# DynamoDB

## Design Patterns and Best Practices

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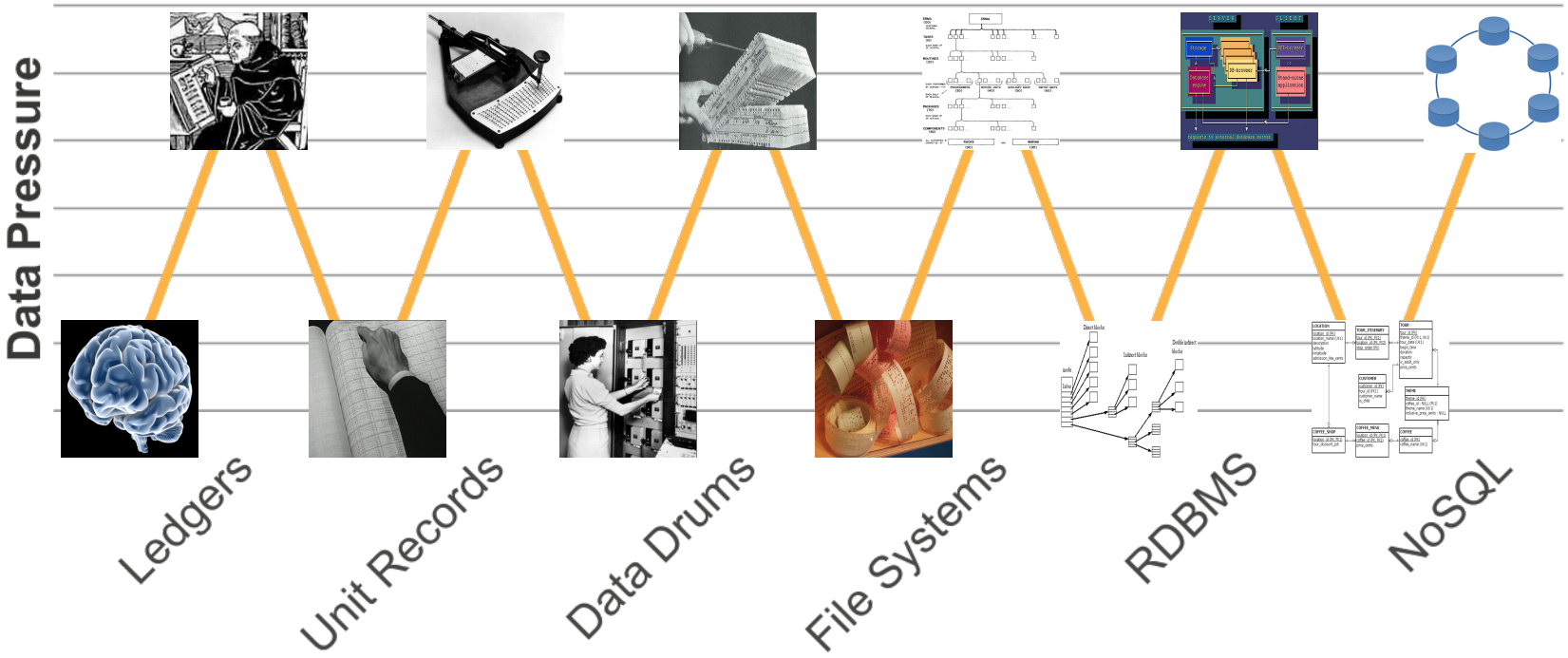
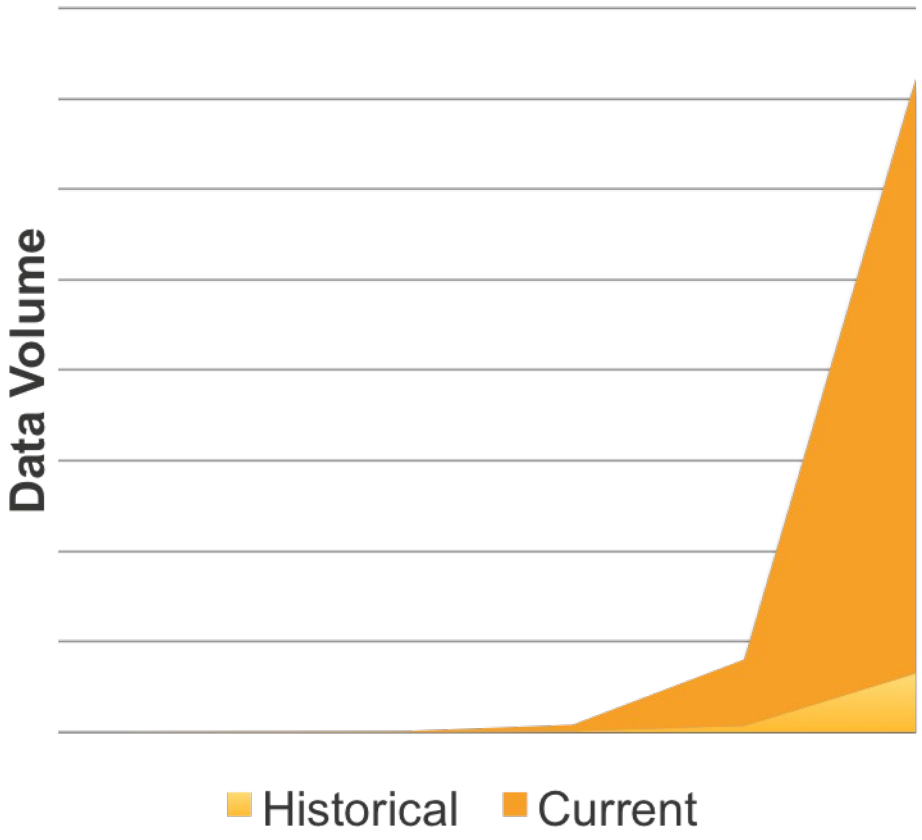
# What to expect from the session

- Brief history of data processing
- DynamoDB Internals
  - Tables, API, data types, indexes
  - Scaling and data modeling
- Design patterns and best practices
- Event driven applications and DDB Streams

# Timeline of Database Technology

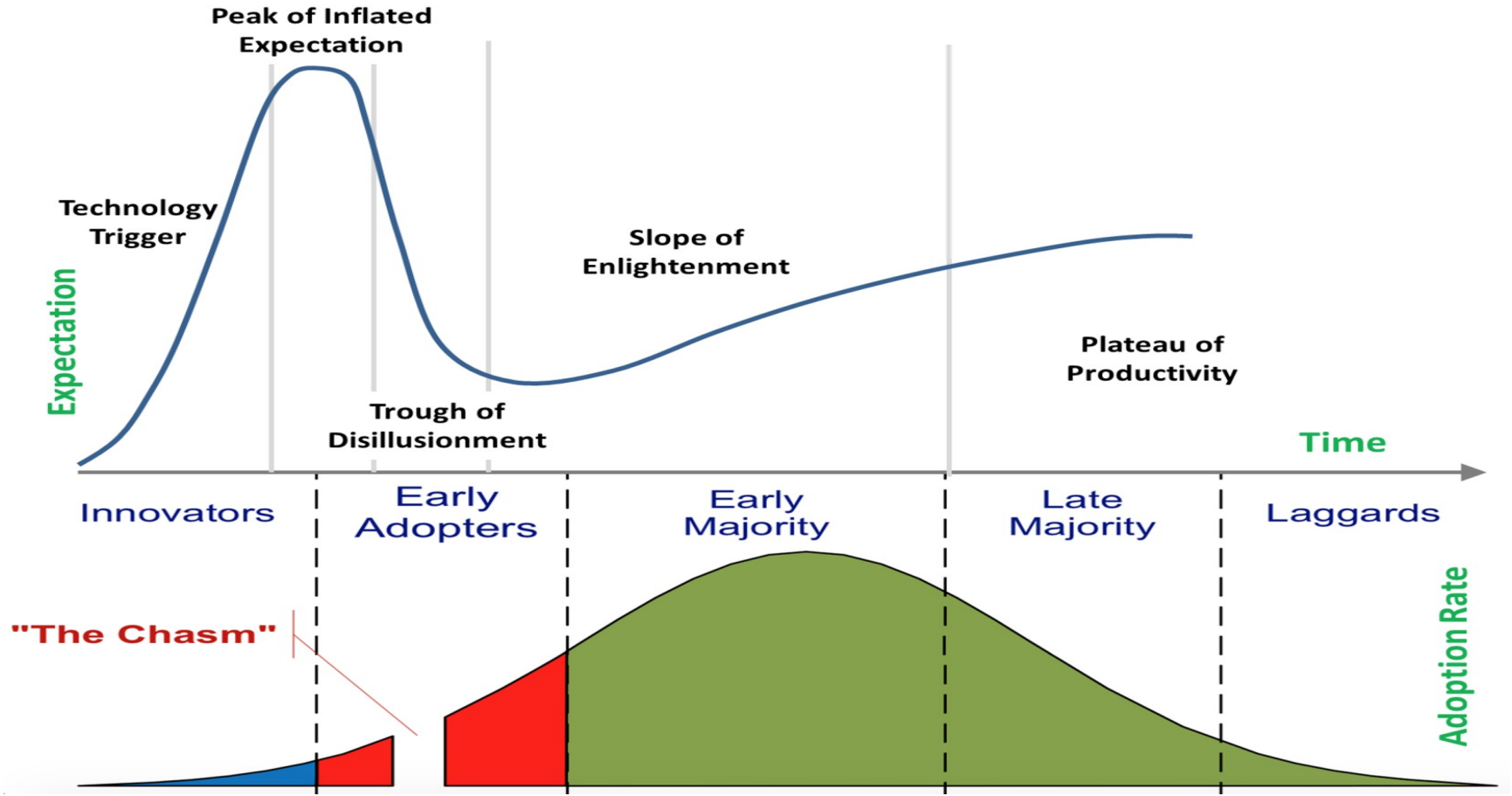


# Data Volume Since 2010




- 90% of stored data generated in last 2 years
- 1 Terabyte of data in 2010 equals 6.5 Petabytes today
- Linear correlation between data pressure and technical innovation
- No reason these trends will not continue over time

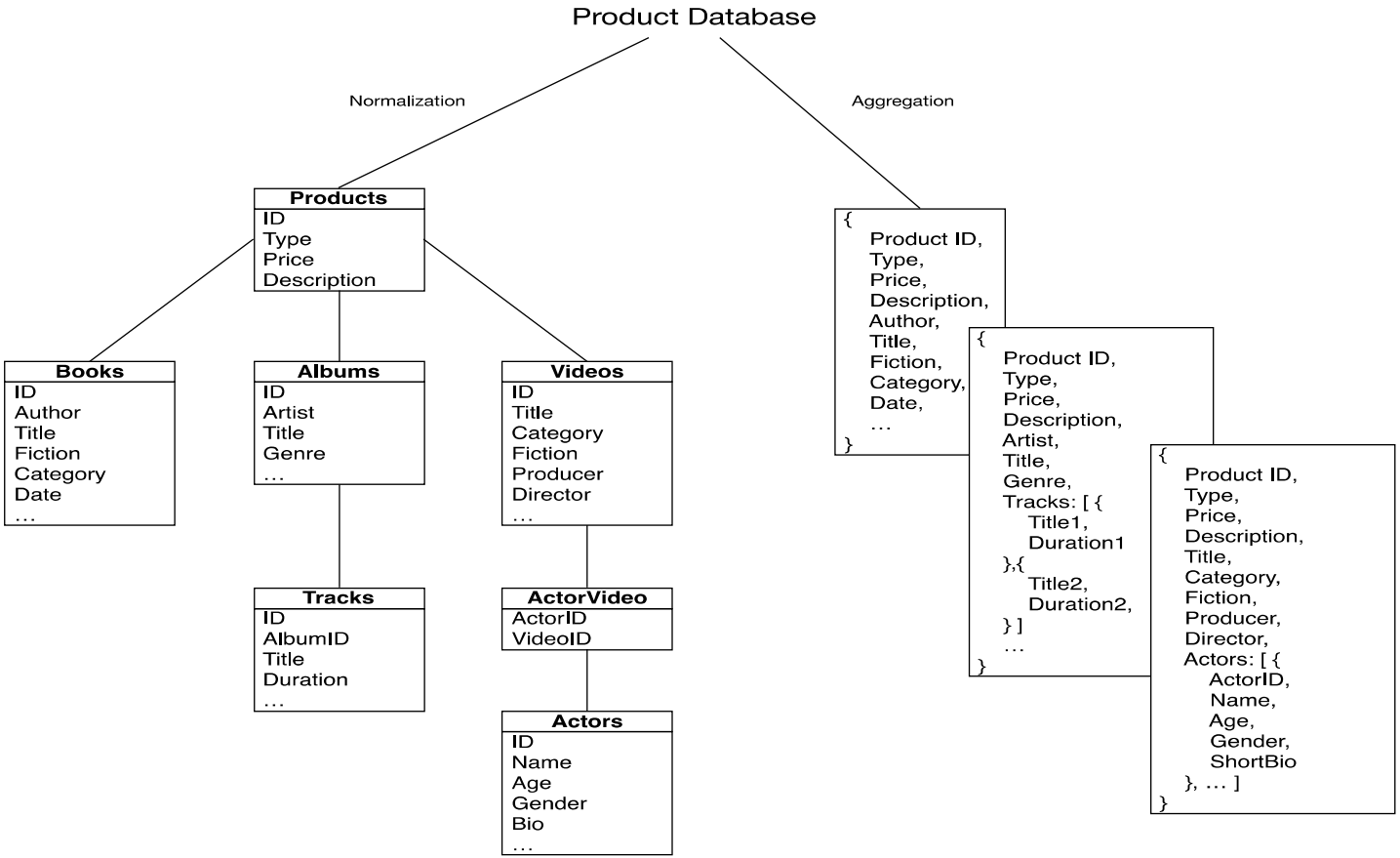
# Technology Adoption and the Hype Curve



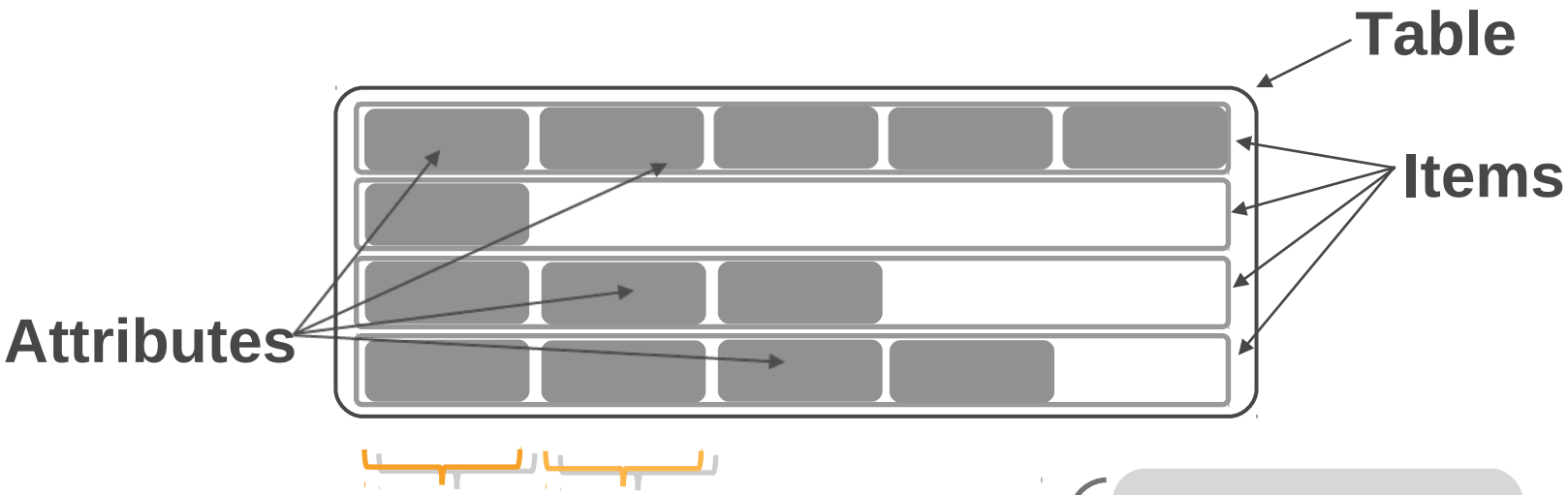
# Why NoSQL?

| SQL | NoSQL |
| --- | --- |
| **Optimized for storage** | **Optimized for compute** |
| Normalized/relational | Denormalized/hierarchical |
| Ad hoc queries | Instantiated views |
| Scale vertically | Scale horizontally |
| Good for OLAP | Built for OLTP at scale |

# SQL vs. NoSQL Access Pattern



# Table



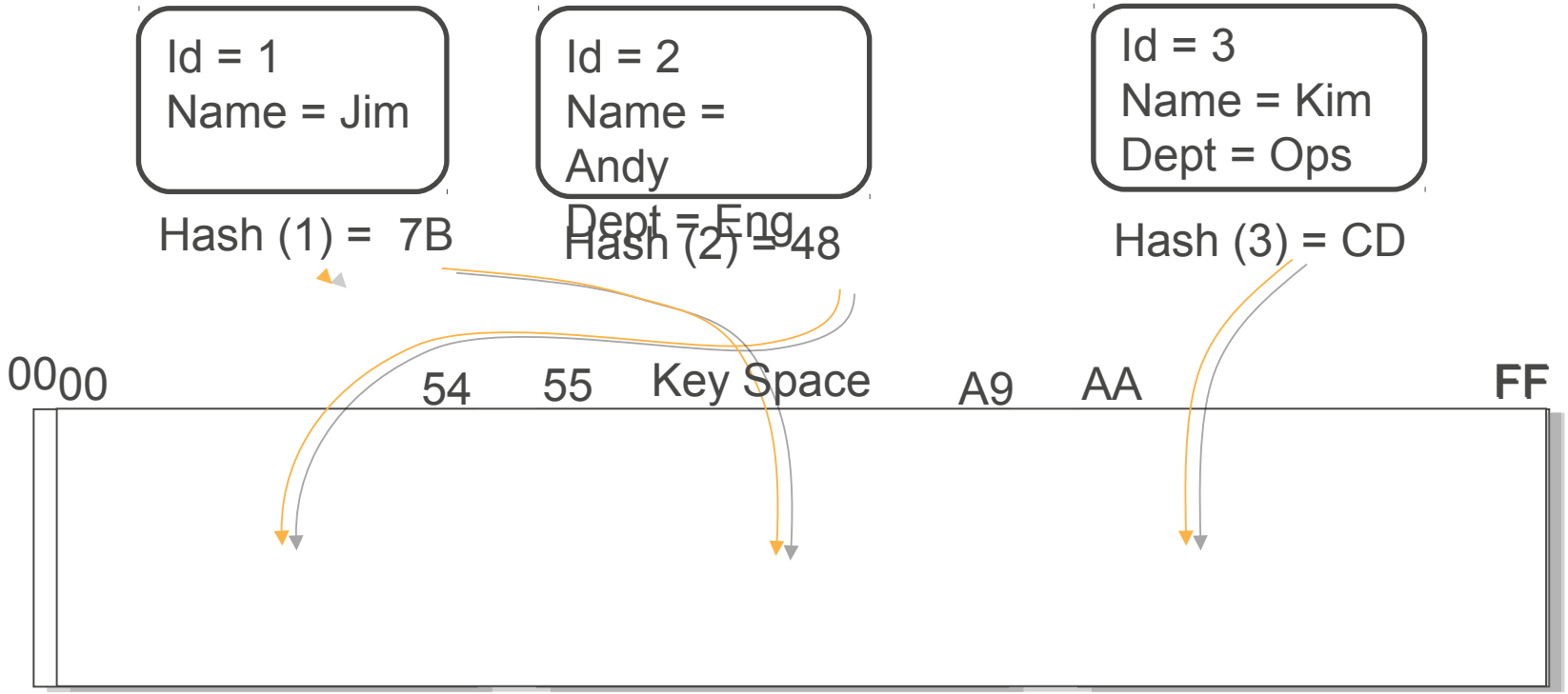

Mandatory
Key-value access pattern
Determines data distribution

Optional
Model 1:N relationships
Enables rich query capabilities

All items for key
==, <, >, >=, <=
“begins with”
“between”
“contains”
“in”
sorted results
counts
top/bottom N values

# Partition Keys

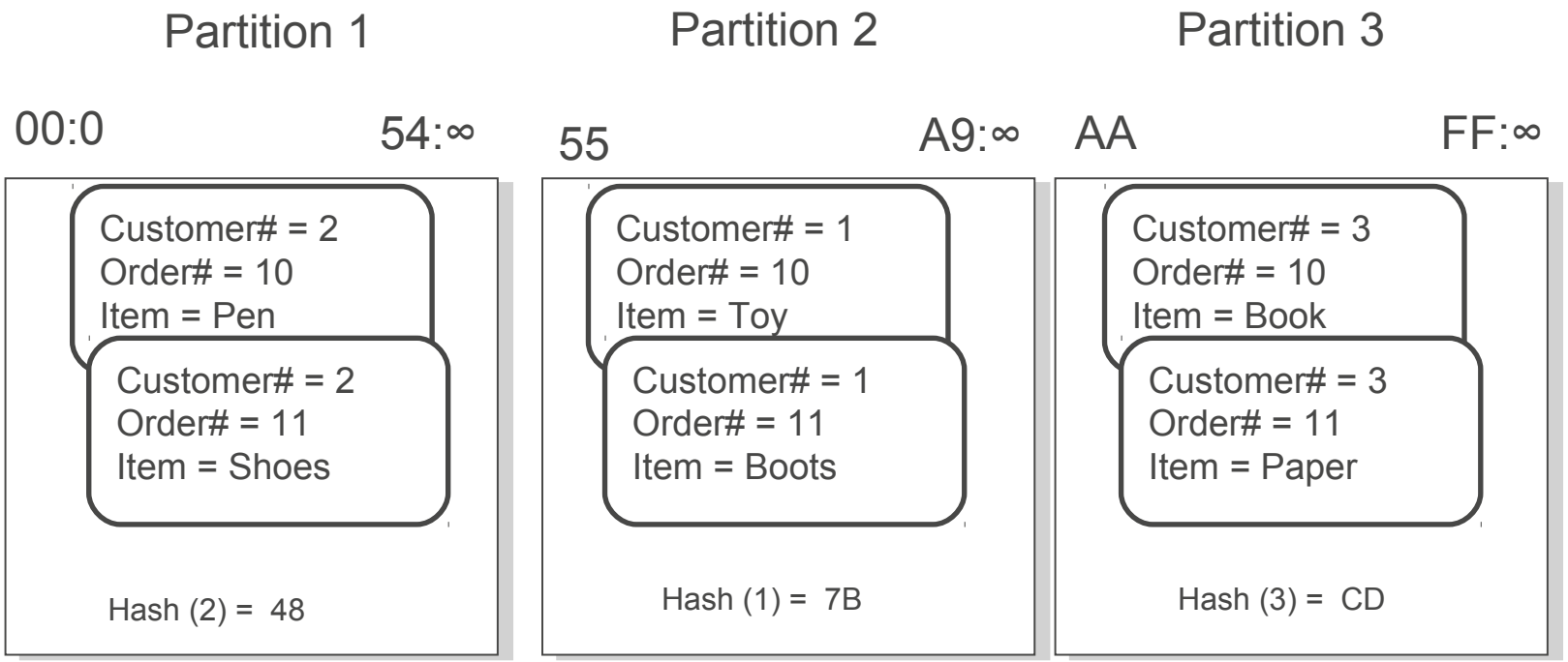
Partition Key uniquely identifies an item
Partition Key is used for building an unordered hash index
Allows table to be partitioned for scale



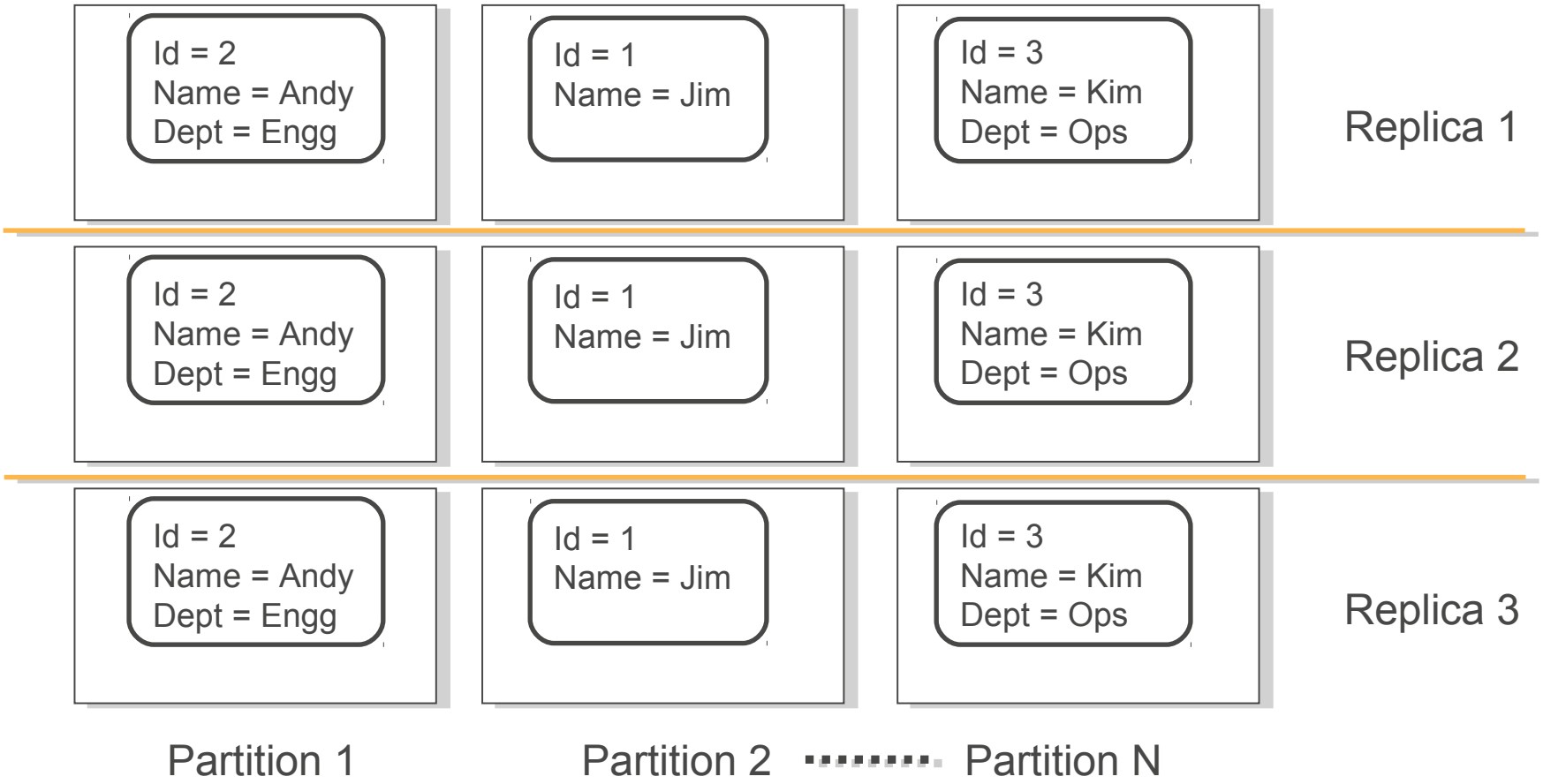
# Partition:Sort Key

Partition:Sort Key uses two attributes together to uniquely identify an Item
Within unordered hash index, data is arranged by the sort key
No limit on the number of items (∞) per partition key

- Except if you have local secondary indexes



# Partitions are three-way replicated

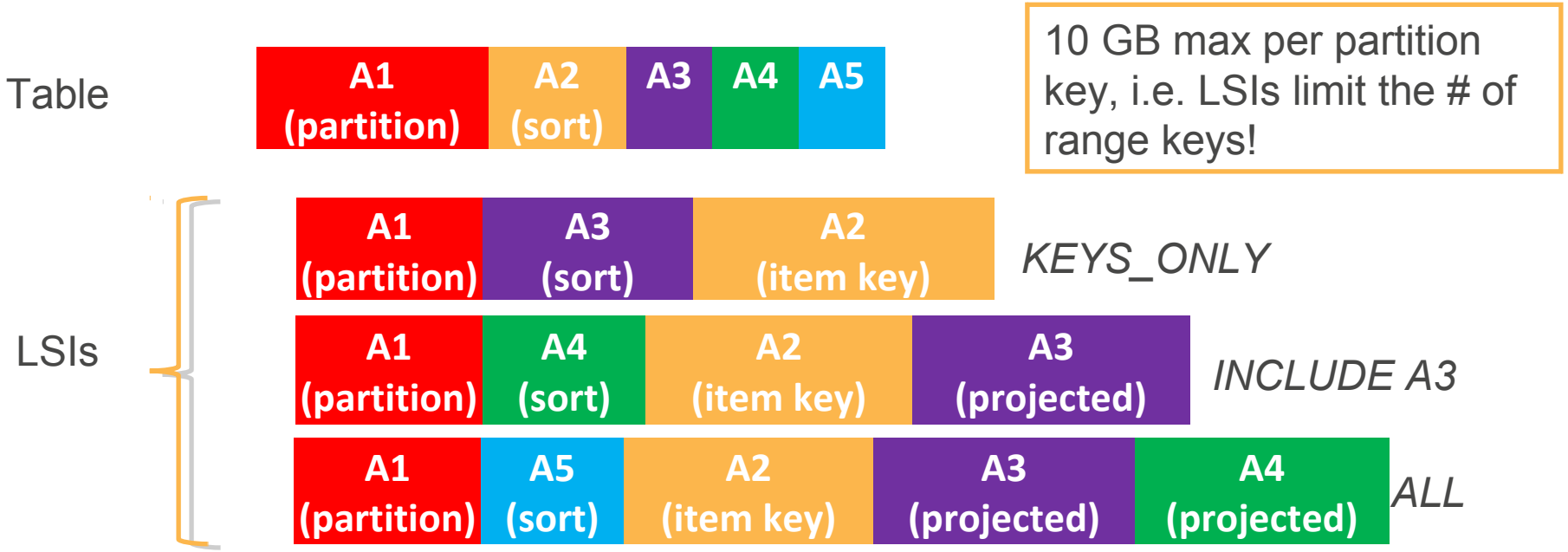


# Indexes

# Local secondary index (LSI)

Alternate sort key attribute

Index is local to a partition key



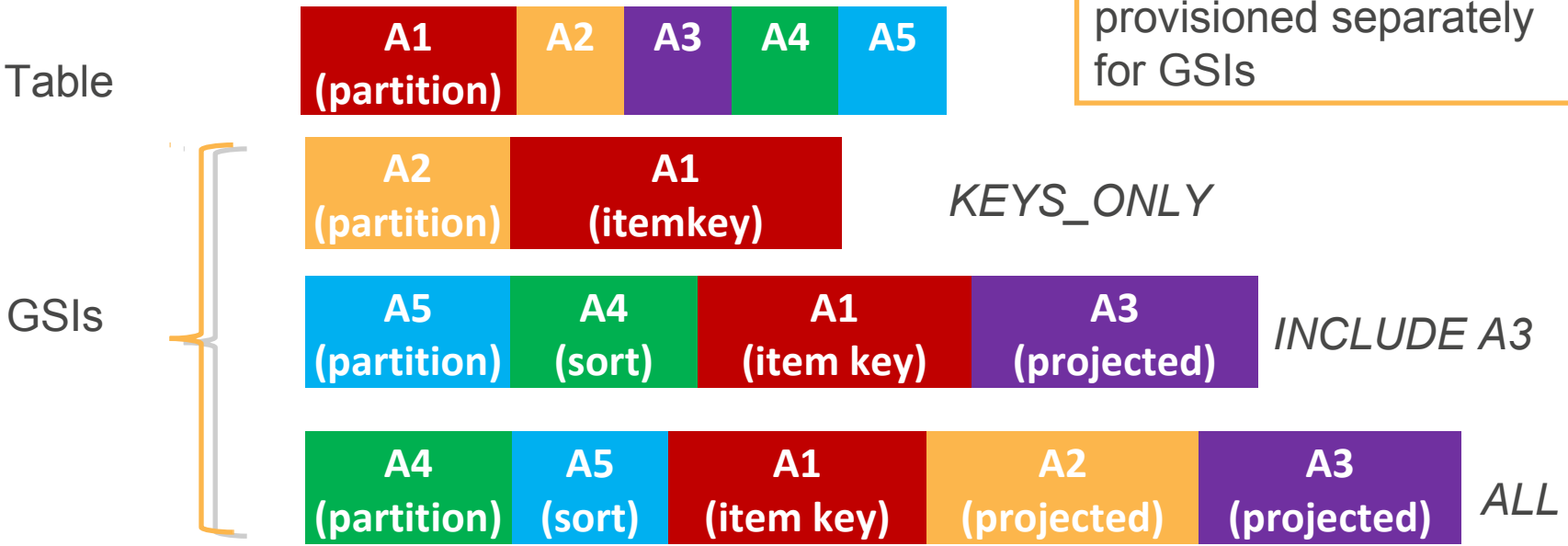
# Global secondary index (GSI)

Online indexing

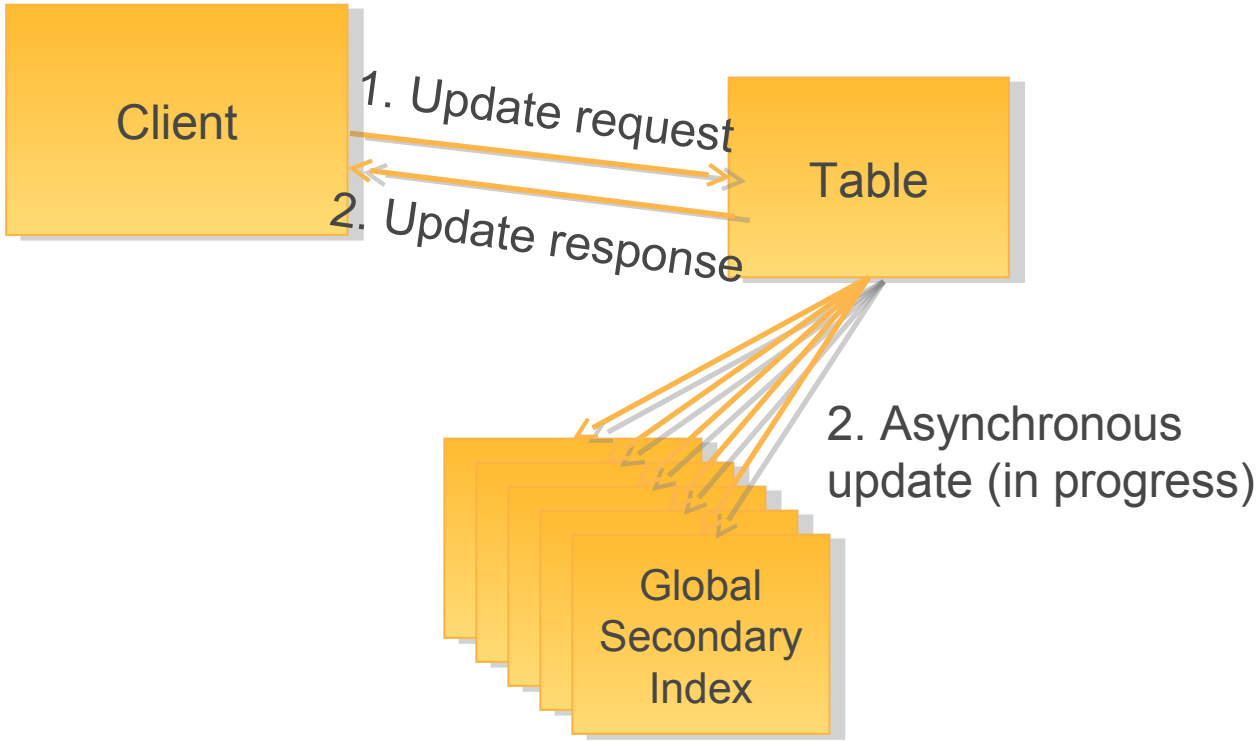
Alternate partition and/or sort key

Index is across all partition keys

RCUs/WCUs provisioned separately for GSIs



# How do GSI updates work?




If GSIs don’t have enough write capacity, table writes will be throttled!

# LSI or GSI?

LSI can be modeled as a GSI

If data size in an item collection > 10 GB, use GSI

**If eventual consistency is okay for your scenario, use GSI!**

# Scaling

# Scaling

## Throughput

- Provision any amount of throughput to a table

## Size

- Add any number of items to a table
  - Max item size is 400 KB
  - LSIs limit the number of range keys due to 10 GB limit

## Scaling is achieved through partitioning

# Throughput

Provisioned at the table level

- Write capacity units (WCUs) are measured in 1 KB per second
- Read capacity units (RCUs) are measured in 4 KB per second
  - RCUs measure strictly consistent reads
  - Eventually consistent reads cost 1/2 of consistent reads

Read and write throughput limits are independent

# Partitioning math

| Number of Partitions | |
|---|---|
| By Capacity | (Total RCU / 3000) + (Total WCU / 1000) |
| By Size | Total Size / 10 GB |
| Total Partitions | CEILING(MAX (Capacity, Size)) |

In the future, these details might change…

# Partitioning example

Table size = 8 GB, RCUs = 5000, WCUs = 500

| Number of Partitions | |
|---|---|
| By Capacity | (5000 / 3000) + (500 / 1000) = 2.17 |
| By Size | 8 / 10 = 0.8 |
| Total Partitions | CEILING(MAX (2.17, 0.8)) = 3 |

RCUs and WCUs are uniformly spread across partitions

RCUs per partition = 5000/3 = 1666.67
WCUs per partition = 500/3 = 166.67
Data/partition = 10/3 = 3.33 GB

# What causes throttling?

If **sustained** throughput goes beyond provisioned throughput per partition

Non-uniform workloads

- Hot keys/hot partitions
- Very large bursts

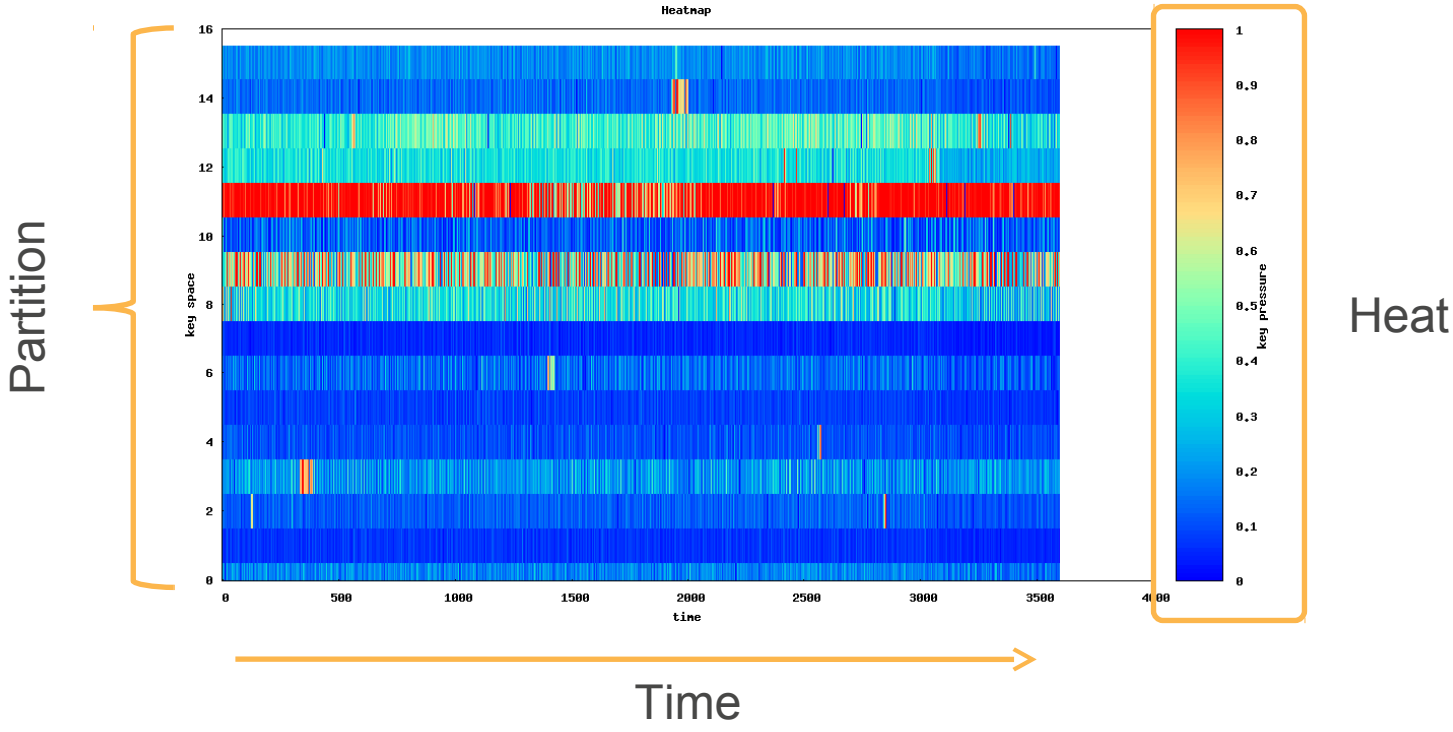
Mixing hot data with cold data

- Use a table per time period

From the example before:

- Table created with 5000 RCUs, 500 WCUs
- RCUs per partition = 1666.67
- WCUs per partition = 166.67
- If sustained throughput > (1666 RCUs or 166 WCUs) per key or partition, DynamoDB may throttle requests
  - Solution: Increase provisioned throughput

# What bad NoSQL looks like…



# Getting the most out of DynamoDB throughput

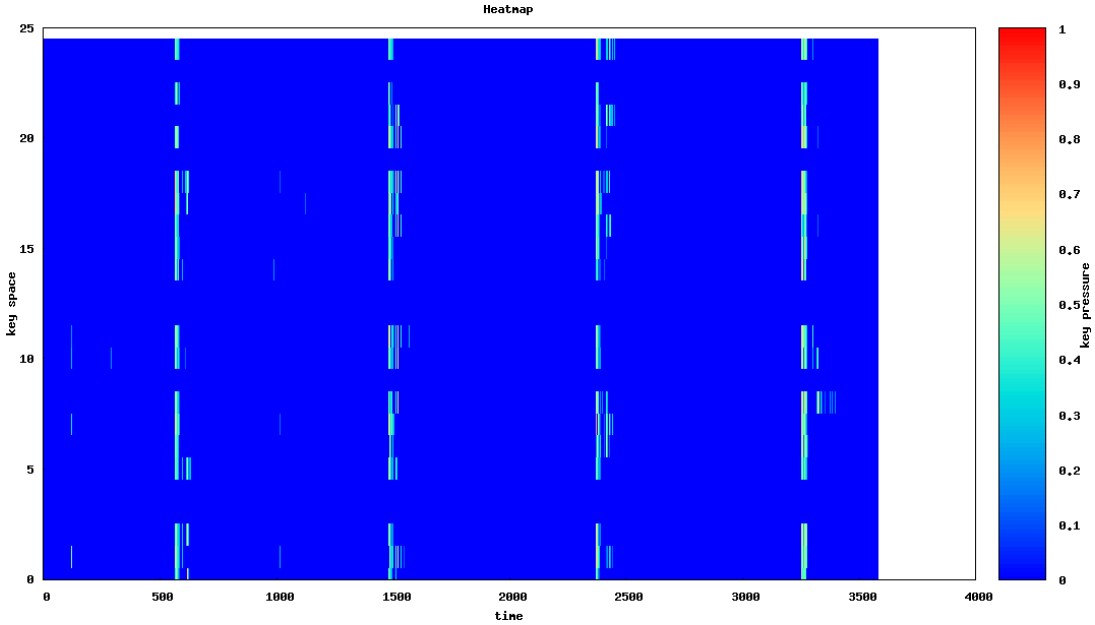
“To get the most out of DynamoDB throughput, create tables where the hash key element has a large number of distinct values, and values are requested fairly uniformly, as randomly as possible.”

—*DynamoDB Developer Guide*

Space: access is evenly spread over the key-space

Time: requests arrive evenly spaced in time

# Much better picture…



# Data modeling

# 1:1 relationships or key-values

Use a table or GSI with an alternate partition key

Use GetItem or BatchGetItem API

Example: Given an SSN or license number, get attributes

| Users Table | |
|---|---|
| Partiton key | Attributes |
| SSN = 123-45-6789 | Email = johndoe@nowhere.com, License = TDL25478134 |
| SSN = 987-65-4321 | Email = maryfowler@somewhere.com, License = TDL78309234 |

| Users-Email-GSI | |
|---|---|
| Partition key | Attributes |
| License = TDL78309234 | Email = maryfowler@somewhere.com, SSN = 987-65-4321 |
| License = TDL25478134 | Email = johndoe@nowhere.com, SSN = 123-45-6789 |

# 1:N relationships or parent-children

Use a table or GSI with partition and sort key

Use Query API

Example:

- Given a device, find all readings between epoch X, Y

| Device-measurements | | |
|---|---|---|
| Partition Key | Sort key | Attributes |
| DeviceId = 1 | epoch = 5513A97C | Temperature = 30, pressure = 90 |
| DeviceId = 1 | epoch = 5513A9DB | Temperature = 30, pressure = 90 |

# N:M relationships

Use a table and GSI with partition and sort key elements switched

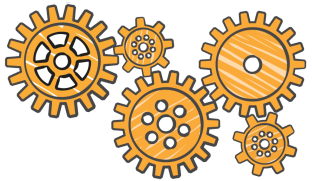
Use Query API

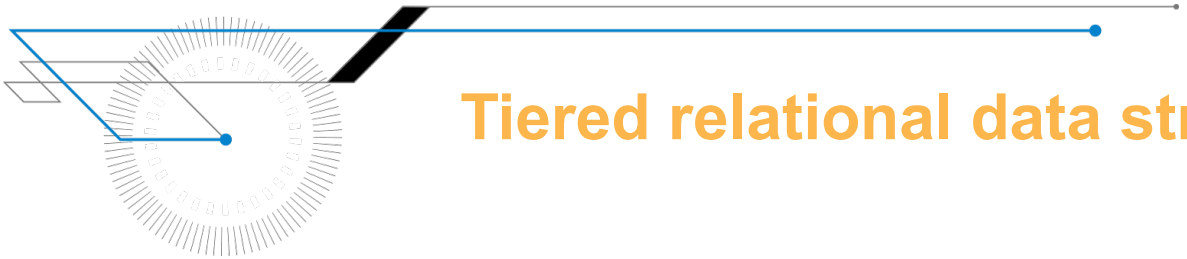
Example: Given a user, find all games. Or given a game, find all users.

| User-Games-Table | |
|---|---|
| Partition Key | Sort key |
| UserId = bob | GameId = Game1 |
| UserId = fred | GameId = Game2 |
| UserId = bob | GameId = Game3 |

| Game-Users-GSI | |
|---|---|
| Partition Key | Sort key |
| GameId = Game1 | UserId = bob |
| GameId = Game2 | UserId = fred |
| GameId = Game3 | UserId = bob |

# Hierarchical Data





## Tiered relational data structures

# Hierarchical Data Structures as Items…

Use composite sort key to define a Hierarchy
Highly selective result sets with sort queries
Index anything, scales to any size

| | Primary Key | | Attributes | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | ProductID | type | | | | | | | |
| Items | 1 | bookID | title | author | genre | publisher | datePublished | ISBN | |
| | | | Ringworld | Larry Niven | Science Fiction | Ballantine | Oct-70 | 0-345-02046-4 | |
| | 2 | albumID | title | artist | genre | label | studio | relesed | producer |
| | | | Dark Side of the Moon | Pink Floyd | Progressive Rock | Harvest | Abbey Road | 3/1/73 | Pink Floyd |
| | 2 | albumID:trackID | title | length | music | vocals | | | |
| | | | Speak to Me | 1:30 | Mason | Instrumental | | | |
| | 2 | albumID:trackID | title | length | music | vocals | | | |
| | | | Breathe | 2:43 | Waters, Gilmour, Wright | Gilmour | | | |
| | 2 | albumID:trackID | title | length | music | vocals | | | |
| | | | On the Run | 3:30 | Gilmour, Waters | Instrumental | | | |
| | 3 | movieID | title | genre | writer | producer | | | |
| | | | Idiocracy | Scifi Comedy | Mike Judge | 20th Century Fox | | | |
| | 3 | movieID:actorID | name | character | image | | | | |
| | | | Luke Wilson | Joe Bowers | img2.jpg | | | | |
| | 3 | movieID:actorID | name | character | image | | | | |
| | | | Maya Rudolph | Rita | img3.jpg | | | | |
| | 3 | movieID:actorID | name | character | image | | | | |
| | | | Dax Shepard | Frito Pendejo | img1.jpg | | | | |

# … or as Documents (JSON)

JSON data types (M, L, BOOL, NULL)

Document SDKs Available

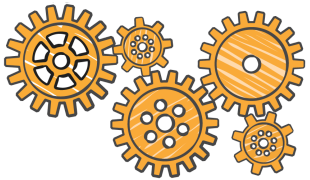
Indexing only via Streams/Lambda

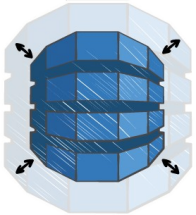
400KB max item size (limits hierarchical data structure)

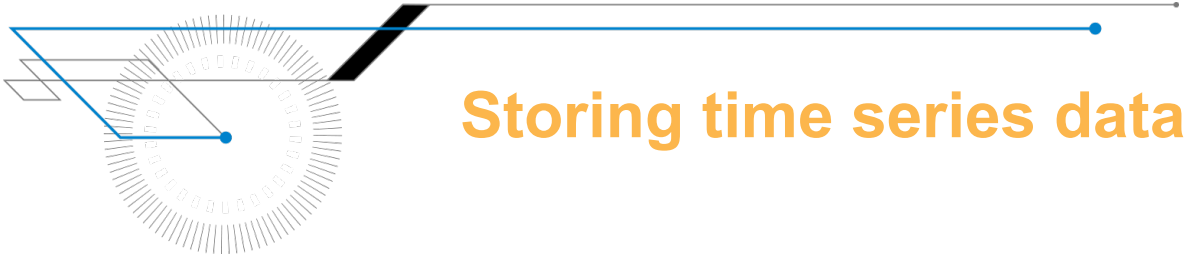
| | Primary Key ProductID | Attributes | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Items | 1 | id | title | author | genre | publisher | datePublished | ISBN | |
| | | bookID | Ringworld | Larry Niven | Science Fiction | Ballantine | Oct-70 | 0-345-02046-4 | |
| | 2 | id | title | artist | genre | Attributes | | | |
| | | albumID | Dark Side of the Moon | Pink Floyd | Progressive Rock | { label:"Harvest", studio: "Abbey Road", published: "3/1/73", producer: "Pink Floyd", tracks: [{title: "Speak to Me", length: "1:30", music: "Mason", vocals: "Instrumental"},{title: "Breathe", length: "2:43", music: "Waters, Gilmour, Wright", vocals: "Gilmour"},{title: "On the Run", length: "3:30", music: "Gilmour, Waters", vocals: "Instrumental"}]} | | | |
| | 3 | id | title | genre | writer | Attributes | | | |
| | | movieID | Idiocracy | Scifi Comedy | Mike Judge | { producer: "20th Century Fox", actors: [{ name: "Luke Wilson", dob: "9/21/71", character: "Joe Bowers", image: "img2.jpg"},{ name: "Maya Rudolph", dob: "7/27/72", character: "Rita", image: "img1.jpg"},{ name: "Dax Shepard", dob: "1/2/75", character: "Frito Pendejo", image: "img3.jpg"}] | | | |

# Scenarios and best practices

# Event logging

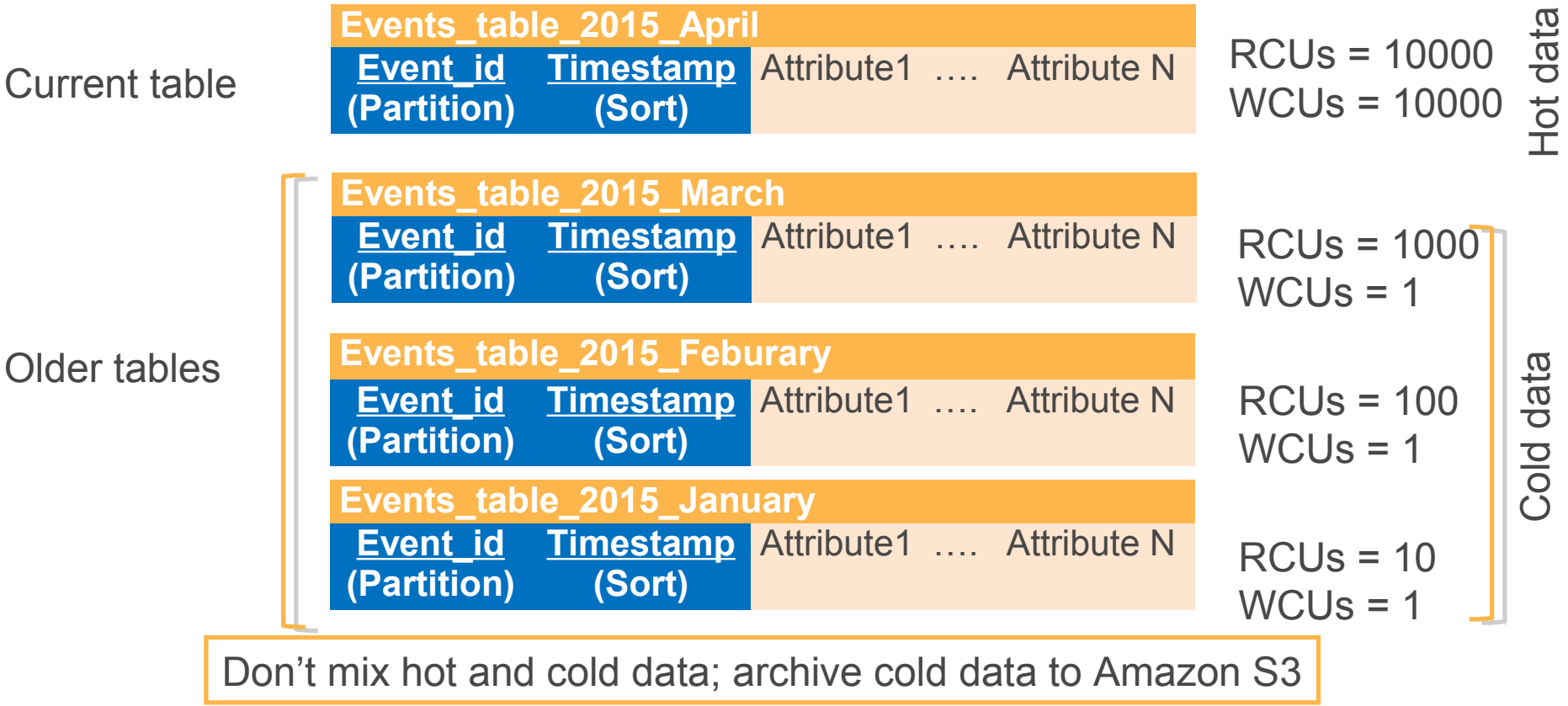






## Storing time series data

# Time series tables



# Use a table per time period

Pre-create daily, weekly, monthly tables

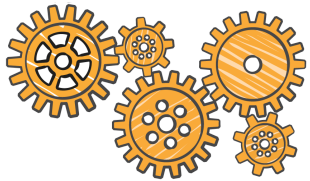
Provision required throughput for current table

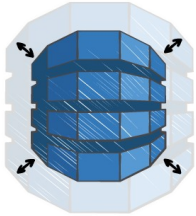
Writes go to the current table

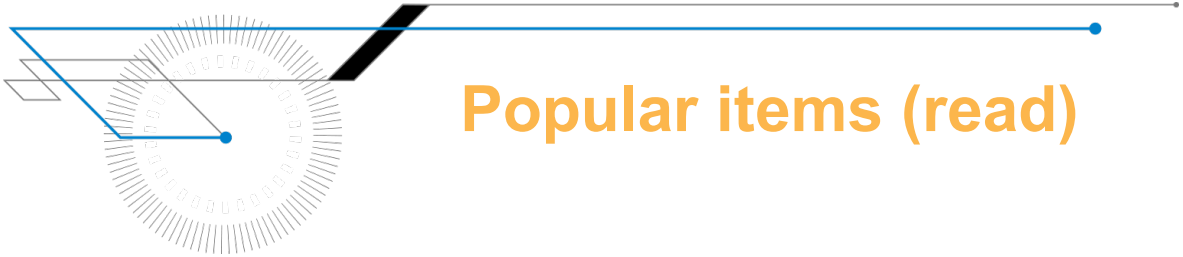
Turn off (or reduce) throughput for older tables

**Important when:** Dealing with time series data

# Product catalog



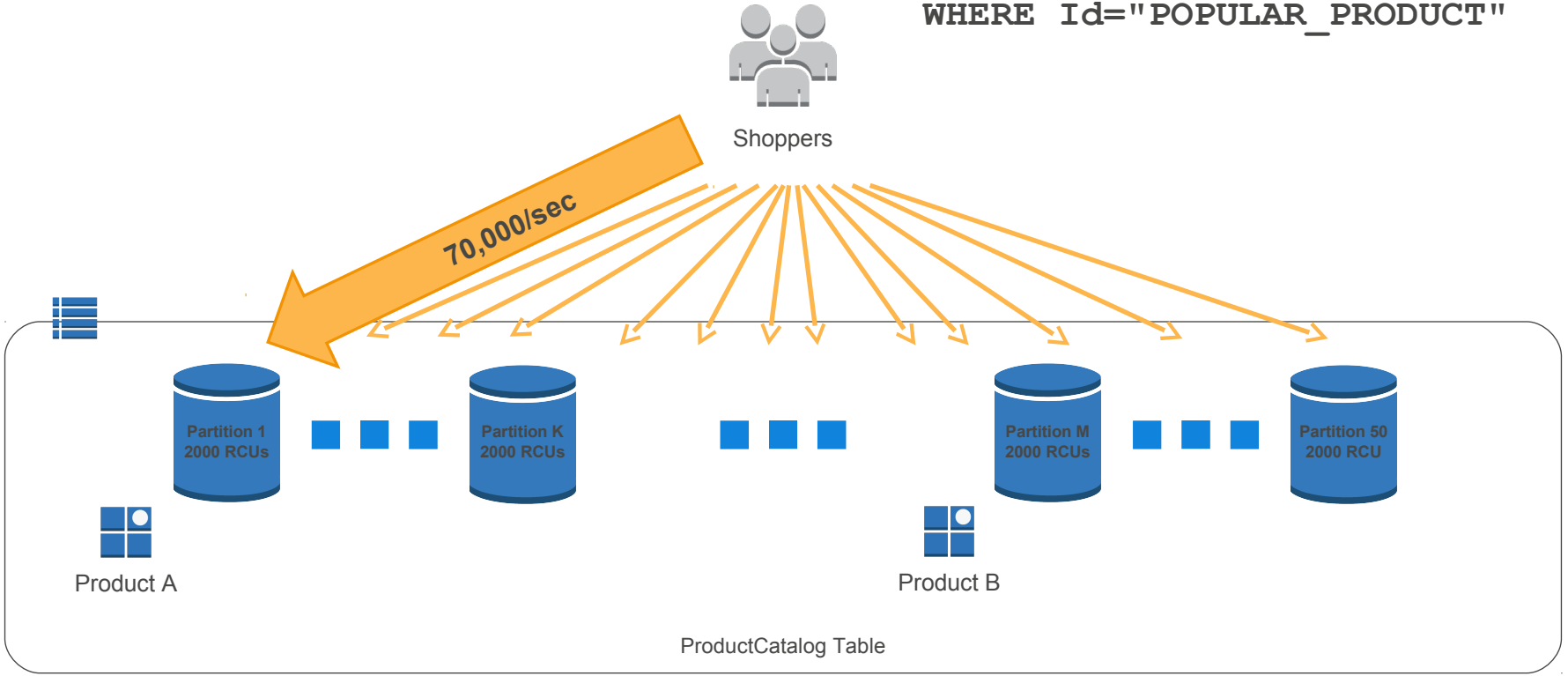


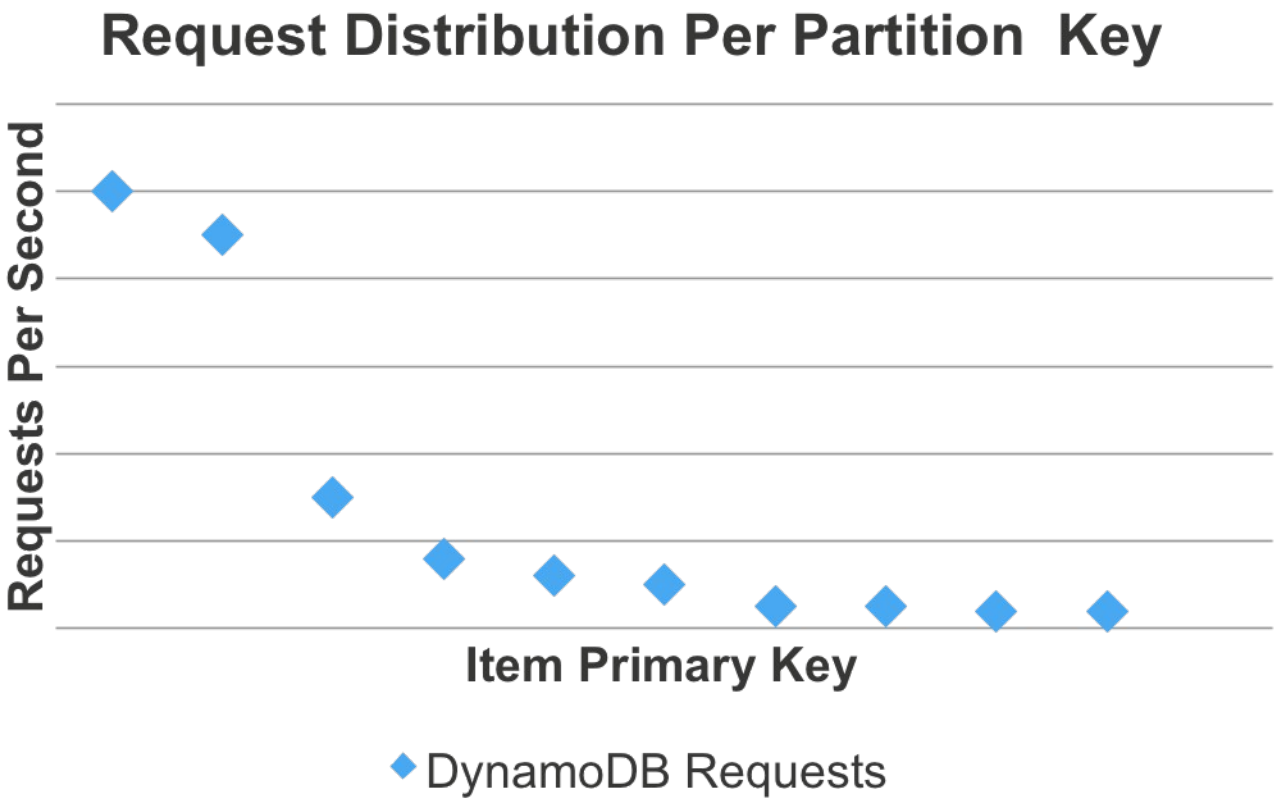


## Popular items (read)

# Scaling bottlenecks

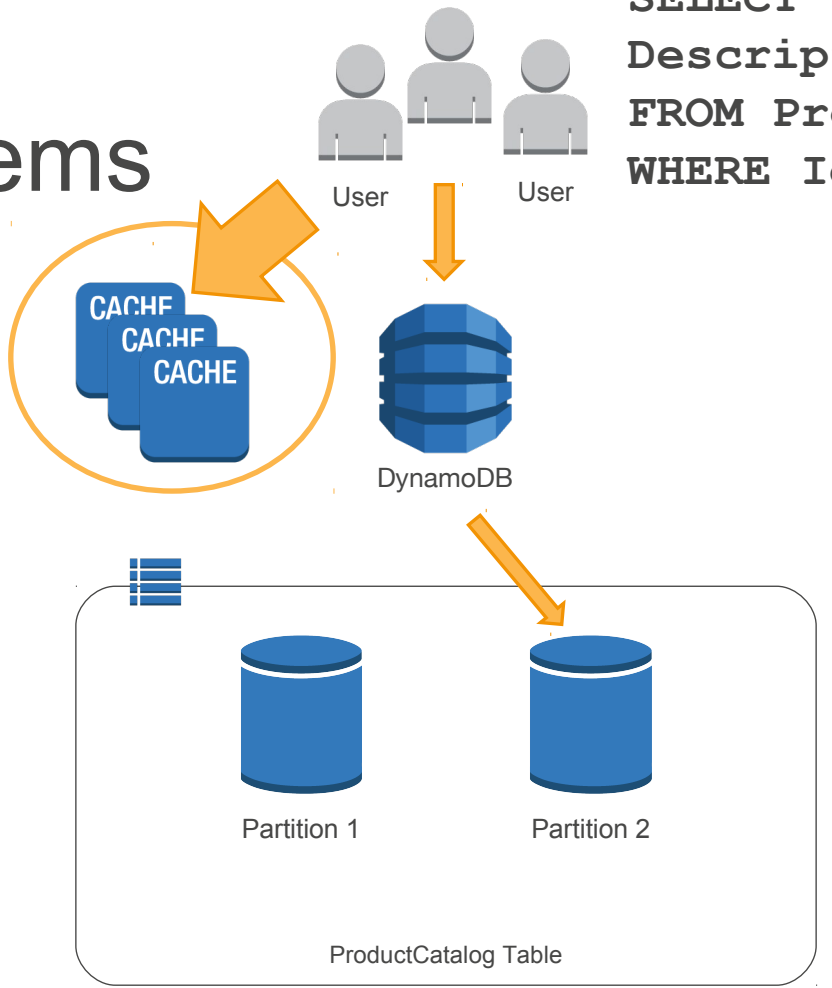
```
SELECT Id, Description, ...
FROM ProductCatalog
WHERE Id="POPULAR_PRODUCT"
```

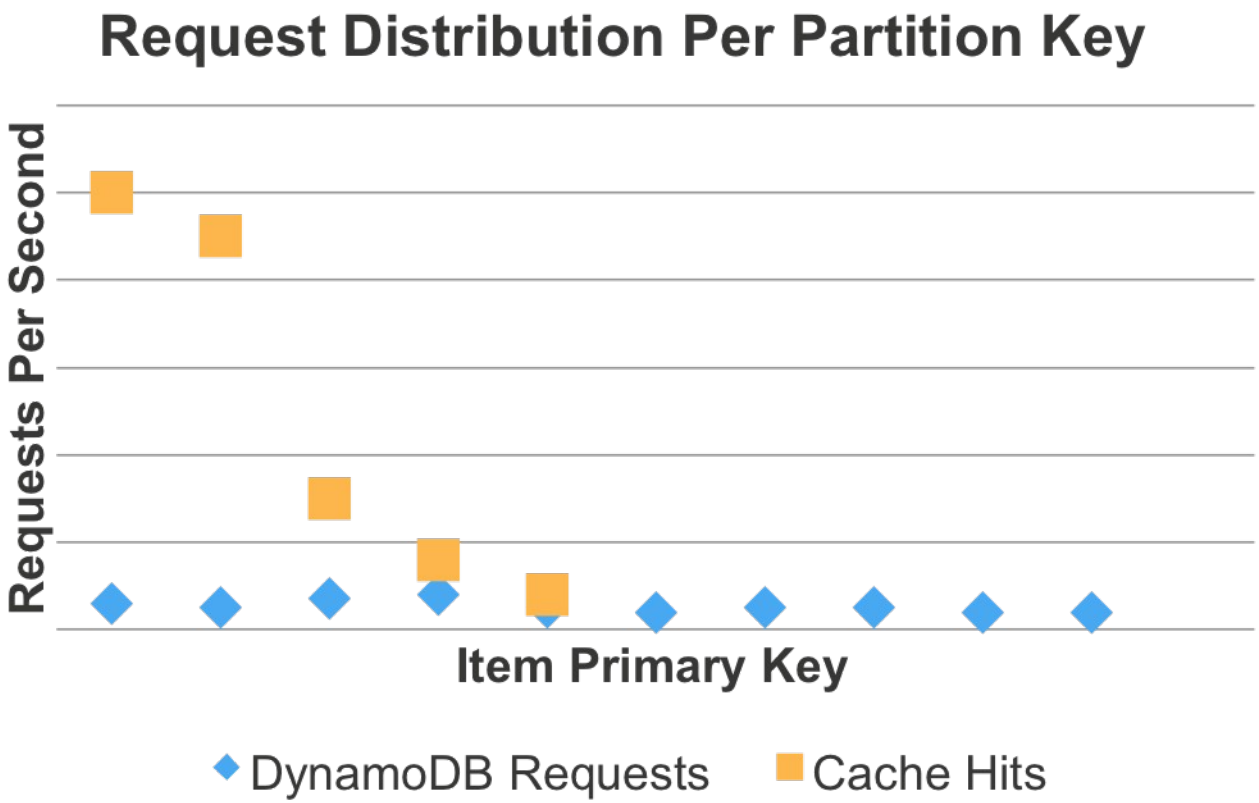



Request Distribution Per Partition Key
Requests Per Second
Item Primary Key
DynamoDB Requests

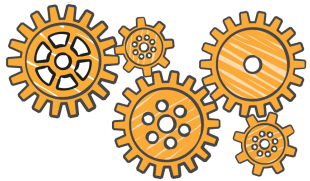
# Cache popular items

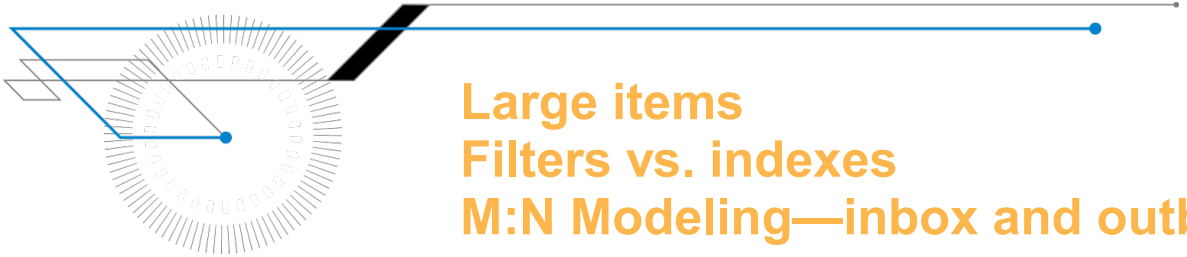
```
SELECT Id,
Description, ...
FROM ProductCatalog
WHERE Id="POPULAR_PRODUCT"
```



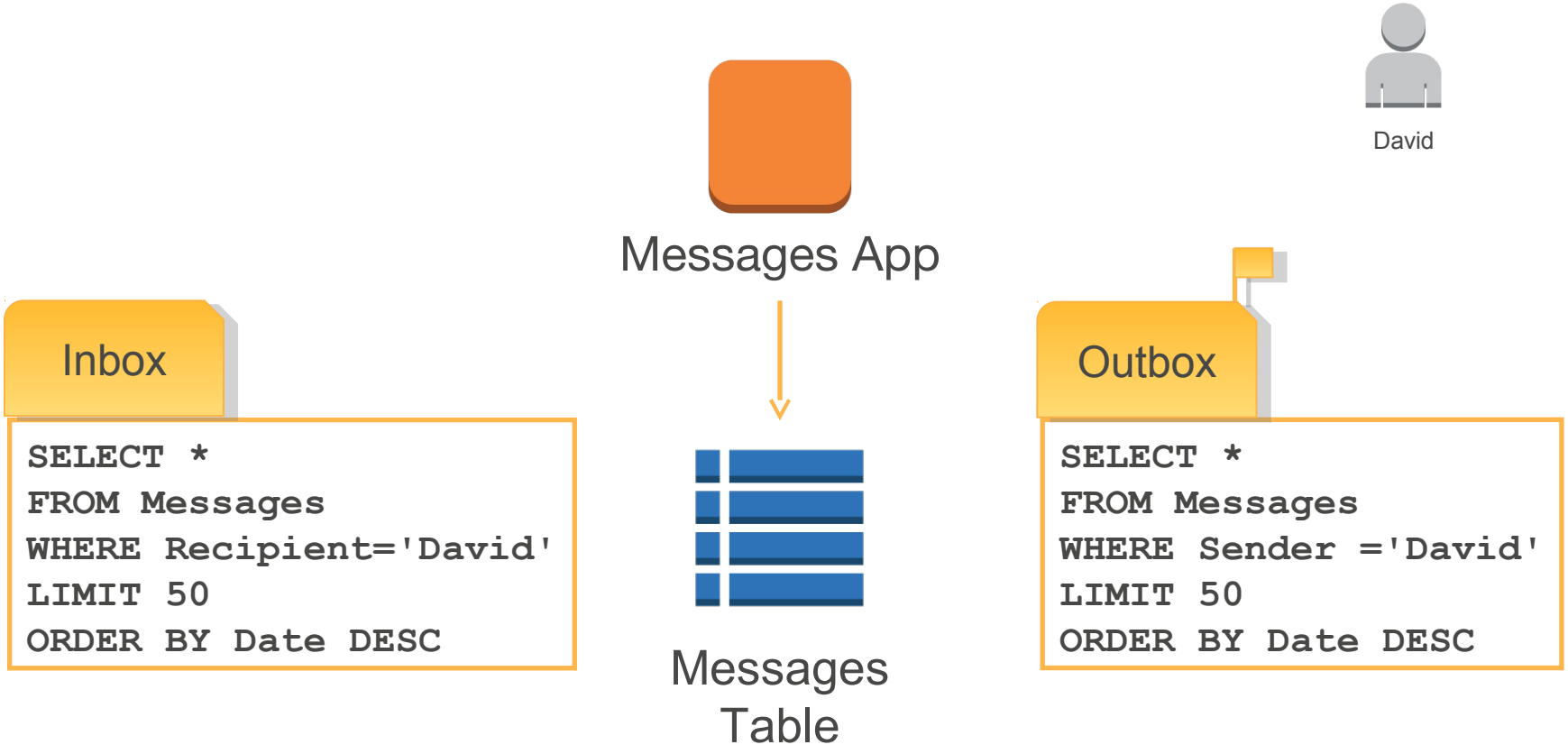

Request Distribution Per Partition Key
Requests Per Second
Item Primary Key
DynamoDB Requests
Cache Hits

# Messaging app





Large items
Filters vs. indexes
M:N Modeling—inbox and outbox


David
Messages App
Inbox
SELECT *
FROM Messages
WHERE Recipient='David'
LIMIT 50
ORDER BY Date DESC
Messages
Table
Outbox
SELECT *
FROM Messages
WHERE Sender ='David'
LIMIT 50
ORDER BY Date DESC

# Large and small attributes mixed

David

Inbox

```
SELECT *
FROM Messages
WHERE Recipient='David'
LIMIT 50
ORDER BY Date DESC
```

Partition key

Sort key

Messages Table

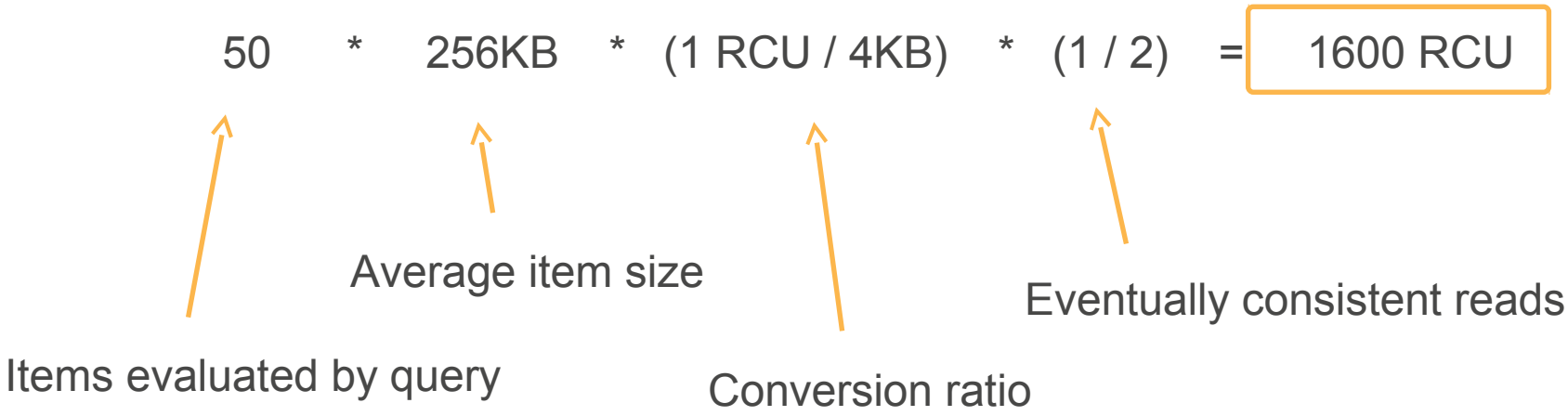
| Recipient | Date | Sender | Message |
|---|---|---|---|
| David | 2014-10-02 | Bob | … |
| … 48 more messages for David … | | | |
| David | 2014-10-03 | Alice | … |
| Alice | 2014-09-28 | Bob | … |
| Alice | 2014-10-01 | Carol | … |

(Many more messages)

50 items × 256 KB each

Large message bodies
Attachments

# Computing inbox query cost



# Separate the bulk data

Uniformly distributes large item reads

(50 sequential items at 128 bytes)

1. Query Inbox-GSI: 1 RCU
2. BatchGetItem Messages: 1600 RCU

(50 separate items at 256 KB)

Inbox-GSI

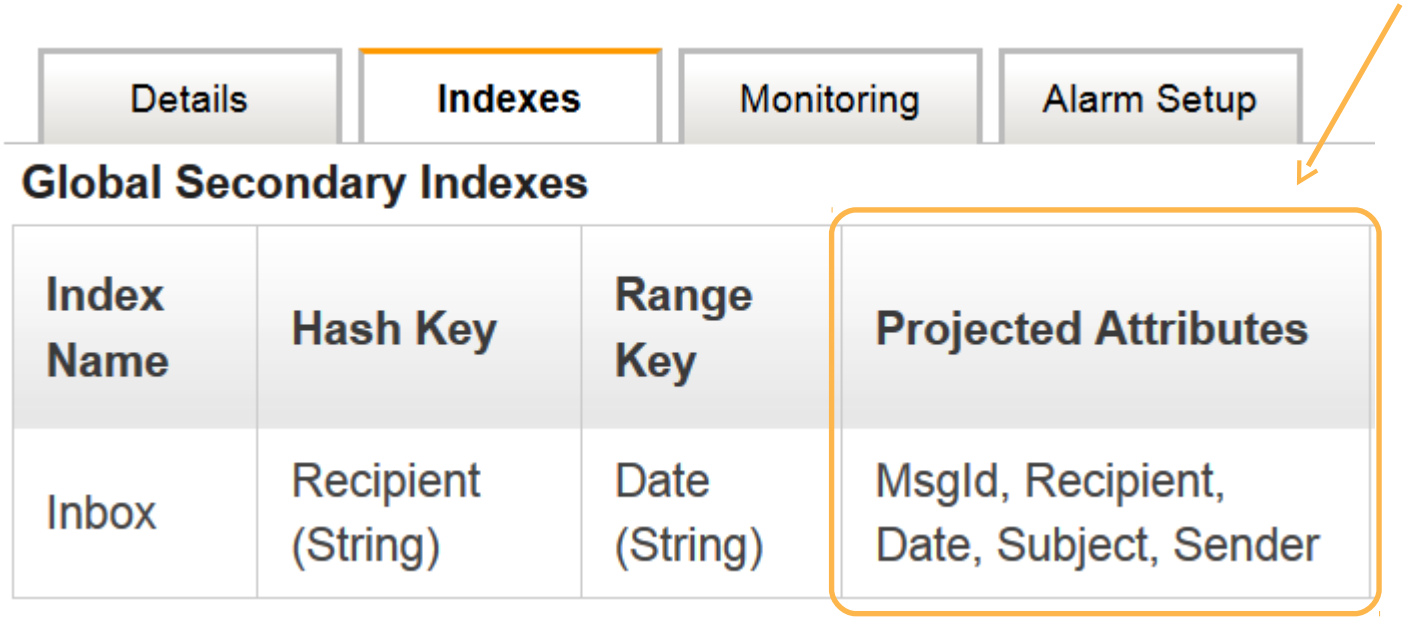
| Recipient | Date | Sender | Subject | MsgId |
|---|---|---|---|---|
| David | 2014-10-02 | Bob | Hi!… | afed |
| David | 2014-10-03 | Alice | RE: The… | 3kf8 |
| Alice | 2014-09-28 | Bob | FW: Ok… | 9d2b |
| Alice | 2014-10-01 | Carol | Hi!... | ct7r |

Messages Table

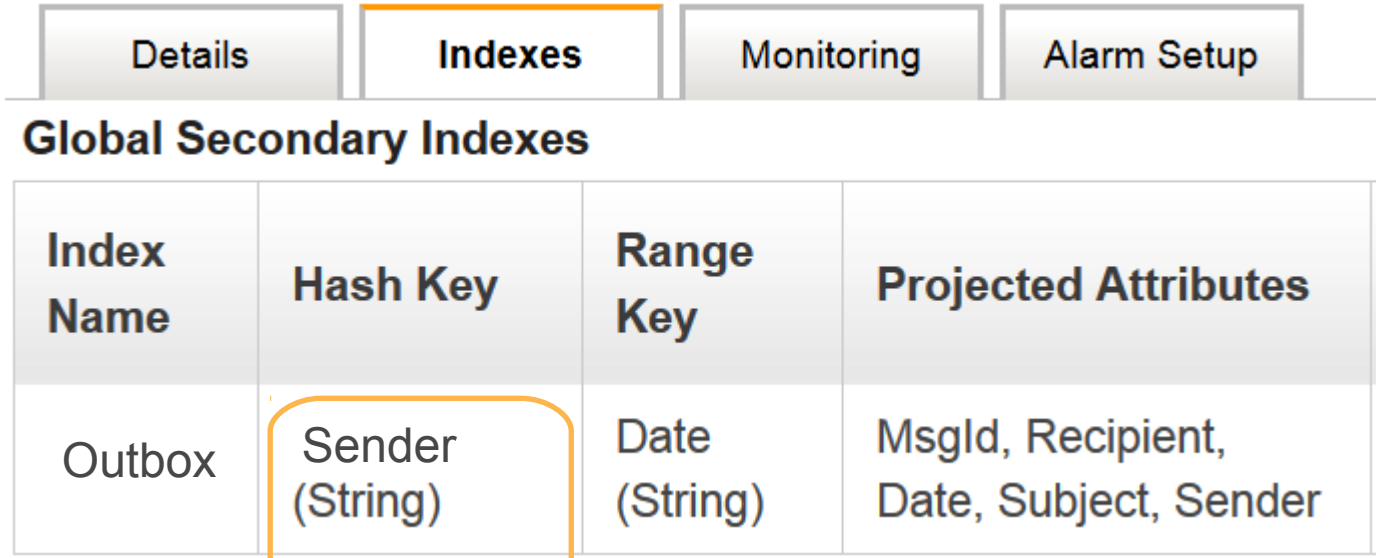
| MsgId | Body |
|---|---|
| 9d2b | … |
| 3kf8 | … |
| ct7r | … |
| afed | … |

# Inbox GSI

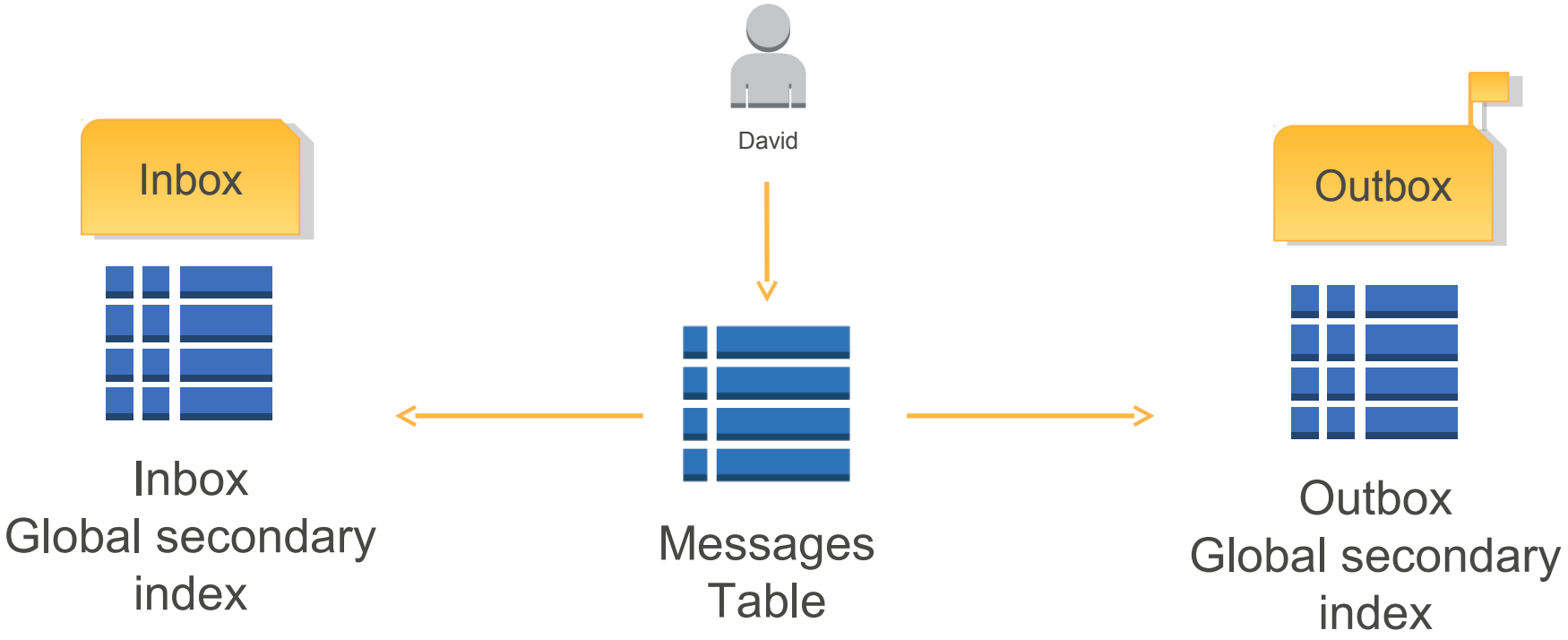
Define which attributes to copy into the index



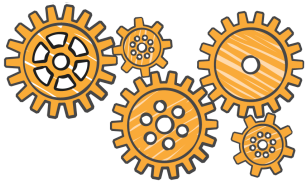
# Outbox GSI


Details
Indexes
Monitoring
Alarm Setup
Global Secondary Indexes
Index Name
Hash Key
Range Key
Projected Attributes
Outbox
Sender (String)
Date (String)
MsgId, Recipient, Date, Subject, Sender
SELECT *
FROM Messages
WHERE Sender ='David'
LIMIT 50
ORDER BY Date DESC

# Messaging app



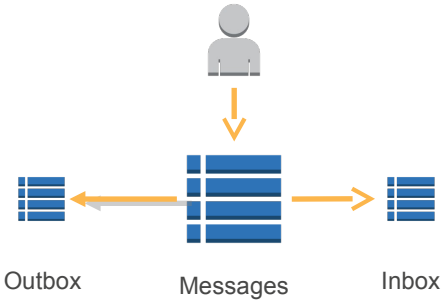
# Distribute large items



Reduce one-to-many item sizes

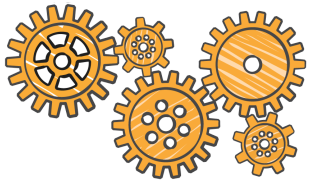
Configure secondary index projections

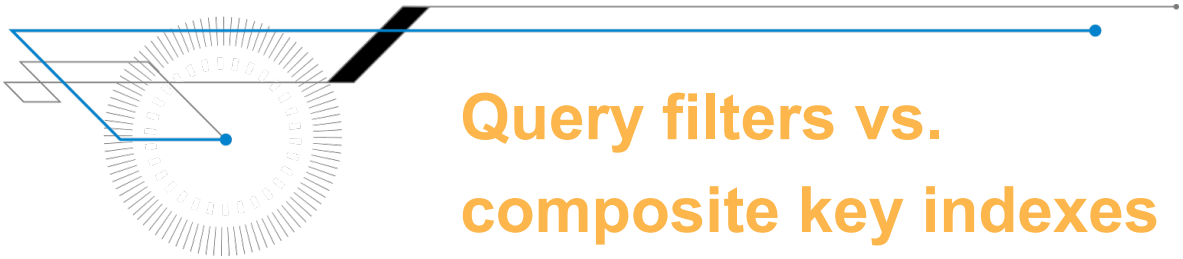
Use GSIs to model M:N relationship between sender and recipient




**Important when:** Querying many large items at once

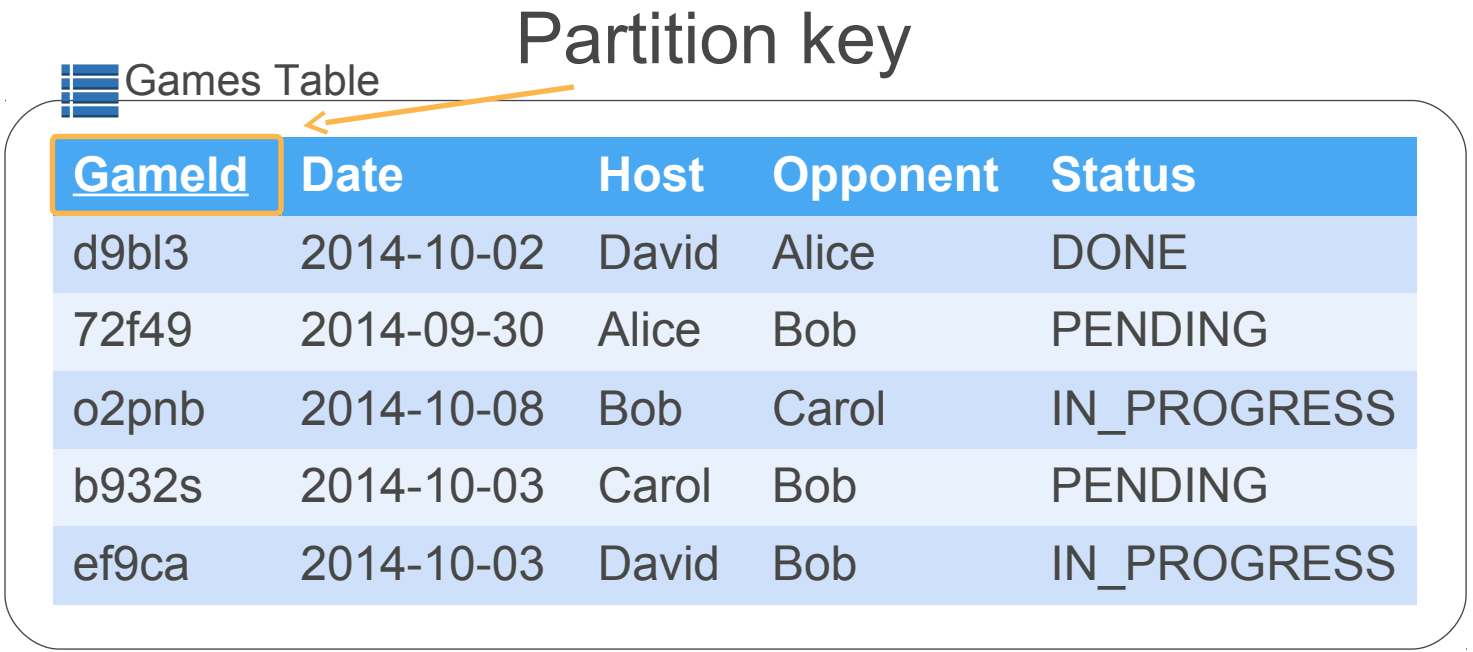
# Multiplayer online gaming





## Query filters vs. composite key indexes

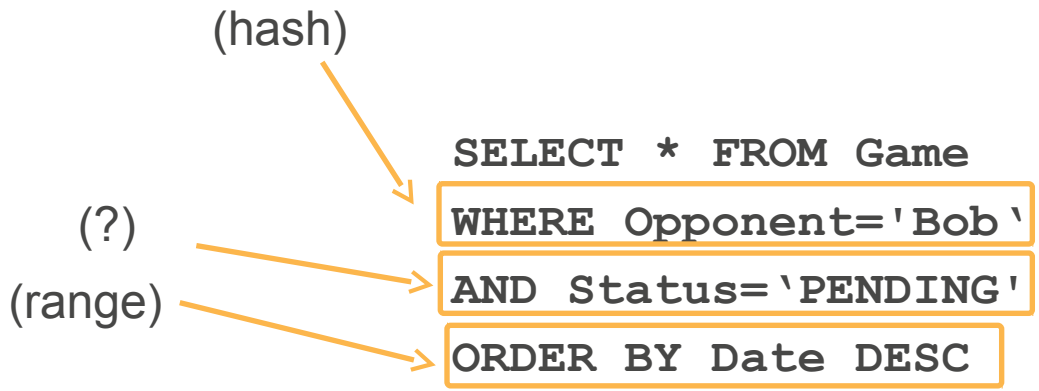
# Hierarchical Data Structures



# Query for incoming game requests

DynamoDB indexes provide partiton and sort

What about queries for two equalities and a sort?



# Approach 1: Query filter

Partition key

Sort key

Secondary Index

| Opponent | Date | GameId | Status | Host |
|---|---|---|---|---|
| Alice | 2014-10-02 | d9bl3 | DONE | David |
| Carol | 2014-10-08 | o2pnb | IN_PROGRESS | Bob |
| Bob | 2014-09-30 | 72f49 | PENDING | Alice |
| Bob | 2014-10-03 | b932s | PENDING | Carol |
| Bob | 2014-10-03 | ef9ca | IN_PROGRESS | David |

# Approach 1: Query filter

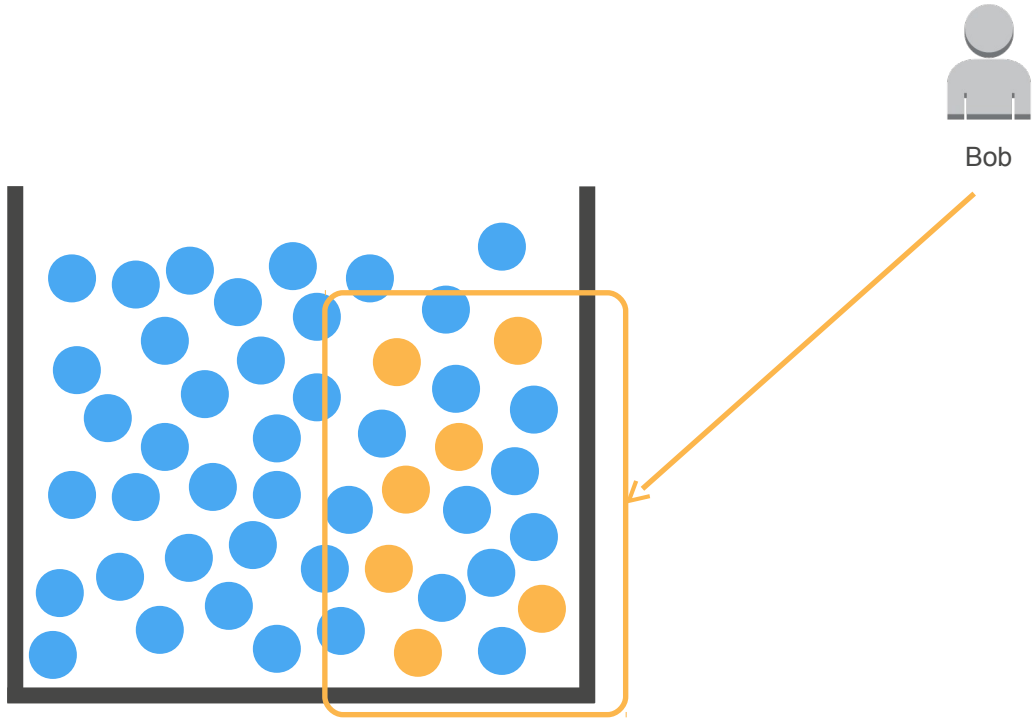
```
SELECT * FROM Game
WHERE Opponent='Bob'
ORDER BY Date DESC
FILTER ON Status='PENDING'
```

Secondary Index

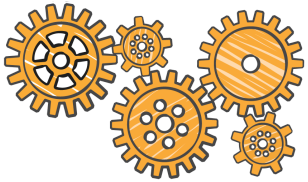
| Opponent | Date | GameId | Status | Host |
|---|---|---|---|---|
| Alice | 2014-10-02 | d9bl3 | DONE | David |
| Carol | 2014-10-08 | o2pnb | IN_PROGRESS | Bob |
| Bob | 2014-09-30 | 72f49 | PENDING | Alice |
| Bob | 2014-10-03 | b932s | PENDING | Carol |
| Bob | 2014-10-03 | ef9ca | IN_PROGRESS | David |

(filtered out)

# Needle in a haystack



# Use query filter



Send back less data “on the wire”

Simplify application code

Simple SQL-like expressions

- AND, OR, NOT, ()

**Important when:** Your index isn’t entirely selective

# Approach 2: Composite key

| Status |
| --- |
| DONE |
| IN_PROGRESS |
| IN_PROGRESS |
| PENDING |
| PENDING |

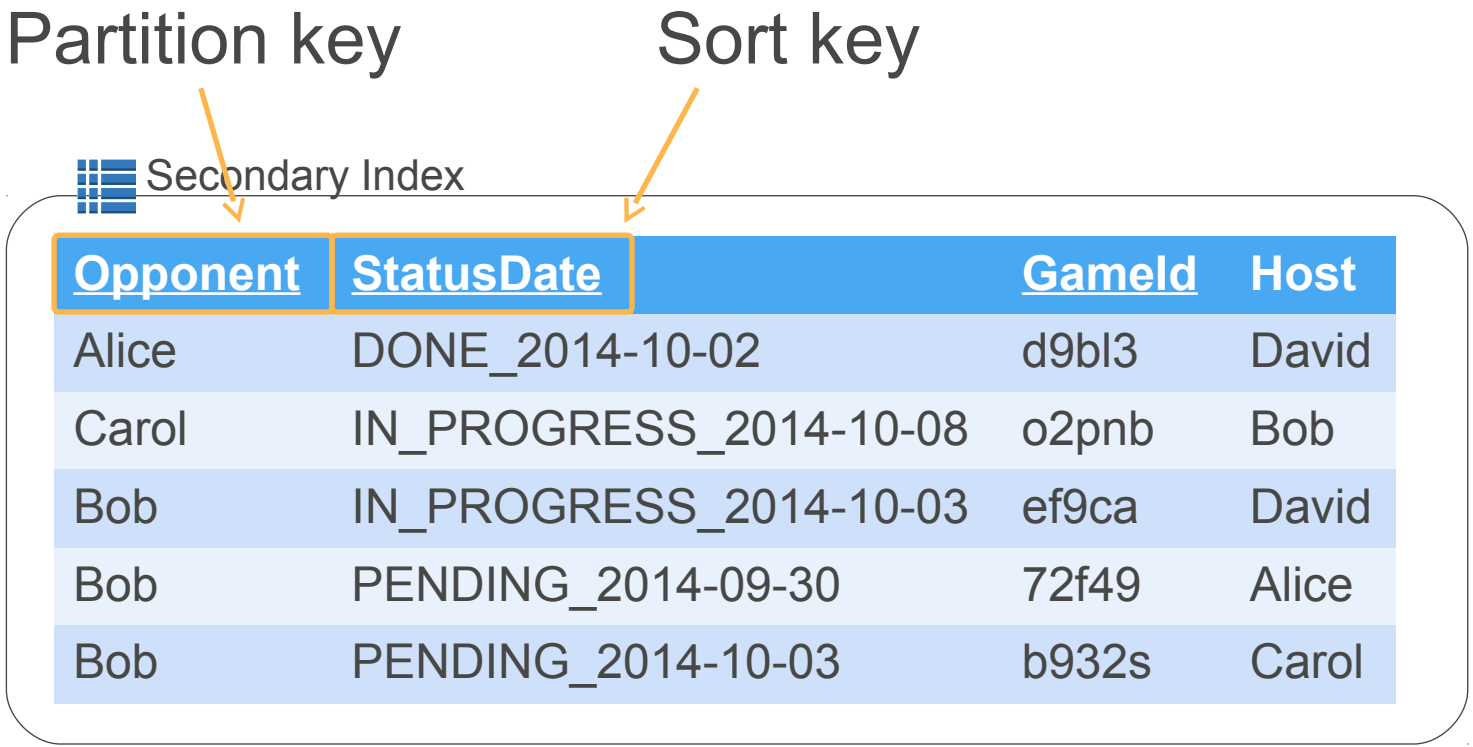
+

| Date |
| --- |
| 2014-10-02 |
| 2014-10-08 |
| 2014-10-03 |
| 2014-10-03 |
| 2014-09-30 |

=

| StatusDate |
| --- |
| DONE_2014-10-02 |
| IN_PROGRESS_2014-10-08 |
| IN_PROGRESS_2014-10-03 |
| PENDING_2014-09-30 |
| PENDING_2014-10-03 |

# Approach 2: Composite key




| Opponent | StatusDate | GameId | Host |
|---|---|---|---|
| Alice | DONE_2014-10-02 | d9bl3 | David |
| Carol | IN_PROGRESS_2014-10-08 | o2pnb | Bob |
| Bob | IN_PROGRESS_2014-10-03 | ef9ca | David |
| Bob | PENDING_2014-09-30 | 72f49 | Alice |
| Bob | PENDING_2014-10-03 | b932s | Carol |

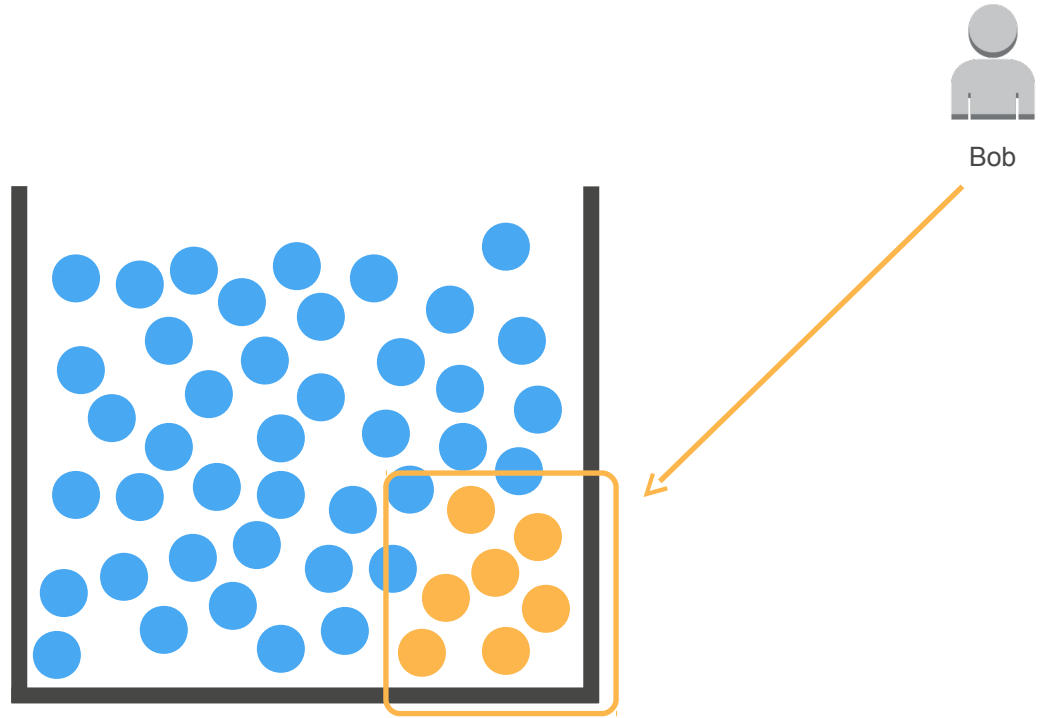
# Approach 2: Composite key

```
SELECT * FROM Game
WHERE Opponent='Bob'
    AND StatusDate BEGINS_WITH 'PENDING'
```

Secondary Index

| Opponent | StatusDate | GameId | Host |
|---|---|---|---|
| Alice | DONE_2014-10-02 | d9bl3 | David |
| Carol | IN_PROGRESS_2014-10-08 | o2pnb | Bob |
| Bob | IN_PROGRESS_2014-10-03 | ef9ca | David |
| Bob | PENDING_2014-09-30 | 72f49 | Alice |
| Bob | PENDING_2014-10-03 | b932s | Carol |

# Needle in a *sorted* haystack



# Sparse indexes

Game-scores-table

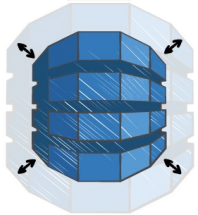
| Id (Partition) | User | Game | Score | Date | Award |
|---|---|---|---|---|---|
| 1 | Bob | G1 | 1300 | 2012-12-23 | |
| 2 | Bob | G1 | 1450 | 2012-12-23 | |
| 3 | Jay | G1 | 1600 | 2012-12-24 | |
| 4 | Mary | G1 | 2000 | 2012-10-24 | Champ |
| 5 | Ryan | G2 | 123 | 2012-03-10 | |
| 6 | Jones | G2 | 345 | 2012-03-20 | |

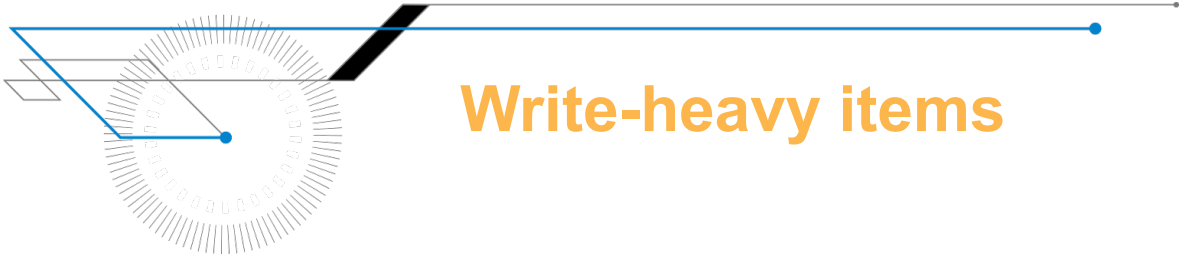
Scan sparse GSIs

Award-GSI

| Award (Partition) | Id | User | Score |
|---|---|---|---|
| Champ | 4 | Mary | 2000 |

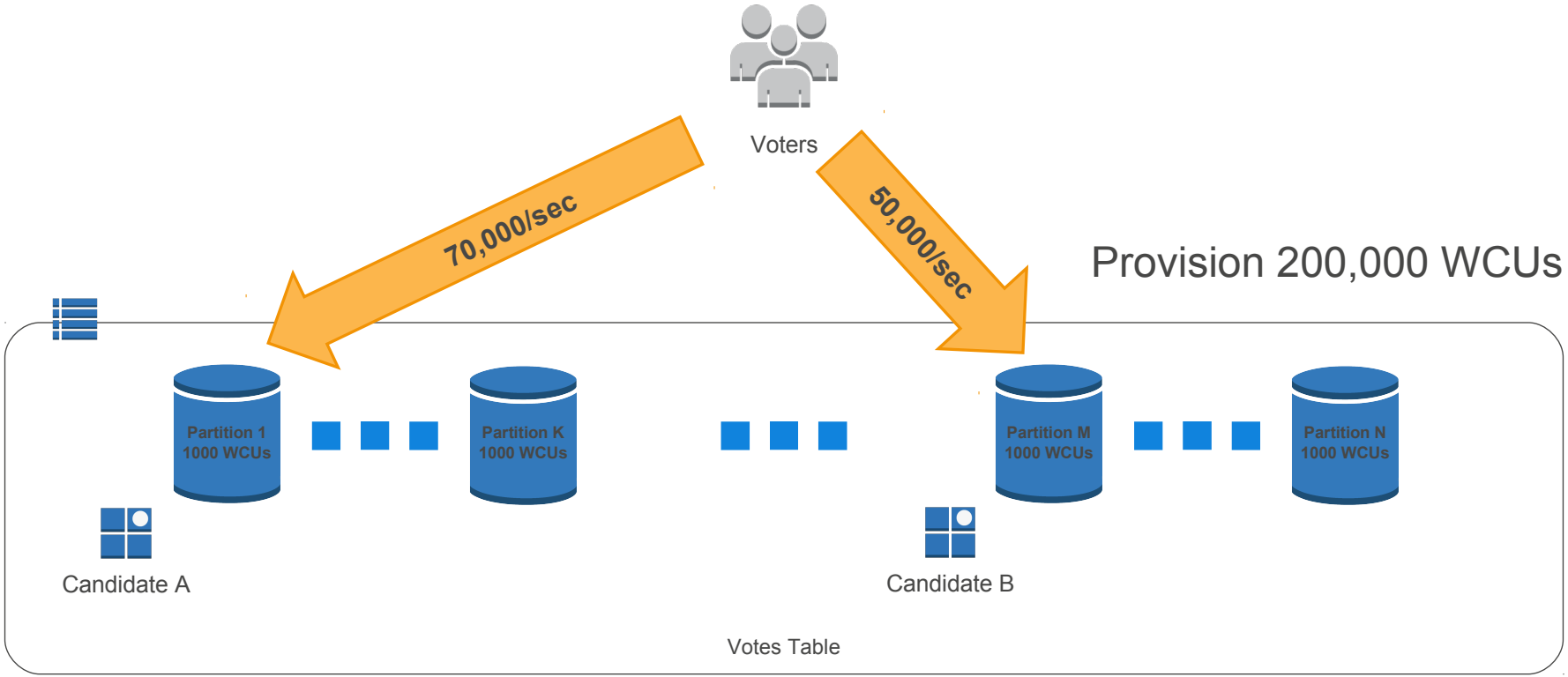
# Real-Time voting



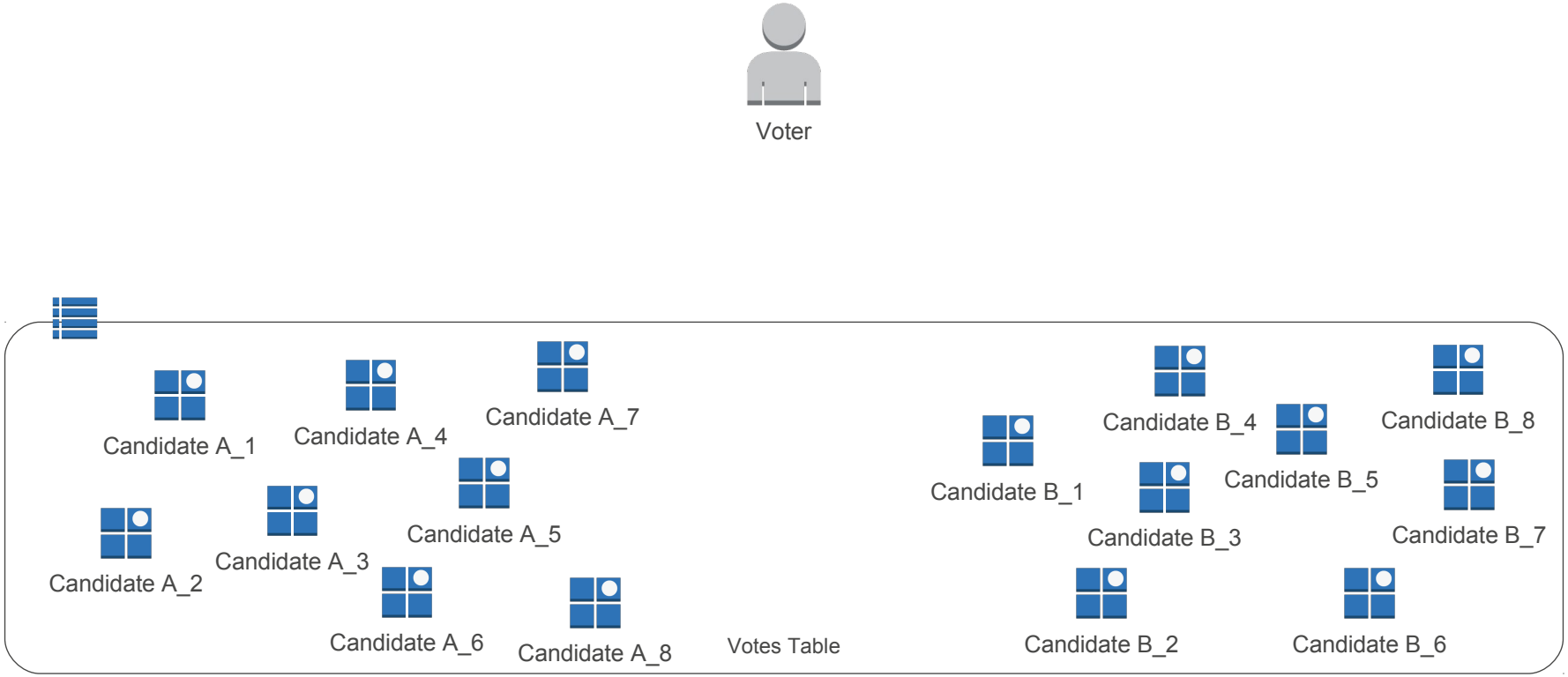


Write-heavy items

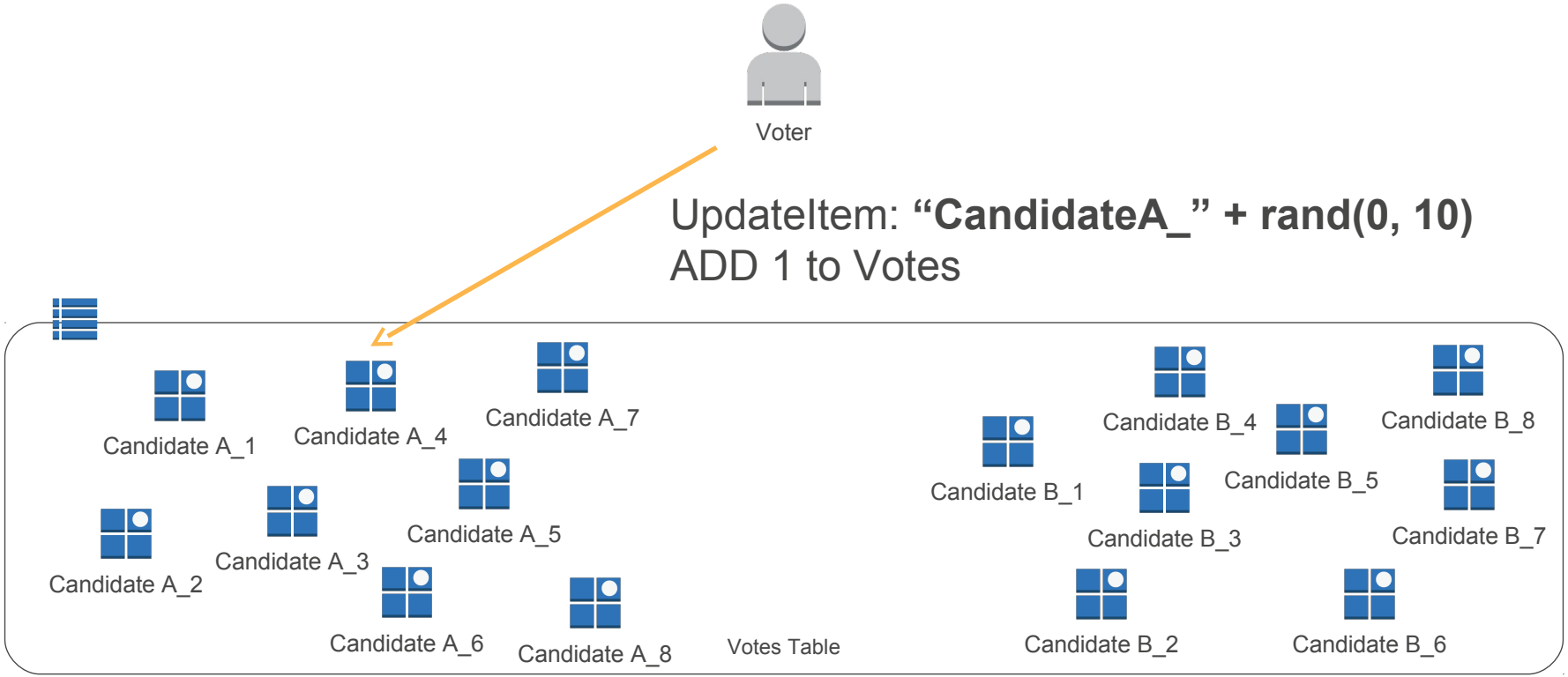
# Scaling bottlenecks



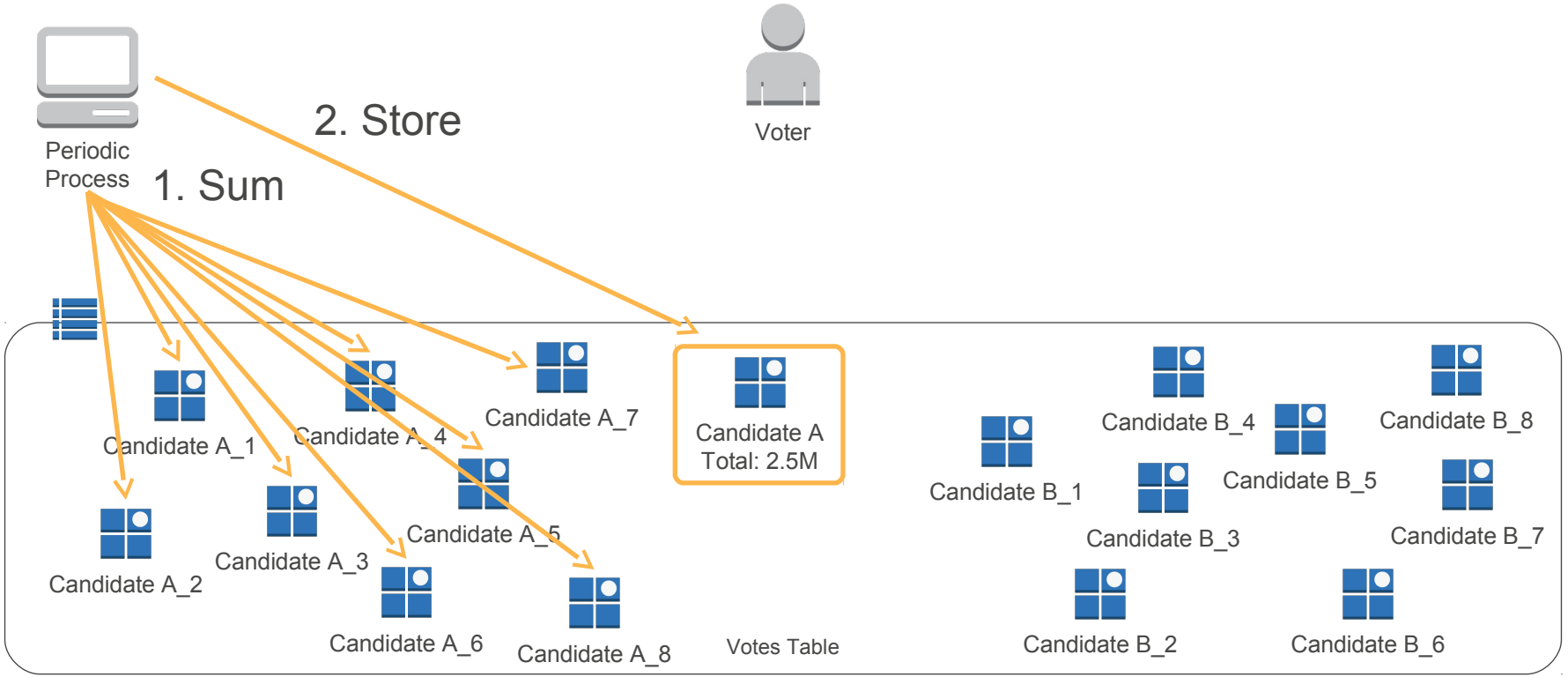
# Write sharding



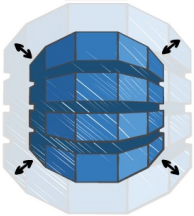
# Write sharding



# Shard aggregation

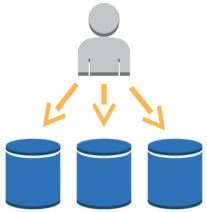


# Shard write-heavy partition keys



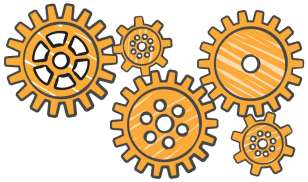
Trade off read cost for write scalability

Consider throughput per partition key



**Important when:** Your write workload is not horizontally scalable

# Replace filter with indexes



Concatenate attributes to form useful secondary index keys

Status + Date

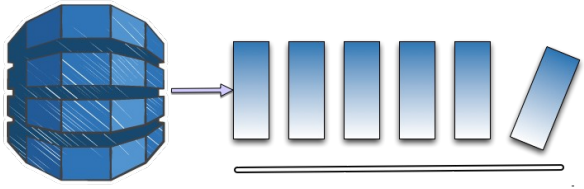
Take advantage of sparse indexes

**Important when:** You want to optimize a query as much as possible

# DynamoDB Streams

amazon web services | Webinars

# DynamoDB Streams



Stream of updates to a table

Asynchronous

Exactly once

Strictly ordered

- Per item

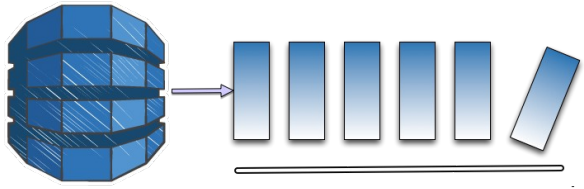
Highly durable

- Scale with table

24-hour lifetime

Sub-second latency

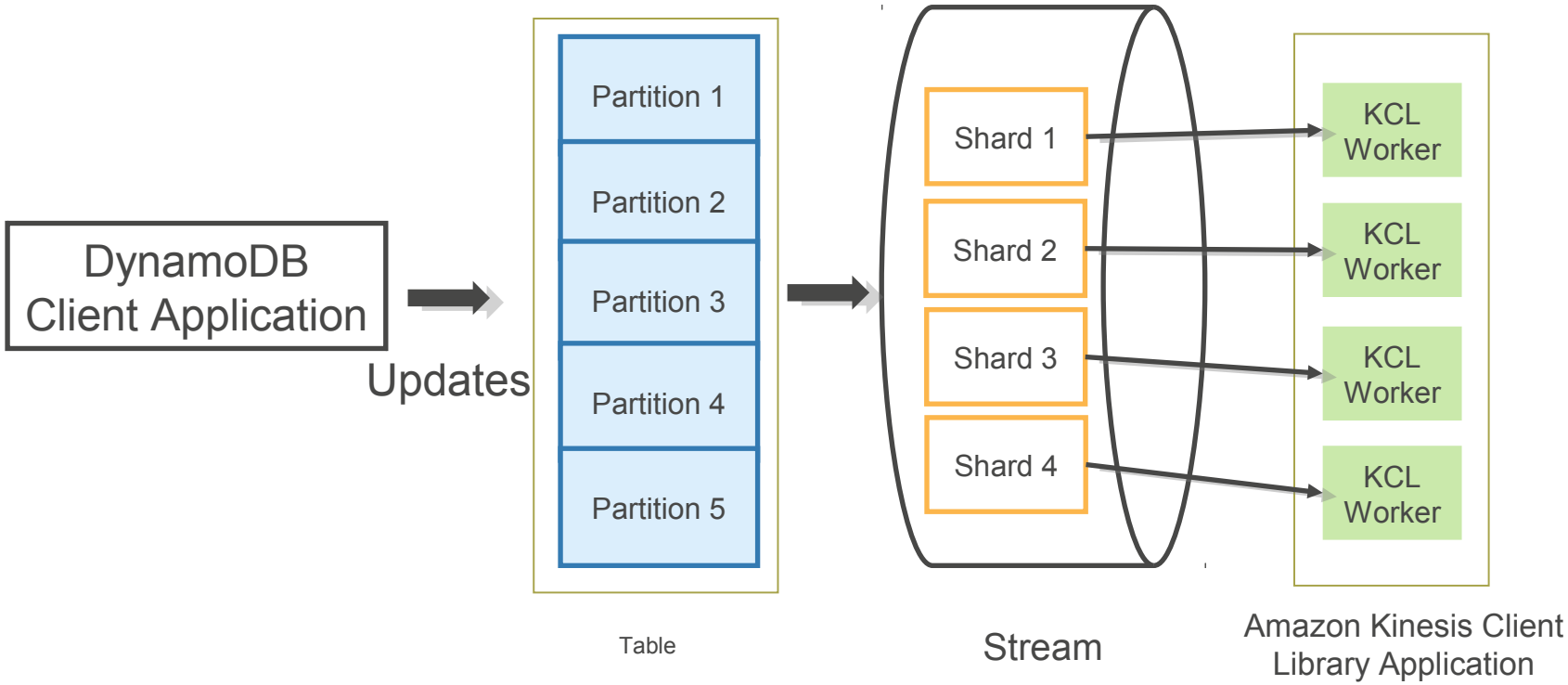
# View types



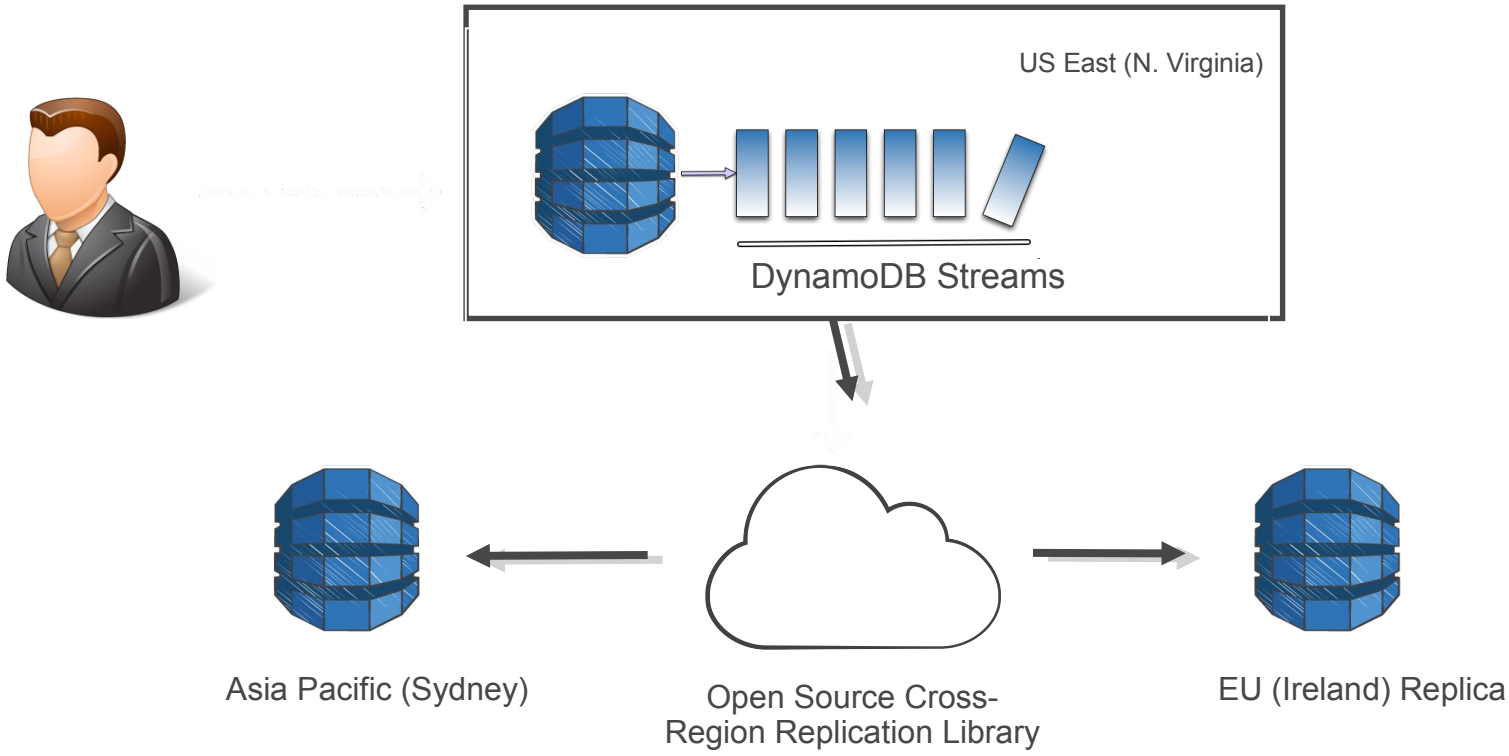
UpdateItem (Name = John, Destination = Pluto)

| View Type | Destination |
| --- | --- |
| Old image—before update | Name = John, Destination = Mars |
| New image—after update | Name = John, Destination = Pluto |
| Old and new images | Name = John, Destination = Mars<br>Name = John, Destination = Pluto |
| Keys only | Name = John |

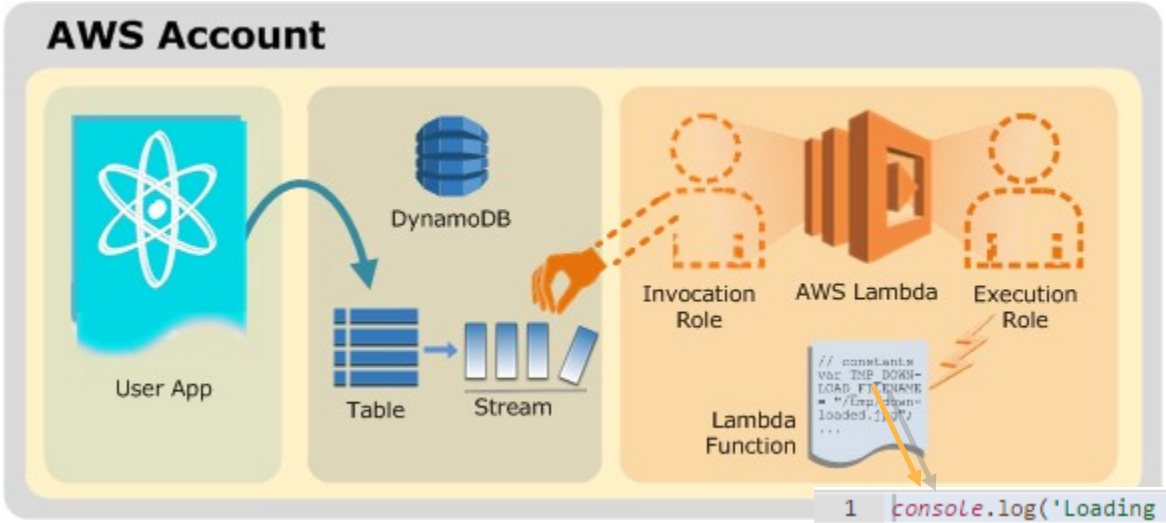
# DynamoDB Streams and Amazon Kinesis Client Library



# Cross-region replication



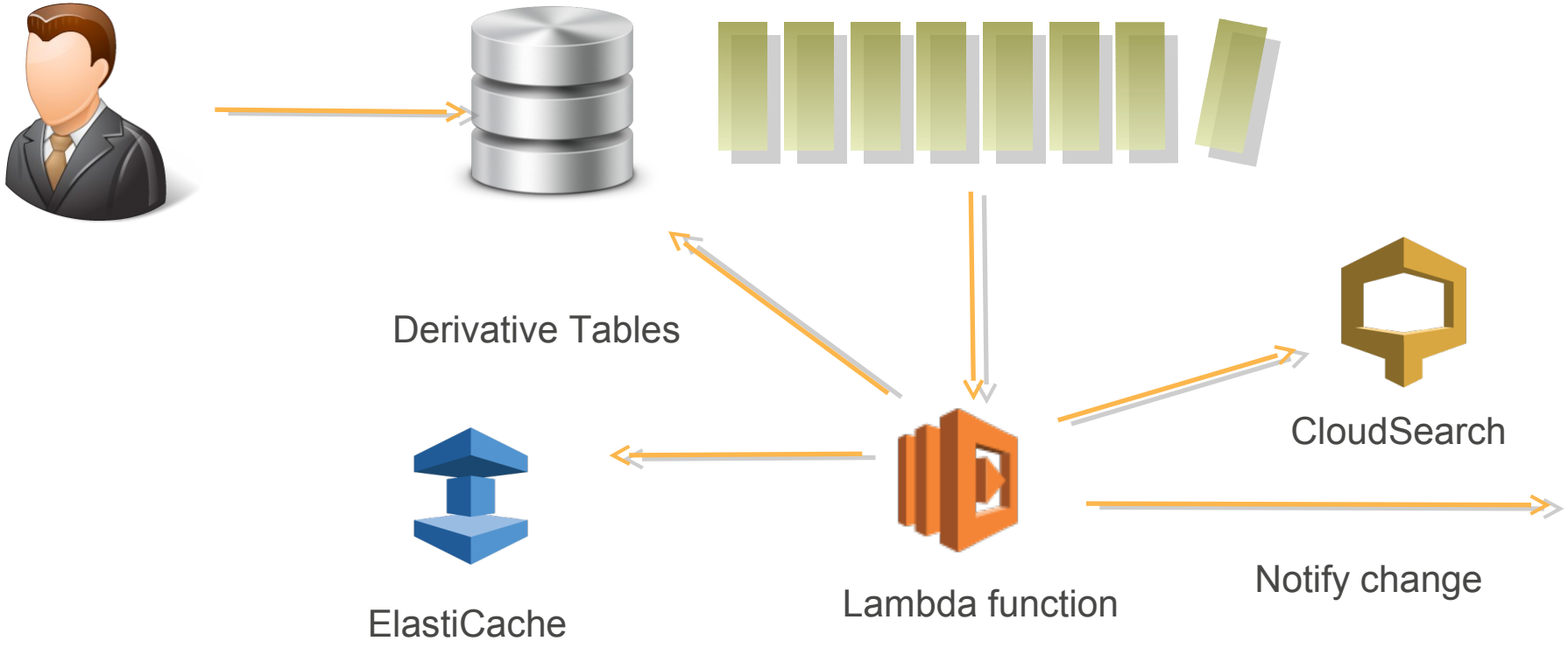
# DynamoDB Streams and AWS Lambda




```
1  console.log('Loading event');
2  exports.handler = function(event, context) {
3    console.log("Event: %j", event);
4    for(i = 0; i < event.Records.length; ++i) {
5      record = event.Records[i];
6      console.log(record.EventID);
7      console.log(record.EventName);
8      console.log("DynamoDB Record: %j", record.Dynamodb);
9    }
10   context.done(null, "Hello World");  // SUCCESS with message
11 }
```

```
2015-03-21T07:44:58.883Z 2ca3769a-cf9e-11e4-b270-ad4d24b312ff INSERT
2015-03-21T07:44:58.883Z 2ca3769a-cf9e-11e4-b270-ad4d24b312ff DynamoDB Record:{ "NewImage": { "name": { "S": "sivar" }, "hk": { "S": "3" } }, "SizeBytes": 15, "StreamViewType": "NEW_AND_OLD_IMAG
2015-03-21T07:44:58.883Z 2ca3769a-cf9e-11e4-b270-ad4d24b312ff Message: "Hello World"
```

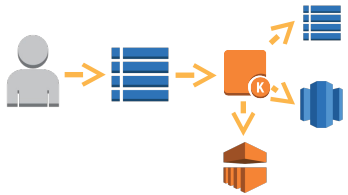
# Triggers


Derivative Tables
CloudSearch
ElastiCache
Lambda function
Notify change

# Analytics with DynamoDB Streams

Collect and de-dupe data in DynamoDB

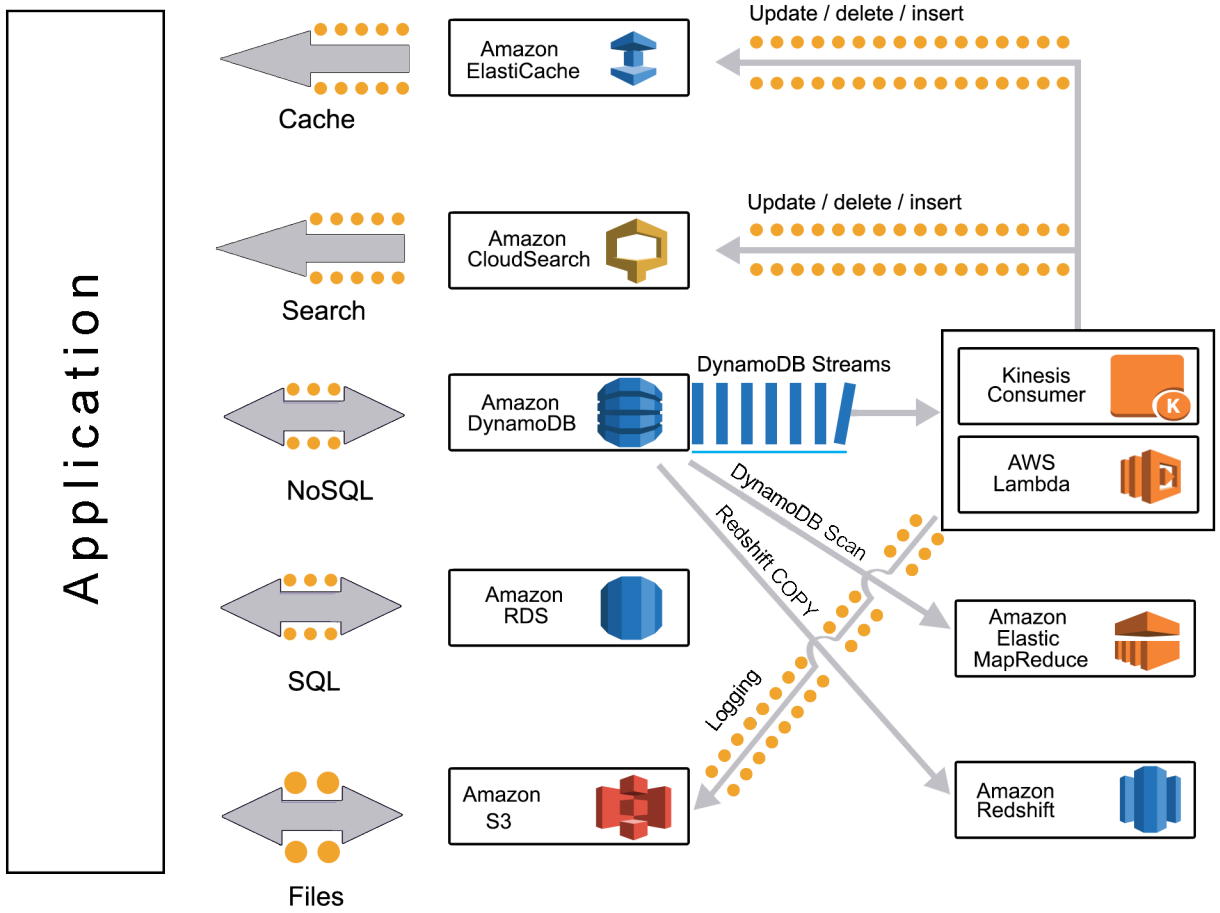
Aggregate data in-memory and flush periodically



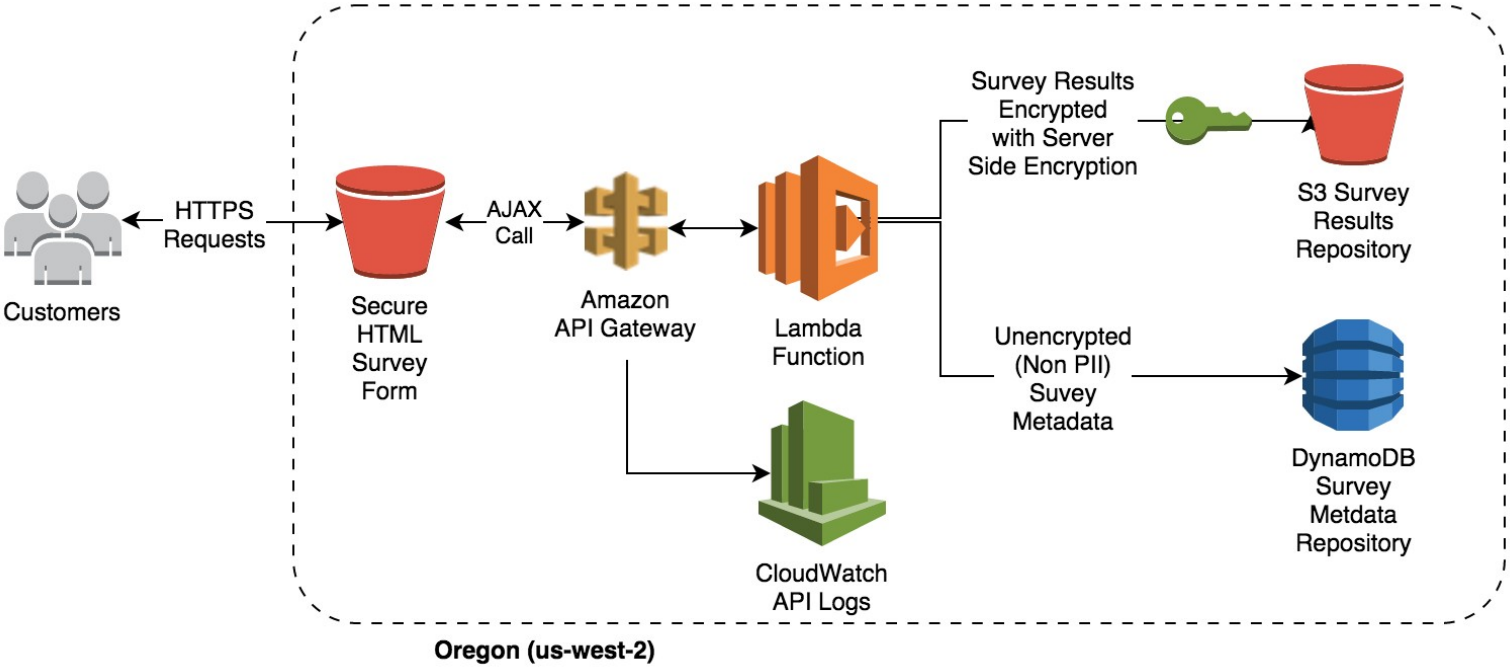
**Important when:** Performing real-time aggregation and analytics

# Architecture

# Reference Architecture



# Elastic Event Driven Applications



# Thank you!