Northeastern University
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Study on
High Availability & Fault Tolerance Application

CS7980 Capstone

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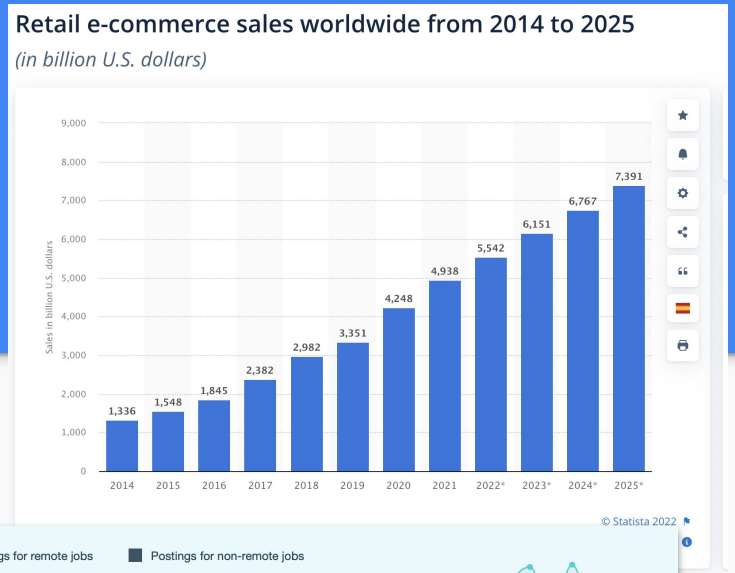
Motivation

Motivation

E-commerce and Remote Working have been the new normal since the pandemic.

e-Commerce trend growed 4 times from 1336 billions in 2014 and expected to be 7391 billions over 10 years

Remote jobs have kept increasing from 30,000 to 60,000 from 2018 to 2021

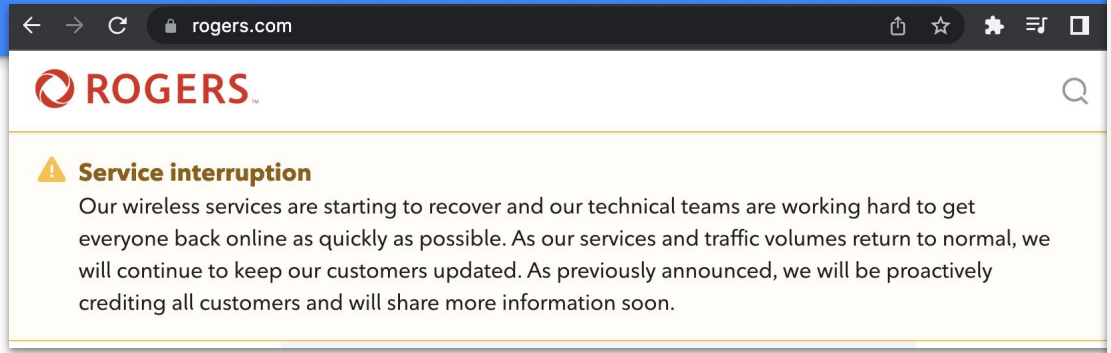


Motivation

As more or more critical system like Online Payment, Air Traffic Control are put online.

It is crucial to design application with **High Availability and Fault Tolerance**, otherwise the consequence will be disastrous…

Catastrophic effect



In this research, we would like to perform deep dive into application design to improve the overall Availability and Fault tolerance

Problem Overview

Problem Overview

The term “Availability” was defined as “The degree to which a system is functioning and is accessible to deliver its services during a given time interval”

⇒ Maximum downtime percentage over a given period

Years of continuous operations	1	2	3
Availability	Maximum allowable downtime		
99.0000% (2–9s)	3 d 15 h 36 min 0 s	7 d 7 h 12 min 0 s	10 d 22 h 48 min 0 s
99.9000% (3–9s)	8 h 45 min 15 s	17 h 31 min 12 s	1 d 2 h 16 min 48 s
99.9900% (4–9s)	52 min 34 s	1 h 45 min 7 s	2 h 37 min 41 s
99.9990% (5–9s)	5 min 15 s	10 min 31 s	15 min 46 s
99.9999% (6–9s)	32 s	1 min 3 s	1 min 35 s

High Availability

Source : Service Availability: Principles and Practice (Maria Toeroe · Francis Tam 2012)

Problem Overview

Availability is a measure of the percentage of time that an application is running properly, i.e.

$$Availability = \frac{uptime}{uptime + downtime} * 100\%$$

To further breakdown the formula, we define uptime & downtime as :

$$Availability = \frac{uptime}{uptime + downtime} * 100\%$$

Problem Overview

$$Availability = \frac{MTBF}{MTBF + MTTR} * 100\%$$

MTBF = Mean Time Between Failure
MTTR = Mean Time To Restore/Recovery

To improve, we can either to ↑ MTBF or ↓ MTTR
In this paper, we will focus on ↓MTTR as much as possible

Problem Overview

$$Availability = \frac{uptime}{uptime + downtime} * 100\%$$

$$Availability = \frac{MTBF}{MTBF\ +\ MTTR} * 100\%$$

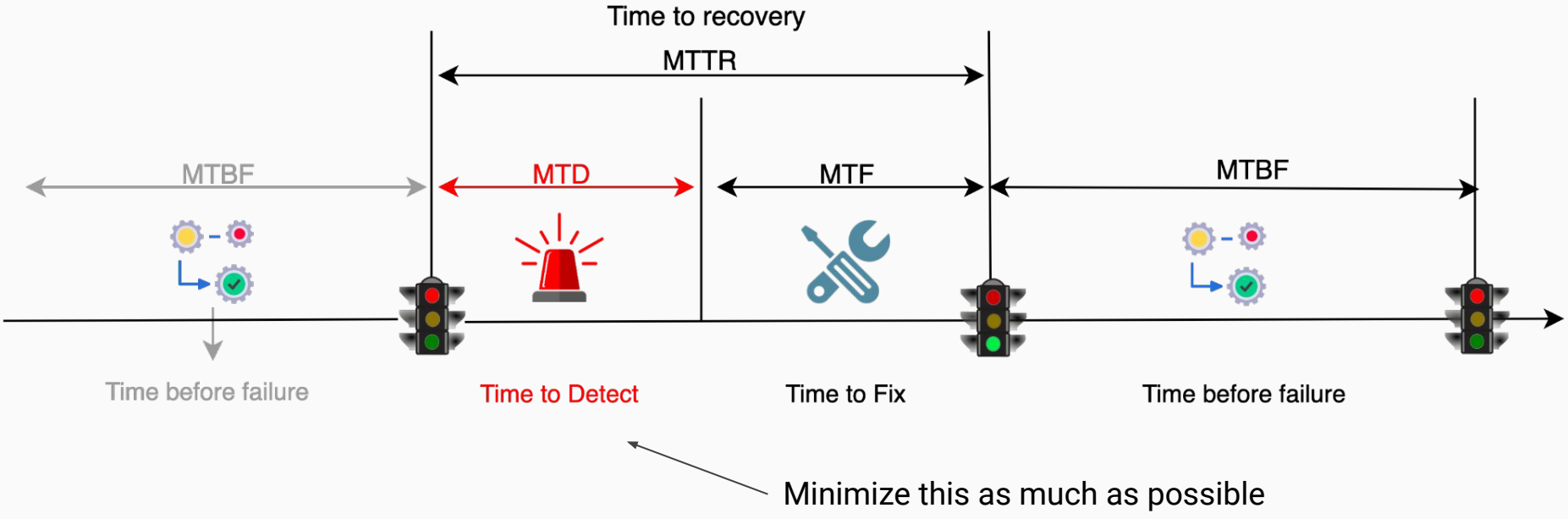
MTTR(Mean Time to Restore) can be further sub-classified into :

- **M**ean **T**ime to **D**etect the failure
- **M**ean **T**ime to **F**ix the failure

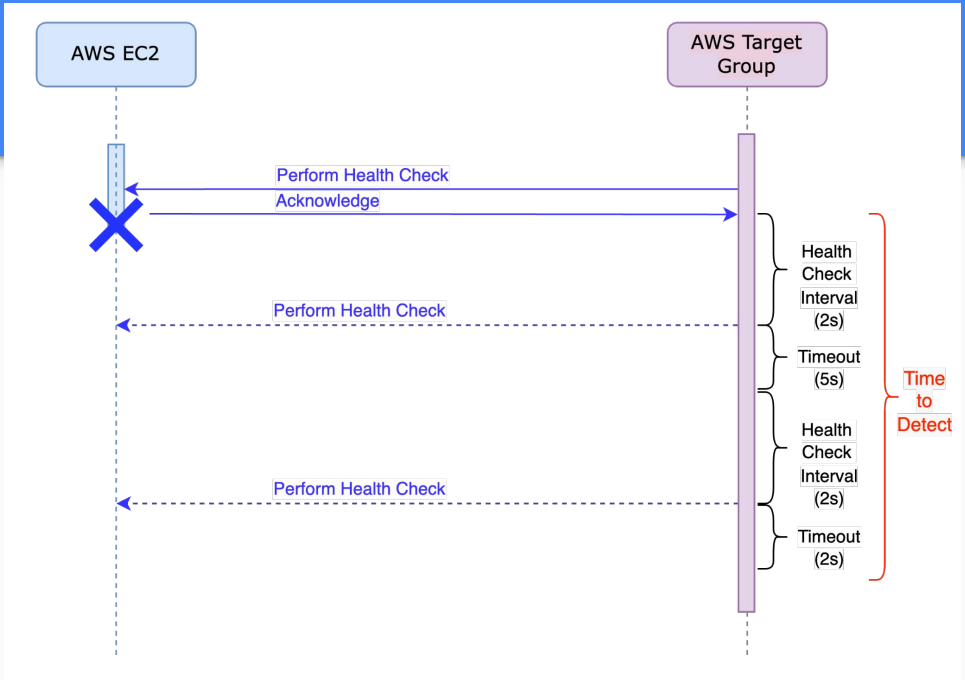
$$Availability = \frac{MTBF}{MTBF\ +\ MTD\ +\ MTF} * 100\%$$

This research will focus on Minimize the **MTD**

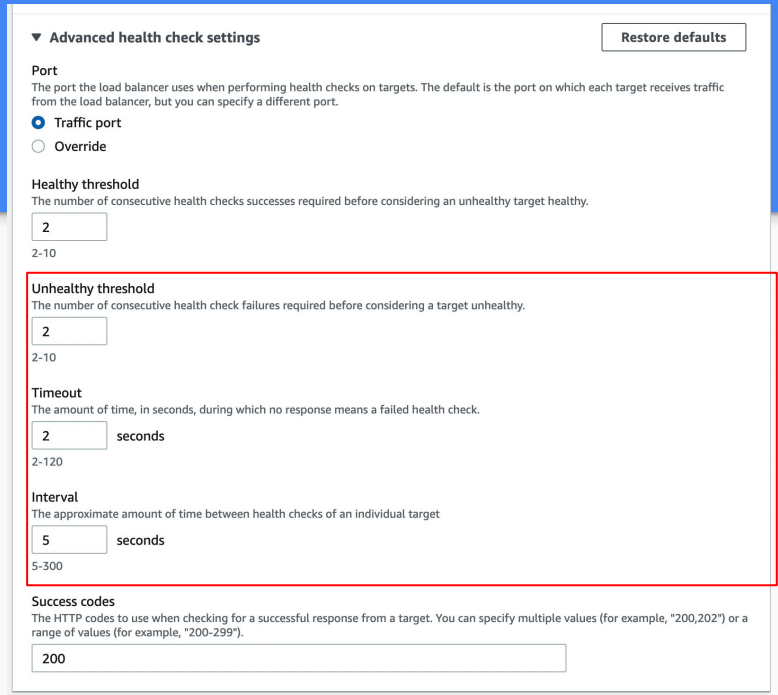
Problem Overview



Industrial Practice



AWS Application Load Balancer



To ensure the underlying application is up and running, typical Load Balancer will perform a “Pull-based” health check (or probe) periodically, which also include a timeout and Retry before declaring the node is unhealthy, worst case up to **14** seconds in AWS

Problem Overview

How can we improve it ?

The Approach

The Approach

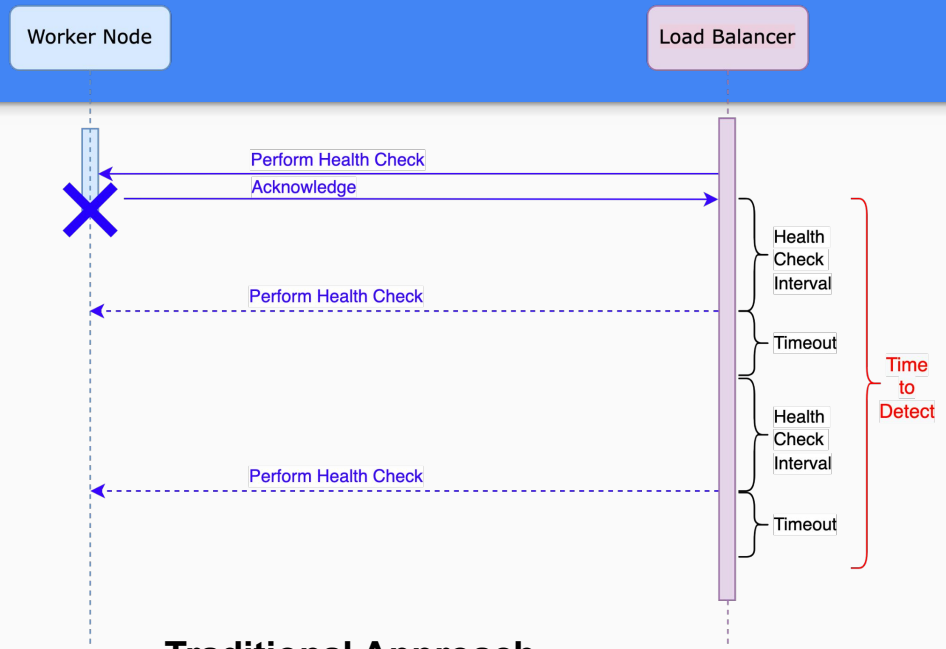
Instead of “Pull Based” health check, we use

- Push Based health check
- Persistent Connection

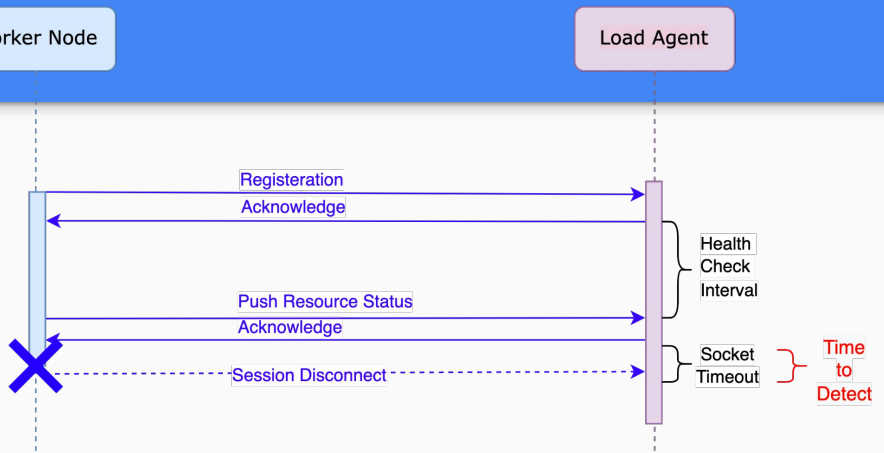
We propose a pluggable “*Resource Agent*” that embedded into worker node, this agent keep a **persistent connection** to the “*Load Agent*”. By **periodically** updating the resource information (CPU / Memory / Network IO), “*Load Balancer*” perform perform a “*Resource Awareness Routing Algorithm*” to dispatch request.

When worker node **crashes**, the “*Persistent Connection*” will be disconnected such that “*Load Agent*” can detect and update the Load Balancer with **minimal delay**.

Minimize “Time to Detect”



Traditional Approach



My Approach

Instead of Pull-based health check, we will use Push Based + Persistent Connection to improve the Time for Detection

Components in this Algorithm

There are 4 major components involves :

1) *Load Agent*
   Wait for worker node connect and update node information to cache

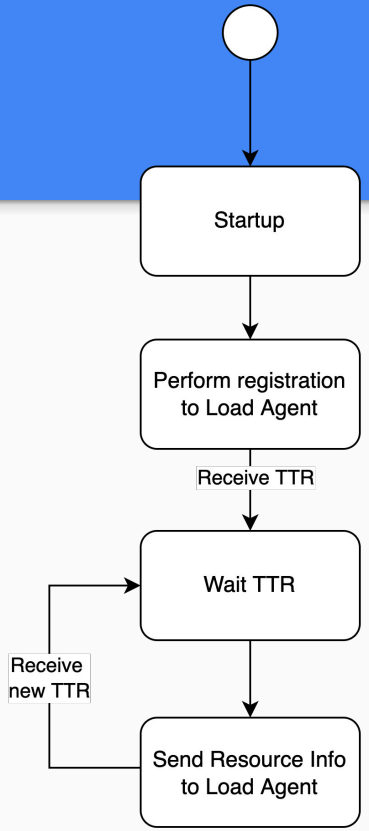
2) *Resource Agent* (Embedded in Worker Node)
   Establish a persistent connection to Load Agent and push status periodically

3) *Load Balancer*
   Run “Resource Awareness Routing Algorithm” to dispatch to Worker Node

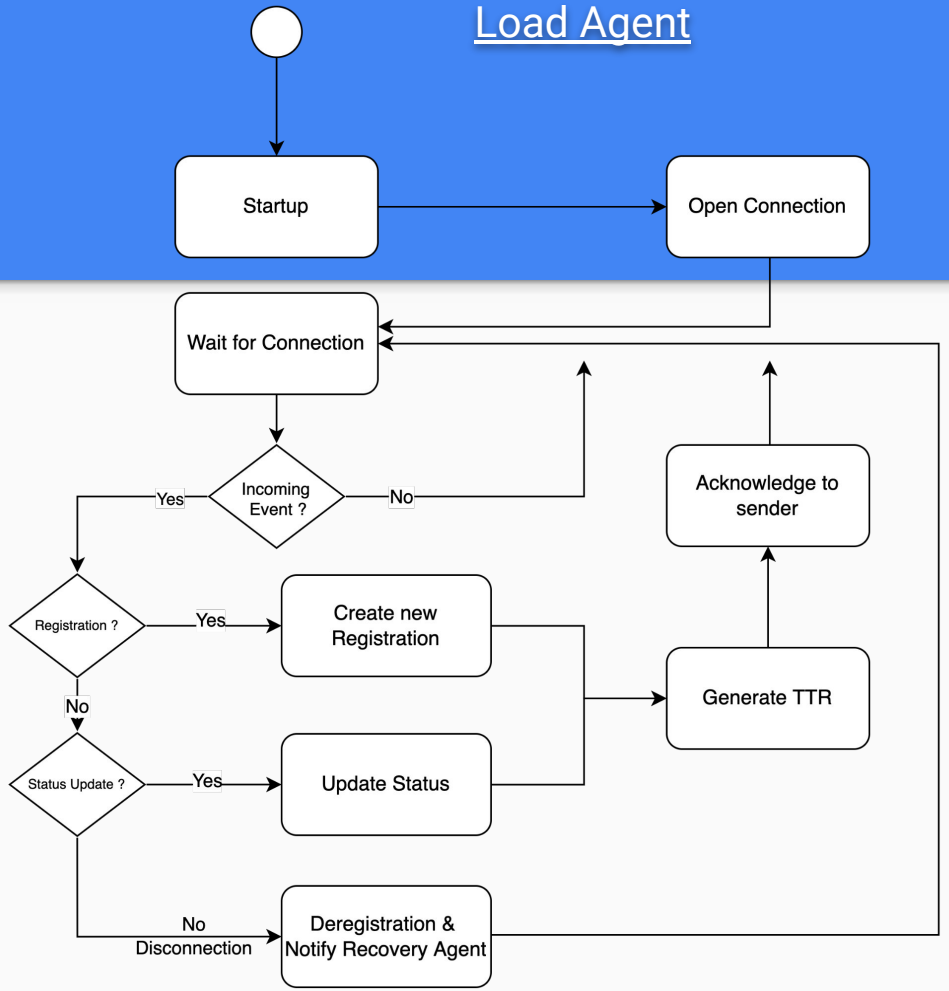
4) *Recovery Agent*
   Perform recovery action upon Load Agent detect outage

Note : Recovery Agent is to minimize the MTF(Mean Time to Fix) instead of MTD

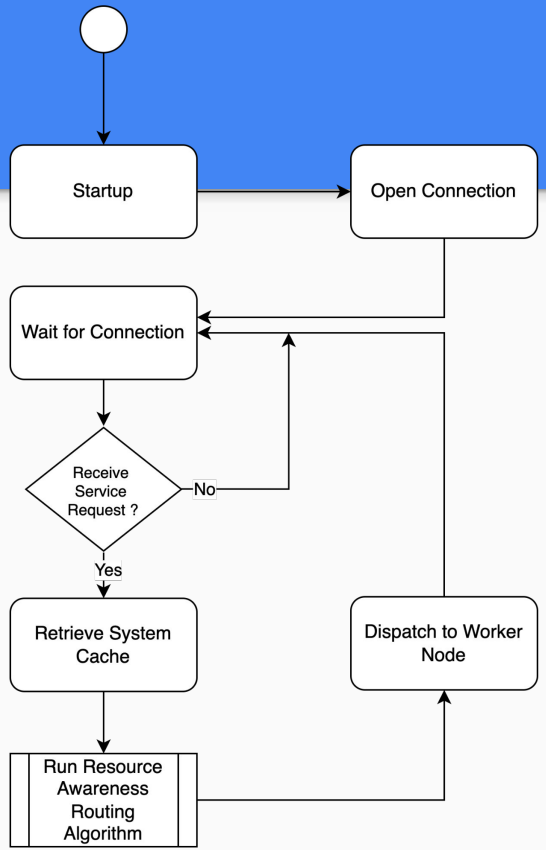
Resource Agent



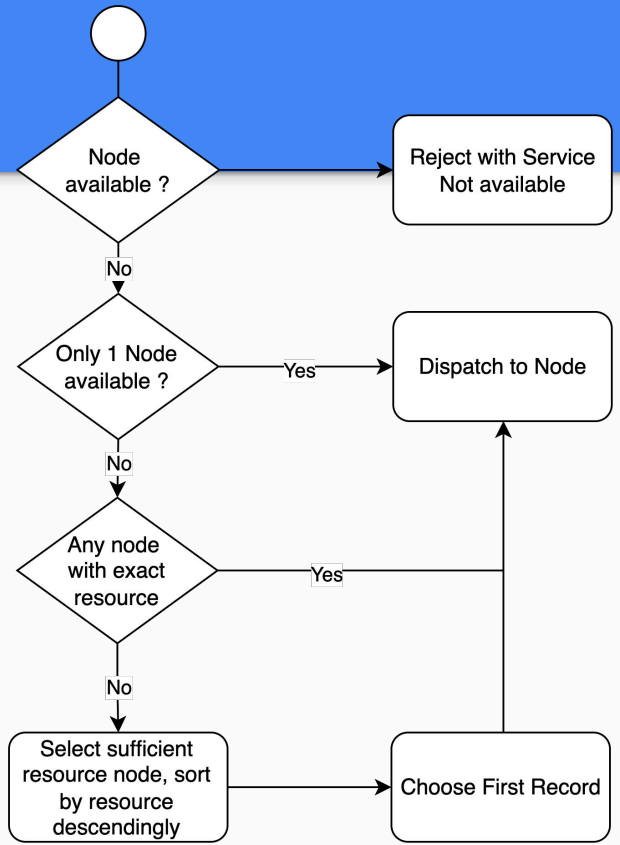
Load Agent



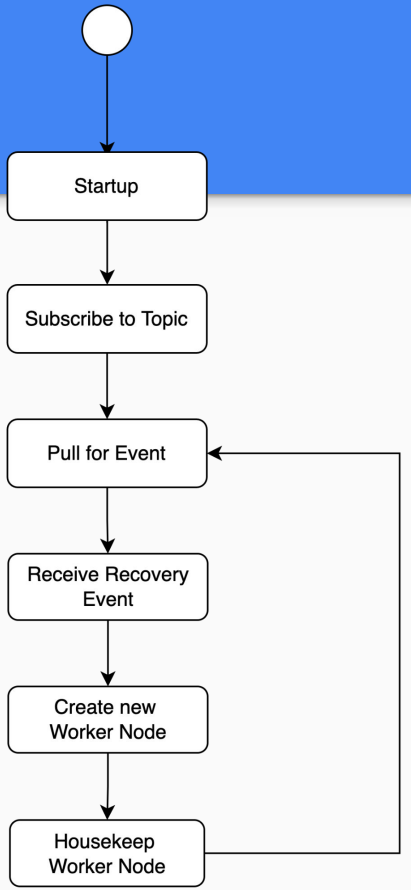
Load Balancer

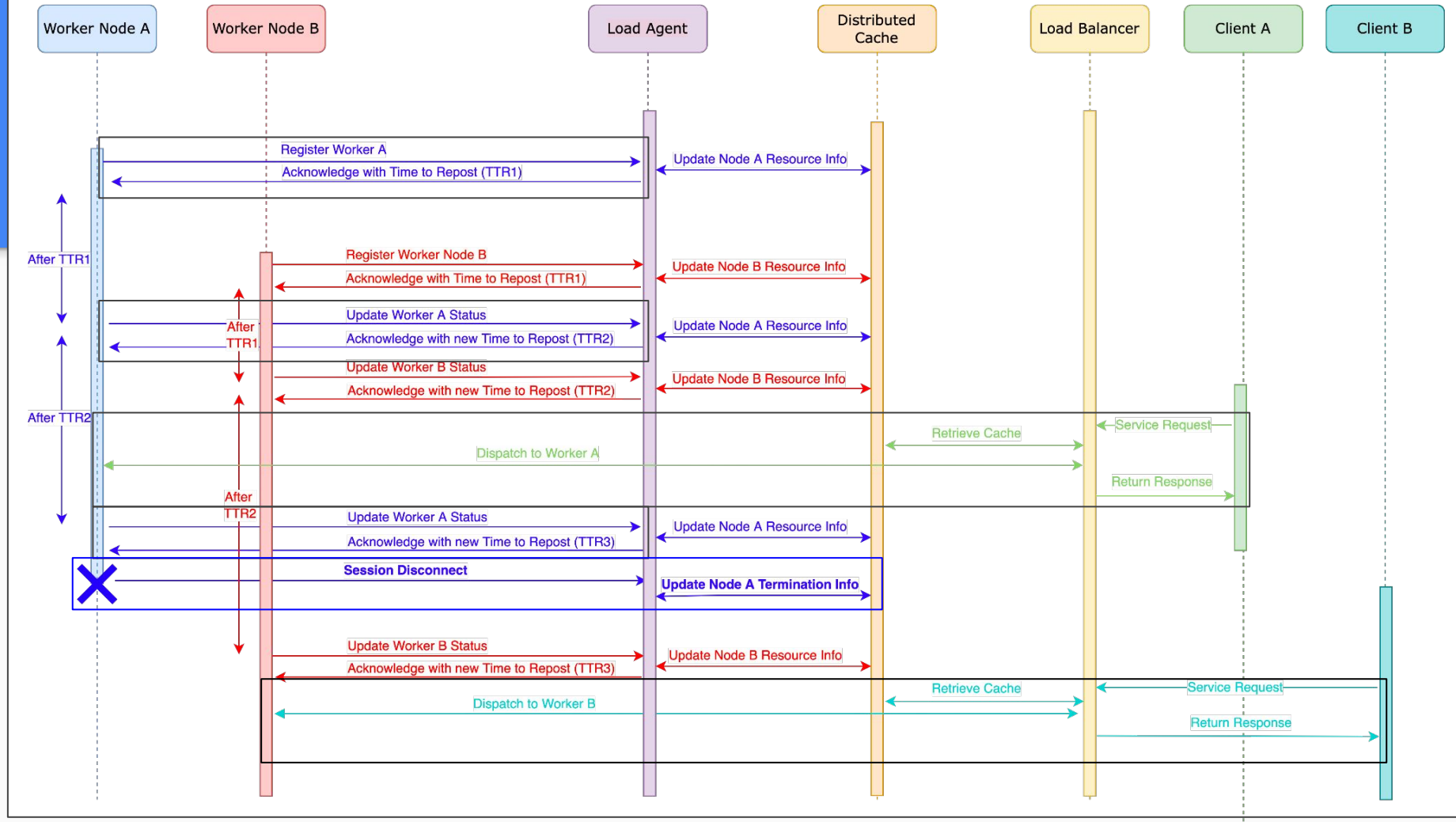


Resource Awareness Routing Algorithm



Recovery Agent




Worker Node A
Worker Node B
Load Agent
Distributed Cache
Load Balancer
Client A
Client B
Register Worker A
Acknowledge with Time to Repost (TTR1)
Update Node A Resource Info
After TTR1
Register Worker Node B
Acknowledge with Time to Repost (TTR1)
Update Node B Resource Info
Update Worker A Status
Acknowledge with new Time to Repost (TTR2)
Update Node A Resource Info
After TTR1
Update Worker B Status
Acknowledge with new Time to Repost (TTR2)
Update Node B Resource Info
After TTR2
Service Request
Retrieve Cache
Dispatch to Worker A
Return Response
After TTR2
Update Worker A Status
Acknowledge with new Time to Repost (TTR3)
Update Node A Resource Info
Session Disconnect
Update Node A Termination Info
Update Worker B Status
Acknowledge with new Time to Repost (TTR3)
Update Node B Resource Info
Retrieve Cache
Service Request
Dispatch to Worker B
Return Response

The Approach - Sample Implementation

All components are deployed as Docker except Recovery Agent, which is need to trigger Docker-CLI to perform recovery action

The Result

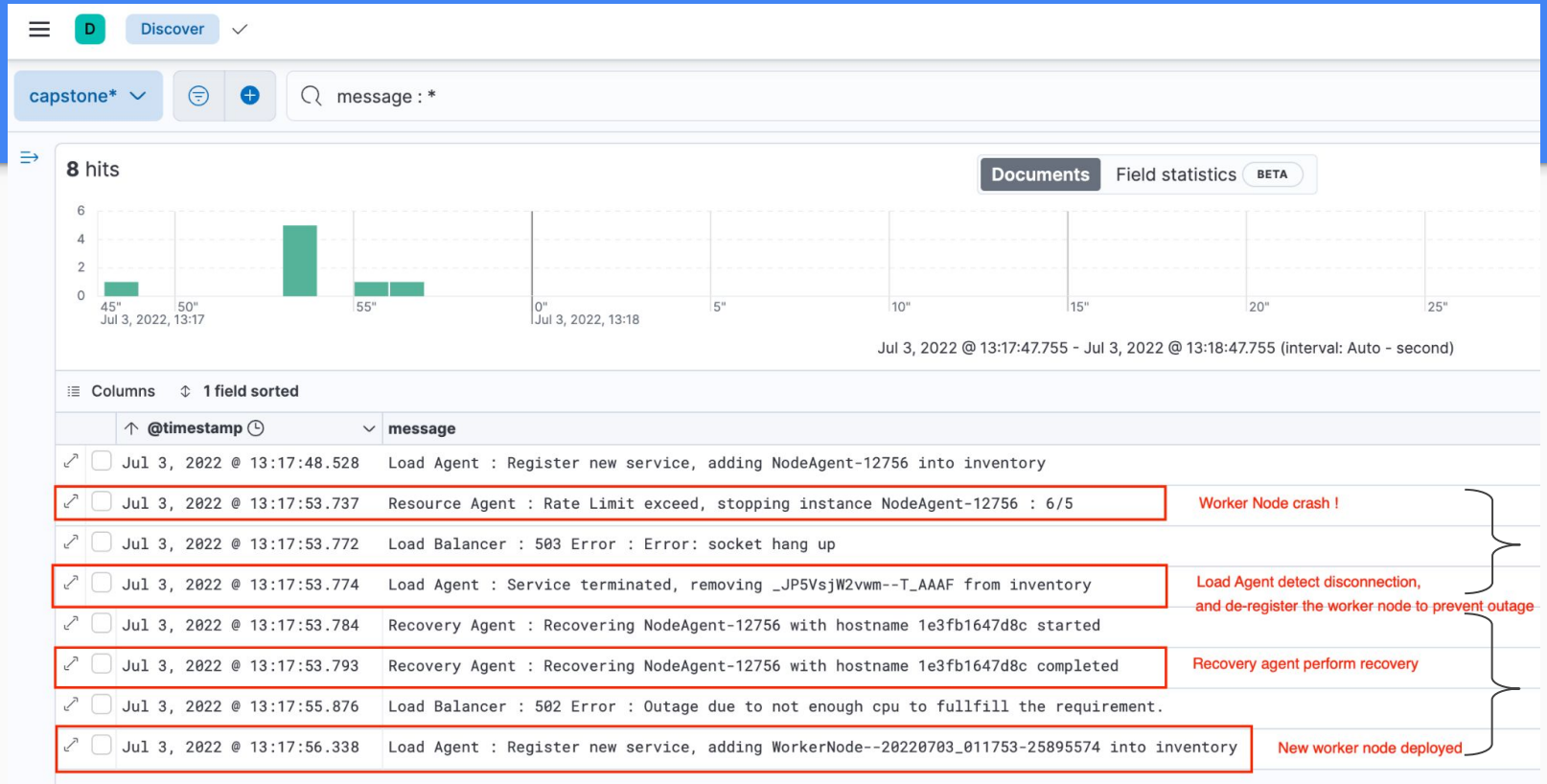
Test Result 1 - Log Analysis

In our proposed scenario, we run 1,000 simulation and average “Time to detect” is

24.5 milliseconds

Recall AWS worst case scenario is 14 seconds, which is 583 times faster !

Test Result 1 - Sample Log Analysis



Test Result 2 - Compare overall SLA

1) Deployed a sample application to AWS EC2
2) Compare with the proposed framework

In order to simulate the system crash, a “Kill Switch” is implemented to crash after pre-defined duration :

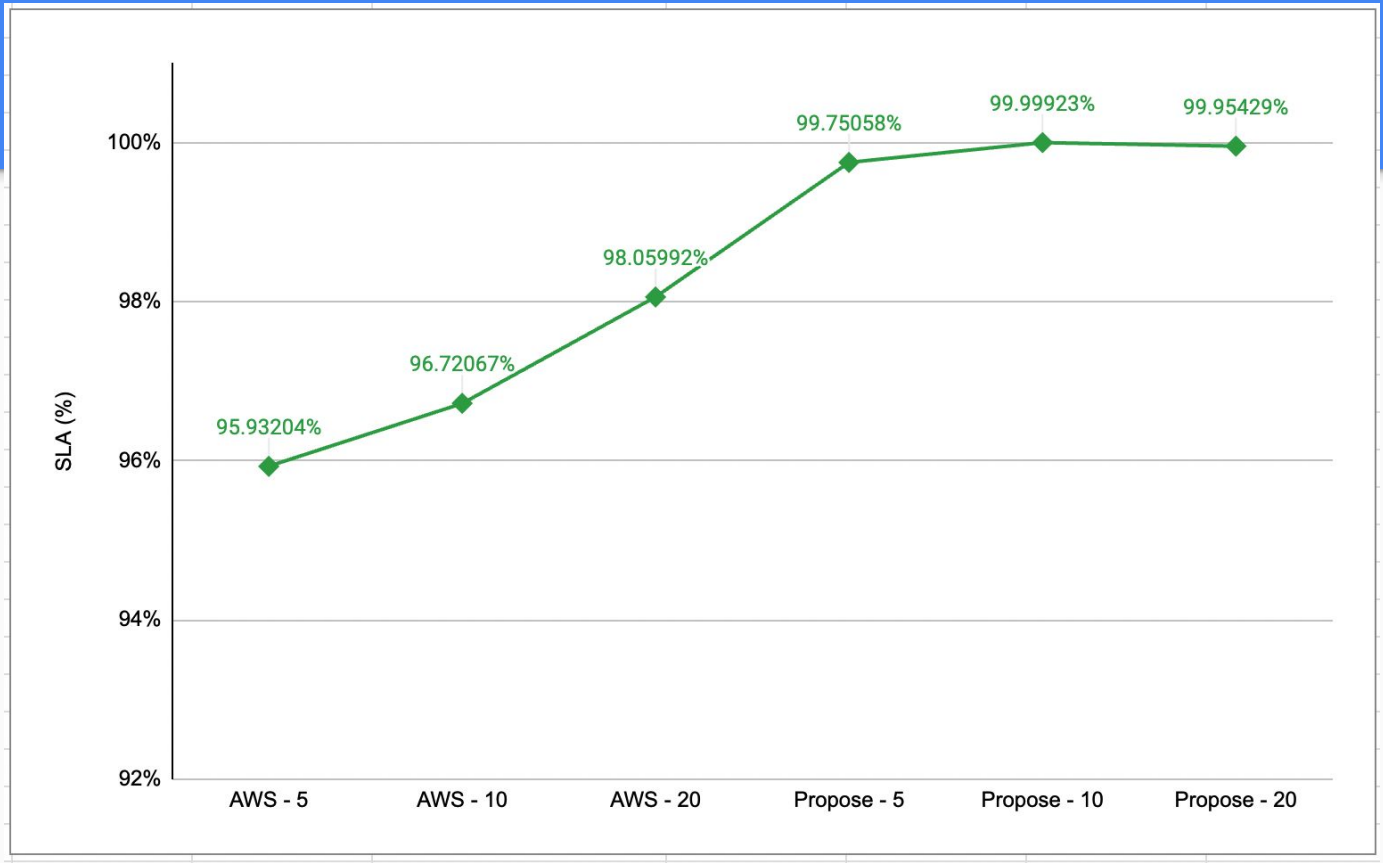
#	Kill Switch Frequency
1	5 minutes of execution
2	10 minutes of execution
3	20 minutes of execution

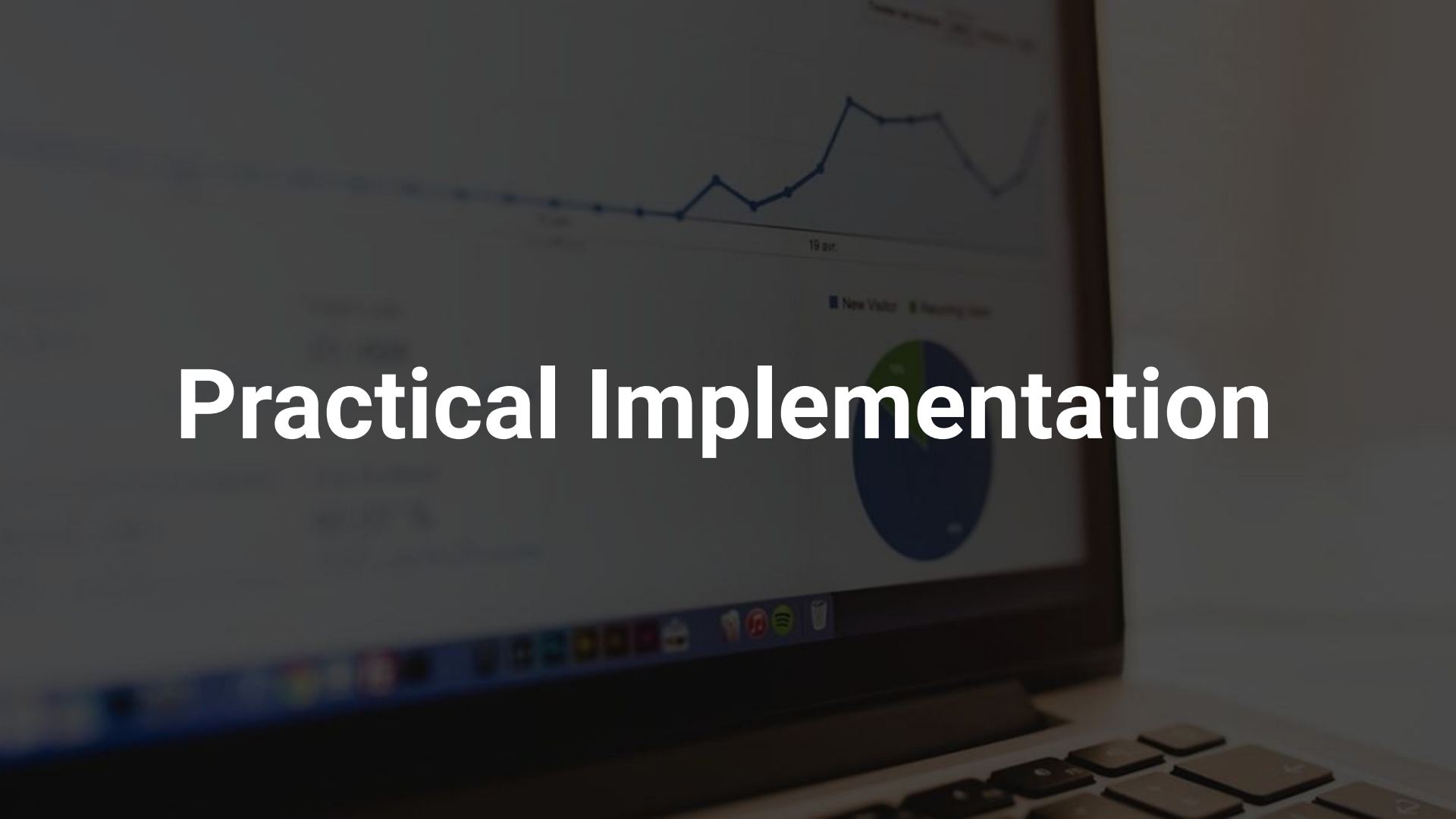
Test Result 2 - Compare overall SLA

	Duration(s)	Up Time(s)	Downtime(s)	SLA(%)	Fail Count
AWS - 5 min	2105.901	2020.234	85.667	95.93204%	2,080
AWS - 10 min	2203.67	2131.404	72.266	96.72067%	1,518
AWS - 20 min	2089.374	2048.838	40.536	98.05992%	1,021
Propose - 5 min	2943.944	2936.602	7.343	99.75058%	3,990
Propose - 10 min	2970.906	2970.883	0.023	99.99923%	600
Propose - 20 min	3005.539	3004.165	1.374	99.95429%	308

Disclaimer : AWS Load Balancer is on Virtual Machine while the simulation is riding on Docker. The recovery time for VM is much higher than docker

Test Result 2 - Compare overall SLA





Practical Implementation

Practical Implementation

Since the push-based + persistent mechanism is CPU resource consuming, this framework is suitable for **Mission Critical** applications like :

1) Security trading system
2) Banking system
3) Air traffic control system

Conclusion

Conclusion

- High availability has been one of the biggest challenges in application design
- Depends on the use cases, there are various techniques can improve the service availability
- This research paper proposes a “Push-based mechanism with persistent connection” to reduce the “Time to Detect” such that the overall Service Level Agreement can be improved

Thank you!