Observability-Driven Software Engineering

Wahab Hamou-Lhadj
Concordia University
Montréal, QC, Canada

Naser Ezzati-Jivan
Brock University
St. Catharines, ON, Canada

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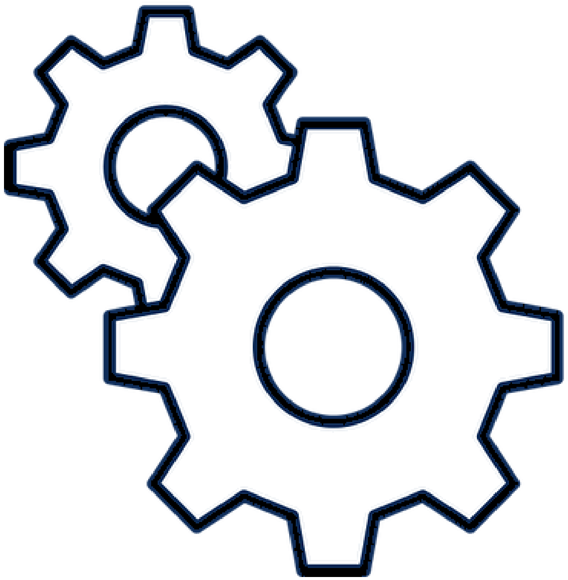
User vs. Operational Data

- **User data** describes information about users.
  - E.g. social media data, user preferences, geo-location data, images, etc.
  - Applications include marketing campaigns, fraud detection, image recognition, etc.

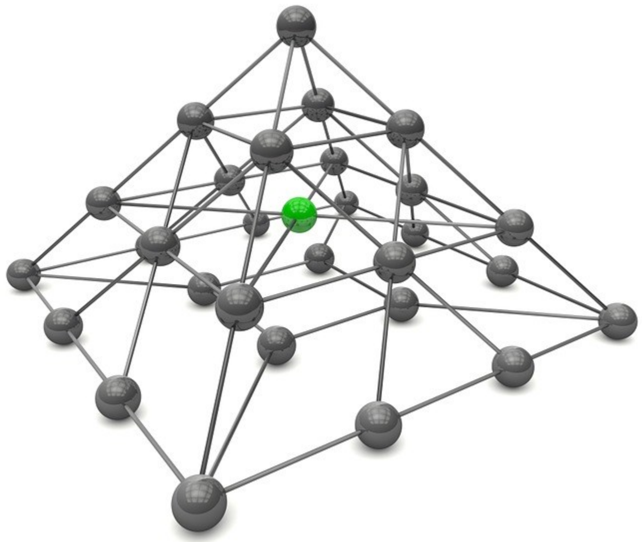
User vs. Operational Data

- **Operational (machine) data** describes information about a system (or a machine)
- It is collected automatically from devices, IT platforms, applications with no direct user intervention.
    - Useful for diagnosing service problems, ensuring reliability, detecting security threats, improving operations, and so on.



Operational Data for Software-Intensive Systems

- The proper functioning of software-intensive systems **relies heavily on operational data** to diagnose and prevent problems.
- New trends in SW dev. make this challenging:
  - Highly distributed and parallel systems
  - Micro-service architectures
  - Virtualisation and containerization
  - Device connectivity and IoT
  - Cyber physical systems
  - Intelligent and autonomous systems
  - Agile, DevOps, and continuous delivery processes

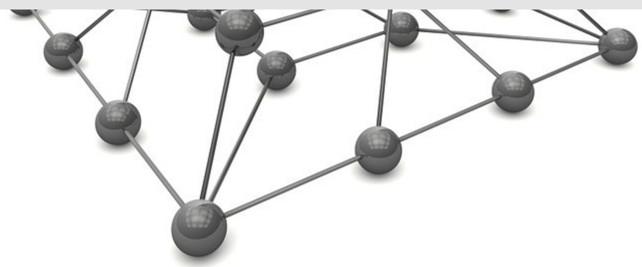


Operational Data for Software-Intensive Systems

- The proper functioning of software-intensive systems **<u>relies heavily on operational data</u>** to diagnose and prevent problems.

We need better runtime system analysis and fault diagnosis and prediction methods that provide full visibility of a system's internal states.

- Virtualisation and containerization
- Device connectivity and IoT
- Cyber physical systems
- Intelligent and autonomous systems
- Agile, DevOps, and continuous delivery processes



Software Observability

- In control theory:
  - **Observability** is "a measure of how well internal states of a system can be inferred from knowledge of its external outputs" [Wikipedia]

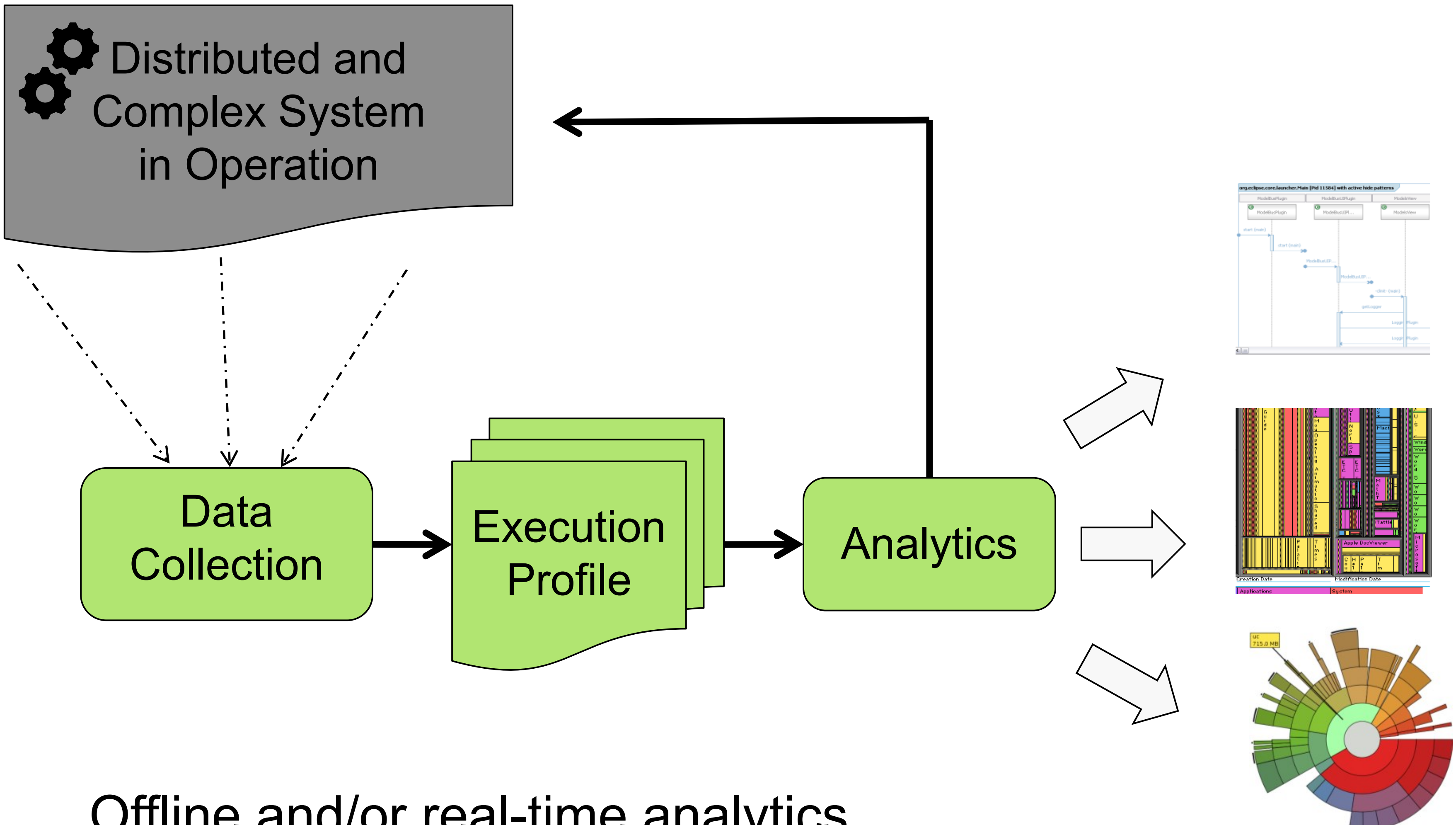
- Software Observability:
  - A set of end-to-end techniques and processes that allow us **to reason** about **what a software system is doing and why** by analyzing its external outputs.

Monitoring vs Observability

- **Monitoring:**
  - Tracks known metrics and raises alerts when thresholds are not met (e.g., 4 golden signals of Google SRE: latency, traffic, errors, and saturation)
  - Answers the question: “how is the system doing?”
  - Helps diagnose known problems

- **Observability:**
  - Answers the question: “what is the system doing and why?”
  - Enables to reason about the system by observing its outputs
  - Helps diagnose known and unknown problems

Building Blocks



Offline and/or real-time analytics

Operational Data

- **Logs:**
  - Records of events generated from logging statements inserted in the code to track system execution, errors, failures, etc.
  - Different types of logs: system logs, application logs, event logs, etc.
- **Traces:**
  - Records of events showing execution flow of a service or a (distributed) system with causal relationship
  - Require additional instrumentation mechanisms
- **Profiling Metrics:**
  - Aggregate measurements over a period of time (e.g., CPU usage, number of user requests, etc.)

Emergence of AI for IT Operations

- AIOps is the application of AI to enhance IT operations
- An important enabler for digital transformation
- Building Blocks:
  - Data collection and aggregation
  - Pattern recognition
  - Predictive analytics
  - Visualization
- Applications:
  - Fault detection and prediction
  - Root cause analysis
  - Security
  - Regulatory compliance
  - Operational intelligence

Characteristics of Logs and Traces

- **Velocity:** the data (in some cases) must be processed in real time
- **Volume:** mountain ranges of historical data
- **Variety:** captured data can be structured or unstructured
- **Veracity:** captured data must be cleaned
- **Value:** not all captured data is useful

Challenges

- **Standards and Best Practices:**
  - Lack of guidelines and best practices for logging, tracing, and profiling
  - Lack of standards for representing logs, traces, and metrics (not the OpenTelemetry initiative)
- **Data Characteristics**
  - Mainly unstructured data
  - Size is a problem
  - Not all data is useful
  - High velocity

Challenges

- **Analytics and Tools:**
  - Mainly descriptive analytics
  - Predictive analytics not fully explored
  - Mainly offline analysis techniques
  - Lack of usable end-to-end observability tools

- **Cost and Management Aspects**
  - Cost vs. benefits not well understood
  - No clear alignment of observability with other initiatives
  - Roles and responsibilities are not well defined

Challenges

- **Analytics and Tools:**
  - Mainly descriptive analytics

There is a need for systematic and engineering approaches to software observability that promote best practices throughout the entire software development lifecycle

- **Cost and Management Aspects**
  - Cost vs. benefits not well understood
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Observability By Design

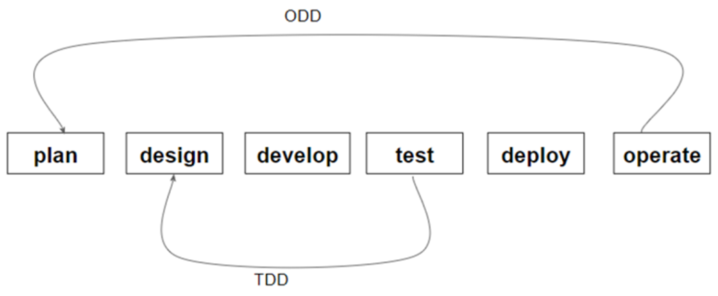
- Bringing observability **to early stages** of the software development lifecycle.

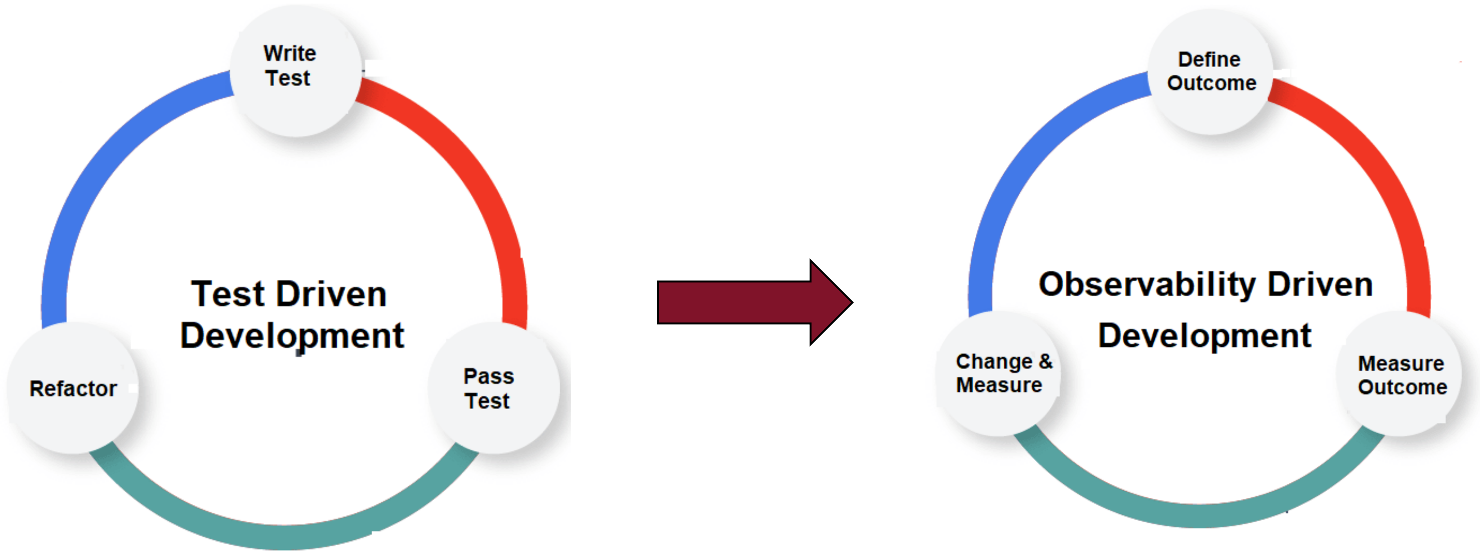
- Defining a set of **observability patterns, best practices, and reusable solutions** to be used as guiding principles for developers.

- A **systematic approach** to tracing, logging and profiling of software systems that considers different phases of the software process.

Observability-Driven Development (ODD)

- Leveraging tools and hands-on developers to observe system state and behavior
  - Interrogating the system, not just setting and measuring thresholds and metrics for it

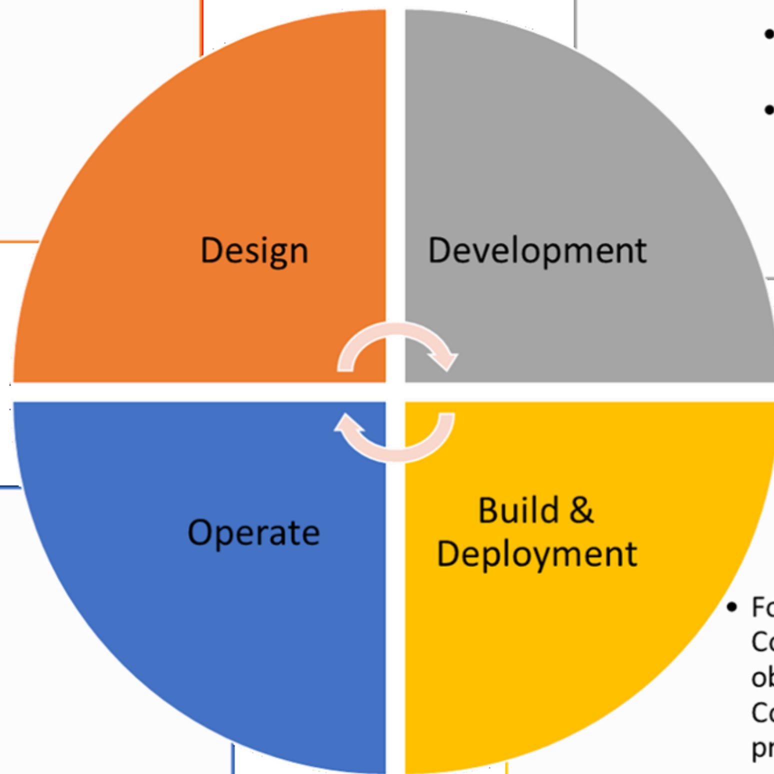




Observability-Driven Development (ODD)

- Determining what to observe based on Quality of Service and KPIs to be met
- Identifying where to observe and designing in such a way to make instrumentation easy

- Standardization of the instrumentation
- Adding sufficient context for getting better insight
- Implementing at framework level



- Proactive monitoring and querying
- Feedback loop from the observations to development team

- Following ‘Observability as Code’ practice to enforce observability as part of Continuous Deployment process.
- Observing for unusual behaviour at an early stage through automation

From Telemetry to OpenTelemetry

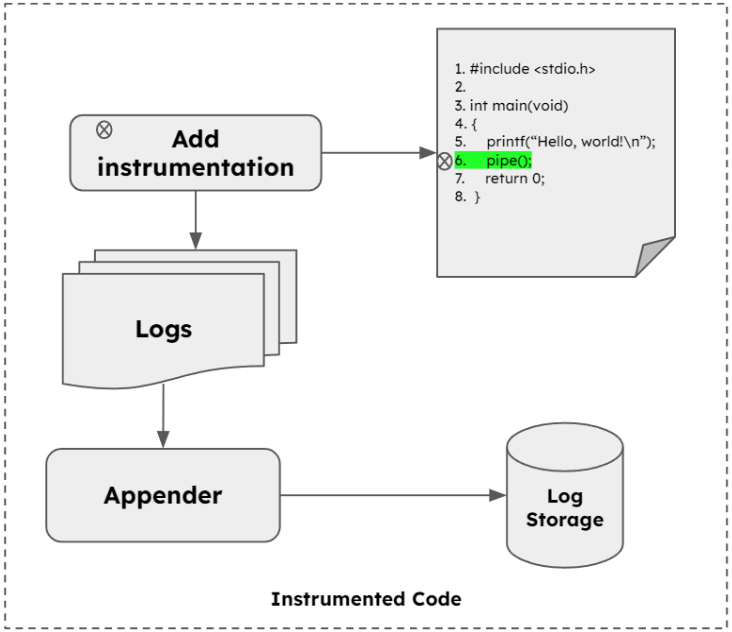
- Observability is often equated with telemetry
  - "If you have metrics, logs, and traces, then you have Observability"
- Observability, is the process of deriving value from telemetry
  - Telemetry is important but not sufficient
- We also need tools to analyze and visualize the telemetry
  - OpenTelemetry

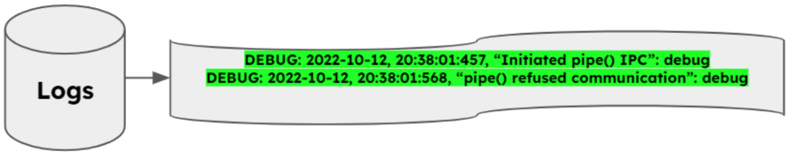
Instrumentation

- Definition
- Example
- Challenges
    - Level of details
    - Lots of noises
    - Cost (overhead)

Instrumentation (Logging)

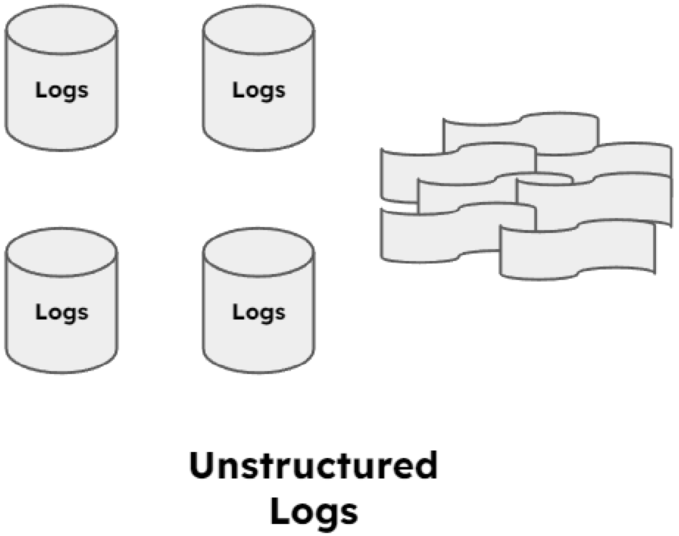
- Limited context of request origin.
  - Can be specific to a certain machine/group.
  - Failure due to other dependency
  - Causal information missing.
- Finding/locating logs for analysis is cumbersome.
- **NOT** an **automatic** process.





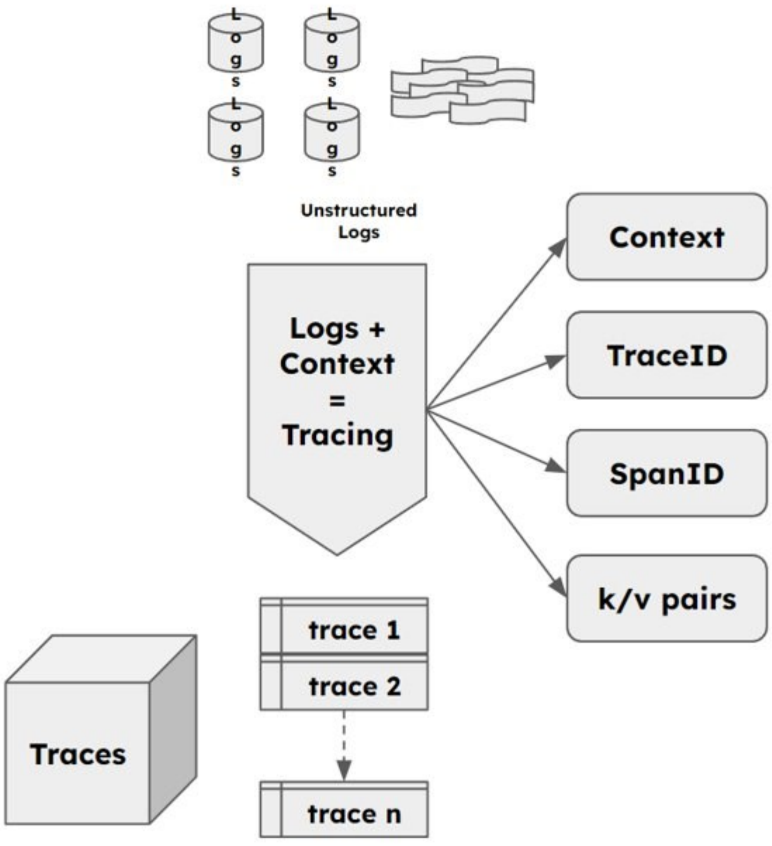
Instrumentation needs context

- Naïve logging is unstructured data.
- Prohibitive in gathering all information (costly).
- Time expensive to reconstruct a request/transaction.
- Sometimes even impossible!



Logging + Context = Tracing

- OpenTelemetry standardizes this transformation.
- Context allows for causal relationship construction.
- Scattered events can be mapped to distributed nodes.
- Unique identifier for each trace allows fast lookups.
- End result = structured data.



Converting logs to traces

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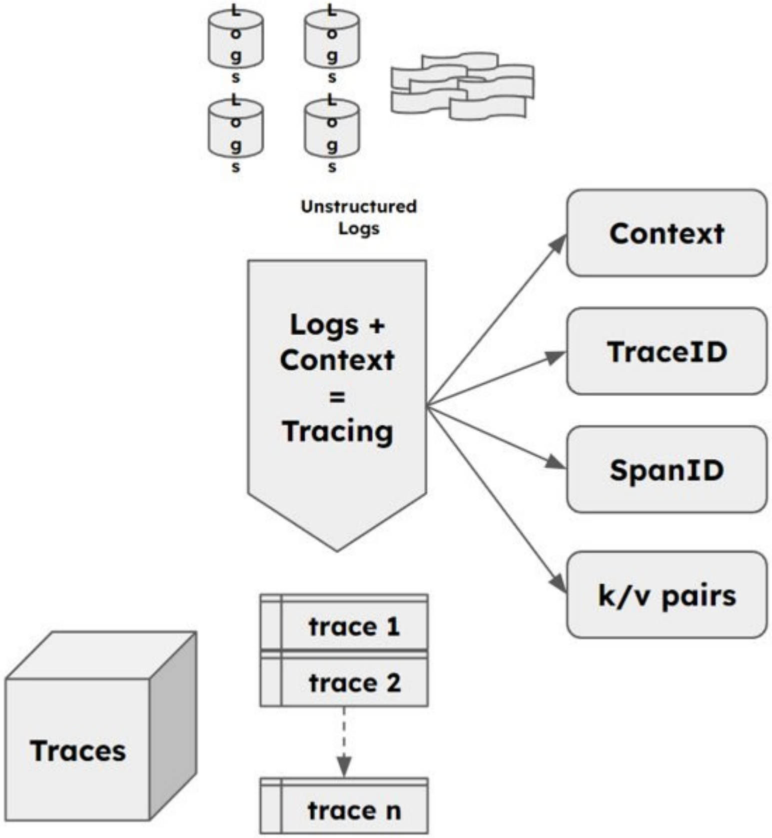


Converting logs to traces

Logs to Events

- Every span has an event
- Every event has a name/message + timestamp + optionally if log has structered data (k/v pairs), add to span
- Switching from Logs to Traces:
  - Context (what)
  - Resources (where)
  - Logs (events attached to traces)

Example Event

- HTTP event
- GET something/somewhere
- Attributes: (unique to the event + generic to the event, but very important for locating this event- static resources), dynamic context: values change from req to req (duration, starttime, error or not, app specific attributes, account id or project id)

TRACING -> GRAPH -> CAUSALITY

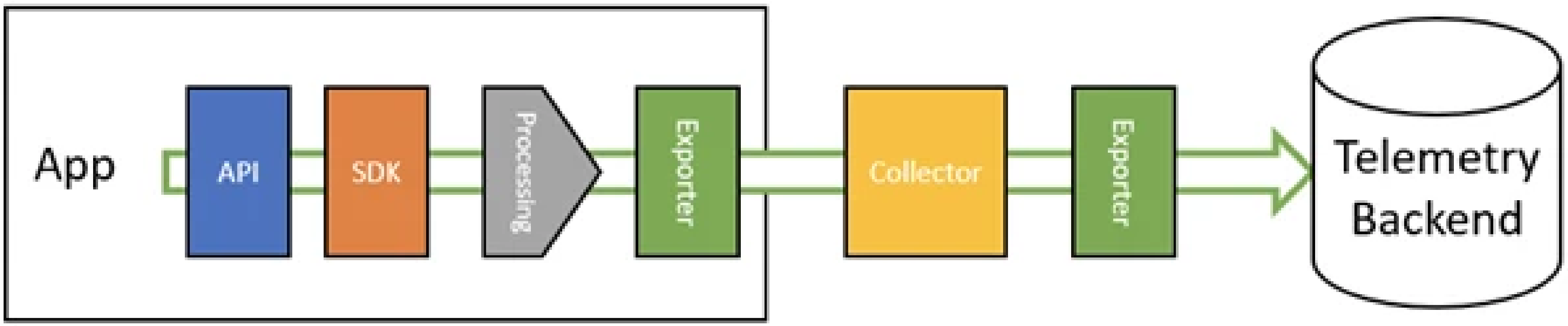
- Needs more contextualization:
  - More attributes
  - Trace-id: identifies transaction
  - Span-id: identifies operation
  - Parent span-id: causality
  - Operation name: compare across different runs of the same operation

Trace Analysis

- Not trying to look at individual transactions
- Correlation across many runs of the same transaction
- Identify that correlation to find the causation (root cause) of the problem.

OpenTelemetry

- Vendor-neutral telemetry



- Instrumentation
  - Changes to the application (source code or configuration)
  - "With great instrumentation comes great observability."
- Data pipeline
- Visualization & Analytics

Client-Server Java Spring Boot Configuration (https://spring.io/)

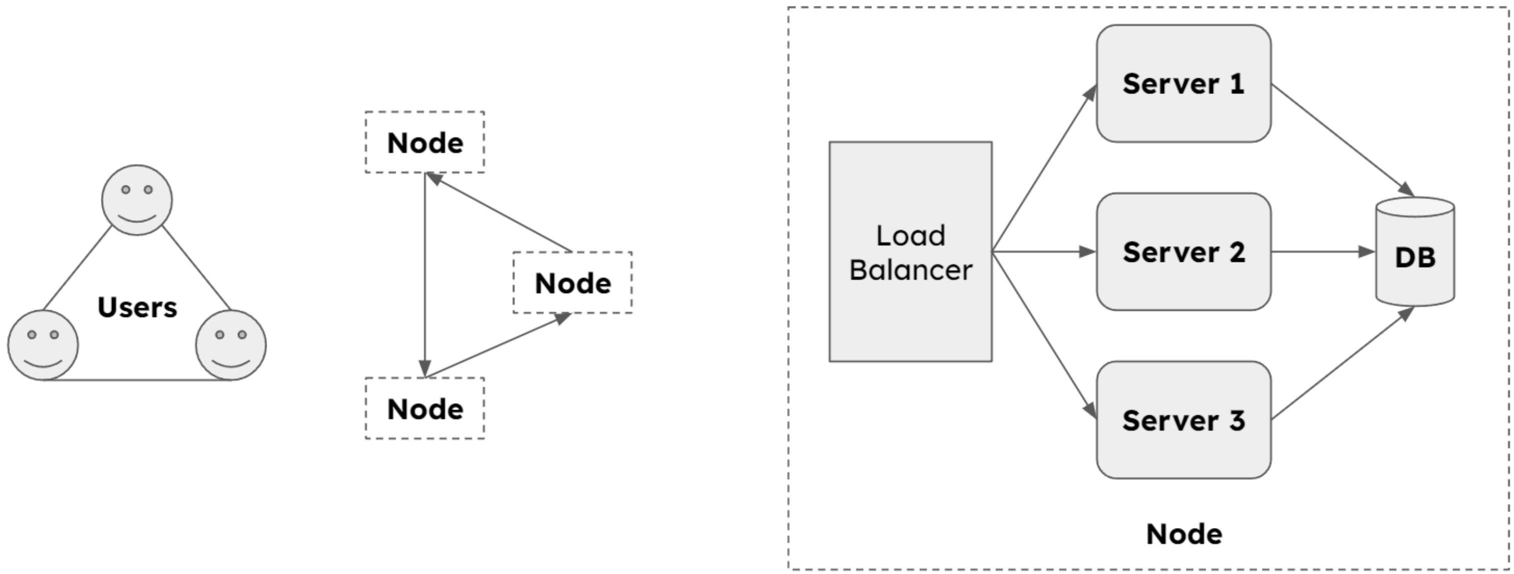


Figure: Microservice Spring Boot Distributed Configuration

Log Providers in Spring

- Nodes serves different endpoints.
- Each endpoint has a logging facility provided by Spring.
- Endpoint activation is internally tracked by the Spring engine.
- Log providers enables live swap in/out.

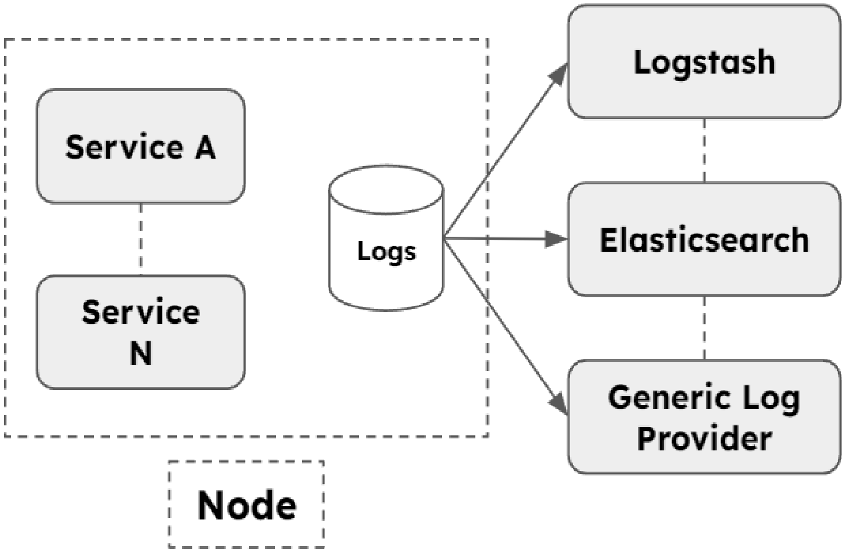


Figure: Log Mechanism Provider within Node

OpenTracing Concept in Spring

- Each unique service can be instrumented.
- OpenTracing API is an interface that Spring Boot provides (Spring Boot Actuator).
- Exposes various metrics (Health, Events, Prometheus, HeapDump)

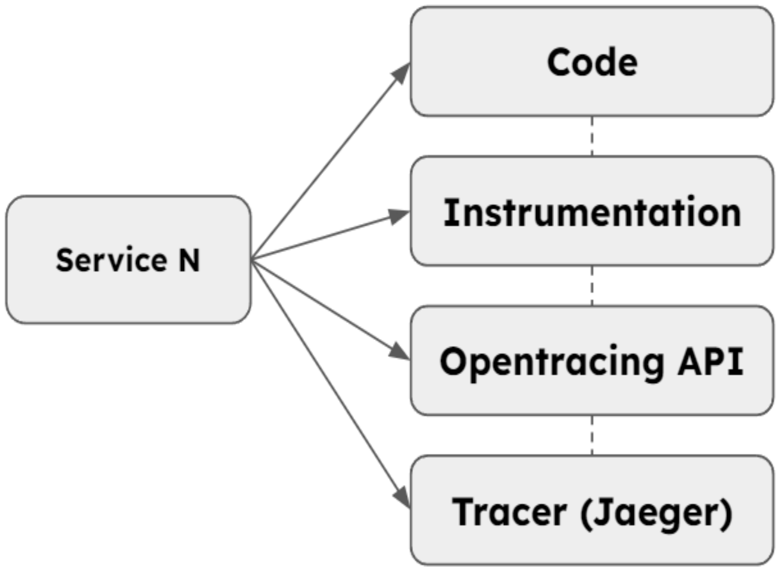


Figure: Trace Mechanism within Service

System Trace Lifecycle (Spans)

- Each Span context is unique storage facility defined from developer's point of view.
- High **cardinality** of data (e.g user_id)
- Context can be augmented with additional information.
- Spans can be analyzed during fault diagnosis without overwhelming trace size.

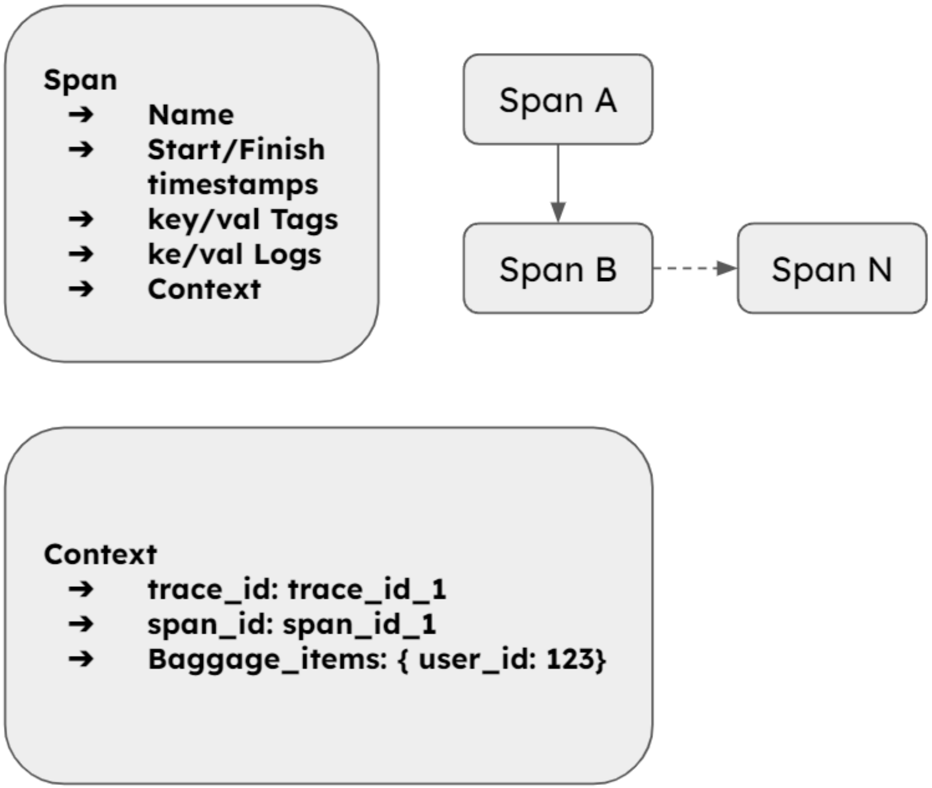
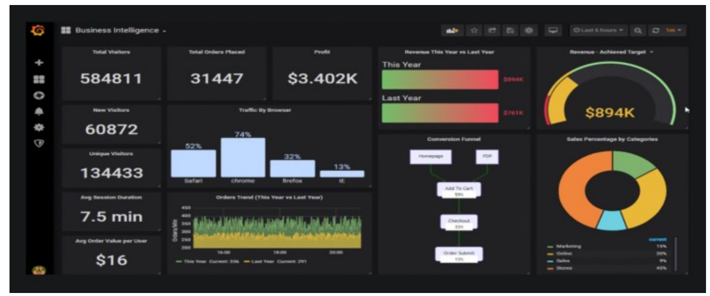


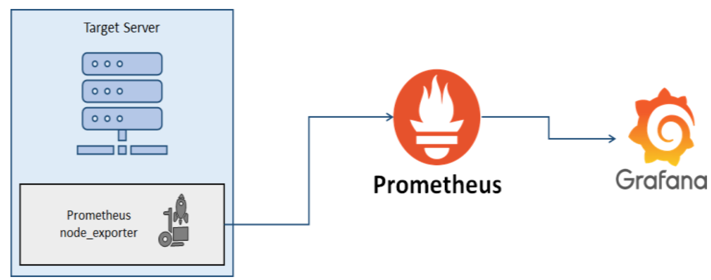
Figure: Custom Span Context Configuration

Metric Analysis & Visualization

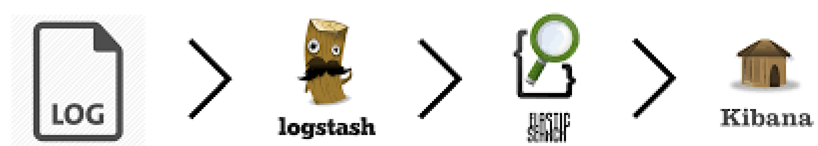
- Grafana
- Prometheus
- Kibana



https://grafana.com/



https://prometheus.io/docs/visualization/grafana/



https://www.elastic.co/guide/en/kibana

Observability Culture

- Observability in action!
- Before and after a problem,
- Data-driven decision making
- Educate team
- Encourage standard tools/techniques
  - Log formatting
  - Metric conventions
- Practice, share success stories, and feedback
- Measure your progress and observer your observability culture!

Contact Information

Wahab Hamou-Lhadj, PhD, ing.

Concordia University

wahab.hamou-lhadj@concordia.ca

http://www.ece.concordia.ca/~abdelw

Naser Ezzati-Jivan , PhD

Brock University

nezzatijivan@brocku.ca

http://www.cosc.brocku.ca/~nezzatijivan/