Mastering Amazon DynamoDB ACID transactions:

When and how to use the new transactional APIs

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Learning Objectives

1. Learn when to use DynamoDB transactions to simplify your code.

2. Learn how the new DynamoDB transactional APIs work and how to implement them in your applications through examples demonstrating transactional design patterns.

3. Learn best practices for using DynamoDB transactions and how the new API calls interact with other DynamoDB features.

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Agenda

1. Introduction to Amazon DynamoDB transactions and atomicity, consistency, isolation, and durability (ACID) in Amazon DynamoDB.

2. Modern application use cases for transactional APIs.

3. Important things to know when integrating the transactional API into your application: metering, concurrency control, and interaction with other features.

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Prerequisites

You should be familiar with basic DynamoDB concepts, such as tables, items, partition keys and sort keys, indexes, Time To Live (TTL), and DynamoDB Streams.

We will only introduce these concepts briefly in this presentation before using them in the examples.

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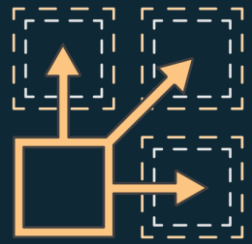
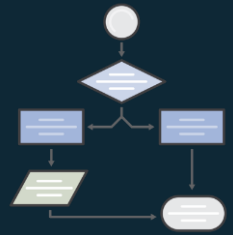
How do developers use transactions?

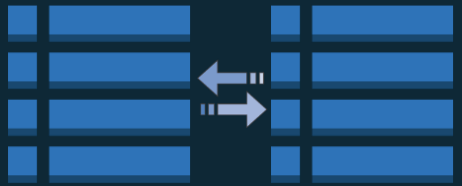
Transactions help developers maintain data correctness by coordinating actions across multiple items and tables.



Make simultaneous writes and updates to multiple items.



Check multiple conditions before making changes.



Update data across tables consistently.

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Developer challenges

Traditionally, developers using non-relational databases faced challenges implementing transactions in their applications:

- No built-in support, had to depend on custom transactions client libraries or create and maintain their own client library.
- Added complexity of modifying their application logic to work around the lack of built-in transactions support.

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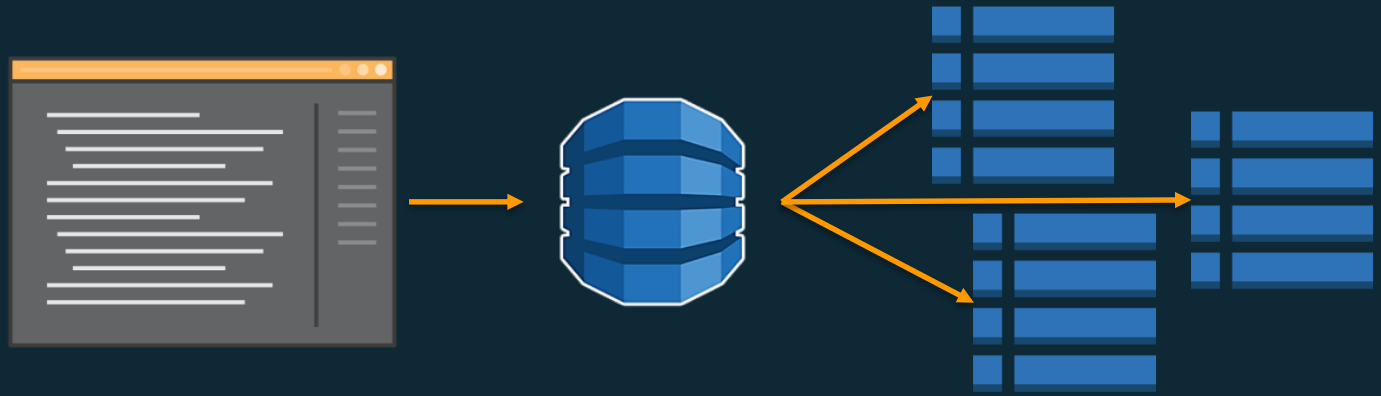
Amazon DynamoDB Transactions

Simplify your code by executing multiple, all-or-nothing actions within and across tables with a single API call.



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Benefits of DynamoDB transactions

Simplifies the developer experience of making coordinated, all-or-nothing changes to multiple items.

Faster performance and lower latency by using server-side transactions library.

Easier to extend the scale, performance, and enterprise features of DynamoDB to a broader set of workloads.

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Use cases for transactions

Execute financial transactions.

Process orders.

Coordinate actions in multi-player games.

Update distributed data.

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Transactional API at a glance

TransactWriteItems

- Include up to 10 unique items per transaction.
- Evaluate conditions.
- If all conditions are simultaneously true, perform write operations.
- Consumes 2 WCUs for every 1 KB of data.

TransactGetItems

- Include up to 10 unique items per transaction.
- Return a consistent, isolated snapshot of all items.
- Consumes 2 RCUs for every 4 KB of data.

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DynamoDB flexibility

The same transaction can include items:

- With the same or different partition keys.
- Within the same table or across different DynamoDB tables.

All items within a single transaction must be:

- Within the same AWS Region.
- Within the same AWS account.
- Within DynamoDB.

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DynamoDB scale

Transactions scale like the rest of DynamoDB:

- Virtually limitless concurrent transactions.
- Low latency, high availability.
- Never deadlocks.
- Request/response-based implementation.
- Scales horizontally.

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Reading and writing data

	Non-transactional (Singleton)	Transactional
Reads	BatchGetItem Query Scan GetItem	TransactGetItems
Writes	BatchWriteItem PutItem UpdateItem DeleteItem	TransactWriteItems

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Examples

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User profile management (example #1)

Requirements

- Users identified by user name and optionally email.
- No two users can share the same identifier (user name or email).
- Users can change their email.

What are we demonstrating

- Enforcing unique constraints.
- Strongly consistent global indexing.
- Heterogeneous tables.

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User profile management

Solution: Users table containing two kinds of records:

- Profile records, keyed by opaque user name with user details.
- Alias records, keyed by user email and referencing the profile record.

Id	UserNameRef	Email	PhoneNum
“John123”		“john@example.com”	“444-555-0110”
“john@example.com”	“John123”		
“jane456”			“444-555-0199”

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Insert new profile

```
data = await dynamoDb.transactWriteItems({ TransactItems: [

  { Put: {

       TableName: 'Users',

       Item: { Id: { S: 'John123' }, Email: {S: 'john123@example.com'}, ...},

       ConditionExpression: 'attribute_not_exists(Id)‘ }},
  { Put: {

       TableName: 'Users',

       Item: { Id: { S: 'john123@example.com' }, UserNameRef: {S: 'John123'}},

       ConditionExpression: 'attribute_not_exists(Id)',}}

   ] }).promise();
```

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Update email address

```
data = await dynamoDb.transactWriteItems({ TransactItems: [
{ Put: { TableName: 'Users',
    Item: { Id: { S: 'John123' }, Email: {S: 'john456@newemail.org'}, ...},
    ConditionExpression: 'attribute_exists(Id) and Email = :old_email',
    ExpressionAttributeValues: {':old_email' :{'S': 'john123@example.com'}}}},
{ Put: { TableName: 'Users',
    Item: { Id: { S: 'john456@newemail.org' }, UserNameRef: {S: 'John123'}},
    ConditionExpression: 'attribute_not_exists(Id)', }},
{ Delete: { TableName: 'Users',
    Item: { Id: { S: 'john123@example.com' }}}).promise();
```

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Hotel reservation management (use case #2)

Requirements

- Guests create room reservations.
- Guests check in to rooms, fulfilling a reservation.
- Guests check out of rooms, closing a reservation.

What are we demonstrating?

- Idempotency – Operations with side effects happen at most once.
- Consistency – Multi-item changes are only triggered when valid.
- Atomicity – Ensuring multi-item changes happen all together.

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Hotel reservation management data model

Guests

- Id (primary key)
- Name, Email, etc.
- Reservations (set)
- OccupiesRooms (set)

Reservations

- Id (primary key)
- GuestId
- FulfilledByRoom
- State

Rooms

- Id (primary key)
- RentedToReservation
- State

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Hotel reservation management data model

Record Type	Id (PK)	Attributes
Guest	“John”	Reservations : { “501”, “502” } OccupiesRooms : { “20014” }
Reservation	“501”	GuestId: “John” State: “FULFILLED” FulfilledByRoom: “20014”
Reservation	“502”	GuestId: “John” State: “PENDING”
Room	“20014”	State: “OCCUPIED” RentedToReservation : “501”

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Creating a reservation

Use idempotency to ensure that only a single reservation is created, even with multiple retries.

Client generates a unique reservation ID.

Client generates TransactWriteItems request with the following operations:

- Conditional Put for the new reservation.
- Update the guest reservations set and add the new reservation.

Client transaction is idempotent and can be retried without double booking.

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Hotel reservation management – Check-in

Record Type	Id (PK)	Attributes
Guest	“John”	Reservations : { “501” } OccupiesRooms : {}
Reservation	“501”	GuestId: “John” State: “PENDING” FulfilledByRoom: null
Room	“20014”	State: “FREE” RentedToReservation: null

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Hotel reservation management – Check-in

Record Type	Id (PK)	Attributes
Guest	“John”	Reservations : { “501” } OccupiesRooms : { “20014” }
Reservation	“501”	GuestId: “John” State: “FULFILLED” FulfilledByRoom: “20014”
Room	“20014”	State: “OCCUPIED” RentedToReservation : “501”

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Hotel reservation management – Checkout

Record Type	Id (PK)	Attributes
Guest	“John”	Reservations : { “501” } OccupiesRooms : { “20014” }
Reservation	“501”	GuestId: “John” State: “FULFILLED” FulfilledByRoom: “20014”
Room	“20014”	State: “OCCUPIED” RentedToReservation : “501”

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Hotel reservation management – Checkout

Record Type	Id (PK)	Attributes
Guest	“John”	Reservations : { ~~“501”~~ } OccupiesRooms : { ~~“20014”~~ }
Reservation	“501”	GuestId: “John” State: “CLOSED” FulfilledByRoom: “20014”
Room	“20014”	State: “FREE” RentedToReservation : ~~“501”~~

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Attachment management (use case #3)

Requirements

- A social media site allows users to attach media to posts.
- Posts need to share media efficiently.
- Posts can have multiple attachments.
- Unreferenced media needs to be deleted.

What are we demonstrating?

- External resource metadata and lifetime management.
- Using Time To Live (TTL) and streams.
- Reference counting using transactions.

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Attachment management data model

Attachment item

- S3Ref (PK) – reference to an object in Amazon Simple Storage Service (Amazon S3).
- RefCount – # of posts referencing this attachment.
- TTL – time when this attachment is eligible to be deleted.

Post item

- Id (PK) – post ID.
- Attachments (set) – set of attachment IDs.

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Attachment management invariants

1. RefCount = number of posts referencing the attachment.
2. If RefCount > 0, then S3Ref refers to a valid Amazon S3 object.
3. TTL is set if, and only if, RefCount = 0.

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Create attachment and link it to a post

- Generate unique Amazon S3 object name.
- Create attachment record in DynamoDB.
  - Set RefCount = 0
  - Set TTL = 24 hours from now.
- Upload object to S3.
- In a TransactWriteItems Request.
  - Check that the attachment is not already referenced by the post.
  - Increase RefCount by 1, remove TTL.
  - Add attachment reference to post.

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Clone attachment reference

- Copy the reference of an attachment from one post to another.
- In a TransactWriteItems Request.
  - Check that the attachment is not already referenced by the new post.
  - Increase RefCount by 1, remove TTL.
  - Add attachment reference to new post.

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Delete unused external resources

- Attachment records will be deleted a day after their reference count drops to zero.
- In AWS Lambda, process stream records representing items deleted by TTL.
- Delete the corresponding objects from Amazon S3.

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Integrating DynamoDB transactions in your applications

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Concurrency control

Optimistic

- No deadlocks possible.
- Low latency.
- Optimized for scale out.

Your responsibilities:

- Design for scale out.
- Avoid unnecessary conflicts.
- Design to avoid hot keys.

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Why didn’t my transaction succeed?

Item-based failure reasons:

- Condition failure.
- Concurrent transaction on the same item is in-progress.

Other reasons:

- Insufficient capacity.
- Internal server error (HTTP 500).
- Malformed request.
- Insufficient permissions.

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Retrying transactions: ClientRequestToken

- Ensures SDK can retry without “replaying” the same intent multiple times.
- ClientRequestToken – idempotency token at the SDK/API level
  - Autogenerated, you can override.
  - Applies for 10 minutes.
  - Provides information about transaction state and outcome.
  - Sometimes doesn’t remove the need for app-level idempotency/intent design.

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App-level retries

Necessary when SDK retries have been exhausted.

- Build a new view of the world.
- Retry with new preconditions and desirable end state.

How can you get a snapshot of the world? Three options:

- Set ReturnValuesOnConditionCheckFailure = ALL_OLD.
- Perform TransactGetItems.
- Work from an eventually consistent view (results of queries, etc.).

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Integrating with other DynamoDB features

- General rule about DynamoDB data
  - Committed state only
  - But may not be isolated
- Examples
  - Streams – Committed writes, sharded
  - Backups and point-in-time recovery (PITR) – Subset of a committed transaction is possible
  - Global secondary index (GSI) – Committed writes are indexed individually
  - Global tables – Transactional API disabled by default; writes are replicated individually.
  - DynamoDB local – Transactional API calls supported, but TransactionConflictExceptions need to be simulated using testing framework.

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Access control

- Individual operations are authorized separately
  - (NEW) dynamodb:ConditionCheck
  - dynamodb:UpdateItem
  - dynamodb:PutItem
  - dynamodb:DeleteItem

- No separate permissions for top level new APIs

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Metering transactions

Transactions uses a two-phase commit protocol.

1 read/write to prepare the transaction and 1 read/write to commit the transaction.

Reads consume 2 RCUs for every 4 KBs of data read.

Writes consume 2 WCUs for every 1 KB of data written.

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Thank you!

Arturo Hinojosa

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