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

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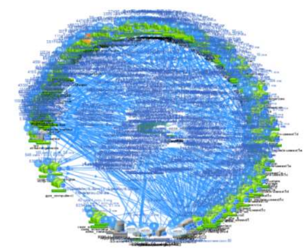
# Motivation

- Most modern services use a distributed architecture
- We can't debug distributed services – complicated, with 1000's of nodes and services
- To find performance issues in distributed systems we need to do tracing

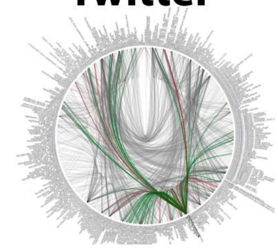
**Debugging services in a distributed system is a complicated problem**

**Netflix**



Why is my movie lagging?

**Twitter**



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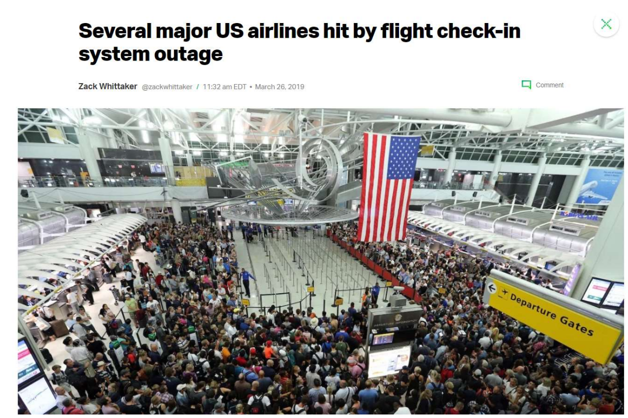

Several major US airlines hit by flight check-in system outage

Zack Whittaker @zackwhittaker / 11:32 am EDT • March 26, 2019

Comment

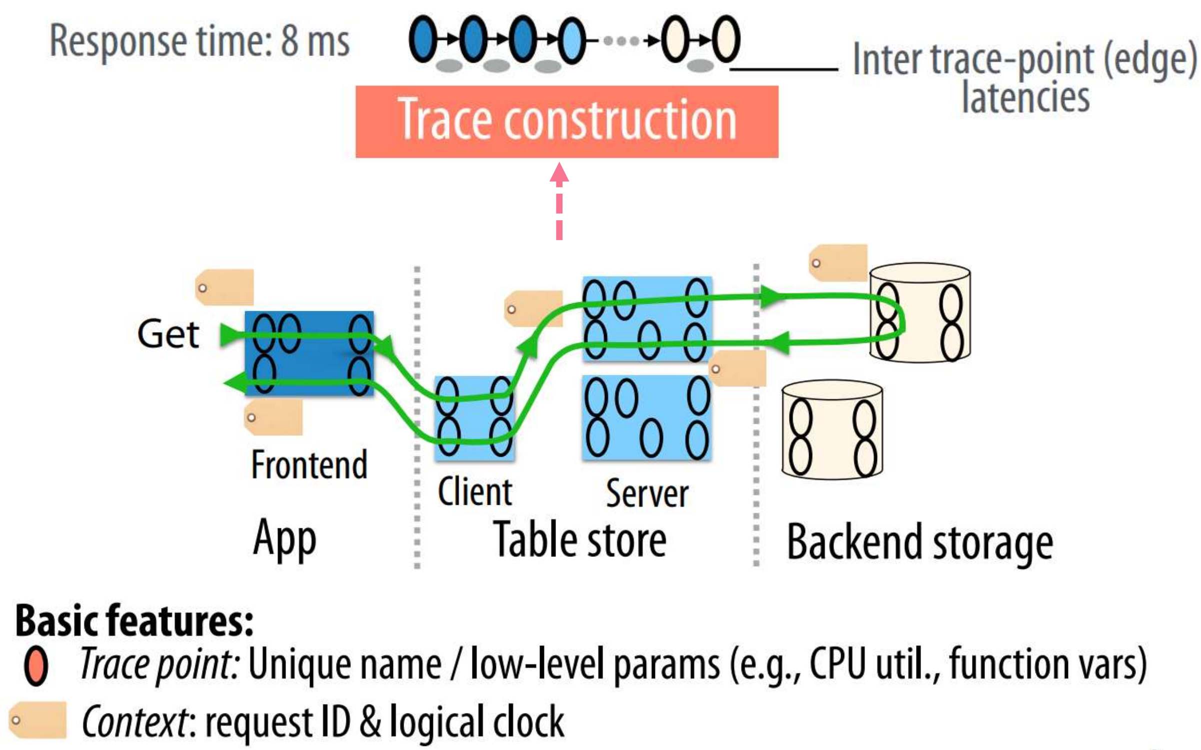


March 26, 2019

# Workflow-Centric Tracing

- Every request involves a workflow
- Machine-centric techniques are insufficient
  - E.g., GDB, GProf, perf. counters, strace, Dtrace
- Workflow: Structure & timing of work done to process them
- Structure: Order, concurrency & synchronization

**Challenge with tracing: real-time construction**



# Problem: Trace Reconstruction is Slow

- Tracking performance requires tracing services through a distributed system
  - Data and computation intense
  - Facebook collects 1 Billion Traces/day

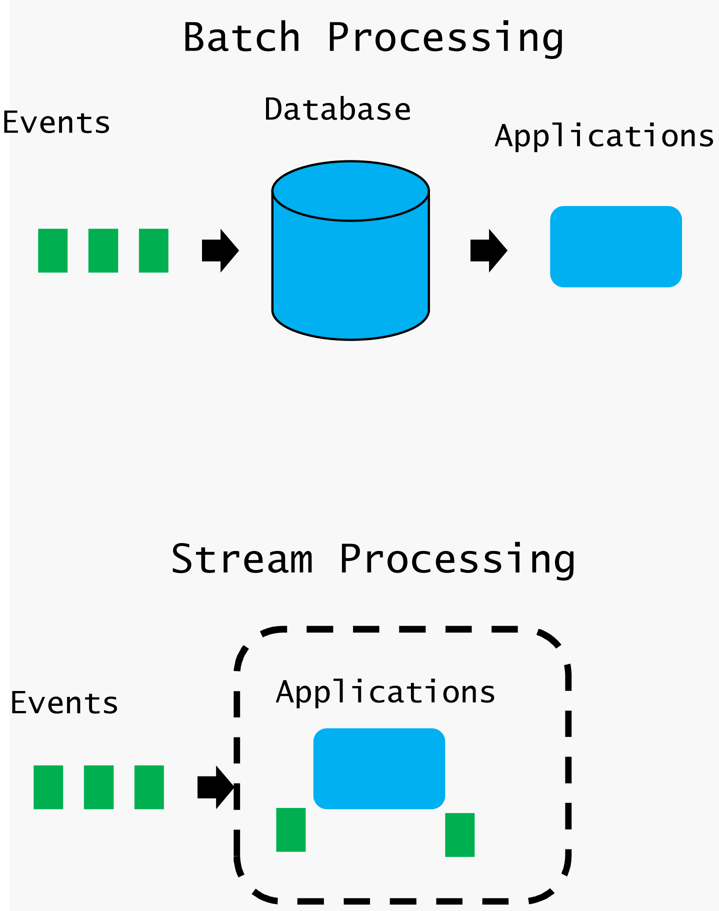
- Existing tracing systems operate in mostly non-real time batch mode (e.g. Facebook ~ 1 day turnaround to find problems)

- The "look-back" approach for finding anomalies or performances issues requires archiving and analyzing massive amount of unorganized log data

**Finding problems in distributed systems is like finding a needle in the haystack**

# Stream Processing Framework

- Tracing data is created as a series of events over time.
- In batch processing data is stored in a database. Applications would query the data or compute over the data as needed
- Stream Processing turns this paradigm around: The application logic, analytics, and queries exist continuously, and data flows through them continuously.
- Upon receiving an event from the stream, a stream processing application reacts to that event: it may trigger an action, update an aggregate or other statistic, or “remember” that event for future reference.



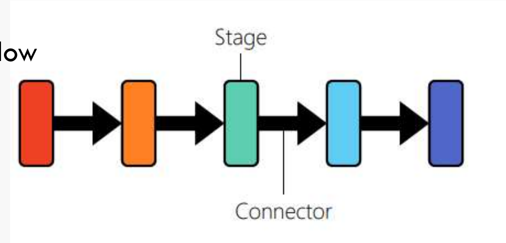
# Timely Dataflow

- Framework for writing dataflow programs

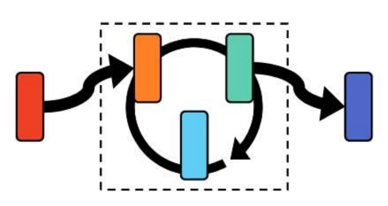
- Dataflow programming is a programming model in which the computation can be represented as a directed graph: The data flows along edges, while the computational logic in the vertices transforms it

- The messages flowing along edges are annotated with timestamps.

Dataflow




Dataflow Iteration



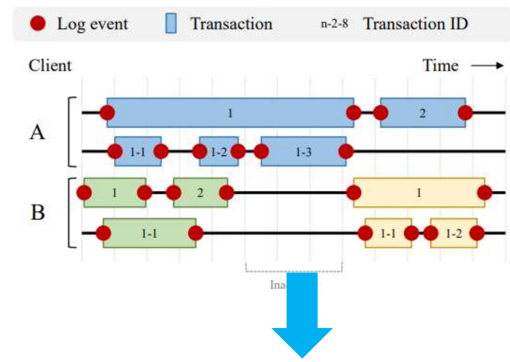
**Timely Dataflow used as the streaming framework**

Reference Naiad: A Timely Dataflow System

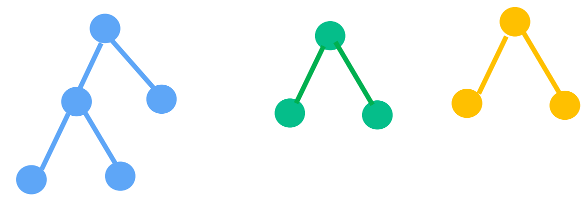
# Previous Work

- 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

**Trees**




**DAG**

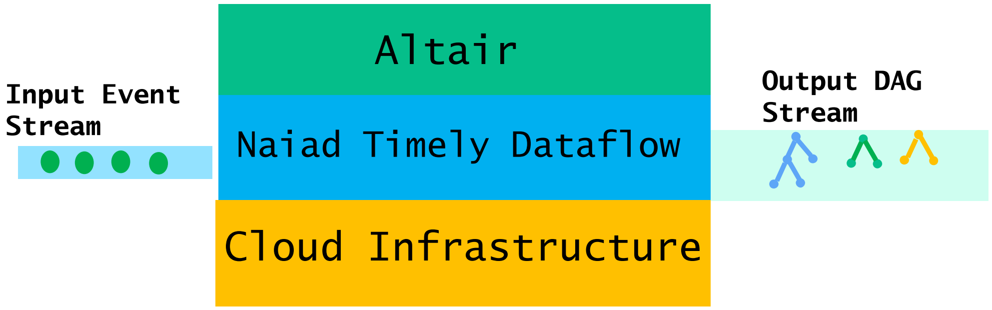


**We developed a new system for processing traces called Altair**


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

# Proposed System For Real Time Trace Reconstruction – **Altair**

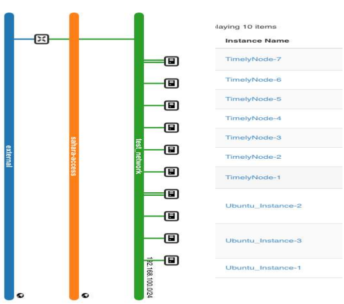
- Altair used Timely dataflow as the stream processing framework
- Input tracing event stream are reconstructed to create workflow model which are represented as DAG
- Interesting DAG’s can be stored or queried for analysis



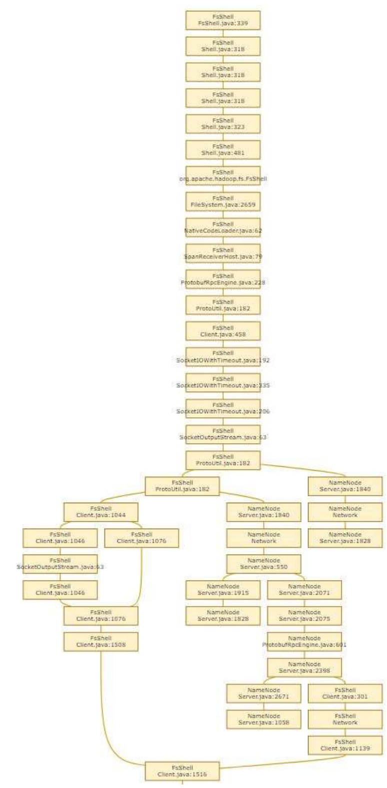
# Evaluation: HDFS Tracing

- 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)**



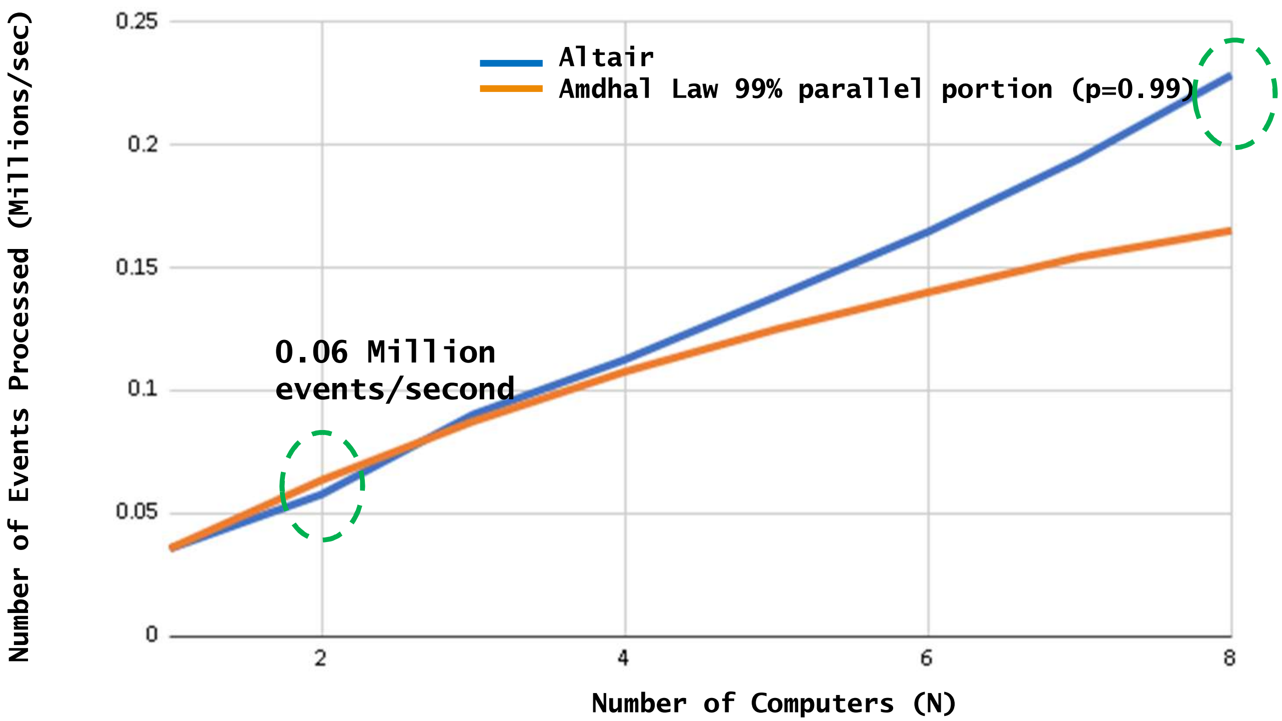

**Altair implemented in Rust**



Acknowledgement : Mass Open Cloud for their support

# Results : Altair

**Altair Events Processing Throughput**




**0.23 Million events/second**

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**

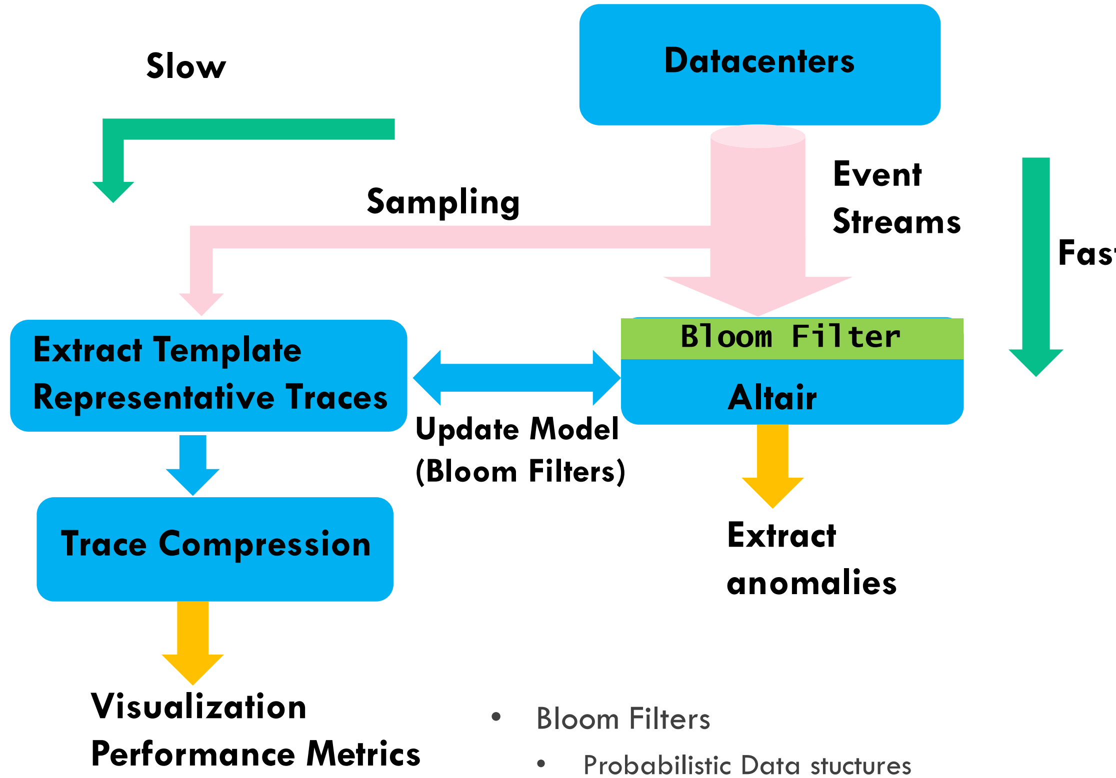
# Altair Use Cases

- 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

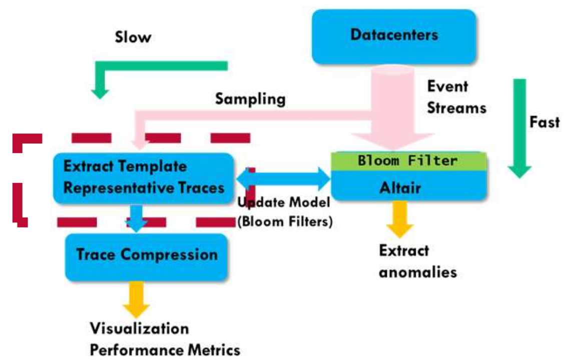
N epochs




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

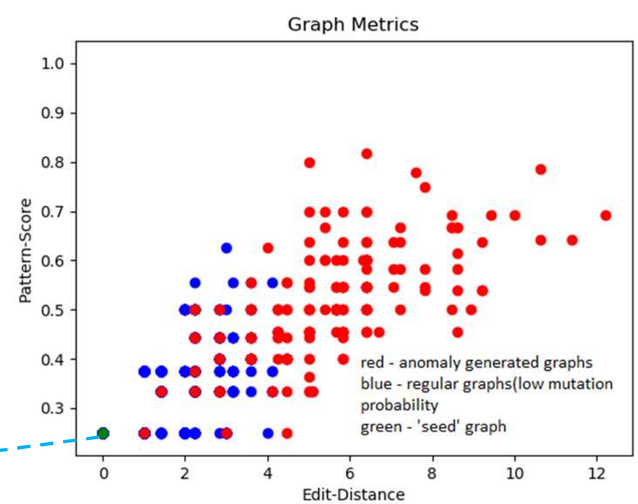
# Clustering to Extract Representative Workflows

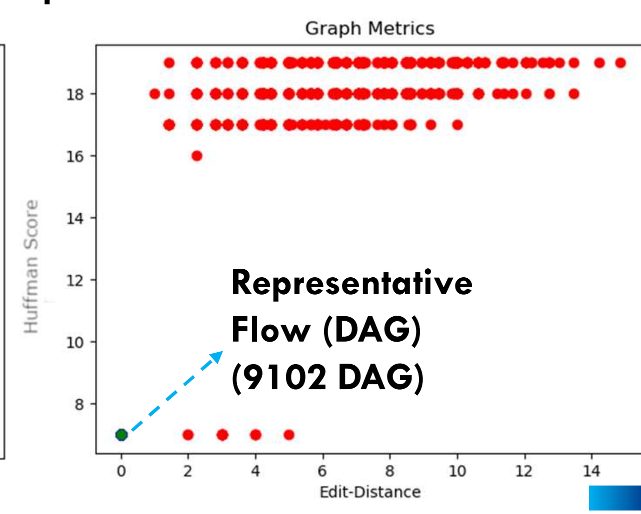
- Use clustering to find unique representative flows in a sample of the event stream
- Trace Compression using feature vectors
  - MDL Score
  - String Edit Distance (Levenshtein Distance)
  - Hoffman Coding
- Feature Vectors provide insight into the flows
  - Used to extract performance metrics
  -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




**Example**

**Representative Flow (DAG) (9072 DAG)**



# Integration with Pythia

- Pythia is a tracing system
- Places trace points for calls and programs and stores trace points in logs.
- Utilizes constructed traces' structure to figure out root cause analysis and adjusts granularity of traces based on it.
- Traces can be constructed faster at a smaller granularity if they don't pertain to the task.
- Altair functions as the primary workflow collection.  It provides data in the form of DAG's from which the workflow skeletons can be generalized
- Integration is ongoing

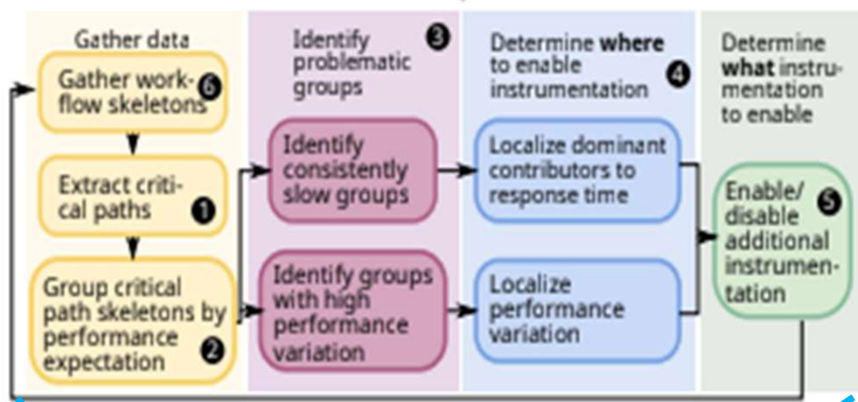
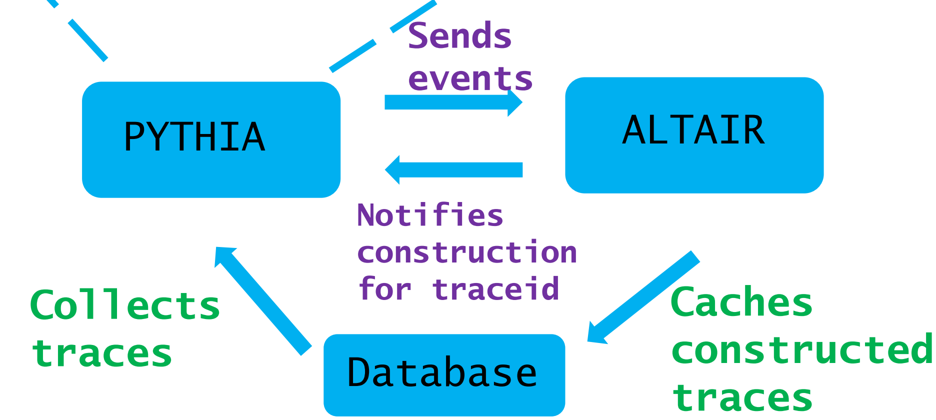



Figure 2: Pythia's continuous cycle ofoperation.

[Ref]




[Ref] Ates, et.al "An automated, cross-layer instrumentation framework for diagnosing performance problems in distributed applications"

# 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
- Integration with Pythia

## Acknowledgement

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# Questions

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