Dissecting Overheads of Service Mesh Sidecars

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From Monolith to Microservices

Monolithic Application

Microservices
From Monolith to Microservices

Frontend

Payment
Product
User
Ad

Function calls

Frontend

Payment
Product
User
Ad

RPCs
Microservices need rich message processing

- Service discovery
- Access control
- Load balancing
- Encryption
- Observability
- Fault tolerance

Diagram:
- Frontend
  - Payment
  - Product
- User
- Ad
- RPCs
Solution: Service Mesh with Sidecar Pattern

90% of the organizations either using or evaluating service mesh

- From a 2022 CNCF Survey¹

¹Service meshes are on the rise - CNCF ‘22
Performance Overhead vs. Functionality

"We are frequently asked how fast is Envoy? ... The answer is: it depends. Performance depends a great deal on which Envoy features are being used and the environment in which Envoy is run...."

- From Envoy FAQ

● Balancing performance and functionality
  ○ What is the latency and CPU usage impact with a given configuration

● Evaluating the impact of optimizations
  ○ What are the primary sources of overhead of a given configuration?
  ○ What if I use an alternative the IPC mechanism between application and sidecars?
Ad-hoc Configuration Tuning is inefficient

- Black-box measurement of different configurations and workloads

- Key limitation:
  - Combinatorial configuration space
    - Protocol
    - Envoy features
    - Workload (Request size and rate)
    - …
MeshInsight: Dissecting Sidecar Overheads

**Goal**: systematically quantify the service mesh sidecar overheads for developers to

- Navigate the performance and functionality tradeoff
- Estimate the impact of their optimizations
Service Mesh Data Path

**without sidecar**

- App
- Read
- TCP/IP
- NIC
- Requests

**with sidecar**

- App
- Read
- TCP/IP
- NIC
- envoy
- Write
- TCP/IP
- Loopback
- Requests

Sidecar Proxy
- TCP Filter
- HTTP Codec
- Rate Limit Filter
- Log Filter
- Stats Filter
- Router Filter

Message processing inside a sidecar
Modeling per-Sidecar Overheads

- Breakdown the overhead into fine-grained components
  - Independent from each other
  - Total overhead = Sum (overhead of each component)

- Metrics
  - Latency (service time)
  - CPU usage
Building Component Profiles

- Component profile is a linear function of message size and rate
  - Latency: $L_x + message\_size \times l_x$
  - CPU: $message\_rate \times (C_x + message\_size \times c_x)$
Predicting the End-to-end the Overhead

- **Extended Call Graph (ECG)**
  - Captures service communication patterns, platform specs, sidecar configurations, and workload information
- E2E overhead = sum of all sidecar-level overheads in ECG
  - Latency overhead requires critical path analysis
MeshInsight Architecture

CPU = “Intel Xeon ...”
OS = “Linux 5.4.0”
OSConfig = “...”
Cont = “K8s 1.23”
SM = “Istio 1.13”
Proxy = “Envoy 1.21” ...
MeshInsight Architecture

Platform Configuration
- CPU = “Intel Xeon …”
- OS = “Linux 5.4.0”
- OSConfig = “…"
- Cont = “K8s 1.23”
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MeshInsight Profiler
- PC
- LP
- CUP

MeshInsight Database

Offline Profiling
- Latency Profile (LP)
- CPU Usage Profile (CUP)

Online Prediction
- MeshInsight Predictor
- CRISP
- Speedup Profile
- Jaeger Traces

Performance Predictions
- Avg Latency:
  - Read +0.5ms,
  - Write +0.7 ms, ...
- Avg CPU Usage:
  - Read +1 vCPUs, ...

https://github.com/UWNetworksLab/meshinsight
Implementation

- Implementation:
  - Istio v1.13 and Envoy v1.21
  - Each component is profiled using an echo server
    - eBPF for latency
    - perf for CPU usage
Evaluation

- Synthetic benchmark
  - Hotel Reservation
- Real-world microservice traces
  - Alibaba microservice trace (~20K services, >20M call graphs)
How Well Can MeshInsight Predict Overhead?

- MeshInsight provides accurate prediction of latency and CPU usage overhead
How Much Overhead Do Sidecars add?

- gRPC mode can increase the latency by up to 2.7X and CPU usage by up to 1.6X
- TCP mode overhead are lower but still noticeable
What Are the Primary Contributors of Latency Overhead?

- IPC, Read, and Write are the major sources of overhead in TCP mode
- Parsing dominates in HTTP mode

TCP Mode (+41µs)

- IPC: 30.0%
- Write: 34.0%
- Notification: 3.0%
- Sidecar Other: 12.0%

HTTP Mode (+165µs)

- Sidecar Parsing: 76.2%
- Read: 7.9%
- Write: 5.0%
- IPC: 6.9%
- Notification: 1.0%
- Sidecar Other: 3.0%

Message size is set to 100B
How Do Overheads Vary Across Configurations/workloads?

- Performance overhead varies by orders of magnitude for
  - Different configurations

CDF of Latency and CPU usage overhead for Alibaba Microservice Trace

Characterizing Microservice Dependency and Performance: Alibaba Trace Analysis - SoCC’21
How Do Overheads Vary Across Configurations/workloads?

- Performance overhead varies by orders of magnitude for
  - Different configurations
  - Different call graphs

Absolute Latency and CPU usage overhead for Alibaba Microservice Trace
What Are the Impacts of Common Linux Features?

- Different optimizations have different impacts
  - Zero-copy write offers negligible improvement
  - Unix Domain socket can provide notable benefits
Conclusion

● Present MeshInsight, a tool to systematically quantify overhead of service mesh sidecars
  ○ Breaks down the data path into independent components
  ○ Predict the overhead based on extended call graphs
● Total Overhead and components' contribution varies substantially in different settings
● Some optimizations can help reduce overhead others do not
● MeshInsight is available at: github.com/UWNetworksLab/meshinsight