Locating Regions of Uncertainty in Distributed Systems Using Aggregate Trace Data

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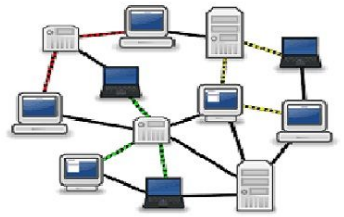
Other notes from meeting

Distributed system - a bunch of computers working together. To help debug we trace our systems, but don’t trace everything. Here are two traces where there’s uncertainty, and we need more implementation (tracepoints). To do that we look at the exclusive and inclusive latencies.

Use one whole example throughout the whole presentation, and don’t just make things A, B, C, use real world examples

Tell them more about HOW you got the ex and in values, animate it, your calculations

Distributed Systems: What Are They?



Distributed systems are networks of devices/machines (servers and computers, for example) that communicate with one another to complete tasks.

Examples:

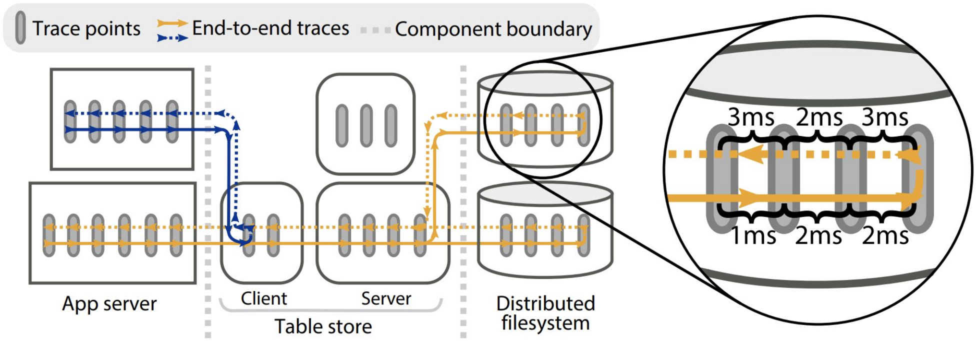
- Google
- Facebook
- Cellular networks

Distributed systems are essential to the modern world!

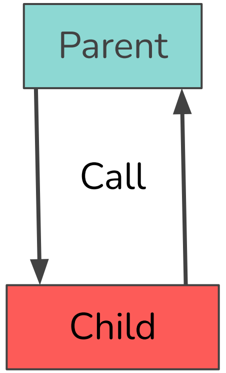
Instrumentation & Distributed Tracing

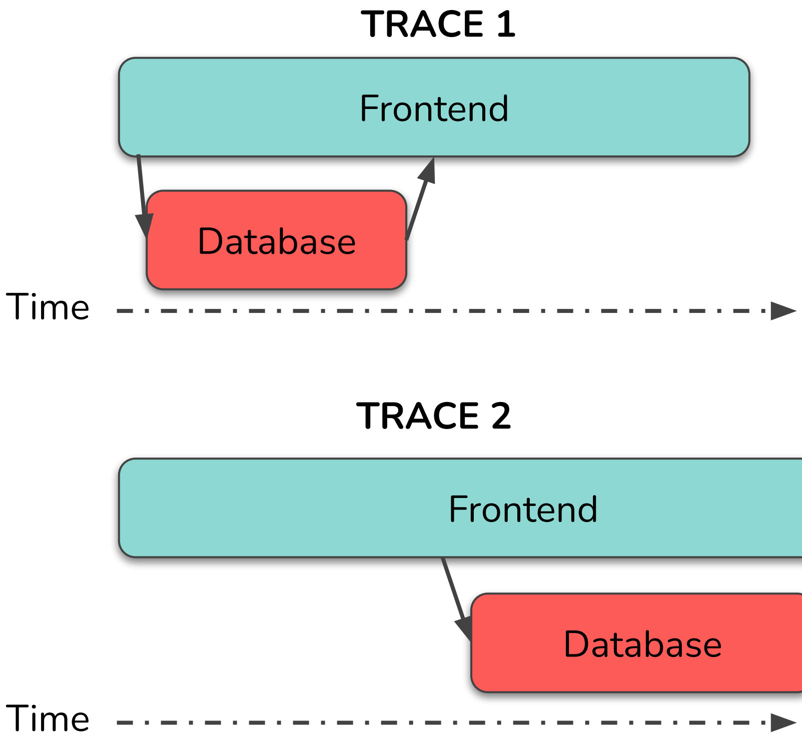
- **<u>Distributed tracing</u>**: a way to observe and record how application requests get propagated through a distributed system.
- Traces are useful for developers to see the architecture of and interactions within the system
    - Have a clearer idea of what's going on when modifying the system codebase identifying errors
- Essential for distributed systems, given their complex structure

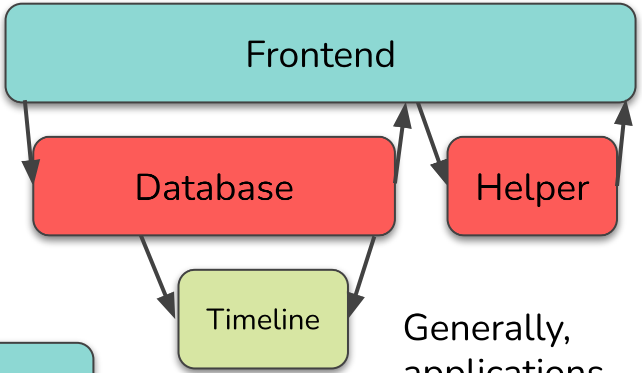
- Instrumentation often consists of **<u>tracepoints</u>** embedded into code.
- They monitor and log information.



Span Model of Tracing

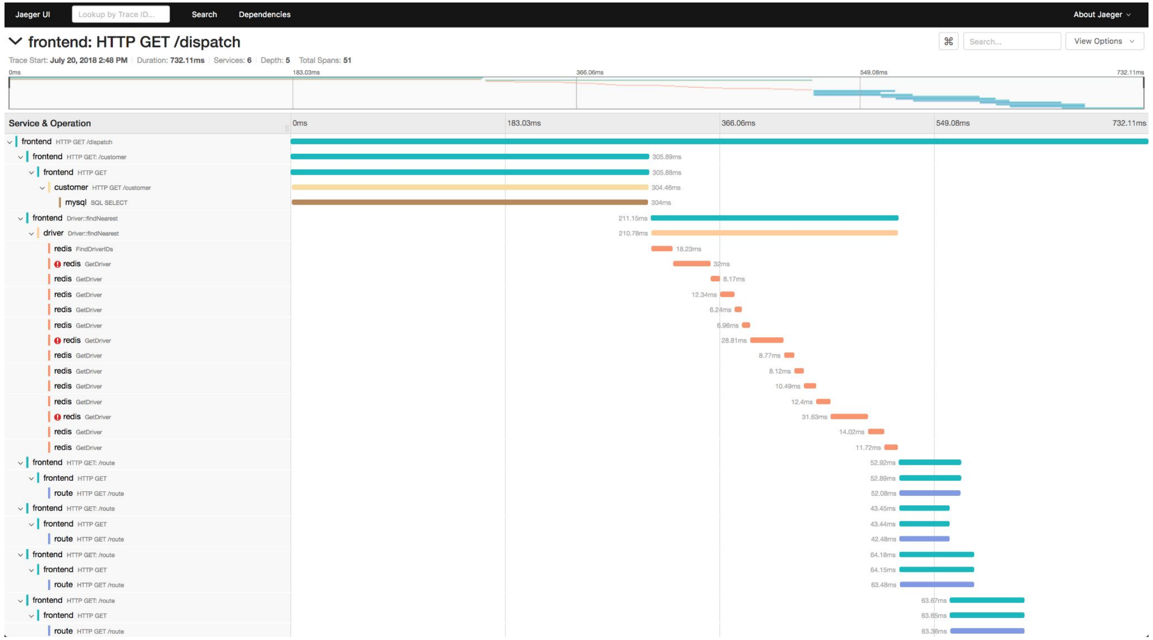






Generally, applications have thousands of spans

HotROD example

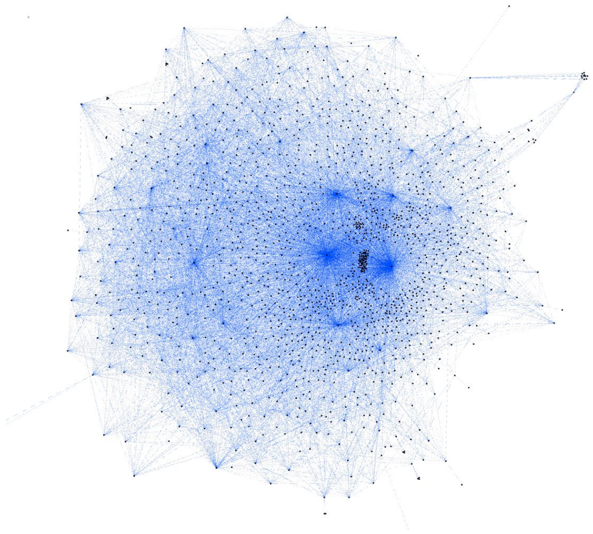


Jaeger UI | Lookup by Trace ID... | Search | Dependencies | About Jaeger

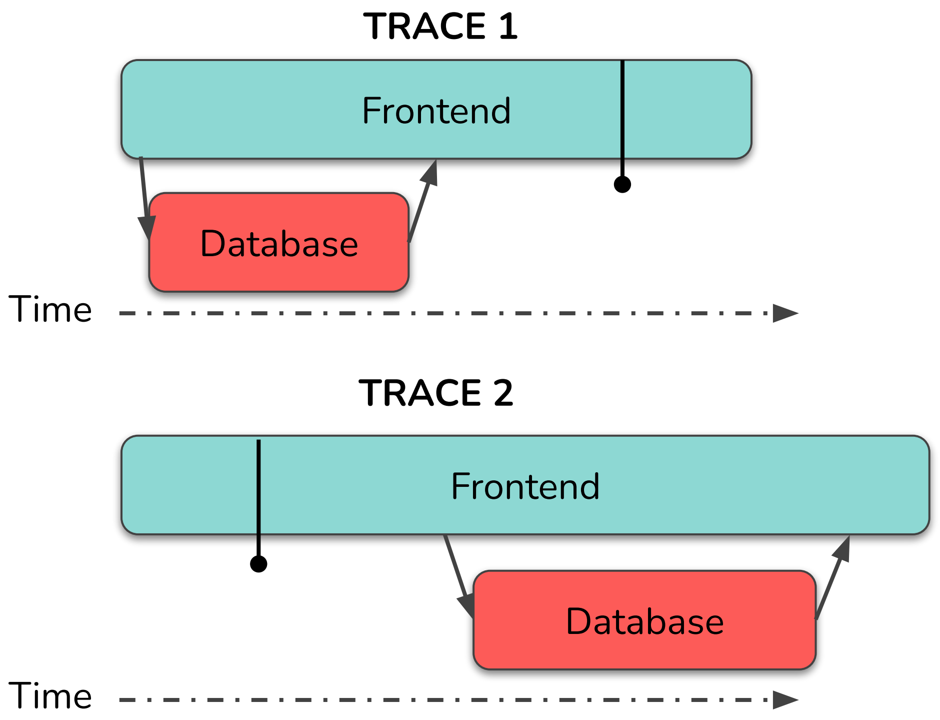
frontend: HTTP GET /dispatch

Trace Start: **July 20, 2018 2:48 PM** | Duration: **732.11ms** | Services: **6** | Depth: **5** | Total Spans: **51**

Service & Operation	Duration
frontend HTTP GET /dispatch	
frontend HTTP GET: /customer	305.89ms
frontend HTTP GET	305.88ms
customer HTTP GET /customer	304.46ms
mysql SQL SELECT	304ms
frontend Driver::findNearest	211.15ms
driver Driver::findNearest	210.78ms
redis FindDriverIDs	18.23ms
redis GetDriver	32ms
redis GetDriver	8.17ms
redis GetDriver	12.34ms
redis GetDriver	6.24ms
redis GetDriver	6.96ms
redis GetDriver	28.81ms
redis GetDriver	8.77ms
redis GetDriver	8.12ms
redis GetDriver	10.49ms
redis GetDriver	12.4ms
redis GetDriver	31.63ms
redis GetDriver	14.02ms
redis GetDriver	11.72ms
frontend HTTP GET: /route	52.92ms
frontend HTTP GET	52.89ms
route HTTP GET /route	52.08ms
frontend HTTP GET: /route	43.45ms
frontend HTTP GET	43.44ms
route HTTP GET /route	42.48ms
frontend HTTP GET: /route	64.18ms
frontend HTTP GET	64.15ms
route HTTP GET /route	63.48ms
frontend HTTP GET: /route	63.67ms
frontend HTTP GET	63.65ms
route HTTP GET /route	63.36ms



The Problem: An Example



Quite different end-to-end latencies across traces → moderate uncertainty

Uncertainty: lack of predictability of behavior of a system based on given information

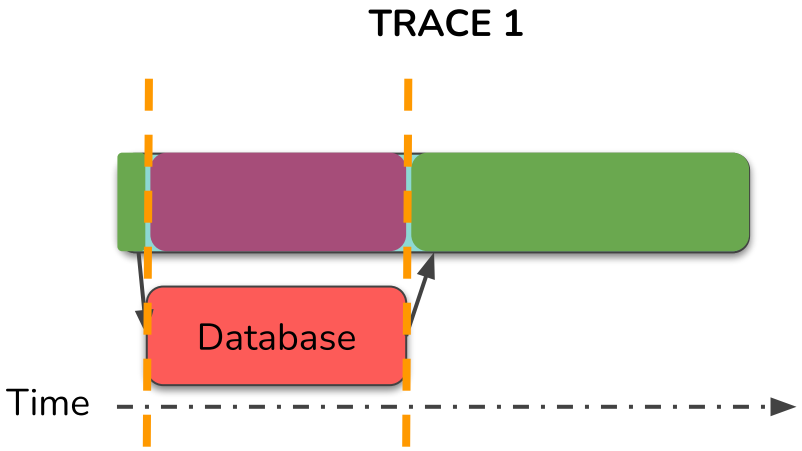
To reduce uncertainty, increase the amount of given information

→ more instrumentation!

But where to instrument?
- Parent?
- Child?

Place with more uncertainty!

Inclusive/Exclusive Latencies



Exclusive Latency

Inclusive Latency

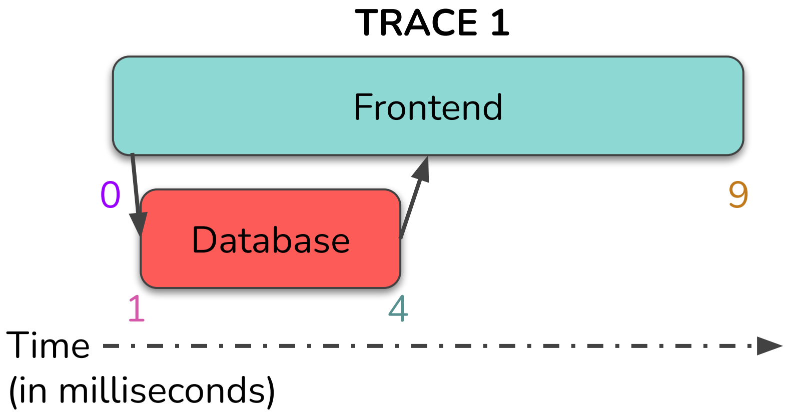
Assuming that parent does nothing but wait for the child's response after creating the child:

Exclusive latency tells us how much latency the parent is responsible for

Calculation of ex/inclusive latencies

- Inclusive latency: the whole length of the span
    - (end of span)-(start of span)
    - 9-0 = 9

- Exclusive latency: the length of the span minus the time spent on waiting for other spans
    - inclusive latency-(end of child span-start of child span)
    - 9-0-(4-1) = 6



Overview of our algorithm

A developer notices their program has latency issues, but isn't sure which operation caused it. Our algorithm:

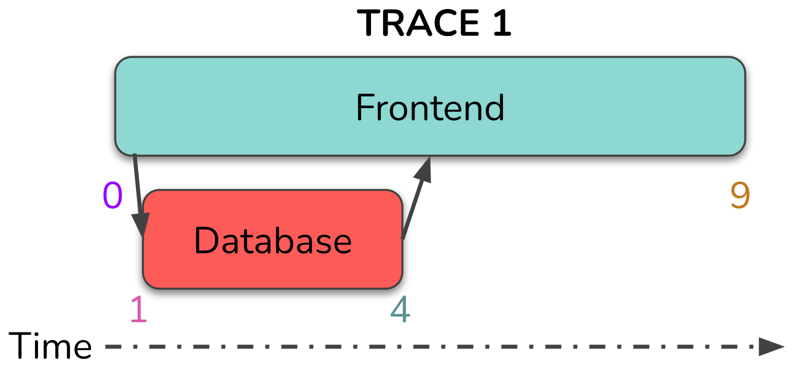
1. Calculate the exclusive latency and inclusive latency values for all spans within all traces
2. For spans with same operation name, combine information across traces to get uncertainty measures.
3. User select an uncertain measure as their rubric to judge the operations
4. Operations are ranked based on this measure -> the higher ranked an operation is, the more implementation is needed there!

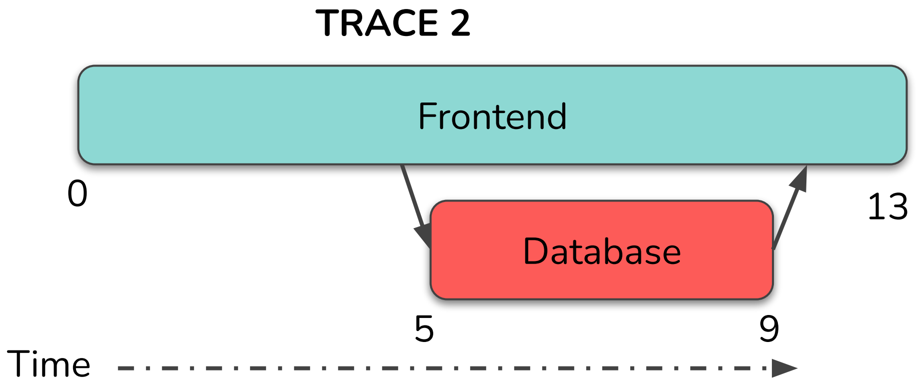
Our Uncertainty Measures

Two of our uncertainty measures are:

1. **<u>Standard deviation in exclusive latency</u>**
   a. Shows us the deviation of exclusive latency values - how much does it vary? How much uncertainty is here?
   b. Exclusive latency: Which operations are doing the most work themselves?
2. **<u>Coefficient of variation in exclusive latency</u>**
   a. Coeff. Of Variation is (standard deviation)/(mean) * 100%
   b. Shows us the relative dispersion of exclusive latency

Algorithm: Step 1





	In	Ex
Frontend	9-0 = 9	9-(4-1)-0 = 6
Database	4-1 = 3	4-1 = 3

	In	Ex
Frontend	13-0 = 11	13-(5-1) = 9
Database	9-5 = 4	9-5 = 4

Algorithm: Step 2

For spans with same operation name, combine information across traces to get uncertainty measures.

	Trace 1 exclusive latency	Trace 2 exclusive latency	Standard Deviation in Ex	Coeff. Of Variation in Ex
Frontend	6	9	2.1	33%
Database	3	4	0.71	20%

Algorithm: Step 2 cont.

User select one from the given values as their rubric.

In this case, the user selects the **std. div. in exclusive latency** as their rubric

	Trace 1 exclusive latency	Trace 2 exclusive latency	Standard Deviation in Ex
Frontend	6	9	2.1
Database	3	4	0.71

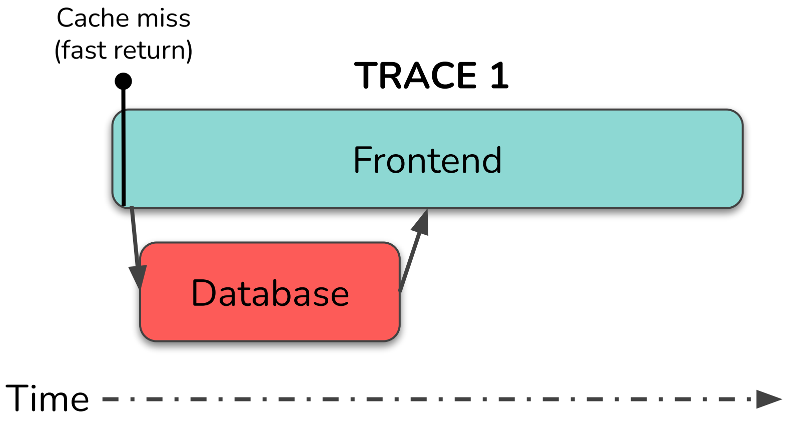
Algorithm: Step 3

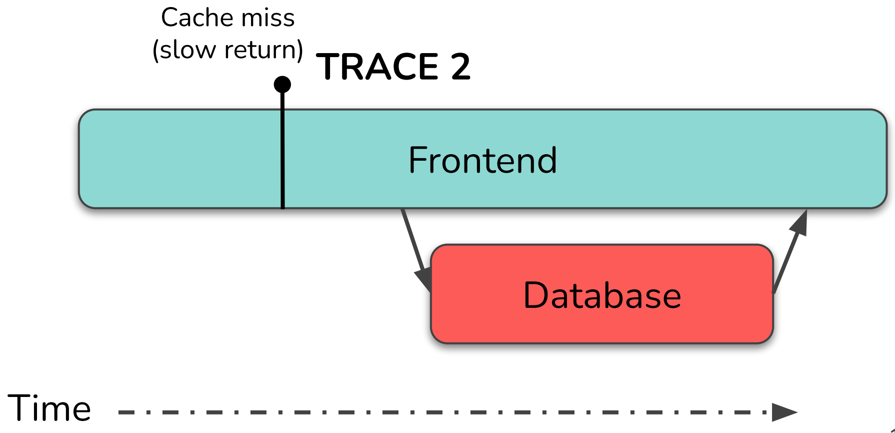
rank areas of uncertainty according to the rubric of their choosing, in this case, the std. div. in Ex

Ranking	Operation Name	Standard deviation in Ex
1st	Frontend	2.828
2nd	Database	0

Resolution

- Frontend ranked higher than database → more instrumentation added to frontend
- Developer may discover an error in the frontend that caused a cache miss to sometimes return slowly prior to reaching for the database to search for the user query.
- Knowing this would allow them to address the error





Limitations

Our algorithm...

- Assumes the presence of "skeleton" trace points to build span model (minimal instrumentation)
- Repeated span names become an issue
- Limited to informing developer about inclusive/exclusive parts of spans

Future Ideas

- Analysis of more of the architecture itself (how is one microservice connected to another, etc.) to better determine uncertainty sources

- There are multiple ways of representing traces
    - We use a span-based model
    - there are also segment-based models and event-based models, which explore dimensions of distributed systems that our span-based model inherently cannot.

Acknowledgements to:

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- Our mentors – Darby Huye, Max Liu, and Dr. Raja Sambasivan

Image Sources

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