Constructing Workflow-Centric Traces in close to Real Time for the Hadoop File System

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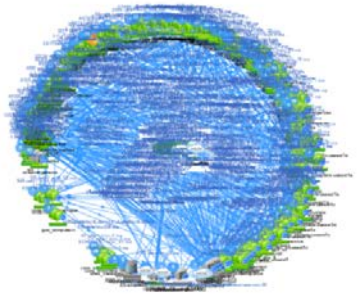
Motivation

- We can't debug distributed services – complicated, with 1000's of nodes and services
- Machine-centric techniques are insufficient
  - E.g., GDB, GProf, perf. counters, strace, Dtrace
- To find performance issues in distributed systems we need to do tracing

Debugging services in a distributed system is a complicated problem

Netflix



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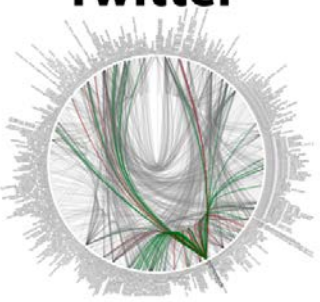
Twitter



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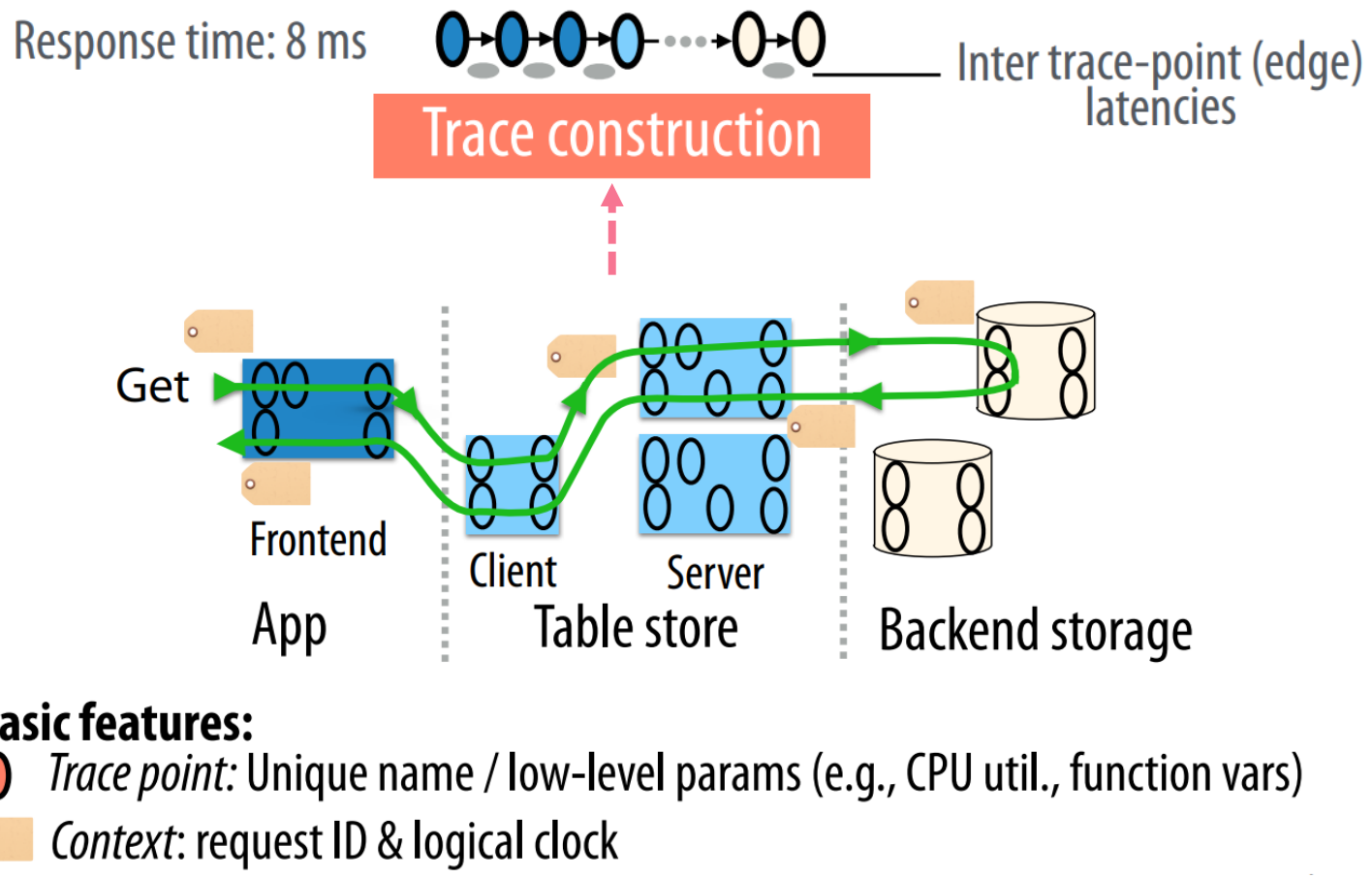
March 26, 2019

Workflow-Centric Tracing

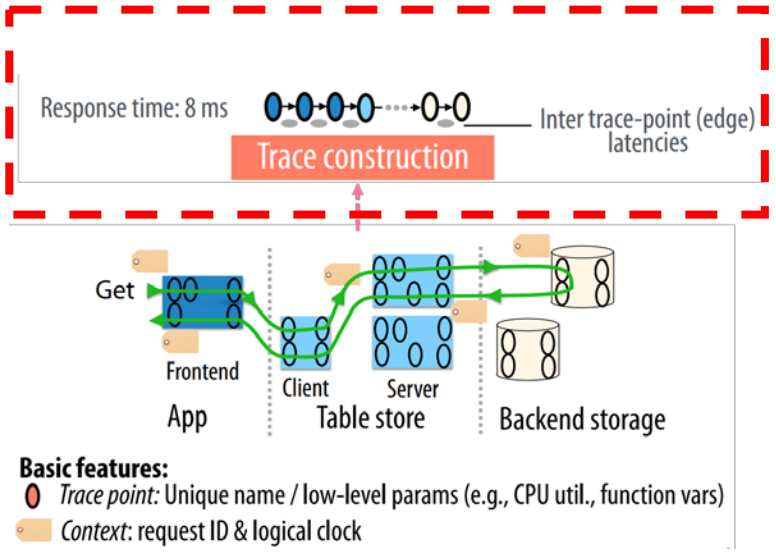
- Every request involves a workflow
- Workflow: Structure & timing of work done to process them
- Structure: Order, concurrency & synchronization
- Facebook collects 1 Billion Traces/day

Challenge with tracing: real-time construction



Problem: Trace Construction is Slow

- Existing tracing systems operate in mostly non-real time batch mode (e.g. Facebook ~ 1 day turnaround to find problems)
  - Data and computation intense

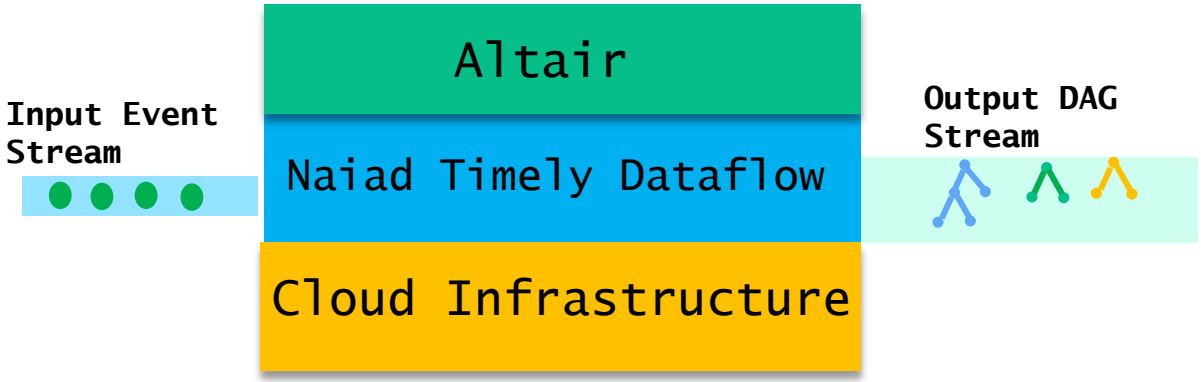


- Use cases
  - Anomaly Detection in distributed systems
  - Cyber Intrusion Detection
  - Failover Management
  - Performance Issues

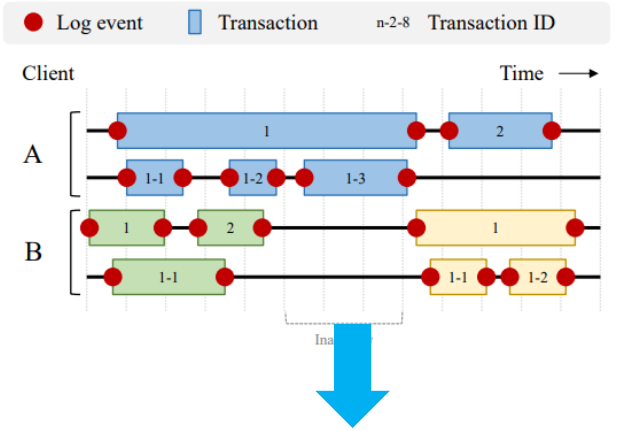
- Developers use stream processing to query continuous data streams and react to important events (e.g. Apache Flink, Timely Dataflow)

Proposed System For Real Time Trace Reconstruction – Altair

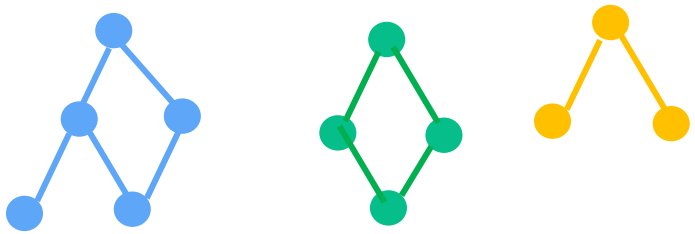
- Several Non-Real Time Approaches
  - Google's Dapper, Facebook's Canopy, Brown's X-Trace
- ETH's Strymon [1] is a real-time stream processing system
  - It builds on Naiad Streaming Timely Dataflow
  - Traces are modelled as trees
- General infrastructure tracing frameworks (OpenTracing, X-Trace) represent traces as DAG (Directed Acyclic Graphs)
  - DAG can capture concurrency
- Strymon's approach can be modified to incorporate DAG's
- Developed real time tracing system for distributed systems - Altair



Trees



DAG



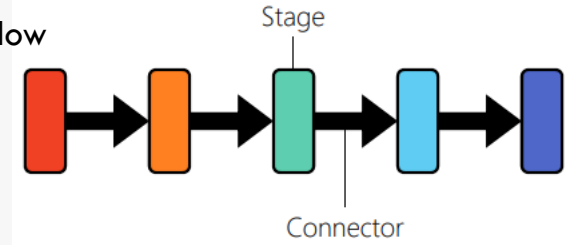
We developed a new system for processing traces called Altair

[1] Chothia, et. All, Online Reconstruction of Structural Information from Datacenter Logs, EuroSys '17

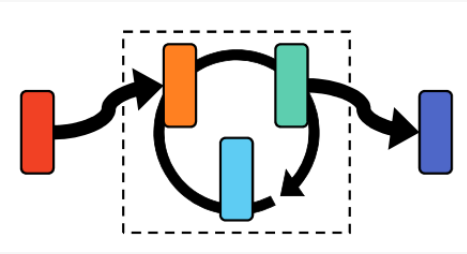
Timely Dataflow

- Framework for writing dataflow programs
- Dataflow programming is a programming model in which the computation can be represented as a directed graph: The data flows along edges, while the computational logic in the vertices transforms it
- The messages flowing along edges are annotated with timestamps.

Dataflow



Dataflow Iteration



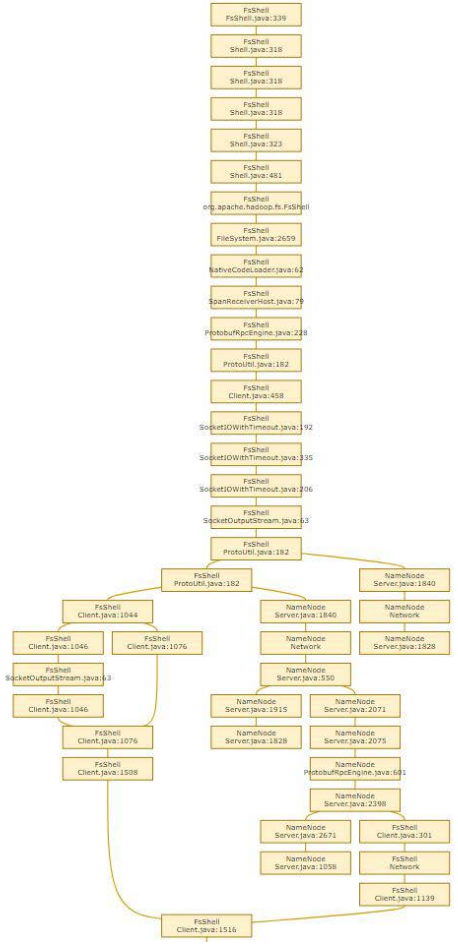
Timely Dataflow used as the streaming framework

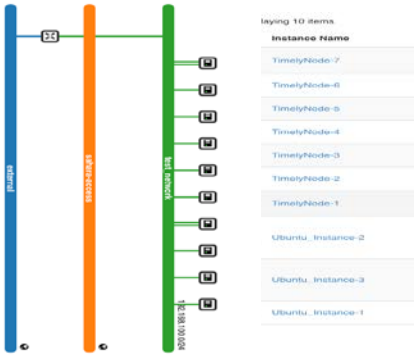
Reference Naiad: A Timely Dataflow System

Evaluation: HDFS Tracing

- Mass Open Cloud runs OpenStack
- Access to 10 compute instances, Altair runs on 8 instances, 2 instances run Trace compression
- Instrumented HDFS and X-Trace server
  - HDFS (Hadoop Distributed File System) is distributed file system, used with MapReduce applications in datacenters
  - Performance of HDFS can directly affect the performance of jobs
- Event Test Data: 3000 Traces, ~350 graph nodes/traces, 0.525 Million event/Epoch
- Streaming simulator to generate event stream, replay and add anomalies, latency in event stream

Sample File Access HDFS DAG (part of a trace)

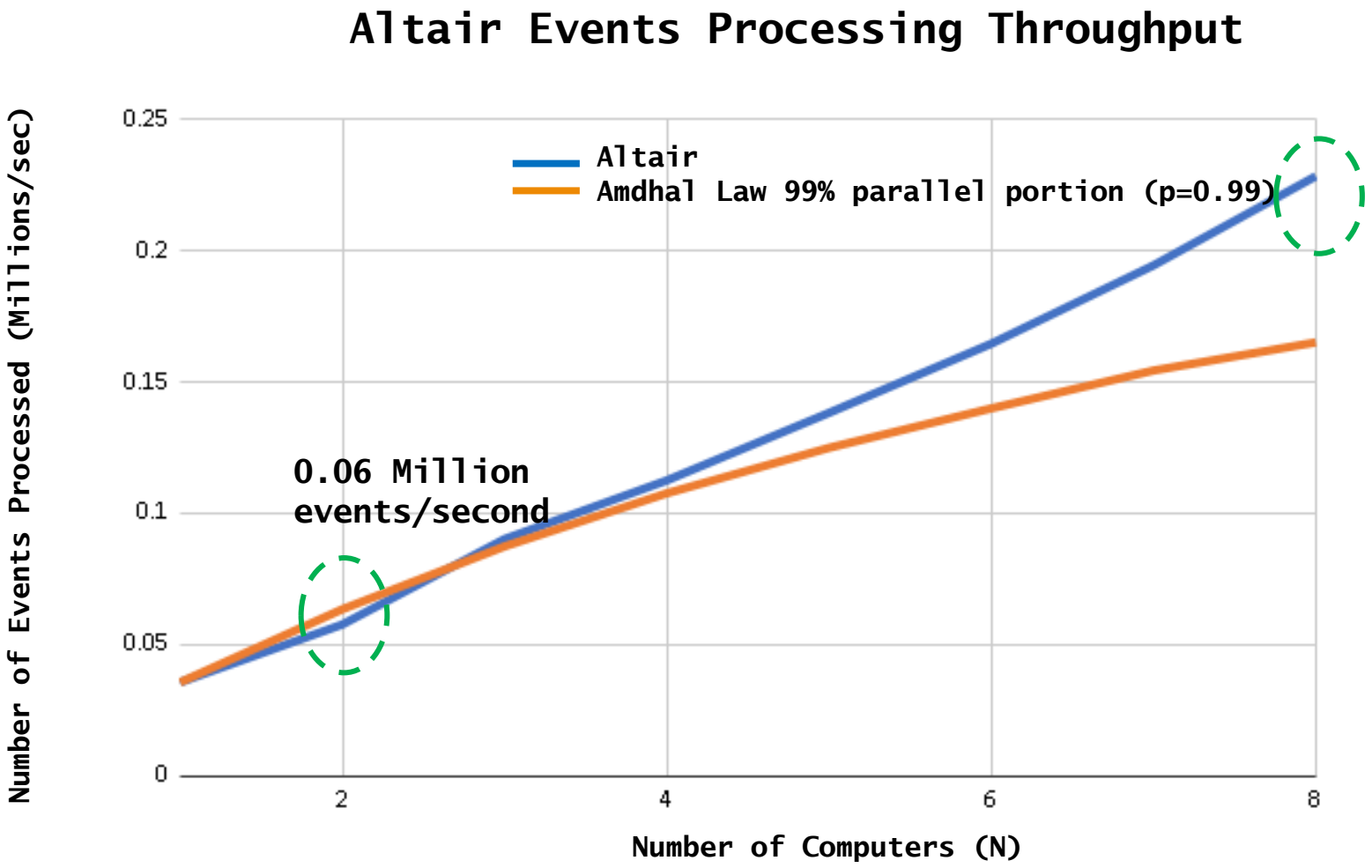




Altair implemented in Rust

Acknowledgement : Mass Open Cloud for their support

Results : Altair



Facebook collects 11 Million events/second (1 Billion Traces/day ~ (1000 nodes/trace))

Amdhal Law: Maximum expected improvement to a system when only part of the system in the parallelized

$$\text{Speedup} = \frac{1}{(1-P) + (\frac{P}{N})}$$

The Altair approach is scalable with more than 99% parallelization

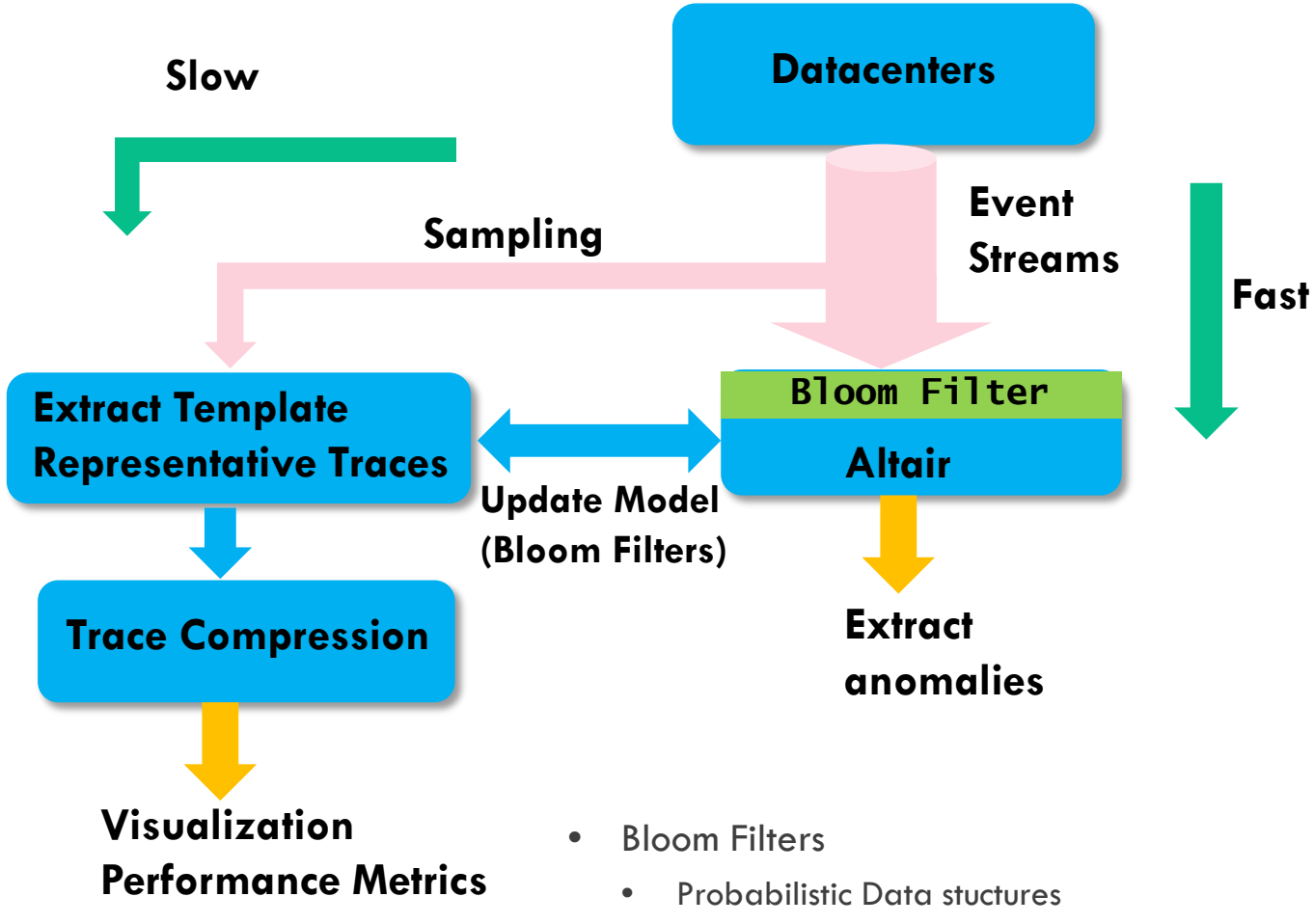
Altair Use Cases

- Anomaly Detection in distributed systems
- Cyber Intrusion Detection
- Failover Management
- Performance Issues

Altair Use Case: Anomaly Detection

- **Anomaly Detection application will be run continuously in two steps**
  - The first step involves designing the Bloom filter. The design of the Bloom filter requires a representative set of graphs. This step is not real-time.
  - We are proposing graph clustering approach to extract template representative graphs that would be programmed into Bloom Filter
  - Second Step with Altair will run in real time
  - Any anomaly traces will be flagged by the Bloom Filter with little overhead

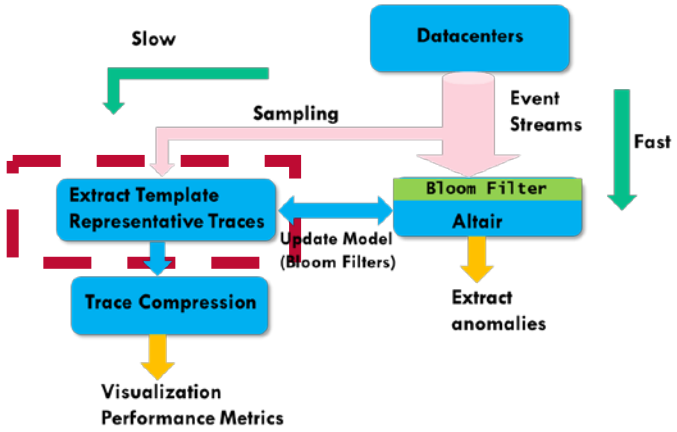
N epochs



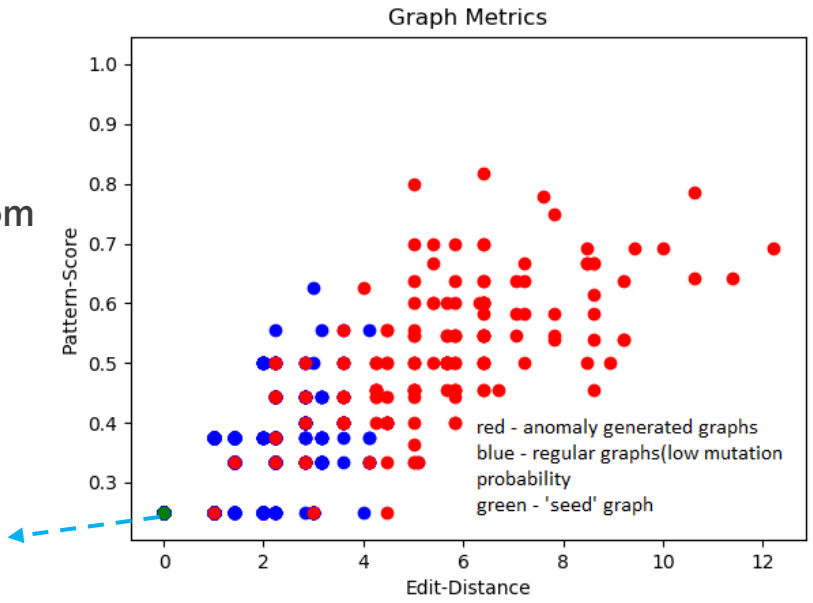
- Bloom Filters
  - Probabilistic Data stuctures
  - "No" answers are always correct
  - Vector bit array (m) and hash functions (k)

Clustering to Extract Representative Workflows

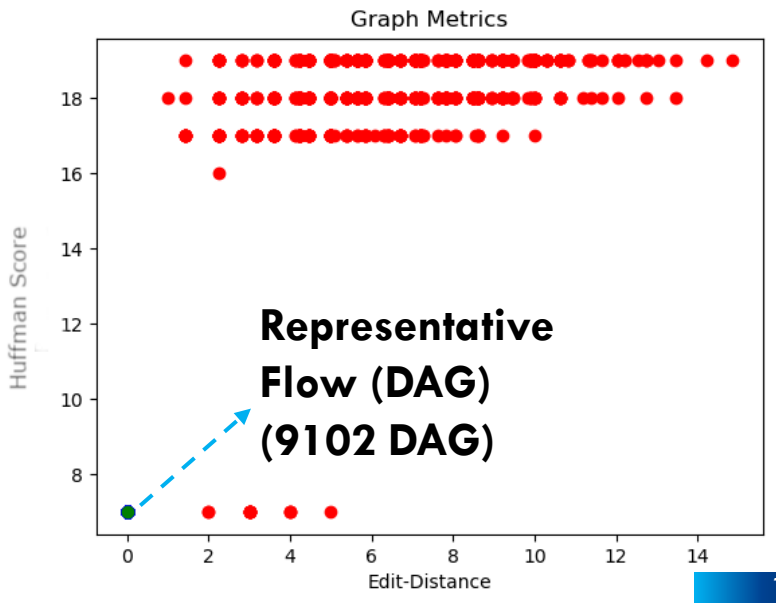
- Use clustering to find unique representative flows in a sample of the event stream
- Trace Compression using feature vectors
  - MDL Score
  - String Edit Distance (Levenshtein Distance)
  - Hoffman Coding
- Feature Vectors provide insight into the flows
  - Used to extract performance metrics
  - Visualization
- Computationally Expensive
- Representative traces used to design Bloom Filters



Example



Representative Flow (DAG) (9072 DAG)



Representative Flow (DAG) (9102 DAG)

Conclusions

- Developed an distributed tracing framework system based on timely dataflow model called Altair that can achieve real time performance
- Evaluated the Altair System on for Anomaly Detection use case
- Evaluation shows that Altair is highly scalable and can be adapted for high production environments

Acknowledgement

Thank you

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  - MIT, Primes for giving me the opportunity to participate in the research program
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Questions

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