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INTISARI

DISTRIBUTED TRACING OUT-OF-BAND: KORELASI TRACE IMPLISIT BERBASIS EBPF UNTUK MIKROSERVIS POLIGLOT

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Distributed tracing merupakan komponen utama observabilitas sistem mikroservis, namun pendekatan instrumentasi aplikasi yang dominan membebani kinerja sekaligus menuntut upaya pengembang yang signifikan, terutama pada lingkungan poliglot. Penelitian ini merancang, mengimplementasikan, dan mengevaluasi SonarProbe, sebuah prototipe *distributed tracing* berbasis eBPF yang mengamati komunikasi antar-layanan pada *transport layer* (L4) secara non-intrusif dan agnostik terhadap protokol.

Sistem tidak menyuntikkan konteks *trace*; korelasi antar-layanan dilakukan secara implisit melalui pencocokan koneksi dan penilaian temporal, sedangkan korelasi intra-layanan memanfaatkan *uprobe* spesifik-*runtime*. Evaluasi pada *testbed* poliglot enam layanan dalam lima bahasa (HTTP/1.1, gRPC/HTTP-2, PostgreSQL, AMQP) menggunakan SDK OpenTelemetry sebagai *ground truth* pada variasi beban *single-node* dan *multi-node* untuk *plaintext* dan TLS.

Akurasi rekonstruksi *trace* mencapai 87,1%–99,2% pada rentang 1–16 `rps` dengan presisi 100% pada rentang beban operasional 1–32 `rps` (tanpa *edge* palsu). Lalu lintas TLS tidak menurunkan akurasi. *Overhead* memori dan latensi jauh lebih rendah daripada SDK, namun CPU membentuk titik silang yang melampaui SDK pada beban tinggi. Berdasarkan temuan, pendekatan ini paling sesuai untuk skenario yang mengutamakan ketepatan struktural relasi antar-layanan, seperti *service dependency mapping*, maupun lingkungan yang didominasi TLS dan poliglot, dibandingkan sebagai pengganti instrumentasi produksi pada *throughput* tinggi, dengan batas akurasi korelasi implisit sebagai *trade-off* yang diterima.

Kata kunci: eBPF, *distributed tracing*, *out-of-band*, mikroservis poliglot, lintas-protokol, korelasi implisit

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ABSTRACT

OUT-OF-BAND DISTRIBUTED TRACING: EBPF-BASED IMPLICIT TRACE CORRELATION FOR POLYGLOT MICROSERVICES

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Distributed tracing is an essential component of microservice observability, yet the dominant application-instrumentation approach incurs performance overhead and requires significant developer effort, especially in polyglot environments. This research designs, implements, and evaluates SonarProbe, an eBPF-based distributed tracing prototype that observes inter-service communication at the transport layer (L4) non-intrusively and protocol-agnostically.

The system does not inject trace context; inter-service correlation is performed implicitly through connection matching and temporal scoring, while intra-service correlation relies on runtime-specific uprobes. Evaluation was conducted on a polyglot testbed of six services across five languages (HTTP/1.1, gRPC/HTTP-2, PostgreSQL, AMQP) using the OpenTelemetry SDK as ground truth under varied load in single-node and multi-node modes for both plaintext and TLS.

Trace-reconstruction accuracy reached 87.1%–99.2% at 1–16 `rps` with 100% precision at operational loads of 1–32 `rps` (no spurious edges). TLS traffic did not degrade accuracy. Memory and latency overhead were far lower than the SDK, but CPU formed a crossover that exceeded the SDK under high load. The findings indicate that this approach is most suitable for scenarios prioritizing structural accuracy of inter-service relations, such as service dependency mapping, as well as TLS-dominated and polyglot environments, rather than as a production-instrumentation replacement under high throughput, with implicit-correlation accuracy bounds as a known limitation of the non-intrusive design.

Keywords: eBPF, distributed tracing, out-of-band, polyglot microservices, protocol-agnostic, implicit correlation