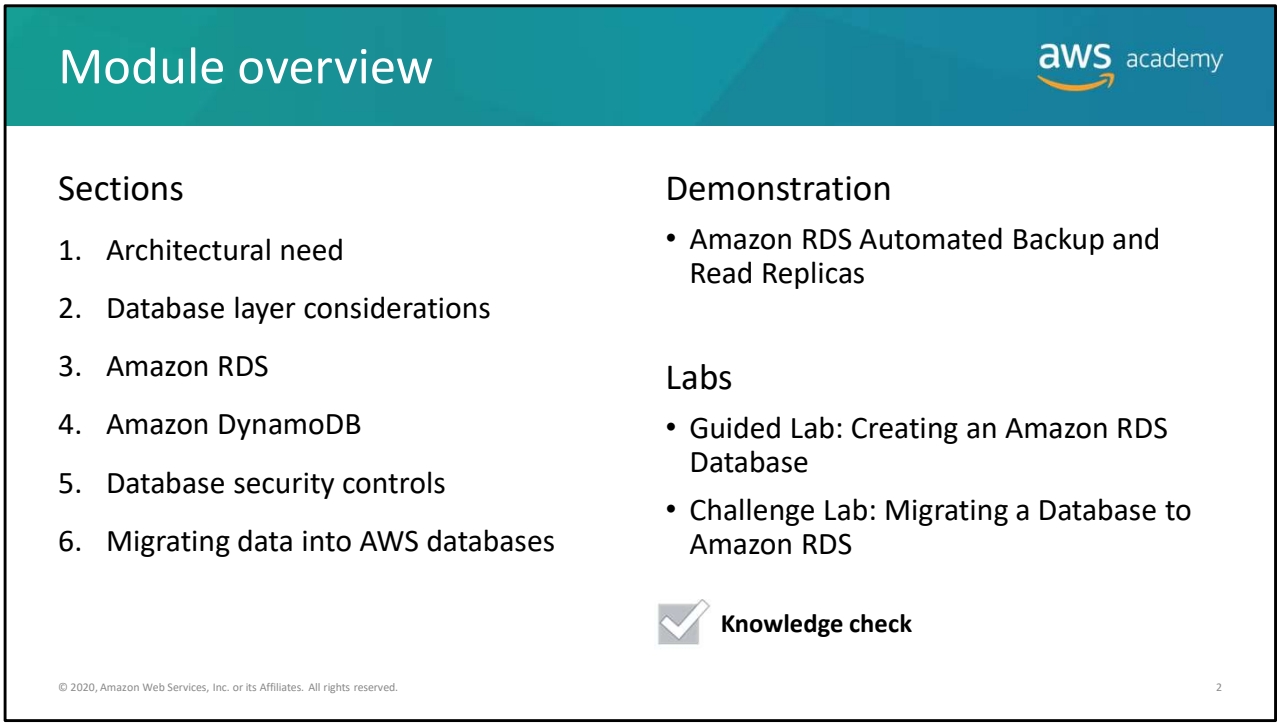
Welcome to Module 5: Adding a Database Layer.



This module includes the following sections:

1. Architectural need
2. Database layer considerations
3. Amazon RDS
4. Amazon DynamoDB
5. Database security controls
6. Migrating data into AWS databases

This module also includes:

- A demonstration of Amazon Relational Database Service (Amazon RDS) automated backup and read replica configuration.
- A guided lab where you create an Amazon RDS database and connect to it by using a simple web application.
- A challenge lab that challenges you to migrate data from a database that runs on an Amazon Elastic Compute Cloud (Amazon EC2) instance to an Amazon RDS database.

Finally, you will be asked to complete a knowledge check to test your understanding of the key concepts that are covered in this module.

Module objectives

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At the end of this module, you should be able to:

- Compare database types
- Differentiate between managed versus unmanaged services
- Explain when to use Amazon Relational Database Service (Amazon RDS)
- Explain when to use Amazon DynamoDB
- Describe available database security controls
- Describe how to migrate data into Amazon Web Services (AWS) databases
- Deploy a database server

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Module 5: Adding a Database Layer

Section 1: Architectural need

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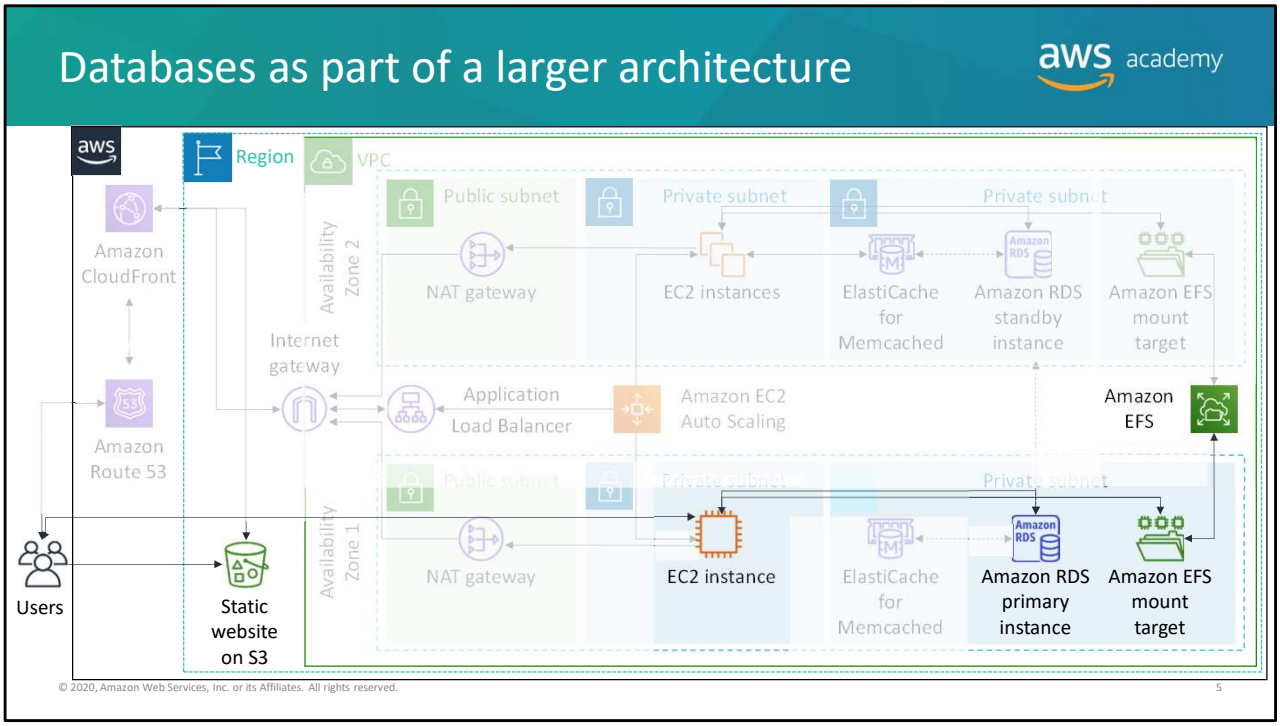
Introducing Section 1: Architectural need.



As each module introduces new features, those parts of this larger diagram will be unveiled.

In this module, you will learn how to create an architecture that uses AWS database services. Different relational and non-relational database service options—including Amazon RDS—are discussed. As you learn about the essential benefits of the various offerings, you will be able to make a more informed decision about the database service that best meets your particular architectural needs.

Café business requirement

The café needs a database solution that is easier to maintain, and that provides essential features such as durability, scalability, and high performance.

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Ever since the cafe added the ability to place online orders to their website, the café staff have noticed that business has increased. In addition, they discovered that the order history that's stored in the database—which they installed on the same EC2 instance where the web server is running—provides valuable business information. Martha uses it for accounting purposes, and Frank looks at it occasionally to get an idea of how many of each dessert type he should bake.

However, Sofía has some concerns. The database needs to be upgraded and patched, and she doesn't always have time to do these tasks on a regular basis. Also, administering the database is a specialized skill, and training others to do it isn't something she wants to spend time on. Meanwhile, she is also concerned that the cafe isn't doing data backups as often as they should.

The café staff wants to reduce the labor costs associated with the technical learning investment that's needed to manage the database themselves. Thus, they decided that they need to use a managed database solution. Ideally, they will find one that provides essential features, such as durability, scalability, and high performance.

Throughout this module, you will learn details about the different database services that AWS provides, and the capabilities that are provided by these different services. With this understanding of the available options, you should be able to choose a database solution that can successfully meet these new business requirements.

Module 5: Adding a Database Layer

Section 2: Database layer considerations

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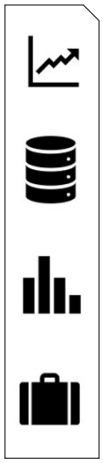
Introducing Section 2: Database layer considerations.

Database considerations: Scalability



Scalability

Total storage requirements

Object size and type

Durability

How much throughput is needed?

Will the chosen solution be able to scale up later, if needed?

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As an architect, you will often need to choose between different database types when you consider which type will best handle a particular workload. Before you choose a database, there are some key considerations that should inform your decision-making process.

First, consider the importance of *scalability*. With traditional on-premises databases, scaling up capacity can be a difficult task even for experienced database administrators. It can take hours, days, or weeks. The impact to database performance while it scales up can be unpredictable, and might require downtime. However, the importance of a properly scaled database cannot be overstated. If you underprovision your database, your applications might stop working. However, if you overprovision your database, you increase your upfront costs by procuring resources that you do not need, which violates the cost-optimization principle of the AWS Well-Architected Framework.

Ideally, you would choose a database solution that has the resources to handle the needed *throughput* at launch, and that can also be easily *scaled* up later if your throughput needs increase.

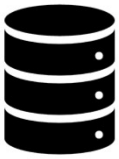
Another nice-to-have capability is the ability to scale down the provisioned database capacity if your throughput requirements or database load later decrease. This enables you to immediately realize cost savings by lowering provisioned capacity. An automated scaling solution could reduce costs and labor overhead.

Database considerations: Storage requirements

- Scalability
- **Total storage requirements**
- Object size and type
- Durability

How large does the database need to be?

Will it need to store GB, TB, or petabytes of data?



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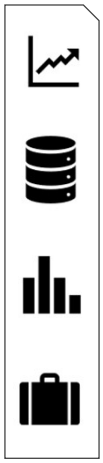
Second, when you must choose a database to handle a certain type of workload, consider the storage requirements of your workload.

How large must the database be to handle your data requirements? Does it need to store gigabytes? Terabytes? Petabytes?

Different database architectures support different maximum data capacities. Some database designs are ideal for traditional applications, while others are ideal for caching or session management. Still others are ideal for Internet of Things (IoT) or big data applications.

Understanding your total storage requirements is essential for choosing a database.

Database considerations: Object size and type



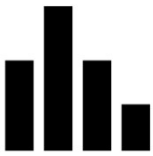
Scalability

Total storage requirements

Object size and type

Durability

Do you need to store simple data structures, large data objects, or both?



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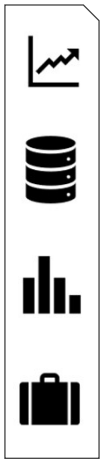
Third, when you choose a database for your specific workloads, consider the size and the type of the objects you must store.

Do you need to store simple data structures, large data objects, or both?

Database considerations: Durability



Scalability

Total storage requirements

Object size and type

Durability

What level of **data durability**, **data availability**, and **recoverability** is required?

Do regulatory obligations apply?

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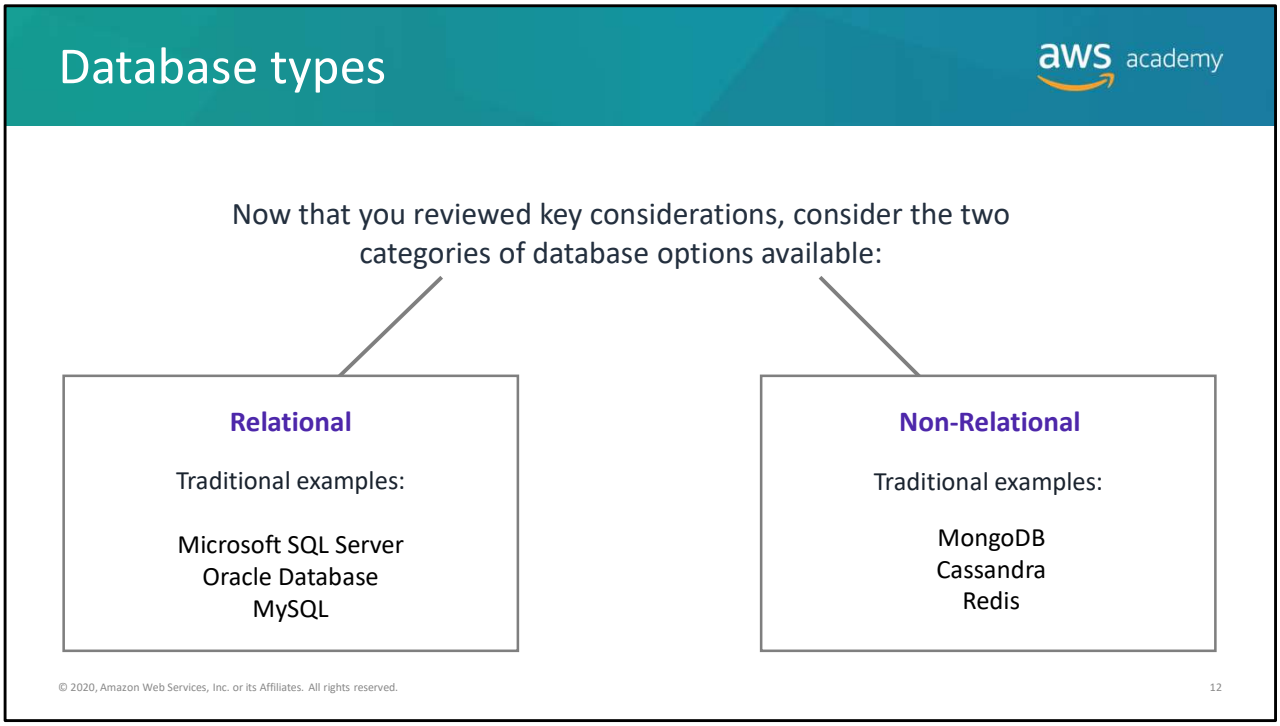
Finally, as a fourth consideration for your database choice, think about the durability requirements for the data you will store.

Data durability refers to the assurance that your data will not be lost, and *data availability* refers to your ability to access your data when you want to. What level of data durability and data availability do you need? If the data you will store is absolutely critical to your business, you should choose a database solution that stores multiple redundant copies of your data across multiple geographically separated physical locations. This solution will usually result in an increased cost, so it is important to balance your business needs with cost considerations.

Another important consideration is to know whether data residency or *regulatory obligations* apply to your data. For example, are there regional data privacy laws that you must comply with? If so, choose a database solution that can support compliance.



You can choose from many types of databases, many of which are purpose-built. However, database types typically fall into one of two broad categories: relational or non-relational.

Relational database systems are the most familiar type of databases to most people. Traditional examples include Microsoft SQL Server, Oracle Database, and MySQL.

Non-relational databases were developed more recently, but have been around for a few decades. They play an essential role in the modern computing landscape. Examples include MongoDB, Cassandra, and Redis.

Relational database type

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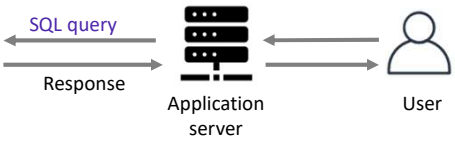
Benefits:

- Ease of use
- Data integrity
- Reduced data storage
- Common language (structured query language, or SQL)

Relational database management system (RDBMS)

Relational is ideal when you:

- Need strict schema rules, ACID compliance, and data quality enforcement
- Do not need extreme read/write capacity
- Do not need extreme performance
  - An RDBMS can be the best, lowest-effort solution



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Relational databases are sometimes referred to as *relational database management system* (RDBMS). They are still the single most-popular and most-used database category in the world. In a 2019 DB-Engines Ranking study, they were found to represent over 75 percent of the popularity score across all categories. The top four were Oracle, MySQL, Microsoft SQL Server, and PostgreSQL—which are all relational databases.

Relational databases maintain their popularity for many reasons. These reasons include their *ease of use*, data integrity controls, excellence at reducing overall data storage, and their support for structured query language (SQL). SQL is a popular language for querying or interacting with structured data stored in RDBMSs, and it is supported by most vendors.

If your use case lends itself well to *strict schema rules,* where the schema structure is well defined and does not need to change often, a relational database would be a good choice. Relational databases transactions are also *ACID*-compliant, which means that they ensure data integrity by providing transactions that are *atomic*, *consistent*, *isolated*, and *durable*. However, if your application needs extreme read/write capacity, a relational database might not be the right choice. Finally, extreme performance is a characteristic of relational databases when you compare them to other options. However, a relational database can be the best low-effort solution for many use cases.

Non-relational database type

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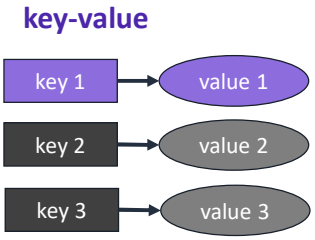
Benefits

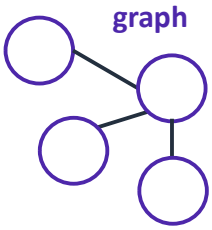
- Flexibility
- Scalability
- High performance
- Highly functional APIs

Non-relational is ideal when:

- Database must scale horizontally to handle massive data volume
- Data does not lend itself well to traditional schemas
- Read/write rates exceed what can be economically supported through traditional RDBMS

Example models





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Non-relational databases are sometimes called *NoSQL databases.* They are different from relational databases because they are purpose-built for specific data models and have flexible schemas for building modern applications. Non-relational databases are widely appreciated for their *flexibility*, *scalability*, *high performance*, and *highly functional APIs*.

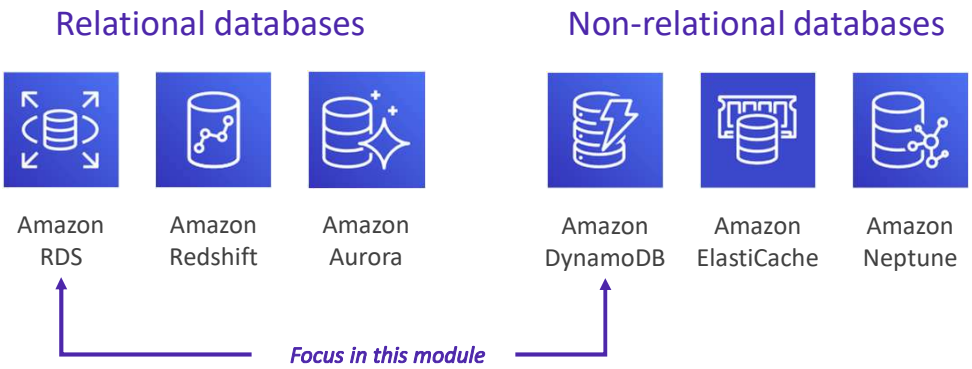
They use a variety of data models, including key-value, graph, document, in-memory, and search. NoSQL schemas are dynamic. For example, a row does not need to contain data for each column. Also, a NoSQL database can *scale horizontally* by increasing the number of servers that it runs on.

Non-relational databases have *flexible schemas*, where each object can have a different structure. They can store structured data, such as relational database records; semistructured data, such as JavaScript Object Notation (JSON) documents; and unstructured data, such as photo files or email messages. Non-relational databases work well when the data might have structural inconsistencies.

Finally, non-relational databases are optimized for specific data models and access patterns that enable *higher performance* instead of trying to achieve the functionality of relational databases.

Amazon database options

More database options exist—these options are common examples



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Now that you learned about the distinctions between relational and non-relational database, consider some example Amazon database offerings that fit into those two categories.

Among the more commonly used AWS *relational* database offerings are Amazon RDS, Amazon Redshift, and Amazon Aurora.

Similarly, some of the more commonly used *non-relational* databases are Amazon DynamoDB, Amazon ElastiCache, and Amazon Neptune.

In this module, you will explore both Amazon RDS and Amazon DynamoDB in more depth. For a full listing of database services that are available on AWS and their most common uses cases, see the AWS Databases – Overview page.

Section 2 key takeaways

- When you choose a database, consider scalability, storage requirements, the type and size of objects to be stored, and durability requirements
- Relational databases have strict schema rules, provide data integrity, and support SQL
- Non-relational databases scale horizontally, provide higher scalability and flexibility, and work well for semistructured and unstructured data

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Some key takeaways from this section of the module include:

- When you choose a database, consider scalability, storage requirements, the type and size of objects to be stored, and durability requirements
- Relational databases have strict schema rules, provide data integrity, and support SQL
- Non-relational databases scale horizontally, provide higher scalability and flexibility, and work well for semistructured and unstructured data

Module 5: Adding a Database Layer

Section 3: Amazon RDS

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Introducing Section 3: Amazon RDS.

Amazon RDS

Relational

Amazon RDS

Amazon RDS is a fully managed relational database service.

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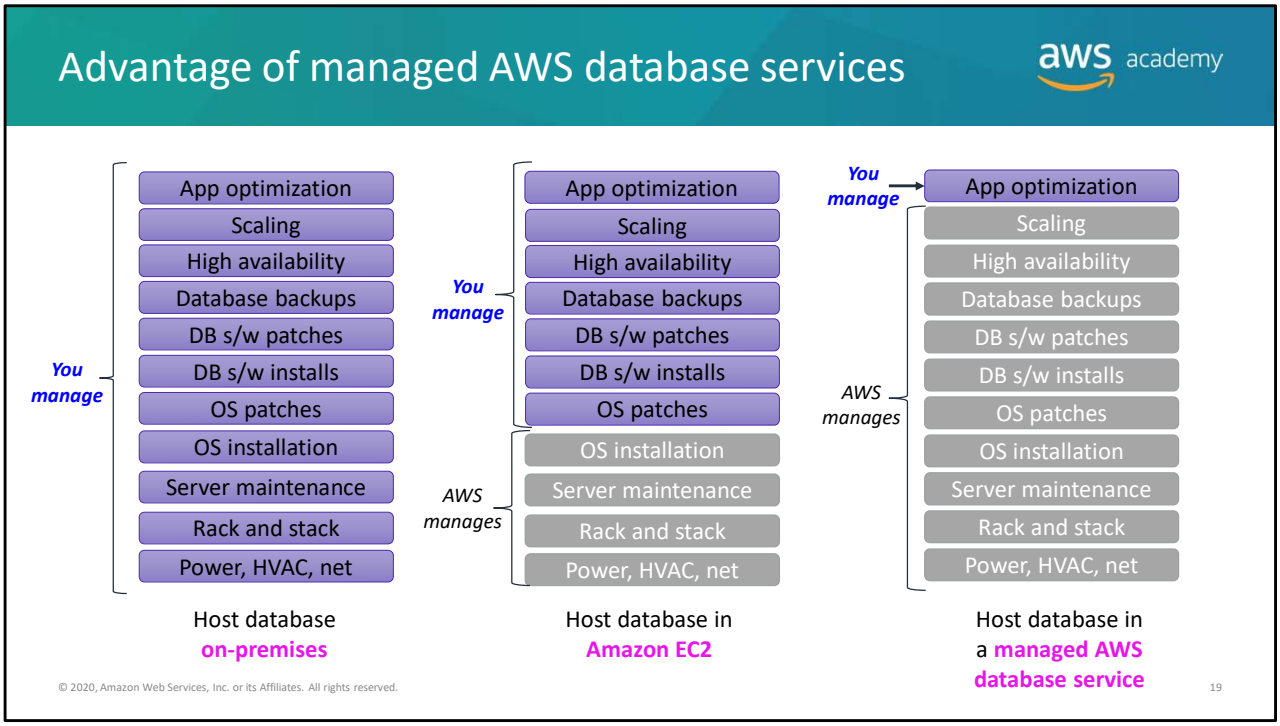
Amazon RDS is a fully managed relational database service that creates and operates a relational database in the cloud. However, before you learn more details about Amazon RDS, you will first review the advantages of Amazon RDS as a *managed* database service.



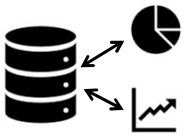
You will now consider some of the advantages of using managed AWS database services.

In the use case on the left, you host the database in your *on-premises* data center. In this case, you are responsible for everything. You must power the racks of physical servers, maintain the operating systems of the servers where the databases run, and performing database software installations and patches. You must also perform backups, configure high availability and scaling solutions, and optimize the applications that use the database.

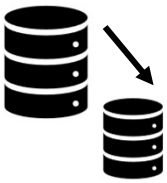
In the center use case, you install a *database on one or more Amazon EC2 instances*. In this case, AWS handles the maintenance of the physical data center environment and the OS is pre-installed on the EC2 instance that you launch. However, you are still responsible for every configuration layer above the OS installation, which means that you must manage many resources manually.

The *AWS managed database offering* is in the use case on the right. These solutions provide high availability, scalability, and database backups as built-in options that you can configure. AWS is responsible for handling common and repetitive database administration tasks. You are only responsible for optimizing your application, and making sure that the database layer works efficiently for your application.

Amazon RDS characteristics



Access pattern
Transactional
Light analytics



Data size
Low-TB range

Performance
Mid to high throughput
Low latency

Business use cases
Transactional
OLAP

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Amazon Relational Database Service (Amazon RDS) is a fully managed relational database service.

Amazon RDS is typically used when the access pattern is transactional, or for light analytics.

As a relational database, the ideal data size ranges up to the low-terabyte range. As storage requirements grow, you can provision additional storage. The Amazon Aurora engine will automatically grow the size of your database volume as your database storage needs grow. It scales up to a maximum of 64 TB, or a maximum you define. The MySQL, MariaDB, Oracle, and PostgreSQL engines enable you to scale up to 32 TB of storage. Microsoft SQL Server supports up to 16 TB. Storage scaling is dynamic, with zero downtime.

In terms of *performance*, Amazon RDS offers two options. First, it offers the general-purpose solid state drive (SSD)-backed storage option. The SSD option delivers a consistent baseline of 3 IOPS per provisioned GB, and it can burst up to 3,000 IOPS above the baseline. This storage type is suitable for a range of database workloads. There is also a Provisioned IOPS SSD storage option, which works well for I/O-intensive transactional database workloads.

Amazon RDS: Uses and database types

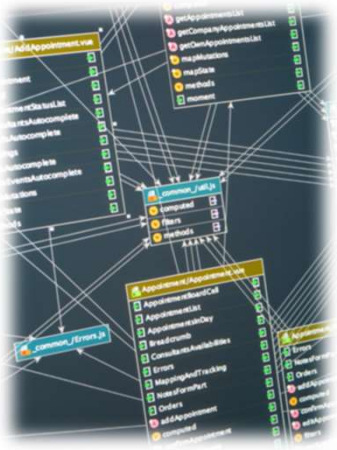
Amazon RDS

Works well for applications that:

- Have more complex data
- Need to combine and join datasets
- Need enforced syntax rules

Six database types supported:

- Microsoft SQL Server
- Oracle
- MySQL
- PostgreSQL
- Aurora
- MariaDB



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As a relational database offering, Amazon RDS is a good choice for applications that have complex, well-structured data. Amazon RDS is a good choice if your workloads must frequently combine and join datasets, and must have syntax rules that are strictly enforced. For example, Amazon RDS is frequently used to back traditional applications, enterprise resource planning (ERP) applications, customer relationship management (CRM) applications, and ecommerce applications.

Amazon RDS is available with six database engines to choose from, including Microsoft SQL Server, Oracle, MySQL, PostgreSQL, Amazon Aurora, and MariaDB.

Database instance sizing

	T family	M family	R family
Type	Burstable instances	General-purpose instances	Memory-optimized instances
Sizing	1 vCPU/1 GB RAM to 8 vCPU 32 GB RAM	2 vCPU/8 GB RAM to 96 vCPU 384 GB RAM	2 vCPU/16 GB RAM to 96 vCPU 768 GB RAM
Networking	Moderate performance	High performance	High performance
Ideal Workload	Smaller or variable	CPU-intensive	Query-intensive, high connection counts
Highlights	T3 can burst above baseline for extra charge	M5 offers up to 96 vCPU	R5 offers up to 96 vCPU 768 GiB RAM

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All Amazon RDS database types run on a serve. The exception is Aurora, which can run as a serverless option. Amazon RDS is available on several database instance types, which are optimized for different kinds of workloads.

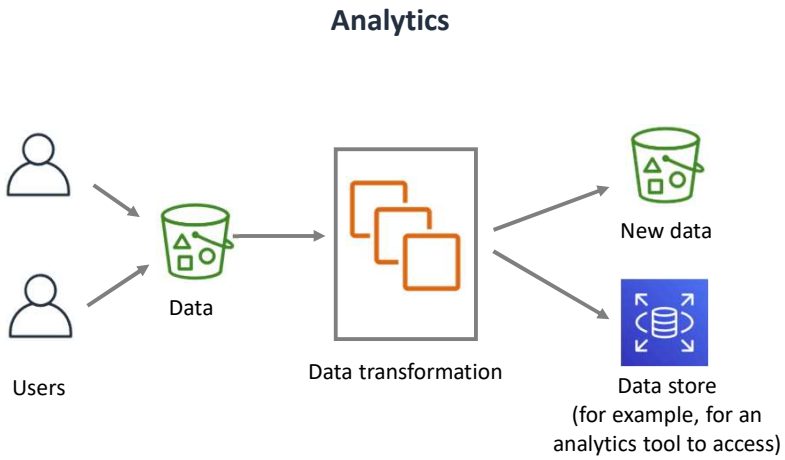
The T family of instance types provides a baseline level of CPU performance with the ability to burst CPU usage at any time for as long as needed. For example, T3 instances offer a balance of compute, memory, and network resources and work well for database workloads with moderate CPU usage that experience temporary spikes in use.

The M family of instances is another general-purpose option. However, the M family provides additional options for CPU-intensive workloads. M instances are a good choice for small and midsize databases for open source or enterprise applications.

Finally, the R family instances are optimized for memory-intensive database workloads.

Some database engines support additional database instance classes. For more information, see Amazon RDS DB Instances, and specifically see the Choosing the DB instance Class AWS Documentation page for instance class details.

Amazon RDS: Example use case



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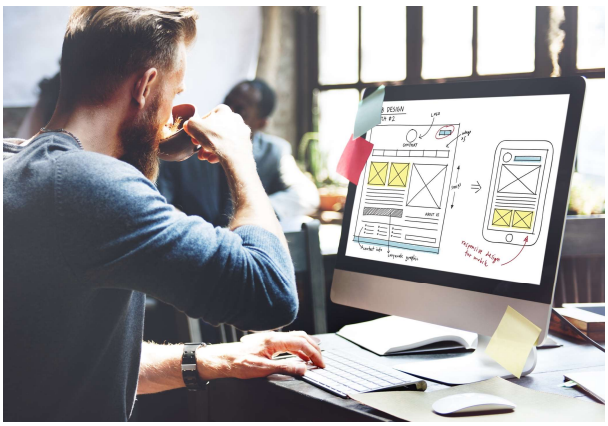
Consider an example use case where Amazon RDS is used as part of a deployed solution to a business challenge.

In this example, a company wants to gain meaningful insight from some of their business data. Users upload the data to an Amazon Simple Storage Service (Amazon S3) bucket. Then, a cluster of Amazon EC2 instances is used to transform the data. This might occur as a batch process at a regular interval. The transformed data is then stored in a different S3 bucket. However, some of the transformed data is also inserted into an RDS instance, which is labeled *Data store*. This RDS instance can then be queried by using analytics software or an AWS analytics service that can make SQL queries to access the data for business insights.

Module 5 - Guided Lab: Creating an Amazon RDS Database



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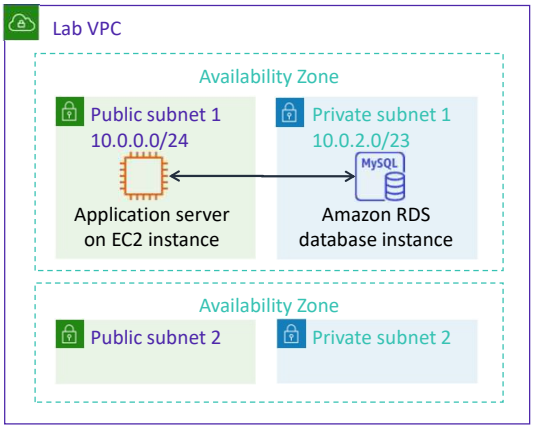
You will now complete Module 5 – Guided Lab: Creating an Amazon RDS Database.

Guided lab: Tasks

1. Creating an Amazon RDS database
2. Configuring web application communication with a database instance



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In this guided lab, you will complete the following tasks:

1. Creating an Amazon RDS database
2. Configuring web application communication with a database instance

~ 20 minutes

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It is now time to start the guided lab.

Guided lab debrief: Key takeaways

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Your educator might choose to lead a conversation about the key takeaways from this guided lab after you have completed it.

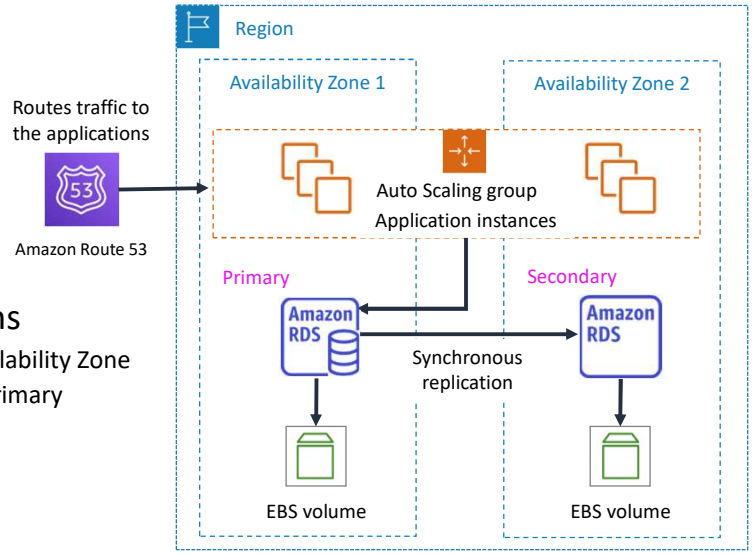
Multi-AZ deployment for high availability

Benefits

- Enhanced durability
- Increased availability
- Fail over to standby occurs automatically

Automated failover conditions

- Loss of availability in primary Availability Zone
- Loss of network connectivity to primary
- Compute unit failure on primary
- Storage failure on primary



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Amazon RDS provides high availability by implementing a Multi-AZ approach. Amazon RDS automatically provisions and maintains a synchronous standby instance in a different Availability Zone. The primary DB instance is synchronously replicated across Availability Zones to the standby instance to provide data redundancy, eliminate I/O freezes, and minimize latency spikes during system backups.

Running a DB instance with high availability can enhance availability during planned system maintenance. It helps protect your databases against DB instance failure and Availability Zone disruption. It also provides enhanced availability and durability for database instances, making it a good choice for production database workloads.

If there is an infrastructure failure, Amazon RDS performs an automatic failover to the standby instance. You can then resume database operations when the failover is complete. The endpoint for your DB instance remains the same after a failover, so your application can resume database operations without manual administrative intervention.

Failover conditions include the loss of availability in the primary Availability Zone, a loss of network connectivity to the primary database, compute unit failure on the primary instance, or storage failure on the primary instance.

Read replicas for performance

Benefits

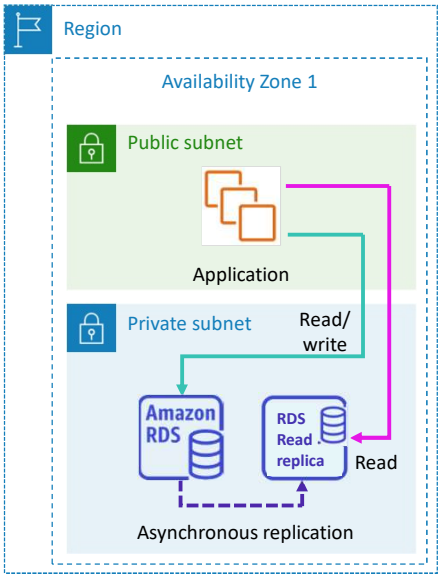
- Enhanced performance
- Increased availability
- Designed for security

Supported by

- MySQL
- MariaDB
- PostgreSQL
- Oracle

Limits

- Five read replicas per primary
- For strict read-after-write consistency, read from the primary



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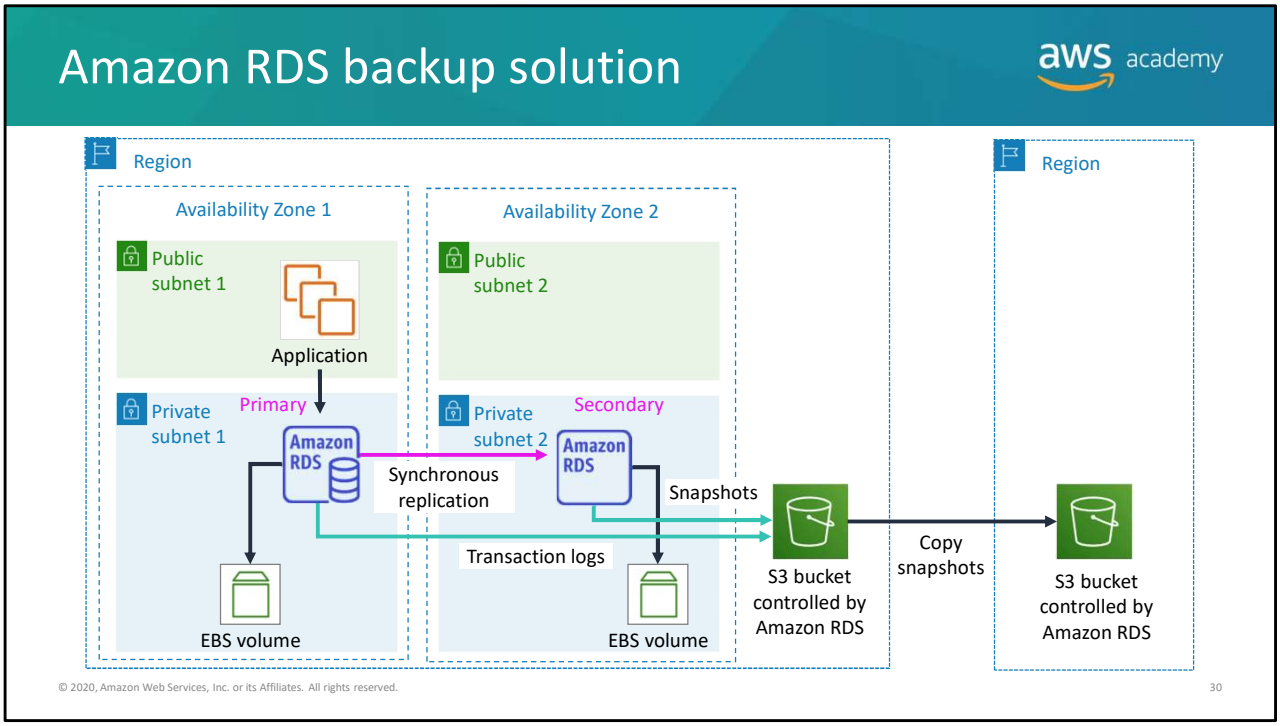
Amazon RDS enables you to use a source database instance to create a special type of database instance, which is called a *read replica*. Updates that are made to the source DB instance are asynchronously copied to the read replica.

Using read replicas enhances *performance.* For example, you can reduce the load on your source database instance by routing read queries from your applications to the read replica. Read replicas also increase *availability.* For read-heavy database workloads, you can elastically scale out beyond the capacity constraints of a single database instance. Read replicas can also be manually promoted to become standalone database instances, when needed.

Read replicas are available in Amazon RDS for MySQL, MariaDB, PostgreSQL, and Oracle. Each of these database engines enables up to a maximum of five read replicas per primary database. If you need strict read-after-write consistency (that is, *what you read is always what you just wrote*, even if you read immediately), then you should read from the main DB instance. Otherwise, you can spread the load, and read from a read replica.



Now, consider an example architecture for a backup solution that is based on Amazon RDS.

Here, snapshots and transaction logs from the RDS database are stored in an S3 bucket that is controlled by Amazon RDS. With Amazon RDS, you can also specify it to copy automated or manual DB to a second AWS Region. You can also copy the snapshots to separate AWS accounts.

For more information, see Copying a Snapshot in the AWS Documentation.

Demonstration: Amazon RDS Automated Backup and Read Replicas

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Now, the educator might choose to demonstrate the configuration of automated backups and read replicas on Amazon RDS by using the AWS Management Console.

Amazon Aurora

Amazon Aurora is a fully managed, MySQL- and PostgreSQL-compatible, relational database engine.

- Used for online transactional processing (OLTP)
- Provides up to five times the throughput of MySQL*
- Provides up to three times the throughput of PostgreSQL*
- Replicates data six ways across three Availability Zones
- Requires little change to your existing application

* Benchmarking details are available for MySQL and. PostgreSQL.

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Amazon Aurora is one of the database engine options for Amazon RDS.

Aurora is a MySQL- and PostgreSQL-compatible relational database that is built for the cloud. It combines the performance and availability of traditional enterprise databases with the simplicity and cost-effectiveness of open source databases.

It is up to five times faster than standard MySQL databases and three times faster than standard PostgreSQL databases. It provides the security, availability, and reliability of commercial databases, but at 1/10th the cost. Detailed instructions on this benchmark and how to replicate it yourself are provided in the Amazon Aurora MySQL Performance Benchmarking GuideMySQL and Amazon Aurora PostgreSQL Performance Benchmarking Guide.

Aurora features a distributed, fault-tolerant, self-healing storage system that automatically scales up to 64 TB per database instance. It delivers high performance and availability, with up to 15 low-latency read replicas, point-in-time recovery, continuous backup to Amazon S3, and replication across three Availability Zones.

Aurora is often used for *online transaction processing* (OLTP). OLTP systems must be able to handle a high volume of concurrent users, and be able to run insert and update requests. A common OLTP example is an order entry system. OLTP is often contrasted with *online analytics processing* (OLAP), which is characterized by a smaller volume of more complex queries.

Amazon Redshift

Amazon Redshift is a data warehousing service.

- Is used for online analytics processing (OLAP)
- Stores very large datasets
  - Store highly structured, frequently accessed data in Amazon Redshift
  - Can also store exabytes of structured, semistructured, and unstructured data in Amazon S3

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Amazon Redshift is a different AWS relational database offering. It does not run on Amazon RDS.

Amazon Redshift provides a petabyte-scale data warehouse and data lake analytics. Amazon Redshift is typically used to store frequently accessed, highly structured data. Amazon Redshift can also access data directly in Amazon S3, so you can also maintain exabytes of structured, semistructured, and unstructured data in Amazon S3.

Amazon Redshift provides consistently fast performance, even with thousands of concurrent queries. It performs consistently whether you are querying data in the Amazon Redshift data warehouse, or querying data in your Amazon S3 data lake. You can query open file formats such as Parquet, JSON, Avro, CSV. You can also query Amazon S3 directly by using SQL.

Section 3 key takeaways

- Managed AWS database services handle administration tasks so you can focus on your applications
- Amazon RDS supports Microsoft SQL Server, Oracle, MySQL, PostgreSQL, Aurora, and MariaDB
- Amazon RDS Multi-AZ deployments provide high availability with automatic failover
- You can have up to five read replicas per primary database to improve Amazon RDS performance
- Amazon Aurora is a fully managed, MySQL- and PostgreSQL-compatible, relational database engine
- Amazon Redshift is a relational database offering for data warehousing

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Some key takeaways from this section of the module include:

- Managed AWS database services handle administration tasks so you can focus on your applications
- Amazon RDS supports Microsoft SQL Server, Oracle, MySQL, PostgreSQL, Aurora, and MariaDB
- Amazon RDS Multi-AZ deployments provide high availability with automatic failover
- You can have up to five read replicas per primary database to improve performance
- Amazon Aurora is a fully managed, MySQL- and PostgreSQL-compatible, relational database engine
- Amazon Redshift is a data warehousing relational database offering

Module 5: Adding a Database Layer

Section 4: Amazon DynamoDB

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Introducing Section 4: Amazon DynamoDB.

Amazon DynamoDB

A fully managed non-relational key-value and document database service.

Performance at any scale

Extreme horizontal scaling capability

Serverless

Event-driven programming (serverless computing)

Enterprise-ready

Encryption, access controls, backups

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Amazon DynamoDB is a fully managed non-relational NoSQL database service. It provides fast and predictable performance with seamless scalability.

Key benefits include:

- Performance at scale
  - It offers consistent, single-digit millisecond response times
  - You can build applications with virtually unlimited throughput
- Serverless
  - No servers to provision, patch, or manage
  - No software to install, maintain, or operate
- Enterprise-ready
  - It supports ACID transactions
  - It encrypts all data at rest by default
  - Multi-Region replication (global tables) is available
  - It provides fine-grained identity and access control
  - You can perform full backups of data with no performance impact

Amazon DynamoDB characteristics

Amazon DynamoDB

Works well for applications that:

- Have simple high-volume data (high-TB range)
- Must scale quickly
- Don't need complex joins
- Require ultra-high throughput and low latency

Key features

- NoSQL tables
- Items can have differing attributes
- In-memory caching
- Support for peaks of more than 20 million requests per second

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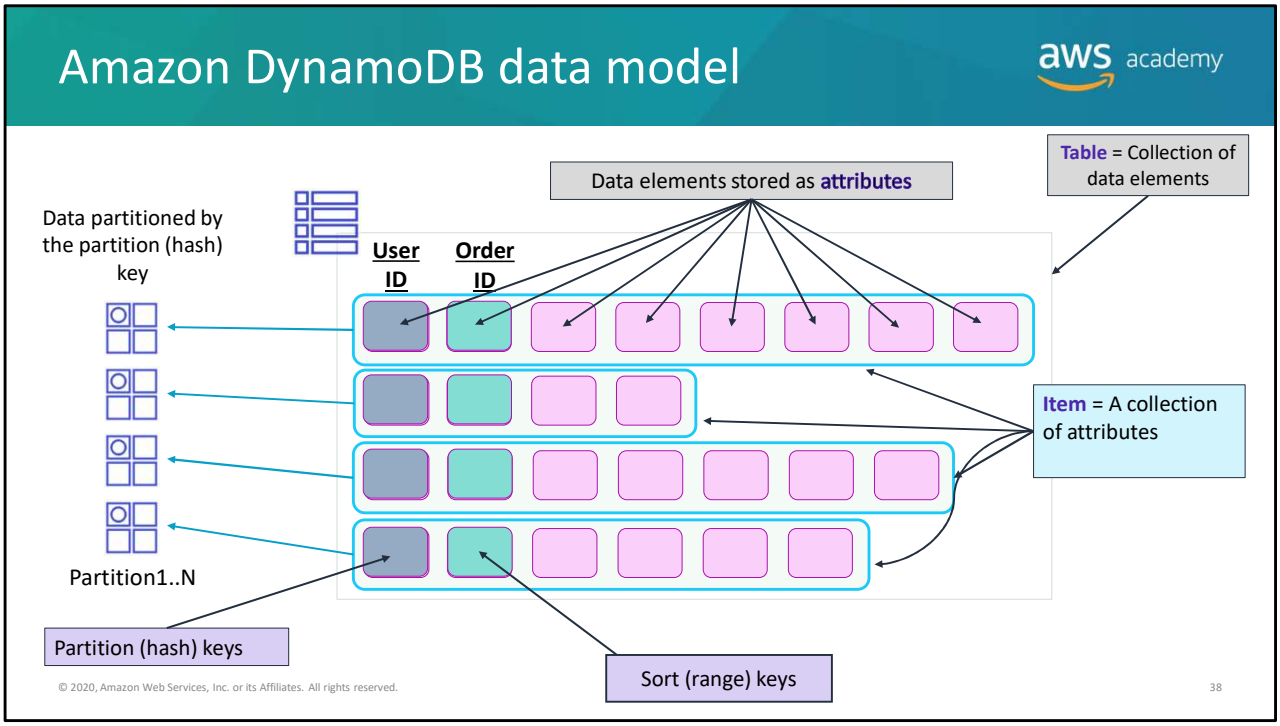
DynamoDB works well for applications that handle a high volume of data and must scale quickly. It also provides ultra-high throughput and low latency, so it is a good option for gaming, adtech, mobile, and other applications that have these requirements. However, a relational database is likely a better choice if your workloads require complex joins.

DynamoDB tables do not have fixed schemas, and each item can have a different number of attributes.

Because DynamoDB provides in-memory caching and can handle more than 20 million requests per second, it is often used for applications that must maintain session state, for serverless web applications, and for microservices.



Now, consider the Amazon DynamoDB data model. Unlike relational databases—and because it is a NoSQL database—DynamoDB does not enforce strict schemas.

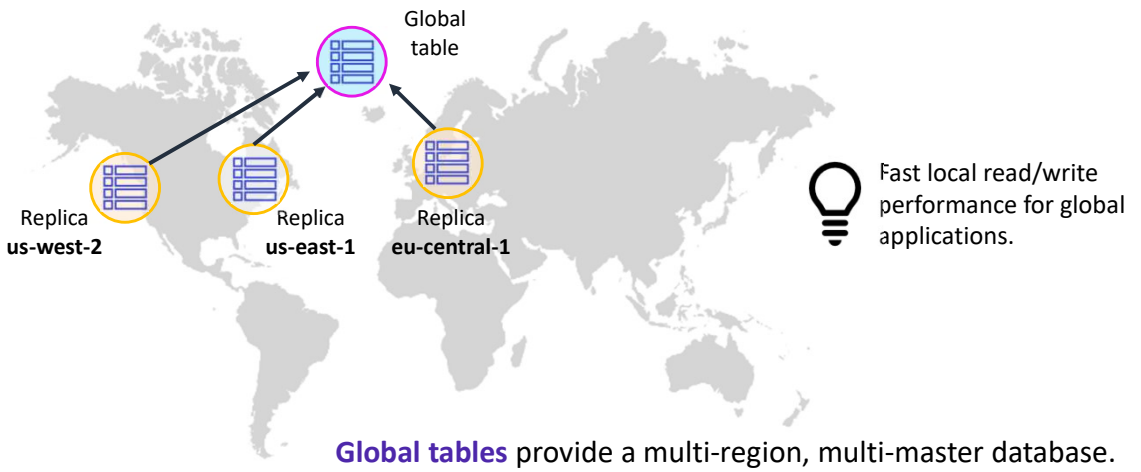
A DynamoDB table holds *items*. An item has a variable number of *attributes*. Each attribute consists of a *key-value pair*.

DynamoDB supports key-value GET/PUT operations that use a user-defined primary key (partition key, also known as a hash key). The primary key is the only required attribute for items in a table and it uniquely identifies each item. You specify the primary key when you create a table. In addition, DynamoDB provides flexible querying by allowing queries on non-primary key attributes using Global Secondary Indexes and Local Secondary Indexes.

Auto-partitioning occurs when the dataset size grows and as provisioned capacity increases.

Consider an example case where you create an Amazon DynamoDB table to hold order information. In the example, your table entries will always have a *User ID* and *Order ID*. However, some of the other details about an order—such as the user's email address—can only be collected for some orders, and not others. As additional items are added to the table, you can continue to collect new attributes. These attributes can include ones that you did not anticipate when you first created the table. This flexibility is what makes DynamoDB a good fit for rapidly changing unstructured, semistructured, and structured data.

Amazon DynamoDB global tables



Global tables provide a multi-region, multi-master database.

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By default, Amazon DynamoDB replicates your data across multiple Availability Zones in a single Region. However, there might be occasions when you want to replicate your data across multiple Regions.

Amazon DynamoDB global tables provide a fully managed solution for deploying a multi-region, multi-master database. You do not need to build and maintain your own replication solution. When you create a global table, you specify the AWS Regions where you want the table to be available. DynamoDB performs all of the necessary tasks to create identical tables in these Regions. DynamoDB then propagates ongoing data changes to all the tables.

To illustrate one use case for a global table, suppose that you have a large customer base spread across three geographic areas—the US east coast, the US west coast, and western Europe. Customers must update their profile information while they use your application.

To handle this business requirement, you could create a global table that consists of your three Region-specific CustomerProfiles tables. DynamoDB would then automatically replicate data changes among those tables. Changes to CustomerProfiles data in one Region would seamlessly propagate to the other Regions. In addition, if one of the AWS Regions became temporarily unavailable, your customers could still access the same CustomerProfiles data in the other Regions.

Amazon DynamoDB use case 1

GameScores

UserId	GameTitle	TopScore	TopScoreDateTime	Wins	Losses	
"101"	"Galaxy Invaders"	5842	"2015-09-15:17:24:31"	21	72	...
"101"	"Meteor Blasters"	1000	"2015-10-22:23:18:01"	12	3	...
"101"	"Starship X"	24	"2015-08-31:13:14:21"	4	9	...
"102"	"Alien Adventure"	192	"2015-07-12:11:07:56"	32	192	...
"102"	"Galaxy Invaders"	0	"2015-09-18:07:33:42"	0	5	...
"103"	"Attack Ships"	3	"2015-10-19:01:13:24"	1	8	...
"103"	"Galaxy Invaders"	2317	"2015-09-11:06:53:00"	40	3	...
"103"	"Meteor Blasters"	723	"2015-10-19:01:13:24"	22	12	...
"103"	"Starship X"	42	"2015-07-11:06:53:00"	4	19	...
...	...	...	...	...	...	

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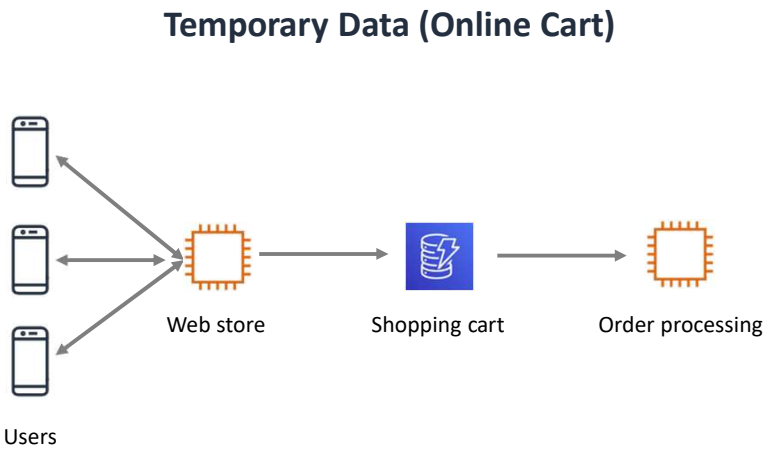
Gaming companies use Amazon DynamoDB in all parts of their game platforms, including game state, player data, session history, and leaderboards. You can scale reliably to millions of concurrent users and requests while you also ensure consistently low latency.

In the example use case, a game score leaderboard is maintained in Amazon DynamoDB. Players who are actively connected to the game servers might see some of this information presented in whatever way the gaming user interface (UI) presents it to them. The GameScores leaderboard is constantly updated when new top scores are achieved and each top scorer's win/loss record changes. As an example, consider Electronic Arts (EA), a large video game company with more than 300 million registered players around the world. For EA, high concurrency can mean more than 100,000 requests per second and millions of daily active users. See DynamoDB Gaming Use Cases for more details.

Amazon DynamoDB use case 2



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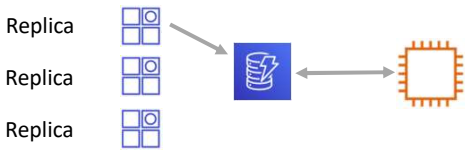
Amazon DynamoDB was developed because customers needed a scalable and highly reliable key-value database to power essential Amazon ecommerce operations, such as the shopping cart.

In 2012, Amazon CTO Werner Vogels explained the business requirements of the Amazon shopping cart in a blog post when he announced the release of Amazon DynamoDB. "This non-relational, or NoSQL, database was targeted at use cases…such as the shopping cart.…Any downtime or performance degradation…has an immediate financial impact and their fault-tolerance and performance requirements for their data systems are very strict. These services also require the ability to scale infrastructure incrementally to accommodate growth in request rates or dataset sizes. Another important requirement…was predictability."

The DynamoDB feature set continues to evolve. However, the core goals that inspired the development of the service remain relevant today to organizations that want to implement a processing solution for a web store shopping cart order.

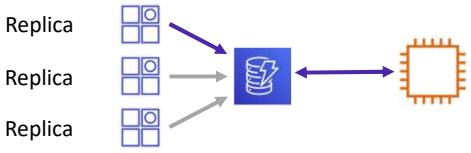
Amazon DynamoDB consistency options

Eventually consistent



The default setting. All copies of data usually reach consistency within 1 second.

Strongly consistent



This feature is optional. Use for applications that require all reads to return a result that reflects all writes before the read.

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Read consistency represents *how* and *when* the successful write or update of a data item is reflected in a subsequent read operation of that same item. Amazon DynamoDB exposes logic that enables you to specify the consistency characteristics you want for each read request in your application.

Eventually consistent reads

When you read data from a DynamoDB table, the response might not reflect the results of a recently completed write operation. The response might include some stale data. If you repeat your read request after a short time, the response should return the latest data.

Strongly consistent reads

When you request a strongly consistent read, DynamoDB returns a response with the most up-to-date data. The response reflects the updates from all previous write operations that were successful. A strongly consistent read might not be available if there is a network delay or outage.

DynamoDB uses *eventually consistent reads*, unless you specify otherwise. Read operations (such as GetItem, Query, and Scan) provide a ConsistentRead parameter. If you set this parameter to *true*, DynamoDB uses strongly consistent reads during the operation.

Now that you know the essential key features of both Amazon RDS and DynamoDB, consider which of these two database services would be a better match for the café's use case.

In an earlier module in the course, you completed a challenge lab where you deployed a MySQL database that runs on an EC2 instance. This database hosts a table that contains details about the café's menu. It also provides the data storage layer for the orders that customers place online.

If the café team decides that they want to migrate the database layer so they can use an Amazon managed database service, which of these two database options would be a better choice?

The educator will lead your class in a conversation about this topic. You are encouraged to participate in the dialog and explain the reasoning behind your answer.

Section 4 key takeaways

- Amazon DynamoDB is a fully managed non-relational key-value and document NoSQL database service.
- DynamoDB is serverless, provides extreme horizontal scaling and low latency.
- DynamoDB global tables ensure that data is replicated to multiple Regions.
- DynamoDB provides eventual consistency by default (in general, it is fully consistent for reads 1 second after the write). Strong consistency is also an option.

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Some key takeaways from this section of the module include:

- Amazon DynamoDB is a fully managed non-relational key-value and document NoSQL database service.
- DynamoDB is serverless, provides extreme horizontal scaling and low latency.
- DynamoDB global tables ensure that data is replicated to multiple Regions.
- DynamoDB provides eventual consistency by default (in general, it is fully consistent for reads 1 second after the write). Strong consistency is also an option.

Module 5: Adding a Database Layer

Section 5: Database security controls

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Introducing Section 5: Database security controls.

Securing Amazon RDS databases

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Recommendations

- Run the RDS instance in a virtual private cloud (VPC)
  - Provides service isolation and IP firewall protection
- Use AWS Identity and Access Management (IAM) policies for authentication and access
  - Permissions determine who is allowed to manage Amazon RDS resources
- Use security groups to control what IP addresses or EC2 instances can connect to your databases
  - By default, network access is disabled
- Use Secure Sockets Layer (SSL) for encryption in transit
- Use Amazon RDS encryption on DB instances and snapshots to secure data at rest
- Use the security features of your DB engine to control who can log in to the databases on a DB instance
- Configure event notifications to alert you when important Amazon RDS events occur

Amazon RDS

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Security is a shared responsibility between you and AWS. AWS is responsible for *security* of *the cloud,* which means that AWS protects the infrastructure that runs Amazon RDS. Meanwhile, you are responsible for *security* in *the cloud*.

One security recommendation for Amazon RDS is to run your RDS instances in a *virtual private cloud (VPC).* A VPC enables you to place your instance in a private subnet, which secures it from public routes on the internet. The VPC also provides IP firewall protection and enables you to securely control the applicable network configuration.

In addition, we recommend that you:

- Use *AWS Identity and Access Management (IAM) policies* for authentication and to control access.
- Configure *security groups* to limit connections. Open the TCP port where the database is accessible. However, you limit where those connections can originate from.
- *Use SSL connections* to ensure that all communication to and from your database is secured.
- *Use Amazon RDS encryption* to encrypt your data and database snapshots.
- *Use the security features of your DB engine*, for example, to enforce password complexity.
- *Enable event notifications* on important events that can occur on your RDS instance. These events can include whether the instance was shut down, a backup was started, a failover occurred, the security group was changed, or your storage space is low.

Securing Amazon DynamoDB

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Recommendations

- Use **IAM roles** to authenticate access
- Use **IAM policies**
  - To define fine-grain access permissions to use DynamoDB APIs
  - Define access at the table, item, or attribute level
  - Follow the **principle of granting least privilege**
- Configure **VPC endpoints**
  - Prevents connection traffic from traversing the open internet
  - VPC endpoint policies allow you to control and limit API access to a DynamoDB table
- Consider **client-side encryption**
  - Encrypt data as close as possible to its origin

Amazon DynamoDB

Security provided by default

- **Encryption at rest** of all user data stored in tables, indexes, streams, and backups
- **Encryption in transit –** All communications to and from DynamoDB and other AWS resources use HTTPS

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To secure Amazon DynamoDB, many of the same best practices that you should use to secure Amazon RDS also apply.

For example, use **IAM roles** to secure authentication, and **use IAM policies** to define access permissions.

If you only require access to DynamoDB from within a virtual private cloud (VPC), you should use a **VPC endpoint** to limit access from only the required VPC. Doing this prevents that traffic from traversing the open internet and being subject to that environment.

Also, If you store sensitive or confidential data in DynamoDB, you might want to encrypt that data as close as possible to its origin so that your data is protected throughout its lifecycle.

Note that DynamoDB provides certain security features by default. For example, DynamoDB protects user data stored at rest and also data in transit between on-premises clients and DynamoDB, and between DynamoDB and other AWS resources within the same AWS Region.

Read the DynamoDB security best practices documentation for additional details.

Module 5: Adding a Database Layer

Section 6: Migrating data into AWS databases

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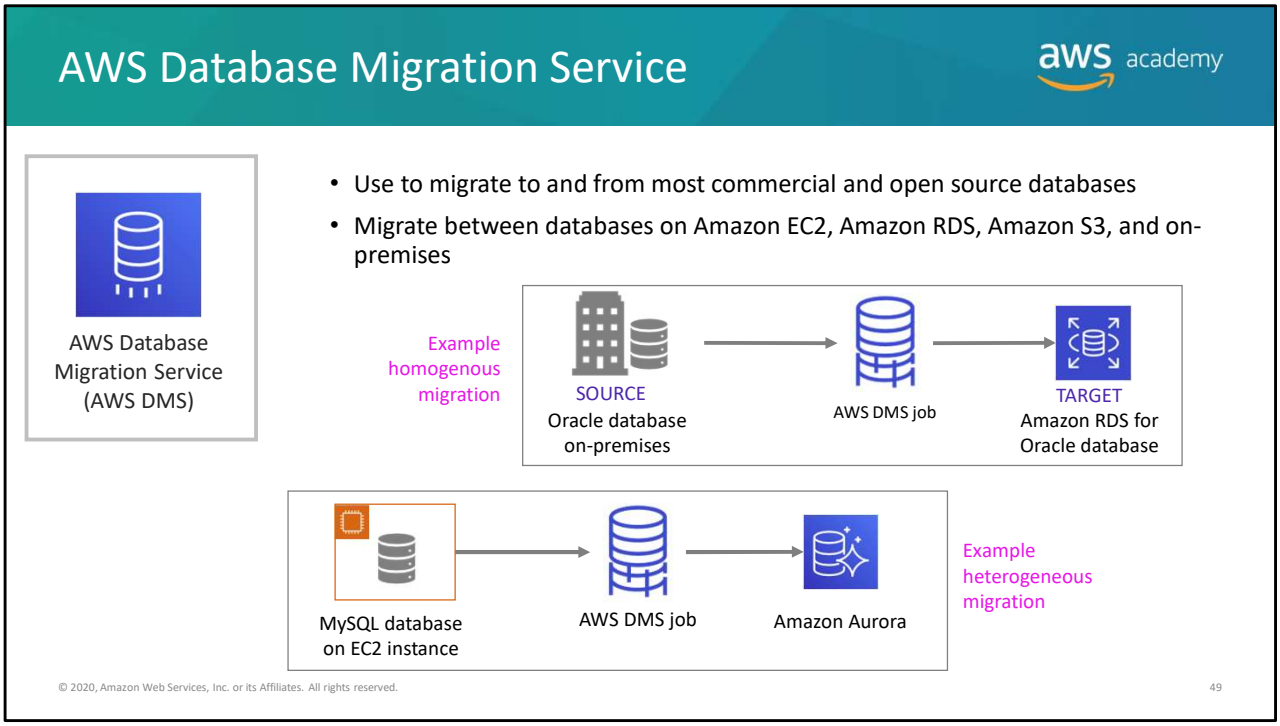
Introducing Section 6: Migrating data into AWS databases.



You can use the AWS Database Migration Service (AWS DMS) to migrate or replicate existing databases to Amazon RDS. AWS DMS supports migration between the most widely used databases.

Supported *source databases* include Oracle, Microsoft SQL Server, MySQL, MariaDB, PostgreSQL, IBM Db2 LUW, SAP, MongoDB, and Amazon Aurora. *Target database* engines include Oracle, Microsoft SQL Server, PostgreSQL, MySQL, Amazon Redshift, SAP ASE, Amazon S3, and Amazon DynamoDB.

AWS DMS also supports both homogenous (same engine) migrations and heterogeneous (different engines) migrations.

The first example shown is a homogenous conversion, where an on-premises Oracle database is migrated to Amazon RDS for Oracle database.

The second example shows a heterogeneous migration, where a MySQL database that runs on an Amazon EC2 instance is migrated to Amazon Aurora.

AWS DMS key features

- Perform one-time migrations
- Or, accomplish continuous data replication
  - Example: Configure continuous data replication of an on-premises database to an RDS instance
- AWS Schema Conversion Tool (AWS SCT) supports changing the database engine between source and target
- Typical migration major steps:
  1. Create a target database
  2. Migrate the database schema
  3. Set up the data replication process
  4. Initiate the data transfer, and confirm completion
  5. Switch production to the new database (for one-time migrations)

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AWS DMS can be used to perform one-time migrations, but it can also be used to accomplish continuous data replication between two databases. For example, you could use it to configure continuous data replication of an on-premises database to an RDS instance.

When you want to perform a heterogeneous migration from one database engine to another, you might want to use the *AWS Schema Conversion Tool (AWS SCT)*.

A typical database migration involves the following major steps:

1. Create a target database
2. Migrate the database schema
3. Set up the data replication process
4. Initiate the data transfer, and confirm completion
5. Switch production to the new database (for one-time migrations)

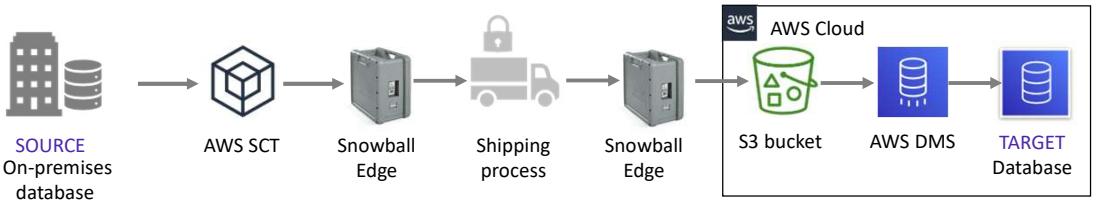
Using AWS Snowball Edge with AWS DMS

When migrating data is not practical:

- Database is too large
- Connection is too slow
- You have privacy and security concerns

Use **AWS Snowball Edge**

- Multi-terabyte transfer without using the internet



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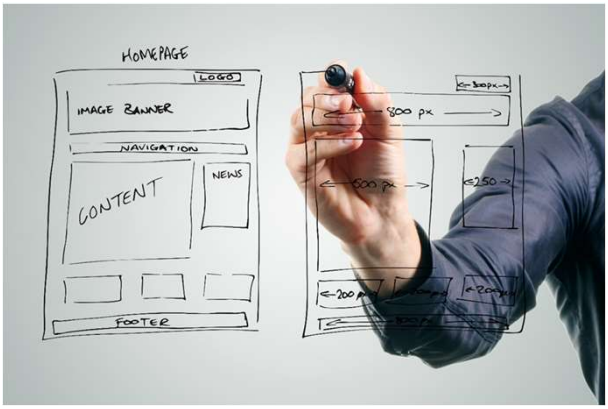
Larger data migrations can include many terabytes of information. This process can be difficult because of network bandwidth limits or the amount of data. AWS Database Migration Service (AWS DMS) can use AWS Snowball Edge and Amazon S3 to migrate large databases more quickly than other methods.

AWS Snowball is an AWS service that provides an Edge device that you use to transfer data to the cloud at faster-than-network speeds. An Edge device is an appliance that is owned by AWS. It provides large amounts of on-board storage. The Edge device also uses 256-bit encryption and an open standard Trusted Platform Module (TPM) to ensure both security and full chain of custody for your data.

When you use an Edge device, the data migration process includes the following stages:

- Use AWS SCT to extract the data locally and move it to the Edge device
- Ship the device back to AWS
- After AWS receives your shipment, the device automatically loads its data into an S3 bucket
- AWS DMS takes the files and migrates the data to the target data store

Module 5 - Challenge Lab: Migrating a Database to Amazon RDS



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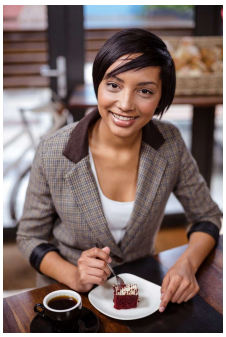
You will now complete Module 5 – Challenge Lab: Migrating a Database to Amazon RDS.

The business need: A managed database

The database that runs on the EC2 instance is becoming difficult for Sofía and Nikhil to maintain.



When Olivia visited the café recently, she told them about the features of Amazon RDS.

Sofía and Nikhil decided to migrate the café's database to Amazon RDS.

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The administration of the café database is becoming difficult for Sofía and Nikhil. For example, they must work extra hours when the café is closed to do weekly database backups.

In addition, they recently struggled to install a required patch. Sofía and Nikhil almost did not complete it during the weekend afterhours window. Frank and Martha now realize that these maintenance tasks increase the business' labor costs because they must pay for the overtime hours that Sofía and Nikhil work.

Raquel, an AWS solutions architect, is a café customer and Sofía’s friend. Sofía mentioned the topic of databases to Olivia during a recent conversation. Olivia suggested that they migrate the database to Amazon RDS.

This solution will reduce the burden of manually performing common database maintenance tasks, such as backups, patch installation, and upgrades. As a fully managed service, Amazon RDS performs these tasks automatically.

In this activity, you will take on the roles of Nikhil and Sofía, and work to migrate the café database to Amazon RDS.

Challenge lab: Tasks

1. Creating an RDS instance
2. Analyzing the existing café application deployment
3. Working with the database on the EC2 instance
4. Working with the RDS database
5. Importing the data into the RDS database instance
6. Connecting the café application to the new database

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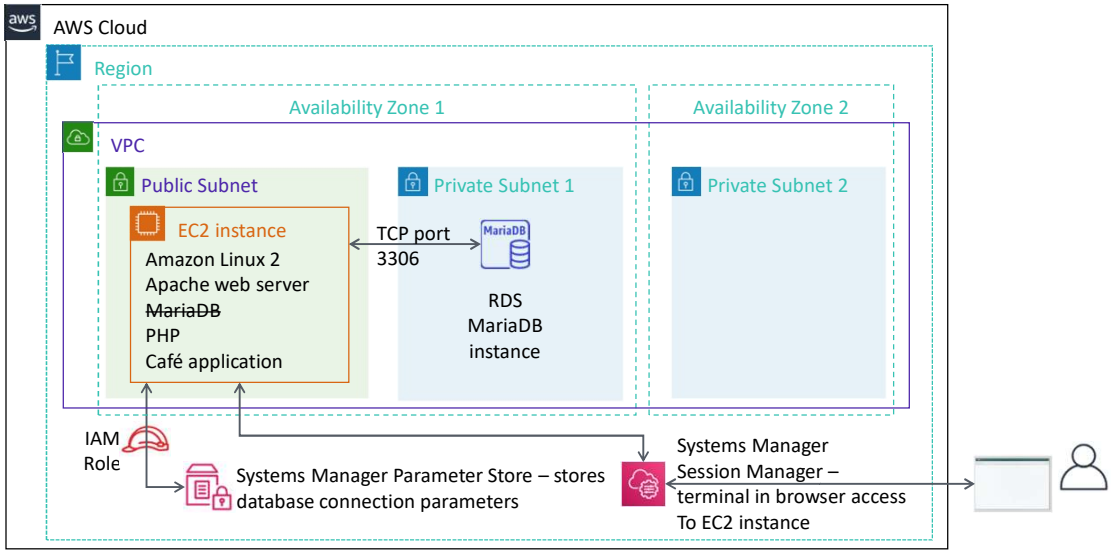
In this challenge lab, you will complete the following tasks:

1. Creating an RDS instance
2. Analyzing the existing café application deployment
3. Working with the database on the EC2 instance
4. Working with the RDS database
5. Importing the data into the RDS database instance
6. Connecting the café application to the new database

Challenge lab: Final product



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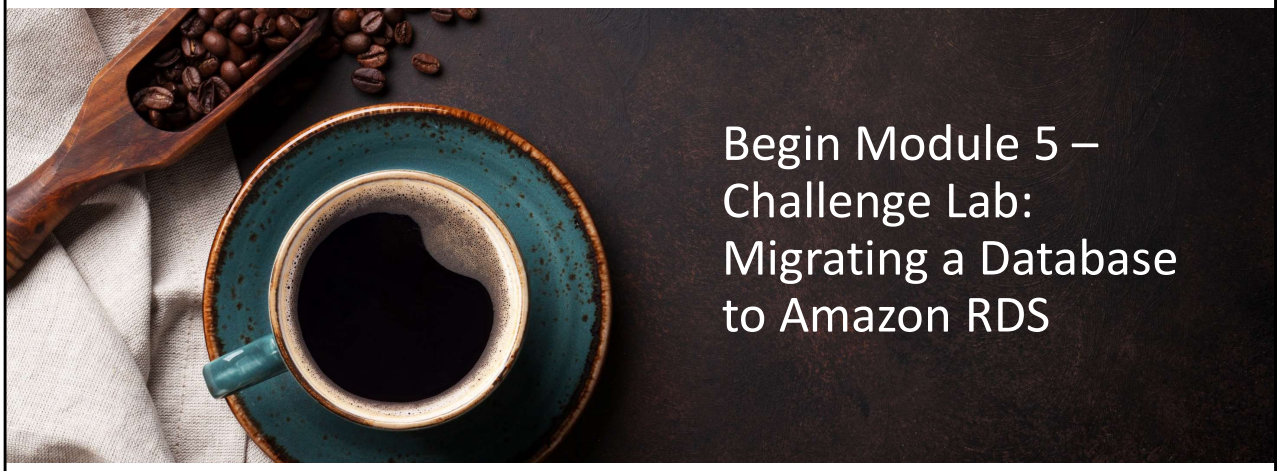
The diagram summarizes what you will have accomplished after you complete the lab.

The café web application originally used the MariaDB that is installed on the EC2 instance. However, in the course of the lab, you create an RDS MariaDB instance, dump the data out of the database on the EC2 instance, and migrate the data into the RDS database.

To accomplish the migration, you connect to the EC2 instance by using the AWS Systems Manager Session Manager, which provides terminal access through a web browser. You use a MySQL client that is installed on the EC2 instance to connect to both databases, as needed, during the migration. Database credentials and database connection information are stored in the AWS Systems Manager Parameter Store. Thus, an IAM role is attached to the EC2 instance to allow the web application to read data out of the Parameter Store.

~ 80 minutes



Begin Module 5 – Challenge Lab: Migrating a Database to Amazon RDS

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It is now time to start the challenge lab.

Challenge lab debrief: Key takeaways

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The educator might now choose to lead a conversation about the key takeaways from the challenge lab after you have completed it.

Module 5: Adding a Database Layer

Module wrap-up

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aws academy

It’s now time to review the module and wrap up with a knowledge check and discussion of a practice certification exam question.

Module summary

In summary, in this module, you learned how to:

- Compare database types
- Differentiate between managed versus unmanaged services
- Explain when to use Amazon Relational Database Service (Amazon RDS)
- Explain when to use Amazon DynamoDB
- Describe available database security controls
- Describe how to migrate data into Amazon Web Services (AWS) databases
- Deploy a database server

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Complete the knowledge check

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It is now time to complete the knowledge check for this module.

Sample exam question

An application requires a highly available relational database with an initial storage capacity of 8 TB. The database will grow by 8 GB every day. To support expected traffic, at least eight read replicas will be required to handle database reads.

Which option will meet these requirements?

A. DynamoDB
B. Amazon S3
C. Amazon Aurora
D. Amazon Redshift

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Look at the answer choices and rule them out based on the keywords that were previously highlighted.

The correct answer is C. Amazon Aurora is a relational database that will automatically scale to accommodate data growth. Amazon Redshift does not support read replicas and will not automatically scale. DynamoDB is a NoSQL service, not a relational database. Amazon S3 is object storage, not a relational database.

Additional resources

- AWS Databases – Resource page
- Amazon RDS Getting Started Guide
- Best Practices for Amazon RDS
- Amazon RDS FAQs
- Amazon DynamoDB Developer Guide
- Amazon DynamoDB FAQs

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If you want to learn more about the topics covered in this module, you might find the following additional resources helpful:

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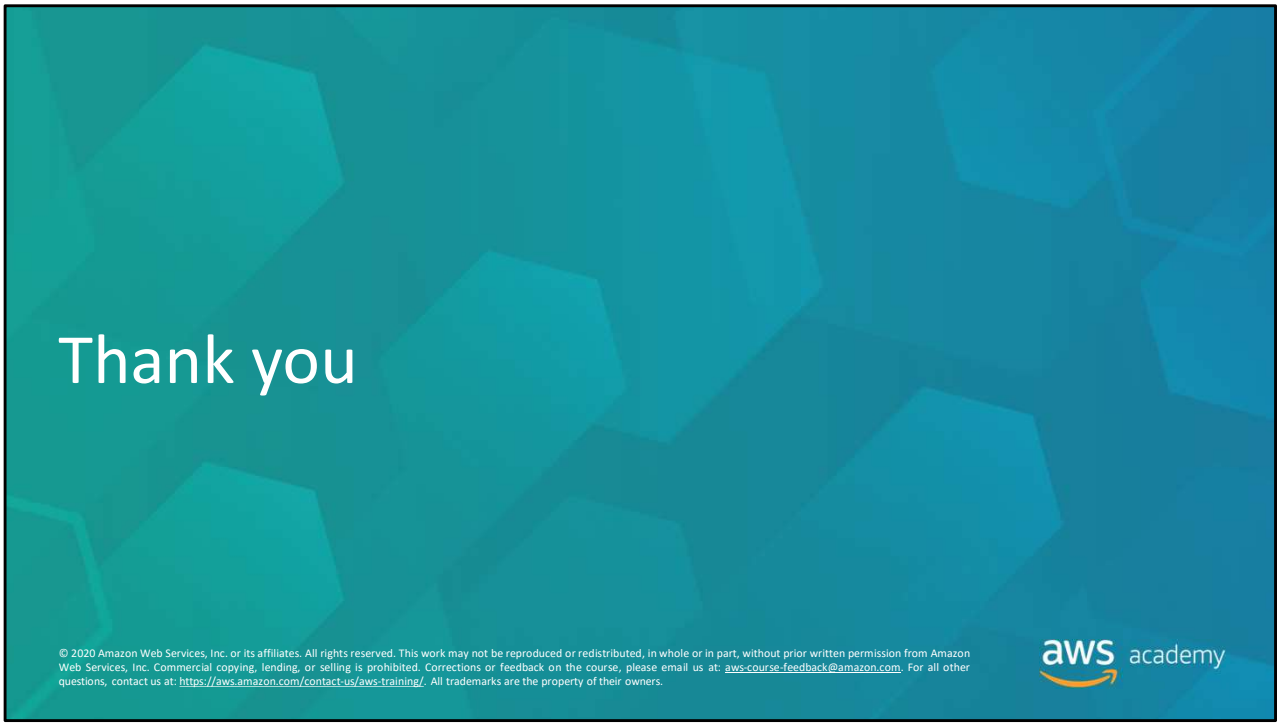
- Best Practices for Amazon RDS
- Amazon RDS FAQs
- Amazon DynamoDB Developer Guide
- Amazon DynamoDB FAQs



Thank you for completing this module.