Diagnosis and Automation for Deployed Distributed Systems

Google™

The Weatherman Effort

Gideon Mann, Mark Sandler, Eyal Even-dar, Darja Krushevskaja, Sudipto Guha, Krzysztof Ostrowski, Sebastian Pueblas, Lev Ratinov, Eran Gabber

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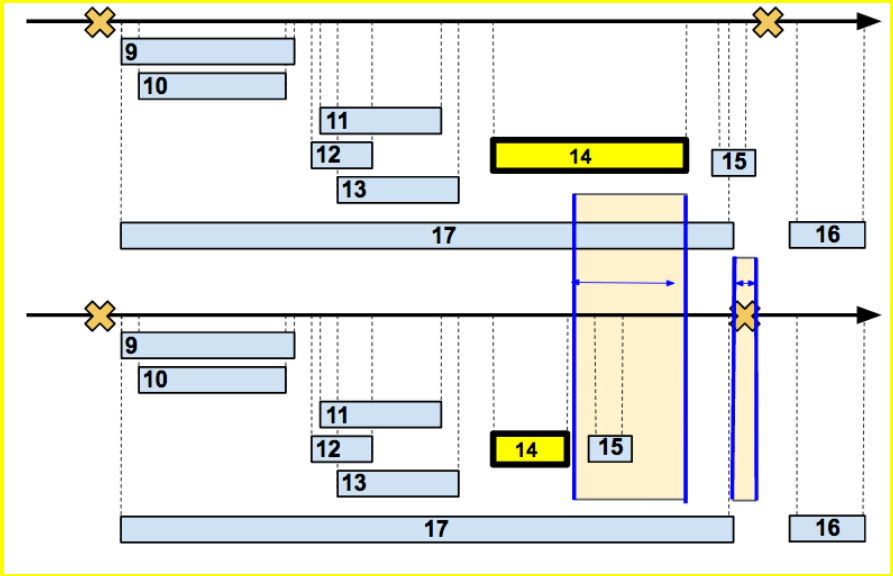
Today: Profiling Latency in Deployed Distributed Systems



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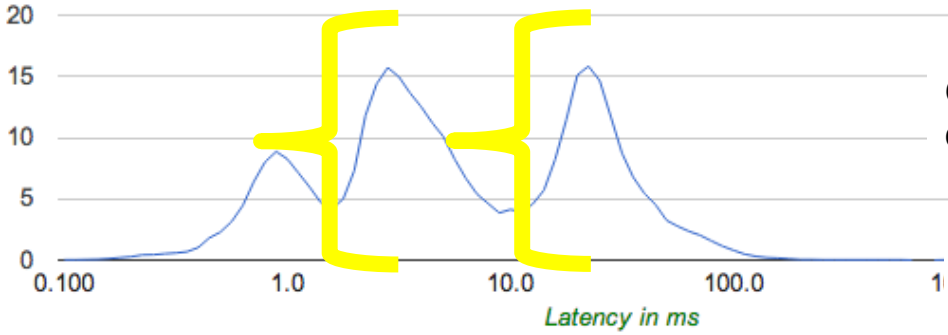
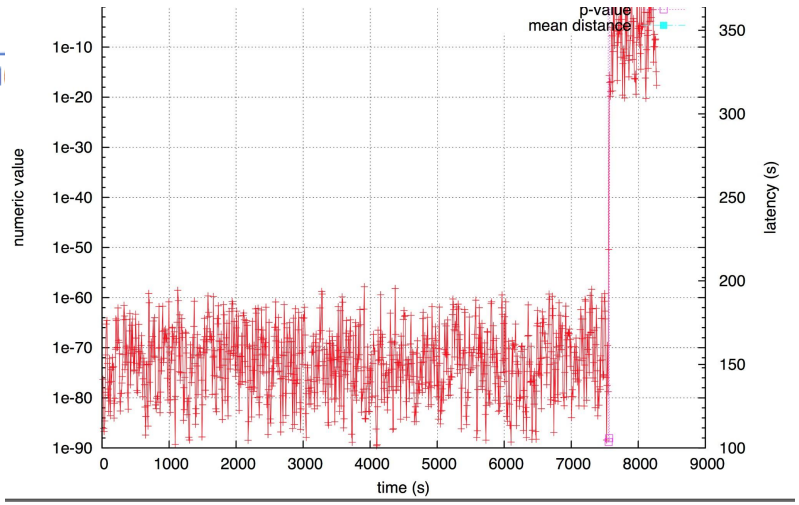
Two Scenarios of Interest

Latency distribution has multiple peaks, at different orders of magnitude.

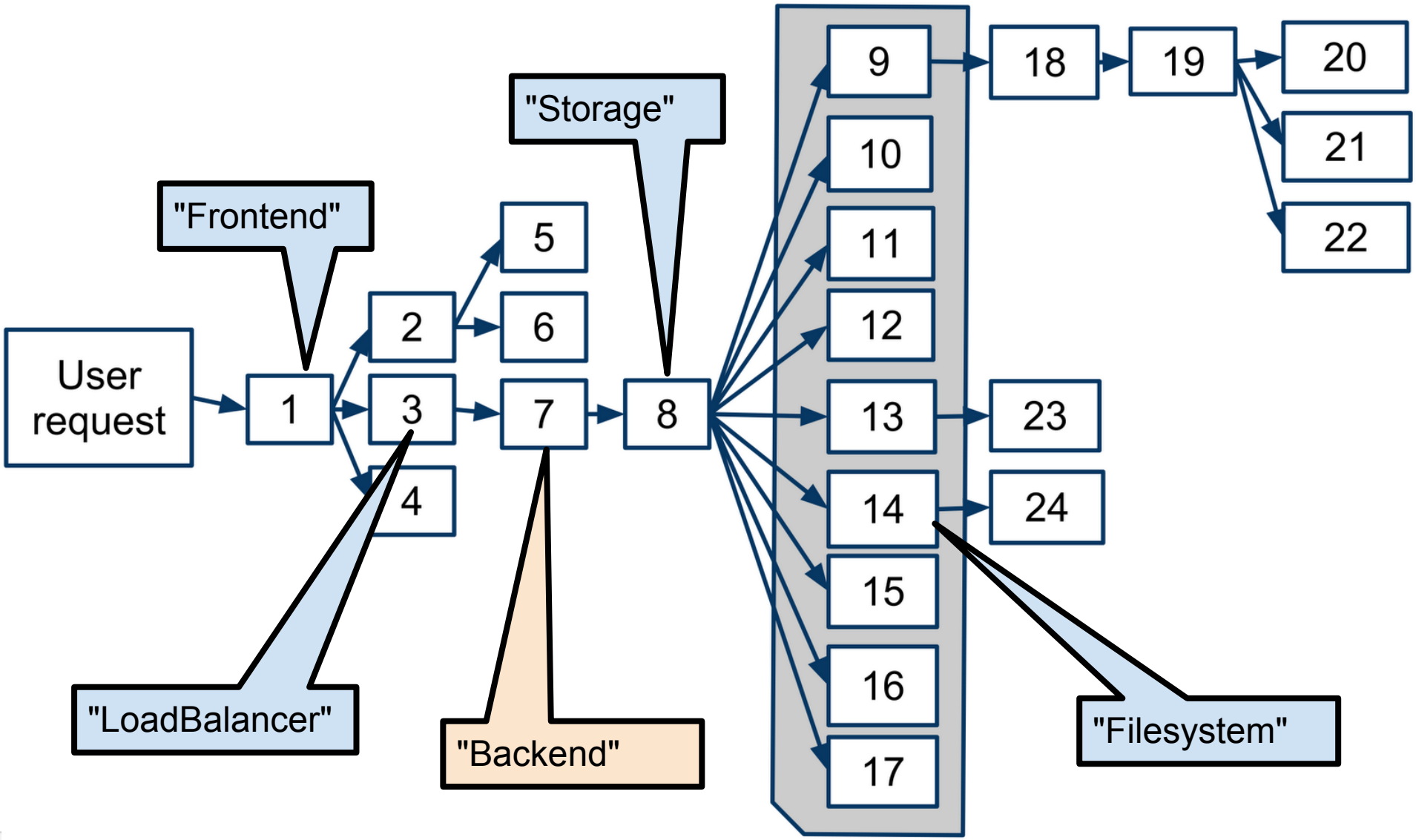


Load-testing isn't enough.

Over time, the latency has dramatically changed ... what happened?



Well, probably a lot has changed. What's the most significant?


User request
1
"Frontend"
2
3
4
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6
7
"Storage"
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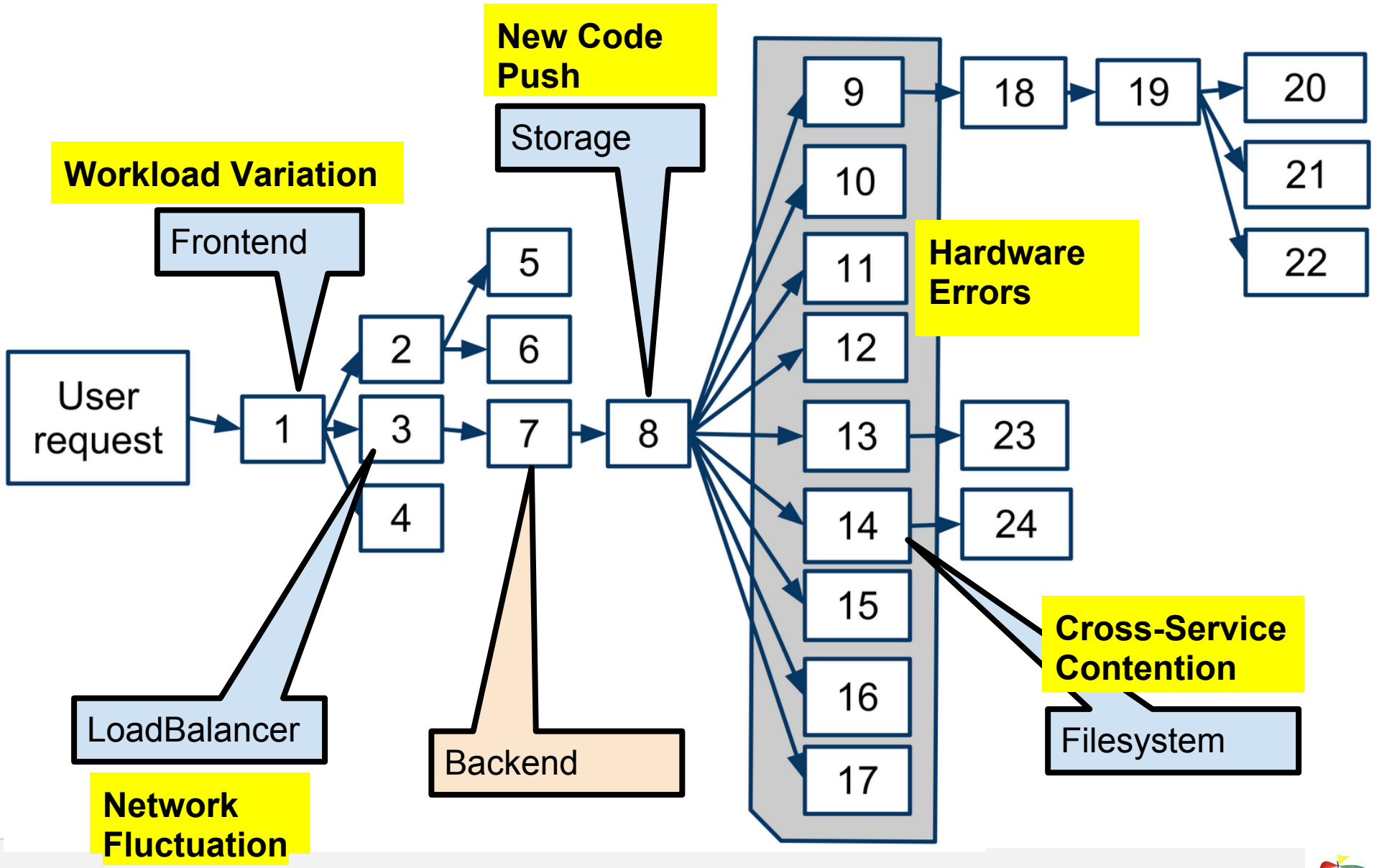
23
24
"LoadBalancer"
"Backend"
"Filesystem"


New Code Push
Storage
Workload Variation
Frontend
User request
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22
23
24
Hardware Errors
Cross-Service Contention
Filesystem
LoadBalancer
Network Fluctuation
Backend

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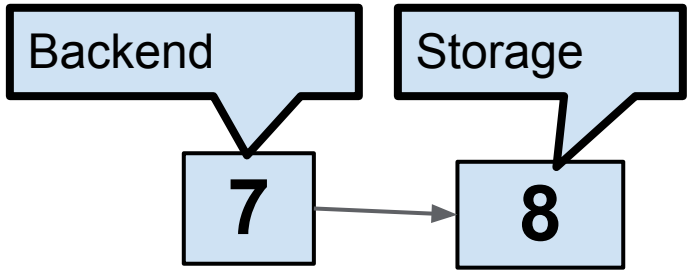
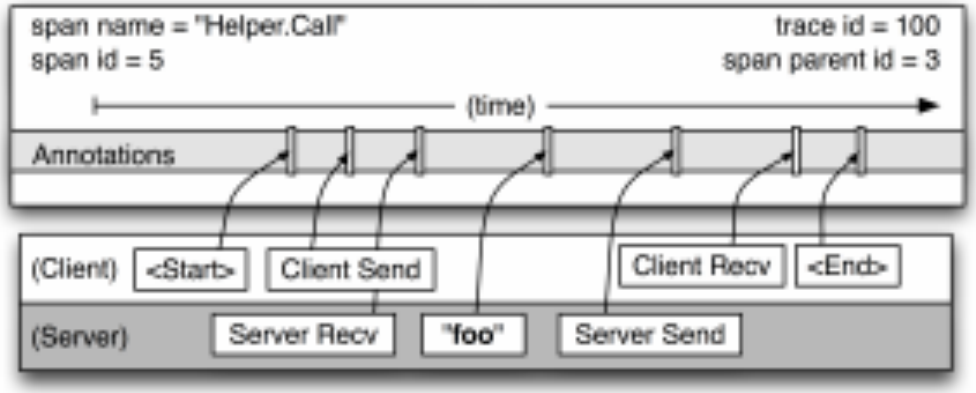
Dapper Distributed Trace Collection

Sigelman, Barroso, Burrows, Stephenson,
Plakal, Beaver, Jaspan, Shanbhag '10





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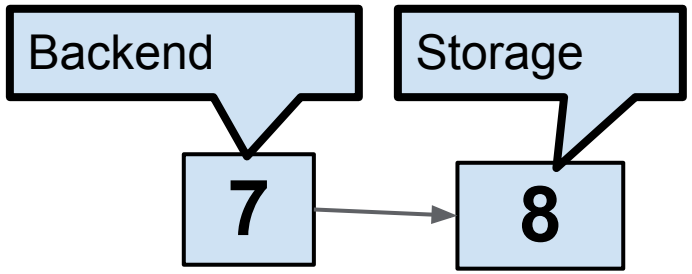
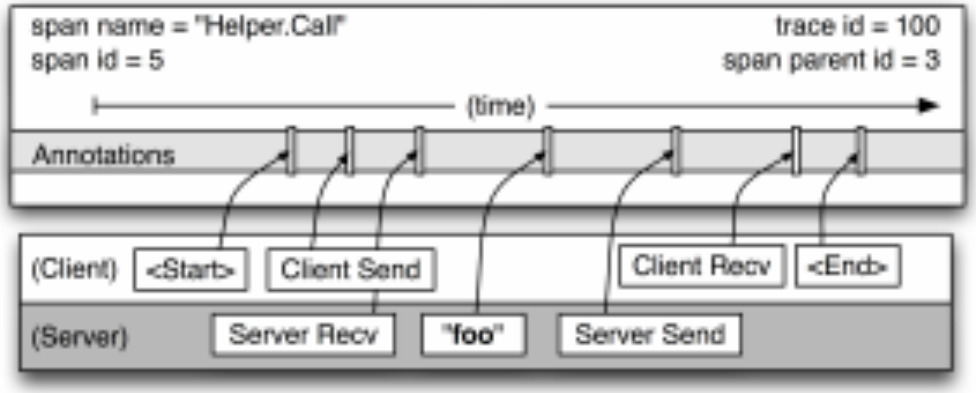
Dapper Distributed Trace Collection

Sigelman, Barroso, Burrows, Stephenson, Plakal, Beaver, Jaspan, Shanbhag '10





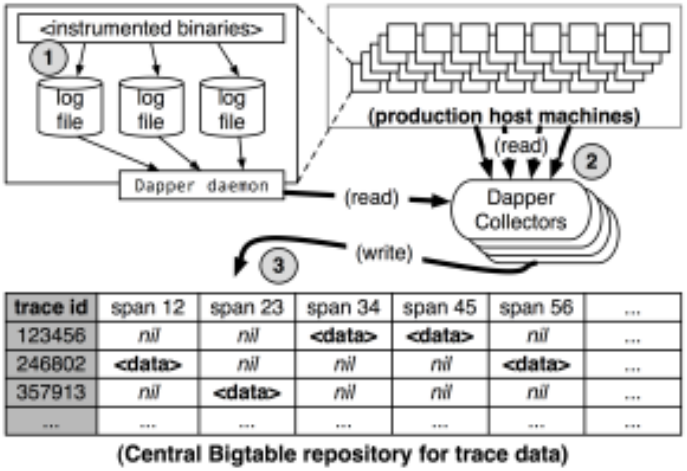
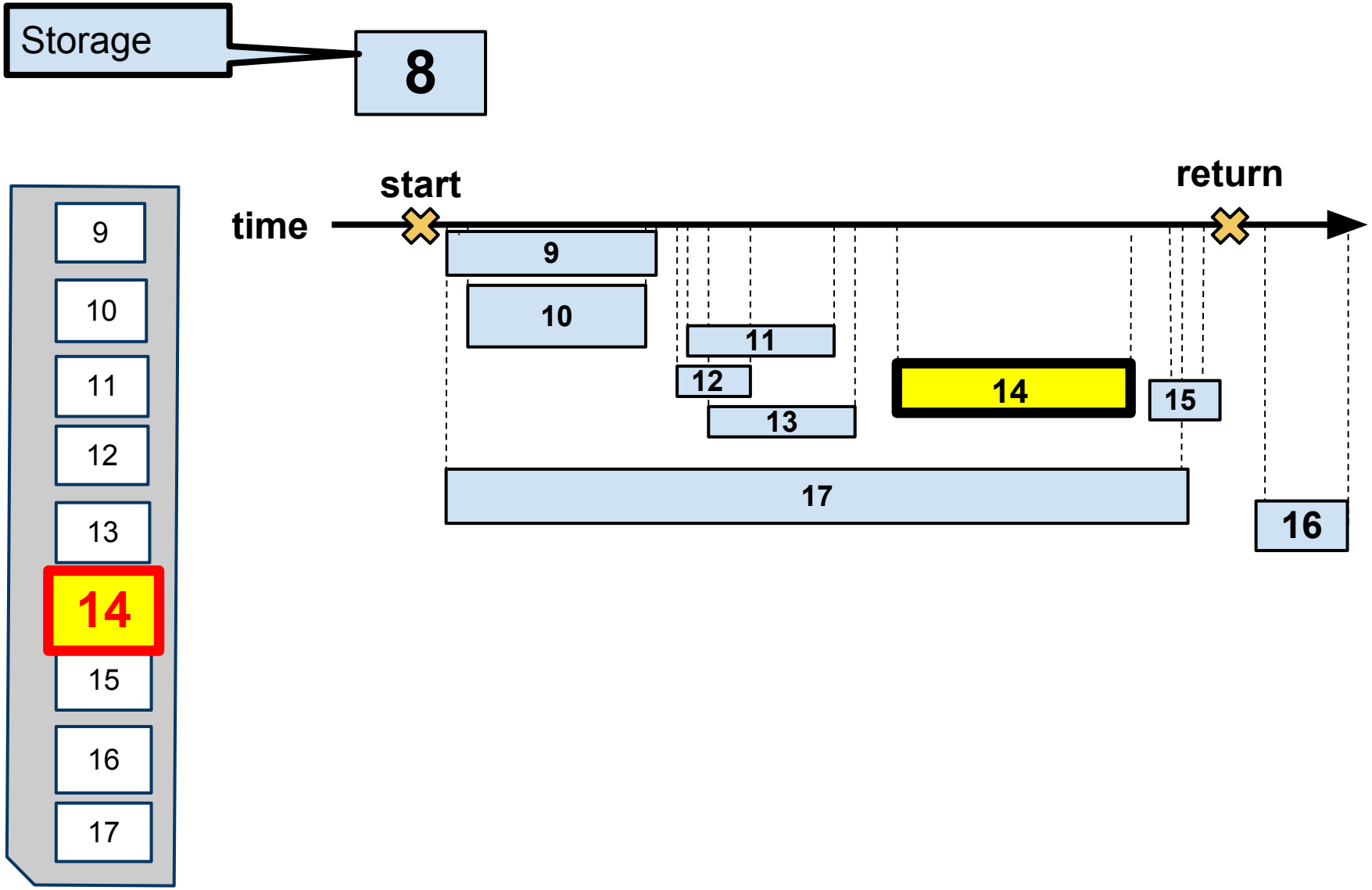


Figure 5: An overview of the Dapper collection pipeline.


Storage
8
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start
return
time
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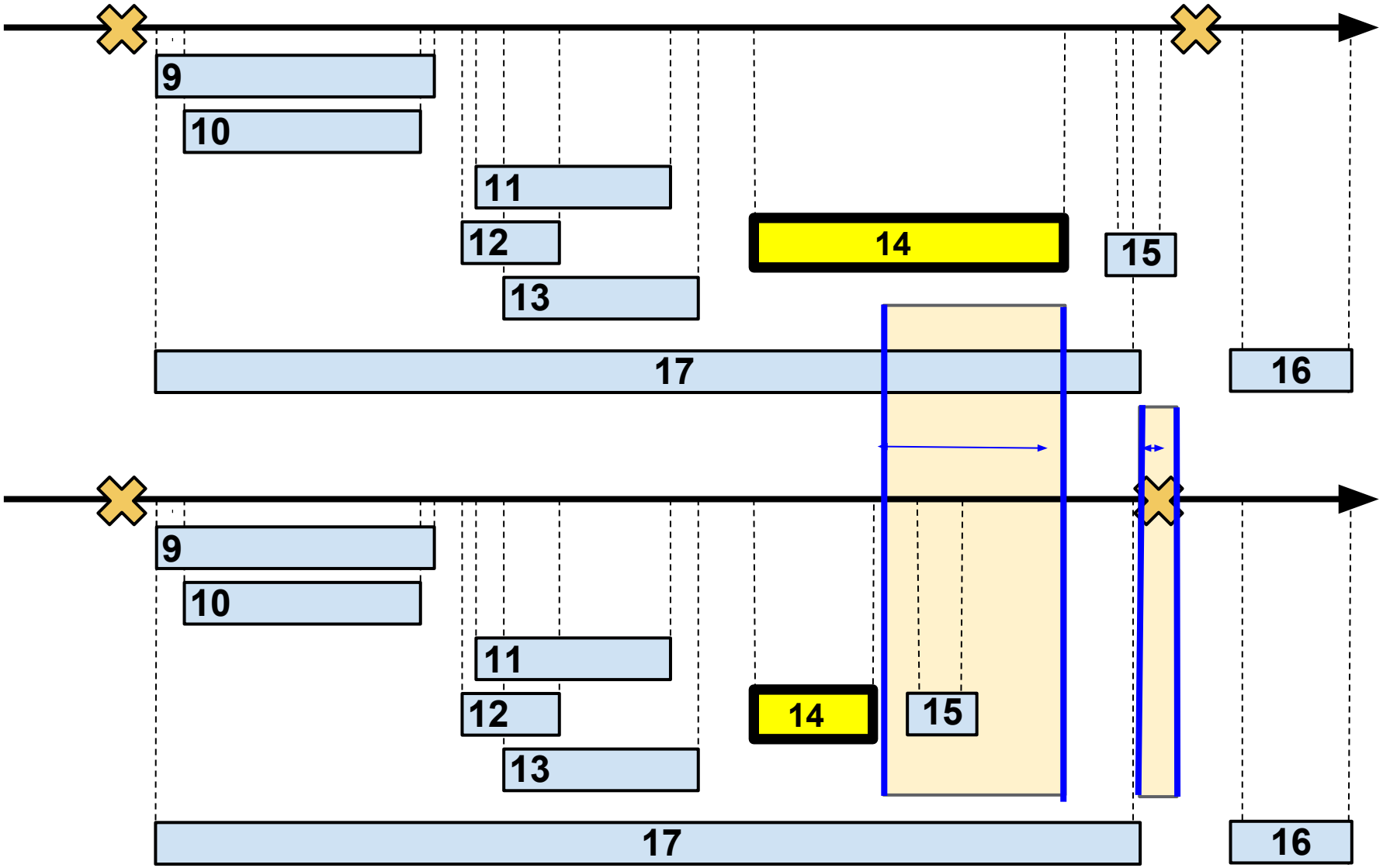
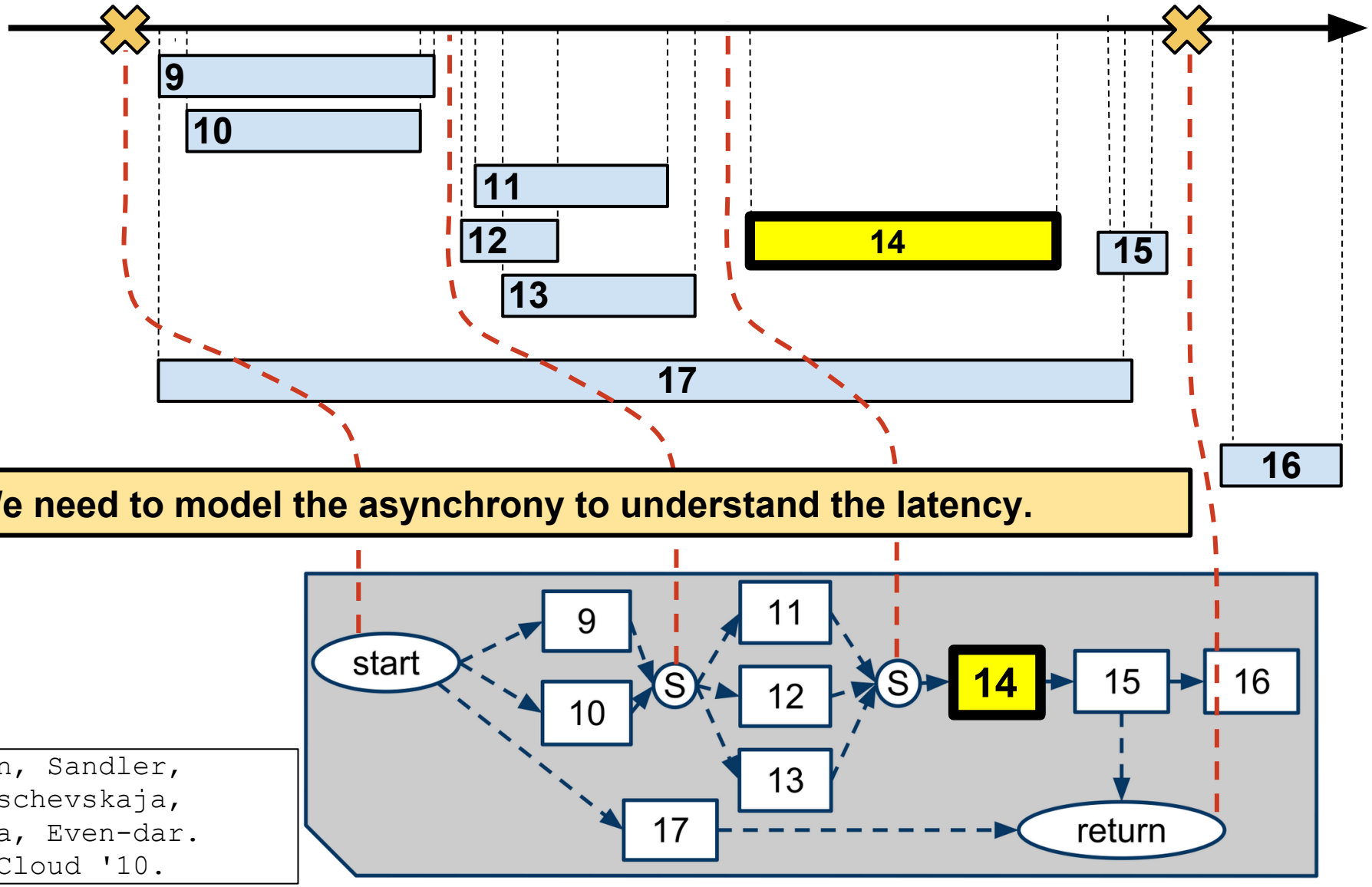
16

Google "If time in 14 is reduced, what is the predicted latency?"



Google



Mann, Sandler, Kruschevskaja, Guha, Even-dar. HotCloud '10.

λ_t observed latency for RPC t

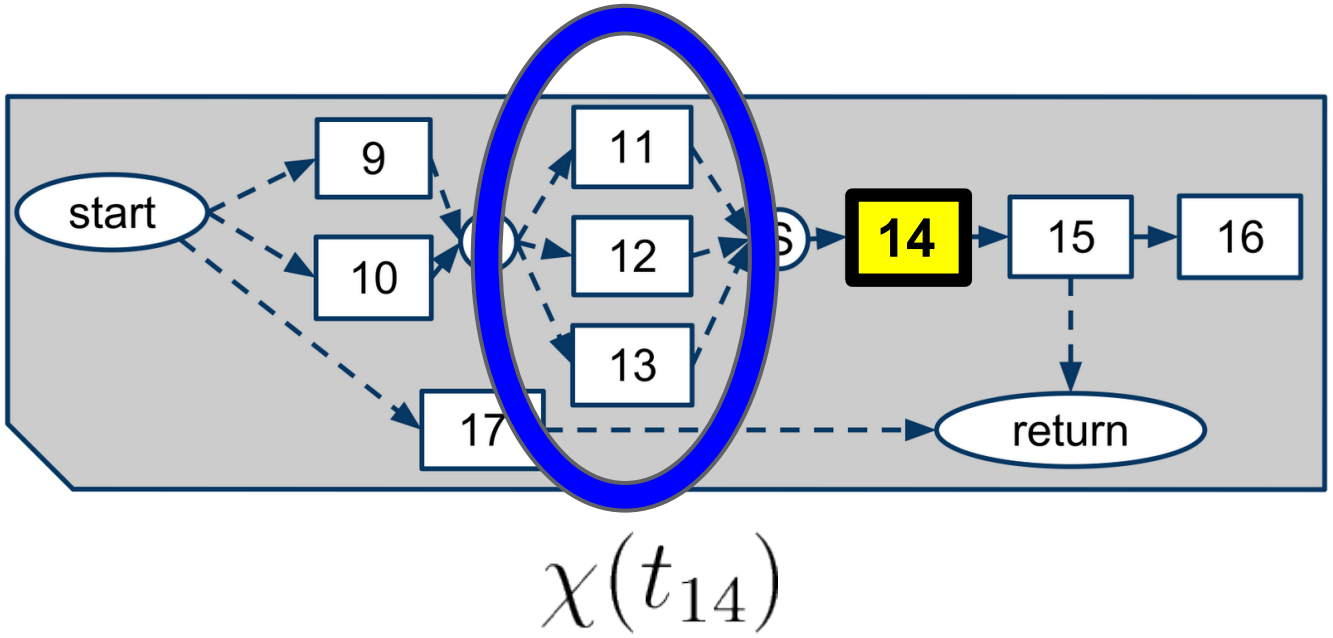
$\hat{\lambda}_t$ predicted latency for RPC t

We predict the latency of a given RPC given the latency of its children C(t), and relevant features of the RPC t and children.

$$\hat{\lambda}_t = \Psi(f_t, f_{C(t)}, \lambda_{C(t)})$$

χ An (asynchronous) execution model

$\chi(t_i)$ The blocking set for a RPC t_i



$\chi(t_{14})$

χ An (asynchronous) execution model

$\chi(t_i)$ The blocking set for a RPC t_i

$$\psi_{\chi(t_i)} = \lambda_{t_i} + \max_{t \in \chi(t_i)} \psi(t)$$

The finishing time for a RPC t_i is it's own latency and the finishing times of the RPCs in its blocking set.

$$\begin{aligned}\hat{\lambda}_p &= \Psi(f_p, f_{C(p)}, \lambda_{C(p)}) \\ &= \Psi(\chi, \lambda_{C(p)}) \\ &= \psi_\chi(t_{return})\end{aligned}$$

Given the children latencies and the execution model, we can compute the latency for a given parent RPC.

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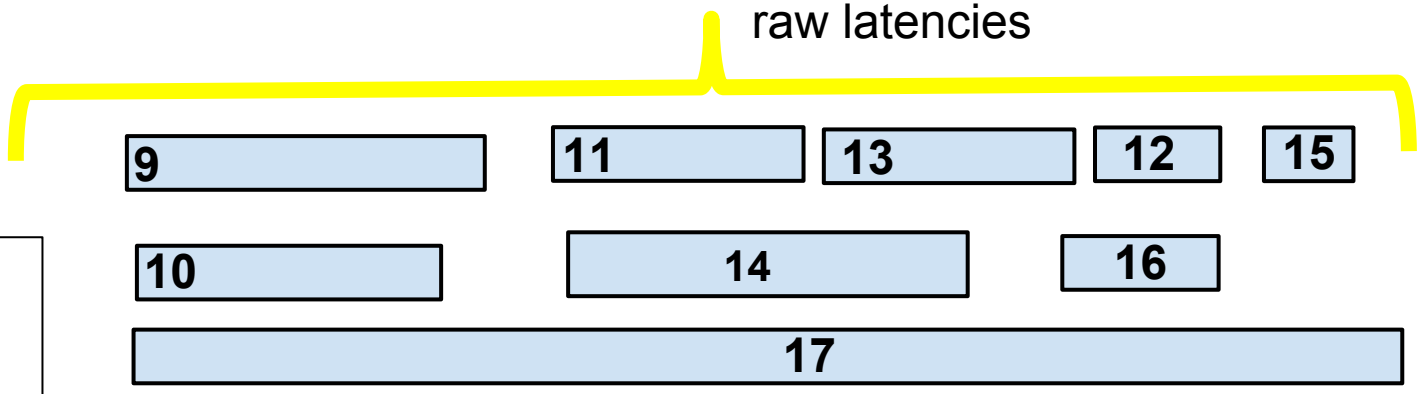
Find best matching flow via Nearest Neighbor :

$$\lambda_{t_i}^{\chi} \sim N(\bar{\lambda}_{t_i}, \bar{\sigma}_{t_i})$$

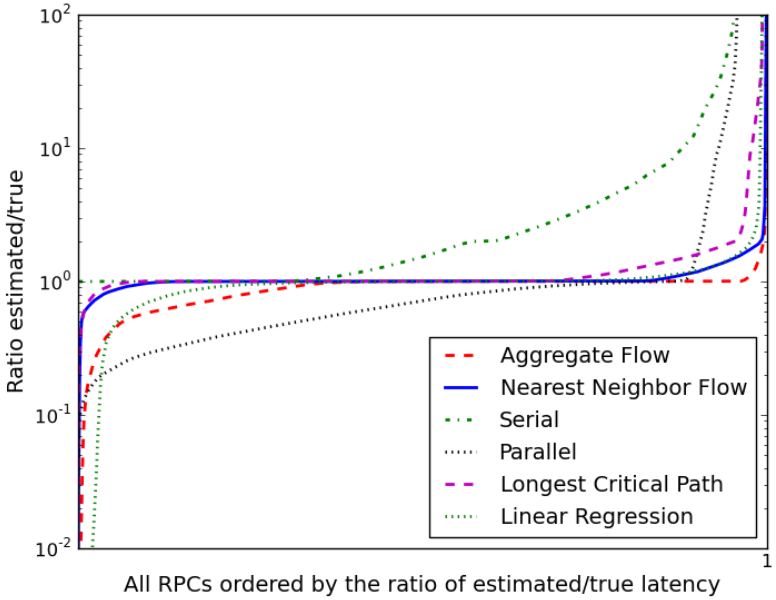
$$\log P_{\chi}(\lambda_t) \propto \sum_{t_i \in C(t)} (\bar{\lambda}_{t_i} - \lambda_{t_i})/\bar{\sigma}_{t_i}$$

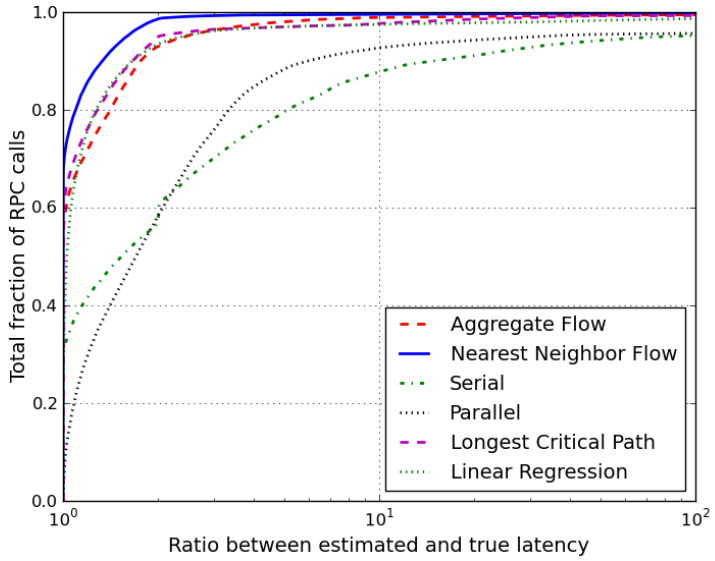


Mann, Sandler, Kruschevskaja, Guha, Even-dar. HotCloud '10.

Google

A perfect model would be a line at y=1.0





Induced models ("Nearest Neighbor Flow") are better predictors of parent latencies from children than:

- Linear regression
- Longest critical path
- Either a full serial or full parallel RPCs

Mann, Sandler, Kruschevskaja, Guha, Even-dar. HotCloud '10.

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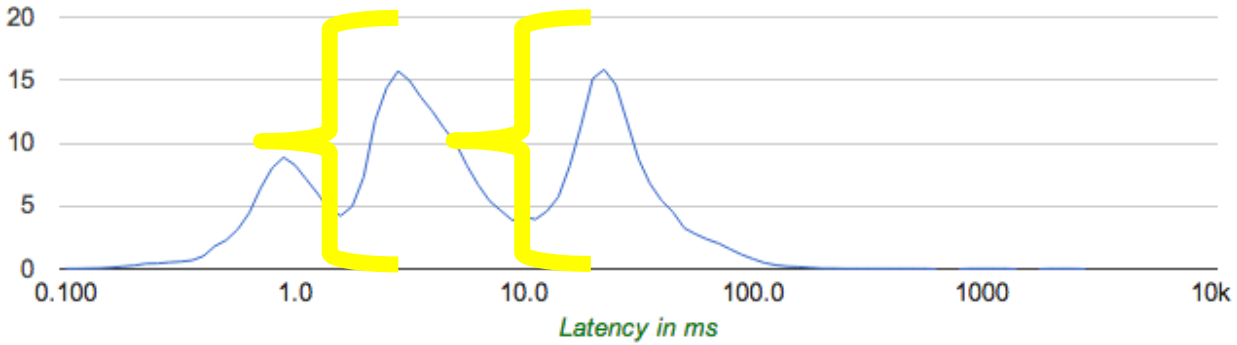
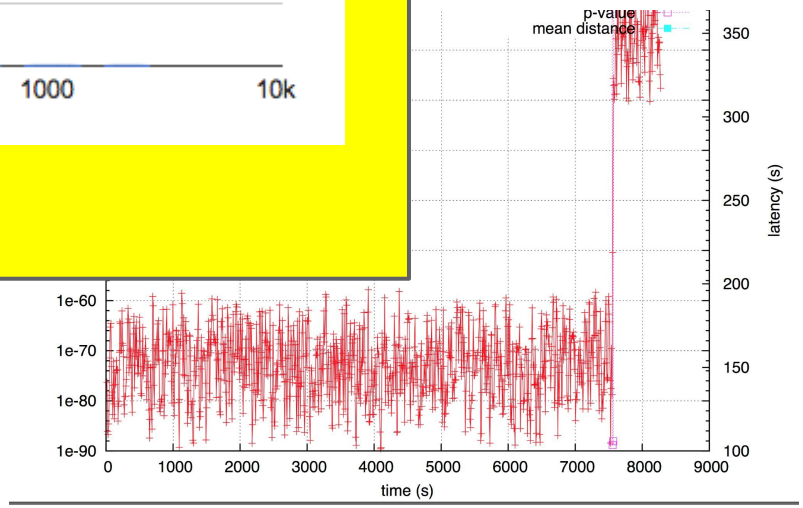
First Scenario of Interest

Latency distribution has multiple peaks at different orders of magnitude.





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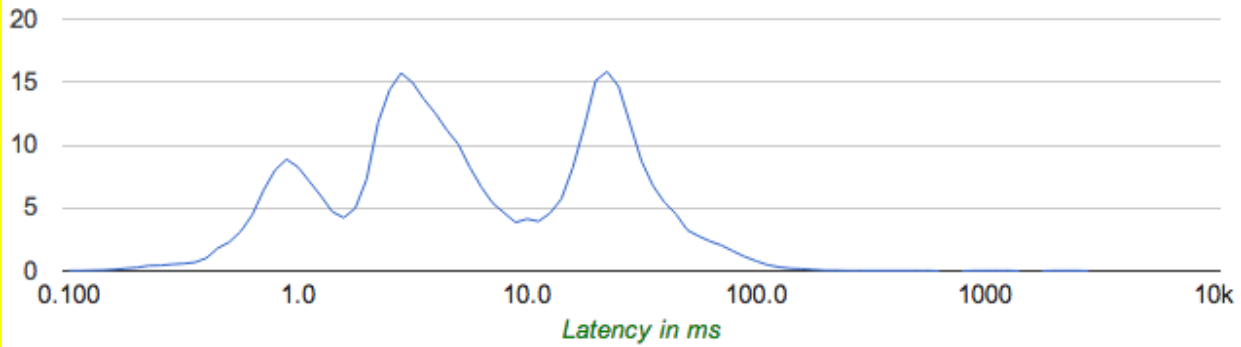
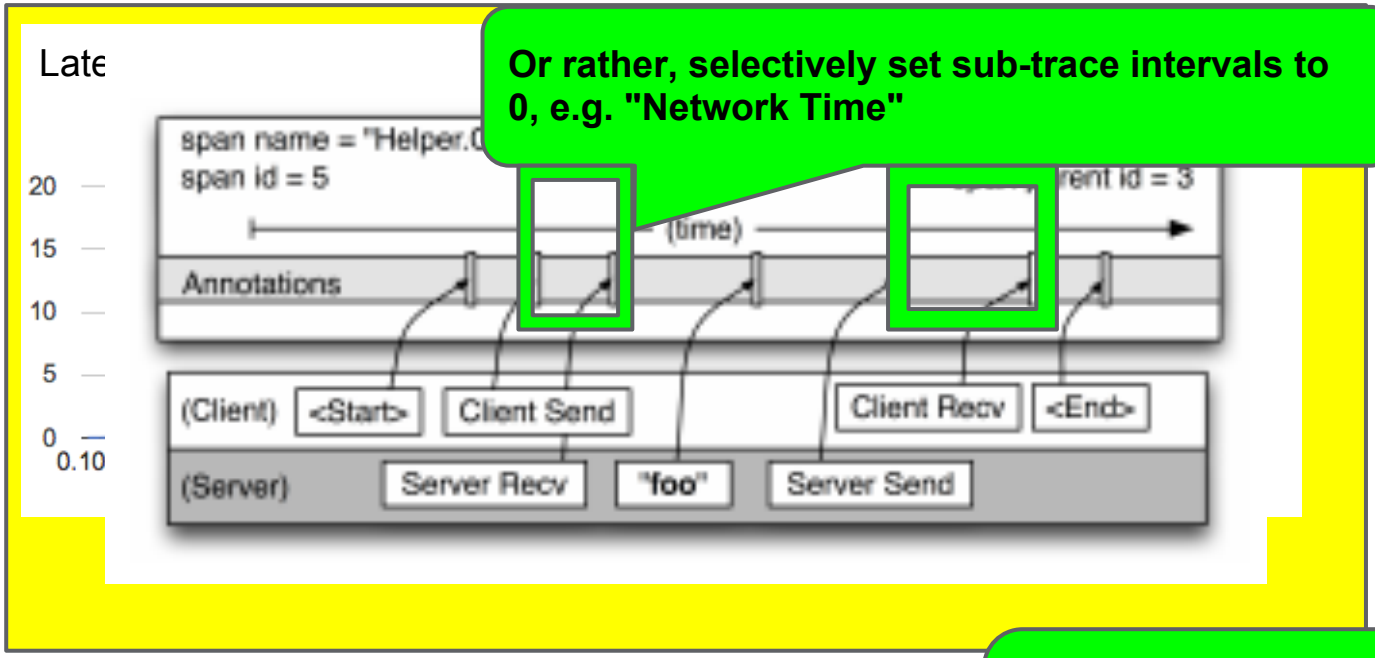
Latency distribution has multiple peaks at different orders of magnitude.



$$\Lambda_A = \mathbb{U}_{t \in A}(\lambda_t)$$

$$\Lambda_{\delta A} = \mathbb{P}_{t \in A}(\Psi(\chi, \lambda_{\delta C(t)}))$$

Selectively set latencies of specific traces to 0, and then simulate the effects.



Or rather, selectively set sub-trace intervals to 0, e.g. "Network Time"

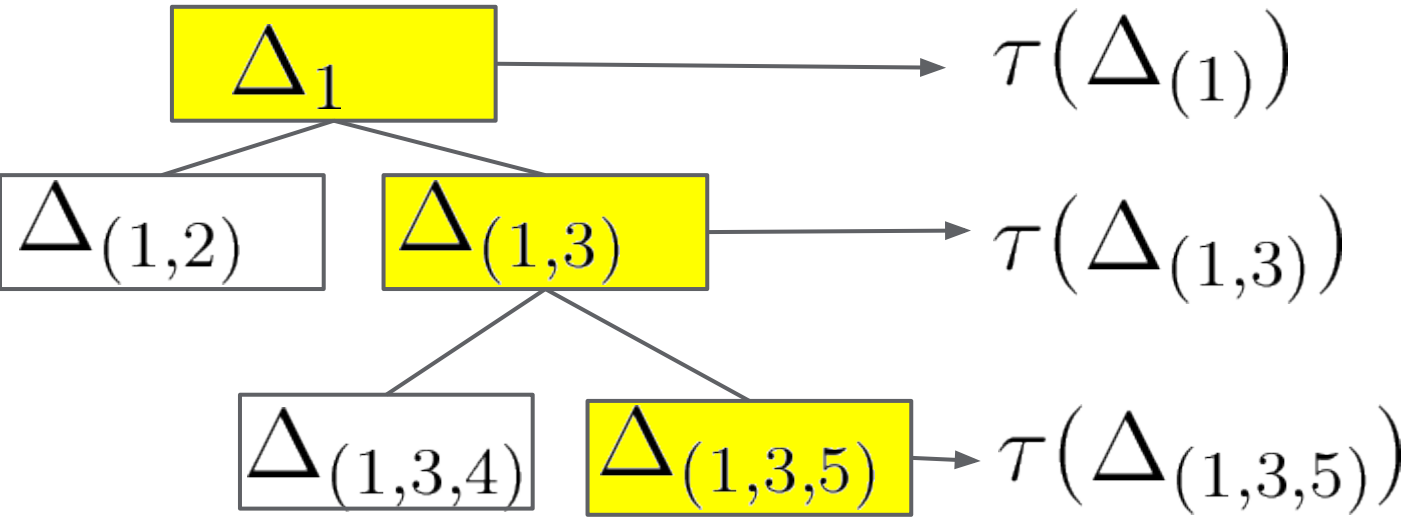
$$\Lambda_A = \mathbb{U}_{t \in A}(\lambda_t)$$

$$\Lambda_{\delta A} = \mathbb{P}_{t \in A}(\Psi(\chi, \lambda_{\delta C(t)}))$$

Selectively set latencies of specific traces to 0, and then simulate the effects.

Λ_A Random variable of Latency

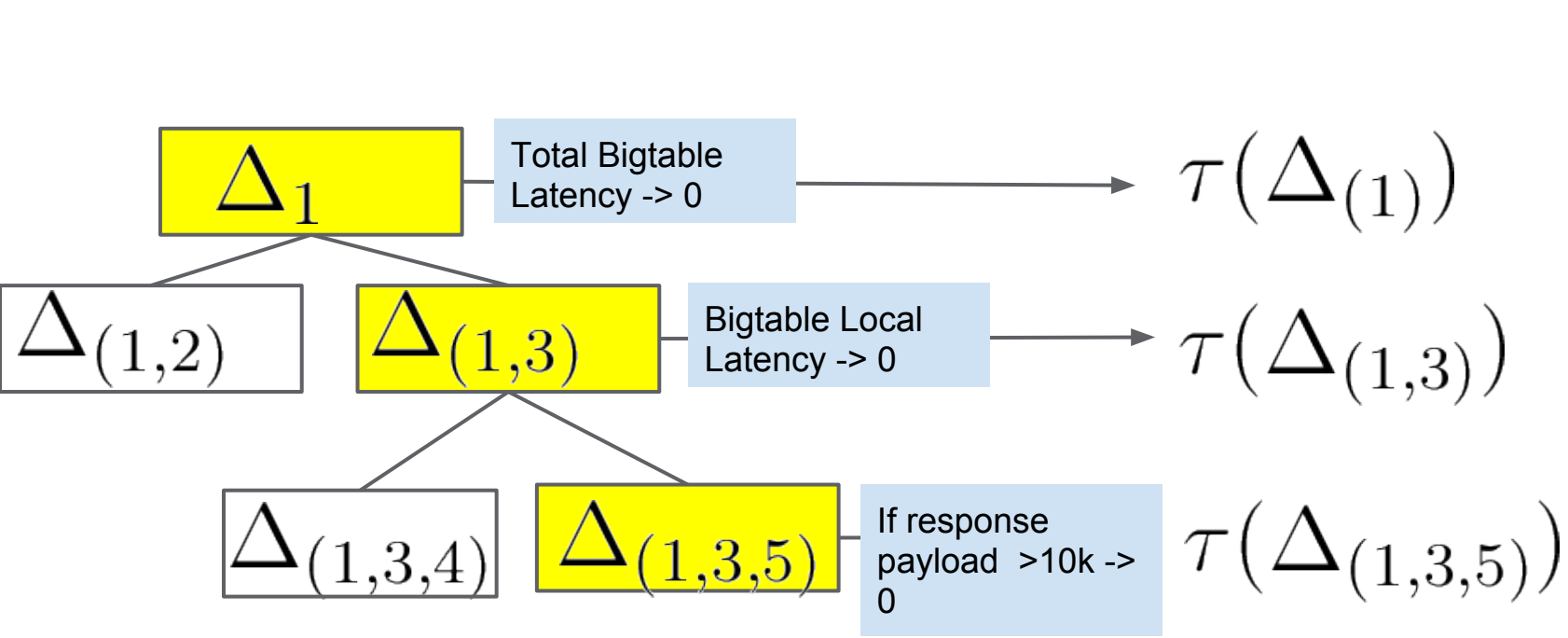
$$\tau(\Delta_j) = \mathbb{E}[\Lambda_{\Delta j A}]$$

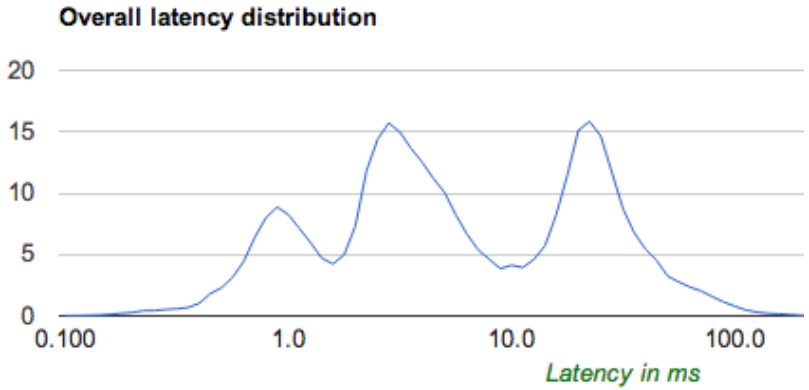


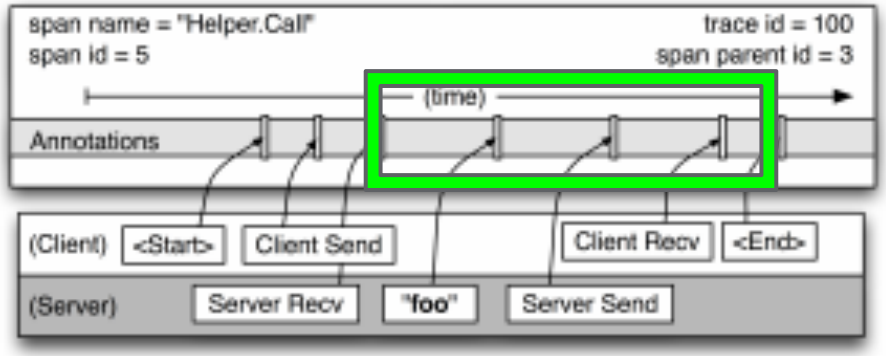
Λ_A Random variable of Latency

$$\tau(\Delta_j) = \mathbb{E}[\Lambda_{\Delta_j A}]$$

Mean Latency at 90% percentile

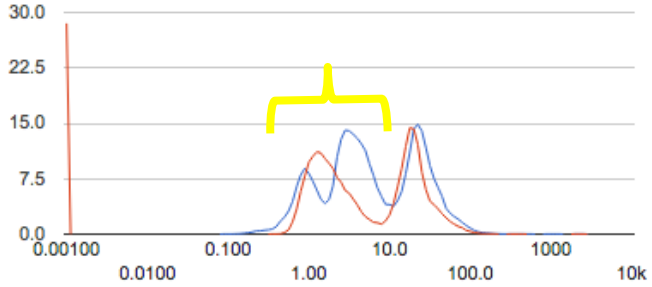


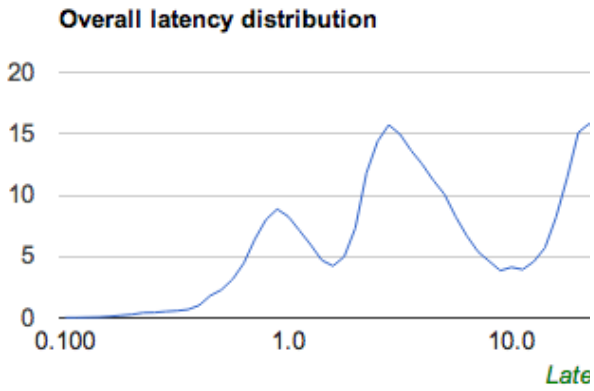


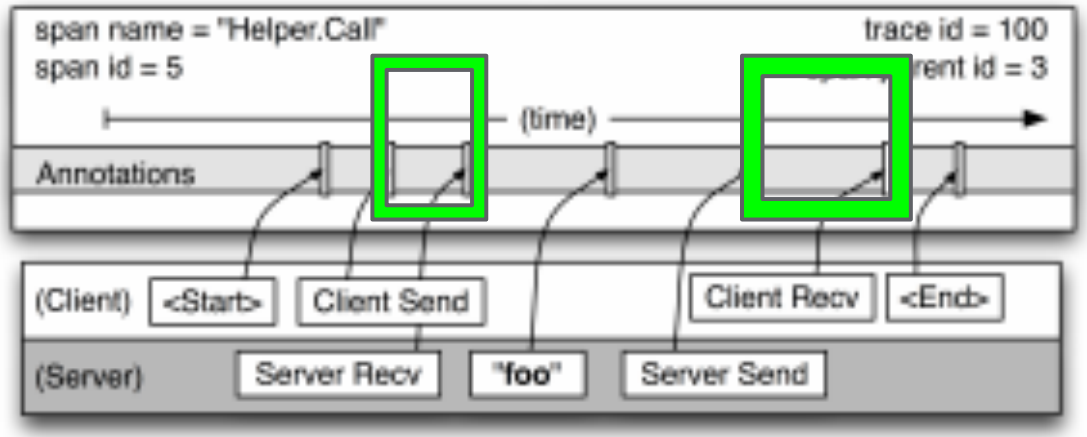


Red Line : top-level latency without time in ...

Bigtable Local Processing

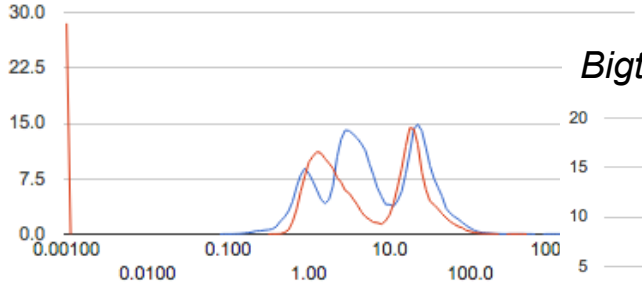




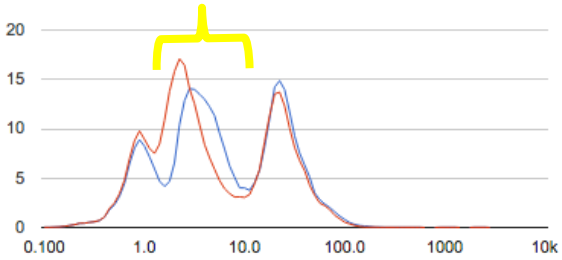


Red Line : top-level latency with

Bigtable Local Processing



Bigtable Outgoing Network



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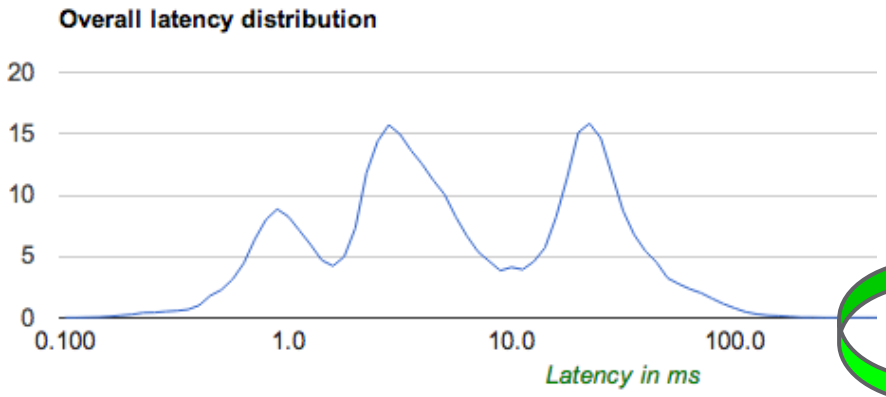
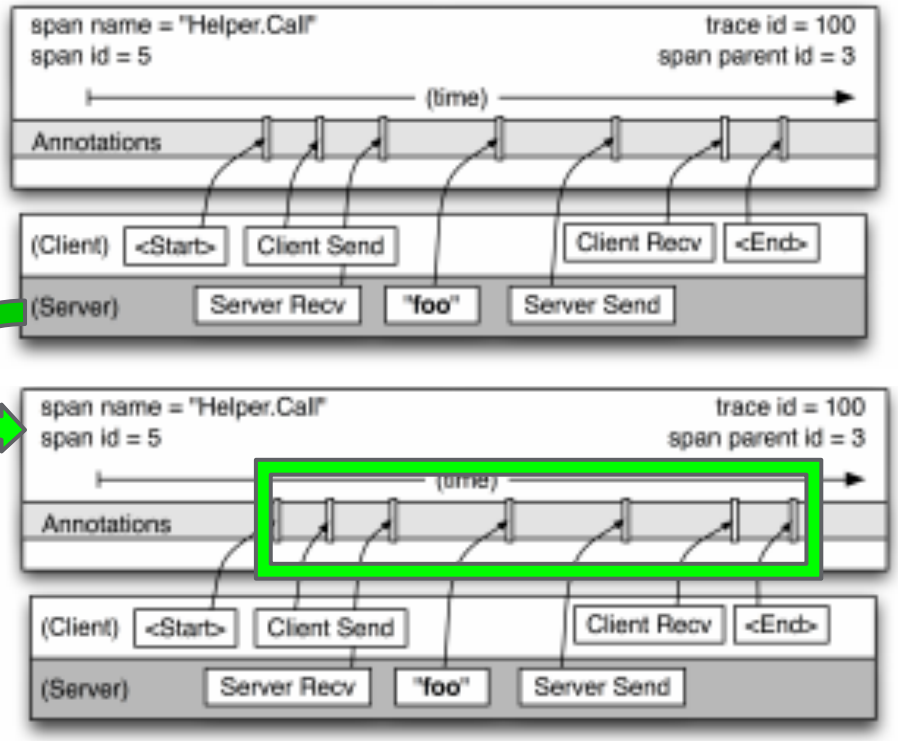
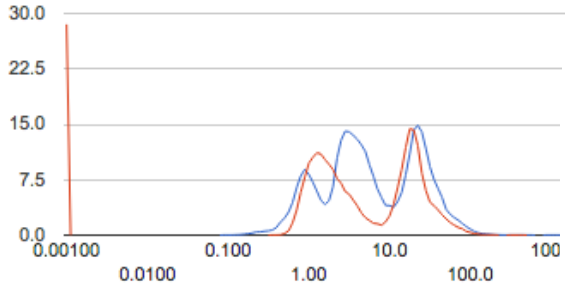


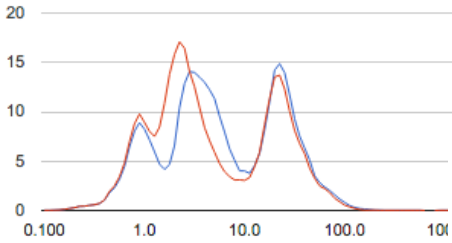


Red Line : top-level latency without time in ...

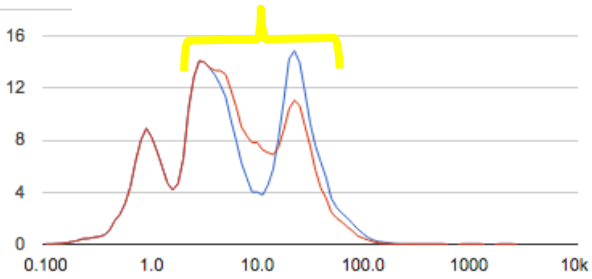
Bigtable Local Processing



Bigtable Outgoin



Total FileSystem Time



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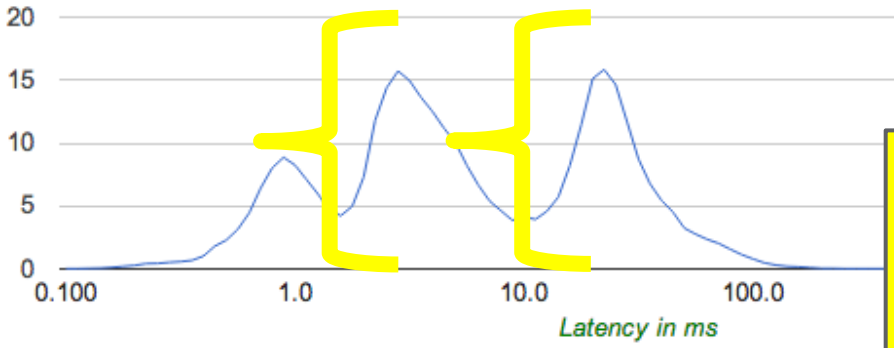
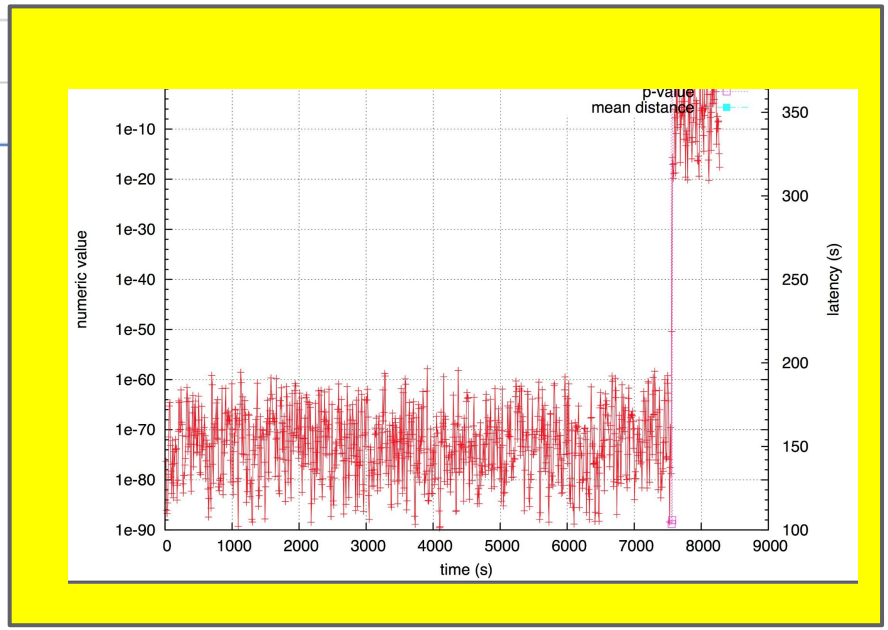
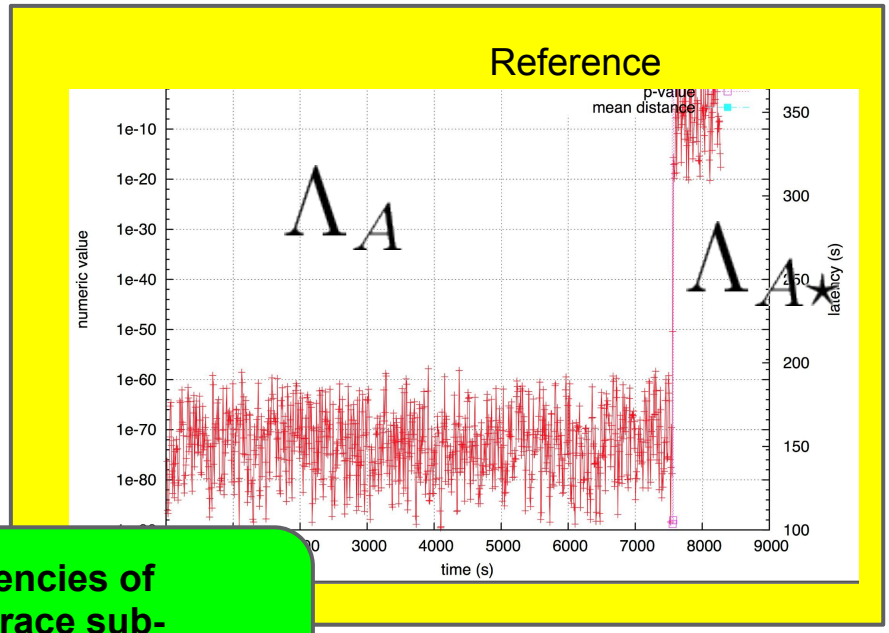






Selectively alter latencies of specific traces (or trace sub-components) and then simulate the effects.

$$\Lambda_{\delta A} = \mathbb{P}_{t \in A}(\Psi(\chi, \lambda_{\delta C(t)}))$$

Alter overall distribution of traces and then simulate the effects.

$$\Lambda_{\delta A} = \mathbb{P}^{\delta}_{t \in A}(\lambda_t)$$

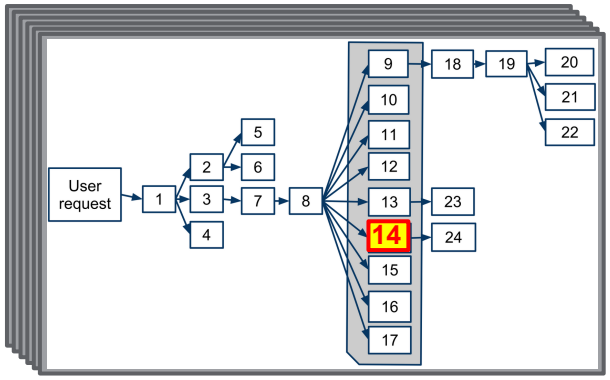
Google

Sample Based Approach

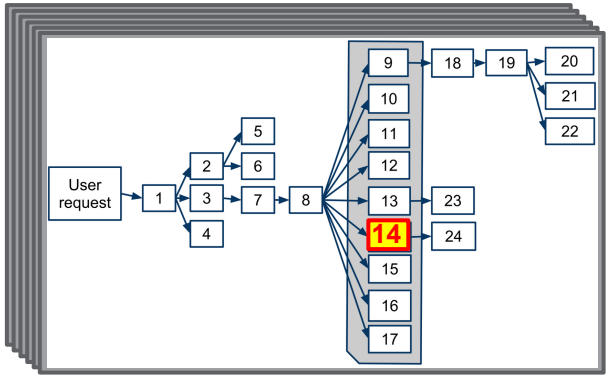
=> shift latency distribution

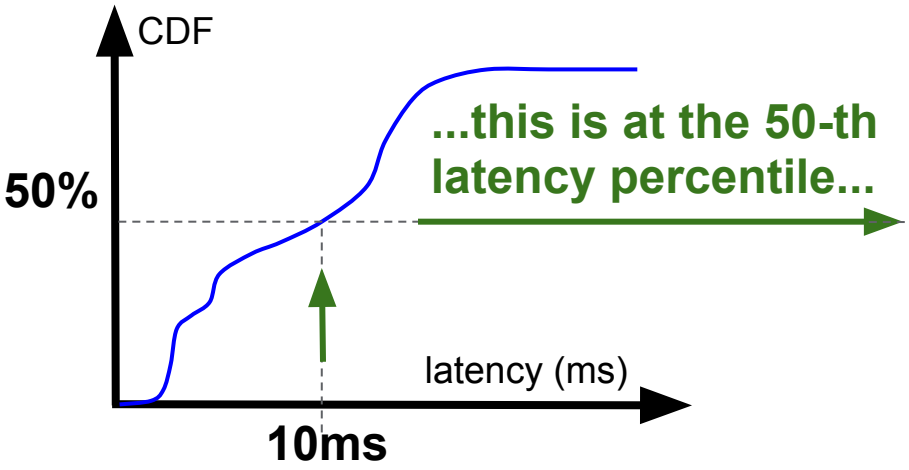
$$\Lambda_{\delta A} = \mathbb{P}_{t \in A}(\Psi(\chi, \lambda_{\delta C(t)}))$$

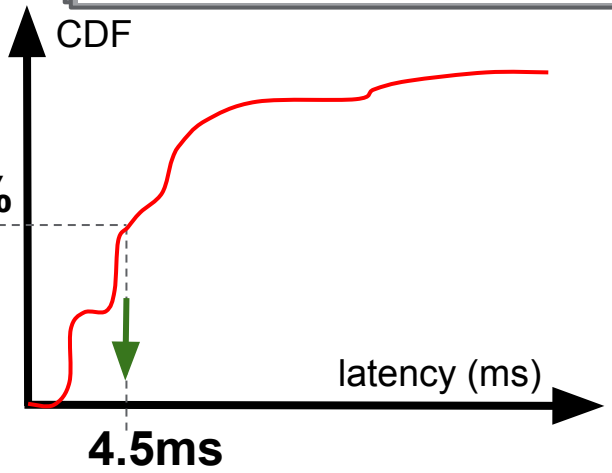
"base" traces



"target" traces







latency of RPC 14 in base trace T = 10ms...

...which used to be 4.5ms

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Sample Based Approach

$$\Lambda_{\delta A} = \mathbb{P}^{\delta}_{t \in A}(\lambda_t)$$

=> shift distribution of traces

= absent
= present

"base" traces

trace 1	trace 2	trace 3

"fix"

modified traces

trace 1	trace 2	trace 3
weight = 1/6	weight = 1/6	weight = 2/3

"target" traces

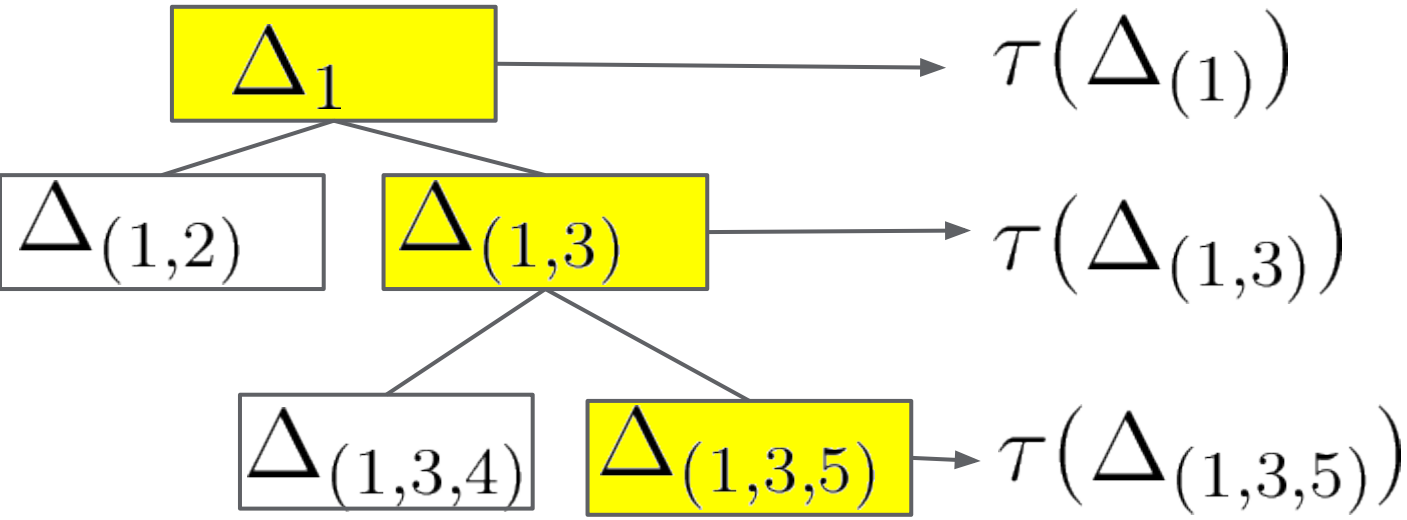
trace 4	trace 5	trace 6

Root Cause	25%	50%	75%	90%	95%	98%
▶ Total Server Detail			-8.67	-1048.20	-1618.00	-583.34
▶ :/Storage Read Detail	0.00	0.02	-9.37	-1015.80	-1516.00	-376.00
▶ Total Local Computation Detail	0.00	0.02	-9.36	-1015.80	-1516.00	-376.00
▶ :--method returned-- Detail	0.00	0.02	-9.36	-1015.80	-1516.00	-376.00
▶ Distribution of Annotation Existence: netsched send (624) Detail @Annotation Existence: netsched send (624): PRESENT Detail Distribution of Annotation Existence: netsched queuing send behind %d others (624) Detail @Annotation Existence: netsched queuing send behind %d others (624): PRESENT Detail	0.00	0.01	-1.89	-950.00	-1501.00	-382.29
▶ @Annotation Existence: starting lock acquisition (610): PRESENT Detail	-0.33	-0.47	-9.85	-1034.20	-1850.00	-6

Sample Expectation at of 90%.

Λ_A Sample $\Lambda_{A\star}$ Reference

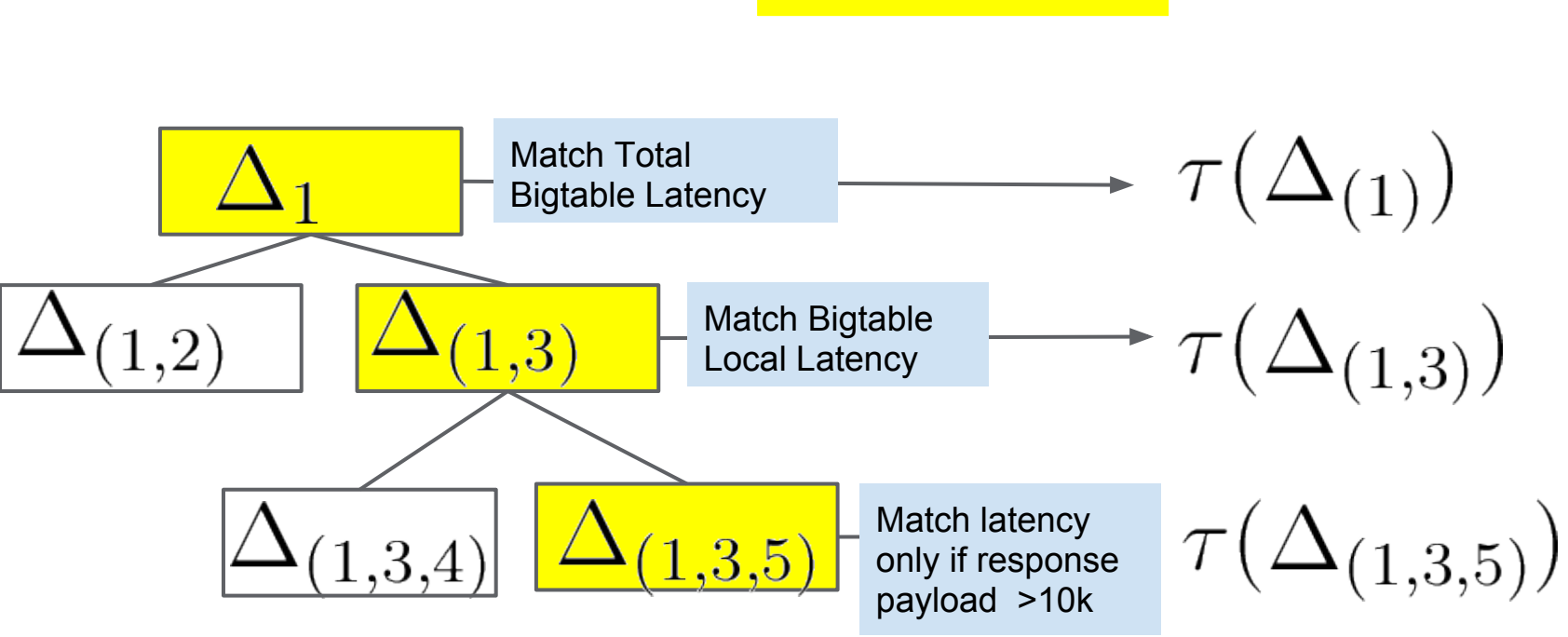
$$\tau(\Delta_j) = \mathbb{E}[\Lambda_{\Delta j A}] - \mathbb{E}[\Lambda_{A\star}]$$



Λ_A Sample $\Lambda_{A\star}$ Reference

$$\tau(\Delta_j) = \mathbb{E}[\Lambda_{\Delta j A}] - \mathbb{E}[\Lambda_{A\star}]$$

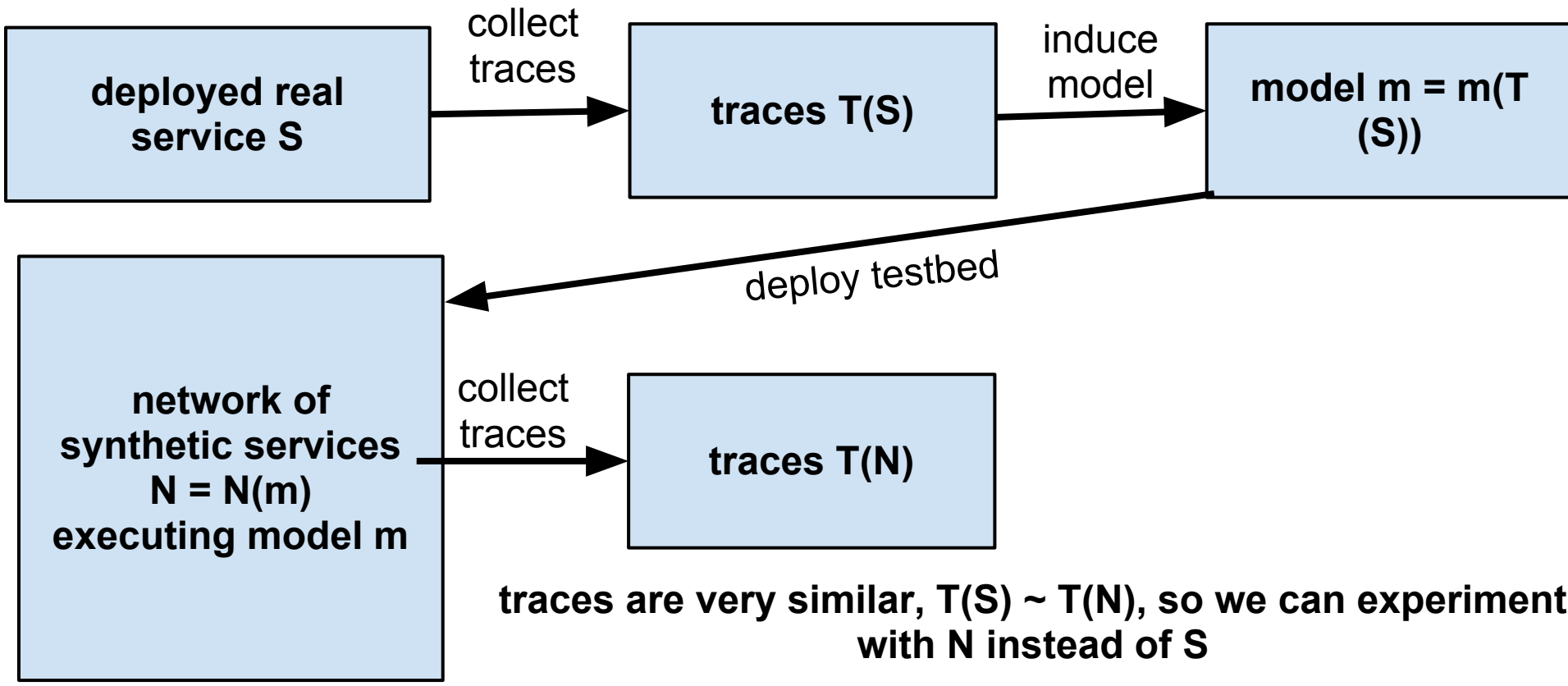
Mean Latency **Difference** at 90% percentile



Evaluation Testbed

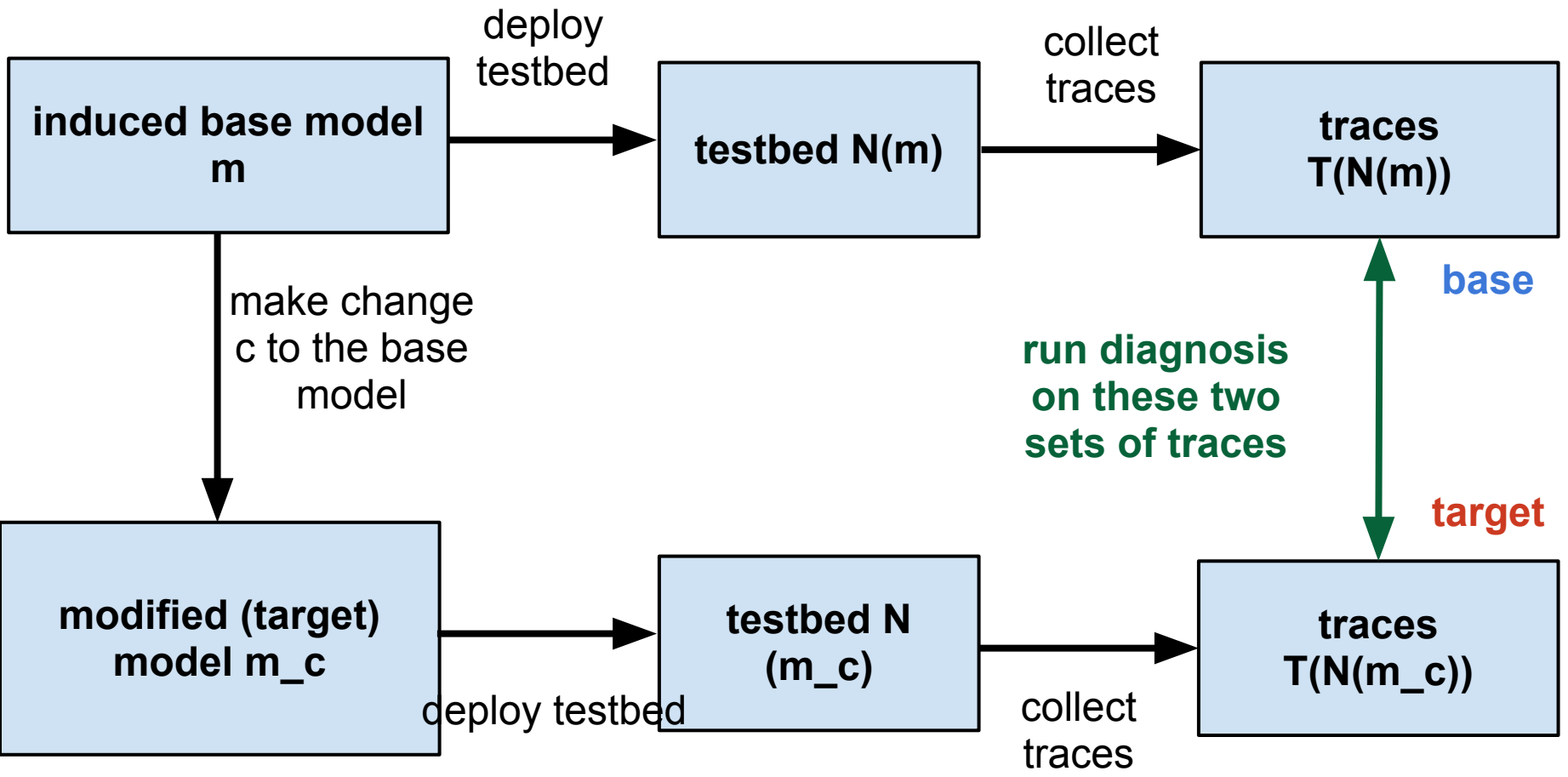
Synthetic Services: physical network delays, random lognormal processing times, temporal dependencies from the induced execution models

Diagnose changes we introduce: Modify the model of a service, generate a new set of traces using the modified model, and diagnose the difference between these sets of traces using our tool



traces are very similar, T(S) ~ T(N), so we can experiment with N instead of S

Ostrowski, Mann, Sandler. LADIS '11.



Ostrowski, Mann, Sandler. LADIS '11.

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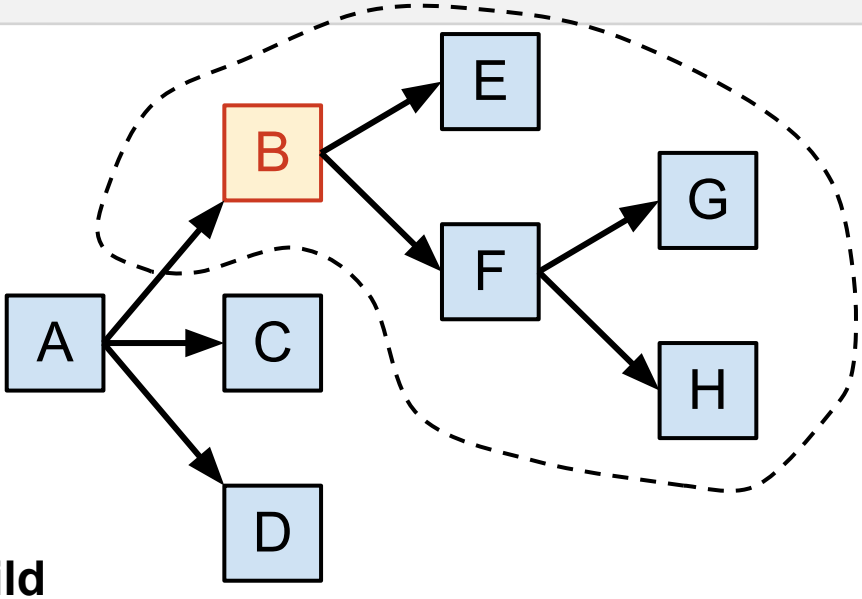
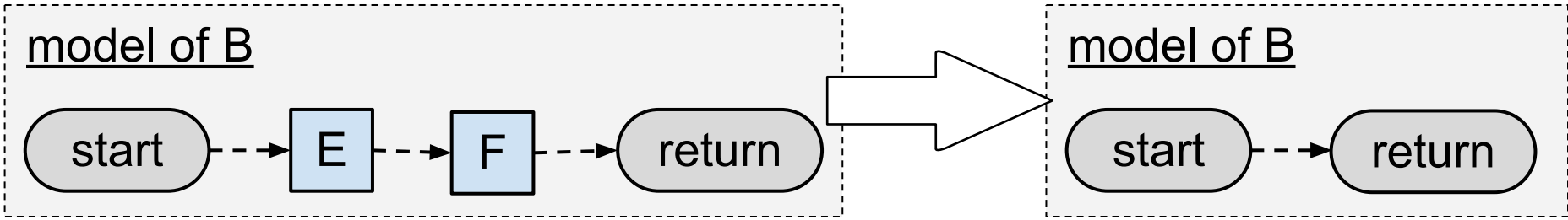
Two Introduced Changes

1. Substitute ("S"): replace the models in a subtree of base services with those from the target. Only on one call path, so if B is called in two different places, only one of them is affected



2. Make Terminal ("T"): remove all child RPCs in a model of a service; make it return immediately



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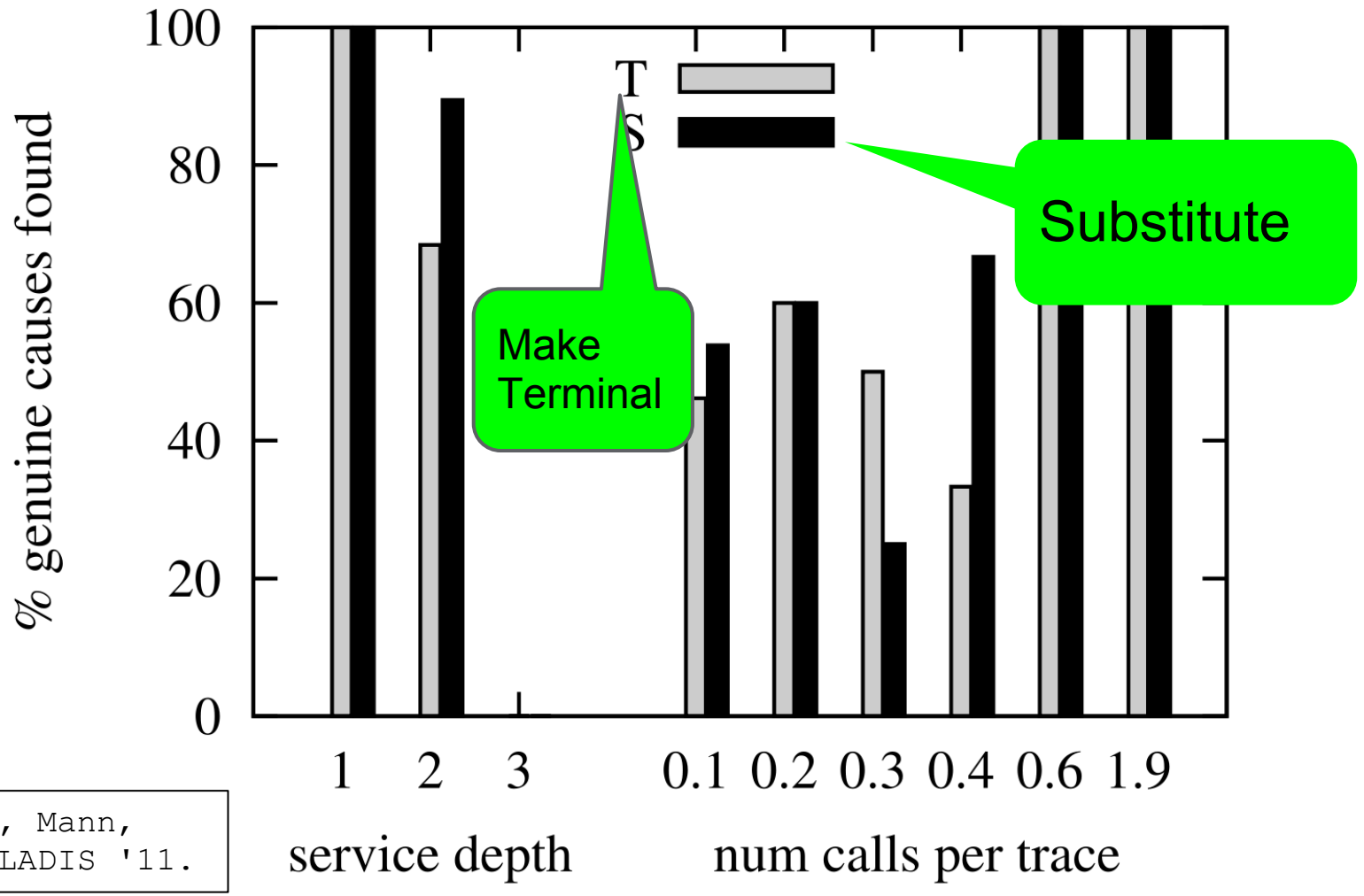
The number of genuine causes found and missed.



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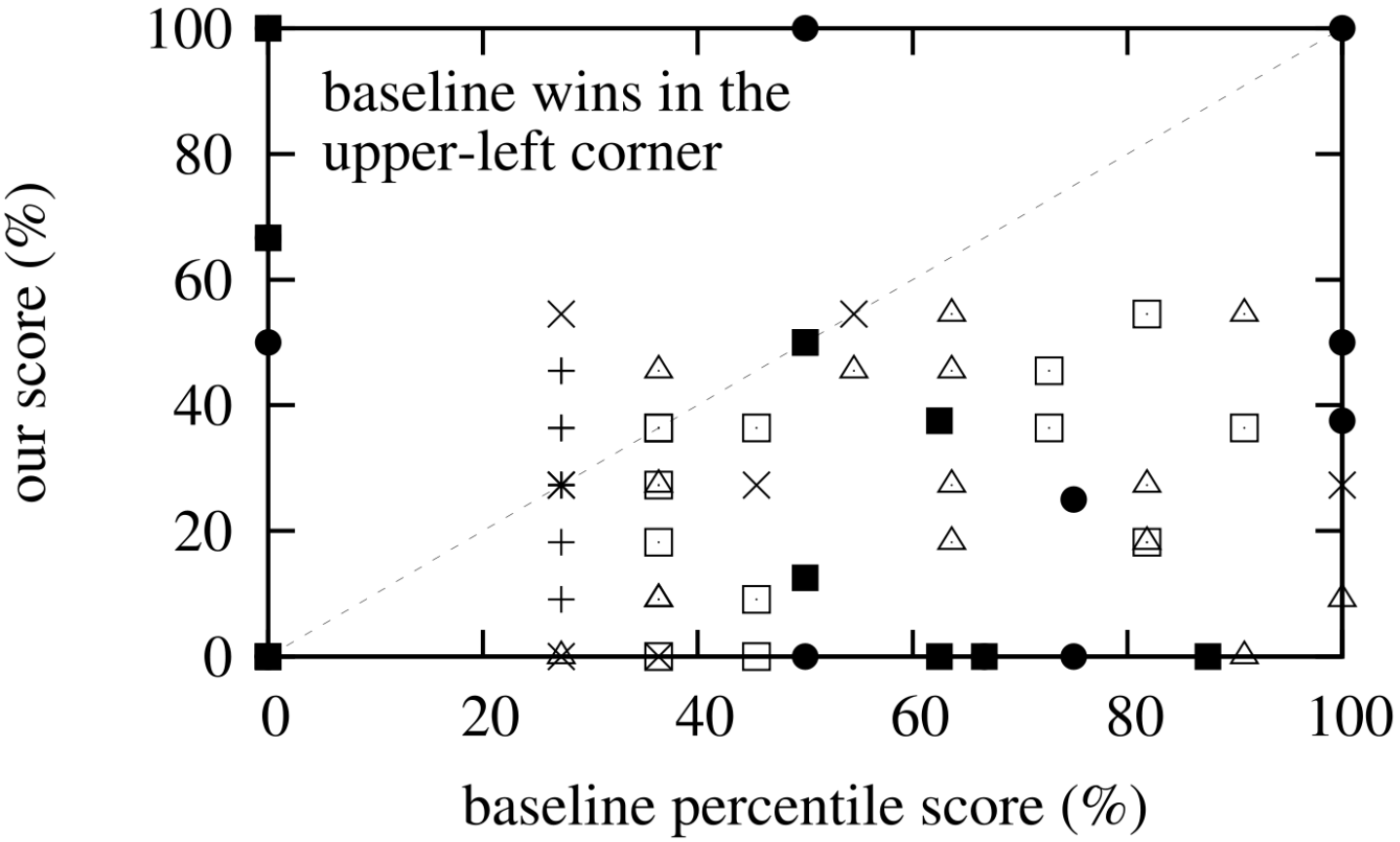
The quality of ranking relative to the K-S baseline.



Ostrowski, Mann, Sandler. LADIS '11.

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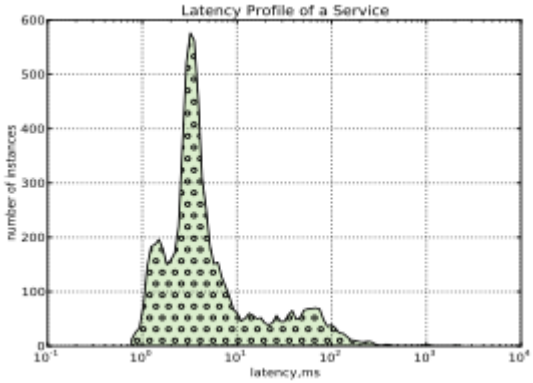
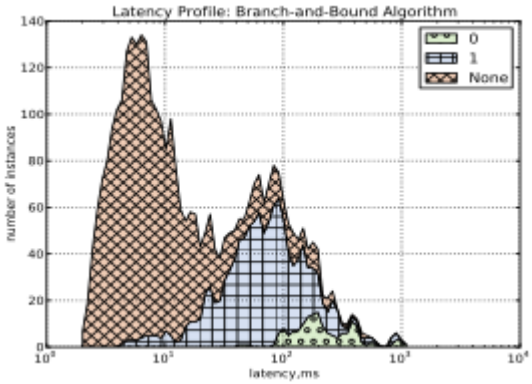
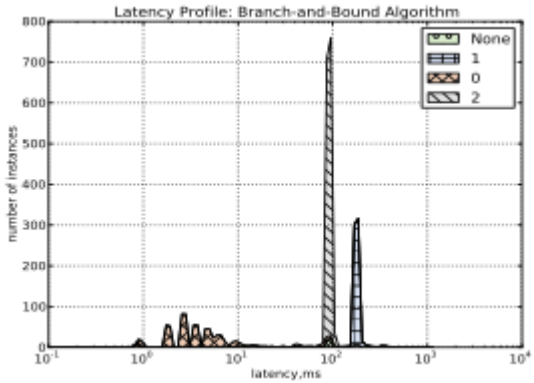
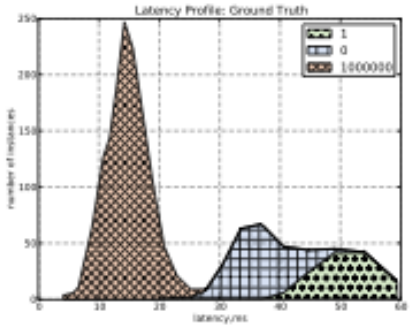
Recent Work

Understanding Latency Variation of Black Box Services









Krushevskaja, Sandler. WWW '13

Diagnosis and Automation for Deployed Distributed Systems

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- Automatic Job Health Assessment
- Real-time Diagnosis of Problem Events
- Diagnosis of Text Bugs
- Intelligent Automation