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RPCShield

Defending Microservices Against Cascading Failures

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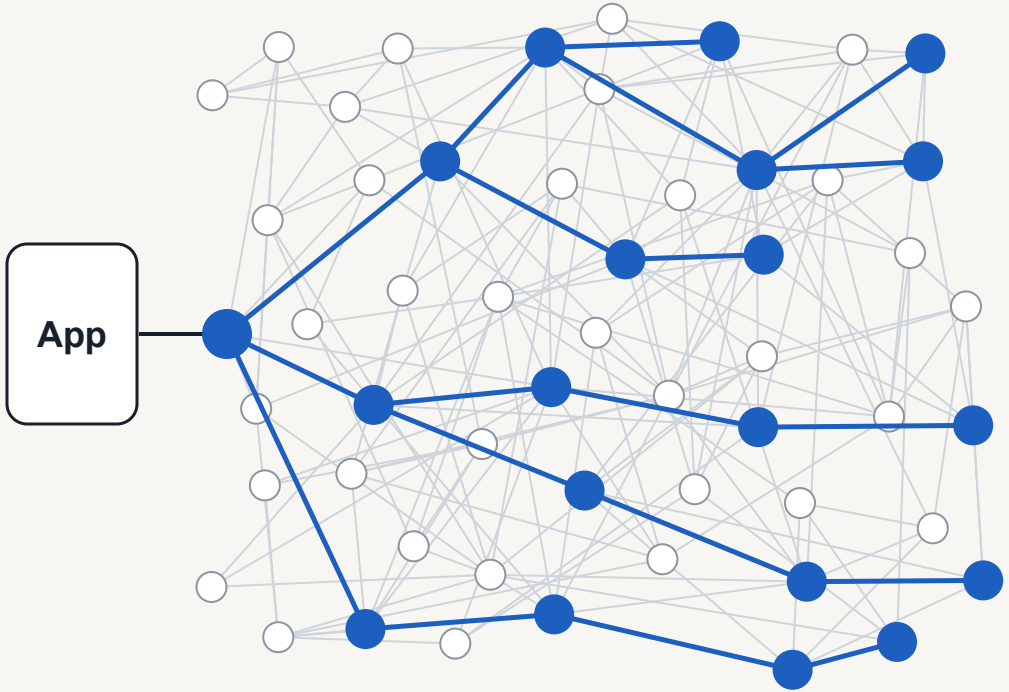
github.com/uber-research/rpcshield

Uber

MOTIVATION

Every tap in the app fans out into many RPCs



One request fans out at many levels

6,000+

microservices

10s of trillions

RPCs per week

1.8M

outbound RPC call sites

MOTIVATION

Not all services are equally critical

	Role	Services
T0	Infrastructure	151
T1	User-facing	1,490
T2	Business-critical	965
T3	Critical tooling	1,787
T4	Employee tooling	491
T5	Auxiliary workloads	1,311

Critical: T0–T2 · **Lower: T3–T5**

~50%

of all RPCs go from a **more-critical** to a **less-critical** tier

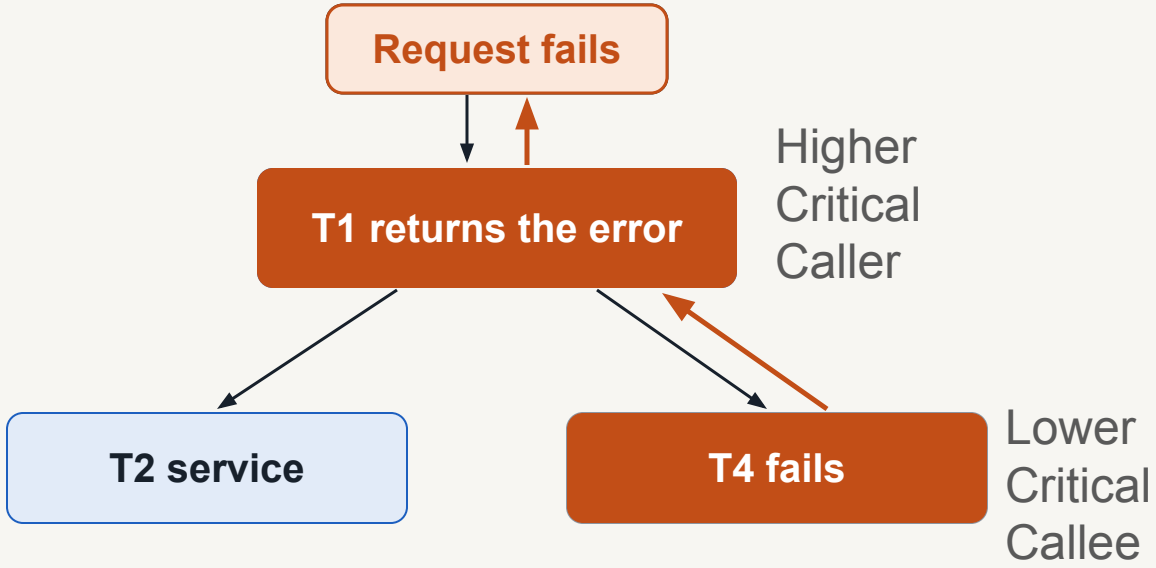
T1 alone sends **~66%** of that traffic

MOTIVATION

A low-tier failure can take down a critical service

Why would T4 fail?

- Failover preemption
- A bad deploy
- Overload, flaky API



Fail-close: the caller fails because a dependency failed

THE PROBLEM

Fail-close vs. fail-open: one line apart

Fail-close

```
func GetFare(req) (*Fare, error) {
  promo, err := promo.Get(req) // RPC
  if err != nil {
    return nil, err
  }
  return price(req, promo), nil
}
```

Promo down → fare request fails

Fail-open

```
func GetFare(req) (*Fare, error) {
  promo, err := promo.Get(req) // RPC
  if err != nil {
    promo = NoPromo
  }
  return price(req, promo), nil
}
```

Promo down → fare without promo

Identical in normal operation; the difference shows only when the dependency fails.

43

highest-severity, customer-facing outages at Uber were caused by fail-close dependencies (2020–2023)

≈ 10 every year

Industry-wide problem: cross-system errors are a leading cause of cloud incidents (Google, Azure, and AWS) — Tang et al., EuroSys ’23

THE PROBLEM

Why fail-close is hard to catch

Latent

Invisible until the dependency fails

Everywhere

~1.8M call sites, deep in call paths

Always changing

Any diff can regress a safe path

We need detection that is…

- In code
- Before deployment
- At fleet scale
- On every diff
- Attributed to code paths

THE SOLUTION

RPCShield

- ✅ In code
- ✅ Before deployment
- ✅ At fleet scale
- ✅ On every diff
- ✅ Attributed to code paths

✅ github.com/uber-research/rpcshield

KEY INSIGHT 1

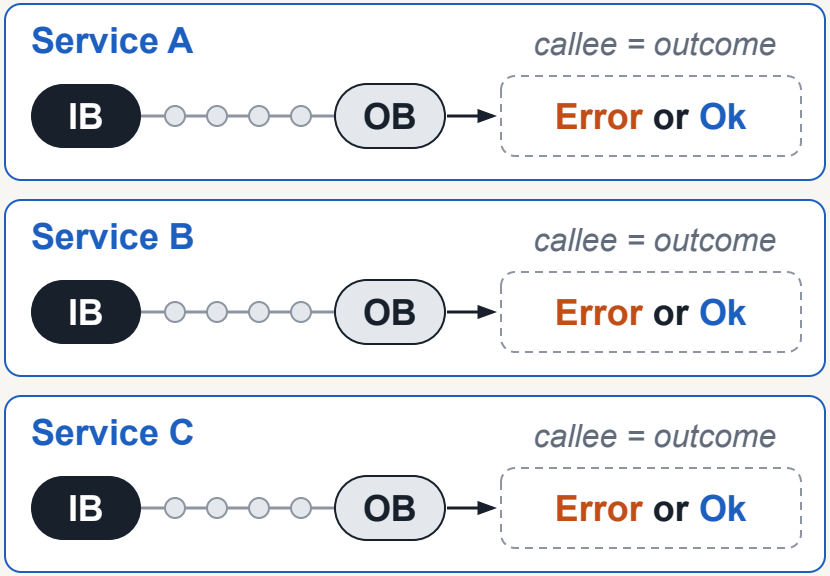
Fail-close is a per-service property

Whether an endpoint fails depends only on **its service's own code**.

A callee enters only as its **outcome**: Error or Ok.

So we can…

- analyze each service alone
- in parallel, in CI
- re-analyze only what a diff touches



One independent analysis per service

KEY INSIGHT 2

What does “caused by” mean?

```
1  func handler() (*S, error) {
2    r1, err1 := rpcA() // Primary
3    if err1 != nil {
4      r2, err2 := rpcB() // Fallback
5      if err2 != nil {
6        return nil, ErrNotFound
7      }
8      return r2, nil
9    }
10   return r1, nil
11 }
```

A fallback pattern from our production corpus

Both errors reach line 6. Which dependency is to blame?

Error reachability (taint):

blames **rpcA and rpcB**

Intuition:

blame **rpcB only**: rpcA already has a fallback

KEY INSIGHT 2

A counterfactual (“but-for”) definition

```
1  func handler() (*S, error) {
2    r1, err1 := rpcA() // Primary
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```

A fallback pattern from our production corpus

Inbound RPC c is **fail-close** on outbound RPC **e** if, in some failure scenario:

1 e fails and c returns Error

2 had e and e **succeeded**, c returns Ok

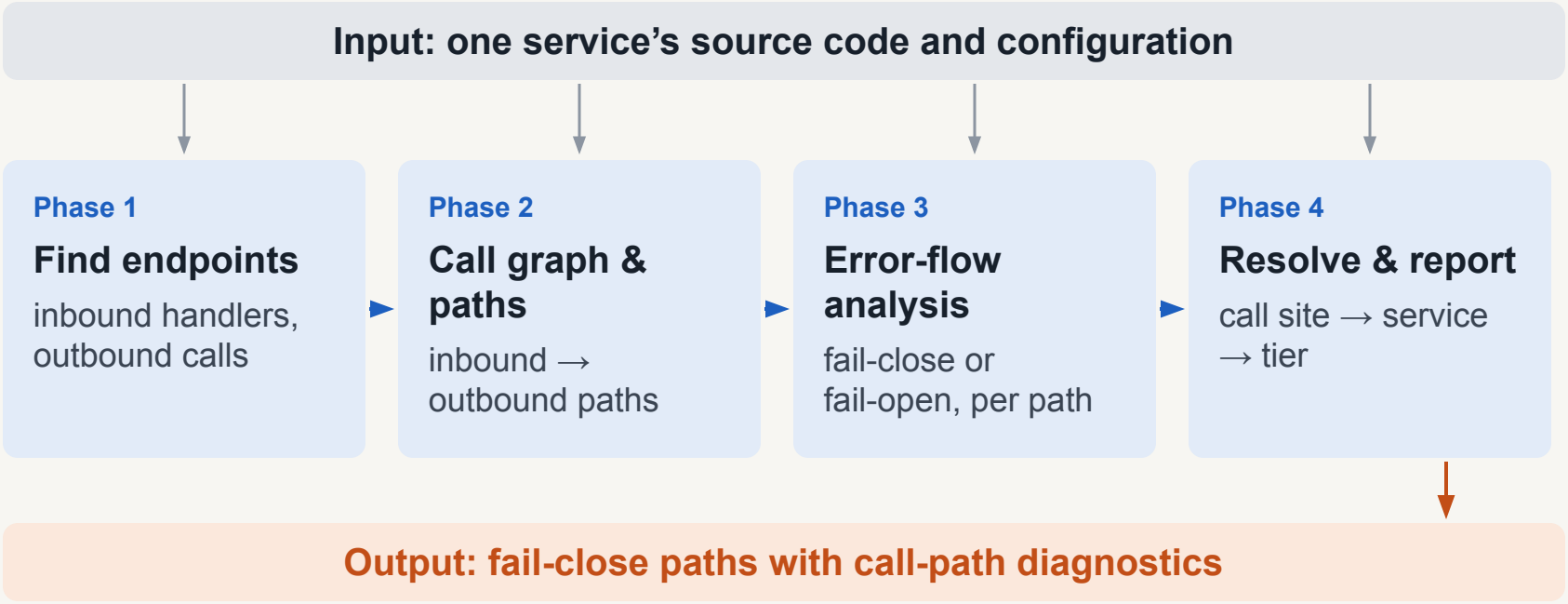
3 no RPC after e fails in either case

Scenario = an oracle fixing each RPC outcome

Intuition: isolate the cause of the failure to a single RPC

DESIGN

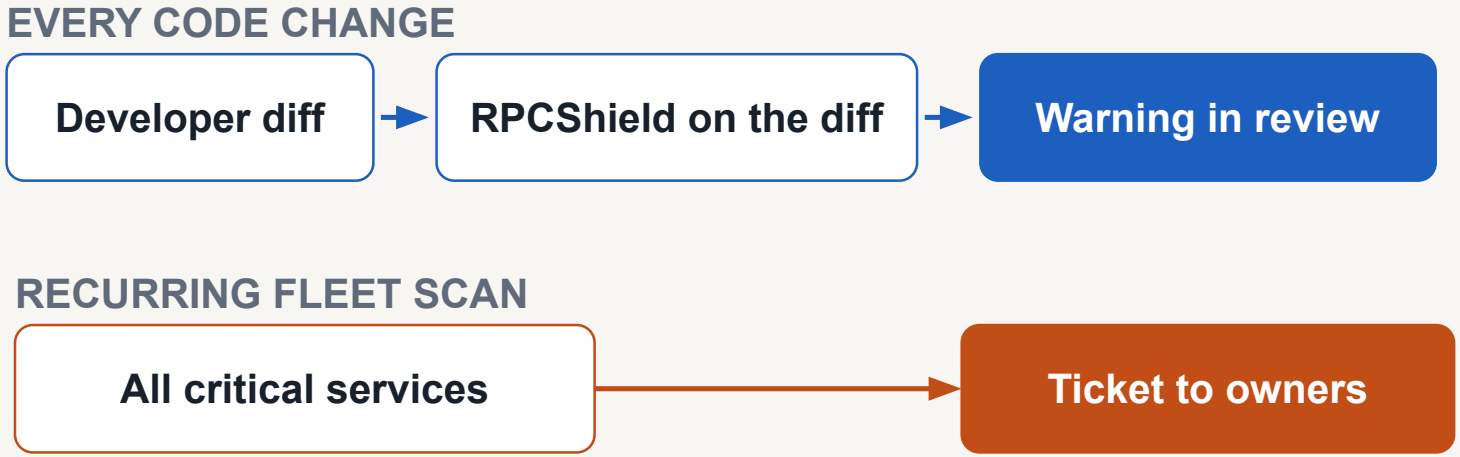
A four-phase pipeline, run per service



DEPLOYMENT

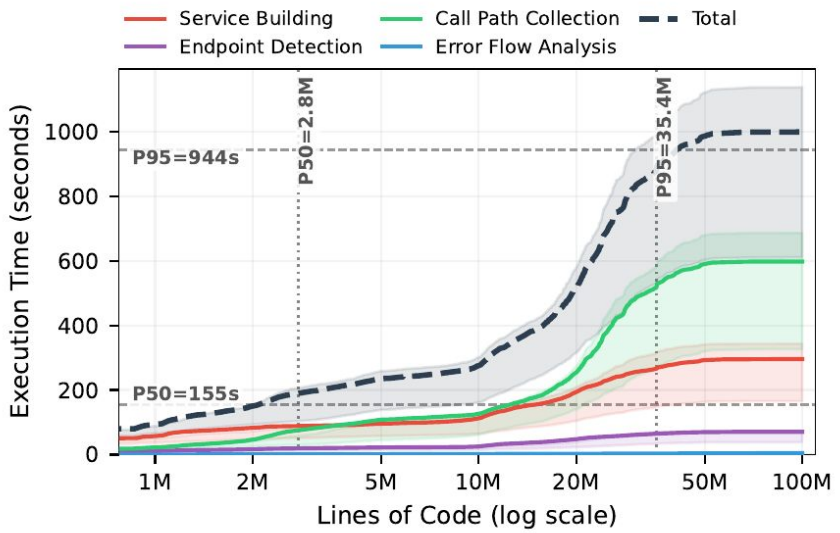
Built for production: runs on every diff

3.8K Fail-close issues found



INTRINSIC EVALUATION

Fast enough for CI, even at 35M lines



3,944 services · median Go service 2.8M lines, P95 35.4M

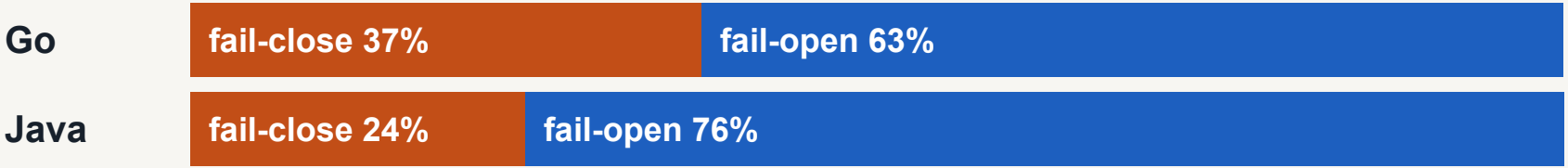
PER-SERVICE ANALYSIS TIME

	median	P95
Go	**2.5 min**	**16 min**
Java	**1 min**	**3 min**

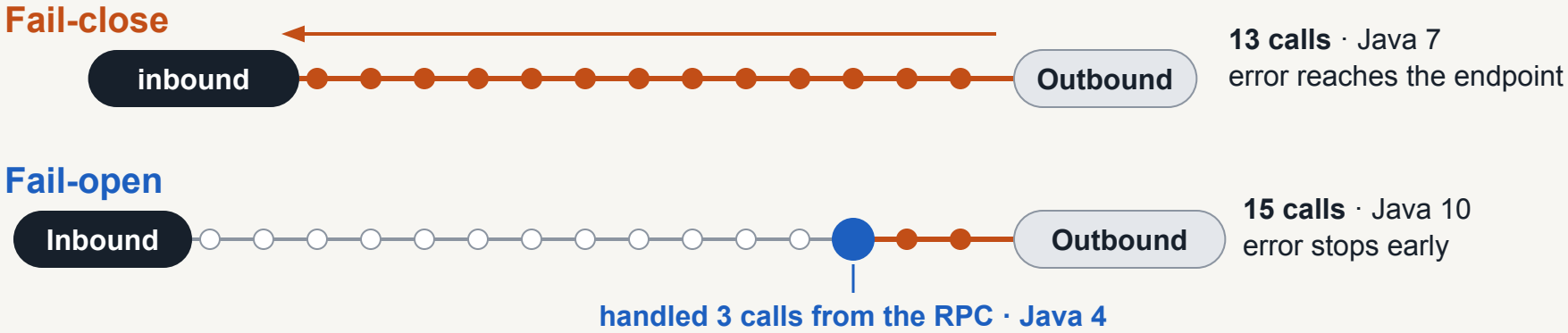
Error-flow analysis itself takes seconds.

What the paths look like: fail-close vs. fail-open

PATH SPLIT (Java: synchronous paths)

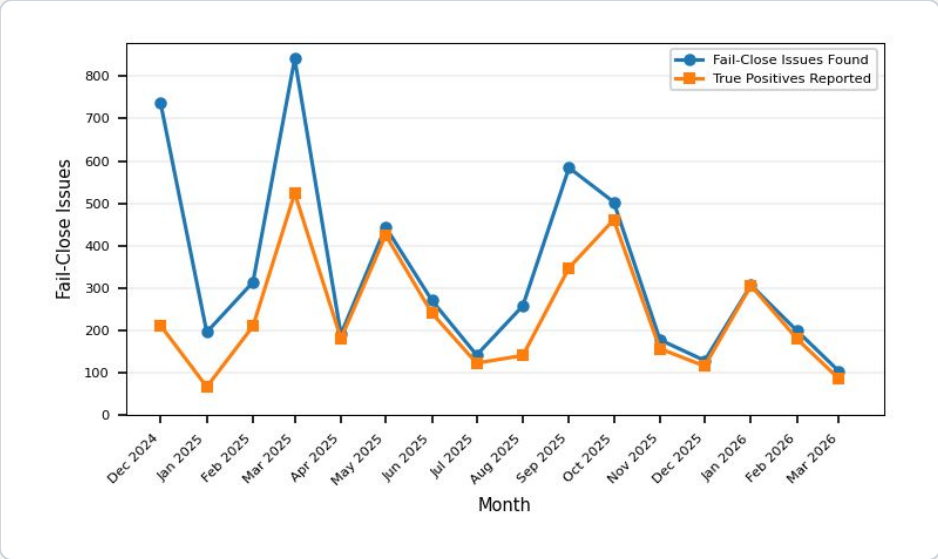


PATH LENGTH AND WHERE THE ERROR STOPS (median calls, Go · Java)



EXTRINSIC EVALUATION

Precise enough that owners trust it



Found vs. true positives per month (Go). TP-rate fit: **54%** → **97%**

< 5%

false positives

< 2.5%

missed vs. runtime analysis

43 / 43

past outages flagged

ADOPTION

Developers: real risks, quick fixes

58%

said it could have caused a major outage (L4/L5)

72%

fixed it within five days of work

1.4K

violations remediated by owners

58%, 72%: survey of 155 engineers who resolved tickets. 1,359: ticket records.

IMPACT

Fail-close outages at Uber

2020–2023

≈10

per year (43 in total)

2025

0

cross-tier fail-close incidents

IMPACT

RPCShield's assurance powers tiered SLAs at Uber

Before
~4M cores
~20% utilized

Tiered SLAs
~3M cores
~31% utilized

On failover, low tiers are preempted for critical ones.

Uber's Failover Architecture — Bansal et al., NSDI '26

~1M

of ~4M CPU cores returned

Preemption is safe **only if no T0–T2 service is fail-close on it.**

RPCShield assures this on every diff.

Contributions

THE PROBLEM Fail-close dependencies have long caused cascading outages

THE IDEA A clean, counterfactual definition of fail-close, mapped to static analysis

10/year → 0/year

top-severity fail-close outages: 2020–23 average → none attributed in 2025

~3.8K

fail-close violations caught across ~4K Go & Java services

1M of 4M

CPU cores freed by tiered SLAs, made safe by RPCShield

WHAT'S NEXT Cross-service analysis of retry storms, data flows, storage, as AI writes code few developers read

github.com/uber-research/rpcshield

Thank you! Questions?

Milind Chabbi

Uber