eBPF-Based Auto-Instrumentation for Java

OpenTelemetry eBPF Instrumentation (OBI) Project

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Why talk about Java eBPF

Talk Agenda

01
The Problem Space
When Java agents can't help

02
OBI Architecture
How OBI correlates kernel events with app semantics

03
Java + eBPF Challenges
JDKs, JVM internals, TLS, frameworks

04
TLS Decryption Deep-Dive
Seeing through encrypted connections

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Operational Value
Real-world scenarios & full-stack correlation

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Live Examples
Spring Boot · gRPC · Quarkus · Keycloak · Kafka

07
Trade-offs & Limits
What works today, what doesn't

The Problem Space

When Java agents can't help

Production Lock-Down

Ops/security teams prohibit JVM deployment modifications

Third-Party Apps

Can't modify startup of vendor-managed services

Regulated Environments

Compliance requirements restrict agent injection

Legacy Systems

Old app servers that are incompatible or run old JVMs

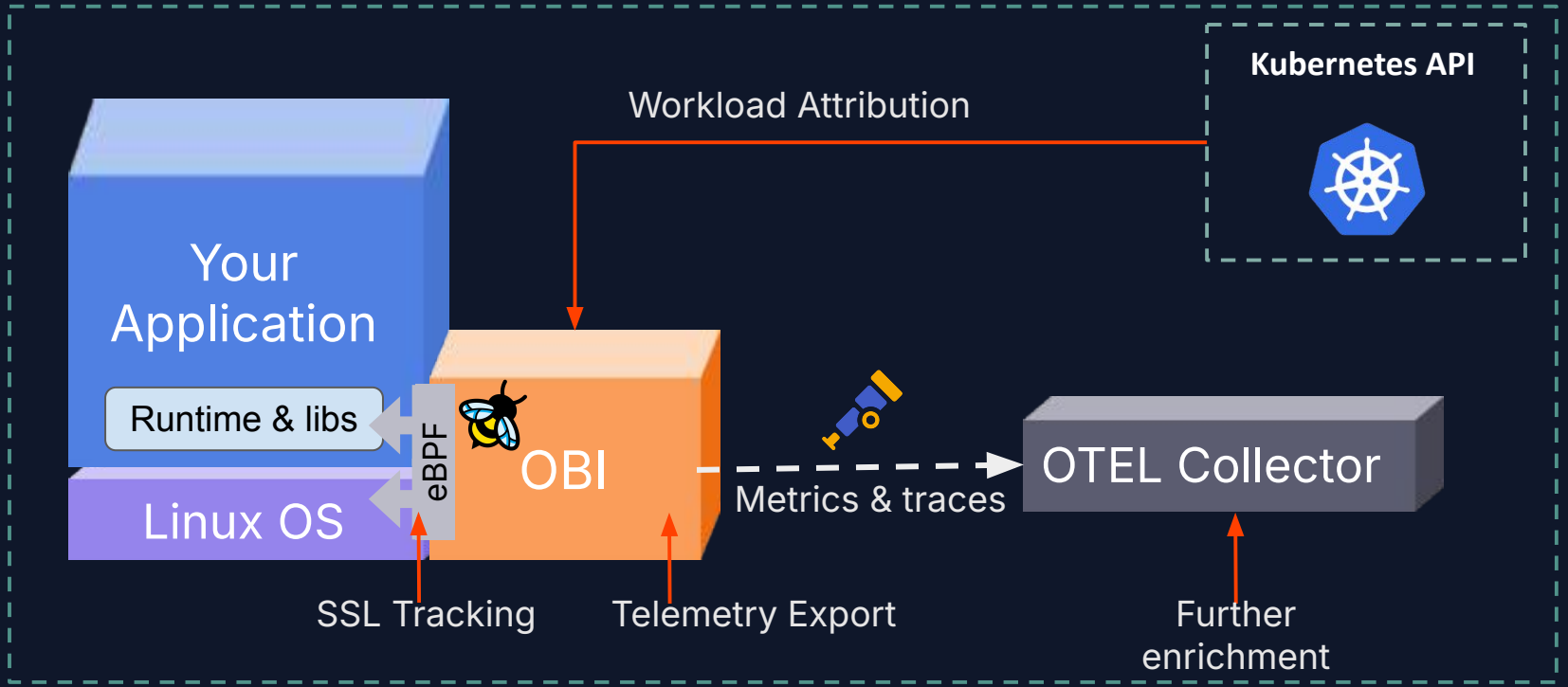
~60%

of enterprises report restrictions on agent deployment in production

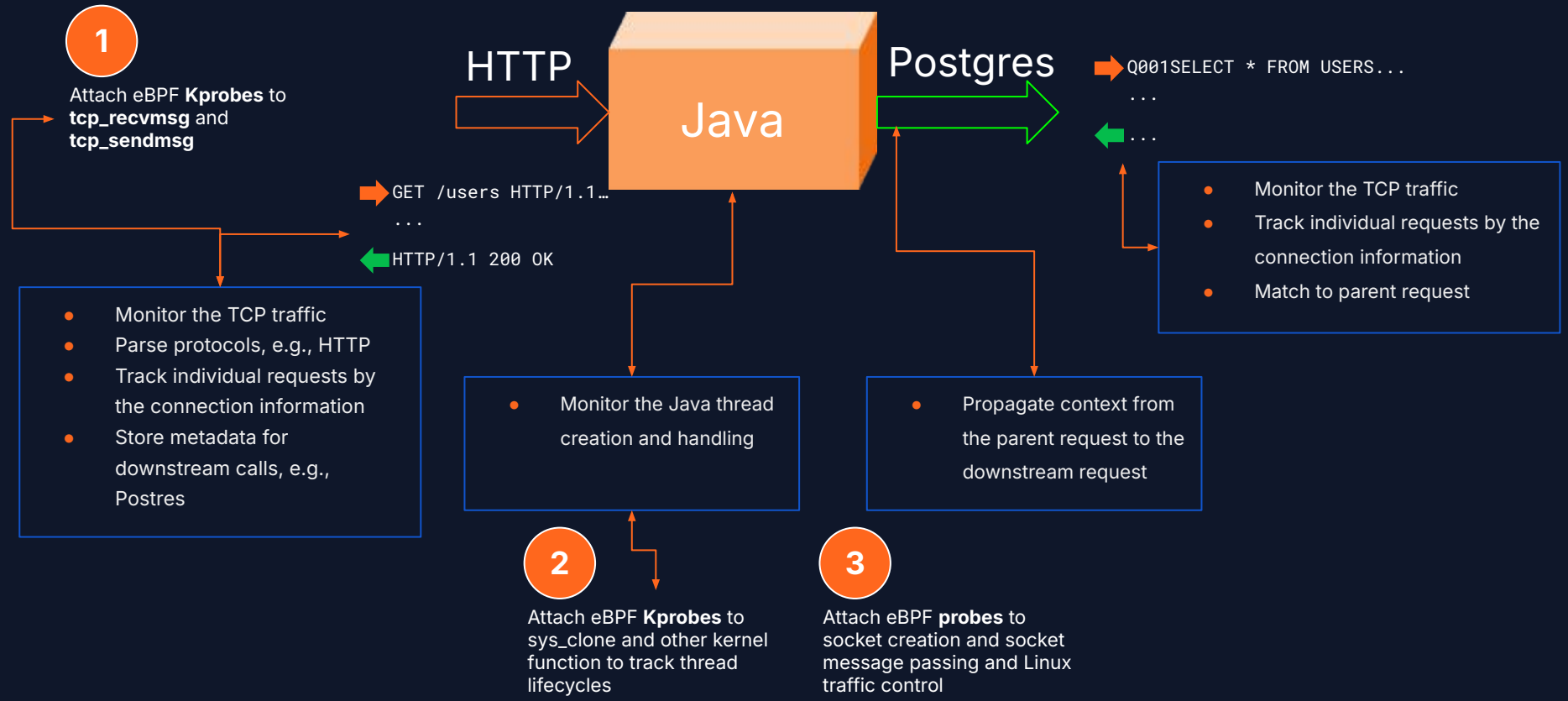
eBPF offers a path forward without touching the JVM

OBI at a glance

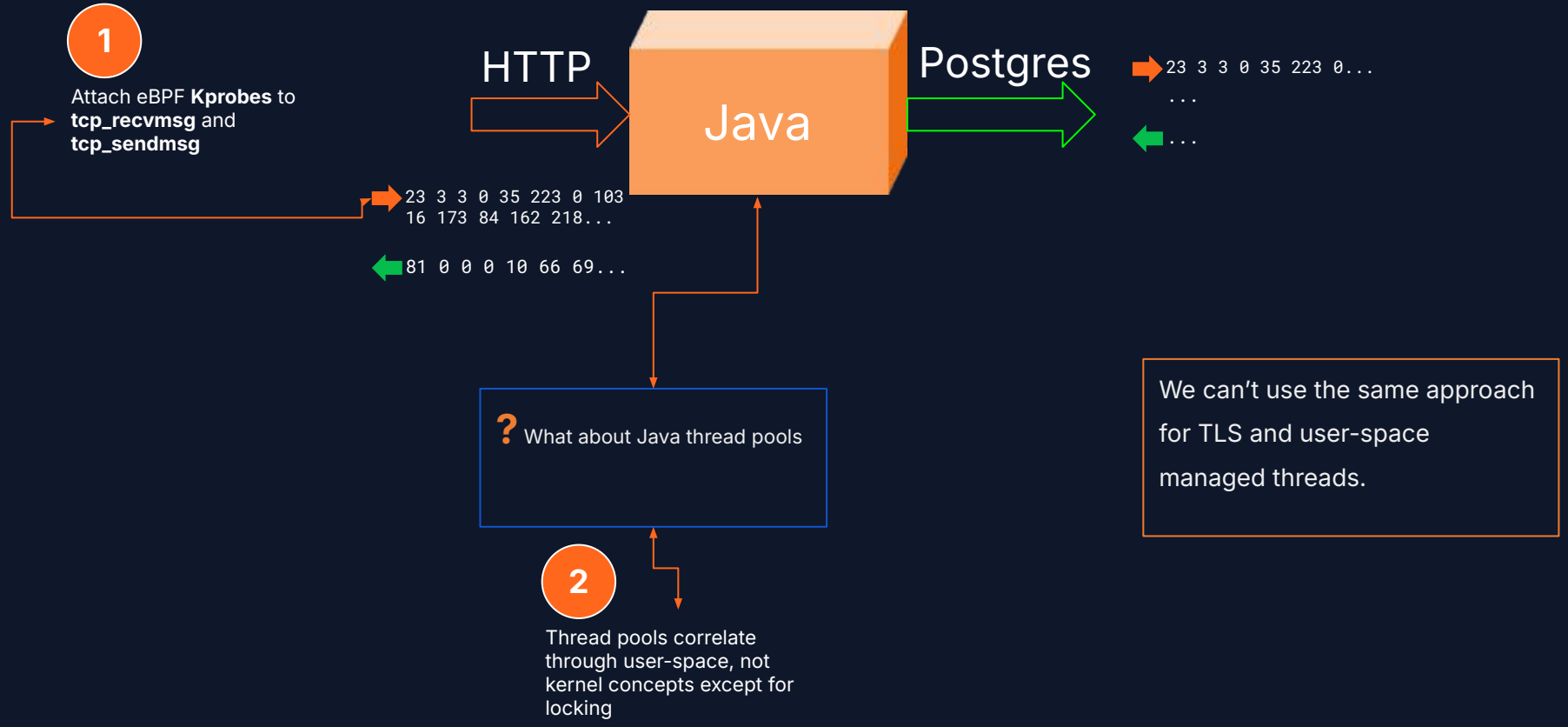
OBI architecture overview



OBI instrumenting a Java application



OBI instrumenting a Java TLS application



We can't use the same approach for TLS and user-space managed threads.

Java + eBPF: The Hard Parts

A combinatorial explosion of complexity

JDK Diversity

Oracle JDK · OpenJDK · Eclipse Temurin · Amazon Corretto · GraalVM — each with internal differences

JIT Compilation

JVM optimizes code at runtime; symbol addresses shift, inlining changes what to instrument.

TLS Everywhere

HTTPS, gRPC, encrypted DB/Kafka — payloads are ciphertext to the kernel without special handling.

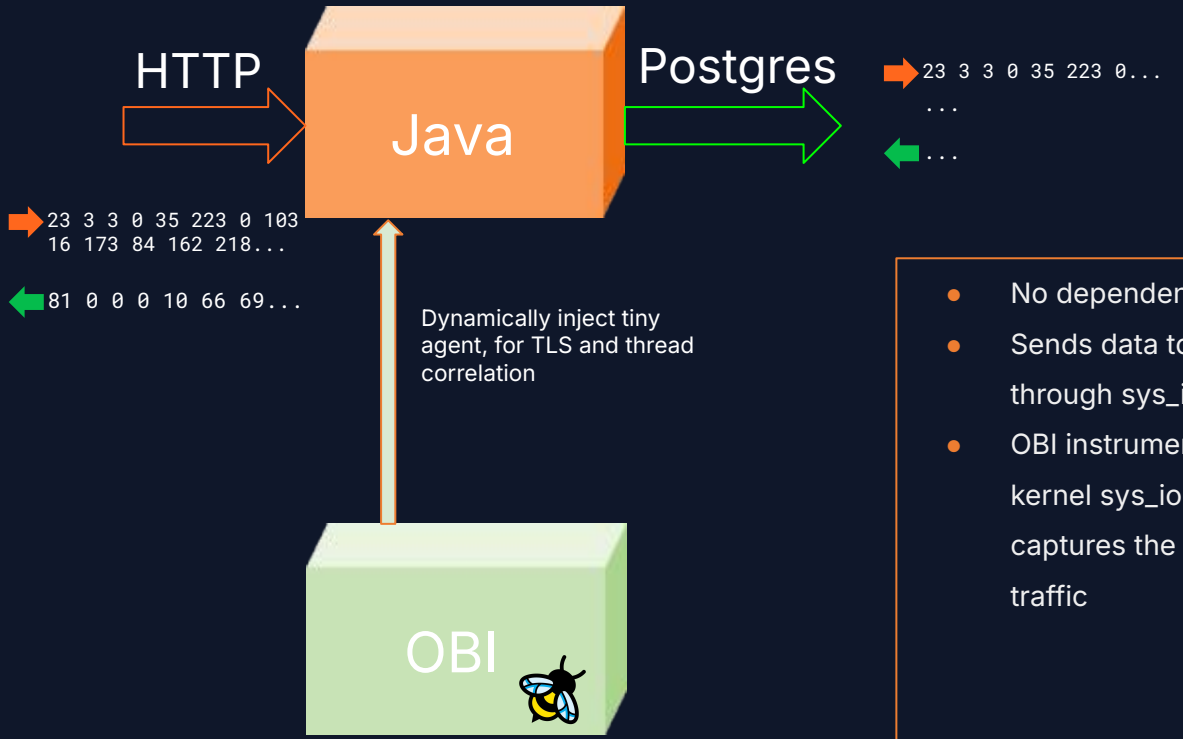
Async / Reactive

Project Reactor, CompletableFuture, virtual threads — correlation across async boundaries is non-trivial.

Anonymous JIT generated code

No uprobes support for anonymous code regions, not without serious hacks.

OBI instrumenting a Java TLS application, again



- No dependencies agent
- Sends data to the kernel through sys_ioctl
- OBI instruments the kernel sys_ioctl and captures the decrypted traffic

TLS Decryption Deep-Dive

Seeing through encrypted connections — without a proxy

THE CHALLENGE

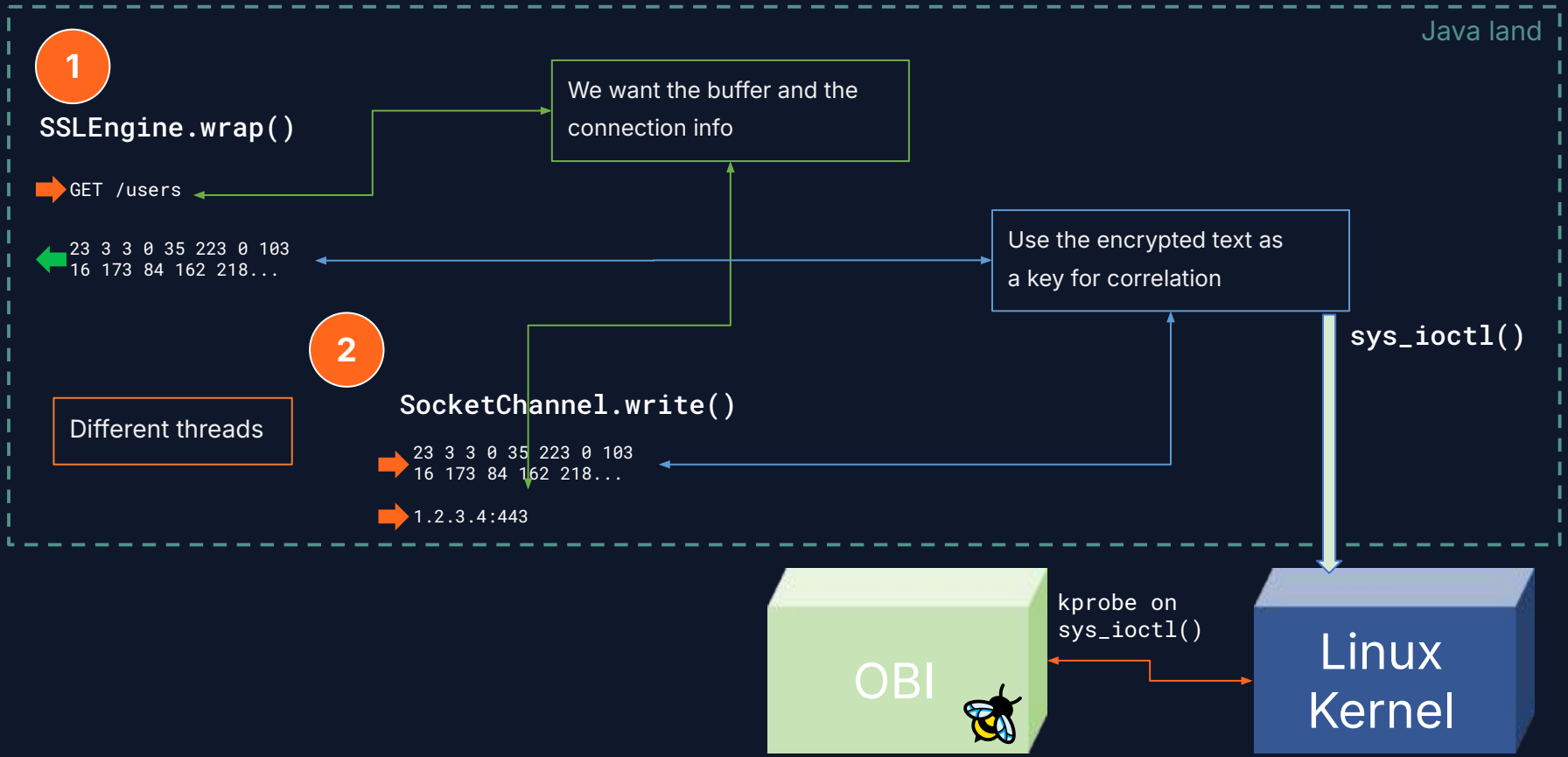
- ✗ Kernel sees only ciphertext on the wire
- ✗ HTTPS, gRPC, TLS-Postgres, TLS-Kafka all affected
- ✗ Traditional MITM proxies break mTLS & add latency
- ✗ SSL_read/SSL_write in OpenSSL/BoringSSL hold plaintext in memory
- ✗ Java has its own TLS implementation written in Java

OBI'S APPROACHES

- Uprobe on SSL_write / SSL_read (OpenSSL & BoringSSL)
- Hook fires before encrypt / after decrypt — plaintext visible
- Injects tiny OBI agent to read Java TLS
- Correlate via encrypted/decrypted buffer pairs
- Works with Java 8 through 25+, GraalVM native images partially

PR #891 — open-telemetry/opentelemetry-ebpf-instrumentation

Async Java TLS encryption



Real-World Examples

Public, reproducible repositories — try them yourself!

01

Spring Boot + HTTPS + Keycloak

Spring Boot · OpenID Connect · TLS

OBI captures OAuth token exchange and downstream REST calls, all over HTTPS

github.com/esara/java-keycloak-microservices

02

Spring Boot + gRPC + Google Pub/Sub

Spring Boot · gRPC · Protobuf · mTLS

OBI decodes HTTP/2 framing and gRPC method semantics from encrypted streams

github.com/esara/pubsub-java-microservices

03

Quarkus + TLS PostgreSQL + Kafka

Quarkus · JDBC TLS · Kafka TLS

Database queries and message production captured with full span correlation

github.com/esara/quarkus-super-heroes

Trade-offs & Current Limitations

What works today — and where the edges are

✓ WORKS RELIABLY TODAY

- HTTP/1.1 & HTTP/2 over TLS (OpenSSL/BoringSSL)
- gRPC method name & status extraction
- Spring Boot (2.x, 3.x) service-to-service calls
- JDBC over TLS (PostgreSQL driver)
- Kafka producer/consumer with TLS
- Distributed trace context propagation via W3C headers
- Quarkus and most CDI-based frameworks

⚠ CURRENT LIMITATIONS

- GraalVM native image (AOT): partial support
- Java TLS requires OBI to inject a small agent
- Reactive / async span correlation (in progress)
- JDK 21+ virtual threads: correlation gaps
- Windows / macOS (Linux-only today)

eBPF vs OTel Java Agent: When to Choose What

Complementary tools — not competitors

Scenario	OTel Java Agent	eBPF (OBI)
Full semantic instrumentation needed	✓ Best choice	Partial
Code / JVM modification prohibited	✗	✓ Best choice
Third-party / black-box services	✗	✓ Best choice
gRPC + TLS traffic	✓ Agent needed	✓ OBI (PR #891)
Custom business metrics	✓ Best choice	Limited
Zero-touch production roll-out	Complex	✓ Best choice
GraalVM native binary	✗ No JVM	Partial (improving)
Multi-language service mesh	Per-language	✓ Unified

Key Takeaways

- eBPF instrumentation is a viable alternative when Java agents cannot be deployed
- OBI correlates kernel-level events with application semantics — no JVM changes needed
- TLS decryption via small dynamically injected agent unlocks visibility into all major encrypted protocols
- Trade-offs exist: prefer OTel JDK agents where full semantic depth is required
- Active upstream development — join us in the OBI project!

Links & Resources

OBI Project
github.com/open-telemetry/opentelemetry-ebpf-instrumentation

Feature Discussion (#880)
github.com/open-telemetry/opentelemetry-ebpf-instrumentation/issues/880

Implementation PR (#891)
github.com/open-telemetry/opentelemetry-ebpf-instrumentation/pull/891

Example: Spring Boot + Keycloak HTTPS
github.com/esara/java-keycloak-microservices

Example: Spring Boot + gRPC + Pub/Sub
github.com/esara/pubsub-java-microservices

Example: Quarkus + TLS Postgres + Kafka
github.com/esara/quarkus-super-heroes