AWS re:Invent

ANT316

Effective Data Lake: Design Patterns and Challenges

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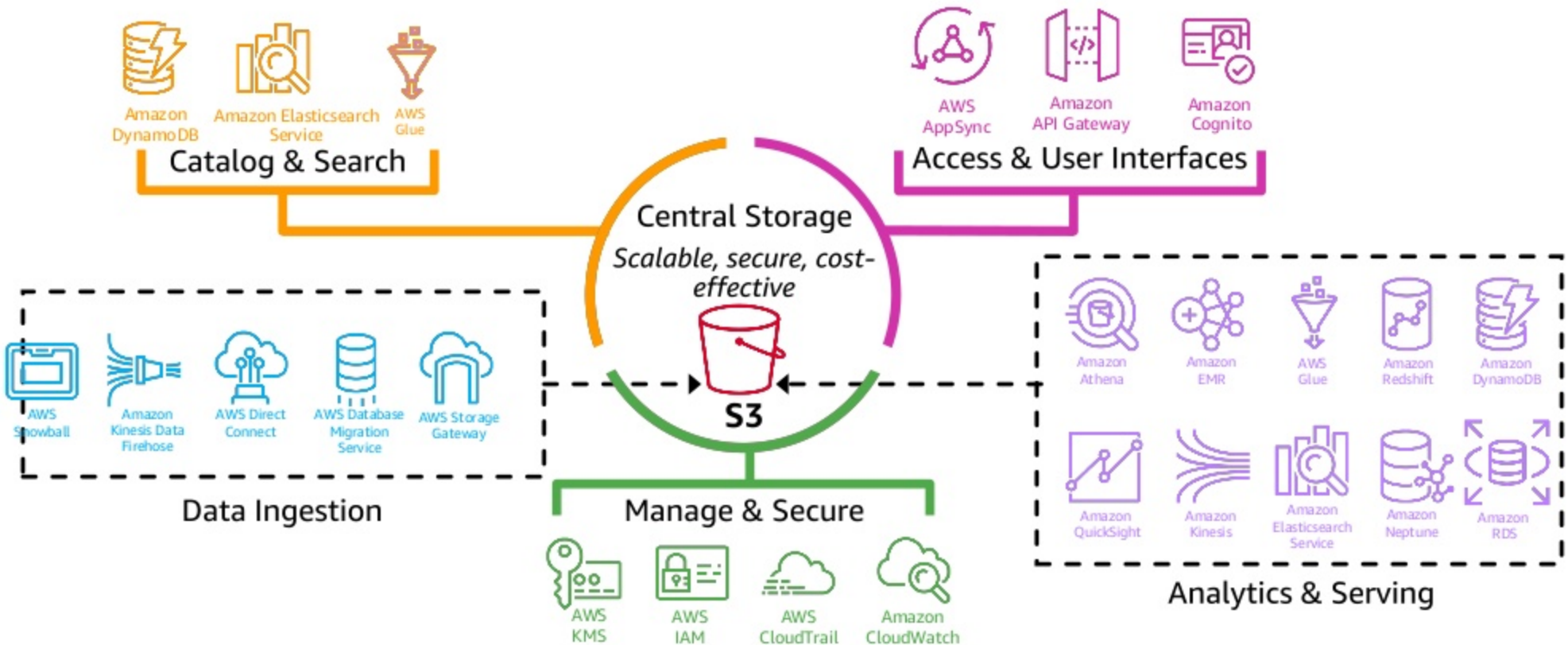
Agenda

- Why a Data Lake?
- Data Lake concepts
- Common asks and challenges
- Data Lake design patterns
- Security and governance patterns
- Q & A

Why a Data Lake?

Data lake on AWS



The core of a Data Lake

Versatile Compute Layers

Athena

Amazon EMR

Amazon Redshift Spectrum

Data Lake

Data & Metadata

Amazon S3

AWS Glue Data Catalog

The concept of a Data Lake

- All data in one place, a single source of truth
- Handles structured/semi-structured/unstructured/raw data
- Supports fast ingestion and consumption
- Schema on read
- Designed for low-cost storage
- Decouples storage and compute
- Supports protection and security rules

Data Lake concepts

Tier 1 Data Lake: Ingestion

Amazon S3

Single source of truth for raw data

Use least transformations

Use lifecycle policies to Amazon Simple Storage Service (Amazon S3) IA or Amazon Glacier

Tier 2 Data Lake: Analytics

Amazon S3

Use columnar formats – Parquet/ORC

Organized into partitions

Coalescing to larger partitions over time

Optimized for analytics

Tier 3 Data Lake: Analytics

Amazon S3

Domain level DataMart

Organized by use cases

Optimized for specialized analysis

Amazon Redshift

Data Warehouse:

Fast speeds over structured schemas

Serves dashboards and reports

Fine-grained access controls

Supports joining native and external tables

Lifecycle back to S3 Data Lake

Common asks and challenges

Some customer asks

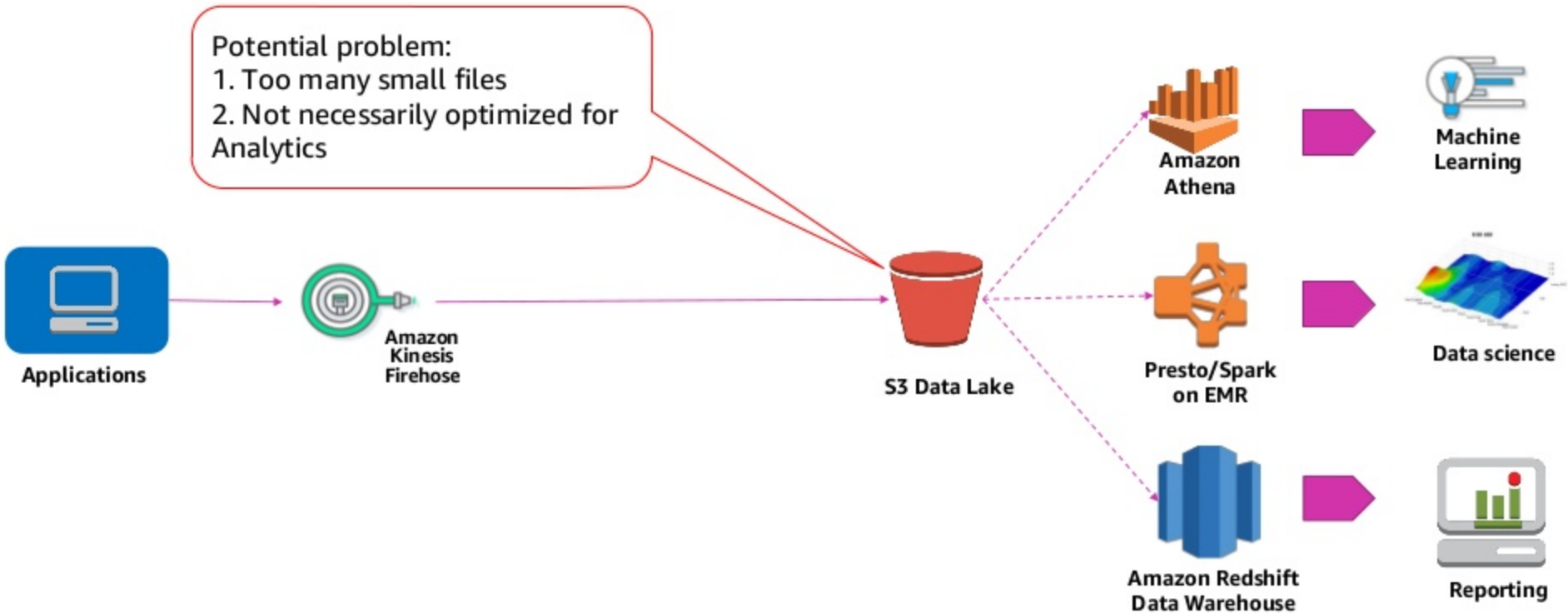
- Can I do streaming ingest into a Data Lake?
- Can a Data Lake replace our database replicas we maintain for analytics?
- How to organize data inside a Data Lake?
- How to handle late events coming in to old partitions?
- How to perform updates and deletes to the data inside a Data Lake?

Some more customer asks

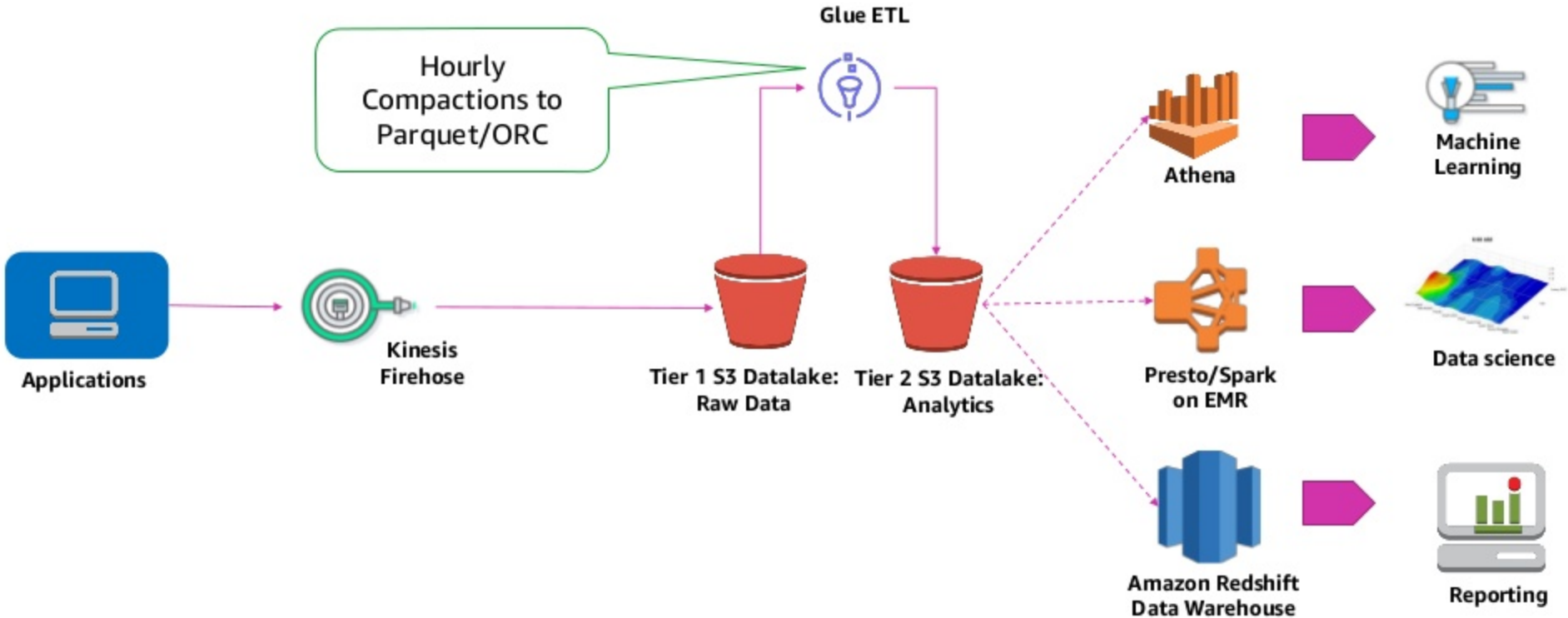
- How can I run Machine Learning training on data in the Data Lake?
- How can I augment the data in my Data Lake with real-time predictions during ETL or ingestion?
- How to enforce data protection rules in the Data Lake?
- What are the authentication and authorization options available?

Data Lake design patterns

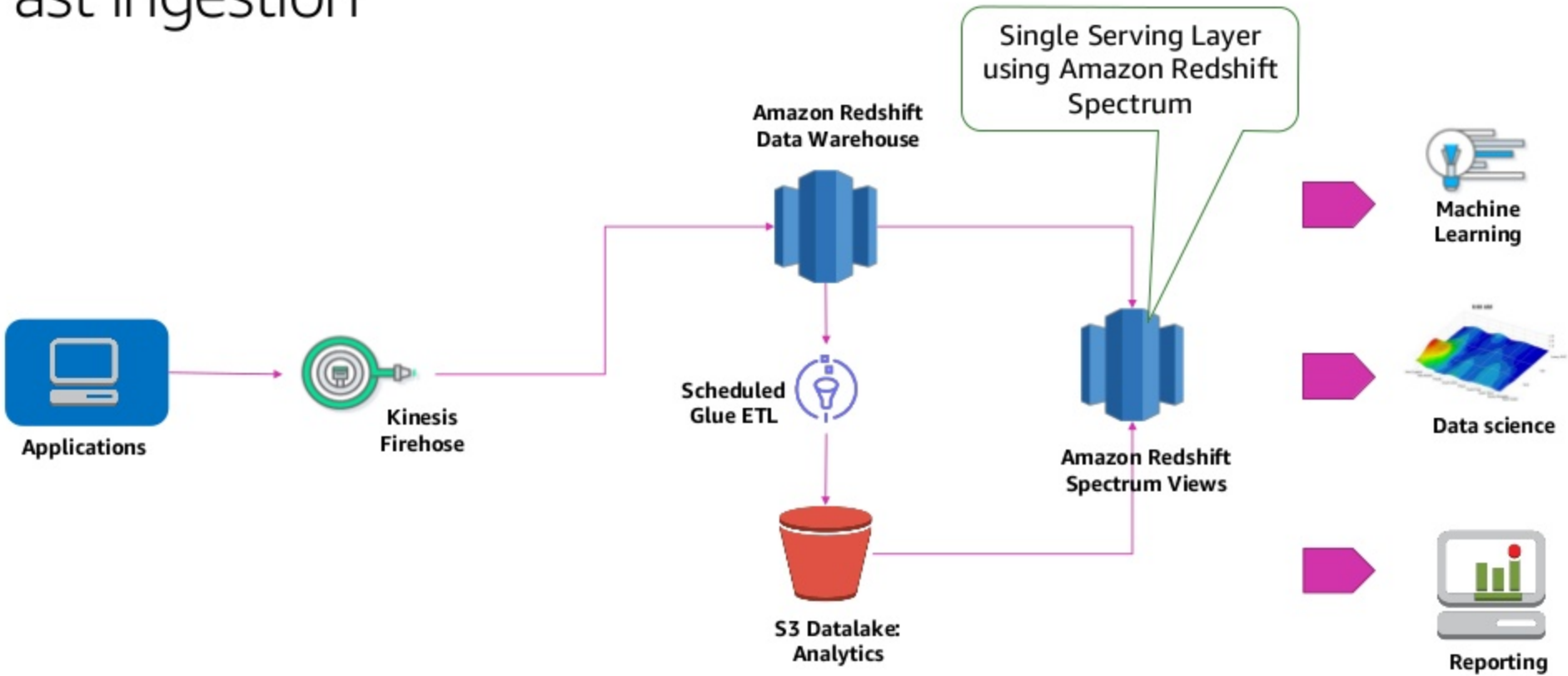
Log analytics, ClickStream analytics, IoT sensor data



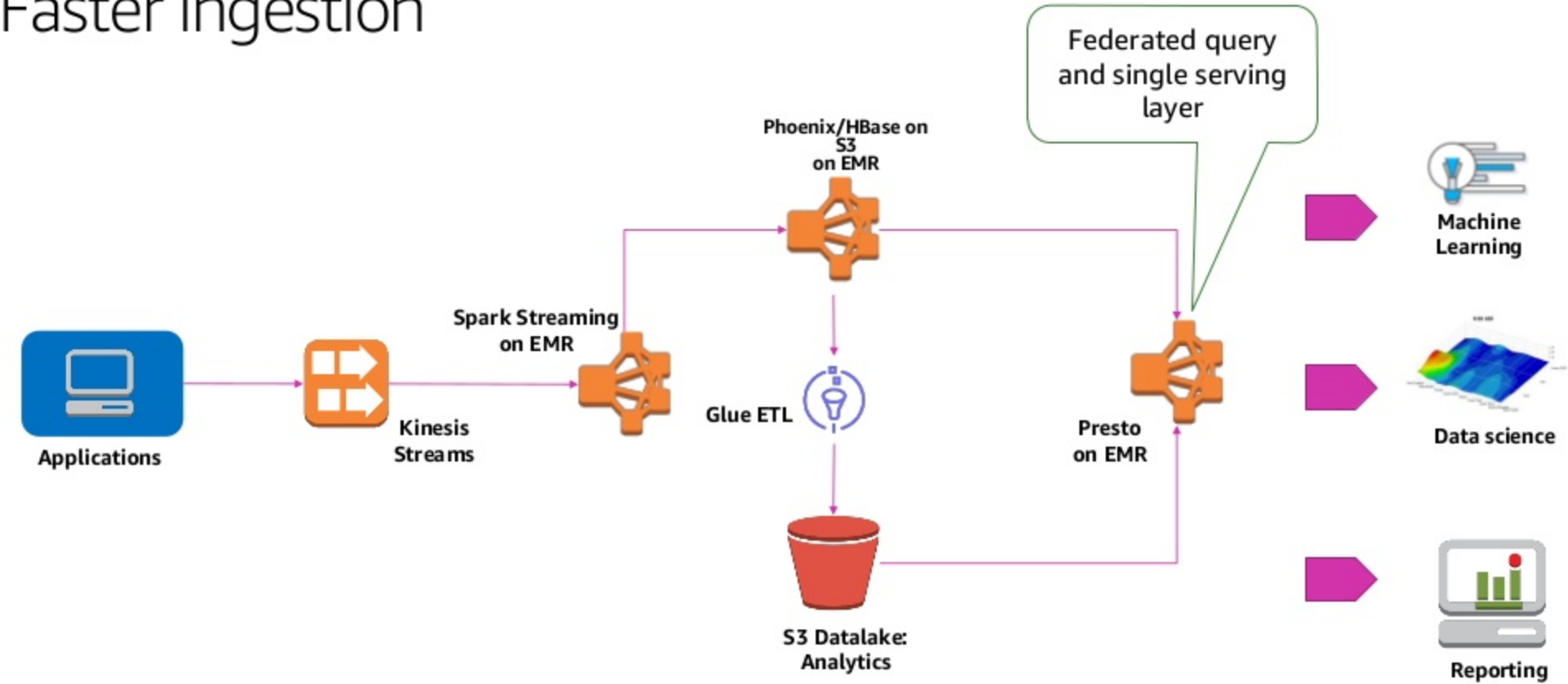
Log analytics, ClickStream analytics, IoT sensor data



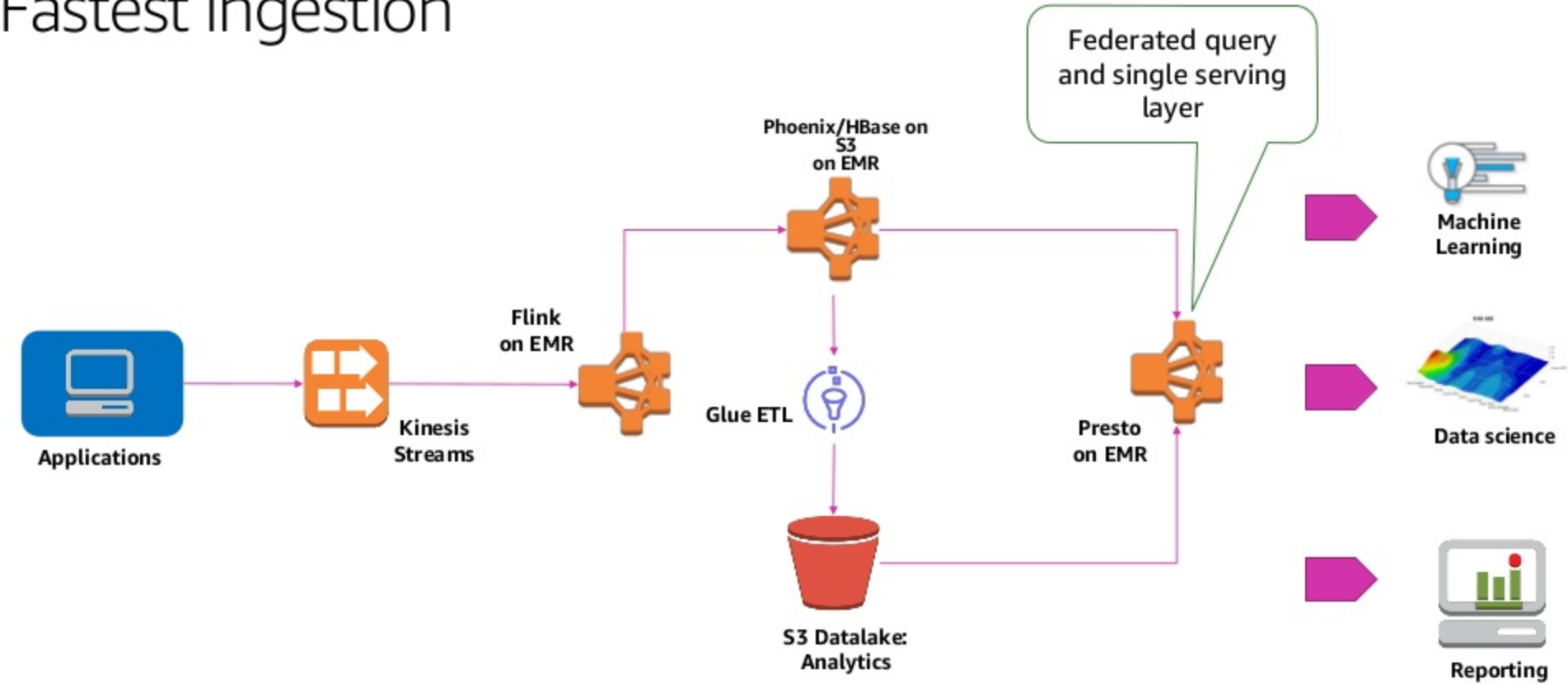
Fast ingestion



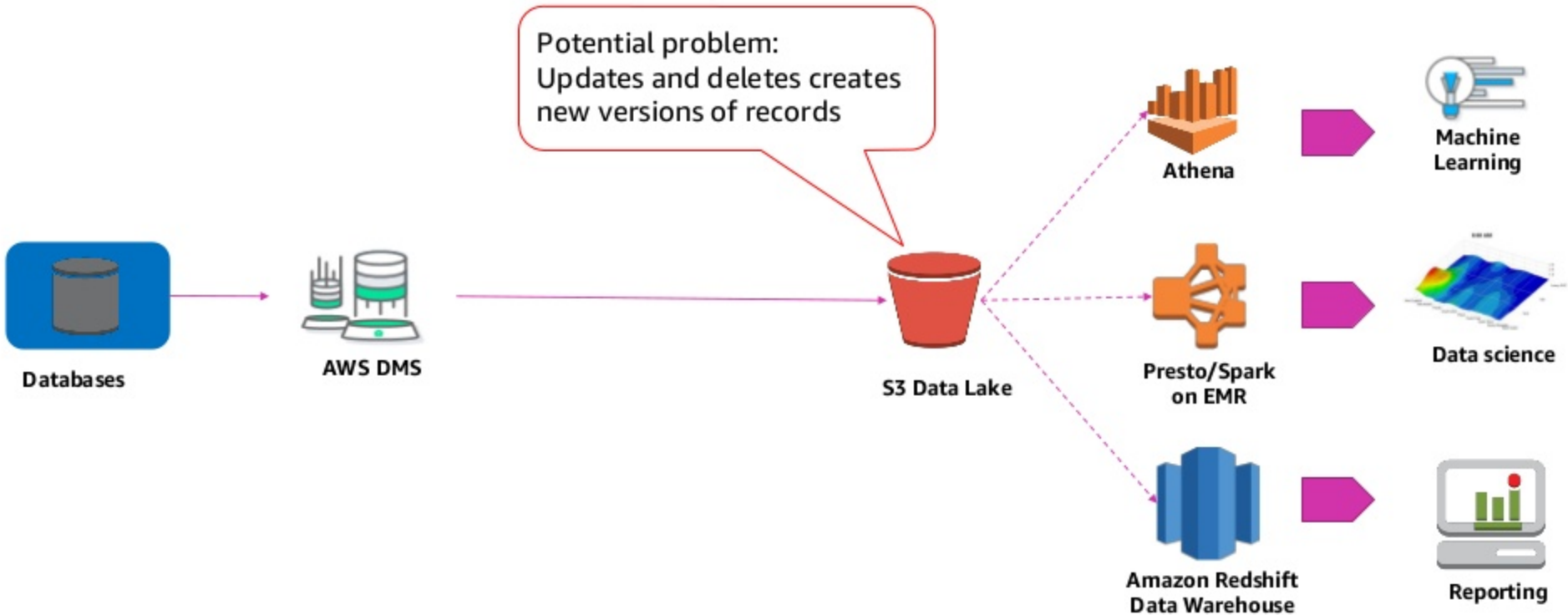
Faster ingestion



Fastest ingestion



Replacing a database replica



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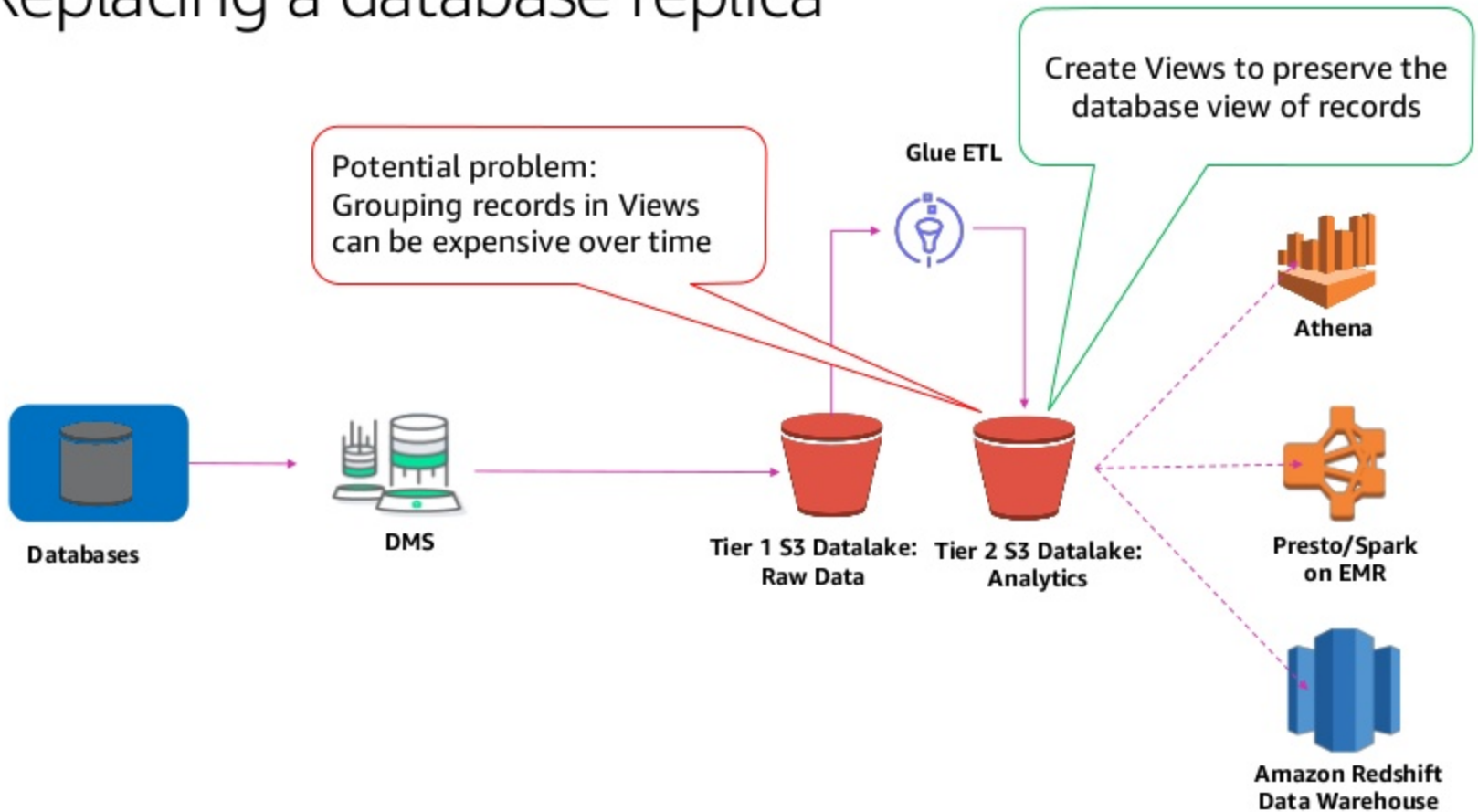
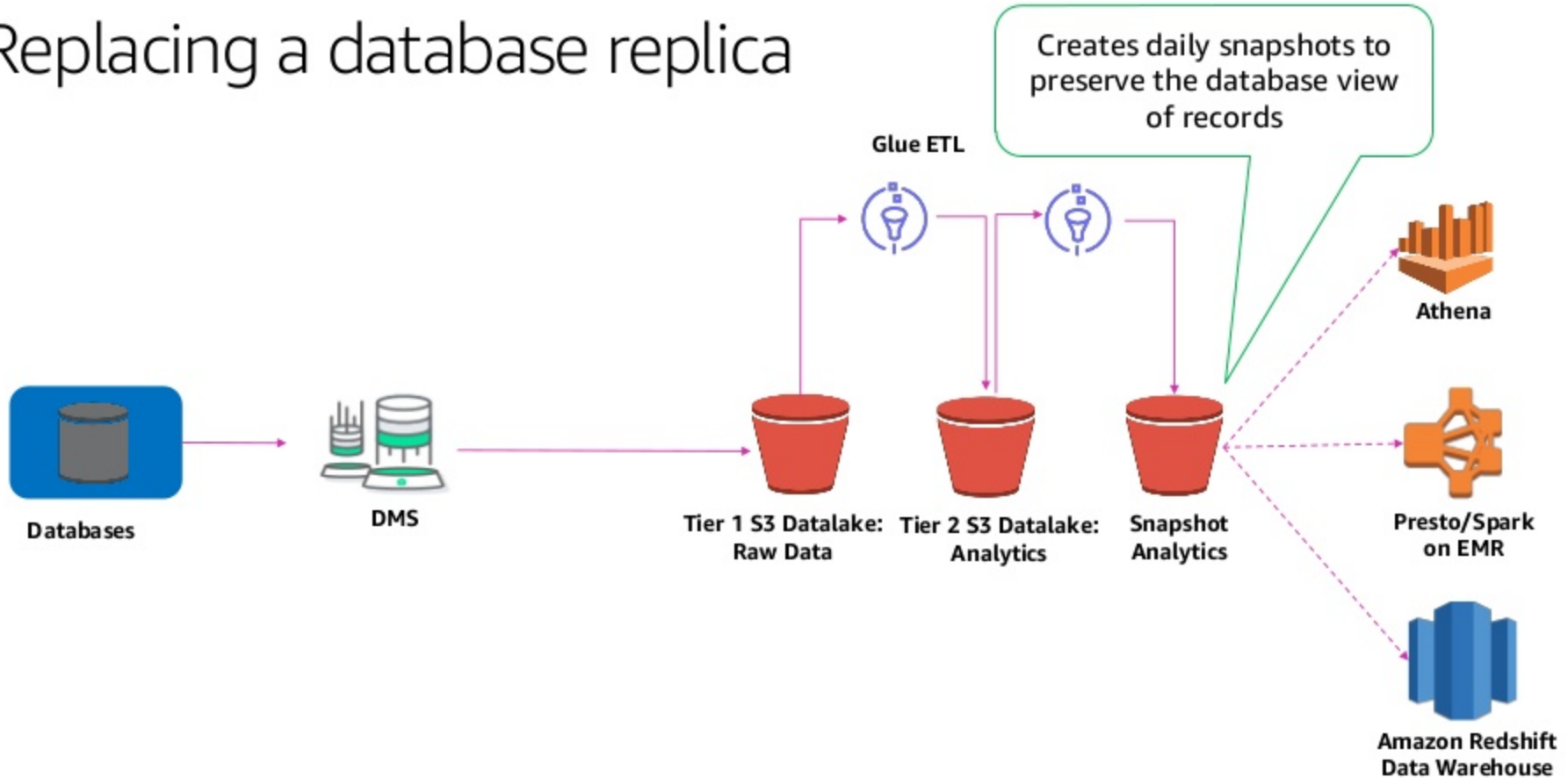
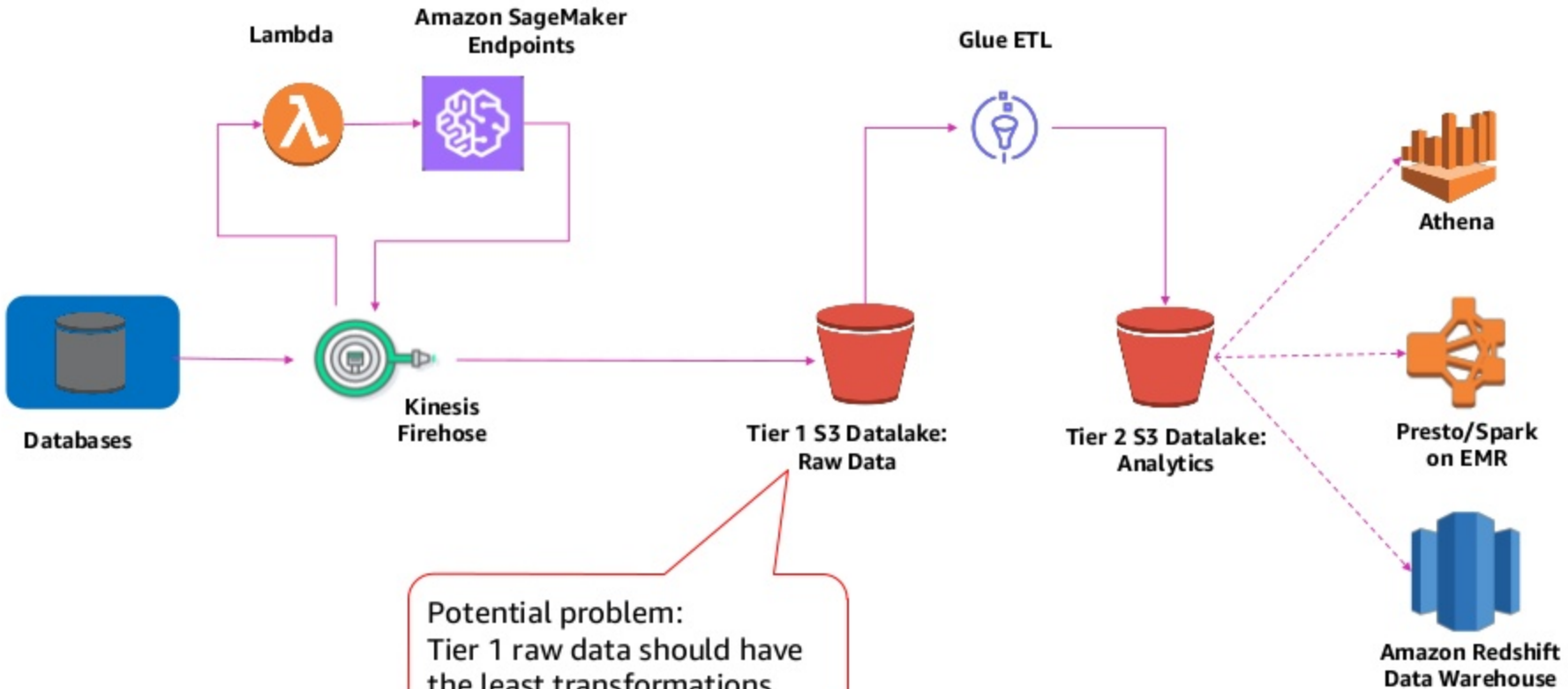


Replacing a database replica

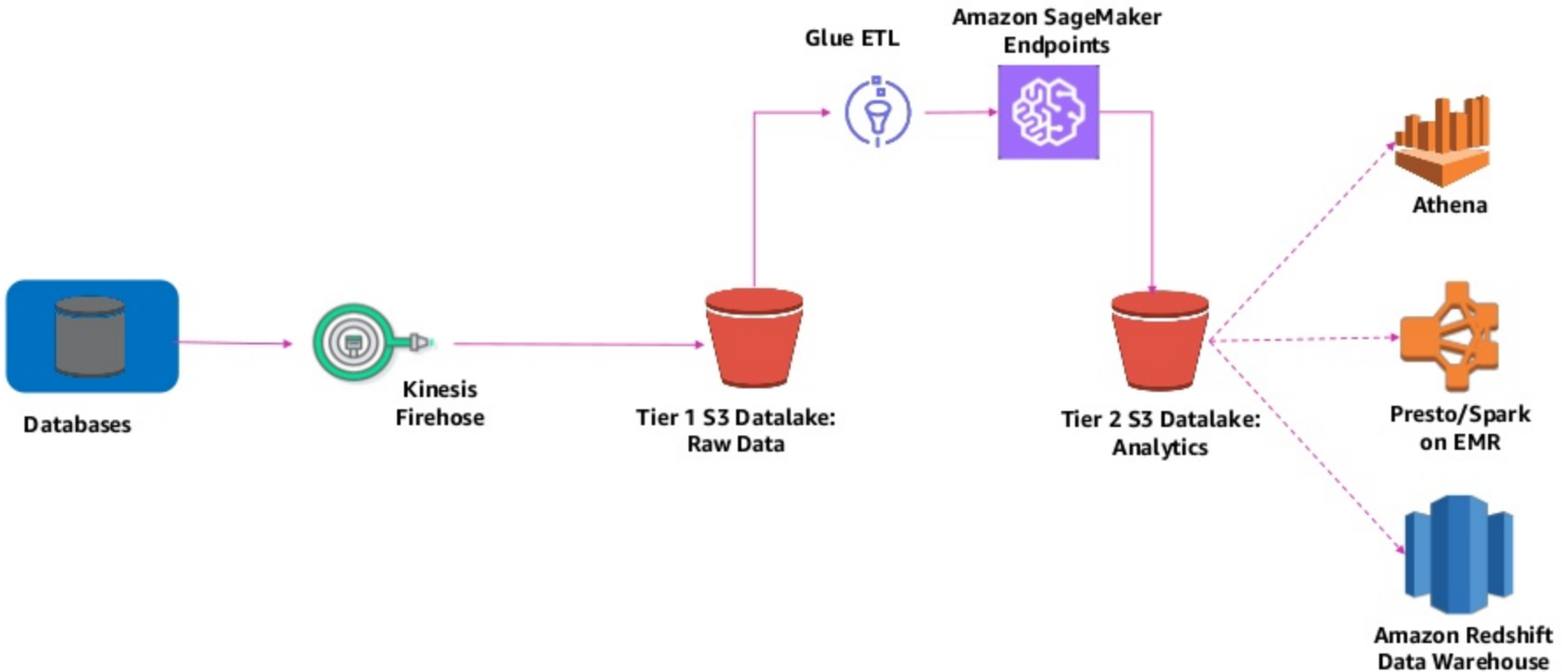


Machine Learning—Batch training pipeline

Machine Learning—Predictions on streaming data



Machine Learning—Predictions on streaming data



Data Lake design principles

- **Ingestion location and frequency**: Decide on a location for ingestion. Select a frequency and ingestion mechanism as meets your needs.

- **Partition data**: Partition the data with keys that align with common query filters used. This enables partition pruning and increases query performance.

- **File Size**: Choose optimal file sizes to reduce S3 roundtrips. Recommended : 256 MB to 1GB files in columnar format per partition.

- **Compactions**: Compact data on a scheduled basis to get the file sizes above e.g., daily compactions into daily partitions if hourly files are small.

How to choose partitioning columns?

- Aim for optimum files sizes—256 MB to 1GB
- Identify the typical query scan range—One year, five years, etc.
- Know your query filters and Group By columns that should align with partition columns

How to choose partitioning columns? An example

Use case: Aggregation of time series data

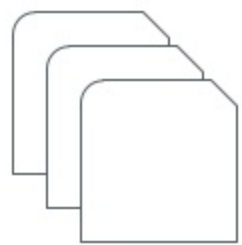
Number of devices: 100

Partition format: device/year/month/day/hour

Data retention/query scan range: Five years

File per partition: One

File Size:10 MB



5*365*24*100= 4.3M partitions

How to choose partitioning columns? An example

Number of devices: 100

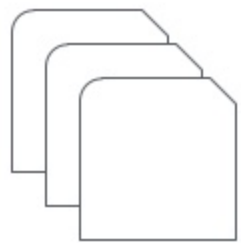
Partition format: year/month/day/~~hour~~

Bucketed by: Device, 50 buckets

Data retention/query scan: Five years

File per partition: 50

File size: 480 MB

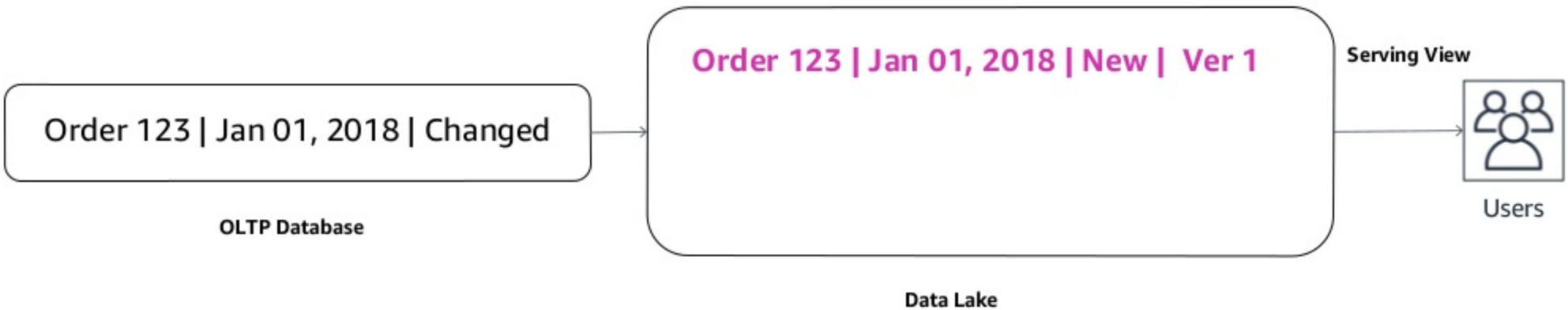


5*365 = 1825 partitions

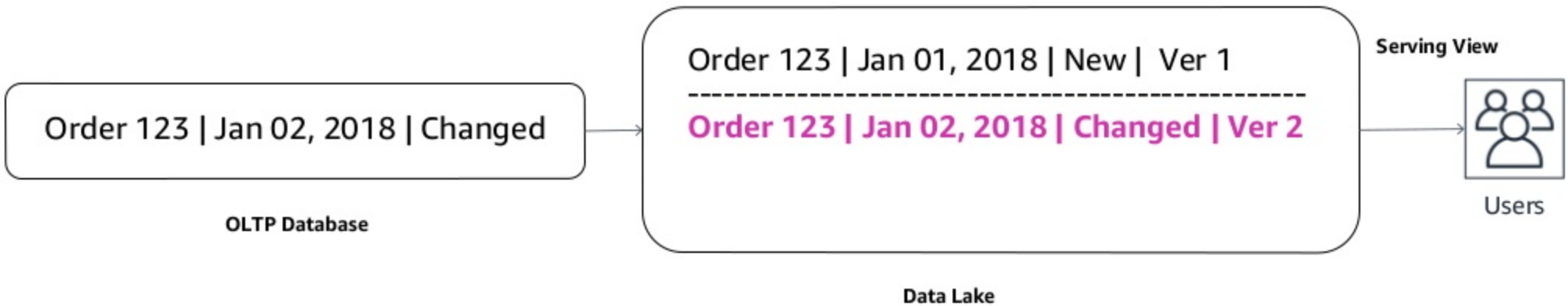
Data Lake design principles

- **Mutable data**: For mutable uses cases i.e., to handle updates/deletes
  - Either use a database like Amazon Redshift/HBase for the time the data can mutate and offload to S3 once data becomes static
  - Or append to delta files per partition and compact on a scheduled basis using AWS Glue or Spark on EMR

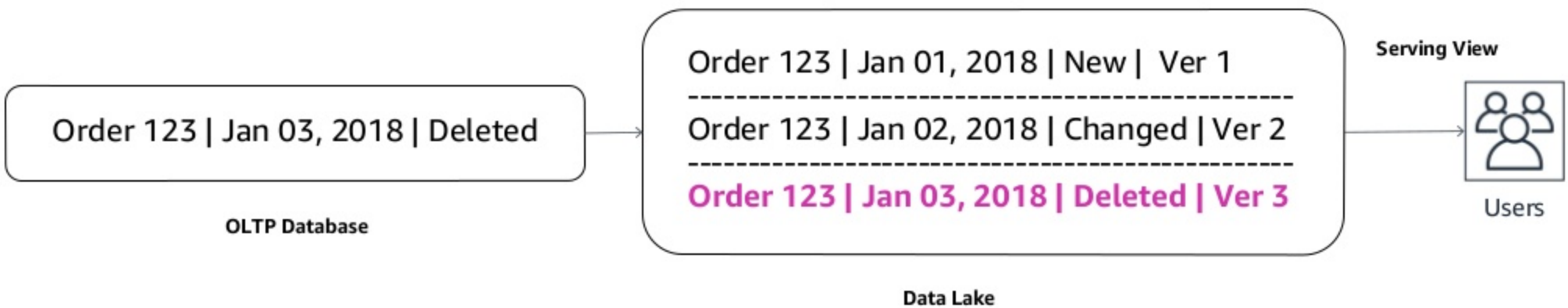
Serving mutable data



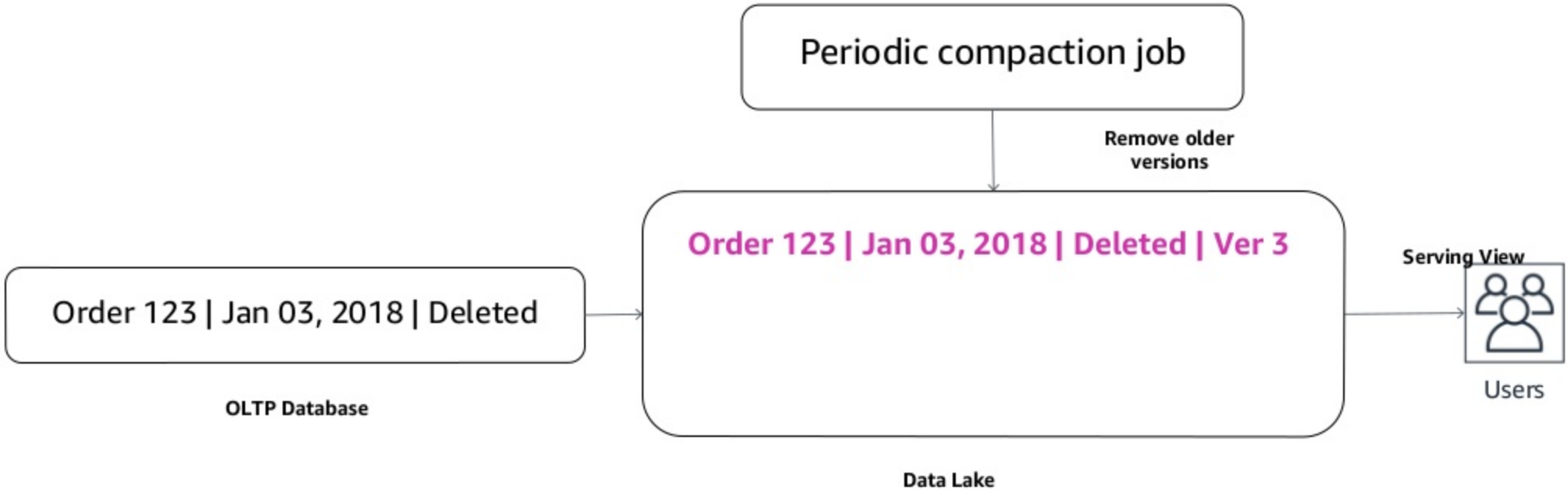
Serving mutable data



Serving mutable data



Serving mutable data



Data Lake optimizations

- **Bucketed data**: For additional performance, bucket data in each partition on a high cardinality key. This is honored by Presto/Athena, Hive and so on, and improves query filter performance on that key.

```
df.write.bucketBy(numBuckets,"col1").parquet(…)
```

- **Order Data**: For additional performance, sort data in each partition by a secondary key. This allows engines to skip part of files to get to the requested data faster.

```
df.repartition(100).sortWithinPartitions(['order_id']
,ascending=True).parquet(…)
```

Data Lake optimizations

- **Bloom filters**: Bloom Filters are space-efficient probabilistic data structures that is used to test whether an element is a member of a set

```
CREATE TABLE
STORED AS ORC
TBLPROPERTIES('orc.bloom.filter.columns'='ORDER_ID')
```

Security and governance patterns

Security and governance concerns

- Authentication
- Authorization on data (and metadata)
- Encryption of data at rest and in transit
- Audit and monitoring
- Centralized management
- Compliance

AWS helps you secure

Customer need to have multiple levels of security, identity and access management, encryption, and compliance to secure their data lake

Security

Amazon GuardDuty

AWS Shield

AWS WAF

Amazon Macie

Amazon VPC

Identity

AWS IAM

AWS SSO

Amazon Cloud Directory

AWS Directory Service

AWS Organizations

Encryption

AWS Certification Manager

AWS Key Management Service

Encryption at rest

Encryption in transit

Bring your own keys, HSM support

Compliance

AWS Artifact

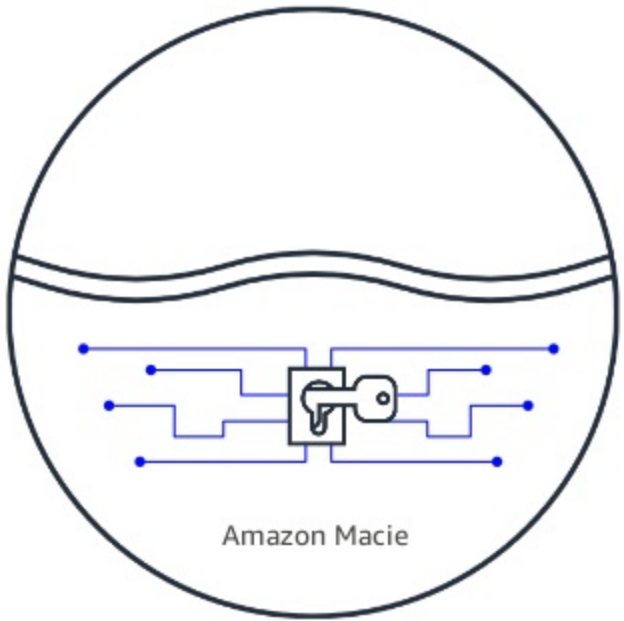
Amazon Inspector

Amazon Cloud HSM

Amazon Cognito

AWS CloudTrail

Security: Machine Learning-powered security



- Machine learning to discover, classify, and protect data
- Continuously monitors data access for anomalies
- Generates alerts when it detects unauthorized access
- Recognizes PII or intellectual property

Data Lake security

- Data storage
- Metadata

Data storage security

Data storage security

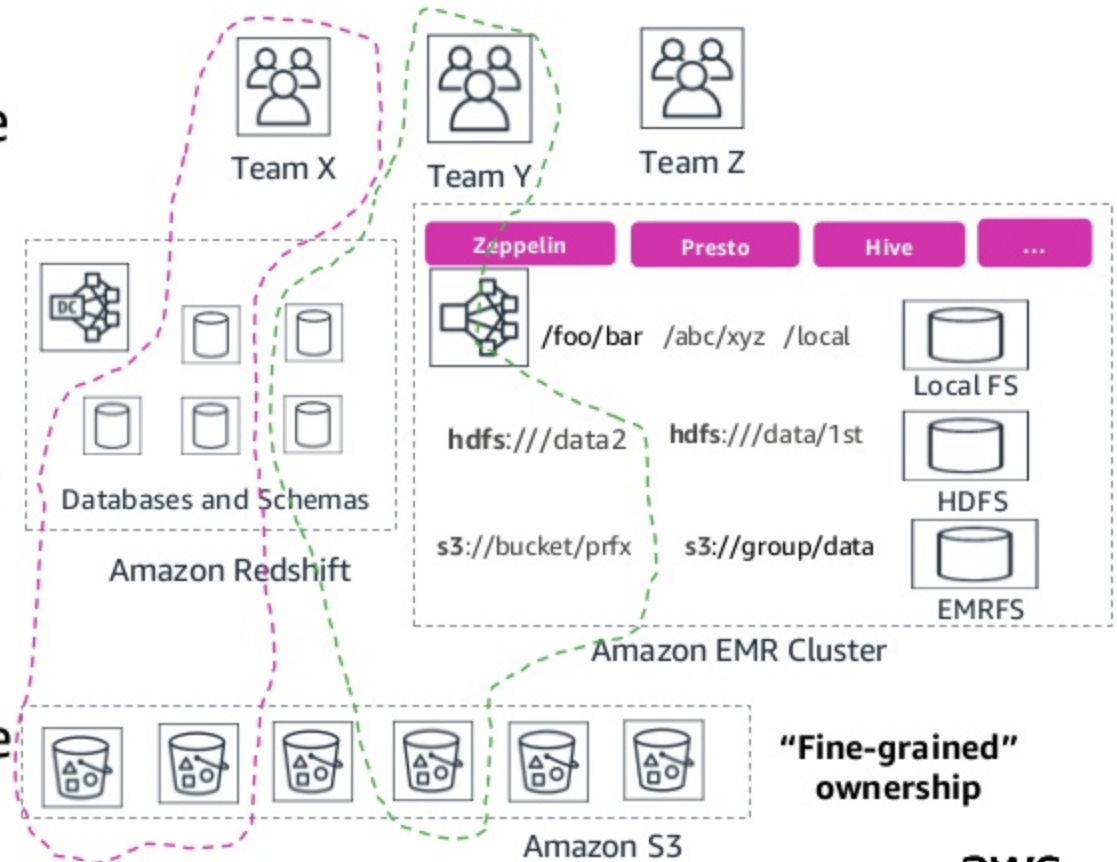
Key learnings

- Implement access control in a multi-team environment
  - Fine-grained
  - Coarse-grained
- Secure and segregated access to
  - Amazon S3
  - Amazon EMR clusters
  - Amazon Redshift clusters
  - Serverless analytics services and other tools used in the pipeline
- Encrypt data assets

Control access to data—Fine-grained ACL

"Fine-grained" data and resource ownership

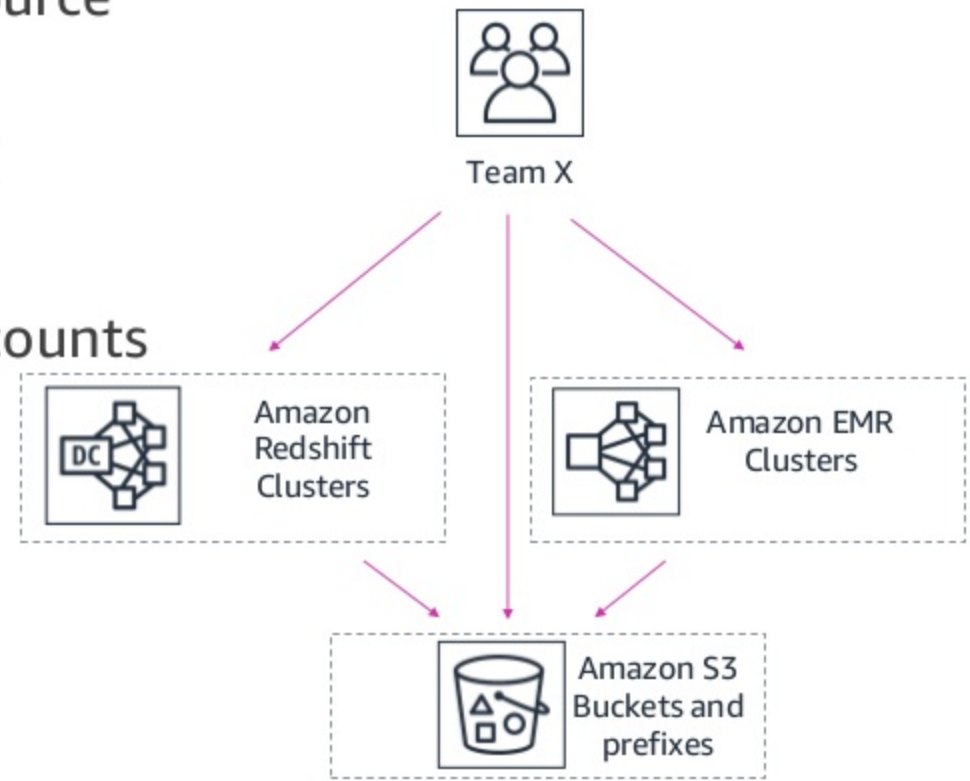
- Teams **share S3 buckets and clusters**
- Access control complex to set up and maintain
- Common in a "**shared services**" architecture



Control data access—Coarse grained

Prefer “coarse-grained” data and resource ownership

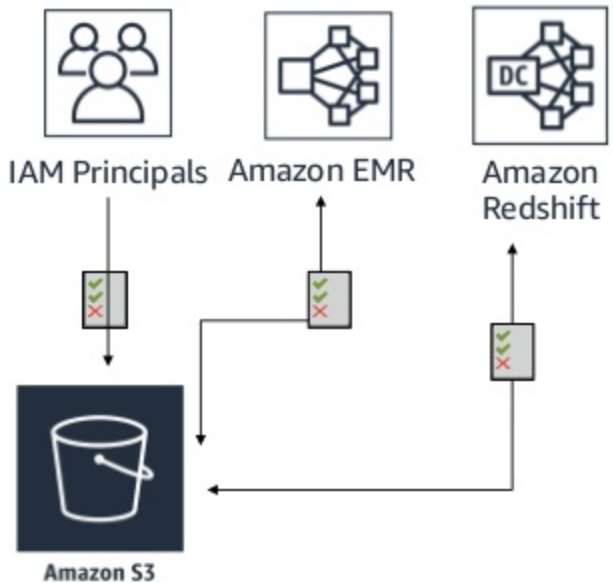
- Teams own **entire S3 buckets and clusters**
- Ownership segregated by AWS accounts
- Access control easier to setup and maintain
- Suitable for **autonomous teams**



Control access to data

Configure **Amazon S3** permissions

- Implement your access control matrix using **IAM policies**
- Use **S3 bucket policies** for easy cross-account data sharing
- Limit role-based access from an **Amazon EMR** cluster's **Amazon Elastic Compute Cloud** (Amazon EC2) **instance profile**
- Authorize access from other tools such as **Amazon Redshift** using IAM roles



Block public access to Amazon S3

Amazon S3 provides four settings

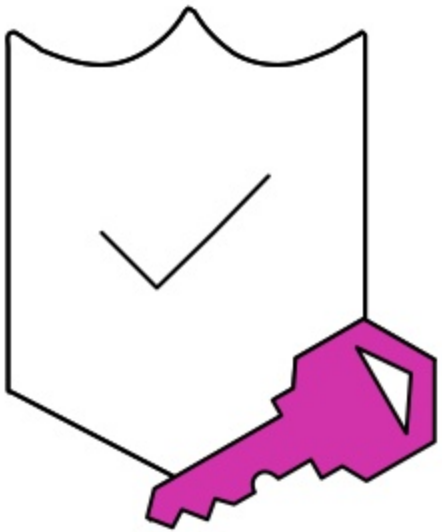
- `BlockPublicAcls` – **rejects new** public object or bucket ACLs
- `IgnorePublicAcls` – **ignores existing** public object or bucket ACLs
- `BlockPublicPolicy` – **rejects new** public bucket access policy
- `RestrictPublicBuckets` – **restricts access** to only AWS services and authorized users within the bucket owner's account

But, what is “public”?

- **Public object (or bucket) ACL** → grants permissions to members of the predefined ***AllUsers*** or ***AuthenticatedUsers*** groups (grantees)

- **Public bucket policy** → **doesn’t** grant permissions to **only fixed values in Principal** and **Condition** elements

Encryption: Data-at-rest and in-motion



- Amazon S3 offers multiple forms of encryption
  - Server-side and Client-side encryption
  - Encryption with keys managed by S3 or AWS Key Management Service
  - Encryption with keys that customers manage
- Encrypts data in transit when replicating across regions
- Data movement services can use the same AWS Key Management Service
- SSL endpoints

Metadata security

Metadata security

AWS Glue Data Catalog

- **Apache Hive metastore compatible**
- Track data evolution using **schema versioning**
- **Integrates with** Hive, Spark, Presto, Amazon Athena and Amazon Redshift spectrum
- Use crawlers **classify** your data in one central list that is **searchable**

Metadata security

Key learnings

- Create and maintain centralized data catalog
- Enable cross account access
- Use IAM policies to control catalog access—similar to S3 bucket policies
- Encrypt metadata in AWS Glue Data Catalog

Glue Data Catalog—Cross account access

Catalog Policy in Account A

```
{
  "Version": "2012-10-17",
  "Statement": [
    {
      "Effect": "Allow",
      "Action": [
        "glue:GetDatabase"
      ],
      "Principal": {"AWS": [
        "arn:aws:iam::account-B-id:user/Bob"
      ]},
      "Resource": [
        "arn:aws:glue:us-east-1:account-A-id:catalog",
        "arn:aws:glue:us-east-1:account-A-
id:database/db1"
      ]
    }
  ]
}
```

Bob's IAM Policy in Account B

```
{
  "Version": "2012-10-17",
  "Statement": [
    {
      "Effect": "Allow",
      "Action": [
        "glue:GetDatabase"
      ],
      "Resource": [
        "arn:aws:glue:us-east-1:account-A-
id:catalog",
        "arn:aws:glue:us-east-1:account-A-
id:database/db1"
      ]
    }
  ]
}
```

Glue Data Catalog—Resource-level permissions

- Fine-grained access control to catalog using IAM policies
- Restrict what they can view and query

```
"Action": [
    "glue:GetTable*",
    "glue:GetPartition*"
],
"Resource": [
    "arn:aws:glue:us-east-1:[redacted]:table/blog_prod/prod_*",
    "arn:aws:glue:us-east-1:[redacted]:database/*",
    "arn:aws:glue:us-east-1:[redacted]:catalog"
],
```

```
"Action": [
    "glue:*Database*",
    "glue:*Table*",
    "glue:*Partition*"
],
"Resource": [
    "arn:aws:glue:us-east-1:[redacted]:table/blog_dev/*",
    "arn:aws:glue:us-east-1:[redacted]:database/blog_dev",
    "arn:aws:glue:us-east-1:[redacted]:catalog",
    "arn:aws:glue:us-east-1:[redacted]:userDefinedFunction/blog_dev/*"
],
```

Security and Governance

	Athena	EMR	Glue	Redshift
Authentication	IAM/EC2 Key pair	Kerberos/LDAP/ EC2 Key pair/IAM	IAM Role	IAM/Native
Authorization	S3 Bucket Policies	S3 Bucket Policies/ Hive Grants/ EMRFS Auth	S3 Bucket Policies/ Fine Grained	S3 Bucket Policies/ Native Grants
Encryption of data at-rest	SSE-S3/ SSE-KMS/ CSE-KMS	SSE-S3/ SSE-KMS/ CSE-KMS/ CSE-CMK	SSE-S3	Database Encryption/ SSE-S3/ SSE-KMS/ CSE-CMK
Encryption of data in-transit	SSL	Yes, through Security Config	SSL	SSL
Audit	CloudTrail	Application Logs	CloudTrail	Database Audit
Compliance	HIPAA	FedRAMP/HIPAA	HIPAA	FedRAMP/HIPAA

Compliance: Virtually every regulatory agency

Global

- **CSA** — Cloud Security Alliance Controls
- **ISO 9001** — Global Quality Standard
- **ISO 27001** — Security Management Controls
- **ISO 27017** — Cloud Specific Controls
- **ISO 27018** — Personal Data Protection
- **PCI DSS Level 1** — Payment Card Standards
- **SOC 1** — Audit Controls Report
- **SOC 2** — Security, Availability, & Confidentiality Report
- **SOC 3** — General Controls Report

United States

- **CJIS** — Criminal Justice Information Services
- **DoD SRG** — DoD Data Processing
- **FedRAMP** — Government Data Standards
- **FERPA** — Educational Privacy Act
- **ISO FFIEC** — Financial Institutions Regulation
- **FIPS** — Government Security Standards
- **FISMA** — Federal Information Security Management
- **GxP** — Quality Guidelines and Regulations
- **HIPPA** — Protected Health Information
- **ITAR** — International Arms Regulations
- **MPAA** — Protected Media Content
- **NIST** — National Institute of Standards and Technology
- **SEC Rule 17a-4(f)** — Financial Data Standards
- **VPAT/Section 508** — Accountability Standards

Asia Pacific

- **FISC [Japan]** — Financial Industry Information Systems
- **IRAP [Australia]** — Australian Security Standards
- **K-ISMS [Korea]** — Korean Information Security
- **MTCS Tier 3 [Singapore]** — Multi-Tier Cloud Security Standard
- **My Number Act [Japan]** — Personal Information Protection

Europe

- **C5 [Germany]** — Operational Security Attestation
- **Cyber Essentials Plus [UK]** — Cyber Threat Protection
- **G-Cloud [UK]** — UK Government Standards
- **IT-Grundschutz [Germany]** — Baseline Protection Methodology

AWS Lake Formation

Build a secure data lake in days

Register existing data or load new data using blueprints. Data stored in Amazon S3.

Secure data access across multiple services using single set of permissions.

No additional charge. Only pay for the underlying services used.

Quickly build data lakes

Move, store, catalog, and clean your data faster. Use ML transforms to de-duplicate data and find matching records.

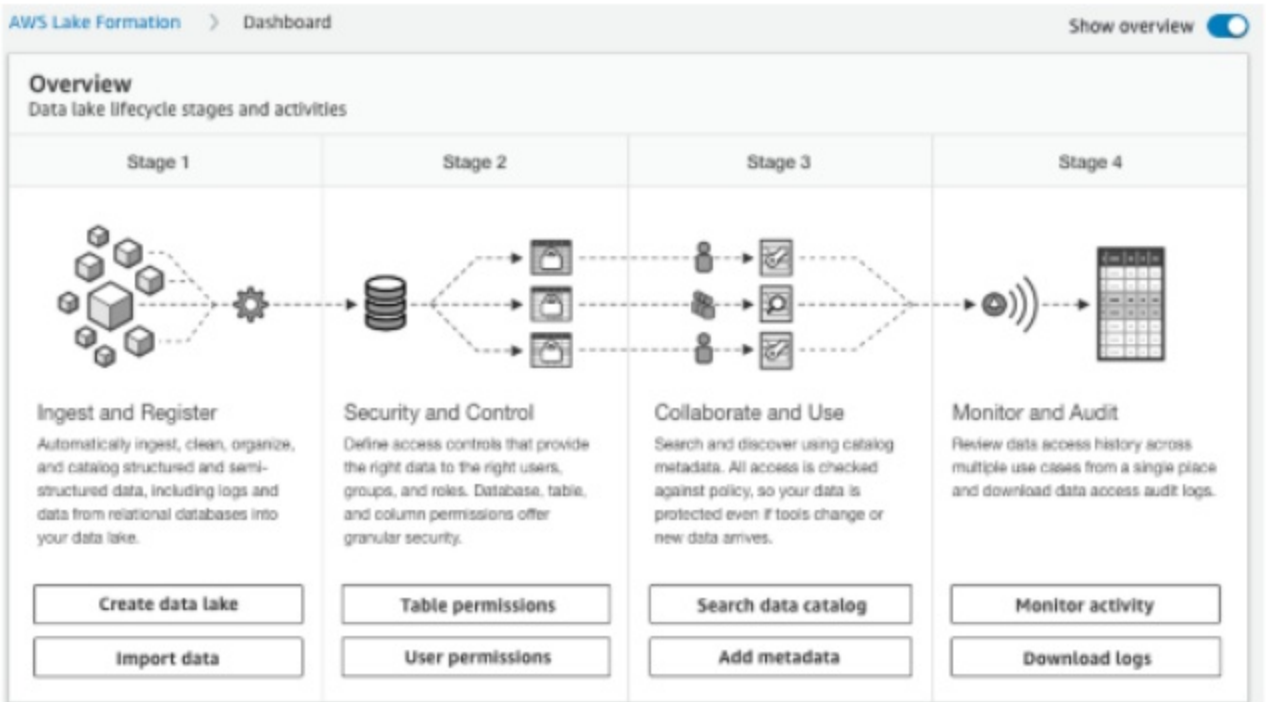
Easily secure access

Centrally define table and column-level data access and enforce it across Amazon EMR, Amazon Athena, Amazon Redshift Spectrum, Amazon SageMaker, and Amazon QuickSight

Share and collaborate

Use data catalog in Lake Formation to search and find relevant data sets and share them across multiple users and accounts

How it works



Thank you!

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