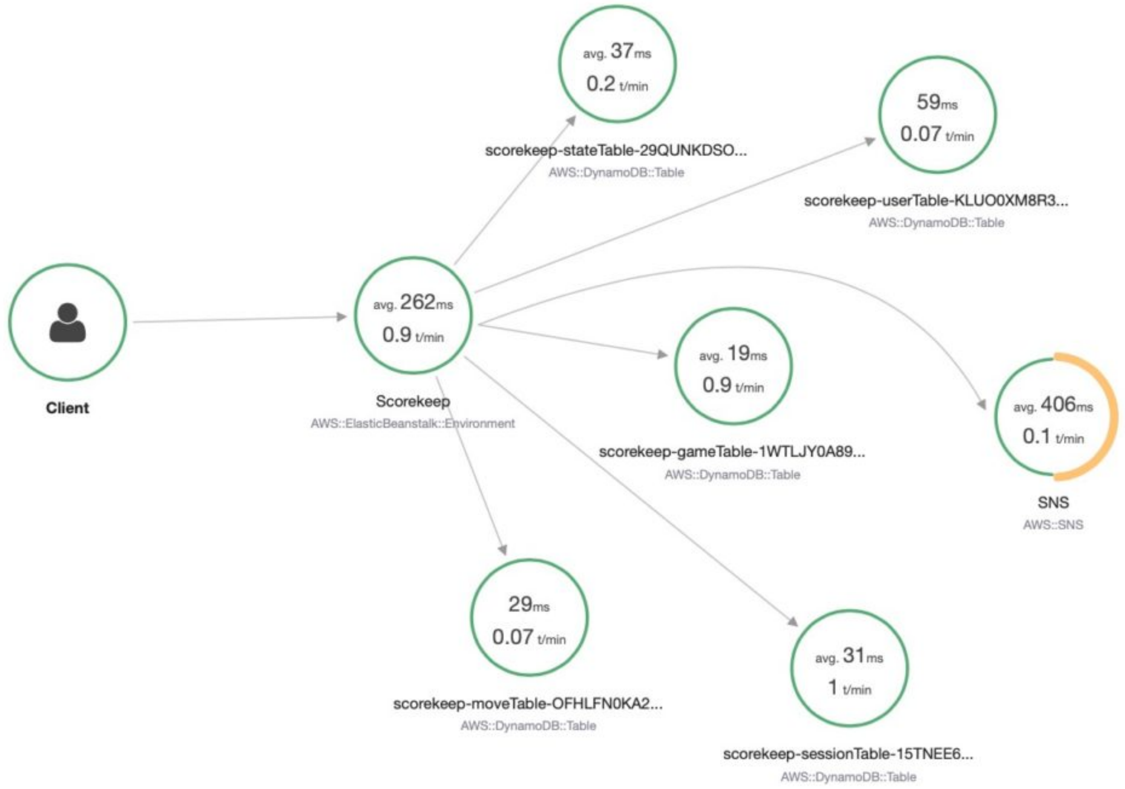
AWS X-Ray is a distributed application tracing service consisting of an Application Programming Interface (API), Software Development Kit (SDK), dashboard, and integrations with other AWS monitoring tools. It supports multiple programming languages to show a map of your application's underlying components. Operations teams commonly use it along with CloudWatch, ServiceLens, and Synthetics to help isolate the root cause of AWS-hosted application slowdowns or outages along various application transaction paths.

In this article, we will look at how X-Ray can help you maintain your AWS-based applications, how to get started and consider X-Ray's strengths and weaknesses.



A service map generated automatically from AWS X-Ray traces

AWS X-Ray Features Summary

Feature	Description	Strengths / Limitations

Feature	**Description**	**Strengths / Limitations**
Trace mapping	Deep visualization of how individual requests make their way through your architecture, including performance and failure details	Easy to navigate and filter, allowing you to sift through relevant information.
Trace details	Breakdown of a request journey into individual components, with timing details, custom metadata, and error logs	Instrumented calls capture code exceptions and make them easy to find here, alongside any custom data you want to pass from your code.
Service mapping	Visualization of the components in your architecture and how traffic moves between them	The automatically generated service map contains failure and performance metrics to enhance your insight into your system. Filtering by time and custom annotations is a powerful tool for incident management.
Trace shipping	Traces are sent to AWS, where they can be queried and retrieved	The free tier provides a monthly allowance of free storage and retrieval.
Instrumentation support	SDKs are provided for Java, .NET, Python, Ruby, Go, and Node.js	Java gets a lot more attention from the AWS documentation than other languages. Most of the SDKs are managed as open-source projects. The CLI and API are available if there is no SDK for your language of choice.

Feature	Description	Strengths / Limitations
OpenTelemetry support	Applications on AWS can be instrumented for X-Ray and other tools simultaneously.	Support exists in AWS Distro for OpenTelemetry, which comes with a separate set of SDKs and different deployment requirements.
APM integration	Popular APMs offer integrations that import X-Ray data by polling the API	Adding tracing data to an integrated suite of monitoring, logging, and process management functionality can promote high operational efficiency.The polling approach can make these integrations less responsive than other tracing solutions.
X-Ray Daemon	A necessary component that collects segment data and manages the connection to AWS X-Ray	Automatically provisioned for several AWS compute solutions like Lambda, but not for EC2.
Insights	Artificial intelligence to detect anomalies and automatically report on incidents	No system-specific configuration is needed. Insights integrates with several AWS messaging options to provide notification and automated response options.

Feature	Description	Strengths / Limitations
Setup & Documentation	Several automatic instrumentation options are available for Java applications. A sample application is available and several language SDKs are open source projects	AWS documentation is strong on how features work and providing examples but light on higher-level operational management and best practice configuration.

Why Tracing?

As an operations engineer or manager responsible for a complex software system, you care about having a relevant view of your system that allows you to focus fast on the components that matter whenever there's an incident.

Tracing and the tools that it enables give you this functionality. Instead of using heuristics, custom log messages, and trial and error to find where a request went wrong in the stack, requests leave behind traces that give you a complete picture of the full request journey in the transaction path.

This feat is achieved by creating a unique trace id as early as possible in the request lifecycle and propagating that id through every component involved in serving that request. Each component reports what it sees to a central service such as X-Ray, which reconstructs the whole picture by matching reports bearing the same trace id.

Why X-Ray?

Standards and tools for tracing and telemetry have made great progress over recent years. AWS X-Ray gives a great combination of a quick start, quick discovery and deep/relevant visualization, insights into AWS and integration with key AWS services out of the box, and optional integration with open standards. It's also able to fit into a more holistic strategy suitable for fast-paced operations departments.

You might want to look beyond X-Ray (such as Jaeger Tracing) if you have strong internal open source capabilities, use multiple cloud providers or on-prem solutions, or for some unusual use-cases or specific customization needs. Even here, you might choose X-Ray as an initial solution that's easy to use.

AWS X-Ray Integrations

AWS X-Ray integrates with whichever AWS compute options you're using – EC2, ECS, EKS, Lambda, and supports tracing through its messaging services SNS, SQS, and EventBridge, and its service mesh AWS App Mesh. The integration that was notably absent previously, Amazon API Gateway, is now available. Aside from these out-of-the-box integrations, X-Ray has options for working with generic HTTP and SQL clients.

Level of Change Needed

How much you need to change your code varies by language and component. For Java code on an EC2 instance making AWS SDK and SQL calls, you can instrument your code entirely through build and application configuration, and outgoing HTTP calls can be traced by swapping in an AWS version of HTTPClientBuilder. You can find the details in this documentation.

Manual code changes are needed in any language to add custom data to trace segments, including custom grouping of calls, and any annotations and metadata you want to add.

Whether automatic or manual, changes to X-Ray tracing will require an application restart or redeployment.

Using AWS X-Ray

AWS provides two sample applications. A Node.js application can be deployed from the AWS X-Ray management console, and a Java application "Scorekeep" is described in detail in the X-Ray documentation.

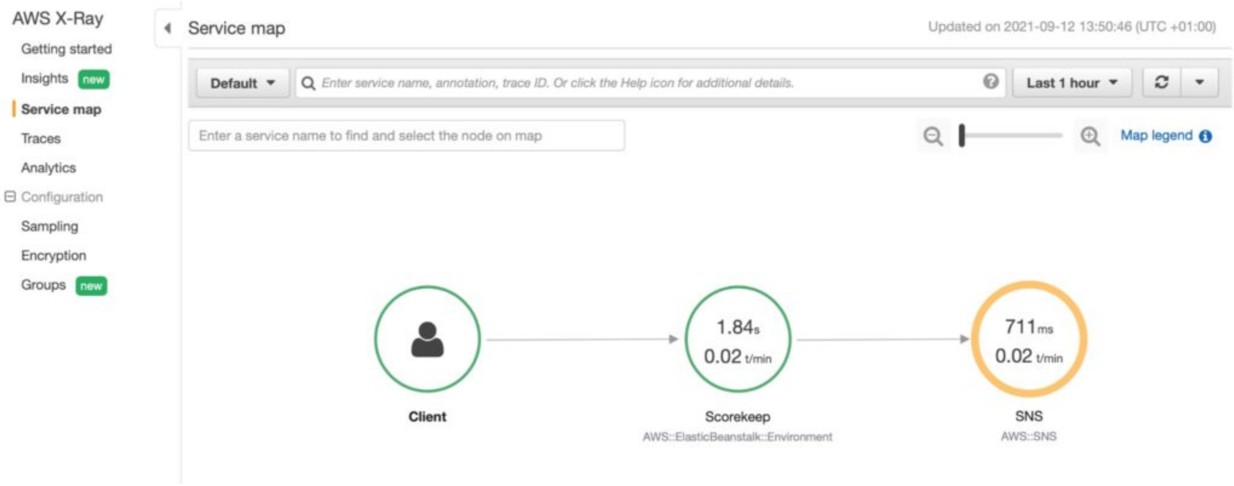
This section will use the Scorekeep tutorial to highlight what you can get out of AWS X-Ray. AWS documentation takes you through it step by step; here, we will focus on the concepts and instrumentation, which is what you will need to trace your applications.

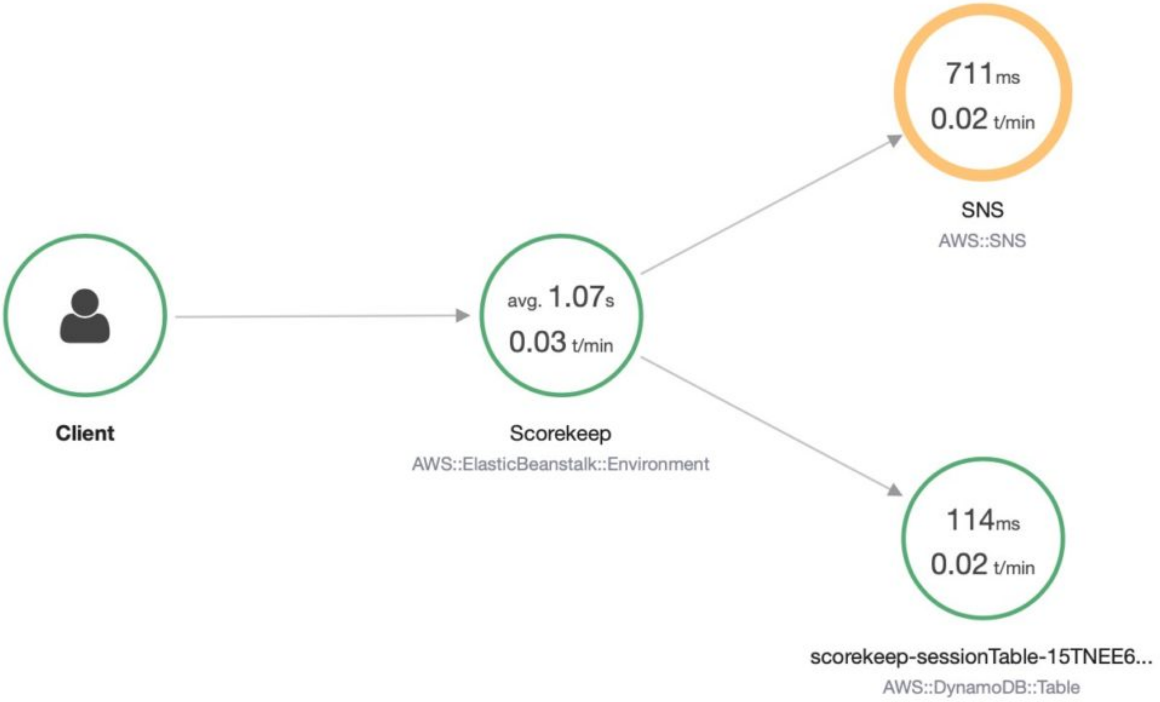
Tracing is very simple at heart but has its concepts that you will need to understand. Before getting hands-on, here are the main tracing terms you will see:

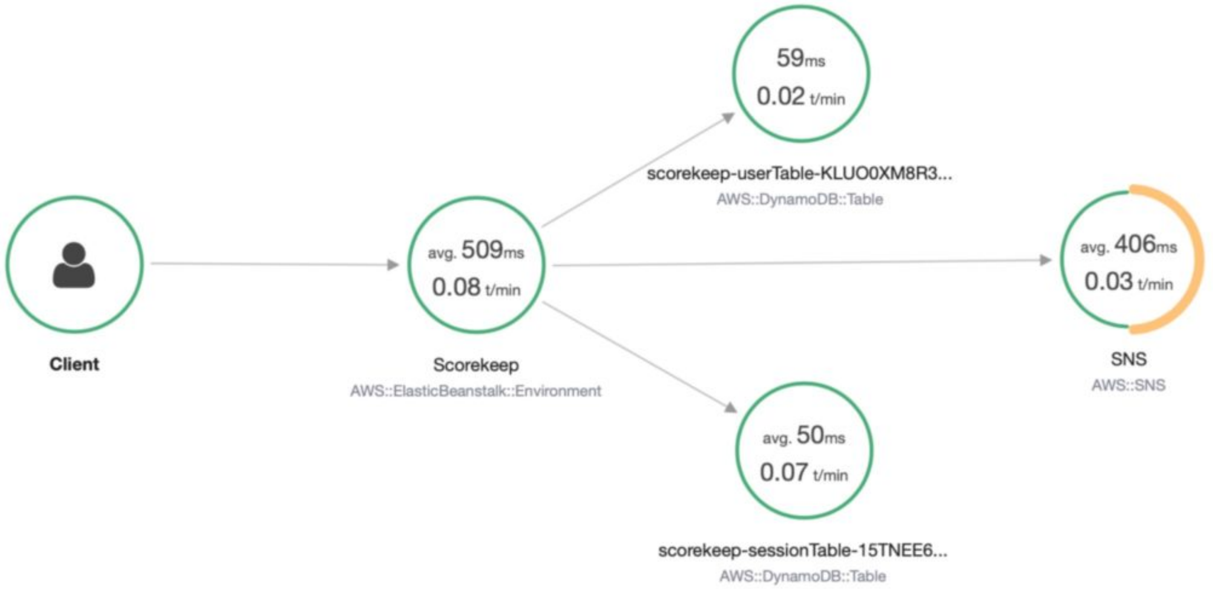
Segment	Like a method call, a segment represents a unit of activity over a specific period of time, from the point of view of a single component. For example, a request in a simple web application can generate segments from the point of view of the client, the webserver, and the database.
Trace	Tracing works by injecting a unique identifier into a request, and including that identifier whenever a segment related to that request is recorded. AWS X-Ray groups segments with the same identifier, forming a trace. If your system is fully instrumented, a trace can describe the whole lifecycle of a single request.
Subsegment	A single component may divide a segment into subsegments, in a similar way to a method calling other methods before returning. The distinction between segments and subsegments is primarily related to the component boundary, and you will find the same data types attached to each. Subsegments can be nested, and let you send more granular, structured data to X-Ray. AWS X-Ray has a useful feature in creating inferred segments from subsegments.
Sampling	In some cases, recording traces for 100% of your traffic across all your components is unnecessary, as a small random sample can give you enough context to see how your system is operating, and you won't want high-performance components spending cycles on tracing for every request. In other cases, you want to trace everything with fine granularity to avoid blind spots. Sampling rules let you control the proportion of requests you collect traces for.
Annotations & metadata	If you want to analyze your trace data by anything other than the component and line of code responsible for collecting the trace, you can add custom information to segments and subsegments. For example, you could annotate calls with the user id or the caller, and be able to see later that an incident only affects calls from certain users. Annotations are indexed for searching, while

	metadata is available but not searchable. You can also add a user id, which can only be scoped to a segment (not a subsegment).

The Scorekeep example uses Elastic Beanstalk and includes Lambda functions. In general, the differences in X-Ray design between the different compute environments are minor, and AWS documentation covers the considerations needed for more complex Lambda, ECS, and EKS environments.


AWS X-Ray
Getting started
Insights new
Service map
Traces
Analytics
Configuration
Sampling
Encryption
Groups new
Service map
Updated on 2021-09-12 13:50:46 (UTC +01:00)
Default
Enter service name, annotation, trace ID. Or click the Help icon for additional details.
Last 1 hour
Enter a service name to find and select the node on map
Map legend
1.84s
0.02 t/min
711ms
0.02 t/min
Client
Scorekeep
AWS::ElasticBeanstalk::Environment
SNS
AWS::SNS

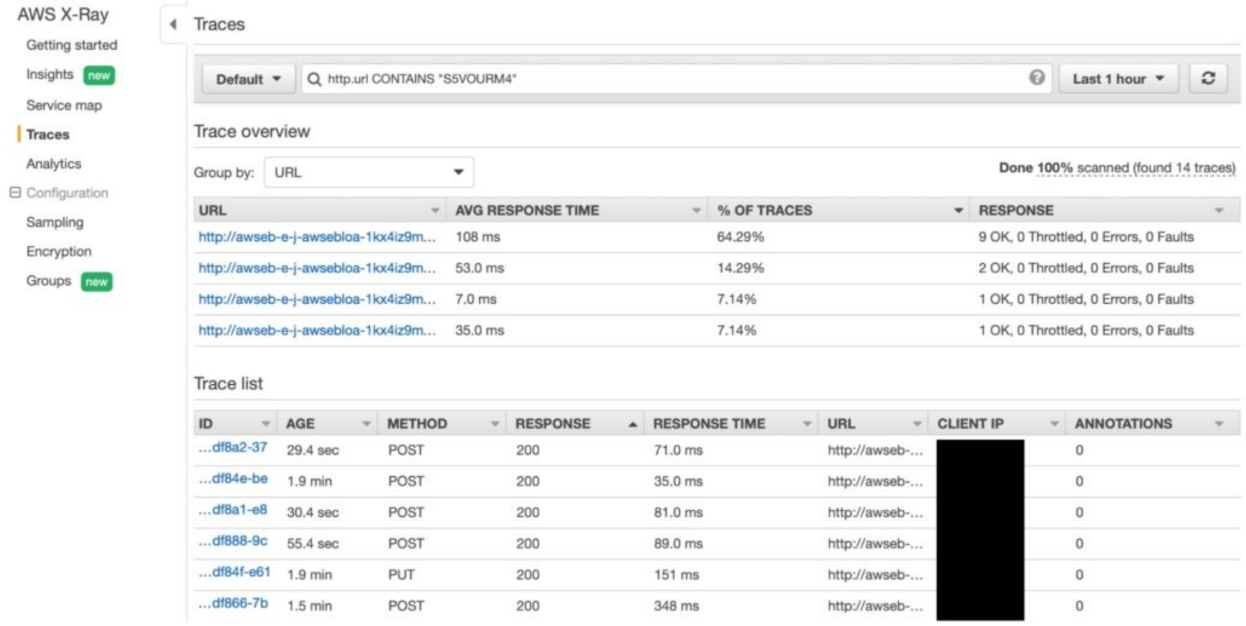




Stepping through the demo application slowly, you can see the service map build up as more components are used.

After Deployment

Once the CloudFormation stack deployment has been completed, you can access the web application. You can get a feel for X-Ray working by interacting with the application slowly and reviewing what can be seen in the X-Ray console after each interaction. You will see each group of components appear on the service graph as you access the parts of the application that use them.



Traces

http.url CONTAINS "S5VOURM4"

Trace overview

Group by: URL

Done 100% scanned (found 14 traces)

URL	AVG RESPONSE TIME	% OF TRACES	RESPONSE
http://awseb-e-j-awsebloa-1kx4iz9m...	108 ms	64.29%	9 OK, 0 Throttled, 0 Errors, 0 Faults
http://awseb-e-j-awsebloa-1kx4iz9m...	53.0 ms	14.29%	2 OK, 0 Throttled, 0 Errors, 0 Faults
http://awseb-e-j-awsebloa-1kx4iz9m...	7.0 ms	7.14%	1 OK, 0 Throttled, 0 Errors, 0 Faults
http://awseb-e-j-awsebloa-1kx4iz9m...	35.0 ms	7.14%	1 OK, 0 Throttled, 0 Errors, 0 Faults

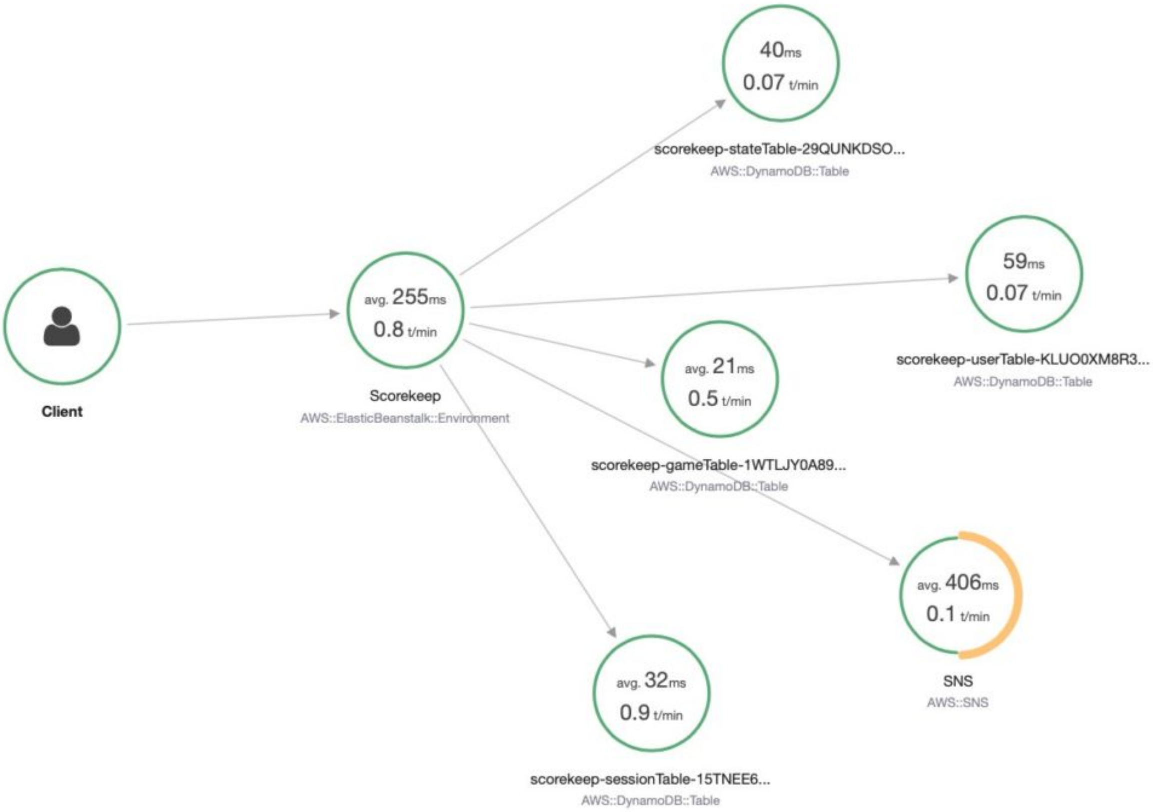
Trace list

ID	AGE	METHOD	RESPONSE	RESPONSE TIME	URL	CLIENT IP	ANNOTATIONS
...df8a2-37	29.4 sec	POST	200	71.0 ms	http://awseb-...	[redacted]	0
...df84e-be	1.9 min	POST	200	35.0 ms	http://awseb-...	[redacted]	0
...df8a1-e8	30.4 sec	POST	200	81.0 ms	http://awseb-...	[redacted]	0
...df888-9c	55.4 sec	POST	200	89.0 ms	http://awseb-...	[redacted]	0
...df84f-e61	1.9 min	PUT	200	151 ms	http://awseb-...	[redacted]	0
...df866-7b	1.5 min	POST	200	348 ms	http://awseb-...	[redacted]	0

The traces dashboard

The Scorekeep example is written with a deliberate error so that you can see how X-Ray allows you to detect the issue and pinpoint the component at fault. In this case, the stack trace attached to the SNS segment is enough to locate and diagnose the code fault. More generally, you can quickly answer a range of diagnostic questions from the service graph view:

- Is there a failure or a performance issue?
- What proportion of requests are affected?
- When did the failure/performance pattern change?



Something went wrong with some SNS calls. Clicking the node gets you to the relevant stack trace. You can also go back in time to find when/if this was last healthy.

These questions take a lot longer to answer using only simple monitoring and logging tools. Thus, tracing can directly improve key operational success metrics like Mean Time To Recovery (MTTR).