Google's Dapper – A Large-Scale Distributed Systems Tracing Infrastructure

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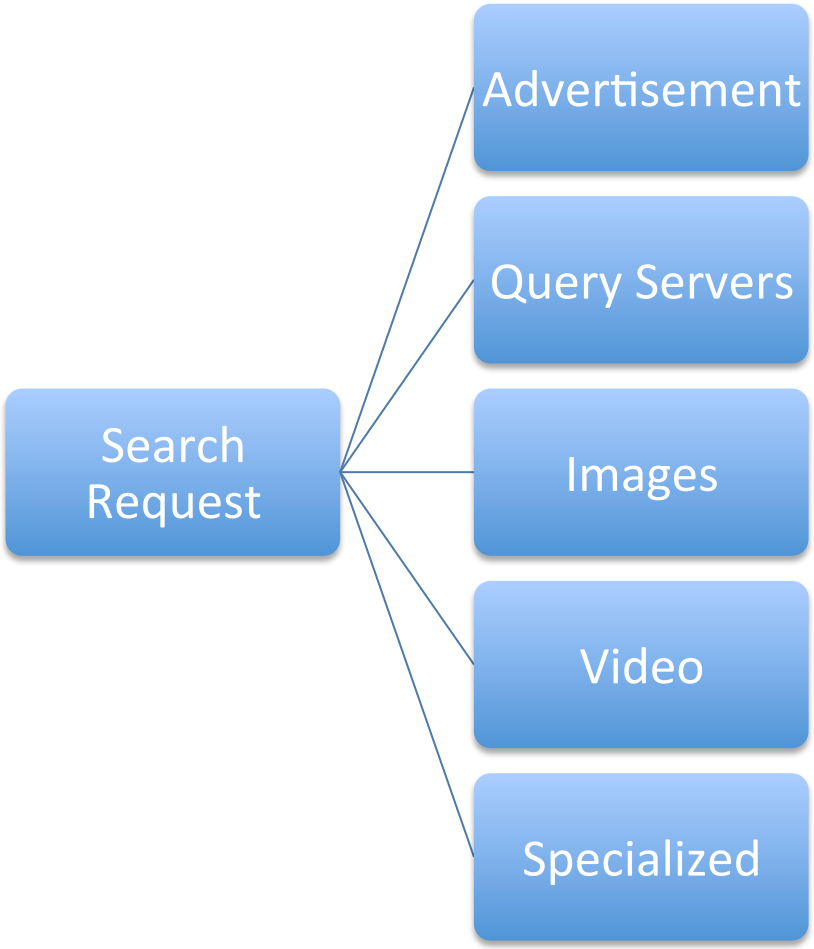
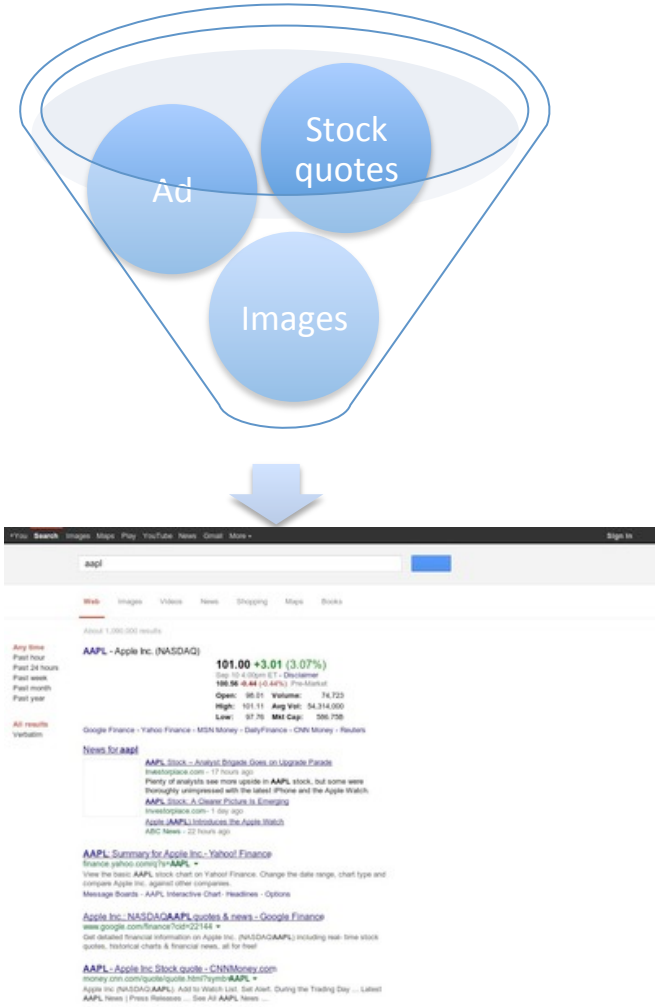
Goals

- Provide developers with
  - Information about behavior of complex distributed systems, applications
  - Tools to debug and analyze production service issues
  - Application level transparency and service dependencies
  - Assist in minimizing end to end latencies

Example: Web Search





Example: Web Search

- Many services
  - A lot of people writing, updating them constantly
- Performance sensitive
  - End to End latency for search needs to be low
- On shared hardware with other services competing for resources

Potential solution

- Write a library or framework that is
  - Embedded into majority of services
  - Continuously collecting and monitoring data
  - Quick turnaround time

Dapper: Requirements

- Low-Overhead
  - Cannot affect performance significantly
- Application Level Transparency
  - Who did what, when, how(RPC?)
- Scalability
  - At Google Scale, can't trace everything.. Sample!
- Making tracing data available quickly (< 1 min)

Dapper: Requirements

- Not an experimental, fringe system
- Runs on production hardware and services
- Tracing

Annotation-Based	Black-box
More instrumentation	Less instrumentation
Less data is required to correlate	Depends on lot of data and statistical regression techniques
As granular as the user needs	Depends

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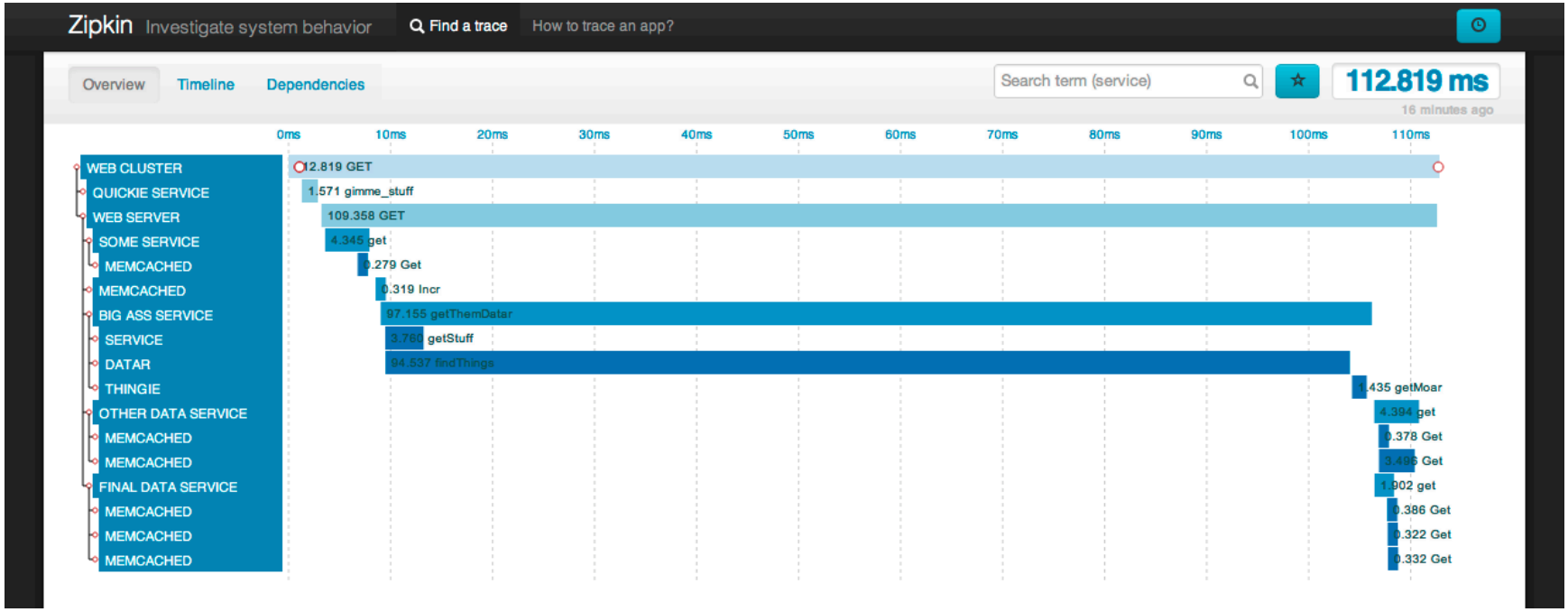
Trace Trees and Spans



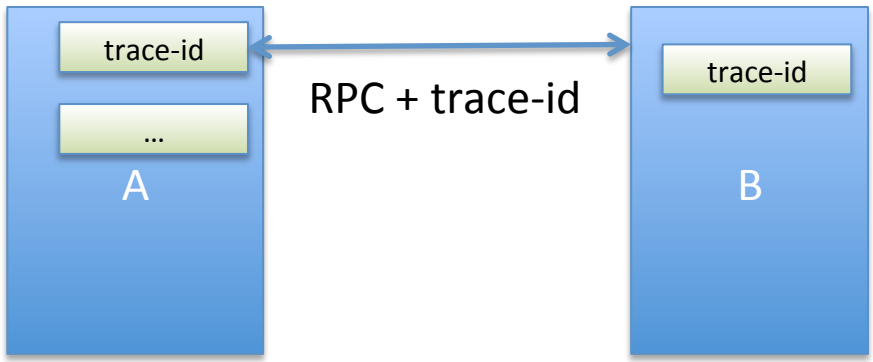
Trace Trees and Spans

- Spans are tree nodes with
  - Id
  - Parent Id
  - Name
  - Start and End times

  Can cover multiple hosts
- Edges indicate causal relationship
- Additional tier of infrastructure adds a level

Instrumenting

- Tracing the control path
  - Dapper attaches a thread-local *trace-context*
  - Async callbacks store the trace context of creator
    - Then associated by callee to the relevant worker thread



Instrumenting

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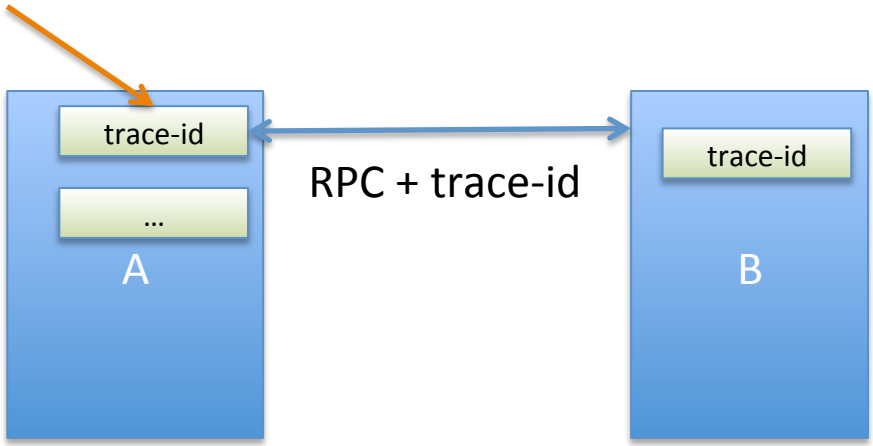
Doesn't need to know about the actual thread in B.. Or aggregate up..



Annotations

- Application developers “enrich” code with annotations
- Allows map of custom key-value annotations

```
// C++:
const string& request = ...;
if (HitCache())
  TRACEPRINTF("cache hit for %s", request.c_str());
else
  TRACEPRINTF("cache miss for %s", request.c_str());

// Java:
Tracer t = Tracer.getCurrentTracer();
String request = ...;
if (hitCache())
  t.record("cache hit for " + request);
else
  t.record("cache miss for " + request);
```

Figure 4: Common-case usage patterns for Dapper’s annotation APIs in C++ and Java.

Sampling

- Two levels
  - How many nodes in the cluster to sample
    - Runs as a daemon in fraction of production services
    - Only applications enriched with annotations are traced
  - Record only fraction of traces
    - On collector too
    - 1 TB of trace data / day => 0.01% of network traffic
    - Needs to be available for at least 2 weeks after initial logging

Implementation

- Very small and efficient implementation
  - No significant impact on network, disk or
- Traces are collected in log files in the machine
  - Then pulled and written to BigTable
  - Median Latency 15 seconds
    - But can take hours
  - There's a way to look at the logs live during "firefighting" operations too

Security & Privacy

- Payloads are not automatically logged
  - But you can opt-in if you need to

Tools

- Depot API
  - Expose clean intuitive interface to the raw data
  - Access By
    - Trace-Id
    - Bulk
    - Indexed Access
      - Compressed trace data is only 26% from actual trace data
- Web based UI for exposing trace trees

Tools

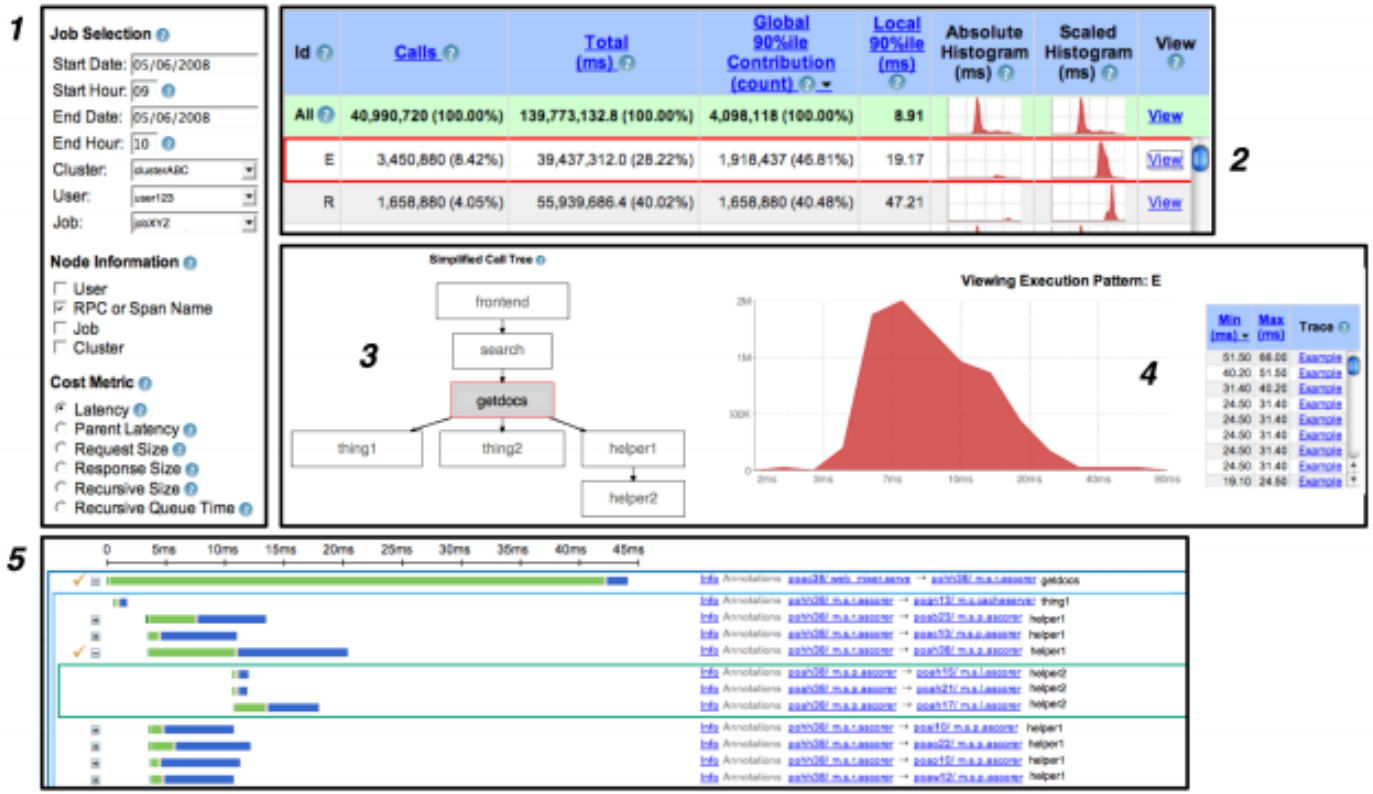


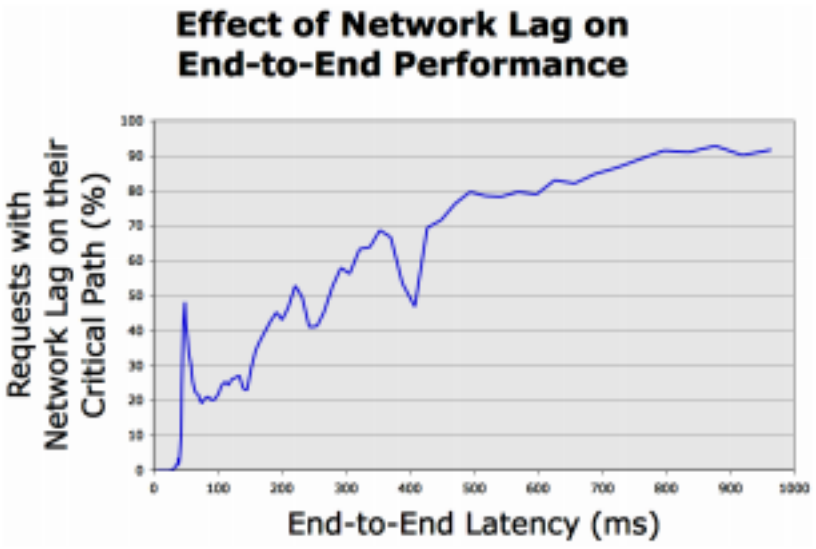
Figure 6: A typical user workflow in the general-purpose Dapper user interface.

Adoption

- 200 active users per week
- Teams use it to make informed refactoring decisions
  - Example AdWords
  - And add additional tools and extensions
- All data is exposed to build better tools and integrations
- Integrated with Exception Monitoring

Adoption

- Addressing Long-Tail Latency



Related Work

- Black-box monitoring systems
  - Project5
  - WAP5
  - Sherlock
- Explicit annotation based systems
  - Pip and Webmon rely on application level annotations
  - X-Trace, Pinpoint and Magpie focus on middleware and libraries modifications

Contributions

- First production distributed tracing framework
- Achieves higher degree of application level annotation
  - Very few workloads that required manual intervention (40 C++ and 33 Java applications)

Problems

- Specific to Google's infrastructure
- Batched workloads for efficiency do not have mapped trace-ids
  - MapReduce for example
- Good at system problems, you still need other tools for specifics
- Kernel levels are not included

Further

- Twitter implemented Zipkin inspired by Dapper
  - It's open source
- Enabled building distributed request flow comparison services at Google

Questions?