# BlkKin: A Low-overhead tracing infrastructure for software-defined storage systems

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# Outline

# Thesis Background

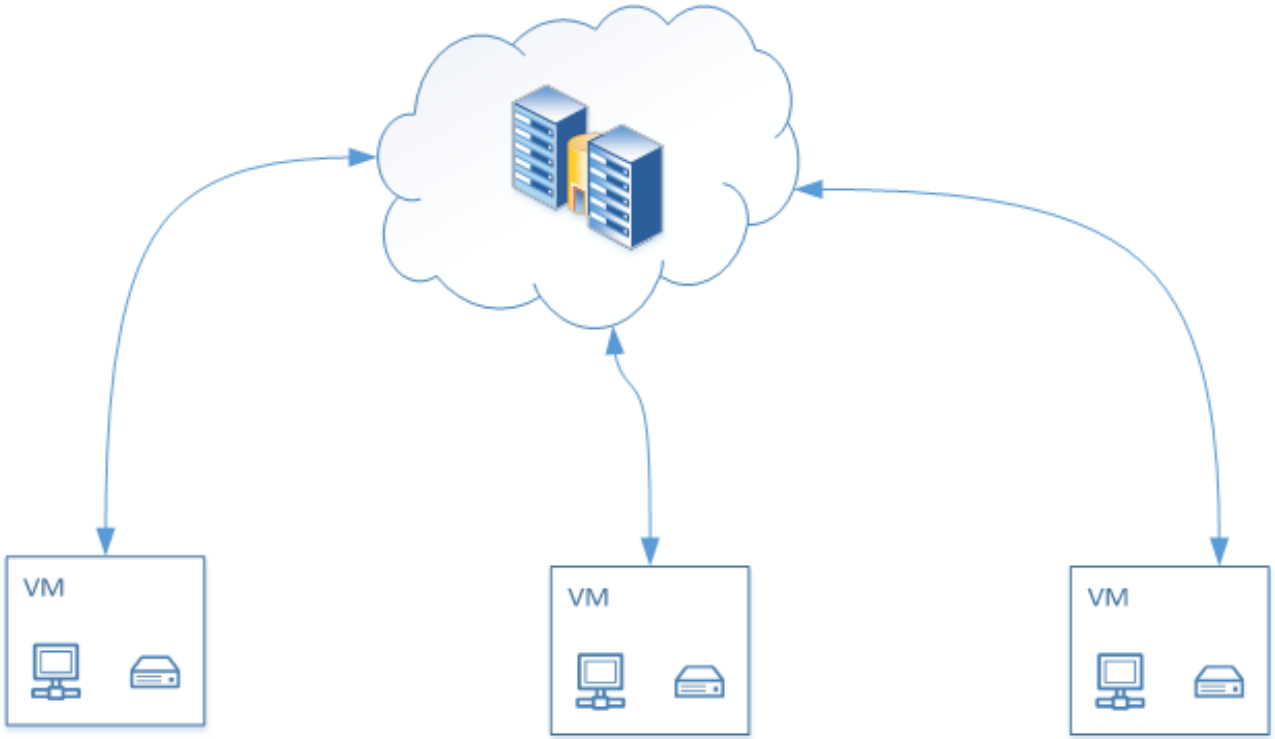
synnefo

Open source, production-ready, cloud software.
Designed since 2010 by GRNET.

okeanos

- IaaS service
- Targeted at the Greek Academic and Research Community
- Designed by GRNET
- In production since 2011

# VM Volume storage

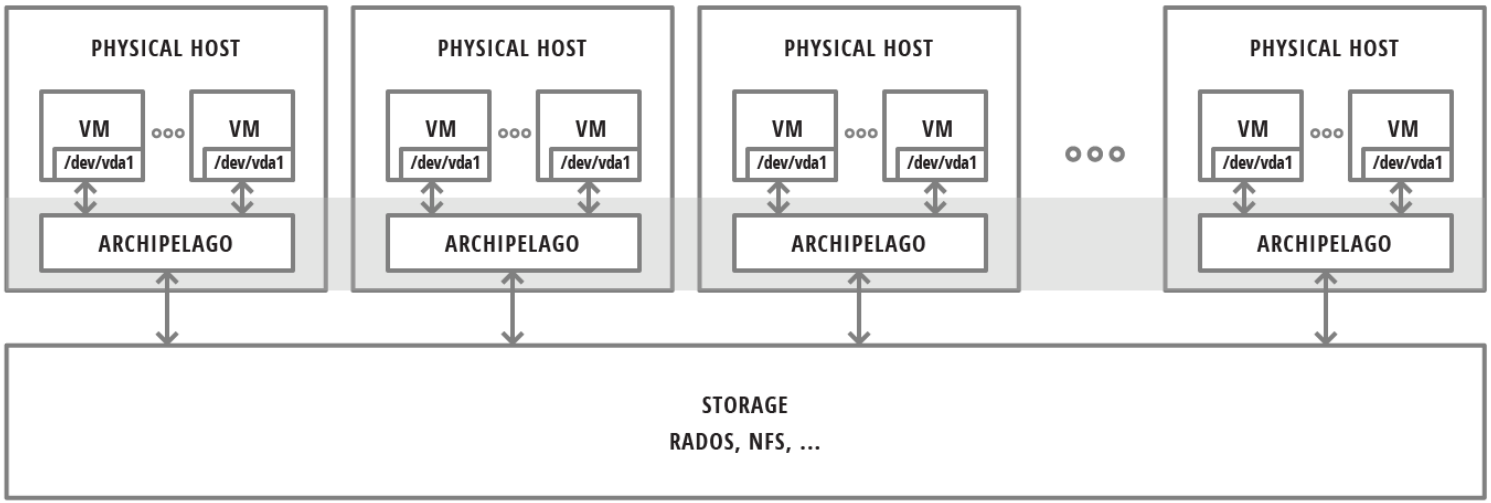


# Archipelago I

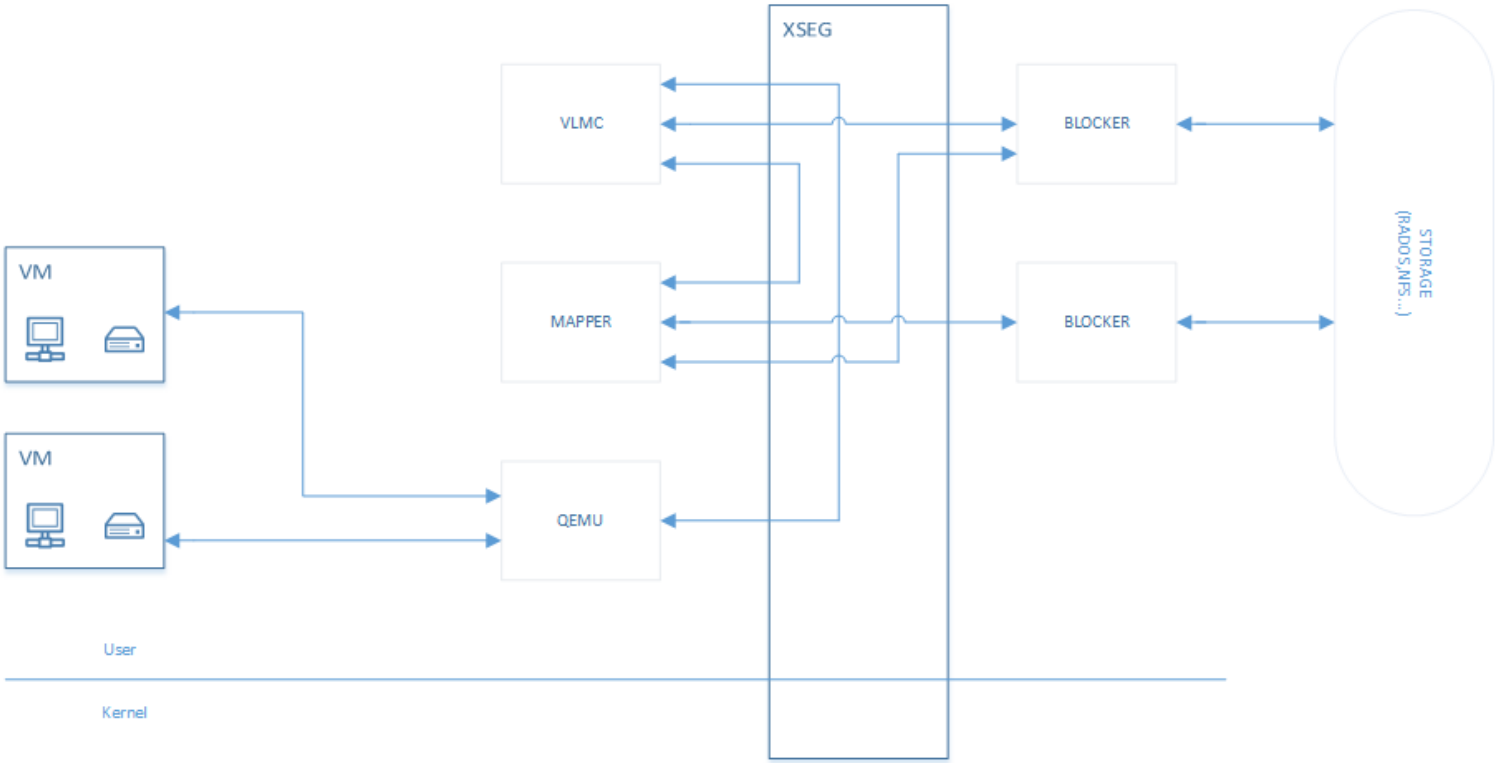
A thin distributed storage layer aiming to:

- Decouple storage logic from the actual data store
- Provide logic for thin cloning and snapshotting
- Provide logic for deduplication
- Provide different endpoint drivers to access Volumes and Files
- Provide backend drivers for different storage technologies

# Archipelago II



# Archipelago III



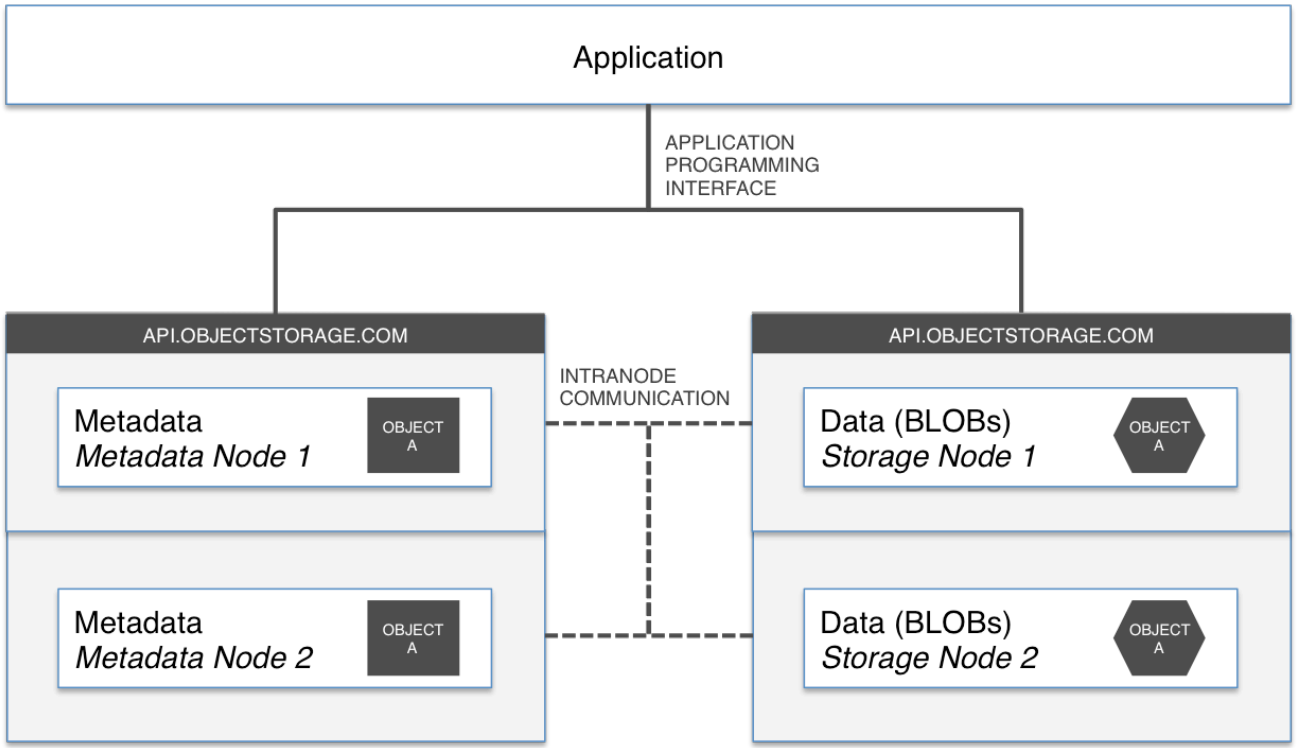
# RADOS

is the storage component of Ceph

RADOS basic characteristics are:

- *Replication*
- *Fault tolerance*
- *Self-management*
- *Scalability*

# Storage Abstraction



# The Problem

- Complex service oriented architectures
- Difficult debugging
- Difficult monitoring
- Non-deterministic execution
- Context-bound faults

# Solution

Distributed end-to-end tracing

&

Central data collection

# BlkKin

A distributed tracing infrastructure to track the IO request from Qemu until RADOS

BlkKin main characteristics:

- low-overhead tracing
- live-tracing
- End-to-end tracing of causal relationships
- User interface

# Main Challenges

- Meaningful and easily correlated tracing data
- Low overhead tracing backend

# Schools of thought

**black-box schemes**

They assume there is no additional information other than the message record described above and use statistical regression techniques to infer that association.

**annotation-based schemes**

They rely on applications or middleware to explicitly tag every record with a global identifier that links these message records back to the originating request.

# The Dapper System

- Large scale distributed systems tracing infrastructure created by Google
- Annotation-based tracing scheme
- Common libraries instrumentation
  - RPC System
  - Control Flow
- BigTable backend
- Closed-source

# Dapper tracing concepts

| | |
|---|---|
| annotation | The actual information being logged. Either *timestamp* or *key-value* |
| span | The basic unit of the process tree. Can represent a subsystem or a function call. To depict causal relationship each span has a parent span or is a *root* span. |
| trace | A different trace id is used to group data related to he same initial request |

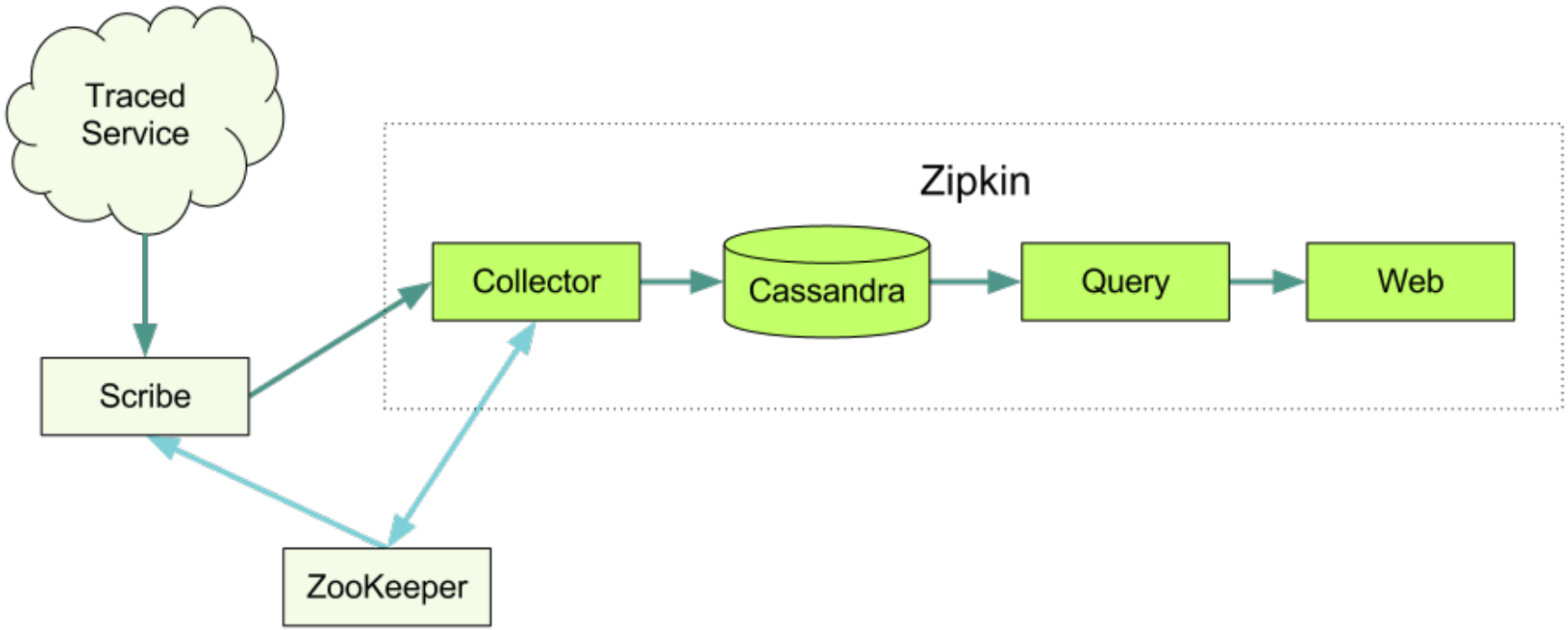
# Zipkin

An open-source Scala implementation of the Dapper paper by Twitter

Zipkin services:

- Data collector
- Database service
- Web UI

# Zipkin Architecture



# Scribe

Scribe is a scalable and reliable logging server created by Facebook

- Written in C++
- Directed graph architecture
- Batch messaging
- HDFS support
- Based on Apache Thrift

# Thrift

A software framework for scalable cross-language services development.

Includes a code generation engine to create RPC services across programming languages based on a Thrift file

Sample target languages: C++, Java, Python, PHP, Ruby, Erlang, Perl, Haskell, OCaml

# Zipkin sum up

| | |
|---|---|
| Zipkin | is a full stack tracing system using |
| Scribe | as its logging server using |
| Thrift | as its transport protocol |

# Tracing

> "Tracing is a specialized use of logging to record information about a program's execution"
>
> Wikipedia

Tracing characteristics:

- Tracing can be low level (eg. kernel tracing, access to performance counters)
- Tracing has mostly debugging purposes and performance tuning
- Tracing may produce notoriously bulky output

# Tracing Systems

DTrace

Released by Sun Microsystems in 2005

SystemTap

Released by Red Hat in 2005

Advantages:

- Dynamic Instrumentation
- User and kernel tracing

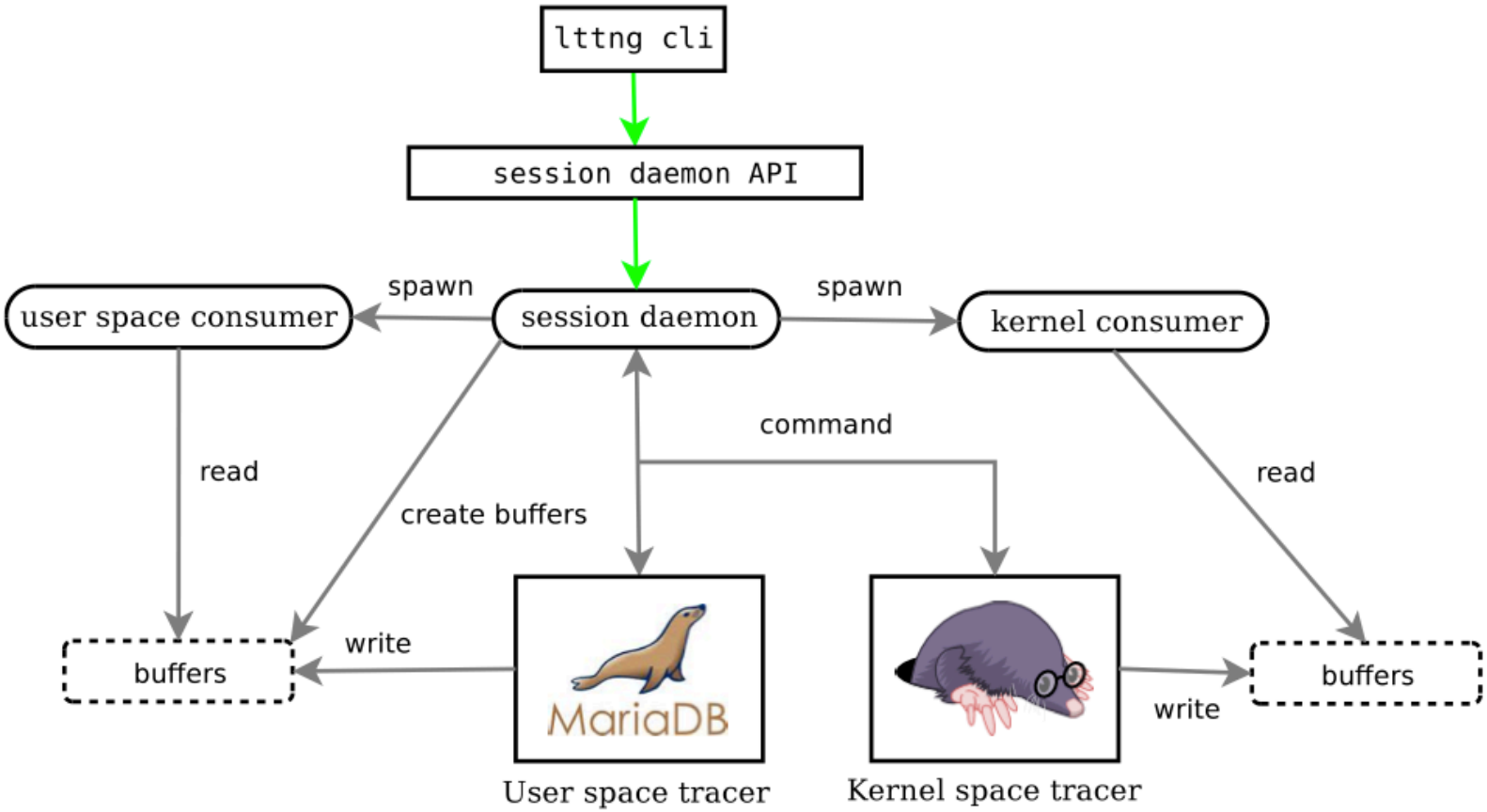
Disadvantages:

- User tracing is based or system calls or breakpoints
- Significant performance overhead
- Inappropriate for live tracing

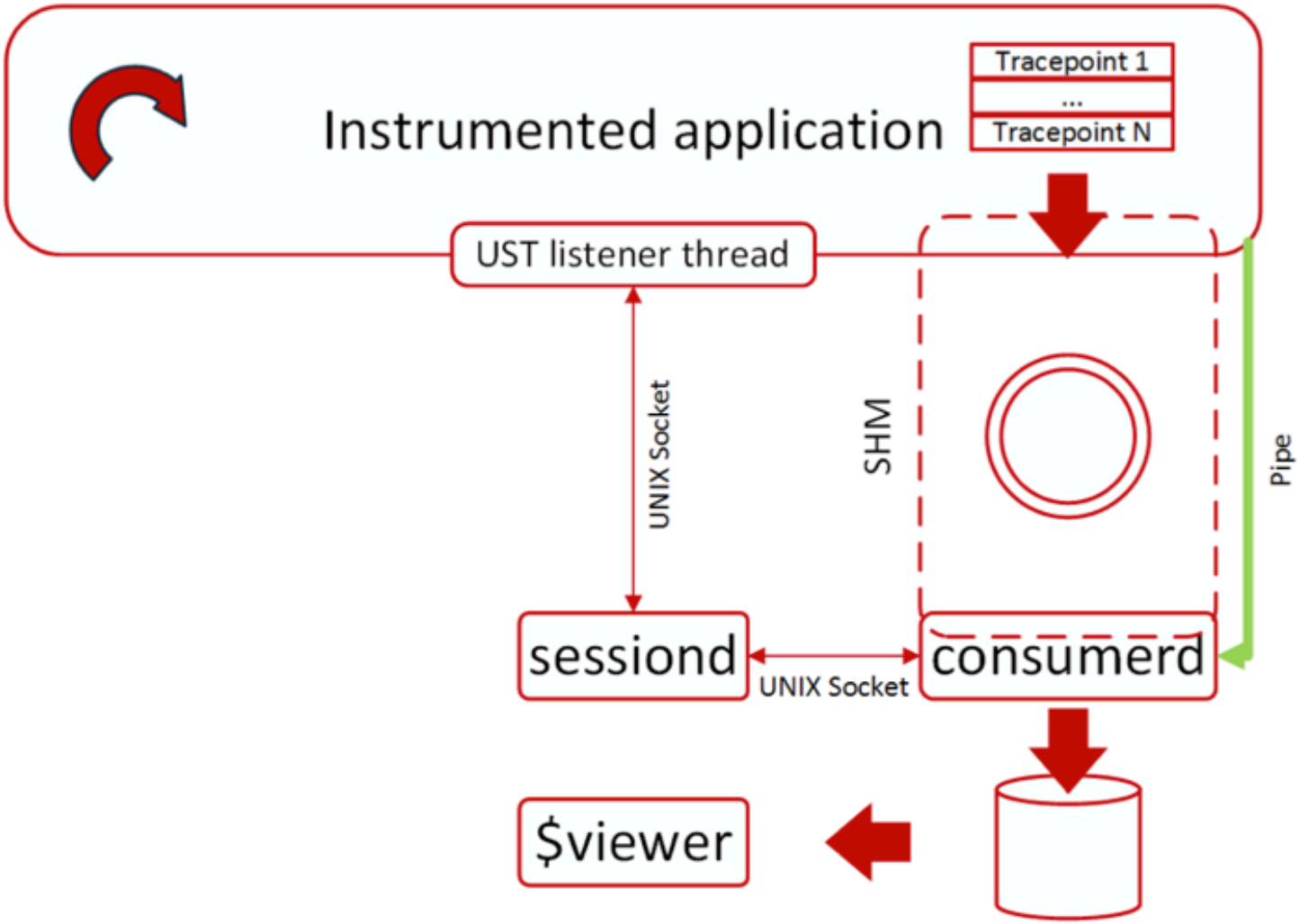
# Linux Trace Toolkit - next generation

- successor of Linux Trace Toolkit
- Mathew Desnoyers PhD dissertation in Ecole Polytechnique de Montreal
- maintained by EfficiOS Inc1and the DORSAL lab in Ecole Polytechnique de Montreal.
- Unified user and kernel tracing
- Low overhead tracing based on Tracepoints
- Static instrumentation
- Live tracing

# LTTng Architecture



# UST architecture



# CTF

Common Trace Format:

- Aimed to cover tracing needs from versatile communities
- Collaboration between the Multicore association and the Linux Community
- Based on Trace Stream Description Language
- Separation between data and metadata
- Separation between event and event-context
- Variety of data types and type inheritance
- Live tracing

# Babeltrace

- Trace reader/writer
- Trace converter
- Babeltrace plugins
- Exports `libbabeltrace`
- Python bindings

Complete environments based on Babeltrace: Trace Compass (Java tool), Eclipse LTTng plugin

# BlkKin = Zipkin + Block Storage

BlkKin is:

- end-to-end tracing infrastructure
- implementing Dapper semantics
- based on Zipkin and LTTng
- providing live tracing

# BIkKin Contribution

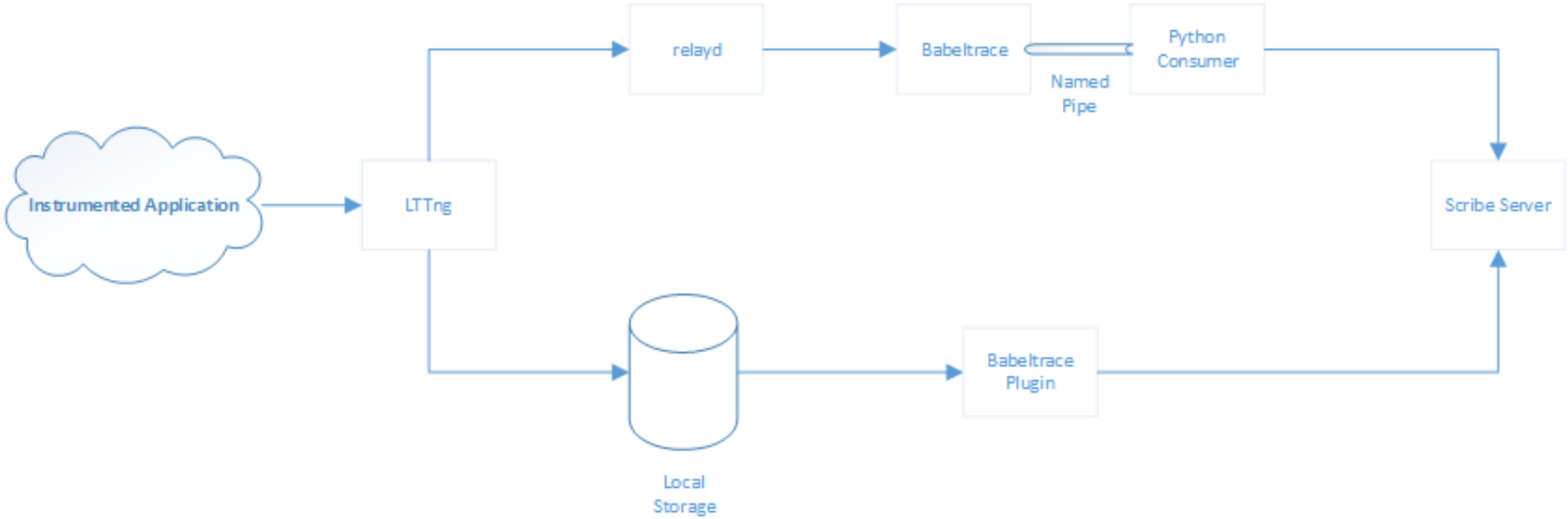
BIkKin instrumentation library:

- C/C++ instrumentation library
- implementing Dapper tracing semantics
- LTTng backend
- sampling

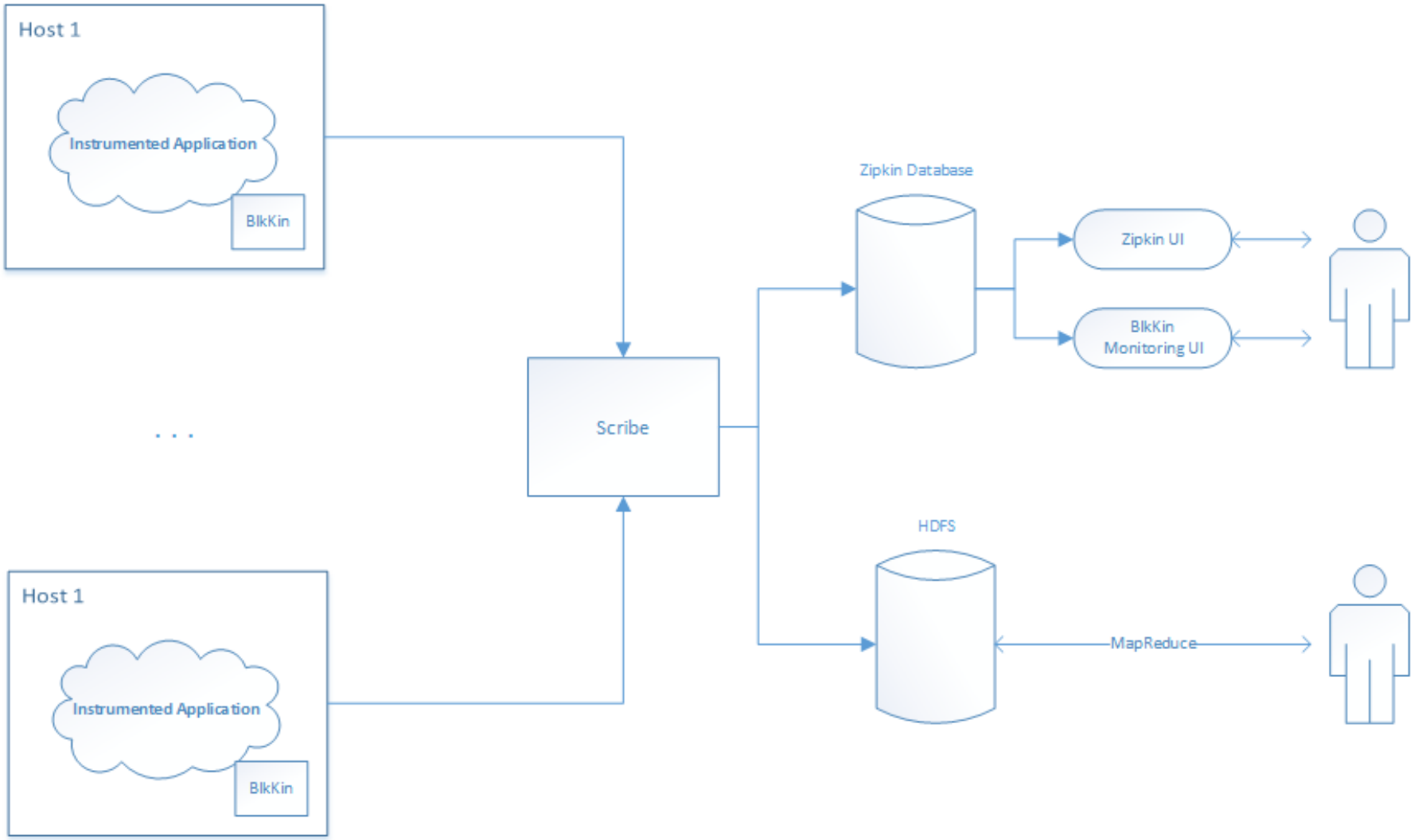
CTF-to-Scribe Babeltrace plugins:

- based on Python bindings
- two output formats:
  - JSON format (generic)
  - Zipkin Thrift (Zipkin specific)

# BlkKin Architecture



# BIkKin Architecture



# Evaluation Environment

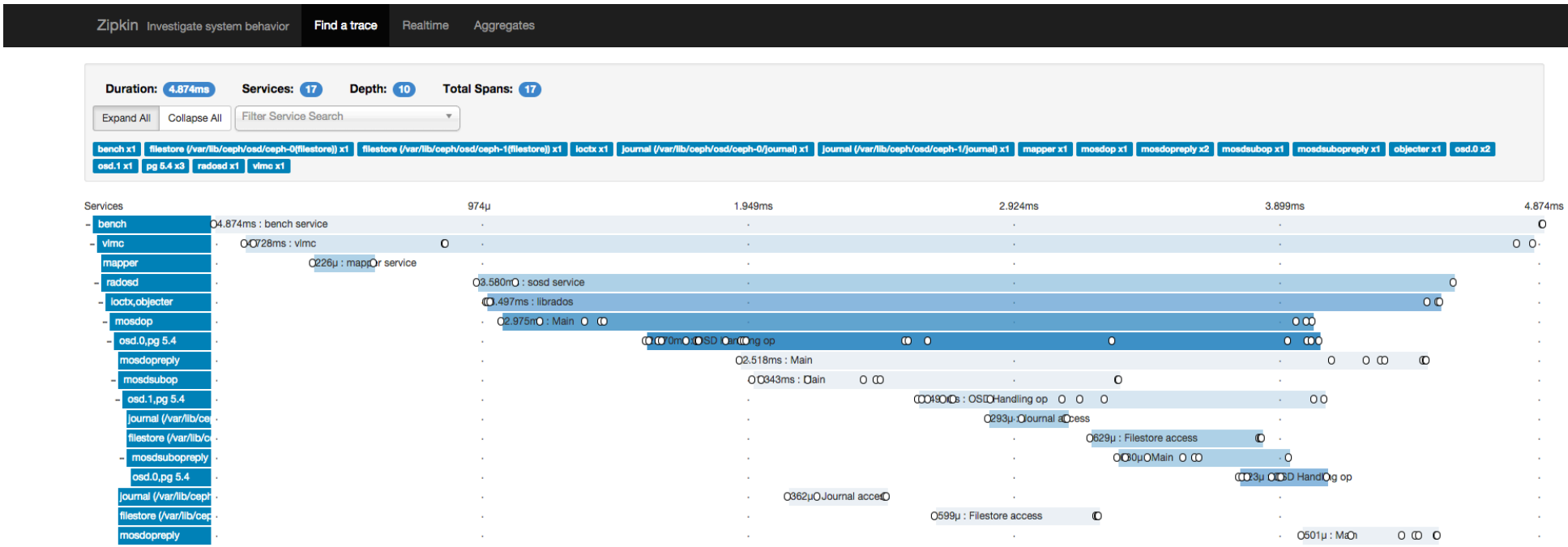
Instrumented:

- QEMU Archipelago driver
- Archipelago and libxseg
- RADOS

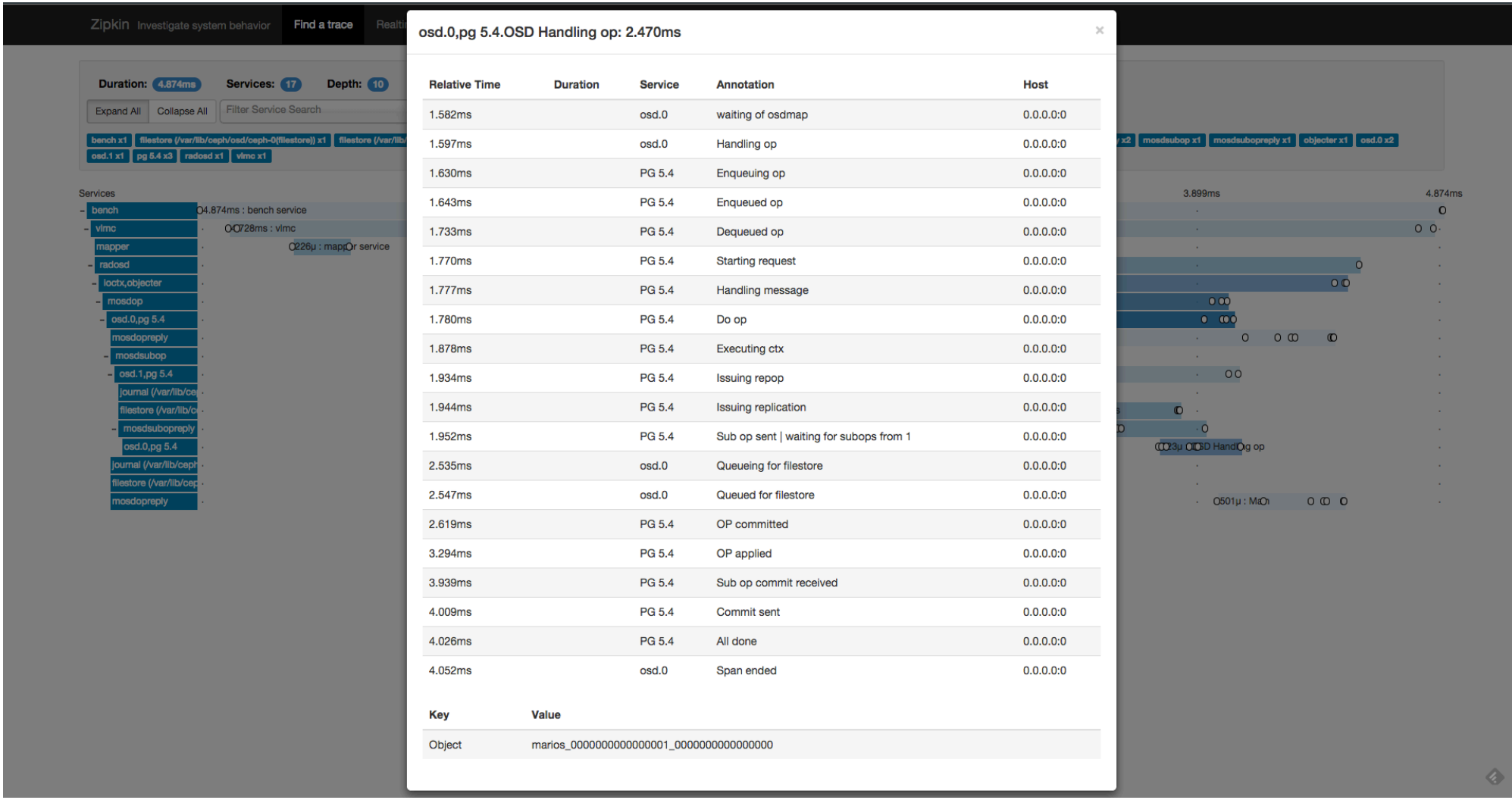
Testbed:

- 2 hosts LAN interconnected
- 2 OSDs per host
- 1 host running QEMU and Archipelago

# Zipkin UI


Zipkin
Investigate system behavior
Find a trace
Realtime
Aggregates
Duration: 4.874ms
Services: 17
Depth: 10
Total Spans: 17
Expand All
Collapse All
Filter Service Search
bench x1
filestore (/var/lib/ceph/osd/ceph-0(filestore)) x1
filestore (/var/lib/ceph/osd/ceph-1(filestore)) x1
ioctx x1
journal (/var/lib/ceph/osd/ceph-0/journal) x1
journal (/var/lib/ceph/osd/ceph-1/journal) x1
mapper x1
mosdop x1
mosdopreply x2
mosdsubop x1
mosdsubopreply x1
objecter x1
osd.0 x2
osd.1 x1
pg 5.4 x3
radosd x1
vlmc x1
Services
974µ
1.949ms
2.924ms
3.899ms
4.874ms
bench
4.874ms : bench service
vlmc
728ms : vlmc
mapper
226µ : mapper service
radosd
3.580m : sosd service
ioctx,objecter
.497ms : librados
mosdop
2.975m : Main
osd.0,pg 5.4
mosdopreply
2.518ms : Main
mosdsubop
343ms : Main
osd.1,pg 5.4
journal (/var/lib/ce
filestore (/var/lib/c
mosdsubopreply
osd.0,pg 5.4
journal (/var/lib/ceph
filestore (/var/lib/ce
mosdopreply
293µ : Journal access
629µ : Filestore access
362µ Journal acces
599µ : Filestore access

# Zipkin UI - Annotations

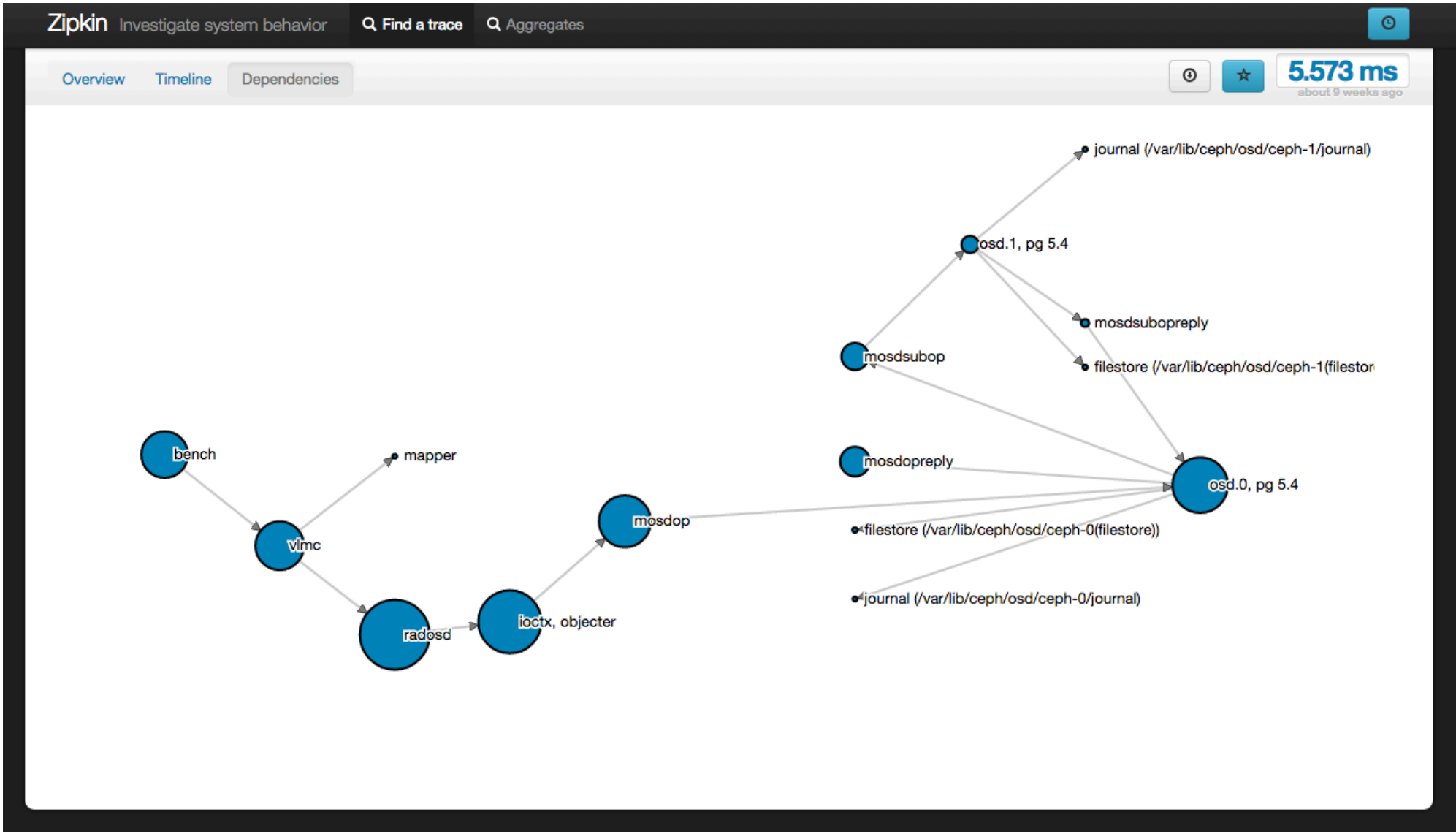



**osd.0,pg 5.4.OSD Handling op: 2.470ms**

| Relative Time | Duration | Service | Annotation | Host |
|---|---|---|---|---|
| 1.582ms | | osd.0 | waiting of osdmap | 0.0.0.0:0 |
| 1.597ms | | osd.0 | Handling op | 0.0.0.0:0 |
| 1.630ms | | PG 5.4 | Enqueuing op | 0.0.0.0:0 |
| 1.643ms | | PG 5.4 | Enqueued op | 0.0.0.0:0 |
| 1.733ms | | PG 5.4 | Dequeued op | 0.0.0.0:0 |
| 1.770ms | | PG 5.4 | Starting request | 0.0.0.0:0 |
| 1.777ms | | PG 5.4 | Handling message | 0.0.0.0:0 |
| 1.780ms | | PG 5.4 | Do op | 0.0.0.0:0 |
| 1.878ms | | PG 5.4 | Executing ctx | 0.0.0.0:0 |
| 1.934ms | | PG 5.4 | Issuing repop | 0.0.0.0:0 |
| 1.944ms | | PG 5.4 | Issuing replication | 0.0.0.0:0 |
| 1.952ms | | PG 5.4 | Sub op sent \| waiting for subops from 1 | 0.0.0.0:0 |
| 2.535ms | | osd.0 | Queueing for filestore | 0.0.0.0:0 |
| 2.547ms | | osd.0 | Queued for filestore | 0.0.0.0:0 |
| 2.619ms | | PG 5.4 | OP committed | 0.0.0.0:0 |
| 3.294ms | | PG 5.4 | OP applied | 0.0.0.0:0 |
| 3.939ms | | PG 5.4 | Sub op commit received | 0.0.0.0:0 |
| 4.009ms | | PG 5.4 | Commit sent | 0.0.0.0:0 |
| 4.026ms | | PG 5.4 | All done | 0.0.0.0:0 |
| 4.052ms | | osd.0 | Span ended | 0.0.0.0:0 |

| Key | Value |
|---|---|
| Object | marios_0000000000000001_0000000000000000 |

# Zipkin UI - Dependencies



# IO Loads - Scenarios

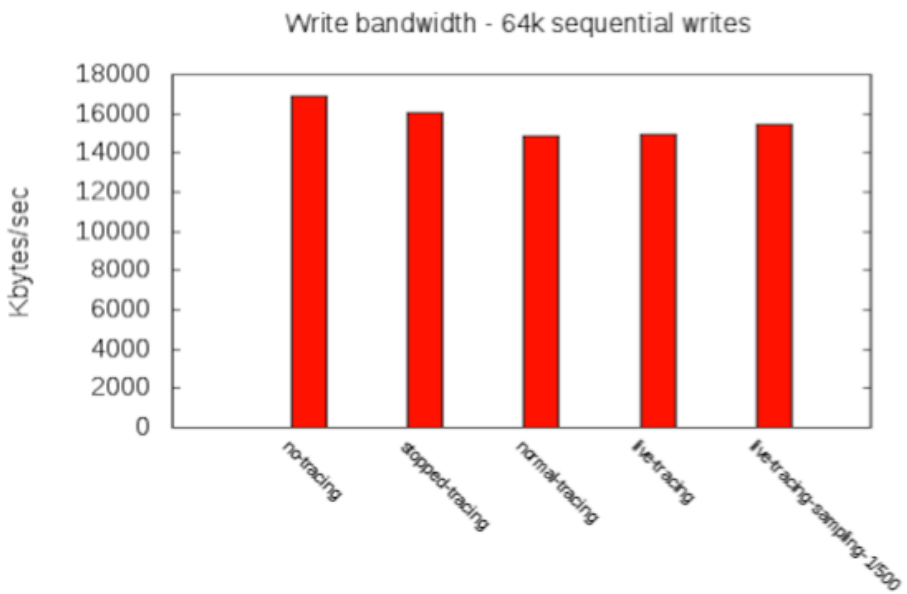
IO loads created within VM using `fio`:

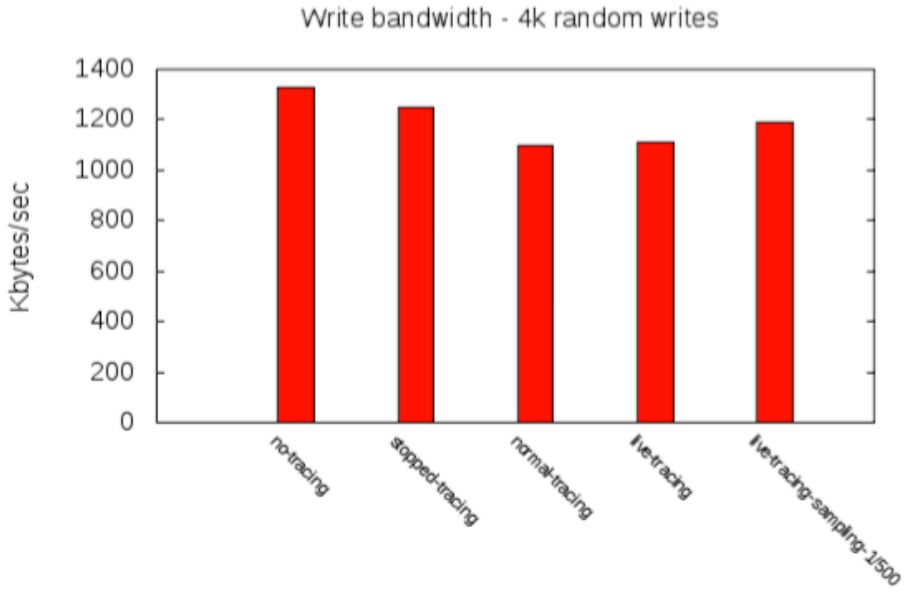
- 4k random writes
- 64k sequential writes

Scenarios:

- no tracing
- stopped tracing
- normal tracing
- live tracing without sampling
- live tracing with 1/500 sampling

# Bandwidth Overhead

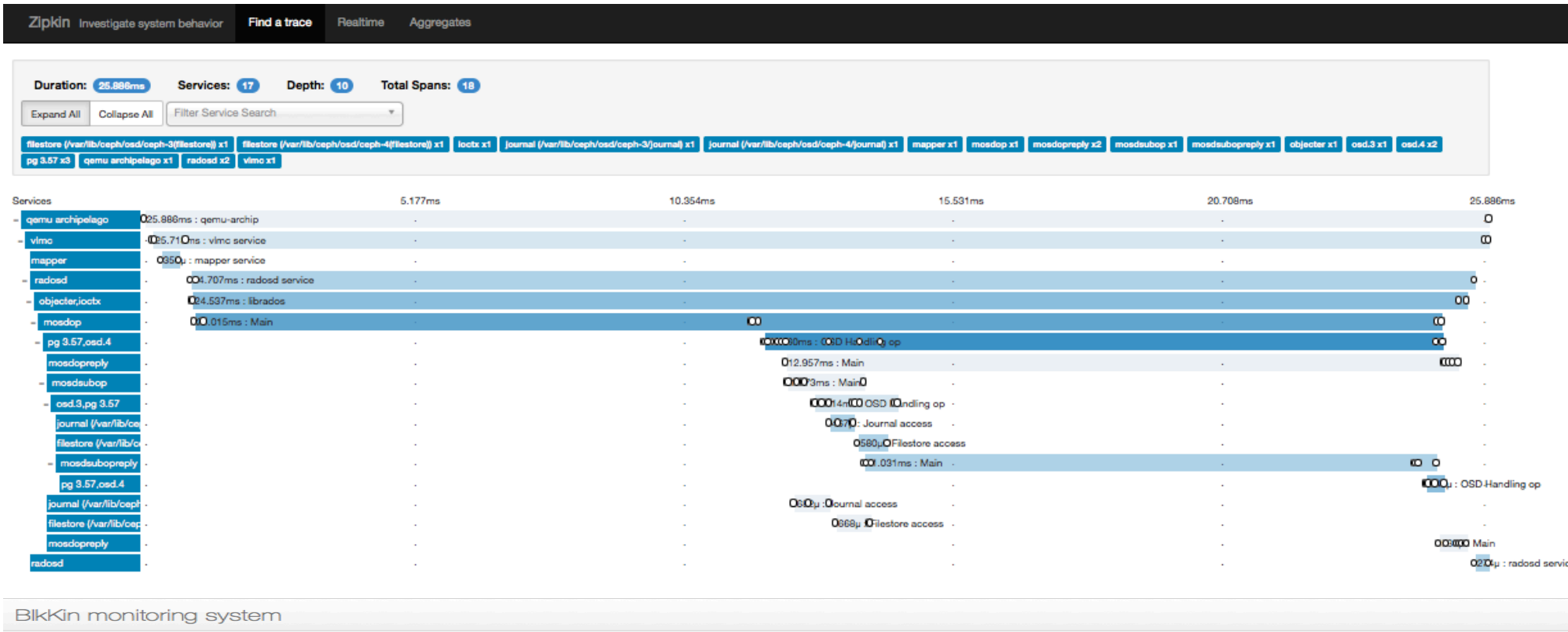


# Fault injection

1. Calculate threshold values using MapReduce in HDFS
2. Simulate faulty environment:
   - Network faults: using `tc`
   - Disk faults: adding extra IO load using `fio`
3. Detect faults using BlkKin monitoring UI

# Network fault




BlkKin monitoring system

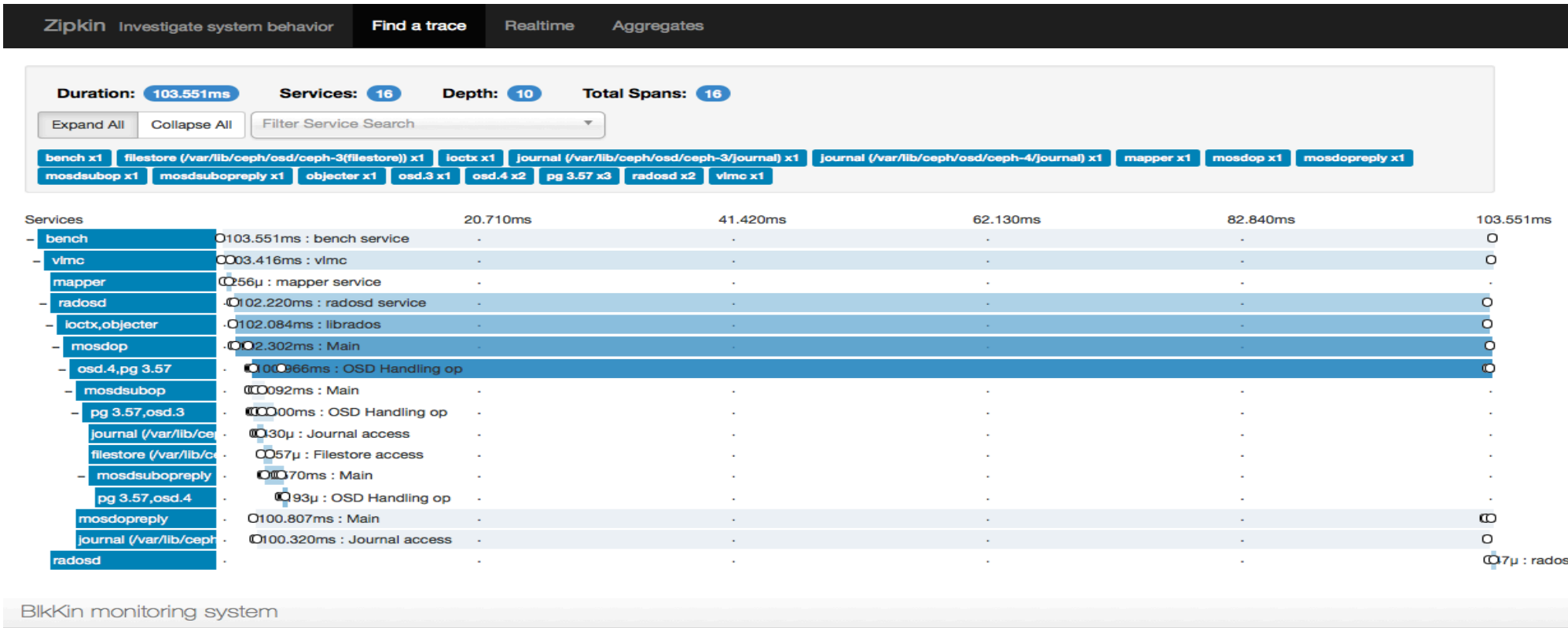
## Network monitor

| Type | Value |
|---|---|
| Communication time | 3960.1623 |

## OSD monitor

| OSD Name | Journal Access |
|---|---|
| ceph-3 | 329.708 |
| ceph-4 | 284.5664 |

# Disk fault




## Network monitor

| Type | Value |
|---|---|
| Communication time | 298.8313 |

## OSD monitor

| OSD Name | Journal Access |
|---|---|
| ceph-3 | 303.2 |
| ceph-4 | 29692.8947 |

# Summarizing

BlkKin:

- end-to-end tracing infrastructure
- based on Zipkin and LTTng
- targeting storage systems tracing
- used in QEMU, Archipelago and RADOS instrumentation

# Questions?

"Judge a man by his questions rather than by his answers."

—Voltaire

Thank you