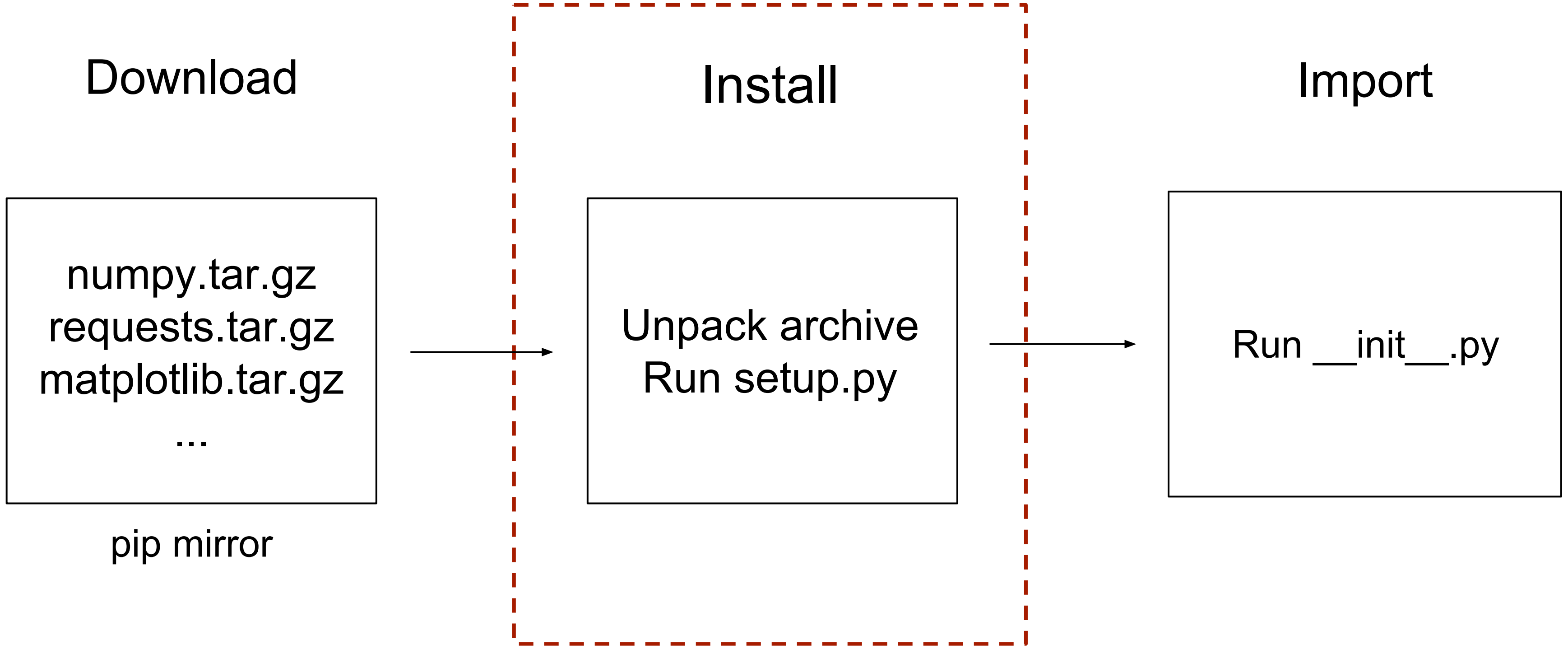
Unpack archive
Run setup.py

→

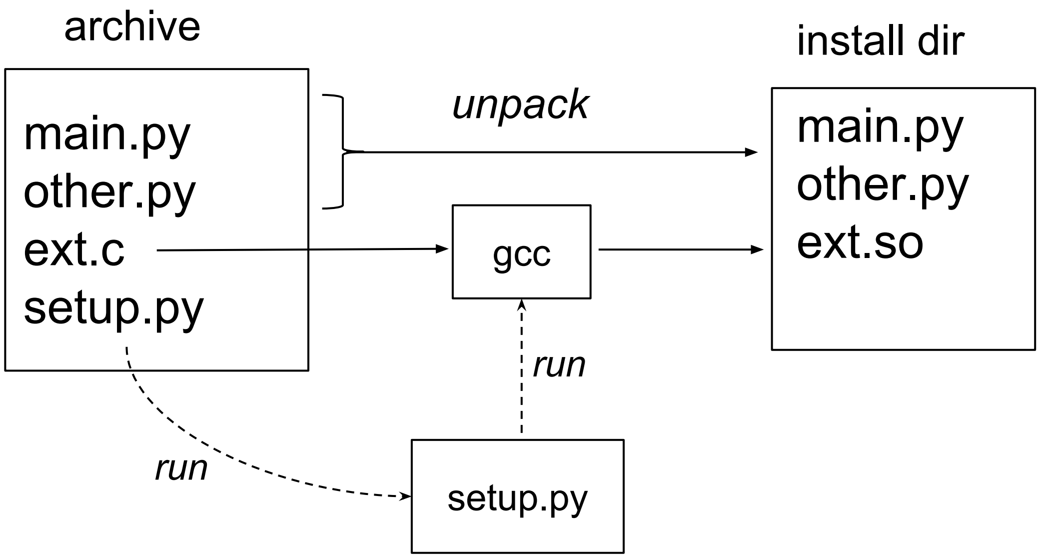
Import

Run __init__.py

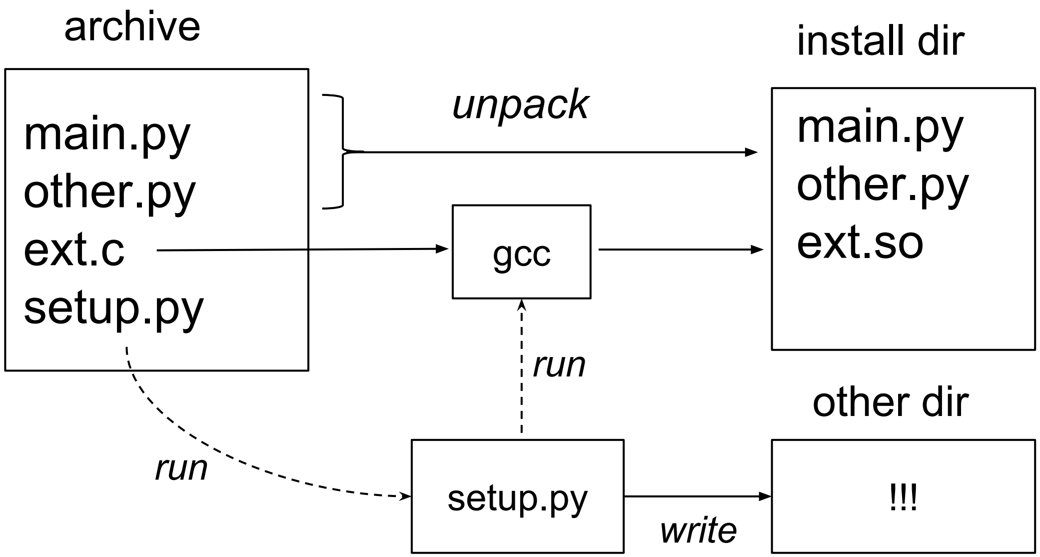
Installation Workflow



Install


archive
main.py
other.py
ext.c
setup.py
unpack
install dir
main.py
other.py
ext.so
gcc
run
run
setup.py

Install



archive
main.py
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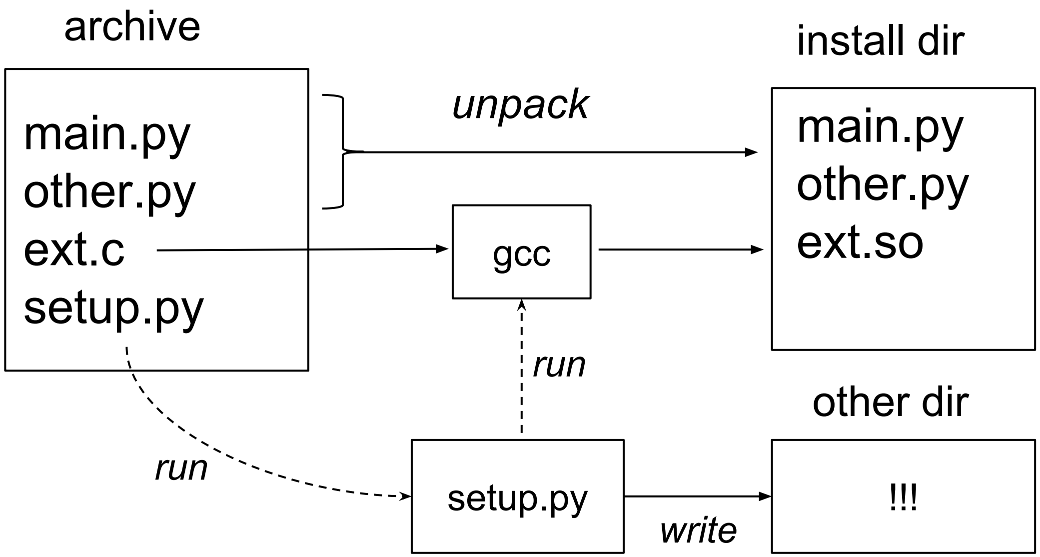
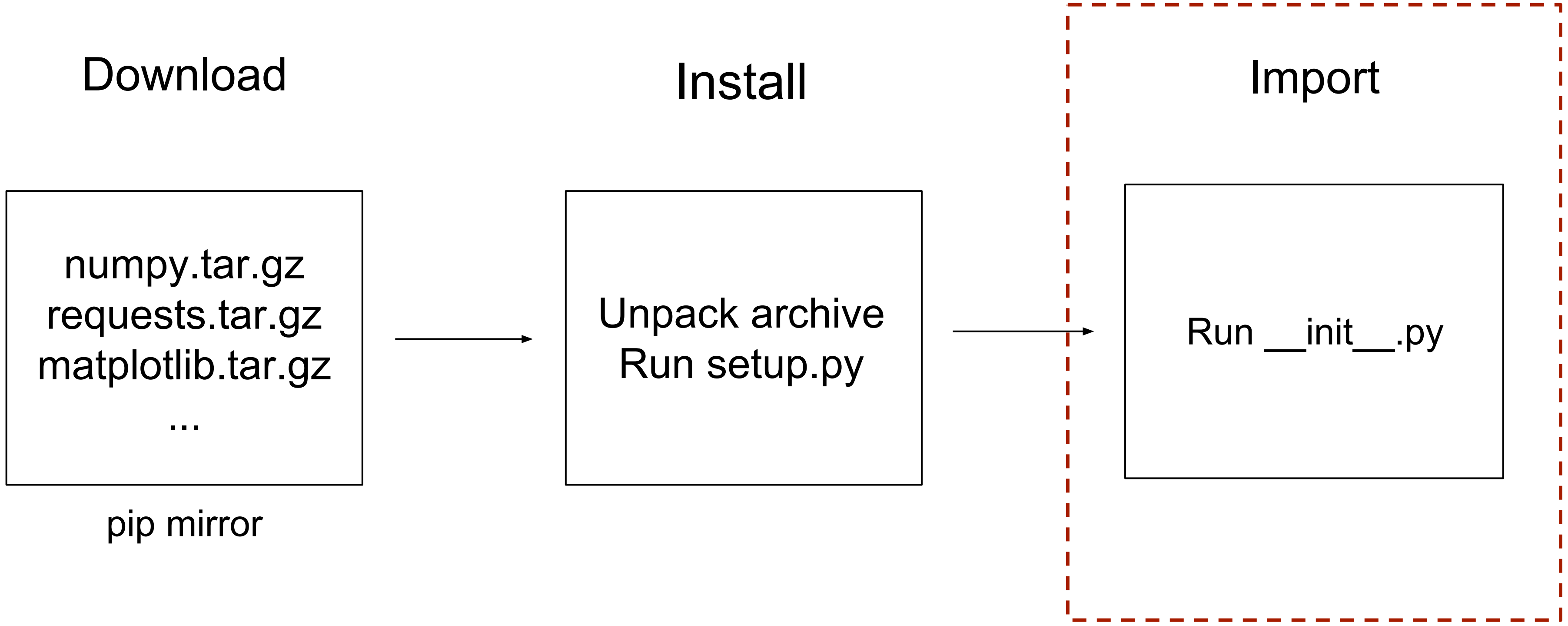
unpack
install dir
main.py
other.py
ext.so
gcc
run
other dir
run
setup.py
write
!!!

Install



Installing pip packages must be considered **unsafe**

Installation Workflow



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1. Search for the named module
2. Bind the module’s metadata to the symbol table
3. Run __init__.py for the module and its dependencies

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- "bugs-everywhere"
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Python Package Analysis

Analysis Questions

- What startup costs are associated with popular packages?
- How large are pip packages?

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Methodology

- Scraped 876K GitHub Python repositories and parsed import statements from all included .py files
- Setup mirror of pip repository (834K total packages)

Python Package Analysis

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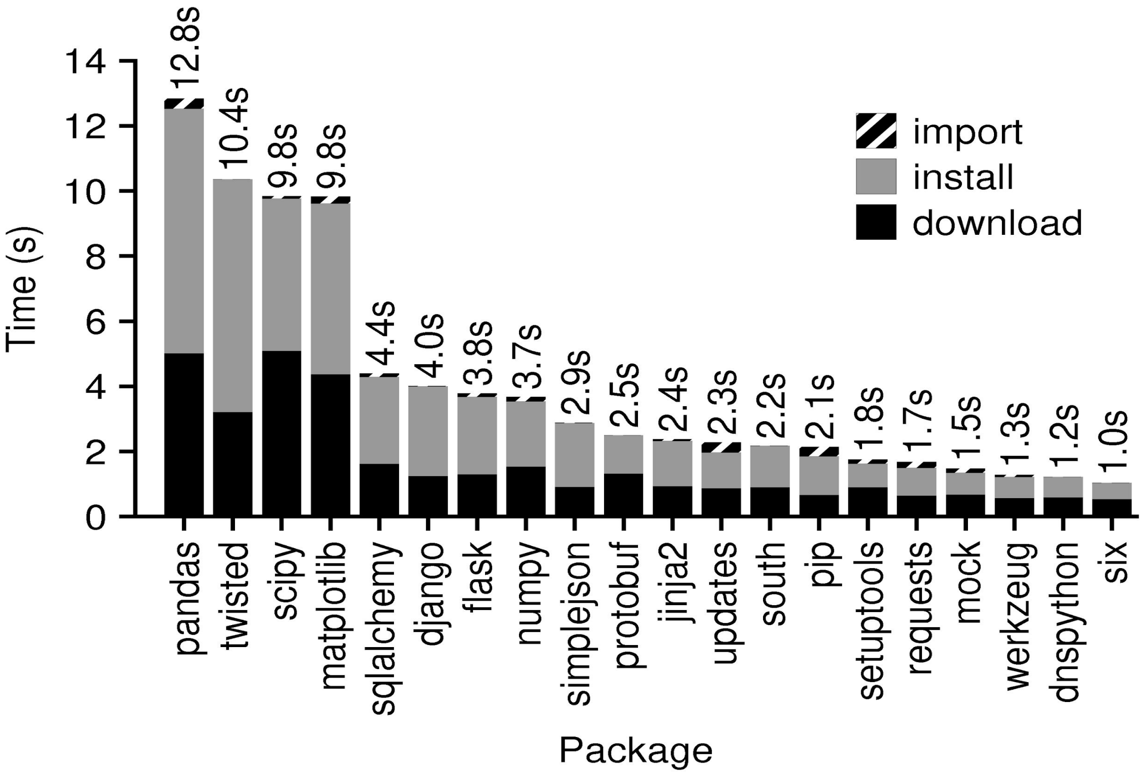
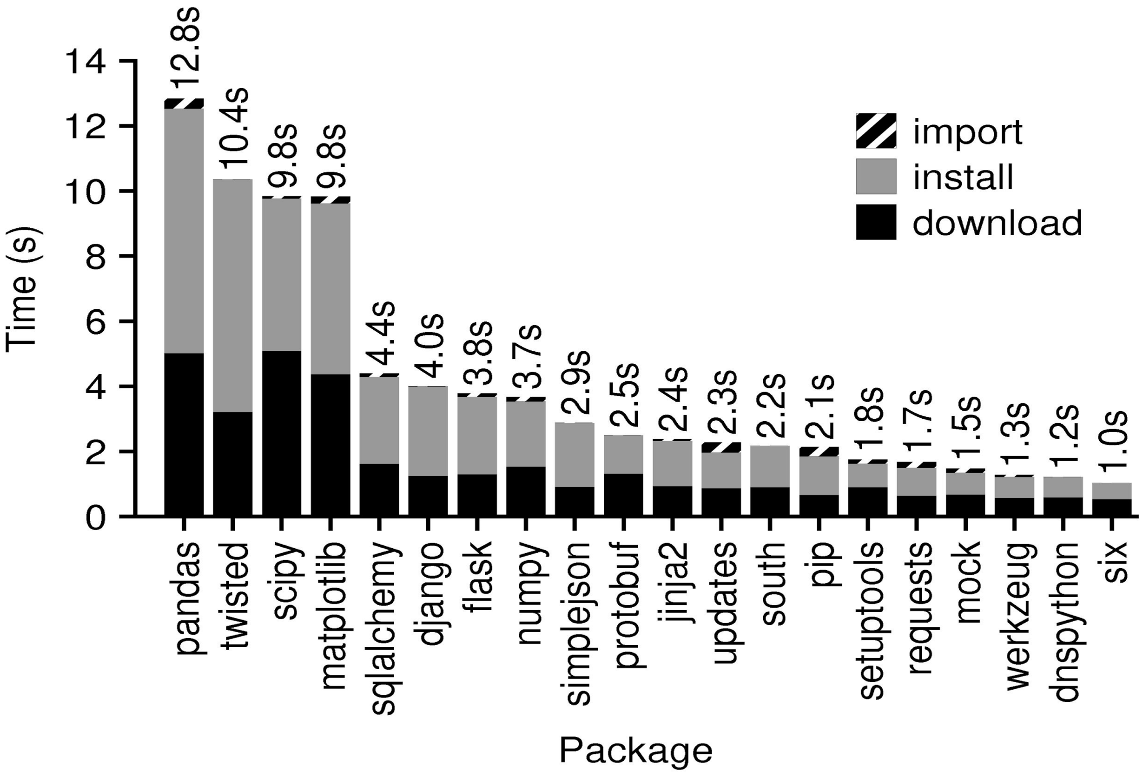
Startup Costs



Startup Costs



Average Times:

- Download: 1.6s
- Install: 2.3s
- Import: 107ms

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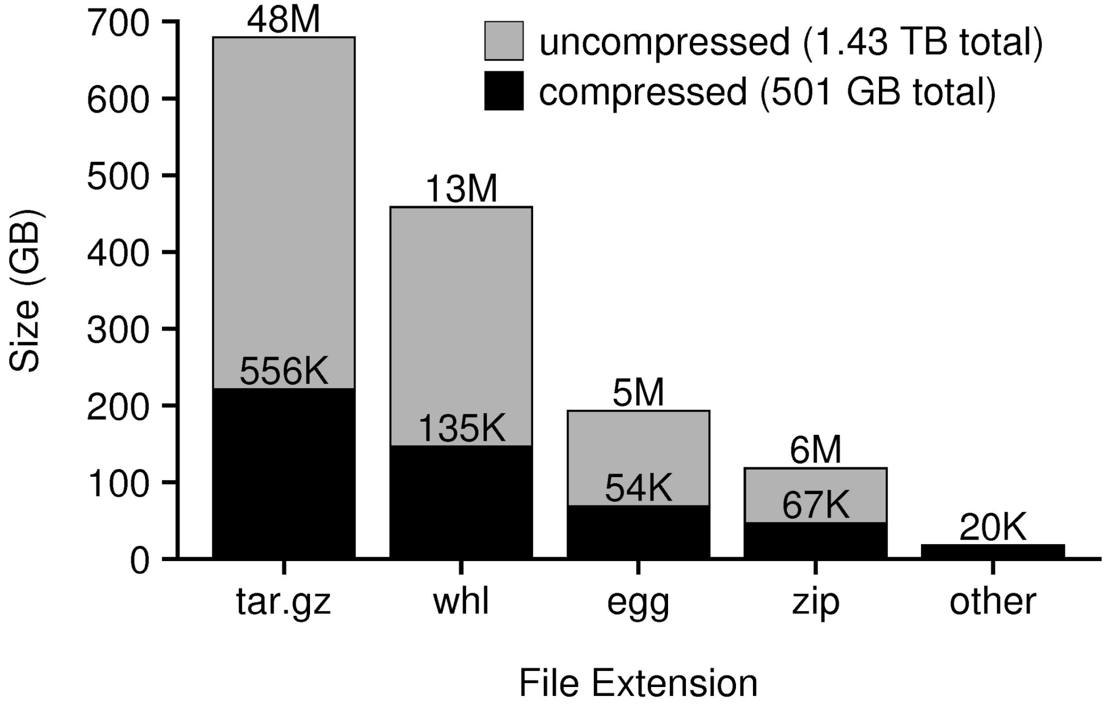
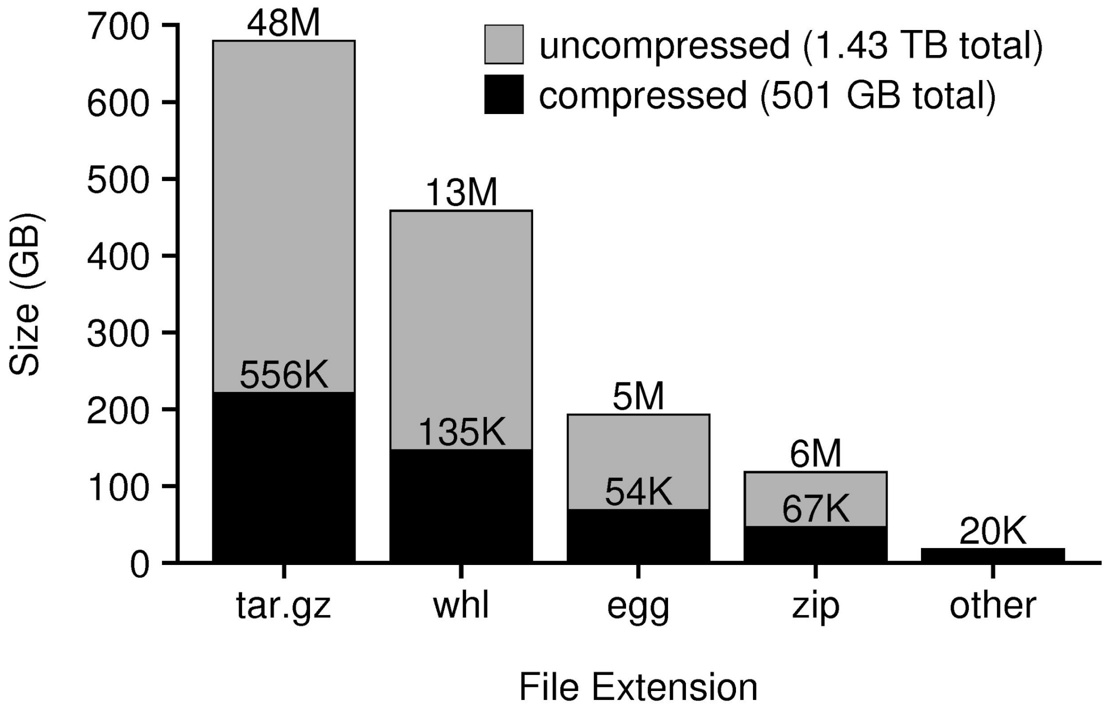
Pip Repository



Pip Repository



Average Sizes:

- Uncompressed: 1.8 MB
- Compressed: 630 KB

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Pipsqueak

Package sharing serverless compute platform

- Extension of OpenLambda
- Pre-initialize download, install, and import steps

Cache pre-initialized packages/interpreters across 3 tiers:

- **Unshared memory**: paused handler containers
- **Shared memory**: interpreter prototypes with pre-imported packages
- **Shared SSD**: pre-installed packages

Three Levels of Caching

Small & Fast

Handler Cache

- Reuse initialized containers *within* a customer

Import Cache

- Reuse initialized interpreters *between* customers

Install Cache

- Reuse installed packages *between* customers

Large & Slow

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Pipsqueak Contribution

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Covered Today

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Handler Cache

- Each customer’s handlers need to be sandboxed in a container, but we can reuse containers for multiple requests
  - Keep recently used containers in a “paused” state
  - Inspired by AWS Lambda mechanism
- Simple LRU policy
  - Evict on memory pressure

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Import Cache

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- Using a cache entry:
  a. Wake up & fork a sleeping Python interpreter
  b. Relocate child process into handler container
  c. Handle requests

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- Using a cache entry:
    a. Wake up & fork a sleeping Python interpreter
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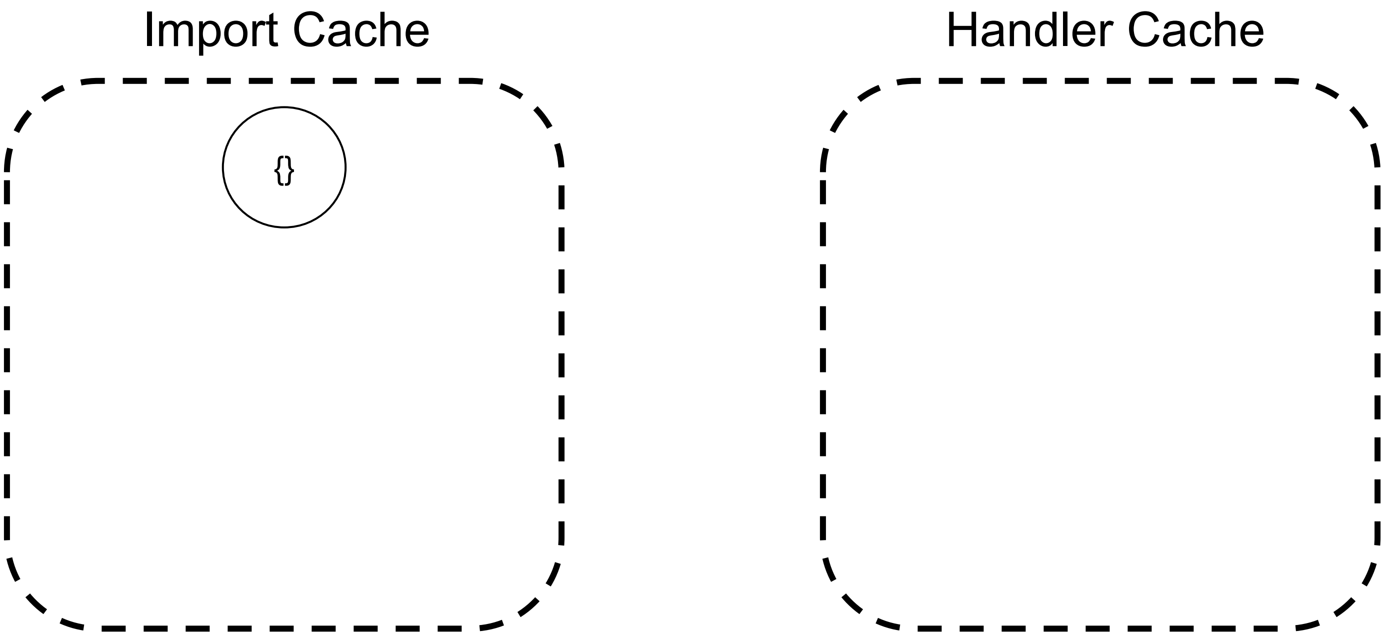
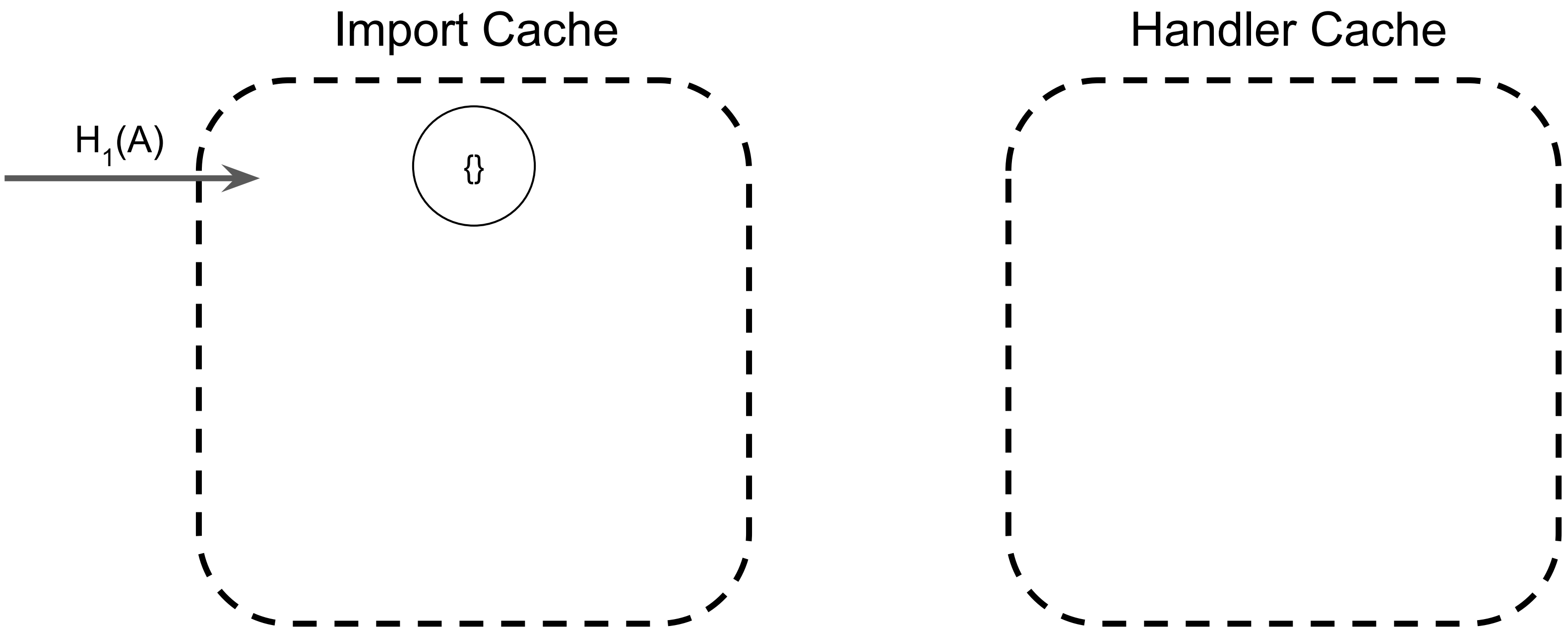
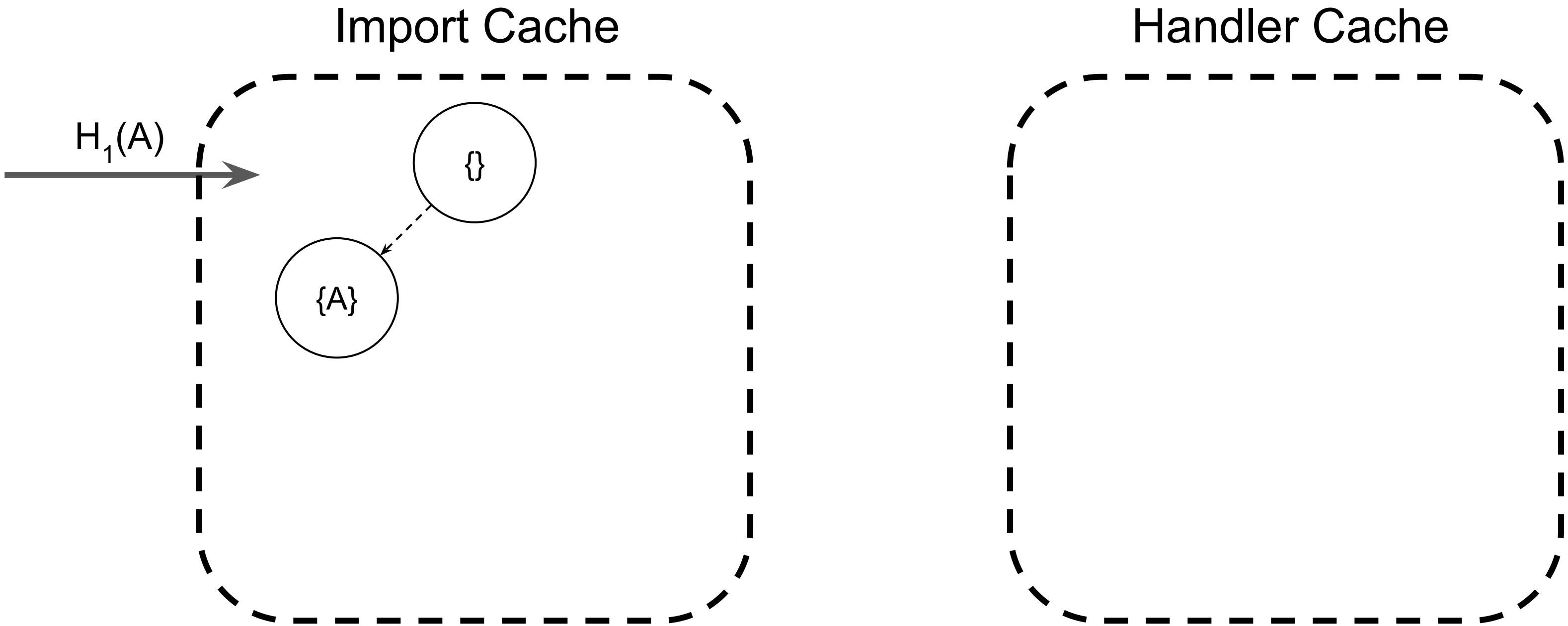
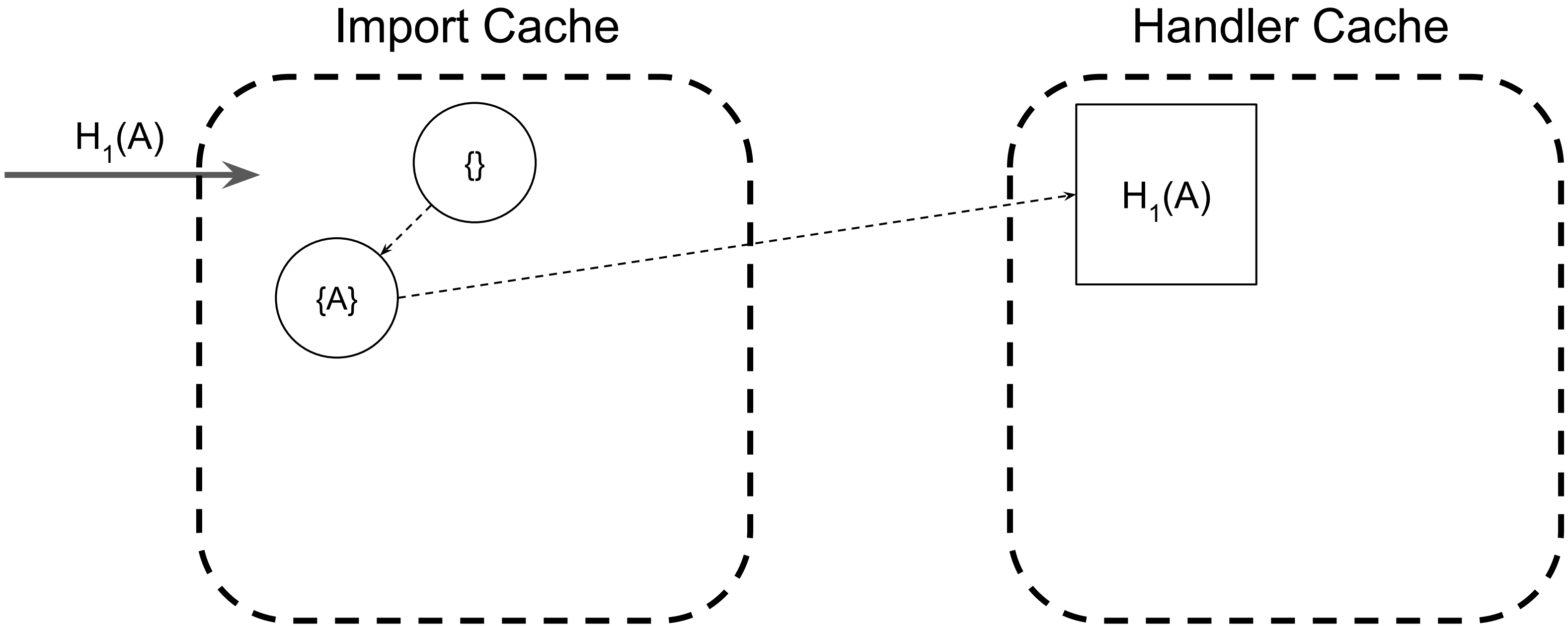
    c. Handle requests

- Creating a cache entry:
    a. Wake up & fork a sleeping Python interpreter
    b. Relocate child process into cache container
    c. Import Python packages & sleep

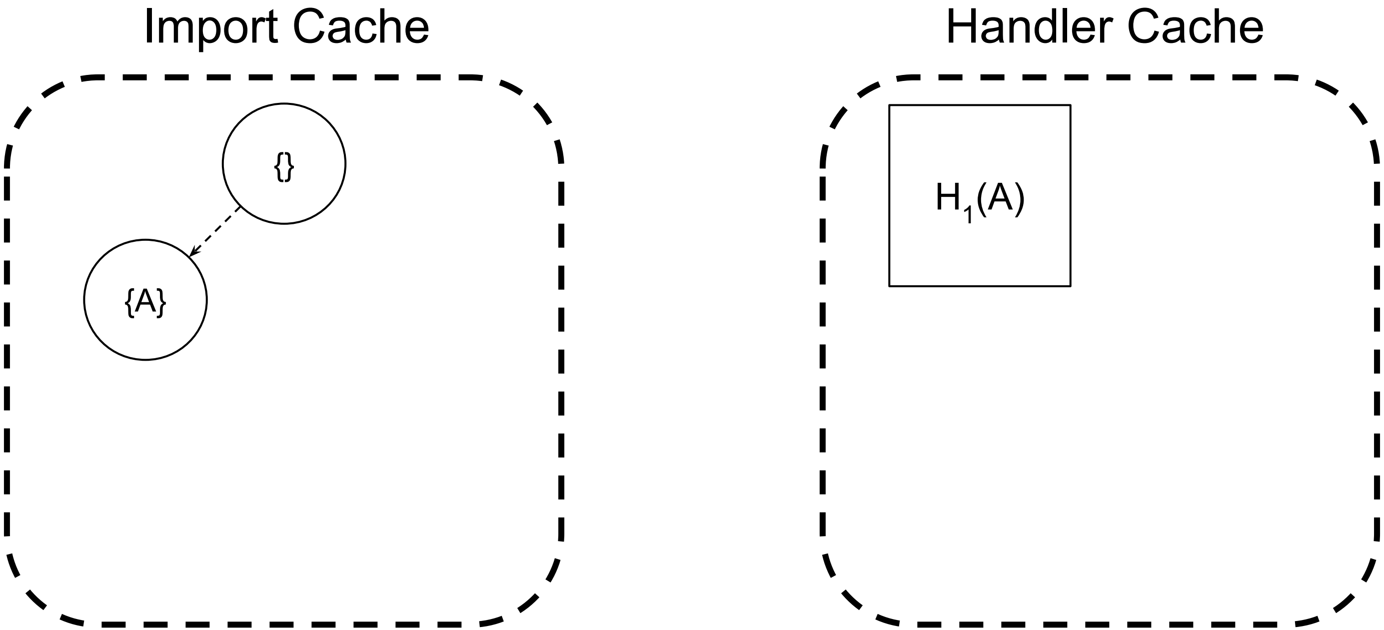

Import Cache
{}
Handler Cache

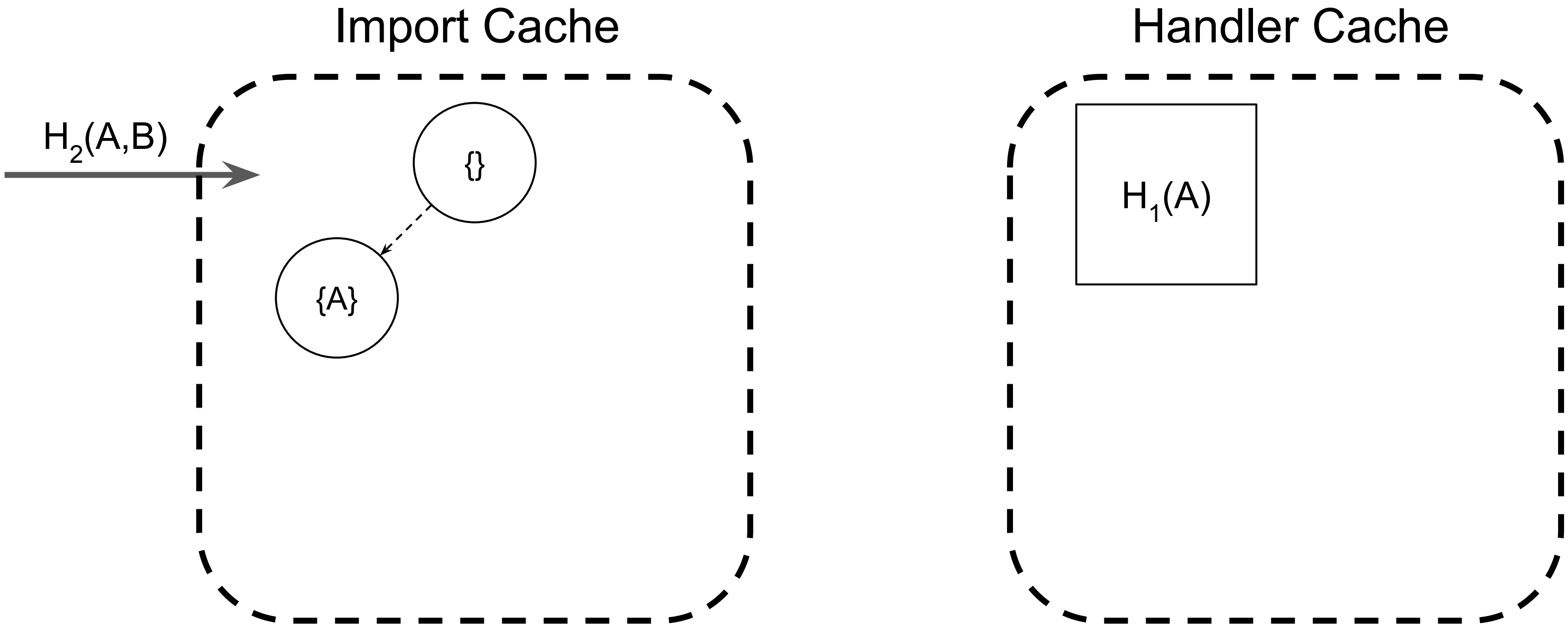

Import Cache
Handler Cache
H1(A)
{}


Import Cache
Handler Cache
H1(A)
{}
{A}

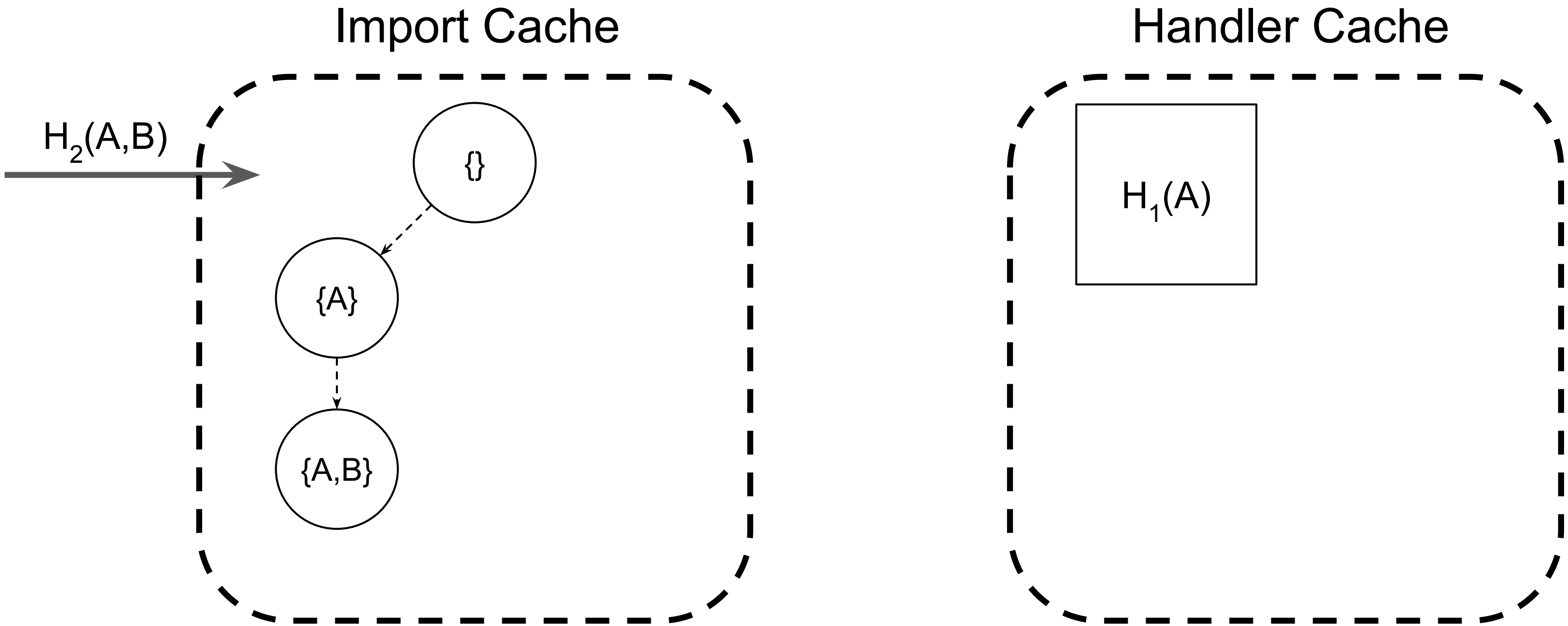


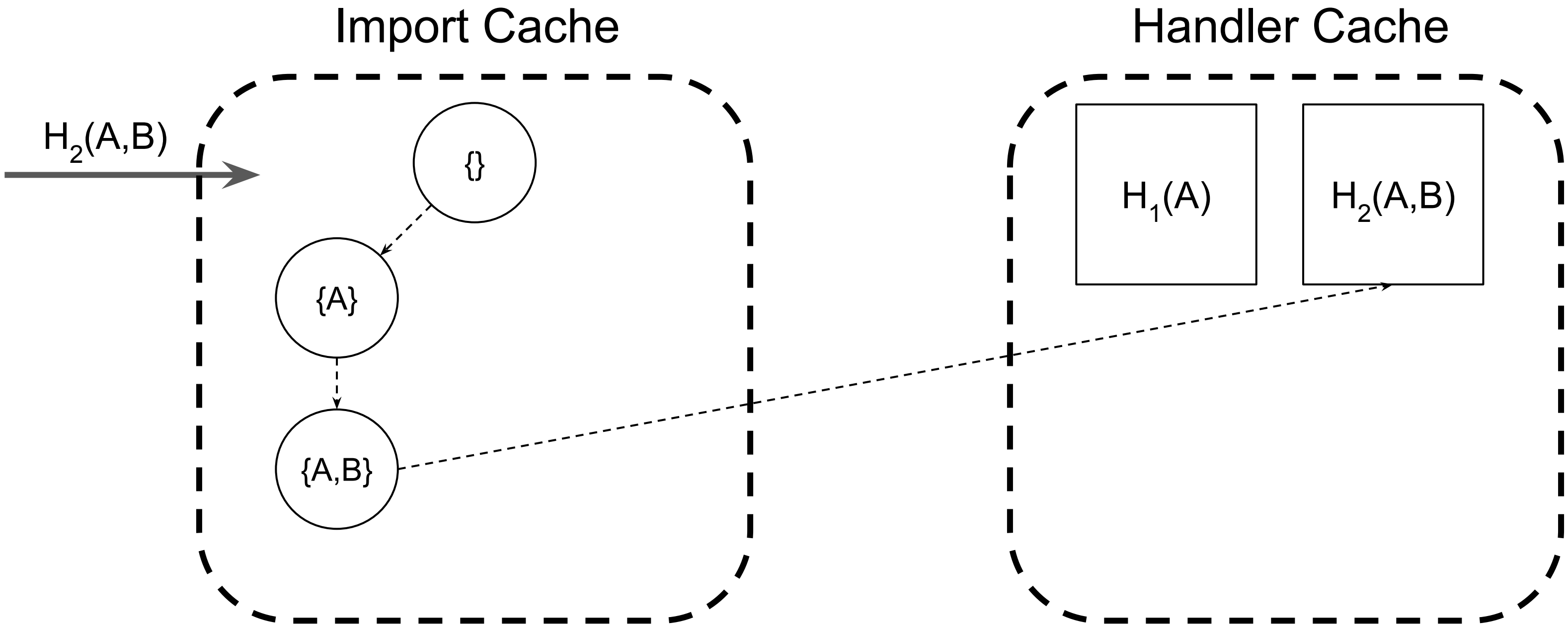
Import Cache
Handler Cache
$H_1(A)$
{}
{A}
$H_1(A)$


Import Cache
{}
{A}
Handler Cache
$H_1(A)$



Import Cache
Handler Cache
$H_2(A,B)$
{}
{A}
$H_1(A)$


Import Cache
Handler Cache
H2(A,B)
{}
{A}
{A,B}
H1(A)



Import Cache
Handler Cache
H2(A,B)
{}
{A}
{A,B}
H1(A)
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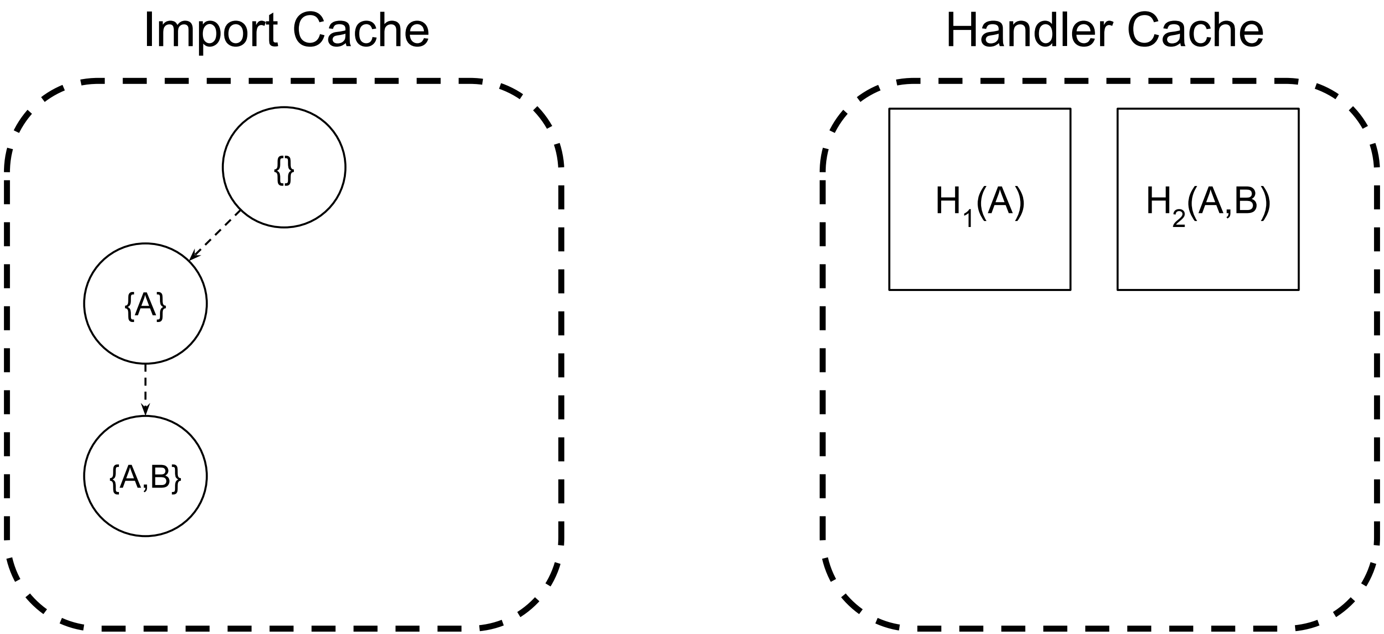
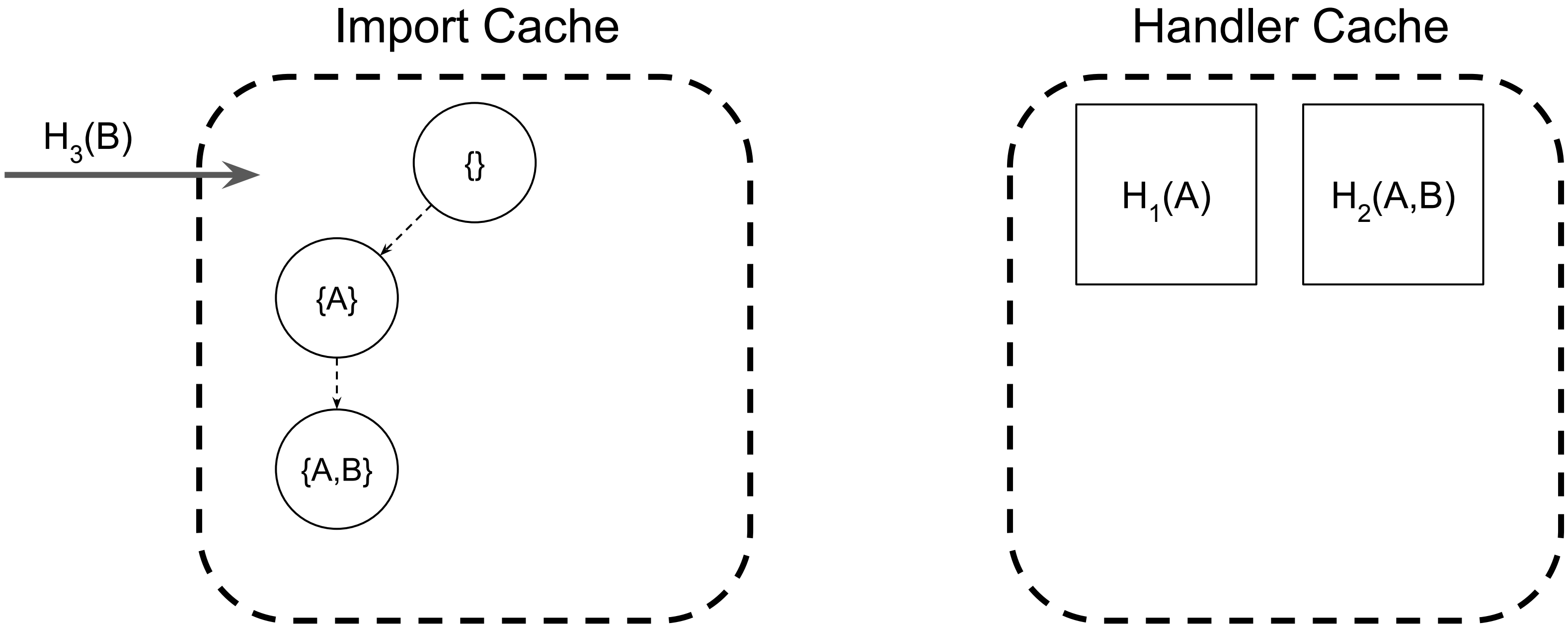
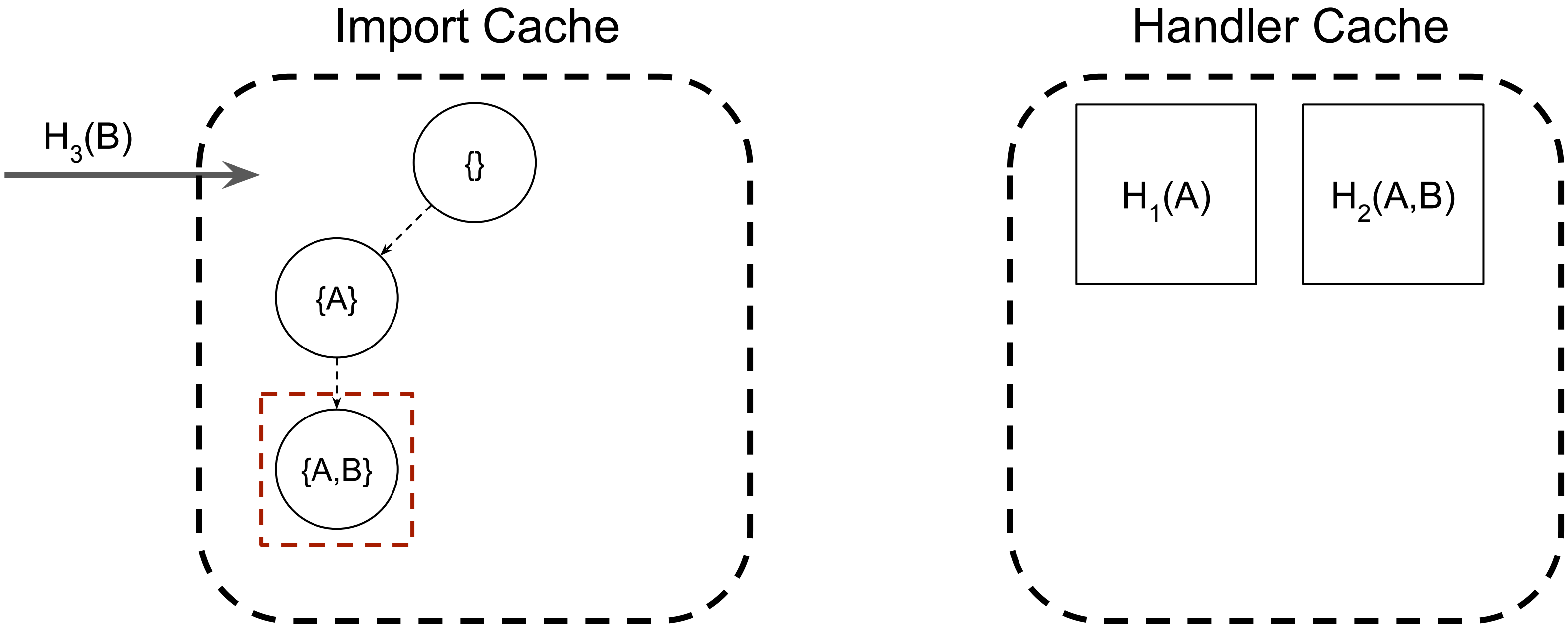

Import Cache
{}
{A}
{A,B}
Handler Cache
H1(A)
H2(A,B)


Import Cache
Handler Cache
H3(B)
{}
{A}
{A,B}
H1(A)
H2(A,B)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$H_3(B)$
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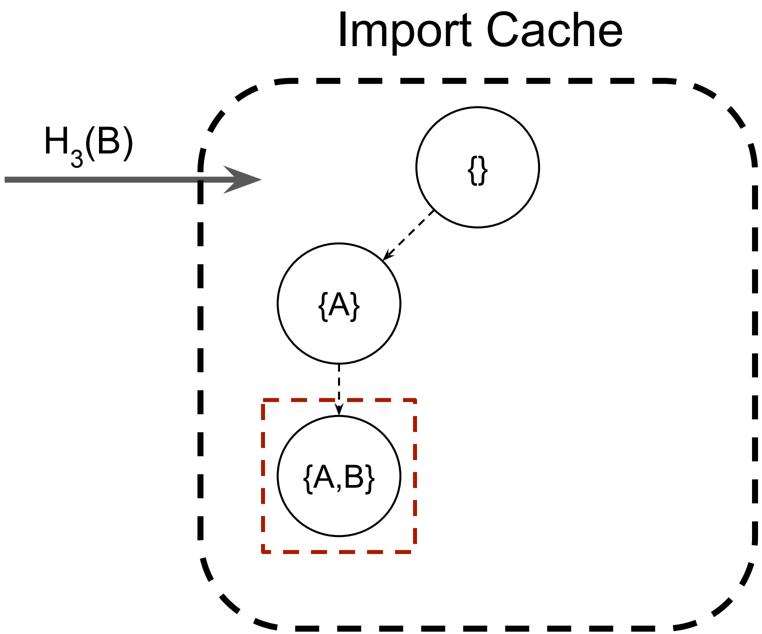
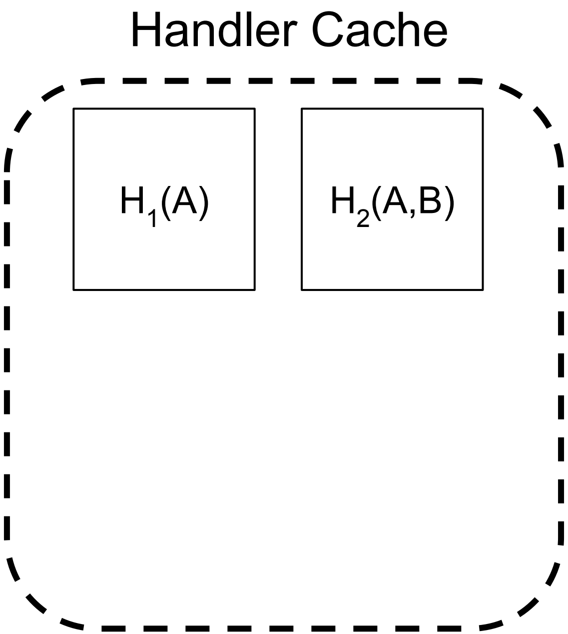
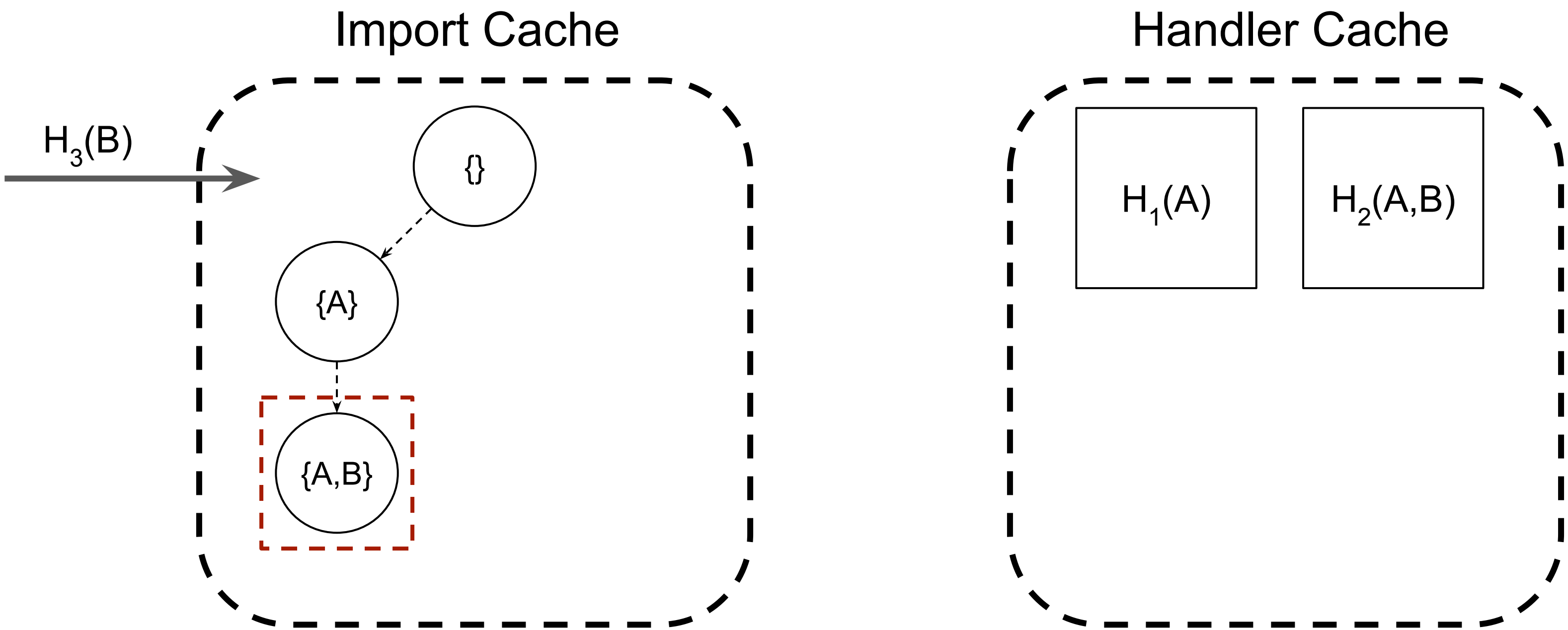
{A}
{A,B}
$H_1(A)$
$H_2(A,B)$





What if package ‘A’ is malicious?



What if package ‘A’ is malicious?

- “Subset only” rule

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Evaluation Questions

1. How much does package sharing improve latency?
2. How do the caching layers interact?

Microbenchmark

Not a stress test, want to examine differences in caching

Experimental Setup:

- 1 OpenLambda worker machine
- 2 random requests per second
- 100 distinct handlers, all importing the same pip package

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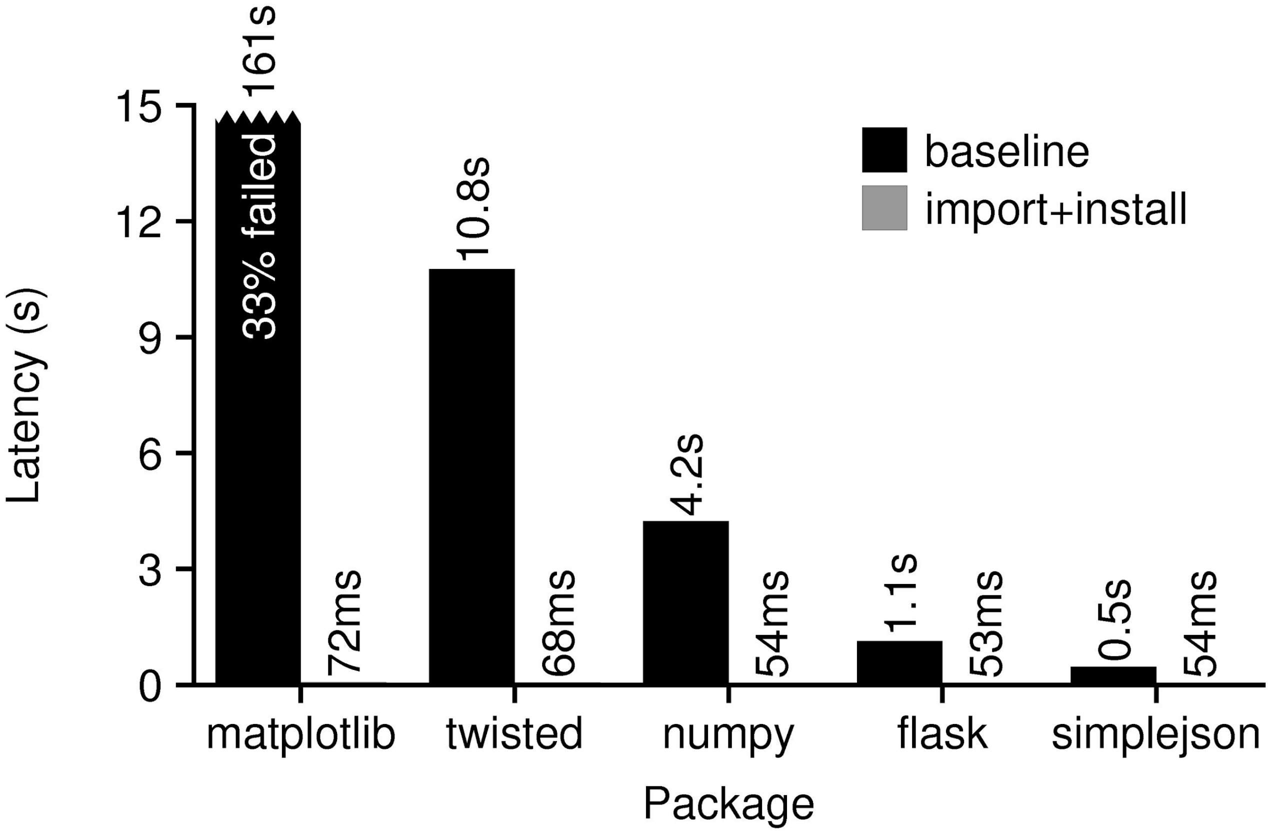
Microbenchmark



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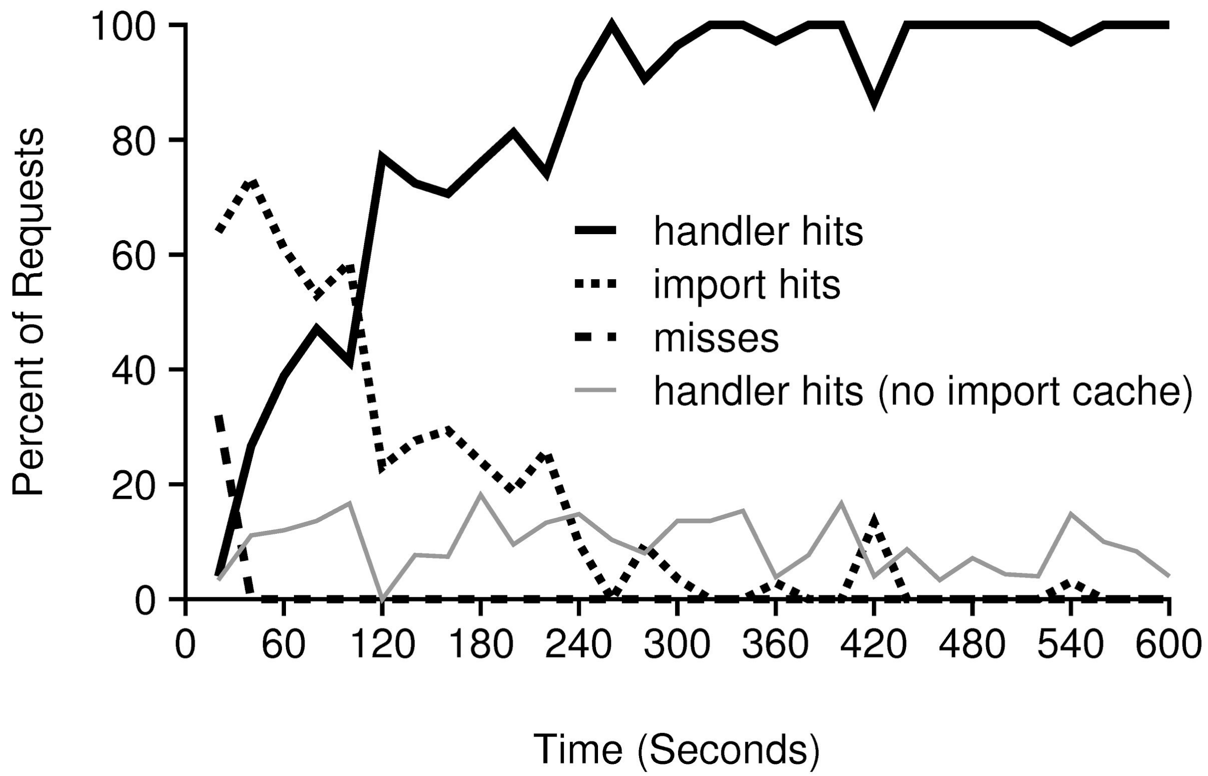

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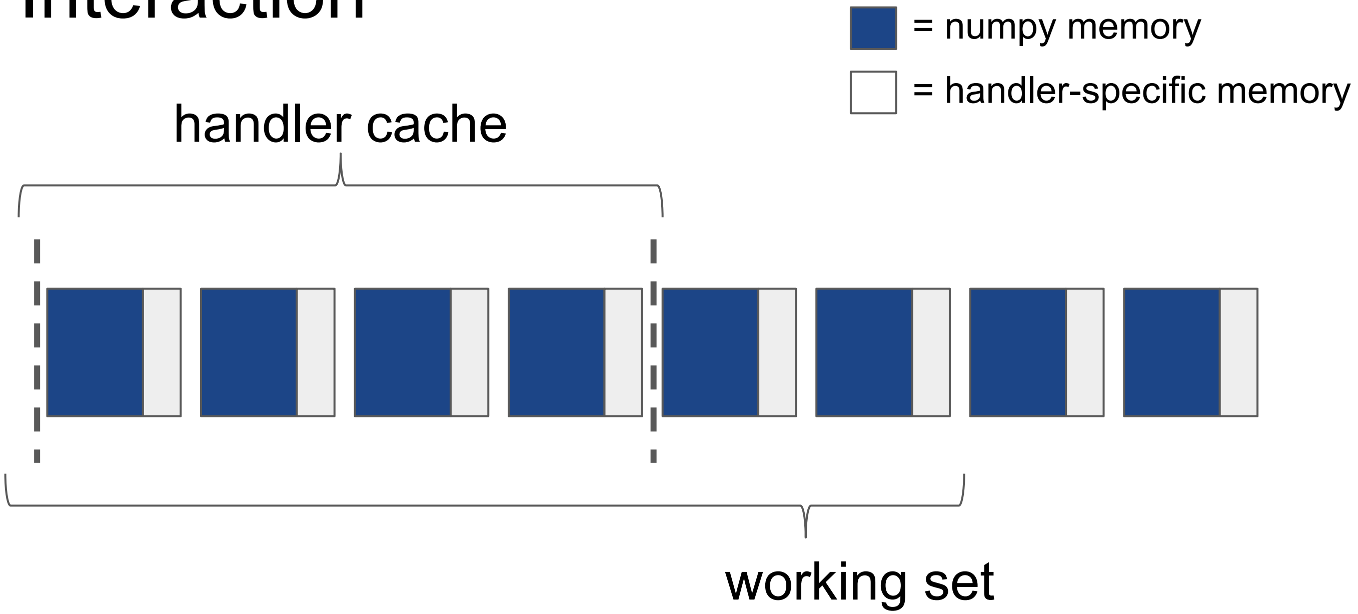

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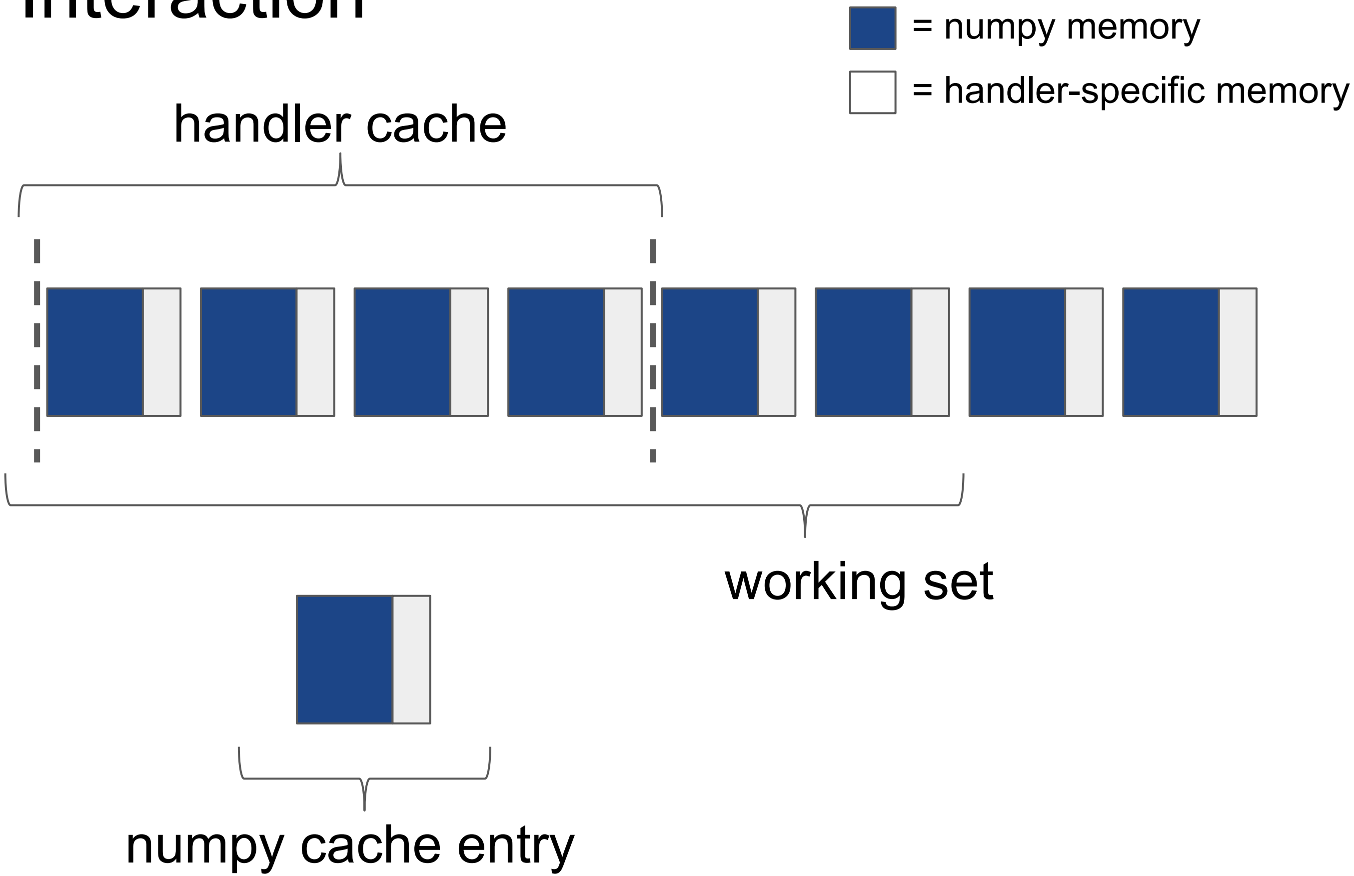

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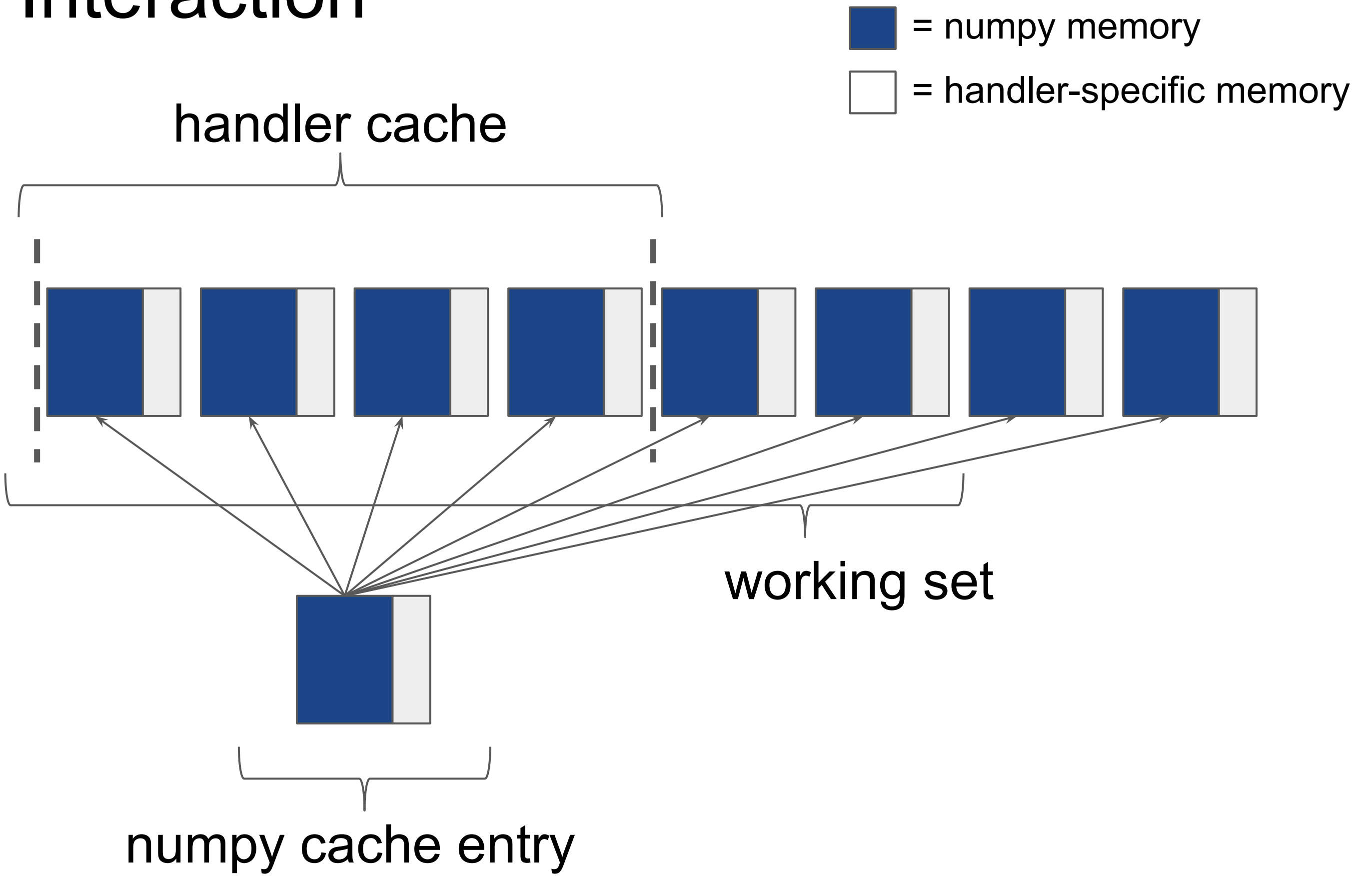

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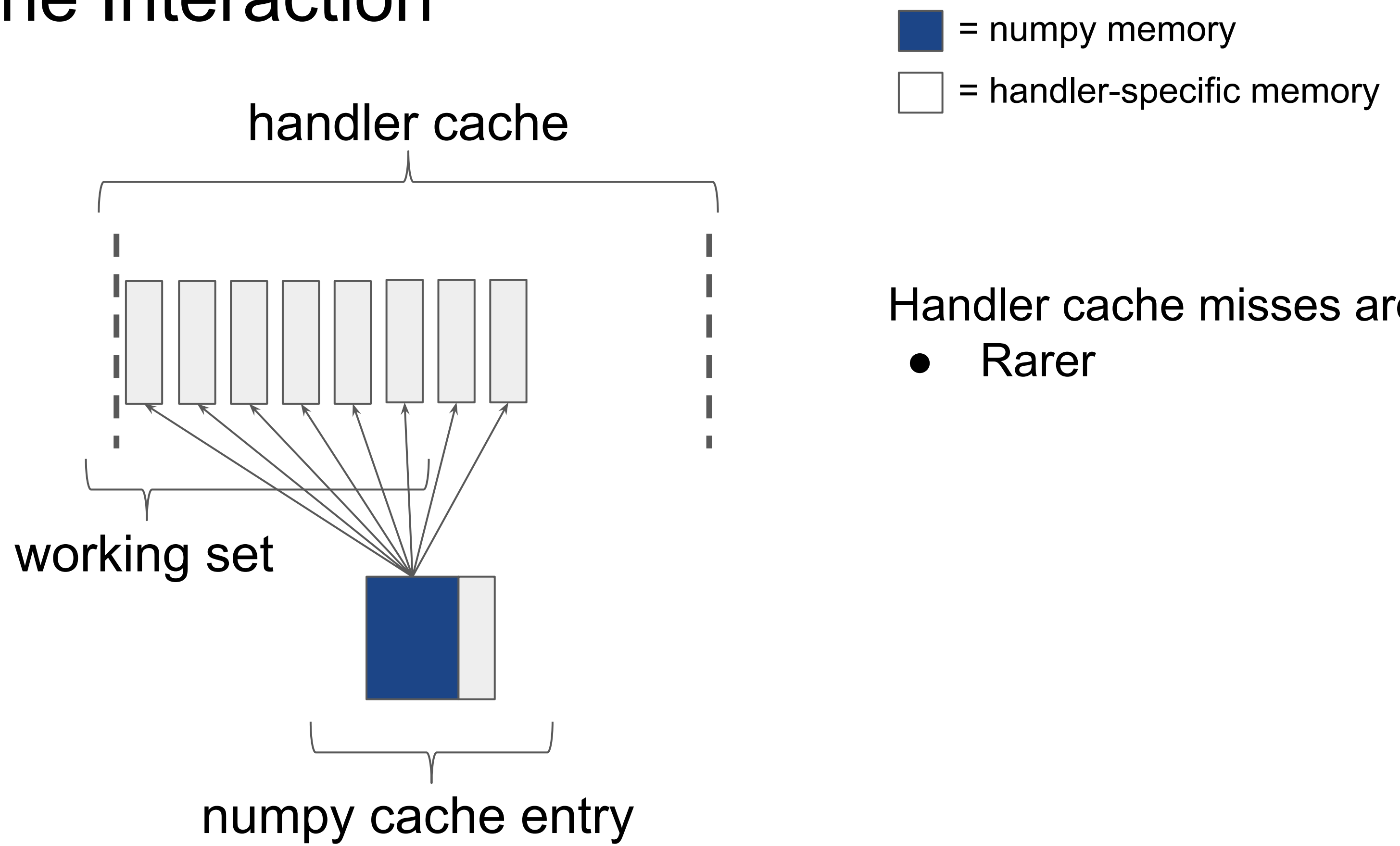
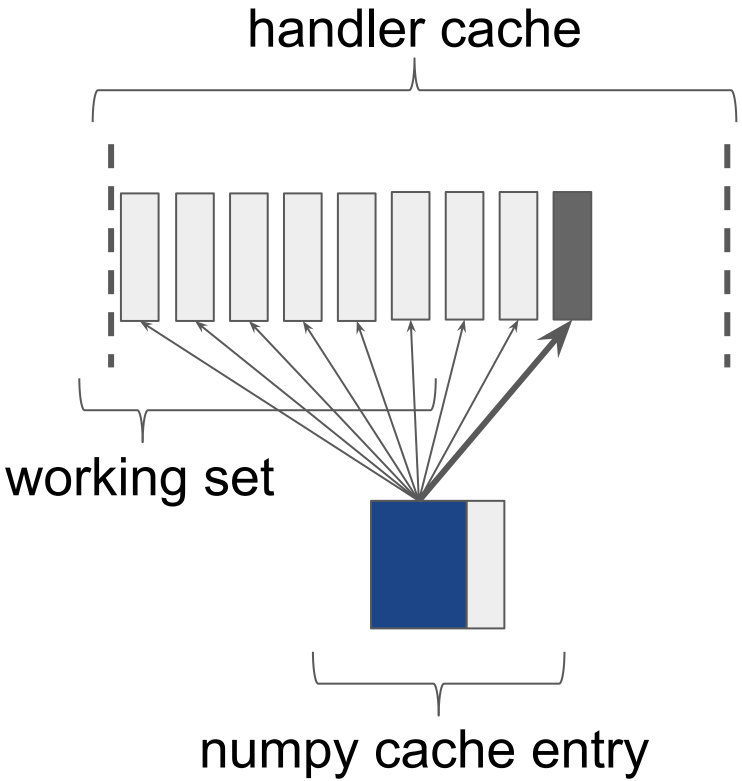
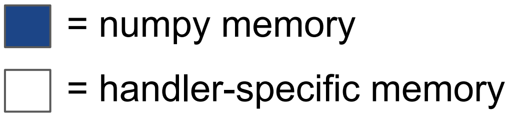


Handler cache misses are:

- Rarer

Cache Interaction





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- Faster

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Problem:

- Lambda handlers are supposed to be small, but developers' reliance on user-space libraries inflates them

Our Solution:

- Share pre-initialized packages among handlers in multi-level cache

Results:

- 9-2000x speedups for single-package workloads

Questions?