

The background features a dark, almost black, field with several large, overlapping, semi-transparent shapes in shades of purple, magenta, and blue. Two thin, light-colored lines cross the scene diagonally, creating a sense of depth and movement. The overall aesthetic is modern and tech-oriented.

# AWS re:Invent

DECEMBER 2 - 6, 2024 | LAS VEGAS, NV

DAT318

# Powering the grid: GE's 600 TB migration to Amazon Keyspaces

**Yogini Parkhi**

Director of Software Engineering  
GE Digital

**Steve Mayszak**

Sr. Software Development Manager  
Amazon



# Speakers



**Yogini Parkhi**

Director: Analytics Strategy  
GE Digital



**Steve Mayszak**

Sr Manager, Software Engineering  
AWS Keyspaces

# Agenda

- 01** Apache Cassandra:
- Introduction
  - Primary components
  - Architecture
  - Common operations

- 02** Amazon Keyspaces
- Introduction
  - Architecture
  - Key differences

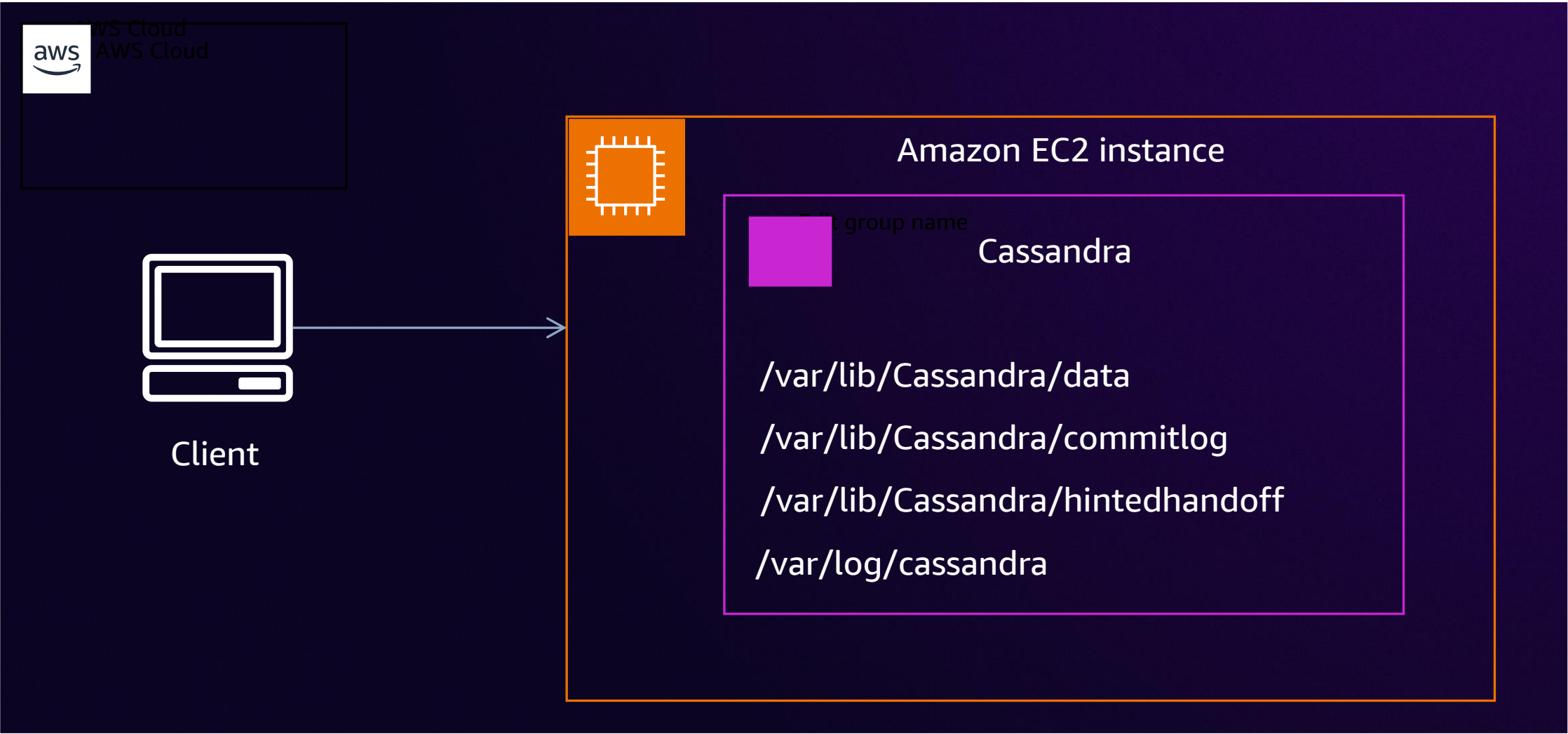
- 03** Introduction to GE Vernova
- Who we are
  - Mission
  - Opportunity

- 04** Migration
- Approach
  - Challenges
  - Learnings
  - Benefits

# Apache Cassandra overview

- Open source
- Distributed / wide-column
- High throughput
- No single point of failure
- Commodity hardware

# Cassandra application – Simple view

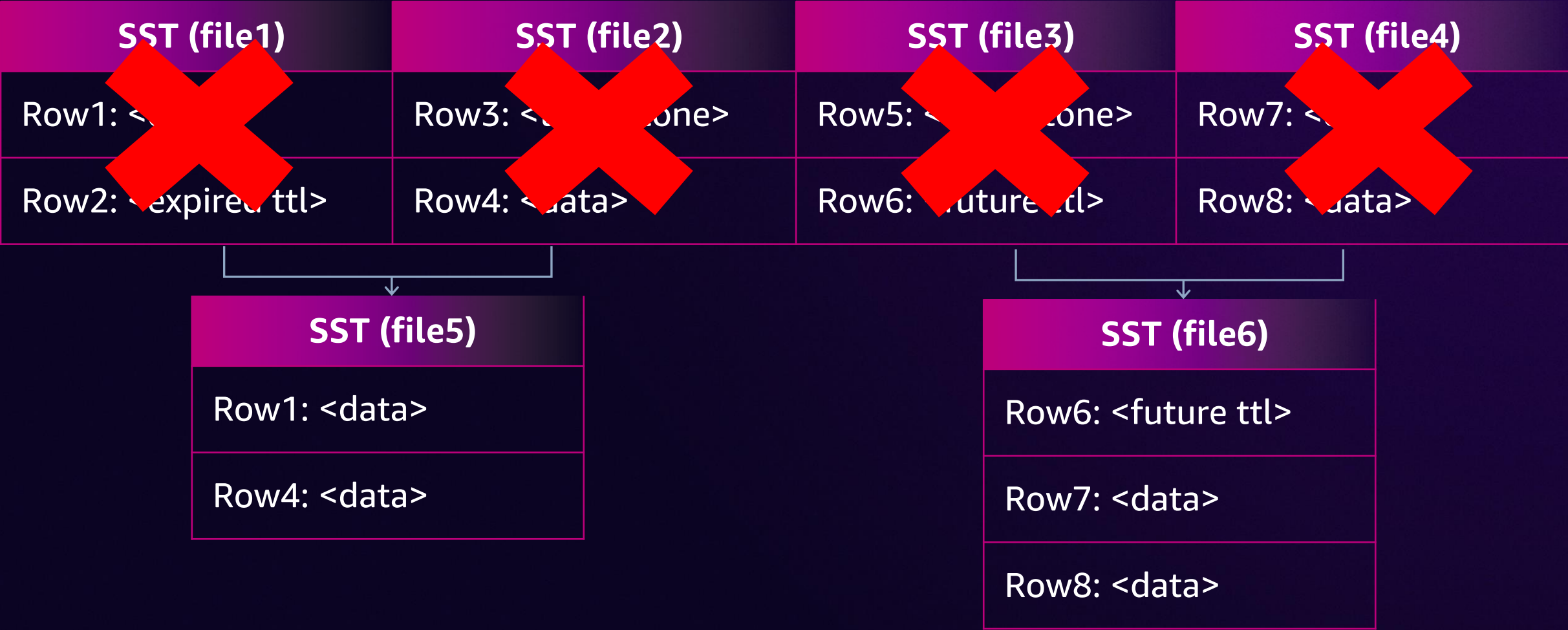


# Data on a Cassandra Node

## New write request

- Append to `/var/lib/Cassandra/commitlog`
- Write to memtable (in memory data structure)
- Write to replica node, or to `/var/lib/cassandra/hintedhandoff`
- When memtable == configured max, flush to disk
- Write an SSTable (`/var/lib/Cassandra/data/<sstables>`)

# TTL, tombstone, and compaction





# Cassandra's token ring

## Token

Determined by output of hash function  
Used to locate data in C\*  
Value:  $-2^{63}$  to  $+2^{63}-1$  (128 bit)

The output of a hash function, known as the *token*, determines the node in which the data resides



### Table:

Partition Key: 1  
<row data>

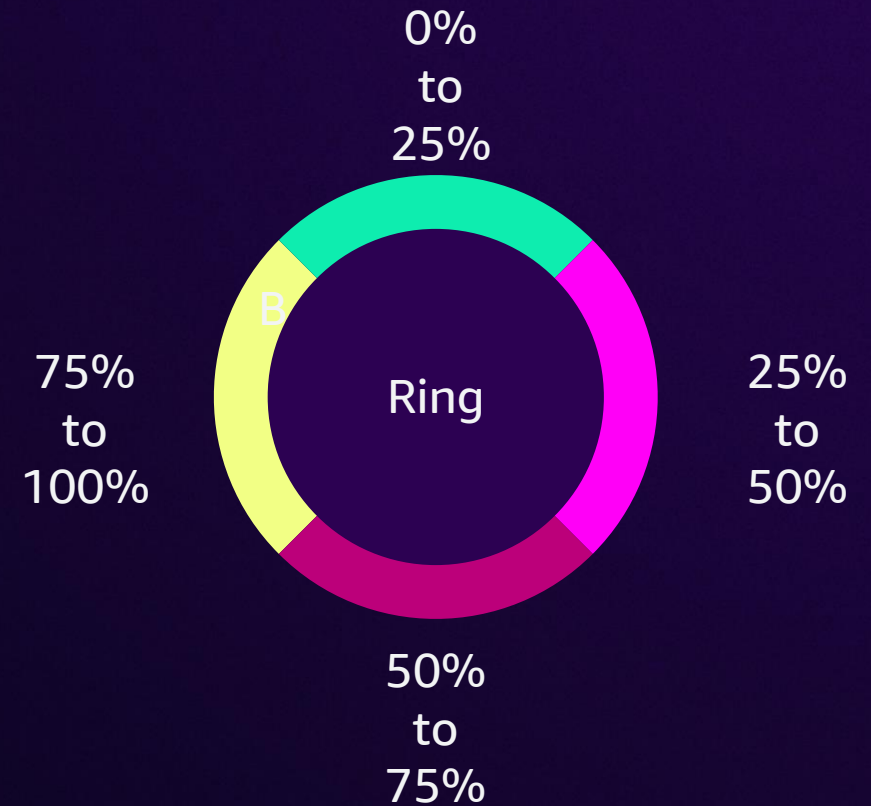
Partition Key: 2  
<row data>

Partition Key: 3  
<row data>

Hash(1) =  $-4.5e18$

Hash(2) =  $2.3e18$

Hash(3) =  $4.6e18$

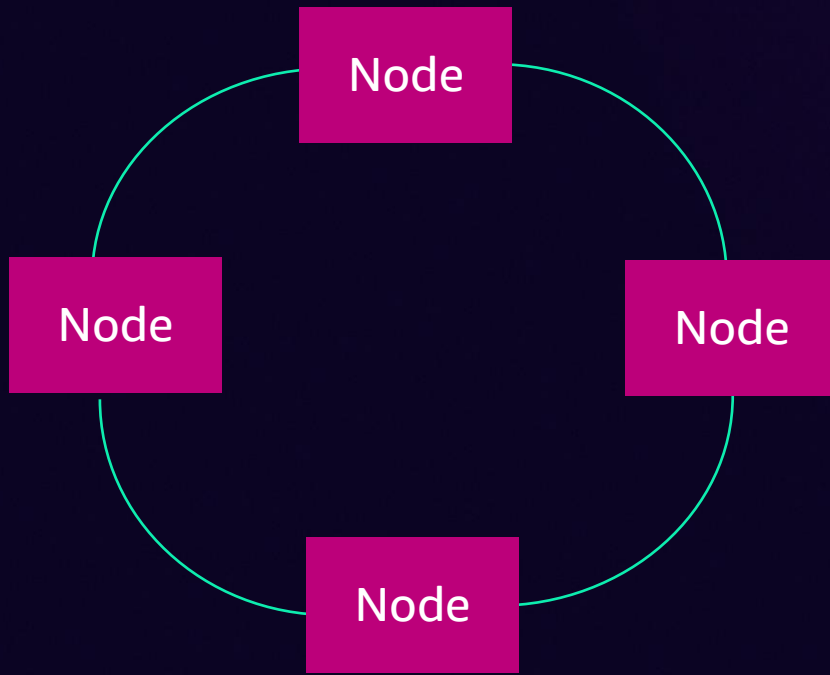


# Replication factor

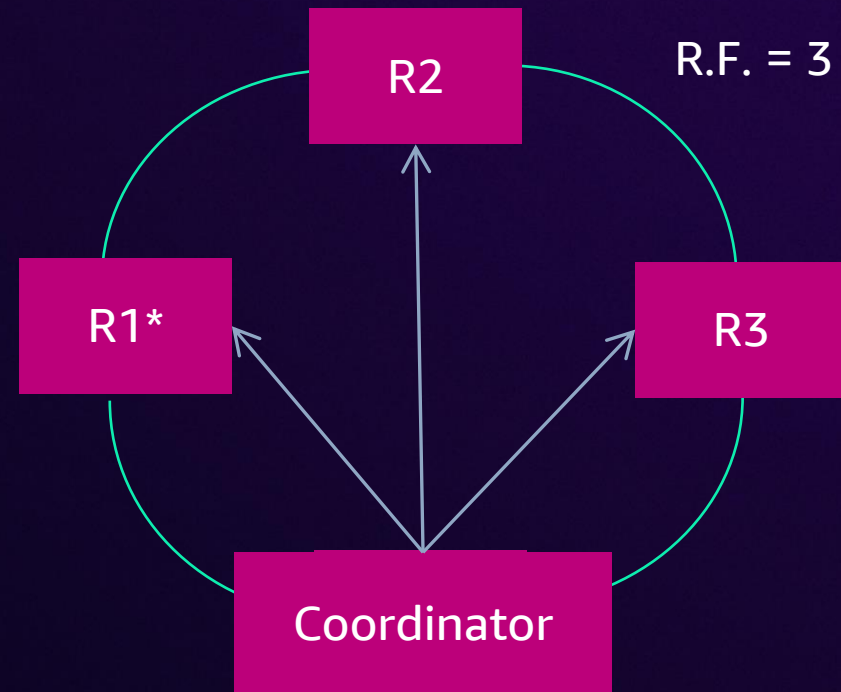
R\* = Replica

A replica is a copy of the data.  
The R.F. determines the number of replicas

All C\* nodes are equal and  
nodes work in a cluster



Replication factor (R.F.)  
determines duplication



# Recap of key terms

|                                  |   |  |
|----------------------------------|---|--|
| CQL (Cassandra Query Lang)       | Drivers (Java, Go, etc...)                              | Node (a Cassandra instance)            |
| WAL (Write ahead log)            | Memtable (in-memory struct)                             | SSTable (sorted string table)          |
| TTL (Time to live)               | Tombstone (marker for delete)                           | Compaction (Cleanup)                   |
| Token ring (collection of nodes) | Cluster (a set of Cassandra instances working together) | Token (64 bit integer – ring position) |
| Partition Key (row identifier)   | Consistent hash (algorithm to minimize data movement)   | Replication factor (how many copies)   |

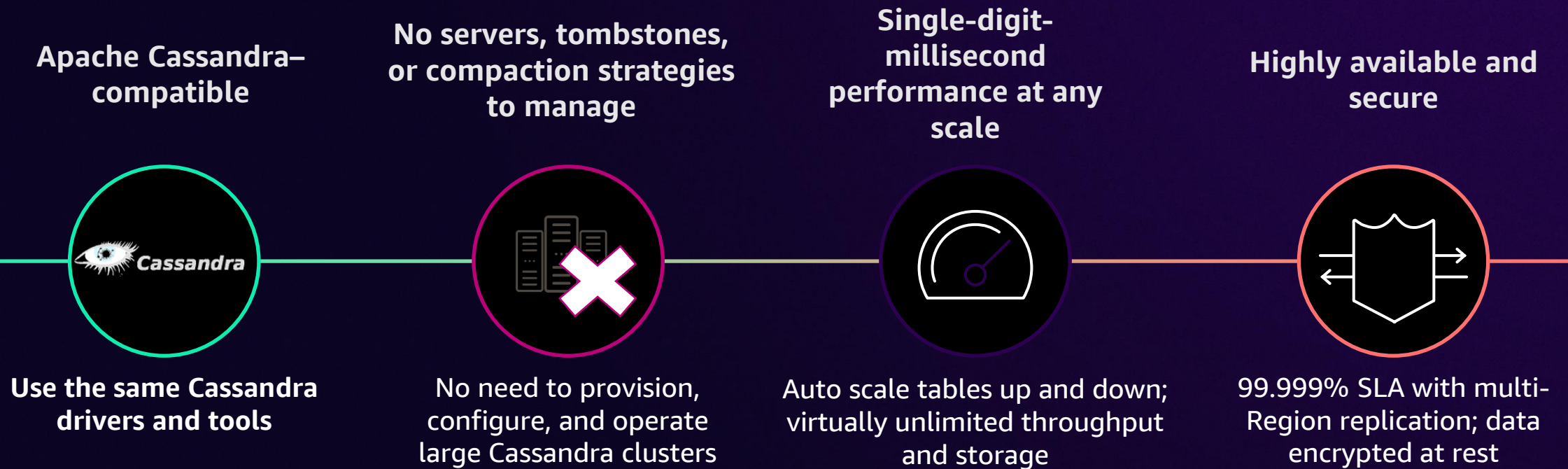
# Cassandra DBA activities

- Cluster management
- Data management
- Performance tuning
- Security and access control
- Capacity planning and scaling
- Disaster recovery
- Monitoring and altering
- Documenting and automation

# Amazon Keyspaces (for Apache Cassandra)



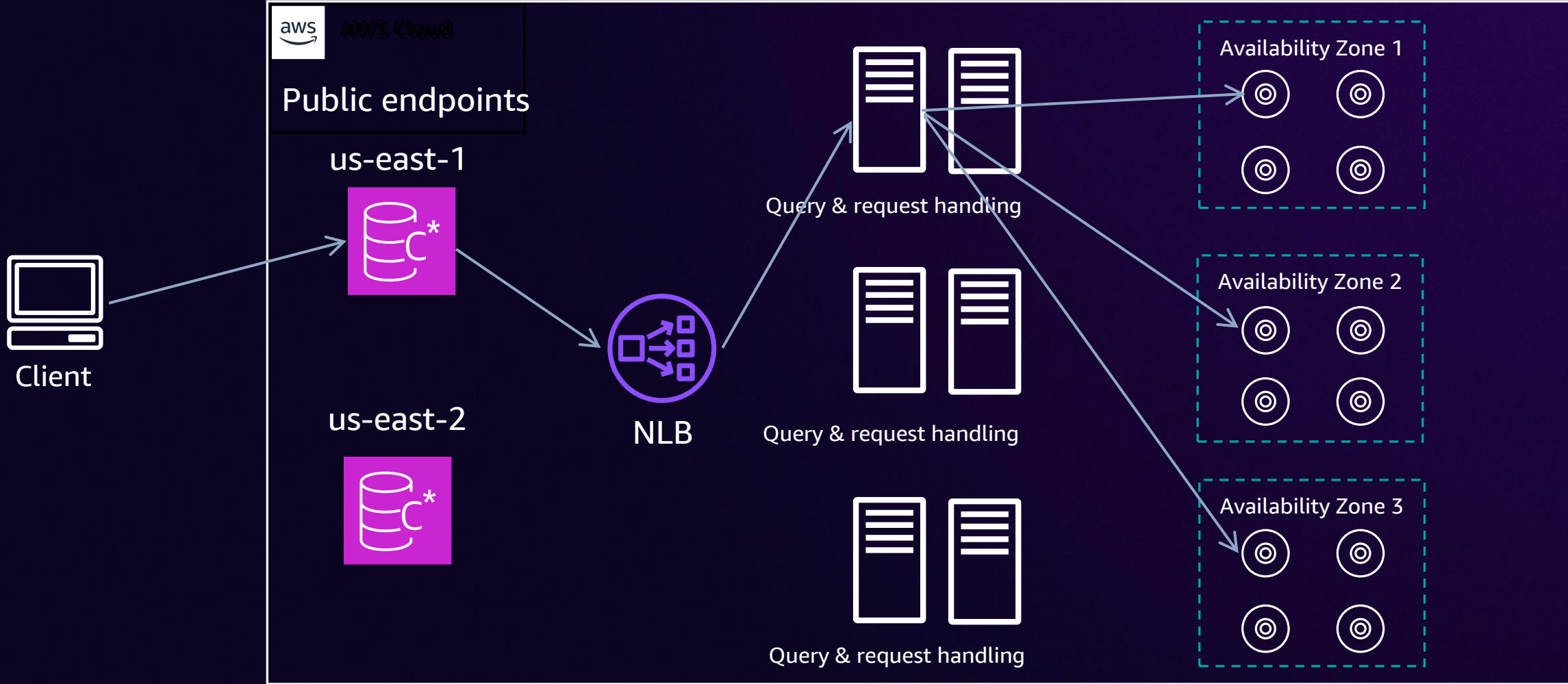
# Amazon Keyspaces (for Apache Cassandra)



# Amazon Keyspaces architecture



# Amazon Keyspaces





# Key takeaways

- Serverless
- Separated concerns
- Storage scales independently
- Compatibility
- Pay for use



# About GE Vernova



# WE ARE



GE VERNOVA

For the new era of energy ... a new company with full focus on the energy transition

• **75K**  
global employees

• **100+**  
countries

## POWER

Gas power, hydro power, nuclear, steam power

## WIND

LM wind power, onshore wind, offshore wind,

## ELECTRIFICATION

Electrification software, grid solutions, power conversion, solar & storage solutions

## ACCELERATORS

Advanced research, consulting services, financial services

- OUR CHALLENGE:

# ELECTRIFY THE WORLD WHILE DECARBONIZING IT

- OUR OPPORTUNITY:

# DRIVE THE ENERGY TRANSITION FORWARD

# Uniquely positioned to help lead the energy transition

ENERGY SOURCE



Nuclear



Gas



Wind



Solar



Water



## GENERATE

Our technology helps to generate approximately 30% of the world's electricity



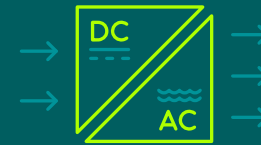
## TRANSFER

Grid solutions to transfer power more reliably and efficiency



## ORCHESTRATE

Automated, digital power management systems



## CONVERT

Science, systems, and advanced technology to improve efficiencies in power conversion



## STORE

Intelligent solar and storage solutions to address the variability of renewable energy supplies

ENERGY DESTINATION



Homes



Business



Industry

# OUR GE VERNOVA WAY

## THE ENERGY TO CHANGE THE WORLD

We **drive INNOVATION** in everything we do to **electrify and decarbonize** the world.

We **serve our CUSTOMERS** with pride and a focus on mutual success and long-term impact.

We challenge ourselves to be better everyday. **LEAN is how we work.**

We break boundaries and cross borders to win as **ONE TEAM.**

We are **ACCOUNTABLE** individually and collectively to deliver on our **purpose and commitments.**

We operate with a founder's mindset. We deliver innovation with passion, speed, and courage. We continuously challenge our thinking and are empowered to dream big and take smart risks.



We listen with humility, and act with urgency. We focus on priorities that create customer value. We anticipate the future and proactively identify solutions for customers and society.



We embrace Safety, Quality, Delivery and Cost as our compass. We engage each other to identify and solve problems using data. We balance long-term breakthroughs with continuous improvements that drive sustainable growth.



We create an inclusive environment where we can be our authentic selves, respecting, promoting, and valuing our diversity. We support each other's growth. We care about each other and work together to succeed as a global team.



We build trust and credibility by acting with integrity and communicating with transparency. We take ownership in everything we do, continuously learning from our experiences. We uphold our commitment to social responsibility.



**WITH THE GE VERNOVA WAY, WE CREATE VALUE FOR OUR PEOPLE, CUSTOMERS, SHAREHOLDERS AND PLANET.**



# The challenge



# Current state

• 600 TB

\* Data migrated

• 300+

\* SaaS subscribers

99.999%

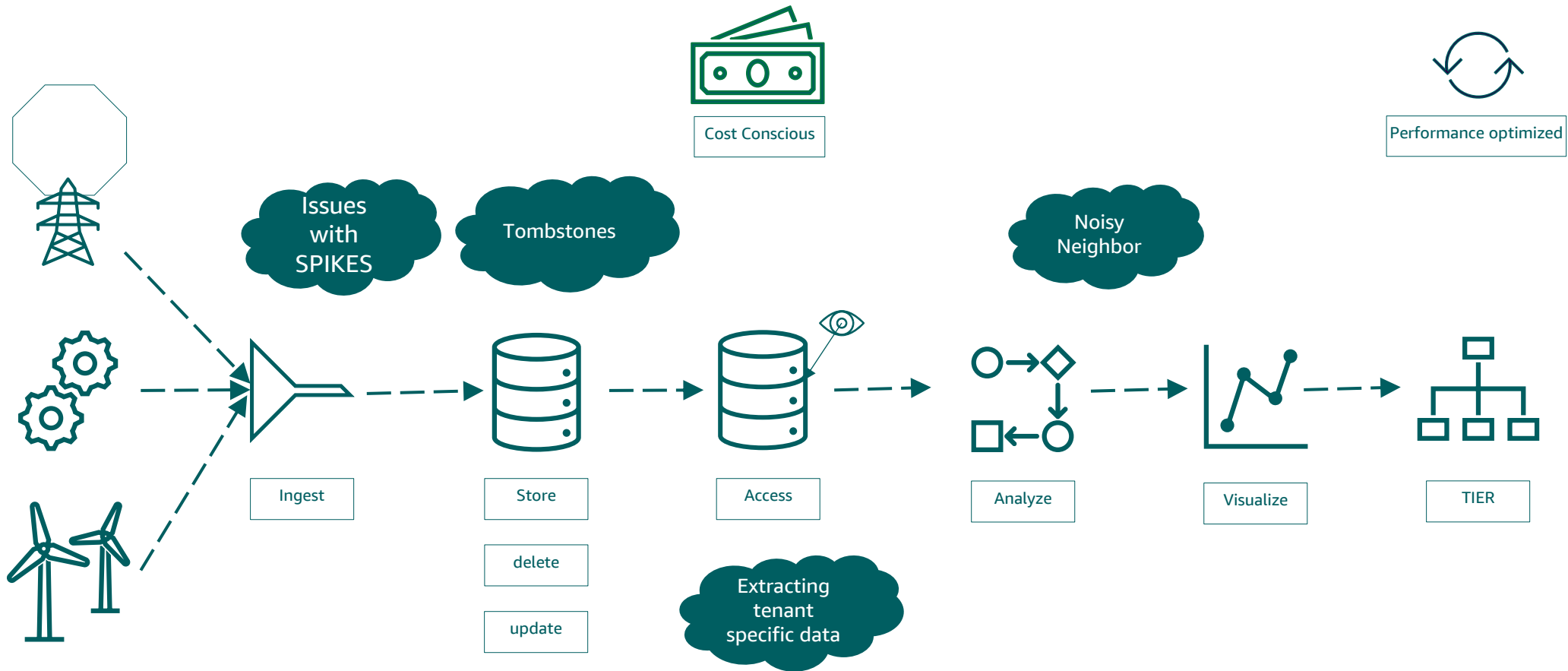
\* Availability

# • Challenge

- 6 months timeline
- 300+ SaaS enterprise customers with countless cloud users
- 99.999% availability target throughout the transformation
- Existing system had scaling challenges when reading data
- Reading must be rate-limited to eliminate any impact on operations
- Read from shared model and sort into siloed tenancy model
- Fully backward compatible for query syntax and performance
- Cost savings of ~50%

# How our customers consume timeseries services

ACCESS, ANALYZE, VISUALIZE



# Why migrate?

- We wanted better cost to performance balance
- Unable to delete stale data easily
- Tombstones made cost run up
- Unable to customize TTL for customers (tenants)
- Noisy neighbor issues in query and ingestion

# The lean experiment



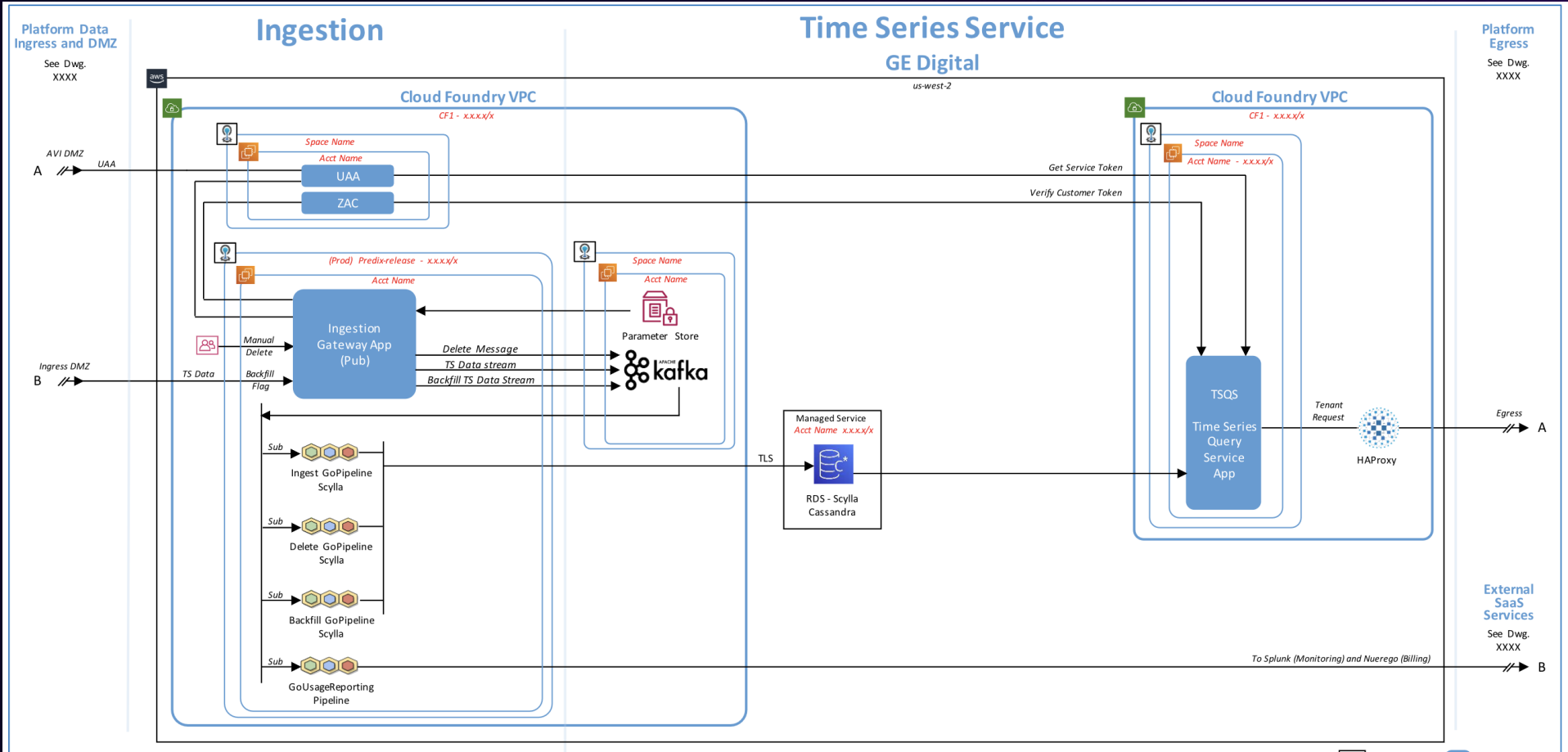
# Prior attempts to migrate

- Challenge of impact on live system
- Limits on reads to avoid noisy neighbor
- Out-of-order writes
- Spikes in ingestion/query
- Not enough observability for debugging

# Small lean experiment

- Send some test data into Amazon Keyspaces
- We routed one of our integration testing tenants to Keyspaces
- Data was inspected by Proserv peers, SMEs on both sides
- Using excellent observability built on both sides, we looked at the usage metrics
- We took into account cost – we design with economic sense

# Architecture before



**Notes**  
 Regions in Scope: AMER  
 Monitoring & Telemetry: Splunk Technology  
 Cloud Formation? Deployment Model: ....  
 EC2 and EKS Config:

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As of GE Digital PROD - Time Series Service Architecture

|                                 |                 |              |
|---------------------------------|-----------------|--------------|
| Owner: Time Series - YP         | Date: 1/16/2023 | Author: DM   |
| Type: Services/Apps - Data Flow | Drawing #:      | Version: 1.0 |



# Learning and planning

- 5x size challenge – unique data model optimized for performance
- Non-uniform reads and writes
- This increased our cost of ingestion by 5 times initially
- Some latency to reads could be seen
- Down the line the cost of deletes would be high too
- We needed to go back to a drawing board

# Optimizing in partnership with ProServ

Lean experiments identified a need to optimize storage

Optimizing for size meant optimizing for cost

Team optimized the data model and created a new hash

ProServ and GE product team worked hand in hand in some fantastic collaboration to optimize schema to get most out of storage

|              | Provisioned Target Utilization | Request Per Second | Average Hourly Provisioned Capacity |                    |                     | Request Per Second | Total OnDemand Request | Strong Consistency | Eventual Consistent |
|--------------|--------------------------------|--------------------|-------------------------------------|--------------------|---------------------|--------------------|------------------------|--------------------|---------------------|
|              |                                |                    | Units                               | Strong Consistency | Eventual Consistent |                    |                        |                    |                     |
| Throughput   |                                |                    |                                     |                    |                     |                    |                        |                    |                     |
| reads        | 50.00%                         | 66,600.00          | 133200                              | 14,585.40          | 7,292.70            | 7,400.00           | 175,024,800,000        | 5,639.69           | \$2,819.84          |
| writes       | 50.00%                         | 40,318.00          | 80636                               | 44,148.21          | 44,148.21           | 4,480.00           | 105,955,704,000        | 17,071.49          | \$17,071.49         |
| Storage      |                                |                    |                                     |                    |                     |                    |                        |                    |                     |
|              |                                |                    | Size In GB                          |                    |                     |                    |                        |                    |                     |
| Raw Size     | 425000                         | 127,500.00         |                                     |                    | 60,000              | 60,000             |                        |                    |                     |
| PITR Back up | 425000                         | 102,000.00         |                                     |                    | 127,500.00          | 7,292.70           |                        |                    |                     |
|              |                                |                    |                                     |                    | 102,000.00          | 44,148.21          |                        |                    |                     |
|              |                                |                    |                                     |                    | 14585.4             | 52,819.84          |                        |                    |                     |
|              |                                |                    |                                     |                    | 44148.21            | \$17,071.49        |                        |                    |                     |
|              |                                |                    |                                     |                    | 5,639.69            | 127,500.00         |                        |                    |                     |
|              |                                |                    |                                     |                    | 17,071.49           | 102,000.00         |                        |                    |                     |
|              |                                |                    |                                     |                    | 370,944.79          | 360,832.24         |                        |                    |                     |

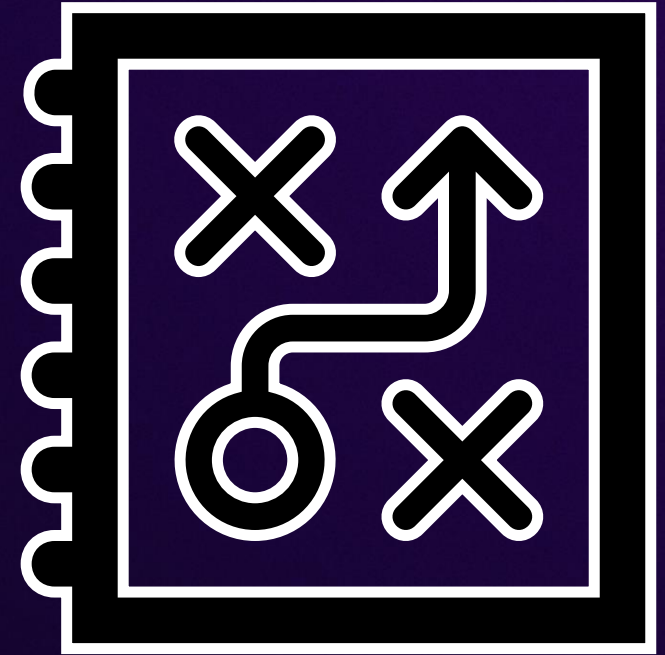
## AWS Keyspace Schema optimization

Created by Pylvas, Simo, last modified on Mar 22, 2023

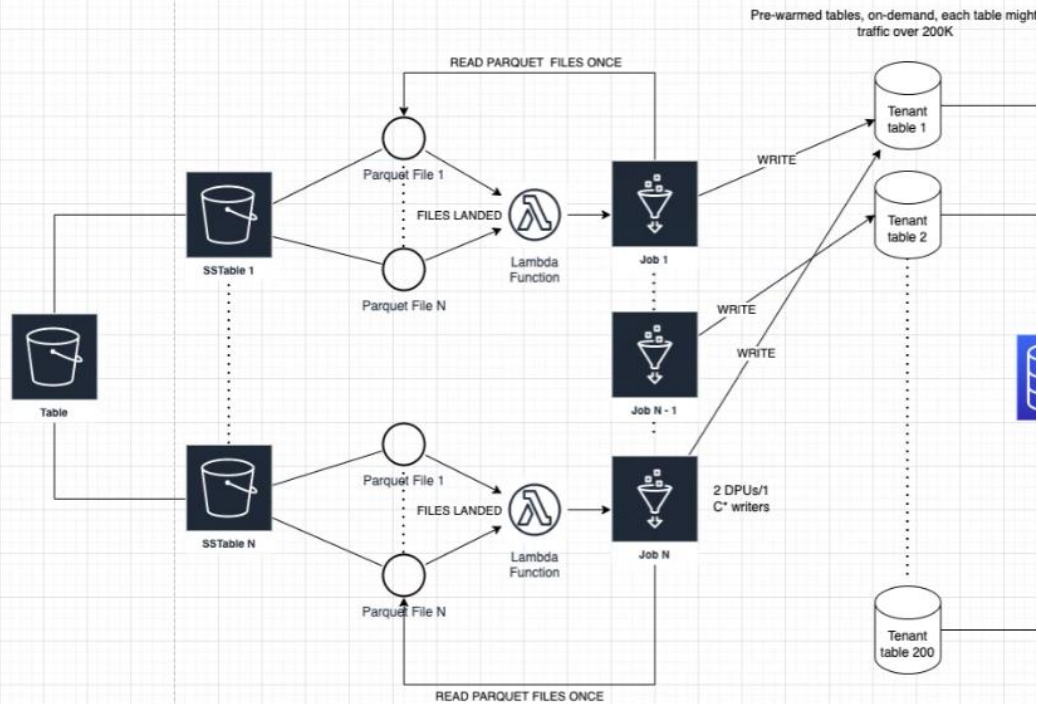
- Option 1. Hashing partition key
- Option 2. Grouping rows by interval with LZ4 compression
- Option 3. Tenant separation
- TTL
- Querying

# Key learnings

- Start with an experiment
- Always have a plan B
- While you are problem solving also brainstorm a plan B
- Take a breath, take a step back, and find out-of-the-box solutions

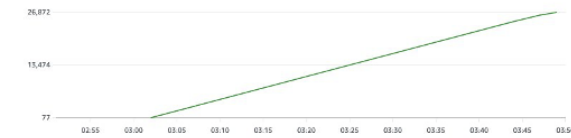


# Migration architecture – ProServ – Iteration 1

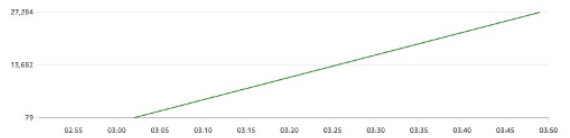


## Mixed workload (50%/50% READ/WRITE)

Read units per second



Write units per second



WRITE/READ MIX WORKLOAD



| Label                                      | Details  | Statistic | Period   | Y axis | Actions  |
|--|--|-----------|----------|--------|--|
| <input checked="" type="checkbox"/> INSERT | <a href="#">AWS/Cassandra</a> • SuccessfulRequestLatency | Average   | 1 second |        | <a href="#">↔</a> <a href="#">Q</a> <a href="#">🔍</a> <a href="#">📄</a> <a href="#">🔊</a> <a href="#">🗑️</a> <a href="#">✖</a> |
| <input checked="" type="checkbox"/> SELECT | <a href="#">AWS/Cassandra</a> • SuccessfulRequestLatency | Average   | 1 second |        | <a href="#">↔</a> <a href="#">Q</a> <a href="#">🔍</a> <a href="#">📄</a> <a href="#">🔊</a> <a href="#">🗑️</a> <a href="#">✖</a> |

# The migration plan and execution

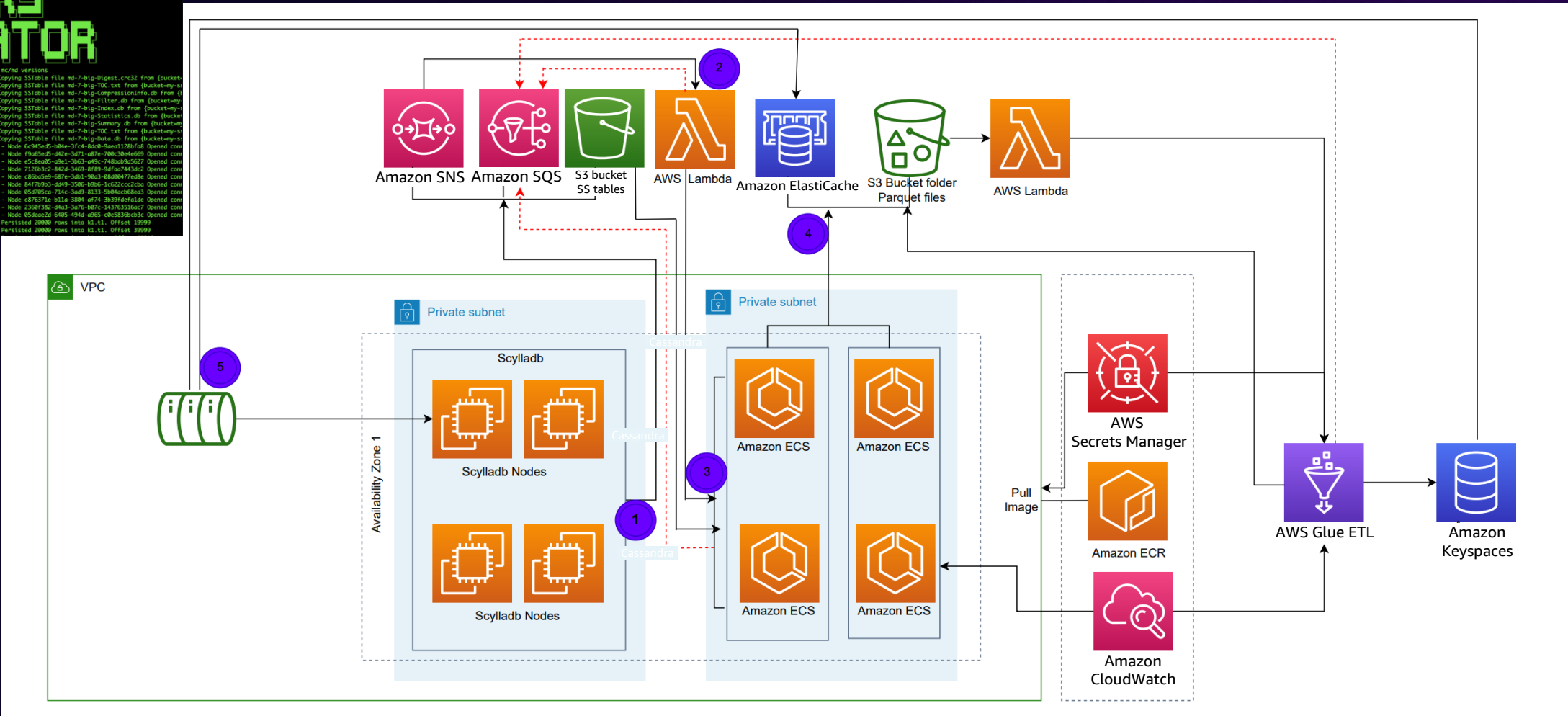


# The architecture – Migration utility

## AMAZON KS SSTMIGRATOR

```

Note: SSTMigrator supports only big format and mc/md versions
2021-04-07 12:21:26.377 [main] INFO o.a.util.Gssandrdtbls - Copying SSTable file md-7-big-Digest.crc32 from (bucket-my-s
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2021-04-07 12:21:54.965 [main] INFO o.a.connectors.SSTableDao - Persisted 20000 rows into ks.t1. Offset: 19999
2021-04-07 12:22:11.353 [main] INFO o.a.connectors.SSTableDao - Persisted 20000 rows into ks.t1. Offset: 19999
    
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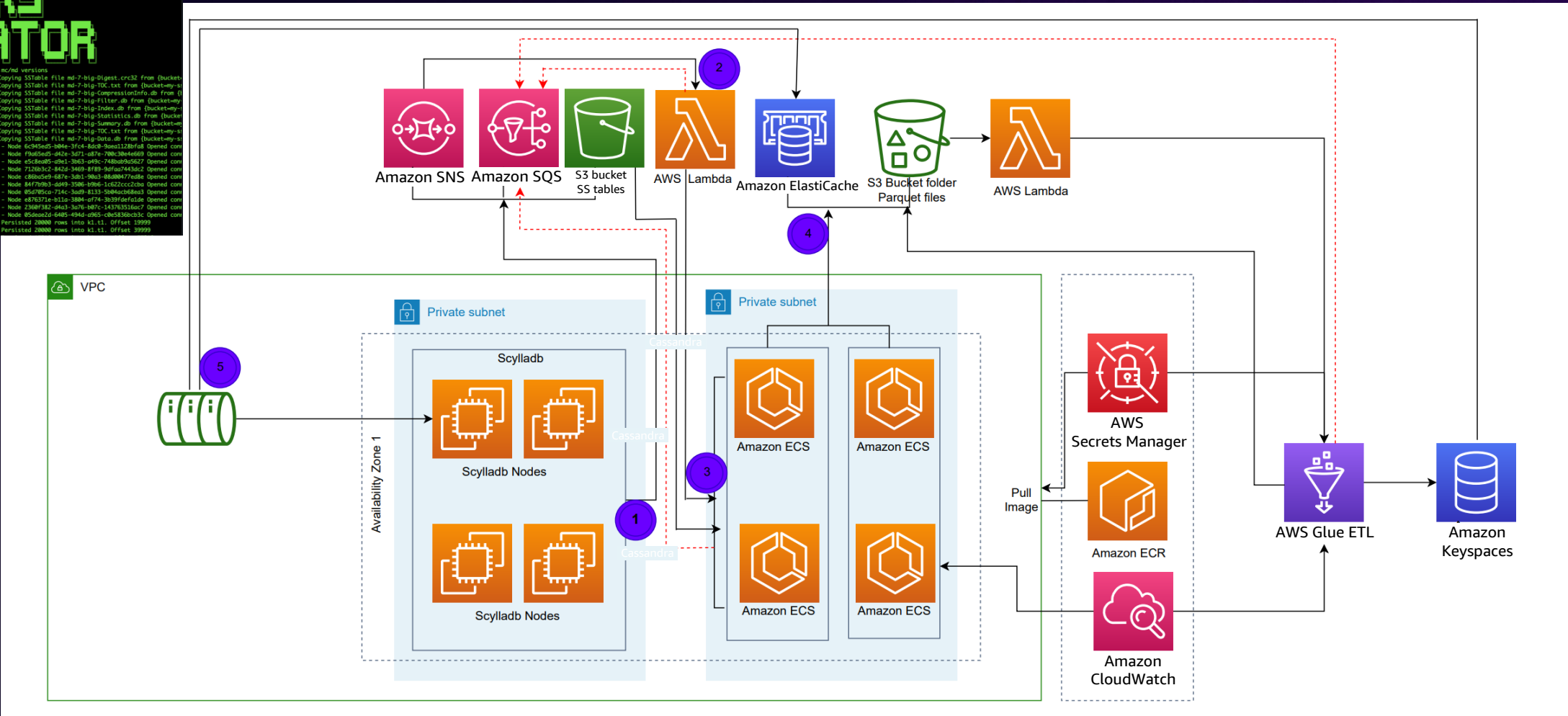


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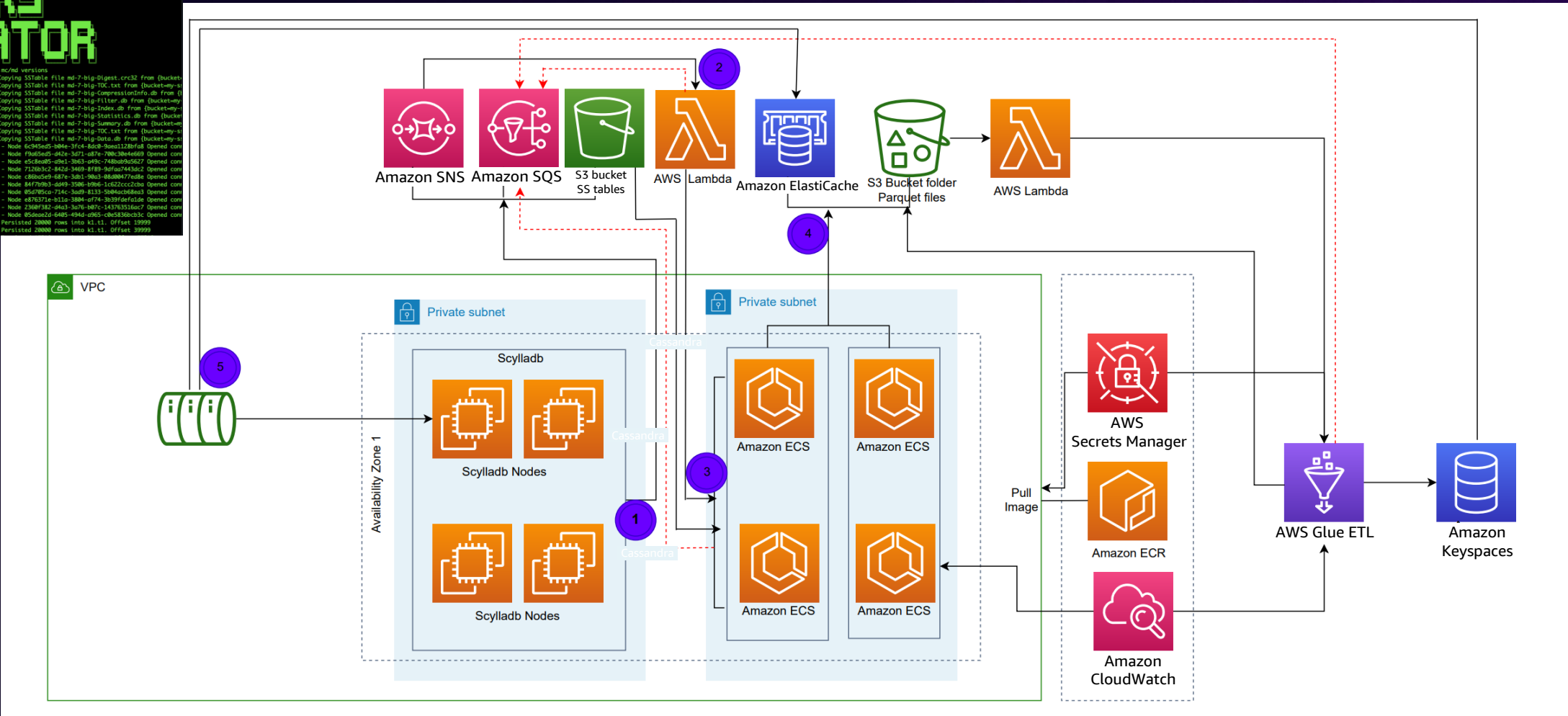


# The architecture – Migration utility

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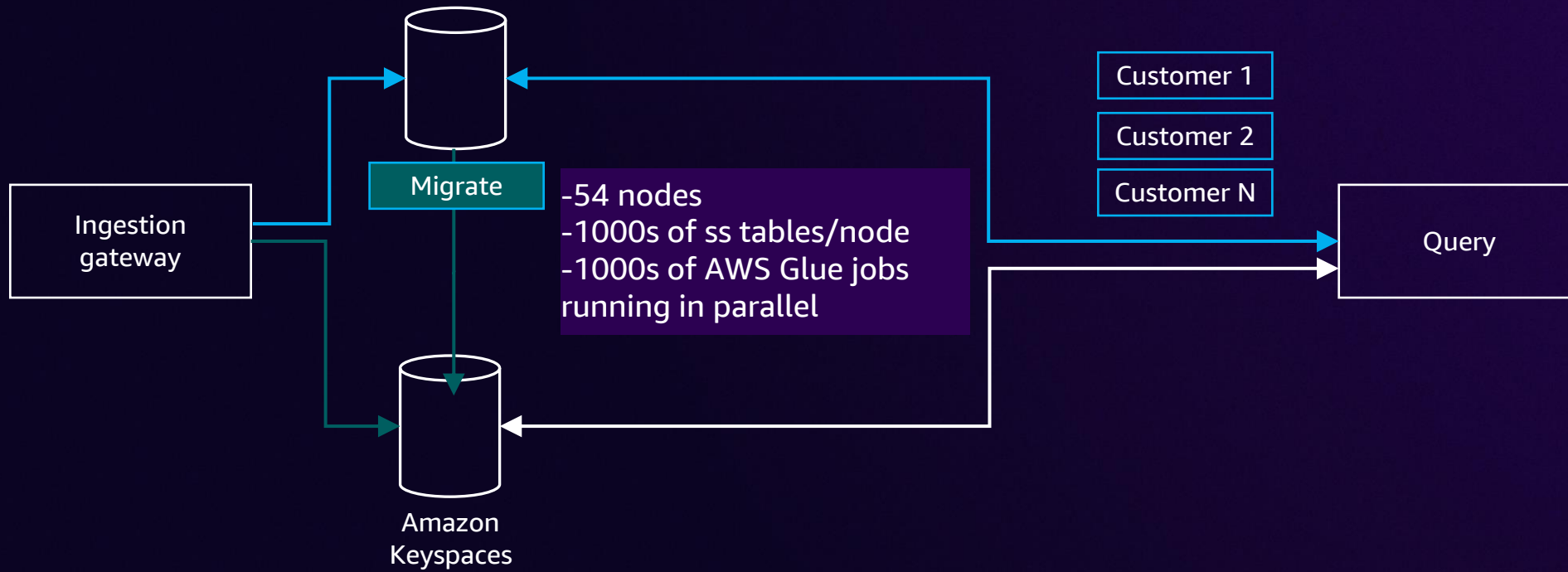
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2021-04-07 12:21:37.409 [main] INFO o.a.connectors.KeyspacesDao - Node e87637e-b11a-3884-d774-3c39dfc1de Opened con
2021-04-07 12:21:37.409 [main] INFO o.a.connectors.KeyspacesDao - Node 2368f382-d4a3-3a76-b87c-143763516ac7 Opened con
2021-04-07 12:21:37.409 [main] INFO o.a.connectors.KeyspacesDao - Node 055a0a2d-6940-494d-c0e5-cb5835c03c Opened con
2021-04-07 12:21:54.965 [main] INFO o.a.connectors.SSTableDao - Persisted 20000 rows into ks.t1. Offset 39999
2021-04-07 12:22:11.353 [main] INFO o.a.connectors.SSTableDao - Persisted 20000 rows into ks.t1. Offset 39999
    
```





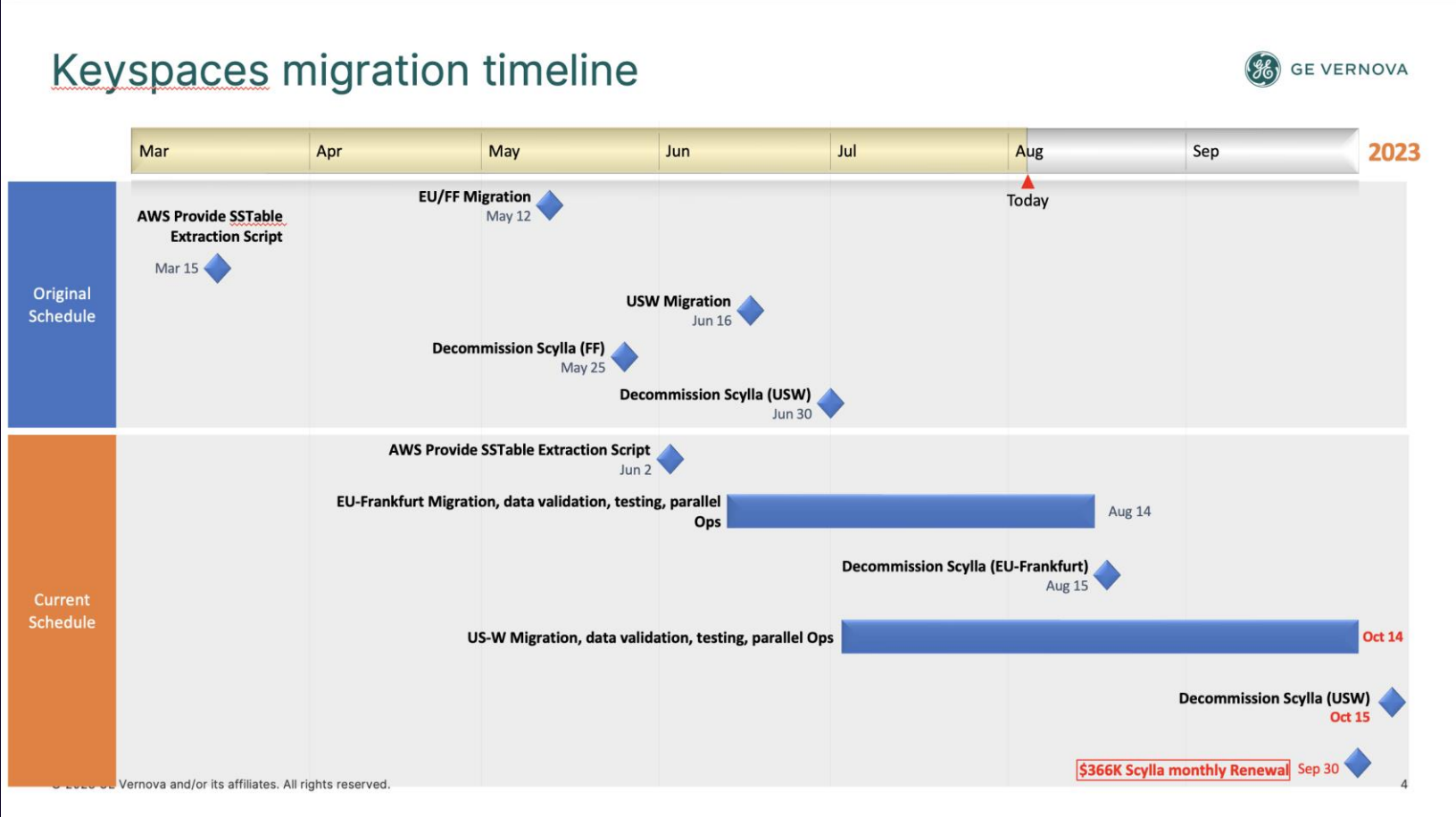
# A live swap!



# The daily management



# Keeping up with Keyspaces schedule



# Combined daily management

## Glue Performance Optimization

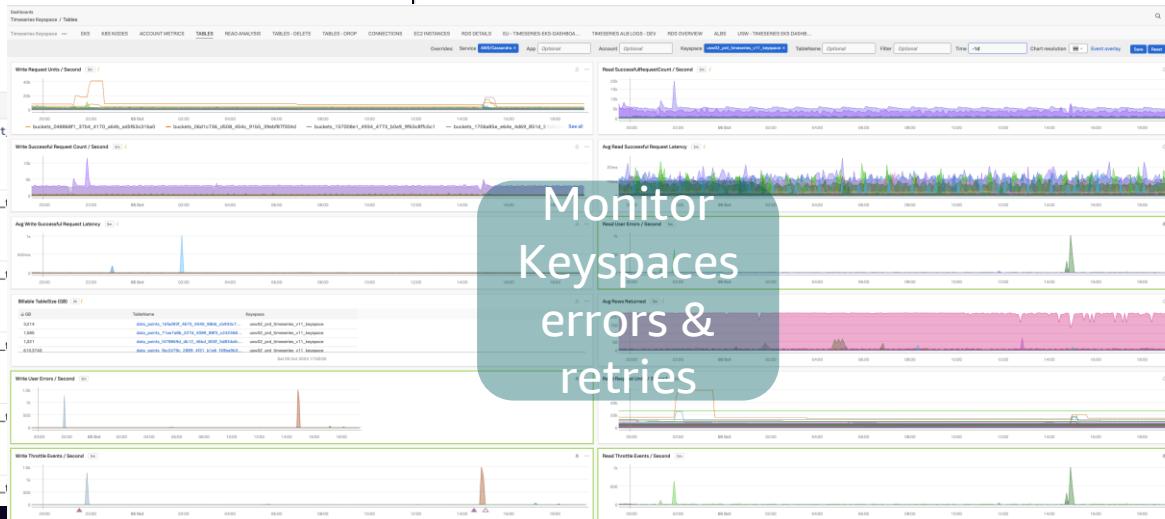
Created by Pylvas, Simo, last modified on Jun 14, 2023

| Workers | Worker type | Writers | PDUs | Processing time |
|---------|-------------|---------|------|-----------------|
| 5       | G1.x        | 5       | 5    | 16-17m          |
| 6       | G1.x        | 5       | 6    | 13-15m          |
| 7       | G1.x        | 5       | 7    | 11 - 14m        |
| 8       | G1.x        | 4       | 8    | 12 -13m         |
| 9       | G1.x        | 4       | 9    | ~12m            |
| 10      | G1.x        | 4       | 10   | 11m 45s         |

Monitor AWS Glue jobs

### EU Processing failure log

| Dataset   | Tenant                               | Table   |
|-----------|--------------------------------------|---------|
| md-158597 | a158699b-9ccd-43cd-b2e4-ac3e25f39526 | tenant_ |
| md-158721 | a158699b-9ccd-43cd-b2e4-ac3e25f39526 | tenant_ |
| md-158473 | a158699b-9ccd-43cd-b2e4-ac3e25f39526 | tenant_ |
| md-158592 | a158699b-9ccd-43cd-b2e4-ac3e25f39526 | tenant_ |
| md-158716 | a158699b-9ccd-43cd-b2e4-ac3e25f39526 | tenant_ |
| md-162317 | 4027d33a-765c-4b24-ac98-b32096f56718 | tenant_ |

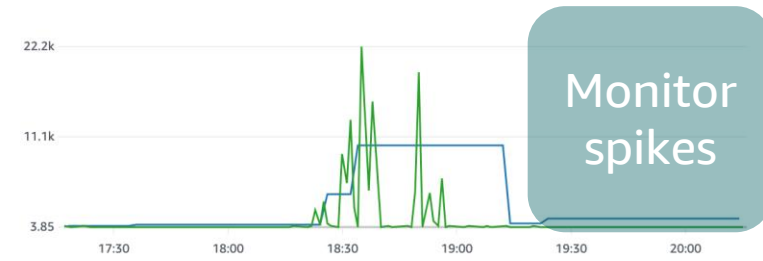


## Capacity metrics [Info](#)

[View all in CloudWatch](#)

1h 3h 12h 1d 3d 1w Custom UTC

### Read units per second



### Write units per second



### Read throttled events (count)

### Write throttled events (count)

## Migration Status Report ( 8/8/23)



| 2 nodes - Live Ingestion (6/11/2023) |                            |                            |   |  |              |              |
|--------------------------------------|----------------------------|----------------------------|---|--|--------------|--------------|
|                                      | Extract from Scylla(ECS)   | Write to keyspaces ( Glue) | Validate(spark)   | Switch Query   | Parallel Ops | Decommission |
| Time:                                | Node1: 100%<br>Node2: 100% | Node1: 100%<br>Node2: 100% | Total: 13 tenants<br>Tenant1,2: Good.<br>Tenant3,4: datapoints reprocessed. Intervals failing continuously. | 7/28/2023 - 8/15/2023<br>Fully migrated: 2/13 tenants<br>Internal tenants ( 9 ) switched query to use keyspaces. GE assuming risk of gaps. | 1-10 days    | 8/15/2023    |

| 4 ( 54 nodes) - Live Ingestion (6/23/2023) |  |   |                     |                          |              |              |
|--|--|---|---------------------|--------------------------|--------------|--------------|
|  | Extract from Scylla(ECS)                         | Write to keyspaces ( Glue)  | Validate(spark)     | Switch Query             | Parallel Ops | Decommission |
| Time:                                      | Node Status Node 54 - 100% Complete - Validating | 8 Nodes complete - Data Points 27/46 nodes processing ( Data points ) 15=all sizes, 12=partial sizes < 17 days per node Aug 11 <sup>th</sup> to get baseline data/accurate estimate | Not Started 10 days | 9/15 to 9/30 ( 15 days ) | 0 + 15 days  | 10/15/2023   |

Transparent daily reporting



# Challenges and solutioning as one team

We found that our data was disparate across customers which created lead time

In Europe – We ran into JVM Memory issues

In USW we had varying sizes of tables which made for some very large files

We tested limits of elasticity – ran into service limits

We ran into unique challenges with AWS Glue jobs that tried to repeatedly process files

GE Vernova + Proserv innovated together to read in metadata and use it for intelligent processing

Proserv experimented and found the right JVM configuration to surpass this

GE Vernova + Proserv worked together to break down the workloads by size into XS, S, M, L, XL and process accordingly

AWS Support team jumped in for prompt problem solve to lift soft limits as per our request

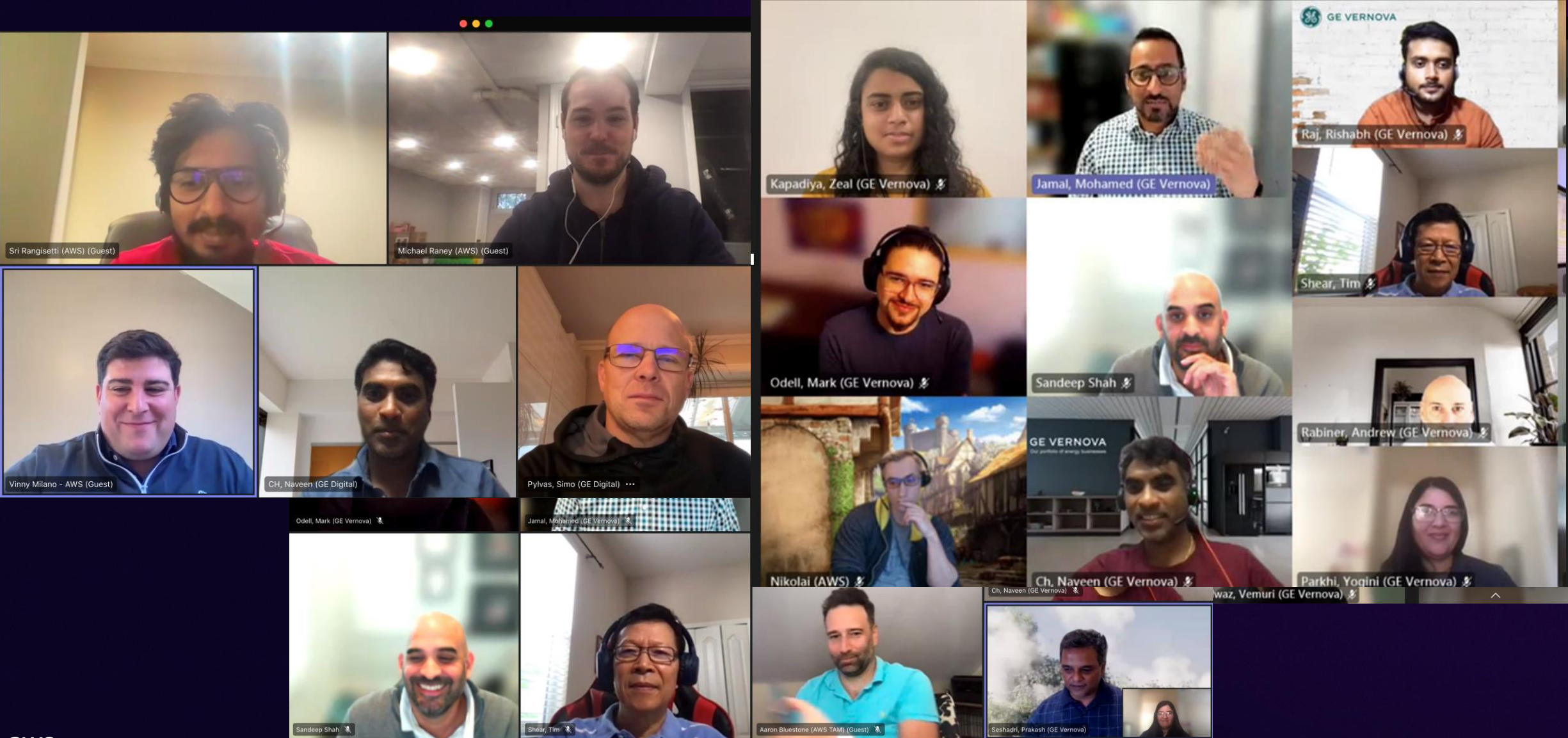
Leadership team helped to mitigate cost of the runaway jobs. GE team wrote a quick Spark job to finish the last remaining workload in one go.

# Key learnings

- Expect some twists and turns
- Bake time into roadmap for validation and iteration
- Parallel workstreams can make issues visible early
- Make sure team is feeling like the challenges are something they can solve



# Teamwork makes the dream work



# Key learnings

- People are key
- Get to know the participants on both sides
- How are they feeling?
- Trust is key to success – Buildup of trust takes diligent work
- Do not get sick! :D Take care of health





# The case of the missing data



# Missing data?

- GE Vernova team ran validation against the migrated data in old store
- We ran various cross-checks and tried to identify specific tags that seem to have this issue
- I worked with product management and specific customers to determine the root cause
- We found that the data was from time when devices were in error and needed to be discarded



Missing data was never sent to Keyspaces during migration

# Key learnings

- If you are migrating historic data – write a comparator utility
- Understand the transformations and have a workstream for validation
- We lost some time because we did not have a validation workstream from the start; we repurposed an existing tool midway



# Observability



# Observability for cost and monitoring

- The scale makes debugging complex
- Needle-in-a-haystack scenarios are common
- Building out good observability as part of your design and development process is key
- Development with economic sense saved us from discovering runaway cost too late

# To finish line



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# To finish line!

• 600 TB

Data migrated

• 300+

SaaS subscribers

0

Issues/outages

## • Highlights

### Just plain beautiful:

- Fully backward compatible query and ingestion
- Zero downtime for customers from the switch
- Monthly usage metrics report per tenant
- PITR backups

### Cultural highlights:

- Global engineering and product team working around the clock
- AWS Proserv collaboration
- Building in observability
- Cost-conscious every day
- Lean in action (daily management, small experiments, many pivots, continuous improvement)

# Benefits

- Point in time recovery enabled
- Siloed tenancy model helps us optimize for unique customer needs
- Performance benefits
- Spike resiliency due to autoscaling
- Excellent observability for continuous improvement
- Helps GE Vernova team focus on our customers' unique needs



Wir sind

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اسان آهيون

BIZ

Amra achi

Hum hai



# Thank you!

**Yogini Parkhi**

Director: Analytics Strategy  
GE Digital

**Steve Mayszak**

Sr Manager, Software Engineering  
AWS Keyspaces



Please complete the session survey in the mobile app

