



Data Partitioning



Data Partitioning is a technique to break a big database into many smaller parts.

It is the process of splitting up a DB/table across multiple machines to improve the manageability, performance, availability, and load balancing of an application.

The justification for data partitioning is that, after a certain scale point, it is cheaper and more feasible to scale horizontally by adding more machines than to grow it vertically by adding beefier servers.

Partitioning Methods

There are many different schemes one could use to decide how to break up an application database into multiple smaller DBs.

Below are three of the most popular schemes used by various large-scale applications.

Horizontal Partitioning

In this scheme, we put different rows into different tables.

For example, if we store different places in a table, we can decide that locations with ZIP codes less than 10000 are stored in one table, and places with ZIP codes greater than 10000 are stored in a separate table.

This is also called **range-based partitioning** as we are storing different ranges of data in separate tables.

Horizontal partitioning is also known as **data sharding**.

The key problem with this approach is that if the value whose range is used for partitioning isn't chosen carefully, then the partitioning scheme will lead to

unbalanced servers.

In the previous example, splitting locations based on their ZIP codes assumes that places will be evenly distributed across the different ZIP codes.

This assumption is not valid as there will be a lot of places in a thickly populated area like Manhattan as compared to its suburb cities.

Vertical Partitioning

In this scheme, we divide our data to store tables related to a specific feature in their own server.

For example, if we are building an Instagram-like application, where we need to store data related to users, photos they upload, and people they follow, we can decide to place user profile information on one DB server, follower lists on another, and photos on a third server.

Vertical partitioning is straightforward to implement and has a low impact on the application.

The main problem with this approach is that if our application experiences additional growth, then it may be necessary to further partition a feature specific DB across various servers.

E.g. it would not be possible for a single server to handle all the metadata queries for 10 billion photos by 140 million users.

Directory-based Partitioning

A loosely-coupled approach to work around issues mentioned in the above schemes is to create a lookup service that knows your current partitioning scheme and abstracts it away from the DB access code.

So, to find out where a particular data entity resides, we query the directory server that holds the mapping between each tuple key to its DB server.

This loosely-coupled approach means that we can perform tasks like adding servers to the DB pool or changing our partitioning scheme without having an impact on the application.

Partitioning Criteria

Key or Hash-based Partitioning

Under this scheme, we apply a hash function to some key attributes of the entity that we are storing. This yields the partition number.

For example, if we have 100 DB servers and our ID is a numeric value that gets incremented by one each time a new record is inserted, our hash function could be $ID \% 100$, which will give us the server number where we can store/read that record.

This approach should ensure a uniform allocation of data among servers.

The fundamental problem with this approach is that it effectively fixes the total number of DB servers, since adding new servers means changing the hash function, which would require redistribution of data and downtime for the service.

A workaround for this problem is to use Consistent Hashing.

List Partitioning

In this scheme, each partition is assigned a list of values, so whenever we want to insert a new record, we will see which partition contains our key and then store it there.

For example, we can decide all users living in Iceland, Norway, Sweden, Finland or Denmark will be stored in a partition for the Nordic countries.

Round-Robin Partitioning

This is a very simple strategy that ensures uniform data distribution.

With n partitions, the i th tuple is assigned to partition $i \bmod n$

Composite Partitioning

Under this scheme, we combine any of the above partitioning schemes to devise a new scheme.

For example, first applying a list partitioning scheme and then a hash-based partitioning.

Consistent Hashing could be considered a composite of hash and list partitioning, where the hash reduces the key-space to a size that can be listed.

Common Problems of Data Partitioning

On a partitioned database, there are certain extra constraints on the different operations that can be performed.

Most of these constraints are due to the fact that operations across multiple tables or multiple rows in the same table will no longer run on the same server.

Below are some of the constraints and additional complexities introduced by data partitioning

Joins and Denormalisation

Performing joins on a database that is running on one server is straightforward, but once a database is partitioned and spread across multiple machines, it is often not feasible to perform joins that span database partitions.

Such joins will not be performant since data has to be compiled from multiple servers.

A common workaround for this problem is to denormalise the database — add redundant data to one or more tables — so that queries that previously required joins can be performed from a single table.

Of course, the service now has to deal with denormalisation's perils, such as data inconsistency.

Referential Integrity

We saw that performing a cross-partition query on a partitioned database is not feasible.

Similarly, trying to enforce data integrity constraints such as foreign keys in a partitioned database can be extremely difficult.

Most RDBMS do not support foreign key constraints across databases on different database servers.

This means that most applications that require referential integrity on partitioned databases often have to enforce it in the application code.

Often in such cases, applications have to run regular SQL jobs to clean up dangling references.

Rebalancing

There could be many reasons as to why we have to change our partitioning scheme:

1. The data distribution is not uniform, e.g. there are a lot of places for a particular ZIP code that cannot fit into one database partition
2. There is a lot of load on one partition, e.g. there are too many requests being handled by the DB partition dedicated to user photos

In such cases, either we have to create more DB partitions or have to rebalance existing partitions, which means that the partitioning scheme changed and all existing data moved to new locations.

Doing this without incurring downtime is extremely difficult.

Using a scheme like directory-based partitioning does make rebalancing a more palatable experience at the cost of increasing the complexity of the system and creating a new single point of failure, i.e. the lookup service/database.