Tracing Kafka with OpenTelemetry

whoami

Harry Kimpel

Principal Developer Relations Engineer
New Relic
@harrykimpel

- Passionate software craftsman
- Microsoft developer ecosystem
- With New Relic since 2017
- Hiker, climber, biker, runner, swimmer, skier

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Request:
“Based on what you **know about me**. draw a picture of what you think my **current life looks like**”

Response:
"Here’s an illustration capturing your **developer life** surrounded by the **inspiring Bavarian Alps**. It shows a blend of productivity and natural inspiration—a high-tech setup with coding on screens, **observability dashboards**, and the beauty of **snowy peaks** outside."

Who uses Kafka?

new relic® uses Kafka!

more than **15** million messages per second

aggregate data rate approaching **1** Tbps

✋ Hands up if you have heard about OpenTelemetry

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✋ Keep your hands up if you use OpenTelemetry

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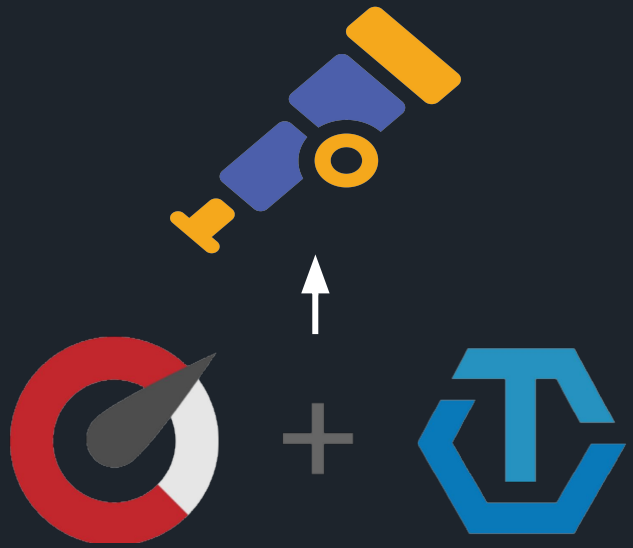
The Rise of OpenTelemetry

- **OpenTelemetry** is a CNCF project
- Formed through a merger of the **OpenTracing** and **OpenCensus** projects in 2019
- Vendor-agnostic - set of APIs, libraries, integrations, and a collector service for telemetry
- **Standardizes** how you collect telemetry data from your applications and services
- Send it to an observability platform of your choice



The Rise of OpenTelemetry

Vendor Neutral

Provides flexibility to change backend

Interoperable

End-to-end visibility with standard instrumentation

Configurable

Pick and choose from the pieces what is needed

By 2025, **70%** of new cloud-native application monitoring will use open-source instrumentation

[1] Source: Gartner Magic Quadrant 2021 for Application Performance Monitoring - link

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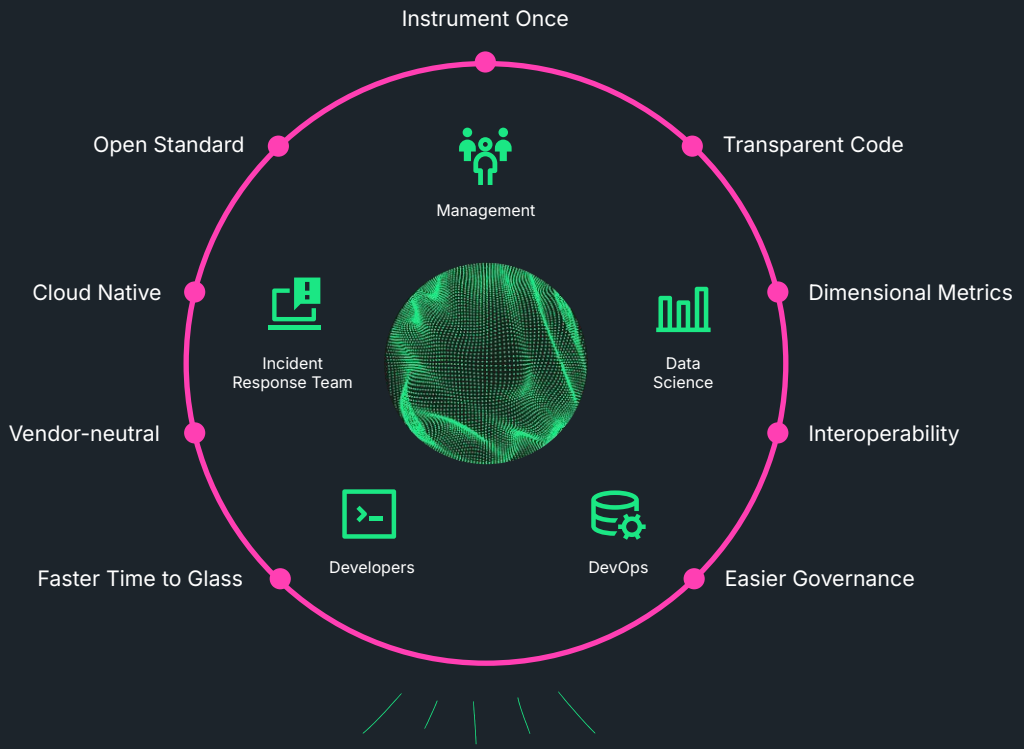
Why OpenTelemetry?



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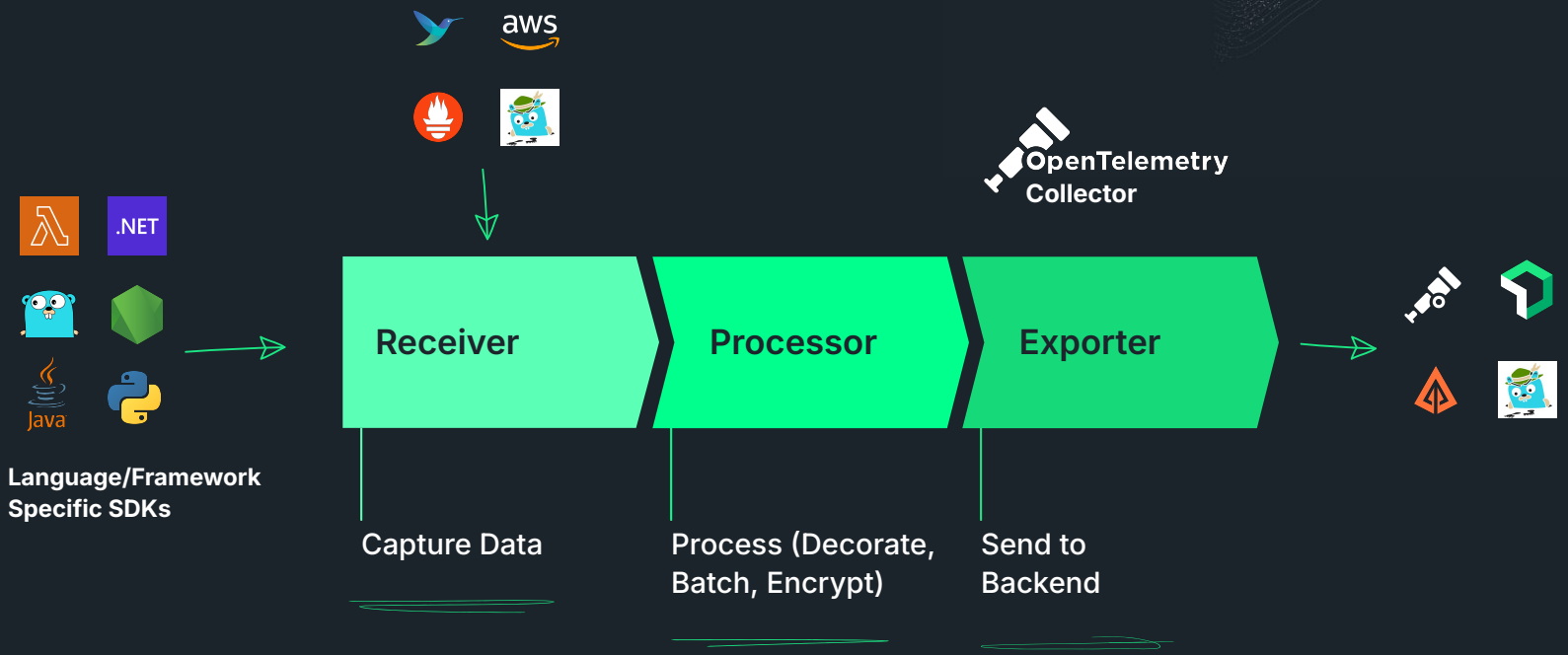
Snapshot of OpenTelemetry



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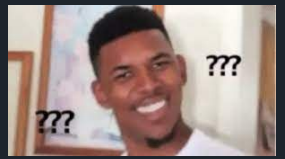
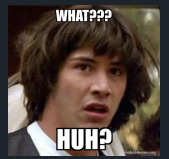
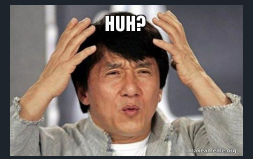
The Rise of OpenTelemetry

Let’s all just
go to **OpenTelemetry**!

BUT WAIT ...







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Design Considerations & Guidelines

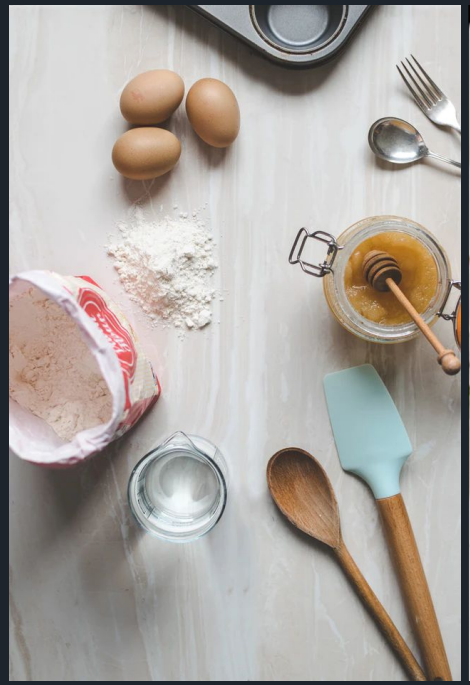
Customize Everything
(manual instrumentation)

Ingredients

Custom Made

Flavours

Java, .NET and others mature



End Product
(auto instrumentation)

Ready to Eat

Packaged

Scalable

Most Languages

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Screenshot from
https://opentelemetry.io/docs/instrumentation/
taken
Ja[illegible]25

Status and Releases

The current status of the major functional components for OpenTelemetry is as follows:

Language	Traces	Metrics	Logs
C++	Stable	Stable	Stable
C#/.NET	Stable	Stable	Stable
Erlang/Elixir	Stable	Development	Development
Go	Stable	Stable	Beta
Java	Stable	Stable	Stable
JavaScript	Stable	Stable	Development
PHP	Stable	Stable	Stable
Python	Stable	Stable	Development
Ruby	Stable	Development	Development
Rust	Beta	Beta	Beta
Swift	Stable	Development	Development

Java supported libraries in OpenTelemetry

... see GitHub repo for details

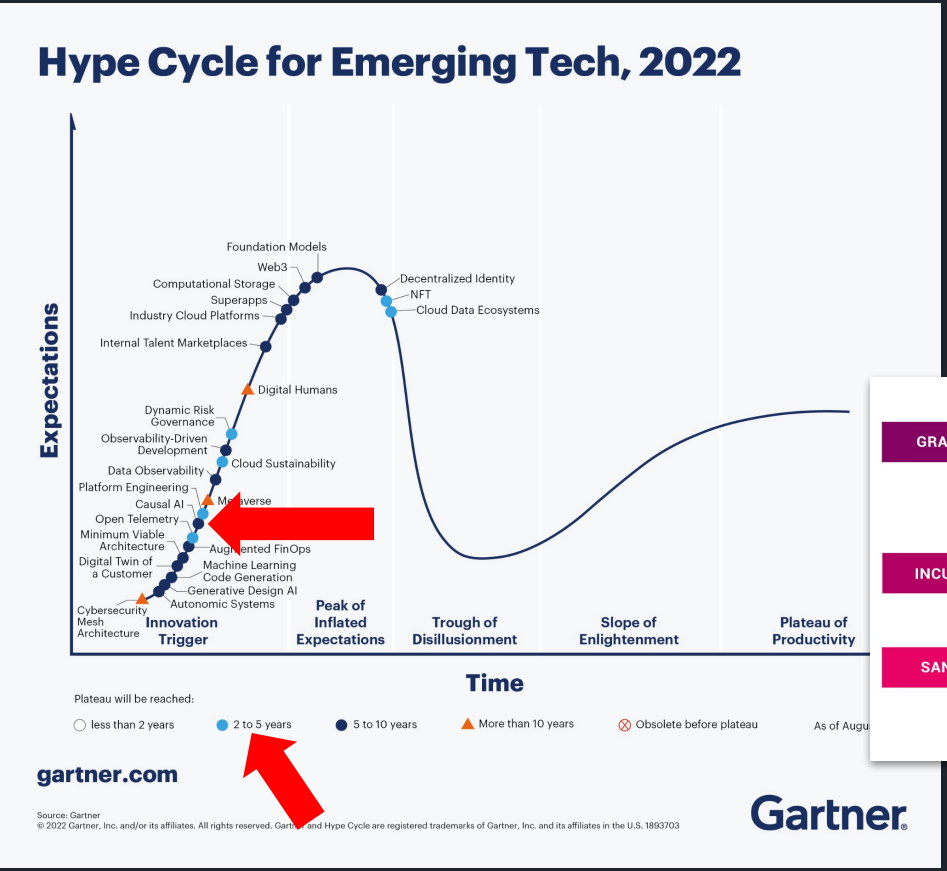
- Disabled instrumentations

Libraries / Frameworks

These are the supported libraries and frameworks:

Library/Framework	Auto-instrumented versions	Standalone Library Instrumentation [1]	Semantic Conventions
Akka Actors	2.3+	N/A	Context propagation
Akka HTTP	10.0+	N/A	HTTP Client Spans, HTTP Client Metrics, HTTP Server Spans, HTTP Server Metrics, Provides `http.route` [2]
Alibaba Druid	1.0+	opentelemetry-alibaba-druid-1.0	Database Pool Metrics
Apache Axis2	1.6+	N/A	Provides `http.route` [2], Controller Spans [3]
Apache Camel	2.20+ (not including 3.x yet)	N/A	Dependent on components in use
Apache CXF JAX-RS	3.2+	N/A	Provides `http.route` [2], Controller Spans [3]
Apache CXF JAX-WS	3.0+	N/A	Provides `http.route` [2], Controller Spans [3]
Apache DBCP	2.0+	opentelemetry-apache-dbcp-2.0	Database Pool Metrics
Apache Dubbo	2.7+	opentelemetry-apache-dubbo-2.7	RPC Client Spans, RPC Server Spans
Apache HttpAsyncClient	4.1+	N/A	HTTP Client Spans, HTTP Client Metrics
Apache HttpClient	2.0+	opentelemetry-apache-httpclient-4.3, opentelemetry-apache-httpclient-5.2	HTTP Client Spans, HTTP Client Metrics
Apache Kafka Producer/Consumer API	0.11+	opentelemetry-kafka-clients-2.6	Messaging Spans
Apache Kafka Streams API	0.11+	N/A	Messaging Spans
Apache MyFaces	1.2+ (not including 3.x yet)	N/A	Provides `http.route` [2], Controller Spans [3]

Design Considerations & Guidelines



Top 6 Questions To Consider

Do you understand the difference between Monitoring vs Observability?

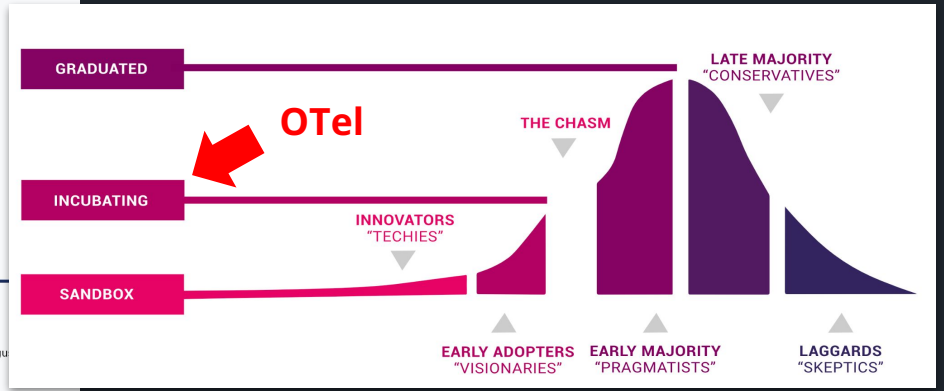
Do you understand the basics of **M**etrics, **L**ogs & **T**races?

Is tracing widely deployed to provide value?

Do you have experience in manual instrumentation?

Is your app, friendly to manual instrumentation?

Is your environment or practice tolerant to change?



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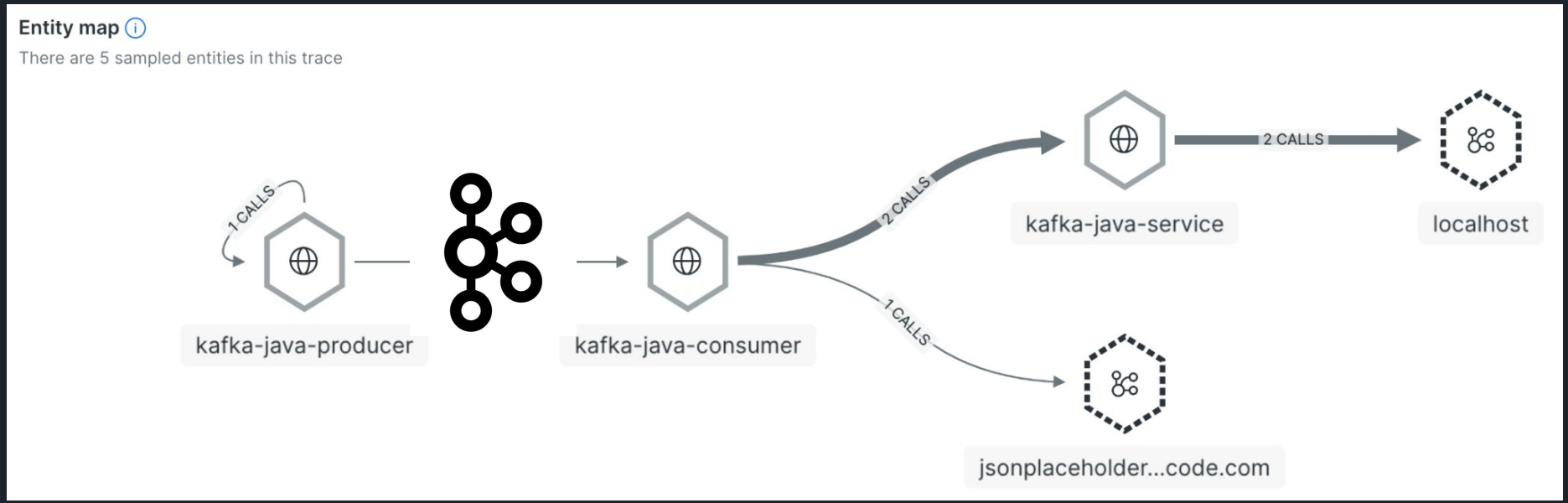
Automatic instrumentation with Java



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Automatic instrumentation - aka zero-code instrumentation - with Java

https://opentelemetry.io/docs/zero-code/

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Automatic instrumentation with Java

otel-auto-instr > demoConsumer > $ run.sh

```
1   export JAVA_TOOL_OPTIONS="-javaagent:/Users/hkimpel/projects/kafka/java-local-test/otel-auto-instr/opentelemetry-javaagent.jar"
2   export OTEL_TRACES_EXPORTER=otlp
3   export OTEL_METRICS_EXPORTER=otlp
4   export OTEL_LOGS_EXPORTER=otlp
5   # US region
6   export OTEL_EXPORTER_OTLP_ENDPOINT='https://otlp.nr-data.net'
7   # EU region
8   #export OTEL_EXPORTER_OTLP_ENDPOINT='https://otlp.eu01.nr-data.net'
9   export OTEL_EXPORTER_OTLP_HEADERS="api-key=NEW_RELIC_LICENSE_KEY"
10  export OTEL_SERVICE_NAME="kafka-java-consumer"
11  export OTEL_SERVICE_VERSION="0.1.0"
12
13  ./mvnw spring-boot:run
```


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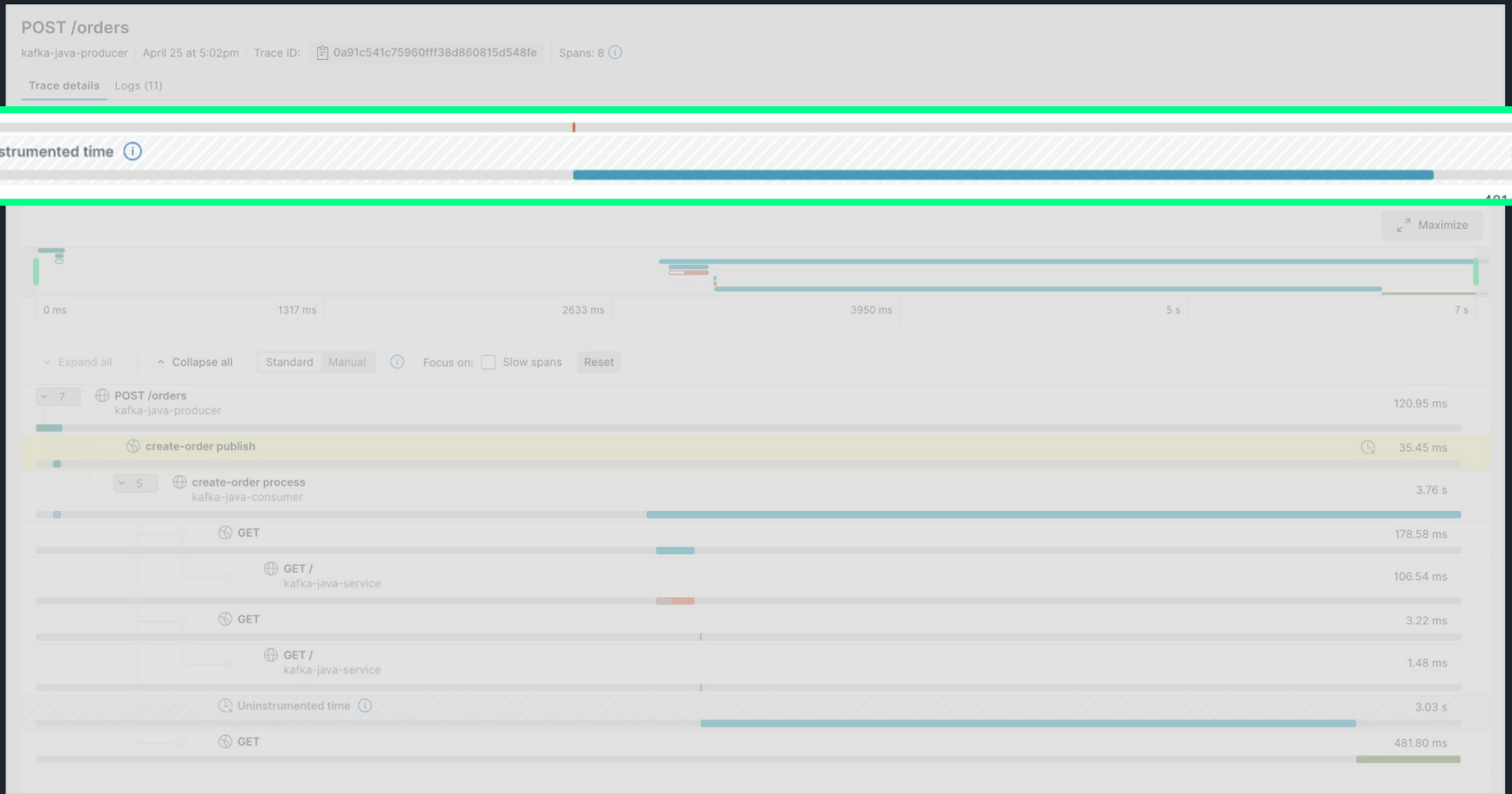
Automatic instrumentation with Java



Manual instrumentation with Java

https://opentelemetry.io/docs/languages/

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Manual instrumentation with Java

application.properties

otel-manual-instr > demoProducer > src > main > resources > application.properties

```
1   spring.kafka.order.bootstrap-servers: localhost:9092
2   spring.kafka.order.topic.create-order: create-order
3   # US region
4   otel.exporter.otlp.endpoint: https://otlp.nr-data.net
5   # EU region
6   #otel.exporter.otlp.endpoint: https://otlp.eu01.nr-data.net
7   otel.exporter.otlp.headers.api-key: NEW_RELIC_LICENSE_KEY
8   otel.jmx.target.system: tomcat,kafka-broker
9   otel.instrumentation.common.default-enabled: true
10  otel.instrumentation.kafka.enabled: true
11  otel.instrumentation.tomcat.enabled: true
12  otel.javaagent.debug: true
13
```

Manual instrumentation with Java

```
Resource resource = Resource.getDefault().toBuilder()
    .put(ResourceAttributes.SERVICE_NAME, value:"kafka-java-producer")
    .put(ResourceAttributes.SERVICE_VERSION, value:"0.1.0")
    .put(key:"otel.jmx.target.system", value:"tomcat,kafka-broker")
    .put(key:"otel.instrumentation.kafka.metric-reporter.enabled", value:true).build();
```

Manual instrumentation with Java

```
Pieces: Comment | Pieces: Explain
SdkTracerProvider sdkTracerProvider = SdkTracerProvider.builder()
        Pieces: Comment | Pieces: Explain
    .addSpanProcessor(BatchSpanProcessor.builder(OtlpGrpcSpanExporter.builder()
        .setEndpoint(
            otlpEndpoint)
        .addHeader(key:"api-key",
            otlpHeadersApiKey)
        .build()).build())
    .setResource(resource)
    .build();
```

Manual instrumentation with Java

```
OpenTelemetry openTelemetry = OpenTelemetrySdk.builder()
    .setTracerProvider(sdkTracerProvider)
    .setMeterProvider(sdkMeterProvider)
    .setLoggerProvider(sdkLoggerProvider)
    .setPropagators(ContextPropagators.create(W3CTraceContextPropagator.getInstance()))
    .buildAndRegisterGlobal();
```

Manual instrumentation with Java - Kafka producer

```
Pieces: Comment | Pieces: Explain
22      @Bean
23      public <K, V> ProducerFactory<K, V> createOrderProducerFactory() {
24          Map<String, Object> config = new HashMap<>();
25          config.put(
26                  org.apache.kafka.clients.producer.ProducerConfig.INTERCEPTOR_CLASSES_CONFIG,
27                  TracingProducerInterceptor.class.getName());
            Pieces: Comment | Pieces: Explain
28          config.put(org.apache.kafka.clients.producer.ProducerConfig.BOOTSTRAP_SERVERS_CONFIG, bootstrapServers);
29          config.put(org.apache.kafka.clients.producer.ProducerConfig.KEY_SERIALIZER_CLASS_CONFIG, value:JsonSerializer.class);
30          config.put(org.apache.kafka.clients.producer.ProducerConfig.VALUE_SERIALIZER_CLASS_CONFIG,
31                  value:JsonSerializer.class);
32          return new DefaultKafkaProducerFactory(config);
33      }
```


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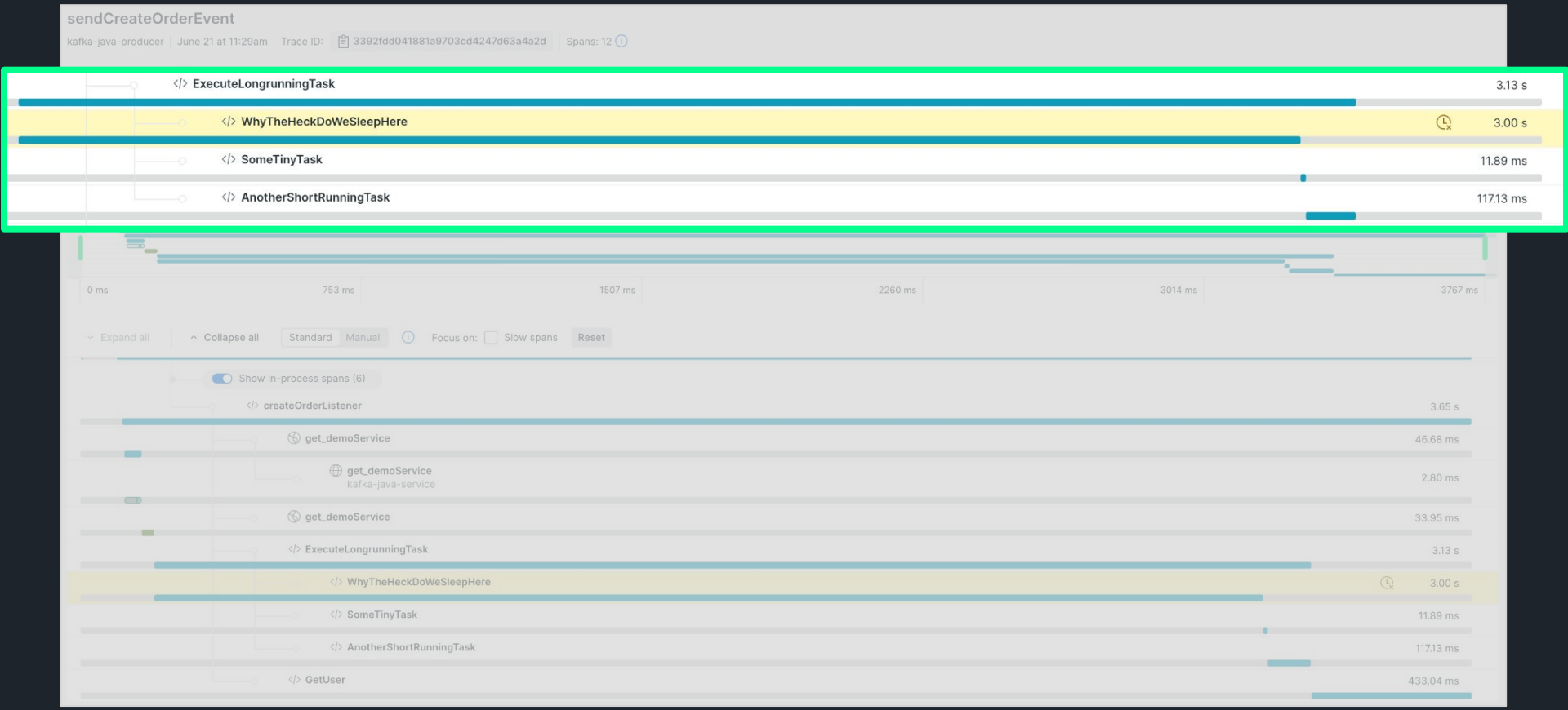
Manual instrumentation with Java - Kafka consumer

```
Pieces: Comment | Pieces: Explain
35    @Bean("orderConsumerFactoryNotificationService")
36    public ConsumerFactory<String, Order> createOrderConsumerFactory() {
37        Map<String, Object> props = new HashMap<>();
          Pieces: Comment | Pieces: Explain
38        props.put(
39            ConsumerConfig.INTERCEPTOR_CLASSES_CONFIG,
40            TracingConsumerInterceptor.class.getName());
          Pieces: Comment | Pieces: Explain
41        props.put(ConsumerConfig.BOOTSTRAP_SERVERS_CONFIG, bootstrapServers);
          Pieces: Comment | Pieces: Explain
42        props.put(ConsumerConfig.GROUP_ID_CONFIG, groupId);
          Pieces: Comment | Pieces: Explain
43        props.put(ConsumerConfig.CLIENT_ID_CONFIG, UUID.randomUUID().toString());
          Pieces: Comment | Pieces: Explain
44        props.put(ConsumerConfig.KEY_DESERIALIZER_CLASS_CONFIG, value:StringSerializer.class);
45        props.put(ConsumerConfig.VALUE_DESERIALIZER_CLASS_CONFIG, value:JsonSerializer.class);
          Pieces: Comment | Pieces: Explain
46        props.put(ConsumerConfig.ENABLE_AUTO_COMMIT_CONFIG, value:false);
47
48        return new DefaultKafkaConsumerFactory<>(props, new StringDeserializer(),
49                new JsonDeserializer<>(targetType:Order.class));
50    }
```

Manual instrumentation with Java



Manual instrumentation with Java - custom spans

```java
private void ExecuteLongrunningTask(Integer secondsToSleep) {
    Span span = tracer.spanBuilder(spanName:"ExecuteLongrunningTask").startSpan();
    //Make the span the current span
    try {
        Pieces: Comment | Pieces: Explain
        Span sleepSpan = tracer.spanBuilder(spanName:"WhyTheHeckDoWeSleepHere")
                Pieces: Comment | Pieces: Explain
                .setParent(Context.current().with(span))
                .startSpan();
        try {
            Pieces: Comment | Pieces: Explain
            sleepSpan.setAttribute(key:"secondsToSleep", secondsToSleep);
            Pieces: Comment | Pieces: Explain
            Thread.sleep(secondsToSleep * 1000);
            Pieces: Comment | Pieces: Explain
            log.info("Executed some long running task that took " + secondsToSleep + " seconds to run.");

        } finally {
            Pieces: Comment | Pieces: Explain
            sleepSpan.end();
        }

        Pieces: Comment | Pieces: Explain
        SomeTinyTask(span);

        Pieces: Comment | Pieces: Explain
        AnotherShortRunningTask(span);
    } catch (Exception t) {
        span.recordException(t);
        //throw t;
    } finally {
        span.end();
    }
```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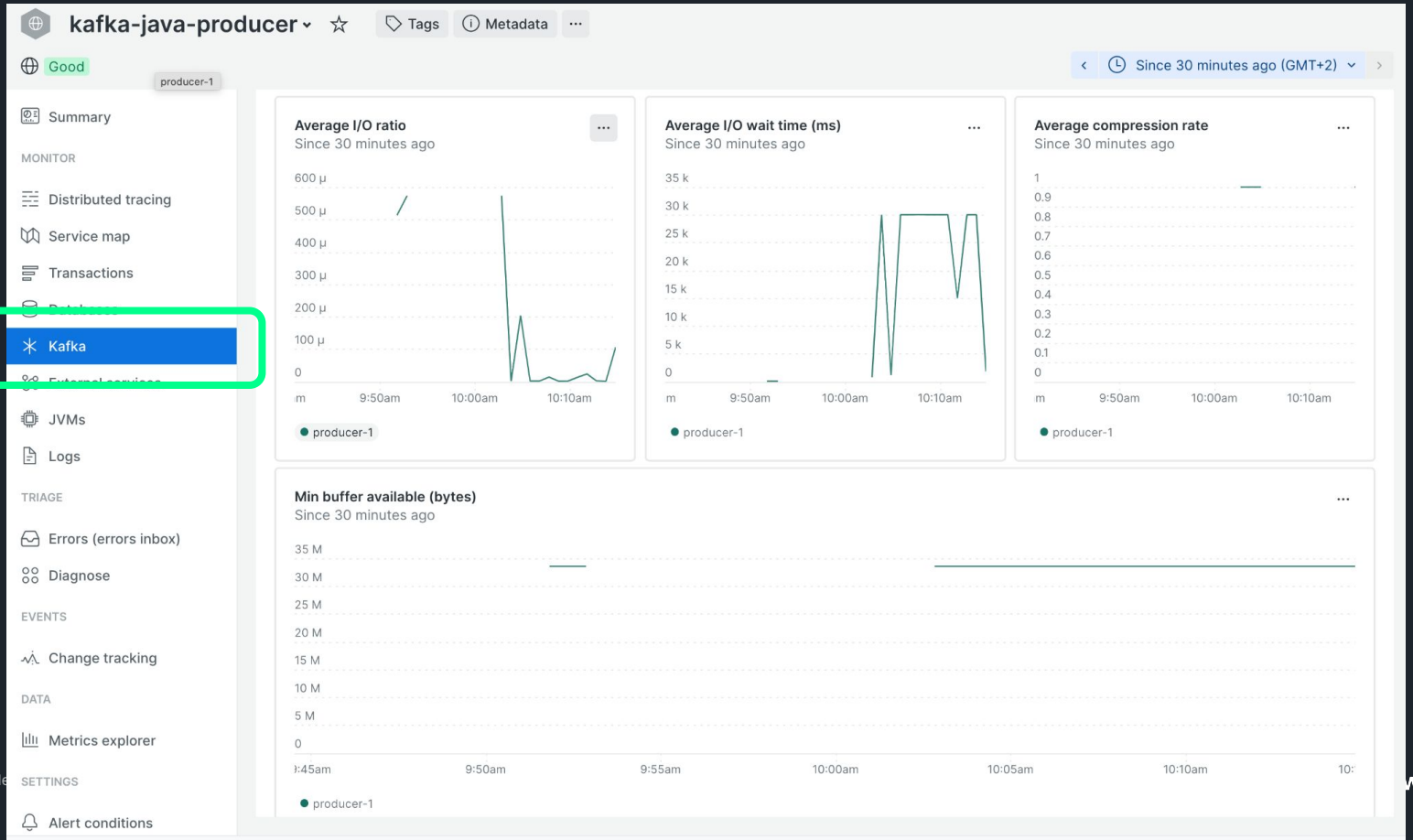
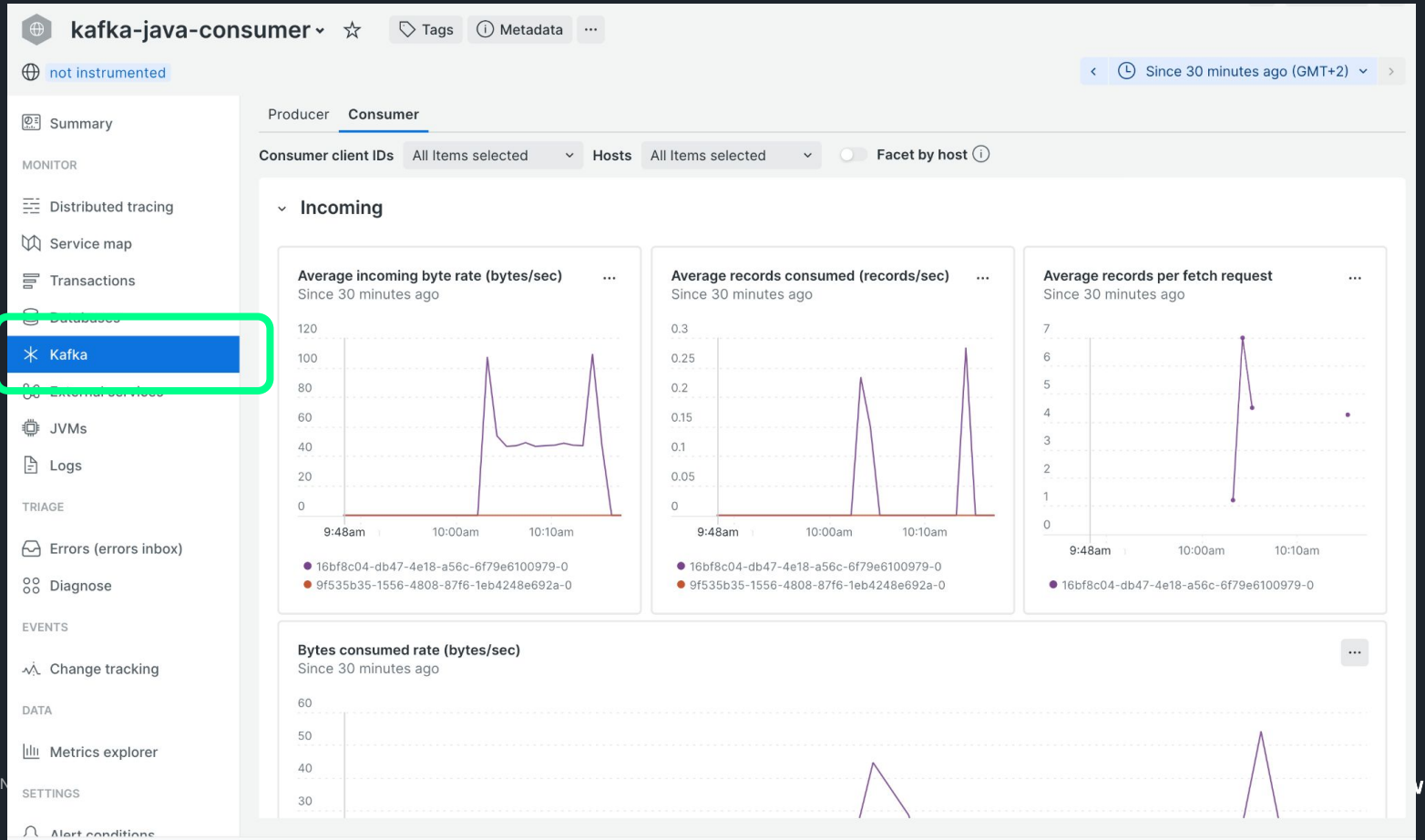
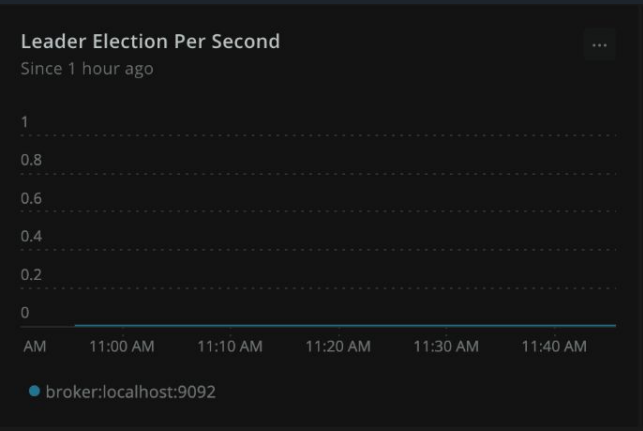
Kafka metrics for producer

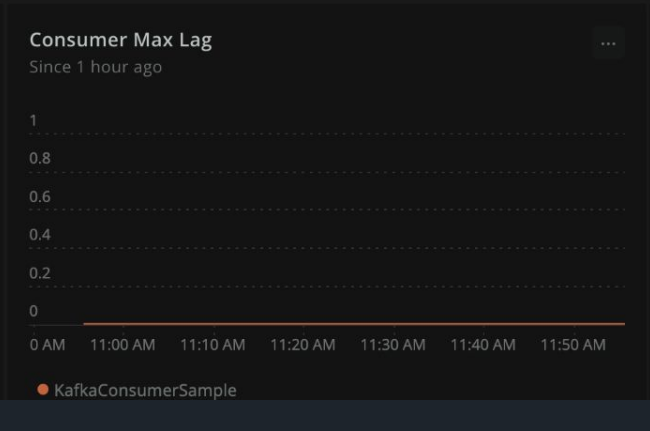


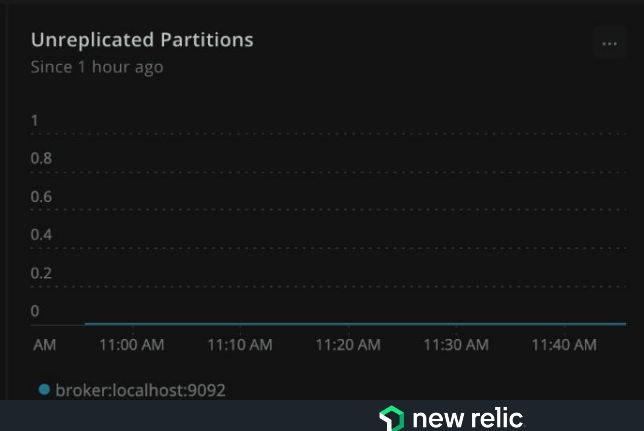
Kafka metrics for consumer



Kafka infrastructure metrics







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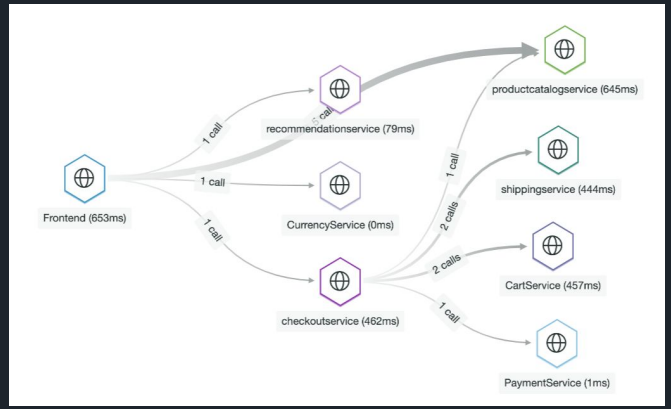
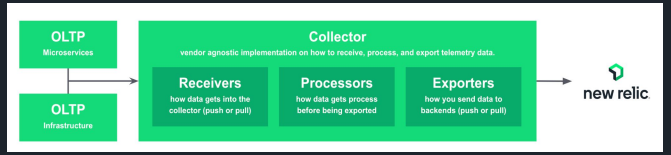
Summary

- Exciting times for open source observability!
  Be mindful about the maturity status, and plan ahead on the adoption of OpenTelemetry.
- The collector is a very useful tool that also comes with challenges, especially scalability.
- Instrumentation can include traces, logs, and/or metrics to improve observations.
- New Relic is actively investing in OpenTelemetry, and helping engineers do their best work based on **data, not opinions**.

The Stack





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Reading Materials for OpenTelemetry

Sample application https://github.com/harrykimpel/java-kafka-otel-producer-consumer

Reading List

- OpenTelemetry project mission
- Observability Primer
- Java - docs
- Go - docs
- Collector - docs
- OpenTelemetry Github repo
- Intro to OpenTelemetry x New Relic
- View your data - Distributed Tracing
- OpenTelemetry x New Relic Best Practices

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Harry Kimpel

Principal Developer Relations Engineer

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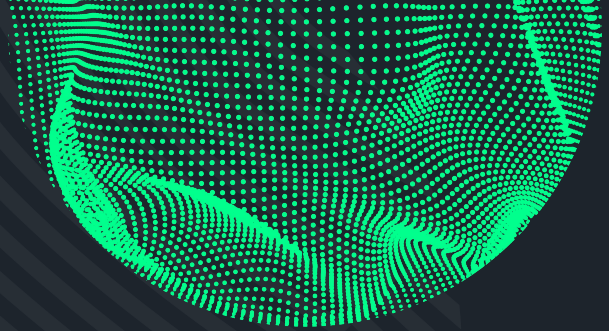

Appendix

some more information

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Kafka Best Practices

https://newrelic.com/blog/best-practices/kafka-consumer-config-auto-commit-data-loss

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Kafka Best Practices - Partitioning 1/2

Understand the data rate of your partitions to ensure you have the correct retention space.

Number of messages

*

Avg. message size

= Data retention space

minimum performance, a single consumer needs to support, without lagging

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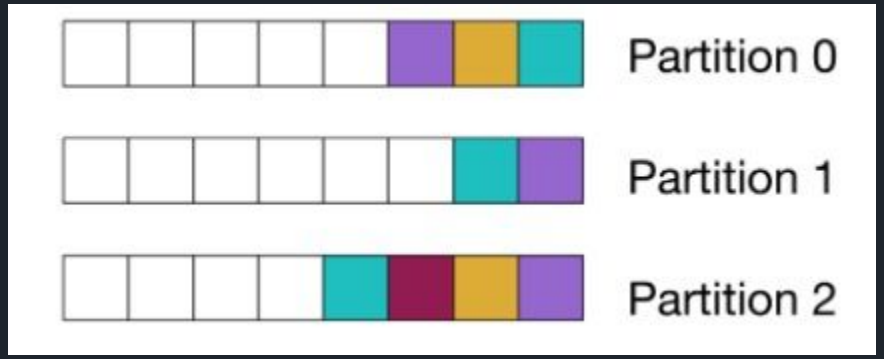
Kafka Best Practices - Partitioning 2/2

Unless you have architectural needs that require you to do otherwise, use random partitioning when writing to topics.



- Evenest spread of load for consumers
- Thus makes scaling the consumers easier
- Particularly suited for stateless or “embarrassingly parallel” services
- Using the default partitioner while not manually specifying a partition or a message key

Kafka Best Practices - Consumers 1/4

If your consumers are running versions of Kafka older than 0.10, upgrade them.

- In version 0.8.x, consumers use Apache ZooKeeper for consumer group coordination
- a number of known bugs can result in long-running rebalances or even failures of the rebalance algorithm, aka "rebalance storms"
- During a rebalance, one or more partitions are assigned to each consumer in the consumer group
- In a rebalance storm, partition ownership is continually shuffled among the consumers, preventing any consumer from making real progress on consumption

Kafka Best Practices - Consumers 2/4

Tune your consumer socket buffers for high-speed ingest

- In Kafka 0.10.x, the parameter is `receive.buffer.bytes`, defaults to 64kB
- In Kafka 0.8.x, the parameter is `socket.receive.buffer.bytes`, defaults to 100kB

- Default values are too small for high-throughput environments
- Particularly if the network's bandwidth-delay product between the broker and the consumer is larger than a local area network (LAN)
- For high-bandwidth networks (10 Gbps or higher) with latencies of 1 millisecond or more, consider setting the socket buffers to 8 or 16 MB
- If memory is scarce, consider 1 MB
- You can also use a value of `-1`, which lets the underlying operating system tune the buffer size based on network conditions
    - However, the automatic tuning might not occur fast enough for consumers that need to start "hot."

Kafka Best Practices - Consumers 3/4

Design high-throughput consumers to implement back-pressure when warranted

- Better to consume only what you can process efficiently
  - rather than it is to consume so much that your process grinds to a halt and then drops out of the consumer group
- Consumers should consume into fixed-sized buffers (see the Disruptor pattern), preferably off-heap if running in a Java virtual machine (JVM)
- A fixed-size buffer will prevent a consumer from pulling so much data onto the heap that the JVM spends all of its time performing garbage collection instead of the work you want to achieve - which is processing messages.

Disruptor pattern: https://lmax-exchange.github.io/disruptor/files/Disruptor-1.0.pdf

Kafka Best Practices - Consumers 4/4

When running consumers on a JVM, be wary of the impact that garbage collection can have on your consumers

- For example, long garbage collection pauses can result in dropped ZooKeeper sessions or consumer-group rebalances
- The same is true for brokers, which risk dropping out of the cluster if garbage collection pauses are too long

Kafka Best Practices - Producer 1/4

Configure your producer to wait for acknowledgments

- this is how the producer knows that the message has actually made it to the partition on the broker
- In Kafka 0.10.x, the settings is `acks`; in 0.8.x, it's `request.required.acks`
- Kafka provides fault-tolerance via replication so the failure of a single node or a change in partition leadership does not affect availability
- If you configure your producers without acks (otherwise known as "fire and forget"), messages can be silently lost

Kafka Best Practices - Producer 2/4

Configure `retries` on your producers

- The default value is `3`, which is often too low
- The right value will depend on your application
  - For applications where data-loss cannot be tolerated, consider Integer.MAX_VALUE (effectively, infinity)
  - This guards against situations where the broker leading the partition isn't able to respond to a produce request right away

Kafka Best Practices - Producer 3/4

For high-throughput producers, tune buffer sizes

- Particularly `buffer.memory` and `batch.size` (which is counted in bytes)
- Because `batch.size` is a per-partition setting, producer performance and memory usage can be correlated with the number of partitions in the topic
- The values depend on several factors:
  - Producer data rate (both the size and number of messages)
  - Number of partitions you are producing to
  - Amount of memory you have available
- Keep in mind that larger buffers are not always better
  - because if the producer stalls for some reason (say, one leader is slower to respond with acknowledgments), having more data buffered on-heap could result in more garbage collection

Kafka Best Practices - Producer 4/4

Instrument your application to track metrics

- Such as
  - Number of produced messages
  - Average produced message size
  - Number of consumed messages
  - ...

Kafka Best Practices - Broker 1/10

Compacted topics require memory and CPU resources on your brokers

- Log compaction needs both heap (memory) and CPU cycles on the brokers to complete successfully
- Failed log compaction puts brokers at risk from a partition that grows unbounded
- Tune `log.cleaner.dedupe.buffer.size` and `log.cleaner.threads` on your brokers
  - Keep in mind, these values affect heap usage on the brokers
- If broker throws an `OutOfMemoryError` exception, it will shut down and potentially lose data
- Buffer size and thread count will depend on both:
  - the number of topic partitions to be cleaned and
  - the data rate and key size of the messages in those partitions
- As of Kafka version 0.10.2.1, monitoring the log-cleaner log file for `ERROR` entries is the surest way to detect issues with log cleaner threads.

Kafka Best Practices - Broker 2/10

Monitor your brokers

- Network throughput
  - transmit (TX)
  - receive (RX)
- Disks
  - disk I/O
  - disk space
- CPU usage

Capacity planning is a key part of maintaining cluster performance

Kafka Best Practices - Broker 3/10

Distribute partition leadership among brokers in the cluster

- Leadership requires a lot of network I/O resources
- For example, when running with replication factor 3
  - a leader must receive the partition data
  - transmit two copies to replicas
  - plus transmit to however many consumers want to consume that data
  - So, in this example, being a leader is at least four times as expensive as being a follower in terms of network I/O used
- Leaders may also have to read from disk; followers only write.

Kafka Best Practices - Broker 4/10

Don’t neglect to monitor your brokers for in-sync replica (ISR) shrinks, under-replicated partitions, and unpreferred leaders

- These are signs of potential problems in your cluster
- For example
  - frequent ISR shrinks for a single partition
  - can indicate that the data rate for that partition exceeds the leader’s ability to service the consumer and replica threads

Kafka Best Practices - Broker 5/10

Modify the Apache Log4j properties as needed

- Kafka broker logging can use an excessive amount of disk space
- However, don’t forgo logging completely
- Broker logs can be the best - and sometimes only - way to reconstruct the sequence of events after an incident.

Kafka Best Practices - Broker 6/10

Either disable automatic topic creation or establish a clear policy regarding the cleanup of unused topics

- For example
  - if no messages are seen for x days
  - consider the topic defunct and remove it from the cluster
  - this will avoid the creation of additional metadata within the cluster that you'll have to manage

Kafka Best Practices - Broker 7/10

For sustained, high-throughput brokers, provision sufficient memory to avoid reading from the disk subsystem

- Partition data should be served directly from the operating system's file system cache whenever possible
- However, this means you'll have to ensure your consumers can keep up
  - a lagging consumer will force the broker to read from disk

Kafka Best Practices - Broker 8/10

For a large cluster with high-throughput service level objectives (SLOs), consider isolating topics to a subset of brokers

- How you determine which topics to isolate will depend on the needs of your business
- For example
  - if you have multiple online transaction processing (OLTP) systems using the same cluster
  - isolating the topics for each system to distinct subsets of brokers
  - can help to limit the potential blast radius of an incident

Kafka Best Practices - Broker 9/10

Using older clients with newer topic message formats, and vice versa, places extra load on the brokers

- … as they convert the formats on behalf of the client
- Avoid this whenever possible

Kafka Best Practices - Broker 10/10

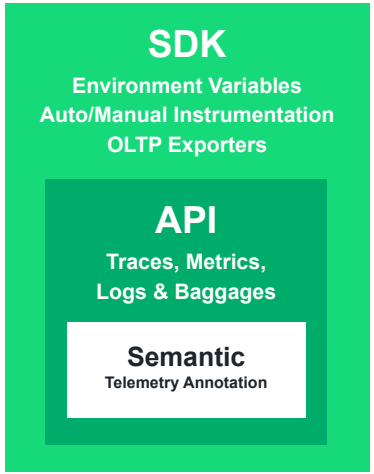
Don’t assume that testing a broker on a local desktop machine is representative of the performance you’ll see in production

- Testing over a loopback interface to a partition using replication factor 1 is a very different topology from most production environments
- The network latency is negligible via the loopback and the time required to receive leader acknowledgements can vary greatly when there is no replication involved

More information

new relic

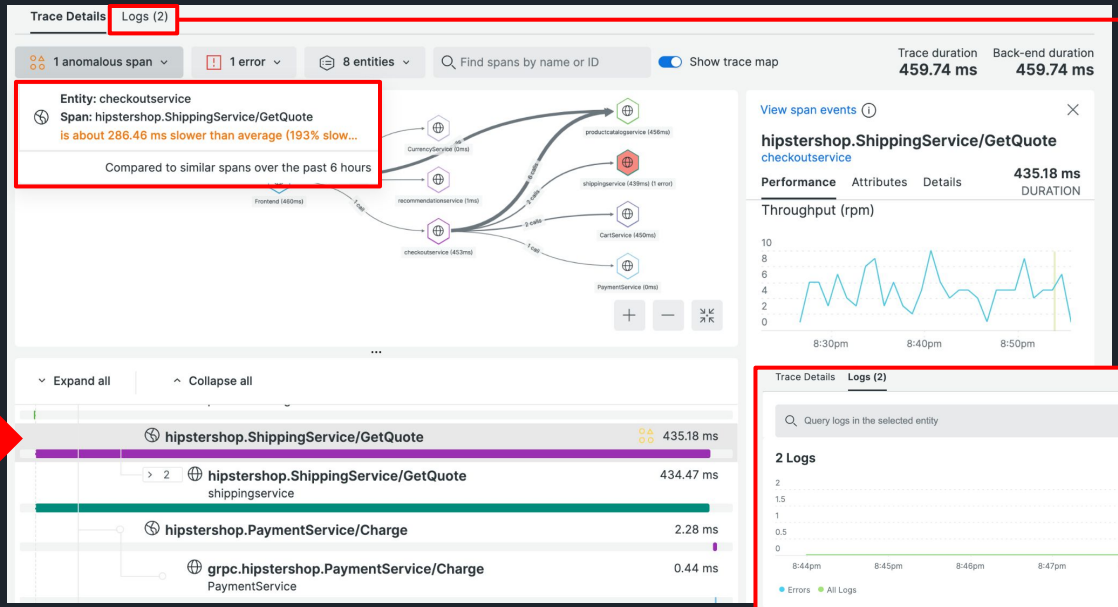
OpenTelemetry - Instrumentation

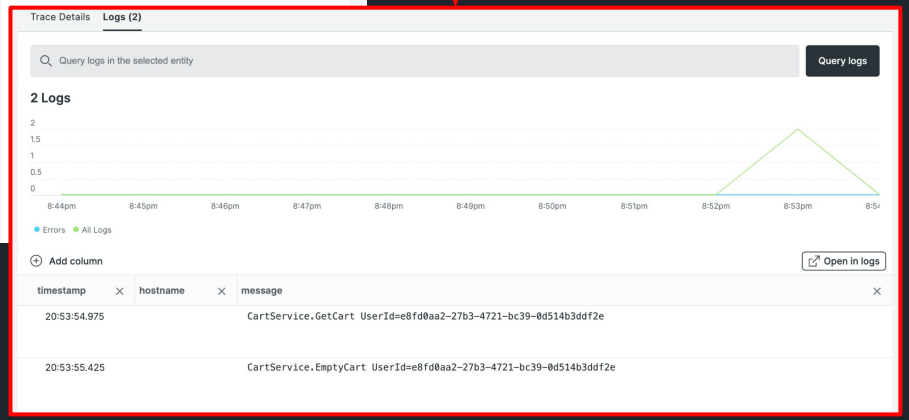


Core Concepts on Instrumentation

- **Semantic Conventions** - annotate telemetry with attributes specific to the represented operation, such as HTTP calls.
- **API** - standard way to collect instrumentation data.
- **SDK** - language-specific implementation of the API.
    - SDKs incorporate automatic instrumentation for common libraries and frameworks for your application.
- **OpenTelemetry Protocol** (OTLP) - used to send data to your backend Observability platform of choice.
- **Specification** (“spec”) - provides blueprints for all of the above to bring standardization across all languages

Instrumentation in Action





Logs in Context
(correlate to the right trace)

Anomalous Span Detection in Distributed Tracing for OpenTelemetry

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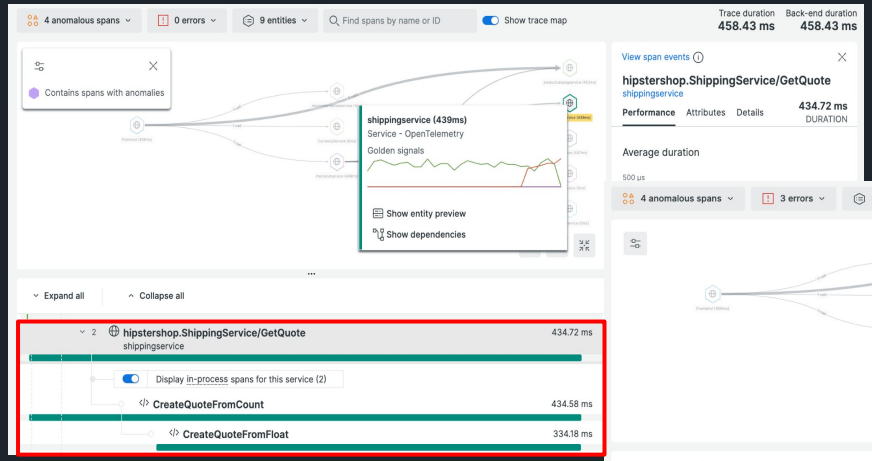
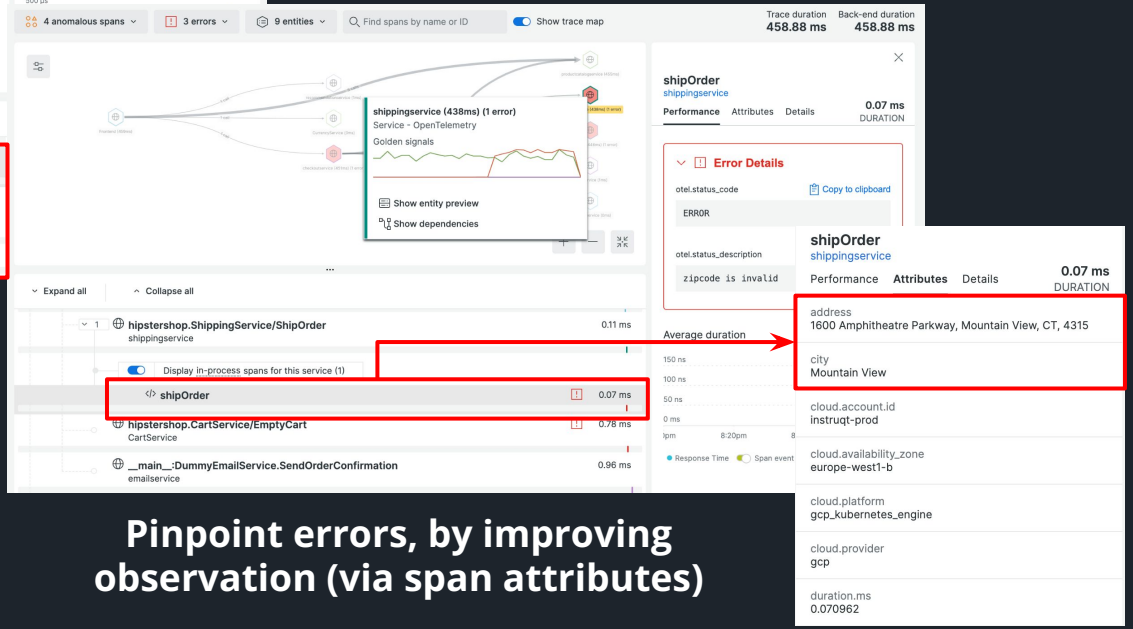
Instrumentation in Action



Get deeper into the app stack, by building spans.



Pinpoint errors, by improving observation (via span attributes)

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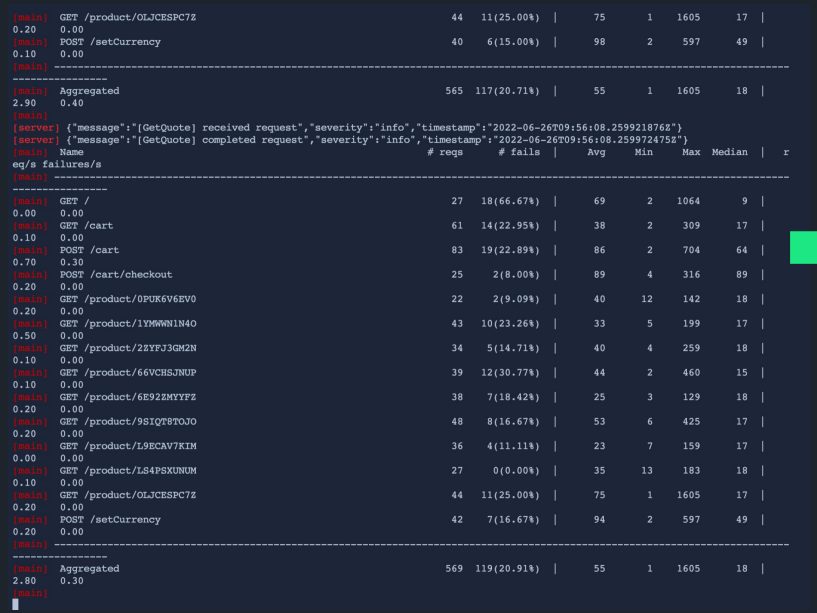
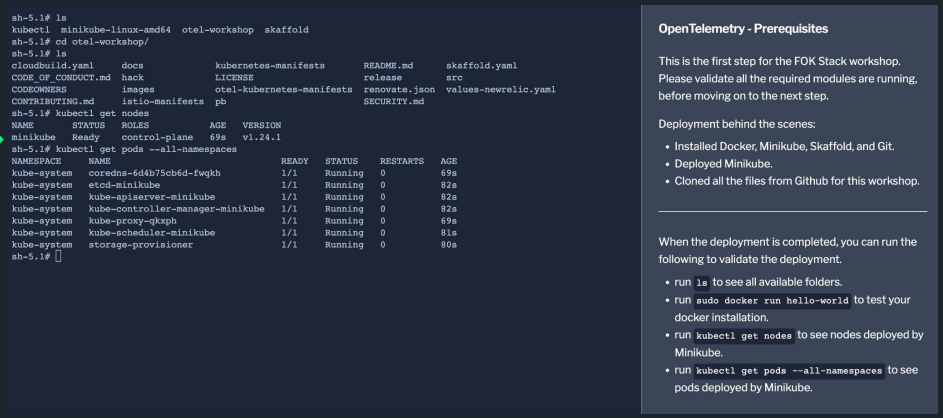
OpenTelemetry in Action



Deploy the app, and generate load (successful deployment)



Validate K8s is running, and follow the instructions

Important - deploy might take up to 10 mins

Need the env var? Go **HERE**.

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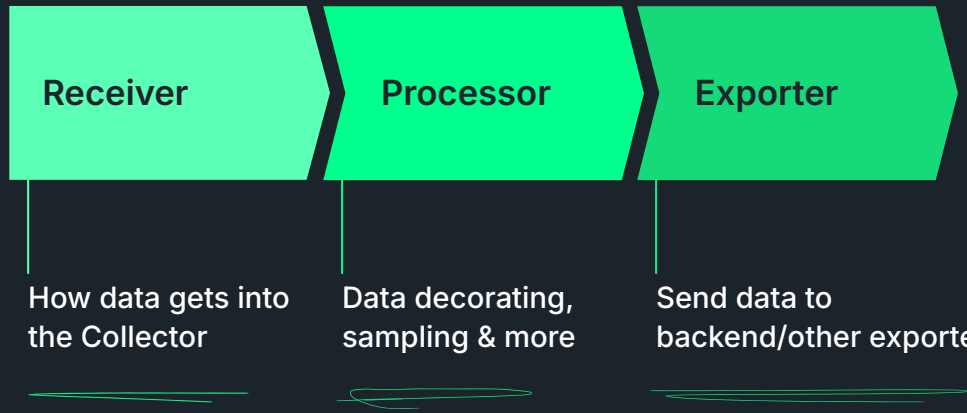
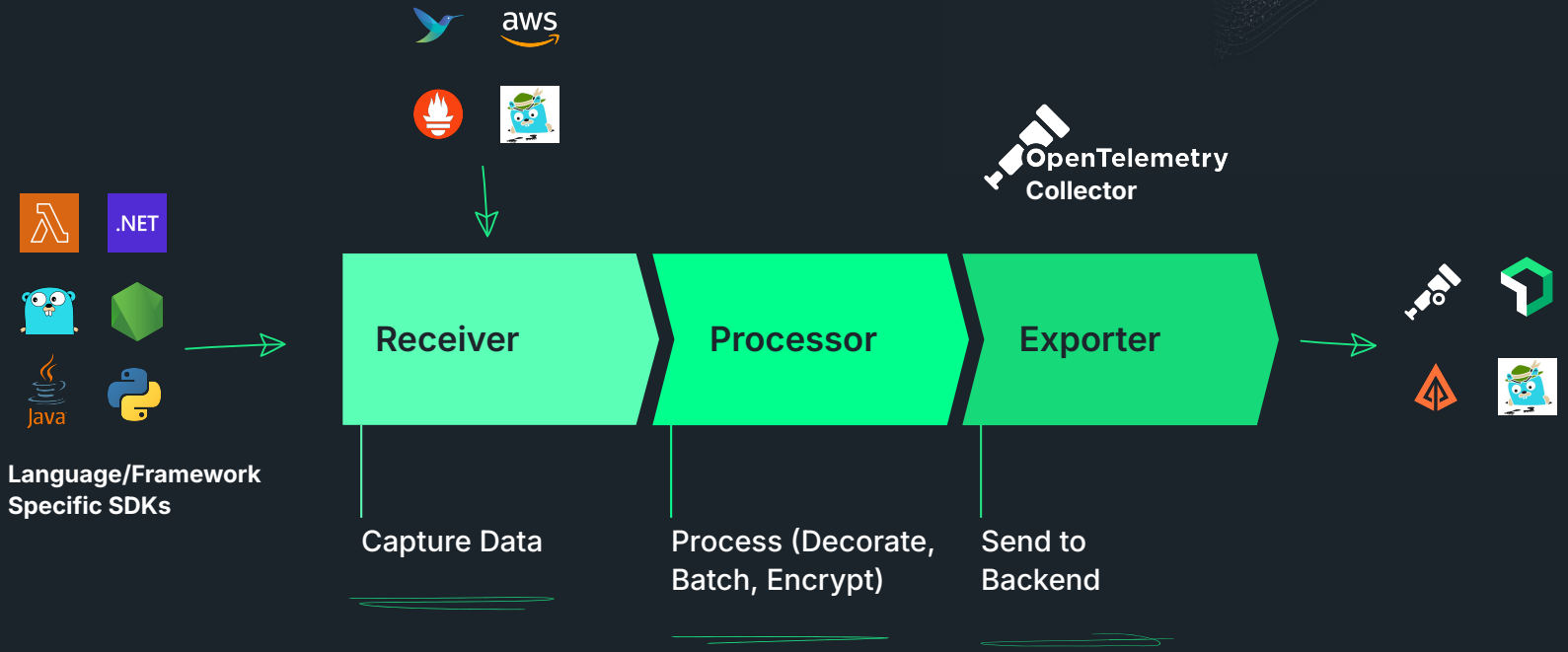
Collector Component

OpenTelemetry



Putting it All Together

OpenTelemetry



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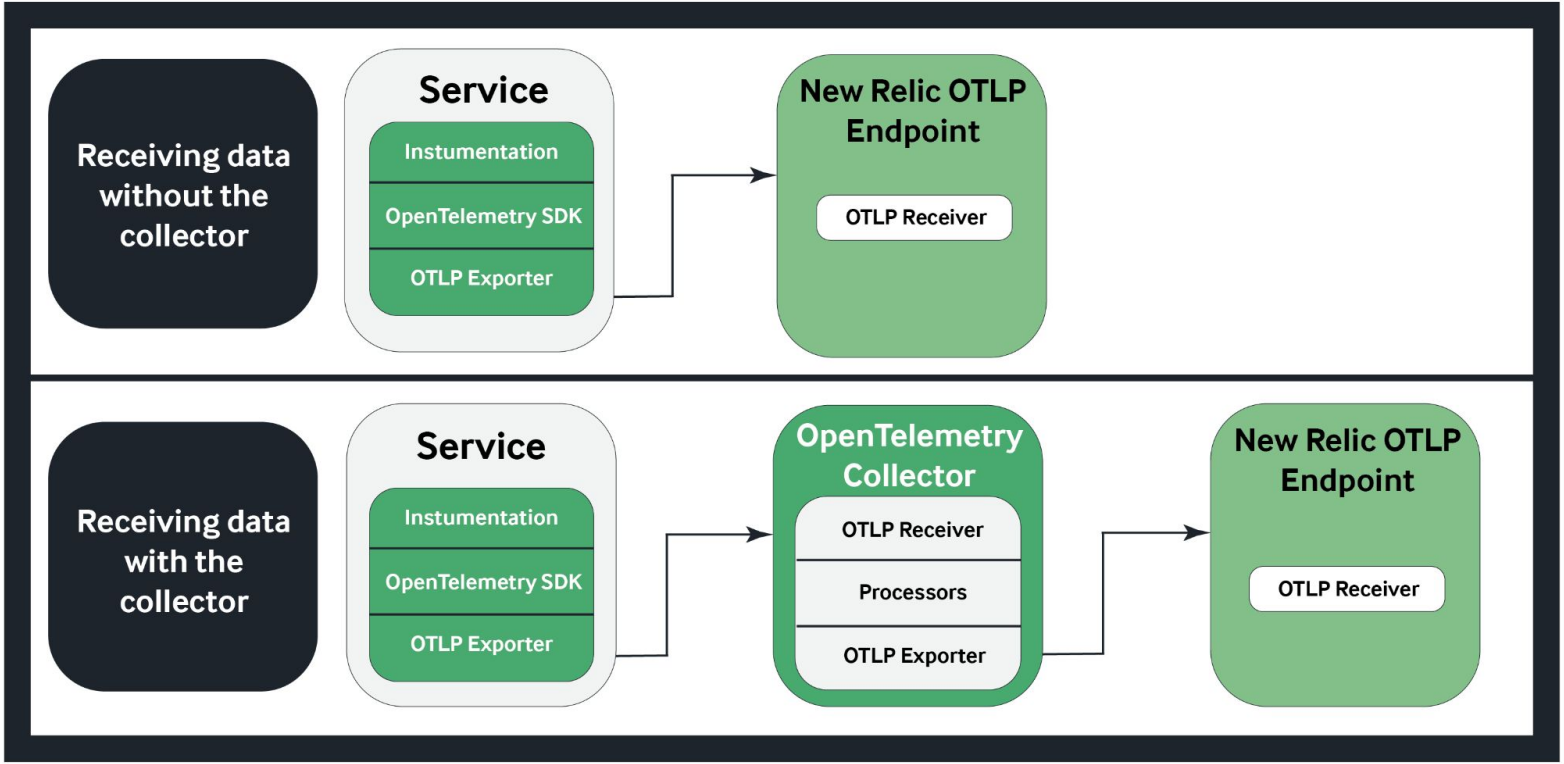
OpenTelemetry - Collector



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OpenTelemetry - Collector

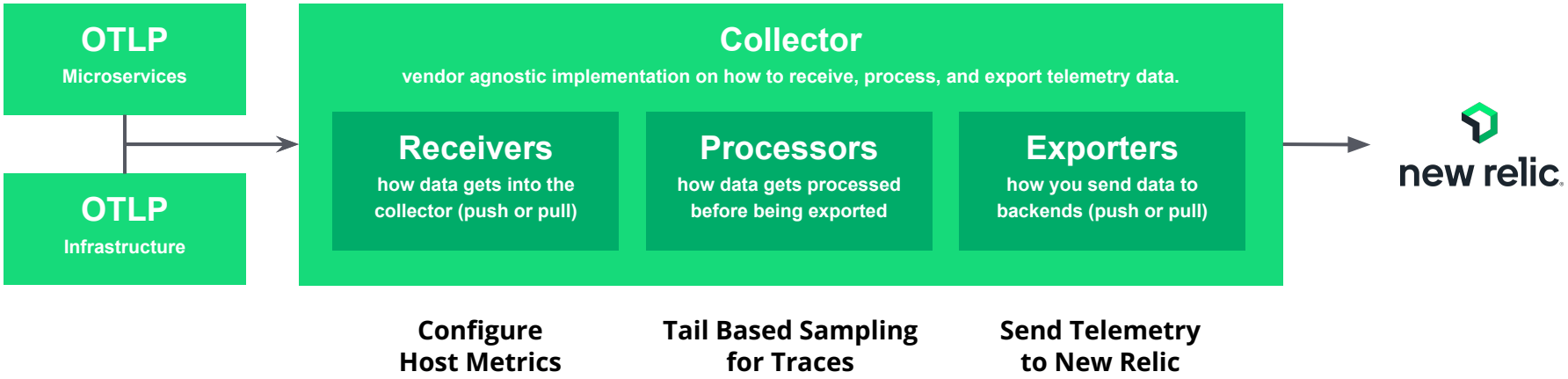
Benefits

- Helps manage ingest costs when using tail sampling
- Reduces app overhead by offloading data management from your apps
- Provides flexibility to handle multiple data formats
- Centralizes configuration of your telemetry pipelines
- Provides ability to export data to multiple backends
- Collects host metrics, e.g., RAM, CPU, and storage capacity
- Provides ability to pull data from monitored systems, e.g., Redis

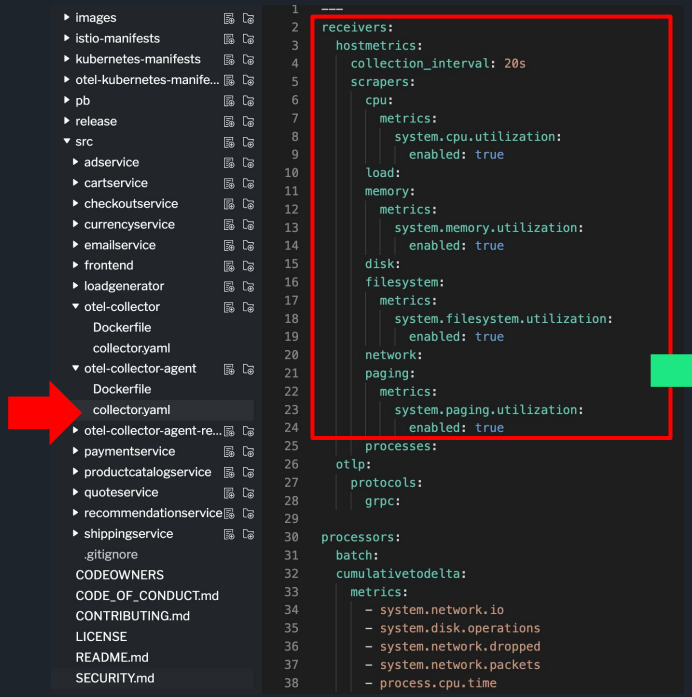
Downsides - nontrivial!

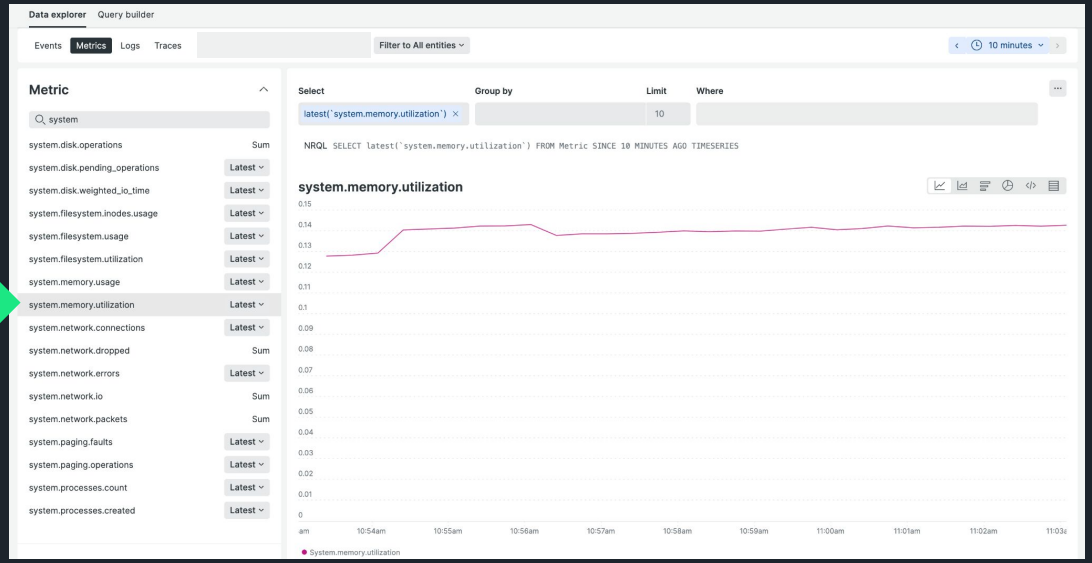
- Complex to scale
  - Deployment patterns
  - Load balancing
- Monitoring the collector is only available with ... the collector itself (at this time)
- Current stability status is “mixed”

OpenTelemetry - Collector



Collector in Action - Host Metrics





Collect additional infrastructure metrics for OpenTelemtry

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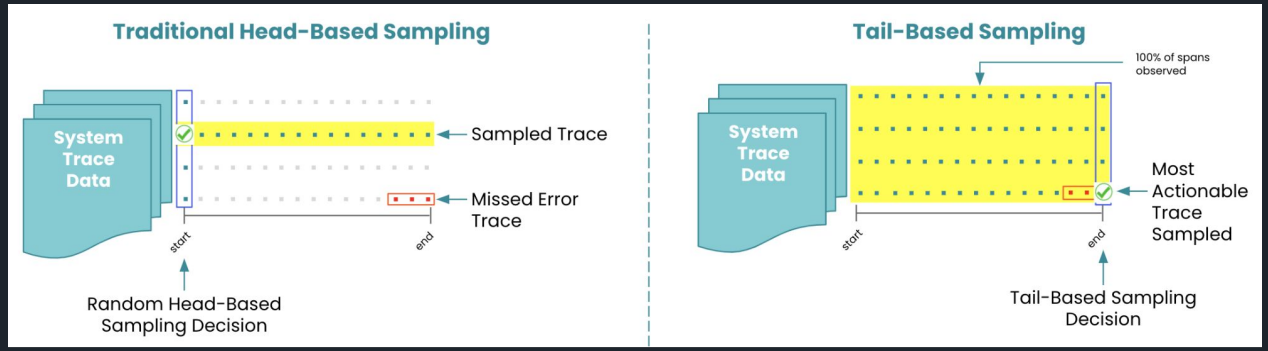
HEAD vs TAIL Sampling

Storing all tracing data is **costly**. Most of the time, you
ONLY NEED THE RIGHT SAMPLING OF DATA



Head-based sampling works well for an overall statistical sampling of requests through a distributed system.

Tail-based sampling is best to decide what to keep, based on isolated, independent portions of the trace data.

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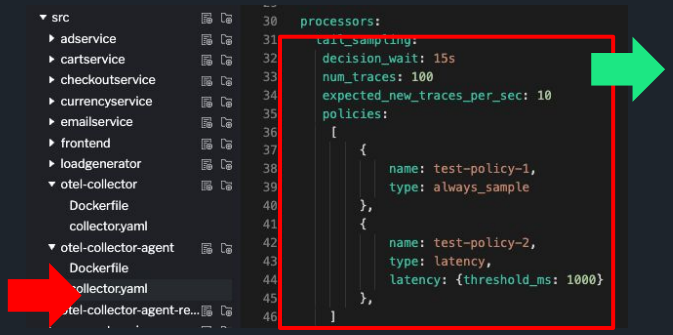
Collector in Action - Tail Based Sampling



Effects from Tail Based Sampling (Client Side)

New Relic Edge with Infinite Tracing (Server Side)

Fully managed tracing service that observes 100% of your application traces, then provides actionable data so you can solve issues faster.

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