Implement Relational Data Stores

Implement relational data stores

Learning Objectives

- Azure SQL Database offerings
  - PaaS vs IaaS
  - PaaS deployment options
  - Purchasing models and Service Tier
  - Elastic Database
  - Managed Database
  - Security
- Azure SQL Datawarehouse
  - Traditional vs Modern Architecture
  - Azure Synapse Analytics
  - MPP Architecture
  - Storage and Sharding Pattern
  - Data Distribution and Table types
  - Partitioning
- Loading methods
  - PolyBase vs SSIS
  - PolyBase steps and demos
- Azure SQL Server vs Datawarehouse

Introduction

Azure SQL Database Deployment Types

Why SQL Server in Azure?

Fully Managed

Predictable performance and pricing

Elastic pool for unpredictable workloads

99.99% availability built-in

Geo-replication and restore services

Supports existing SQL Server tools, libraries, and APIs

Scalability with no downtime

Secure and compliant for your sensitive data

Azure IaaS vs PaaS Database offerings?

SQL Server on Azure VMs

SQL Server inside a
fully-managed VM in Azure

Azure SQL Database

Database-as-a-service (DBaaS)
hosted in Azure

Responsibility comparison

SQL Server on Azure VMs

SQL Server inside a
fully-managed VM in Azure

Azure SQL Database

Database-as-a-service (DBaaS)
hosted in Azure

Benefits comparison

SQL Server on Azure VMs

SQL Server inside a
fully-managed VM in Azure

Azure SQL Database

Database-as-a-service (DBaaS)
hosted in Azure

Limitations comparison

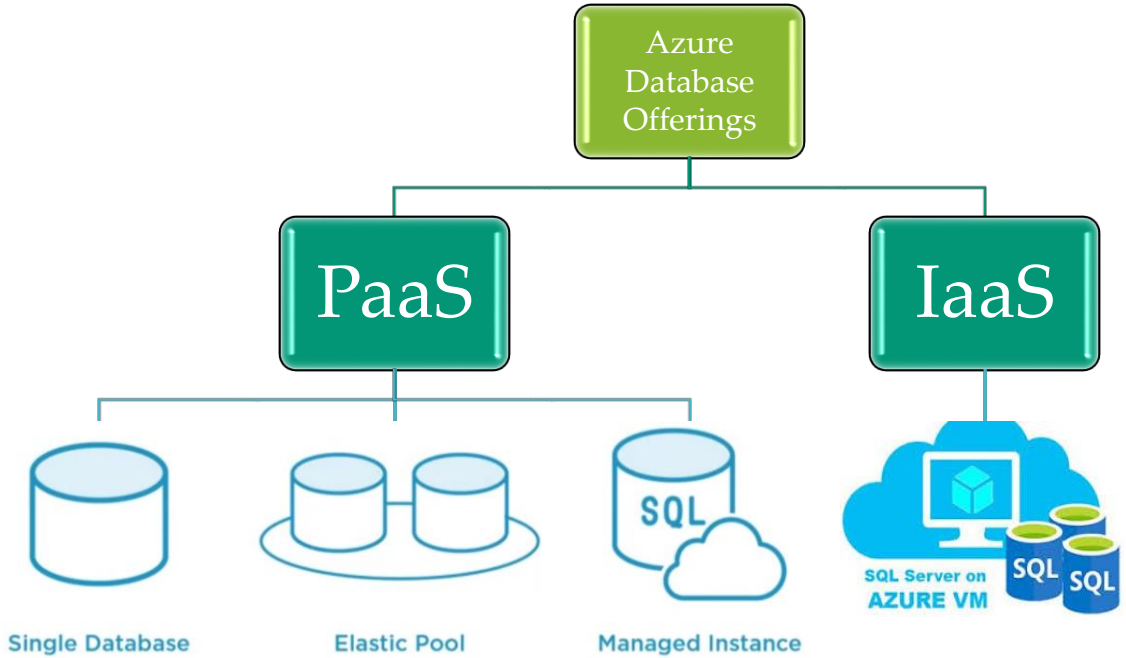
SQL Server on Azure VMs

SQL Server inside a
fully-managed VM in Azure

Azure SQL Database

Database-as-a-service (DBaaS)
hosted in Azure

Azure Database Deployment options



SQL Server(PaaS) Deployment Options

Single Database

Single database

Each DB with its own guaranteed compute, memory, and storage

Elastic pool

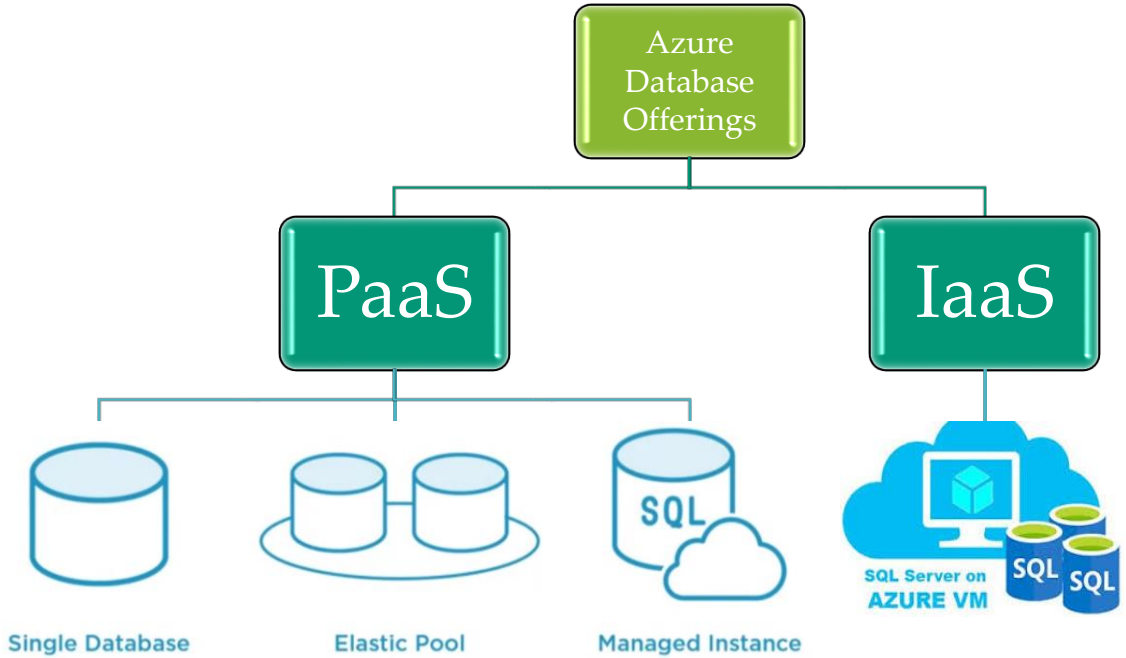
Fixed resources will be shared by all databases in the pool

Managed Instance

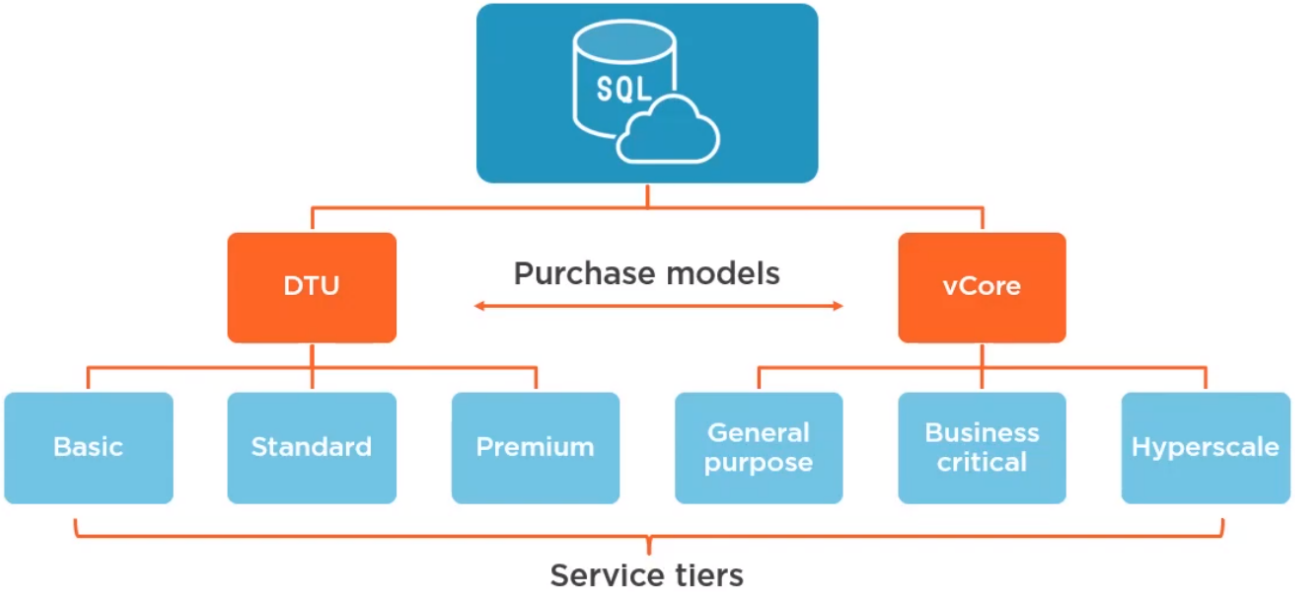
Managed instance

Each managed instance has its guaranteed resources

Azure Database Deployment options



Azure SQL Database Service Tiers



vCore-based vs DTU-based Model

vCore-based

- For Single database, elastic pool and managed instance
- Best for customers who need flexibility, control, and transparency
- Straightforward way to translate on-premises workload to the cloud
- Microsoft recommends vCore-based model

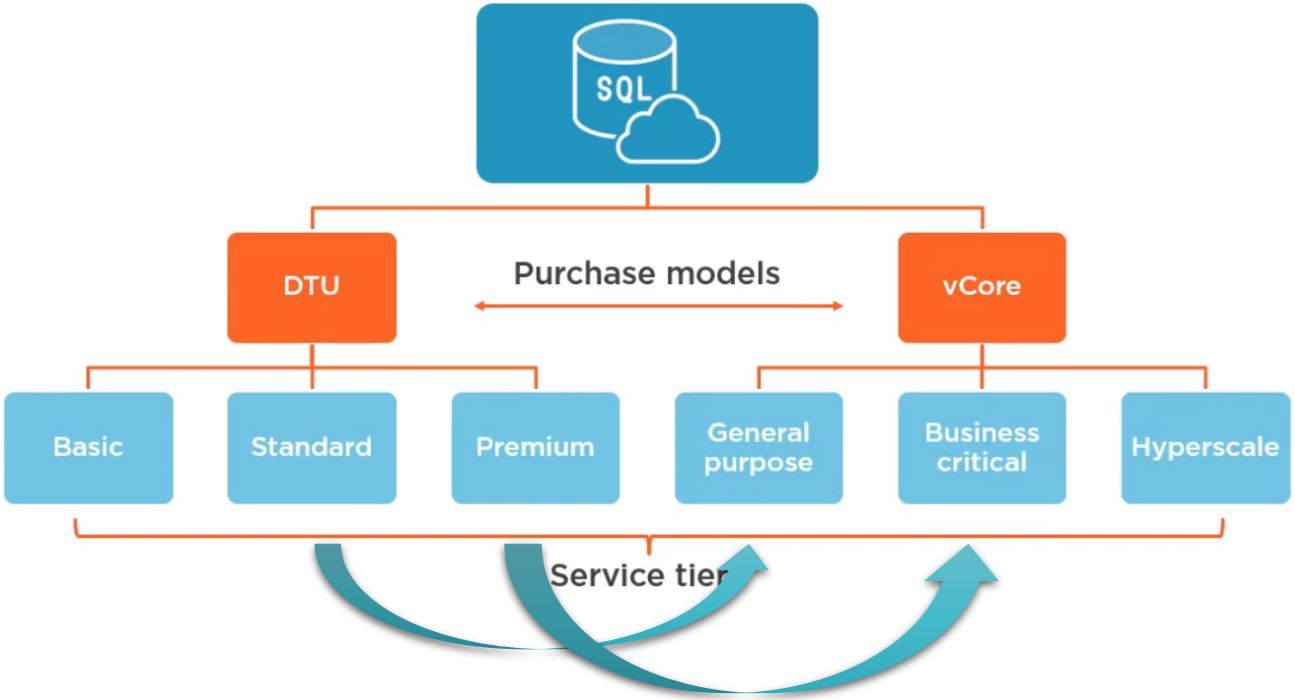
DTU-based

- Only for single database and elastic pool
- Best for customers who want single, preconfigured resource options
- Might need to calculate the needed DTUs before migration
- If the DTU-based purchasing model needs your performance and business requirements, you should continue using it.

Converting DTU-based Model to vCore-based

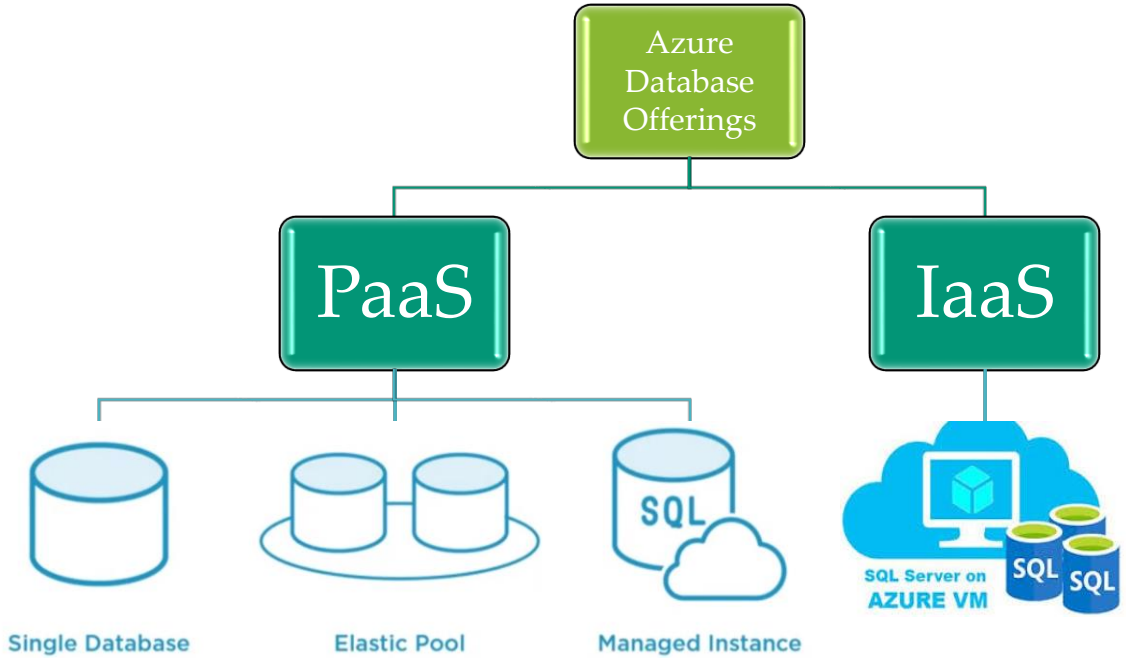
- If you single database or elastic pool consumes more than 300 DTUs, converting to the vCore-based model might reduce your costs
- You can use API of your choice or Azure Portal to convert to vCore based model with ‘no downtime’.
- Azure SQL Database managed instance only supports vCore-based purchasing model.

Azure SQL Database Service Tiers



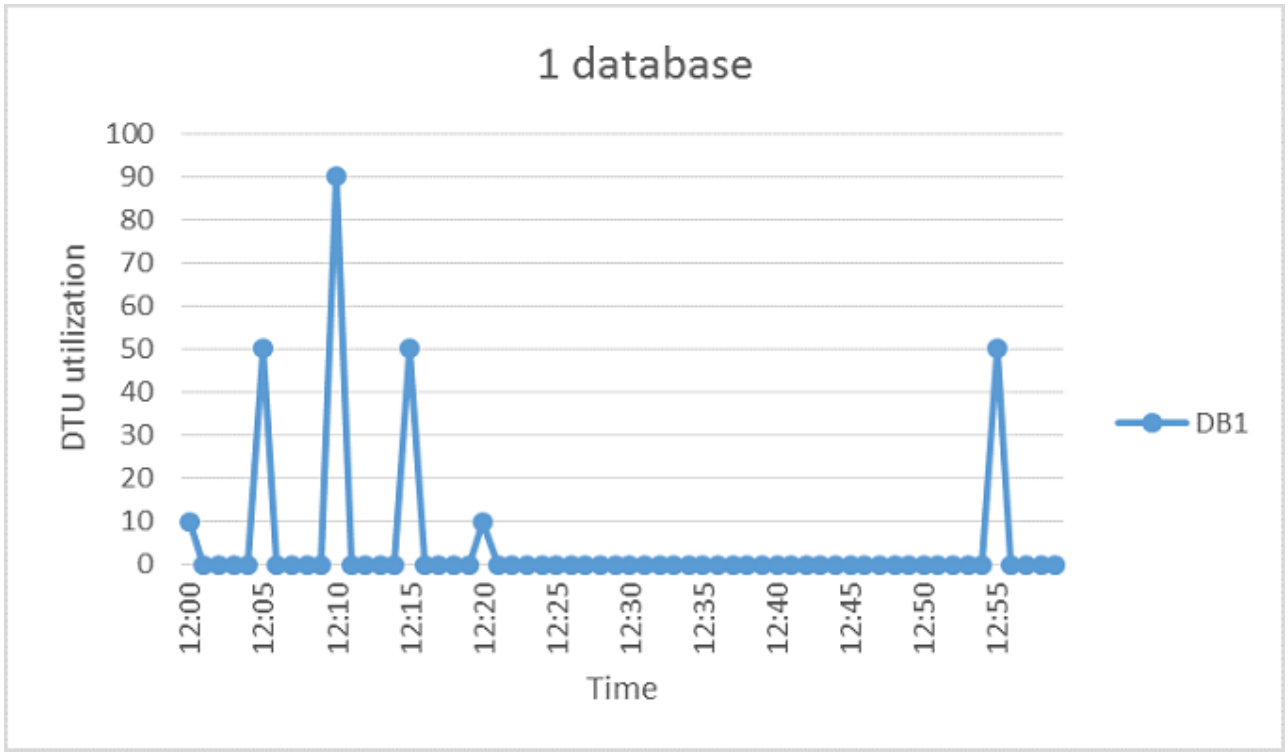
Azure SQL Database Options

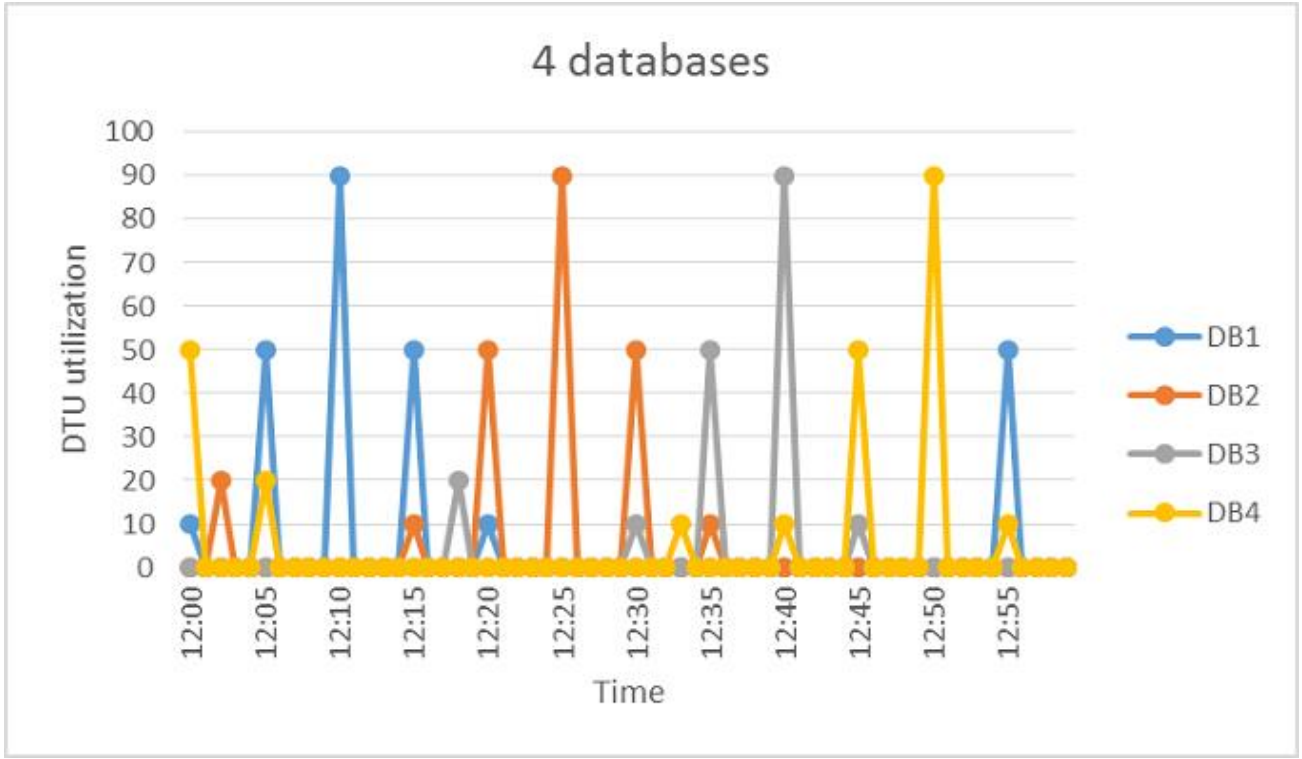
Azure Database Elastic Pool

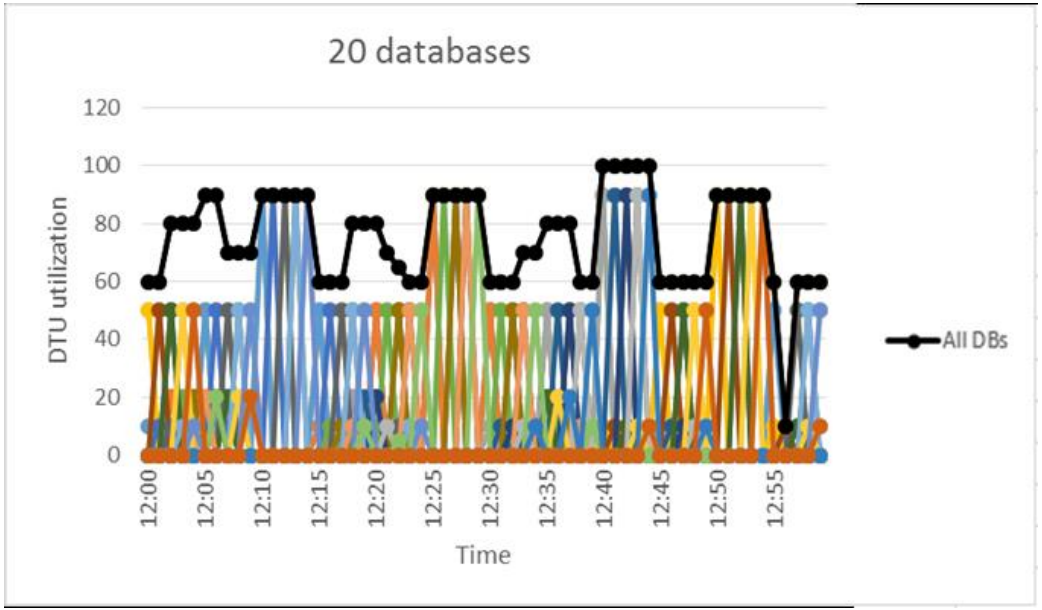


SQL Database Elastic Pools

An Azure SQL Elastic Pool allows you to allocate a shared set of compute resources to a collection of Azure SQL databases,


1 database
DTU utilization
100
90
80
70
60
50
40
30
20
10
0
12:00
12:05
12:10
12:15
12:20
12:25
12:30
12:35
12:40
12:45
12:50
12:55
Time
DB1

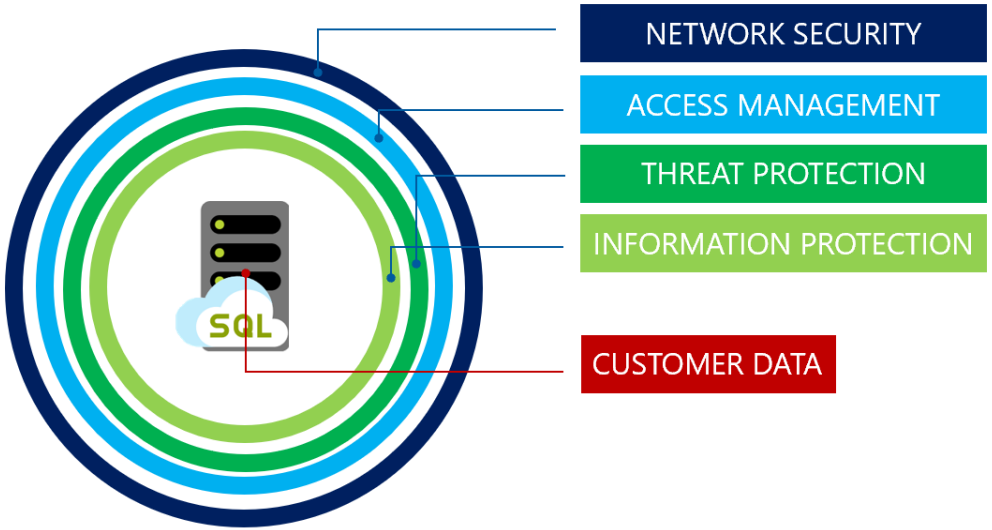

4 databases
DTU utilization
100
90
80
70
60
50
40
30
20
10
0
12:00
12:05
12:10
12:15
12:20
12:25
12:30
12:35
12:40
12:45
12:50
12:55
Time
DB1
DB2
DB3
DB4


20 databases
120
100
80
60
40
20
0
DTU utilization
12:00
12:05
12:10
12:15
12:20
12:25
12:30
12:35
12:40
12:45
12:50
12:55
Time
All DBs

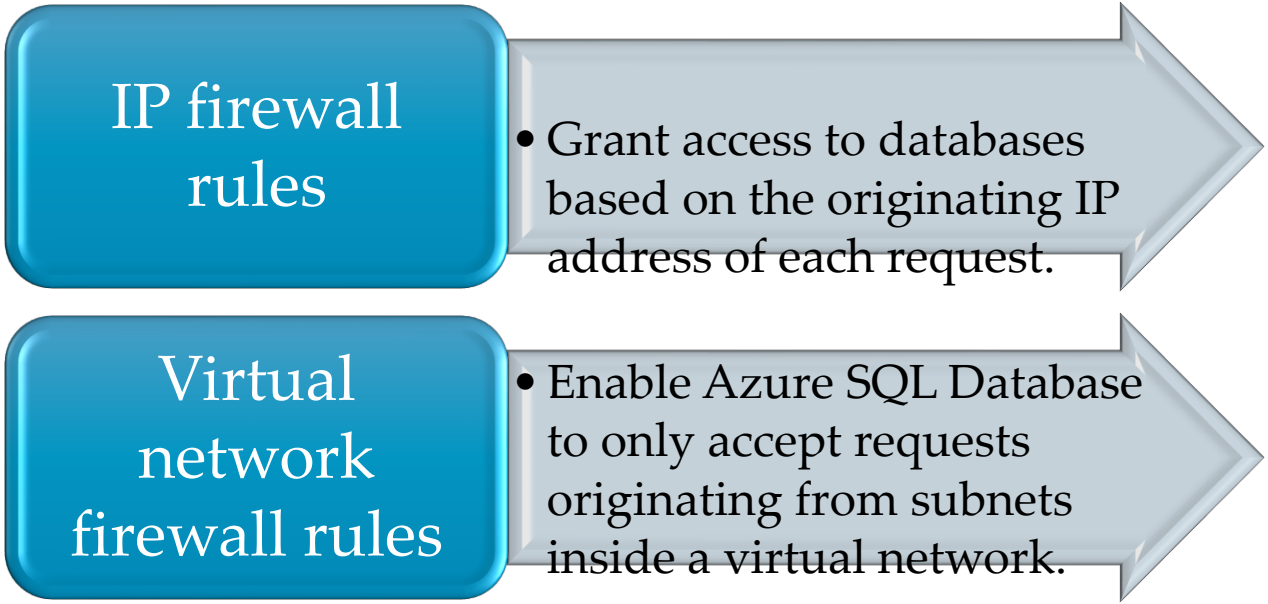
Azure SQL Database Elastic Pool

- So Azure SQL elastic pool is a cost- effective solution for managing and scaling multiple databases that have varying and unpredictable usage demands.
- The databases in an elastic pool are on a single Azure SQL Database server and share a set number of resources at a set price.
- Elastic pool enables developers to optimize the price performance for a group of databases within a prescribed budget.
- Elastic pools prevent over-provisioning or under-provisioning of resources.

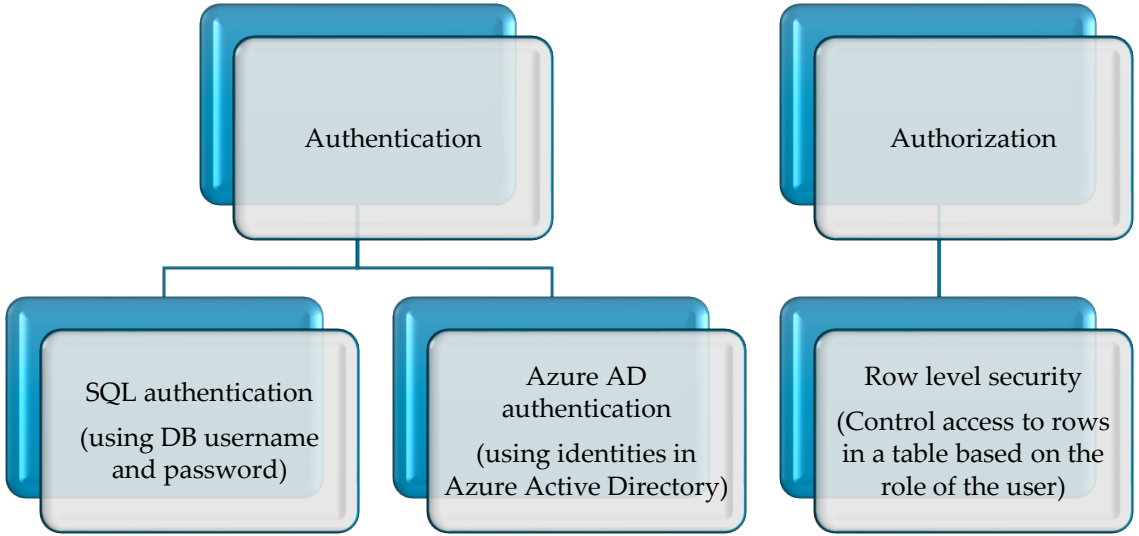
Security


NETWORK SECURITY
ACCESS MANAGEMENT
THREAT PROTECTION
INFORMATION PROTECTION
CUSTOMER DATA
SQL

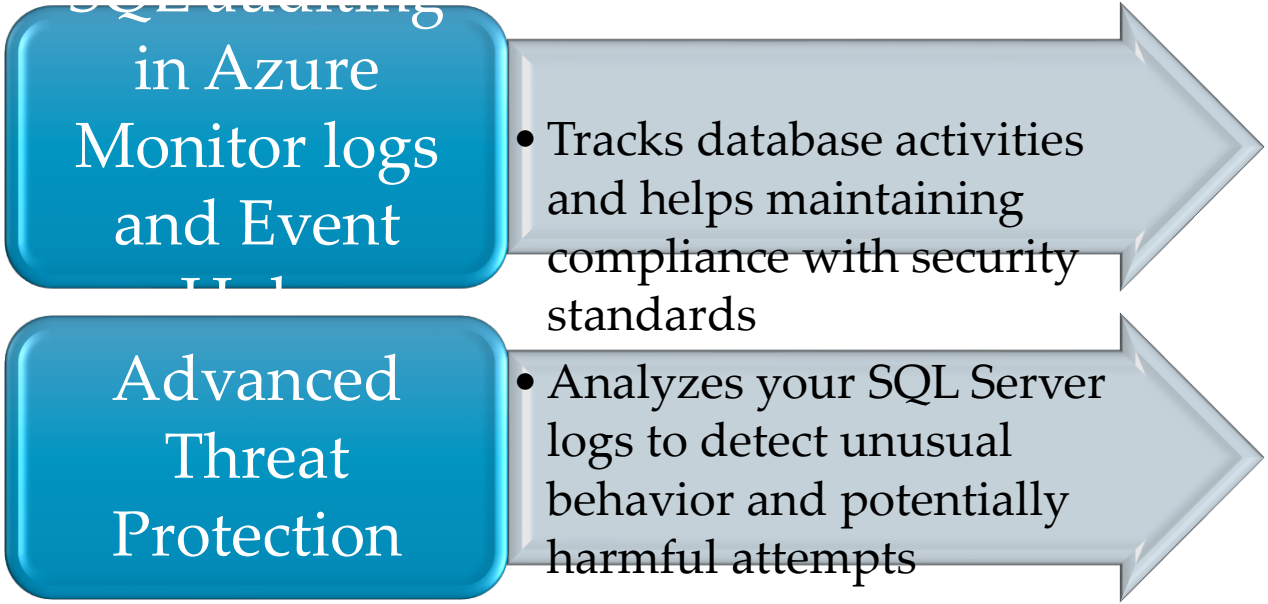
Network security



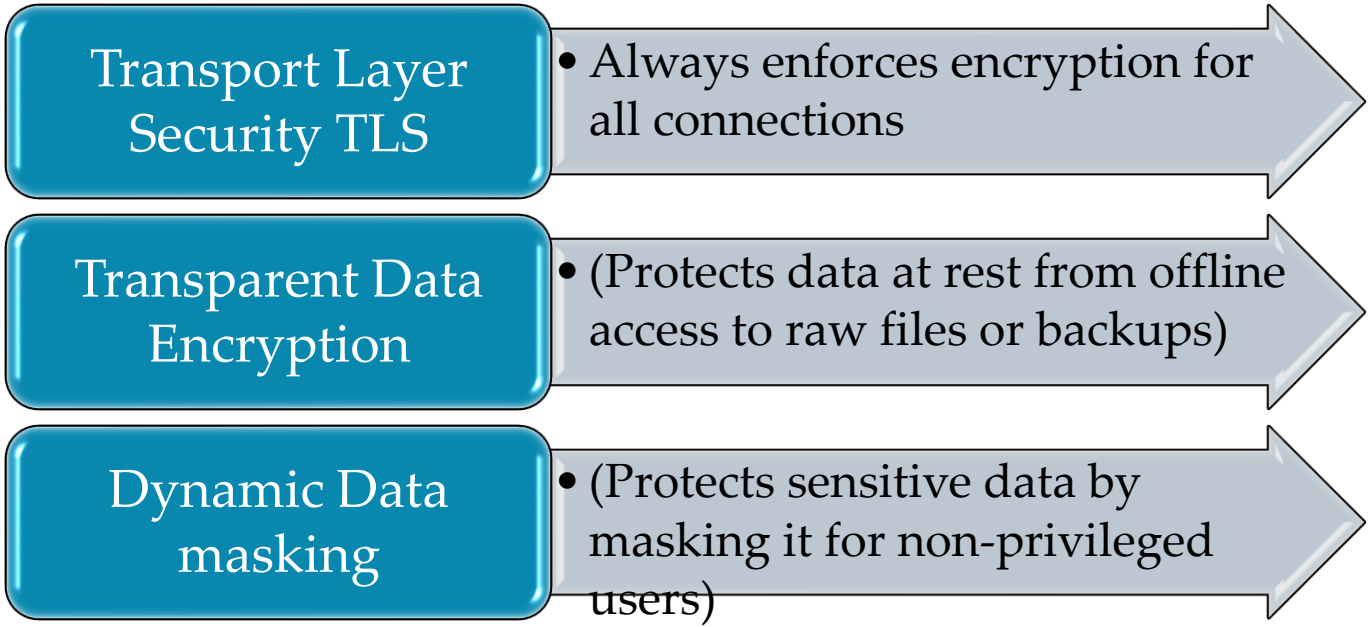
Access Management



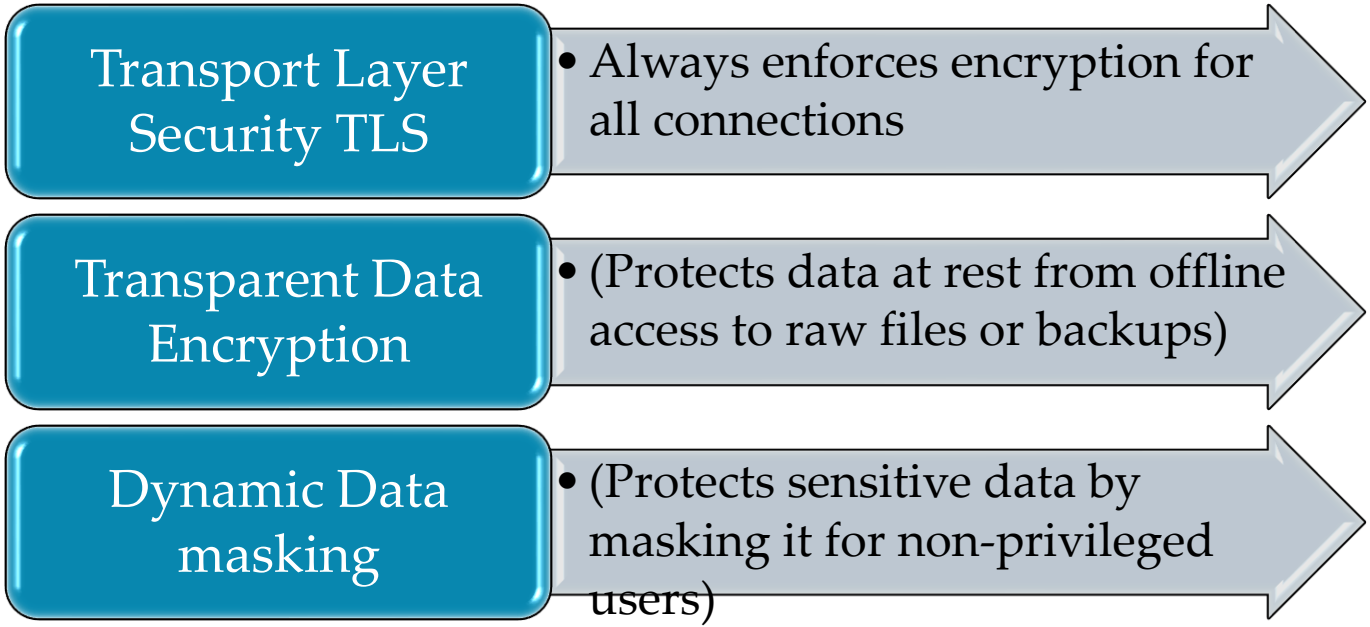
Threat Protection



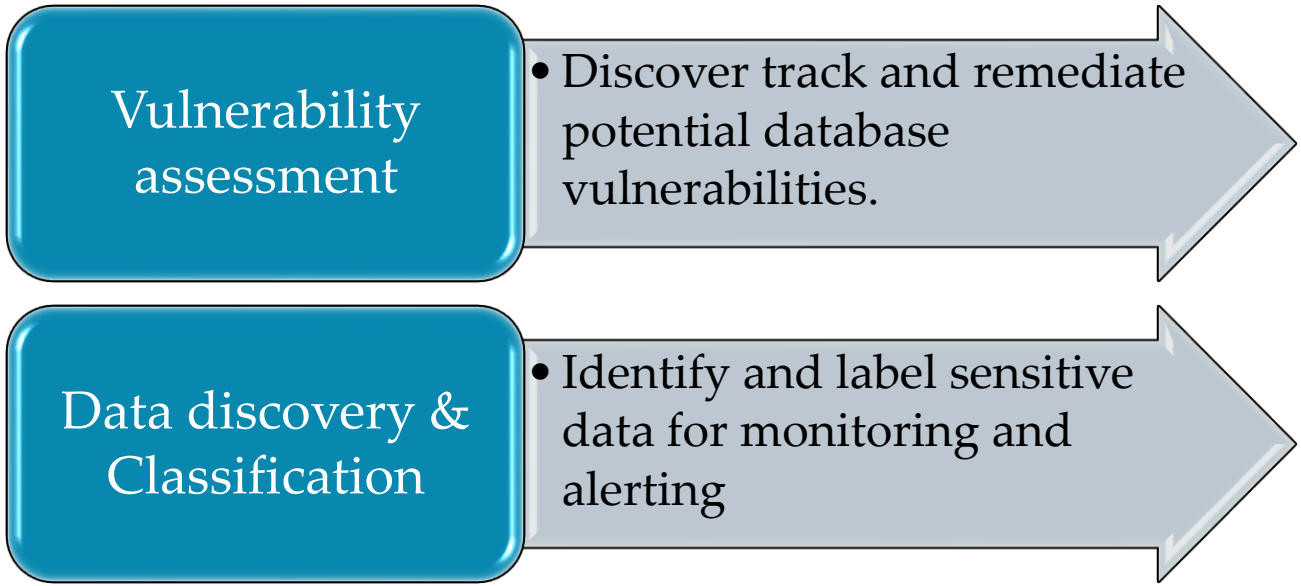
Information Protection



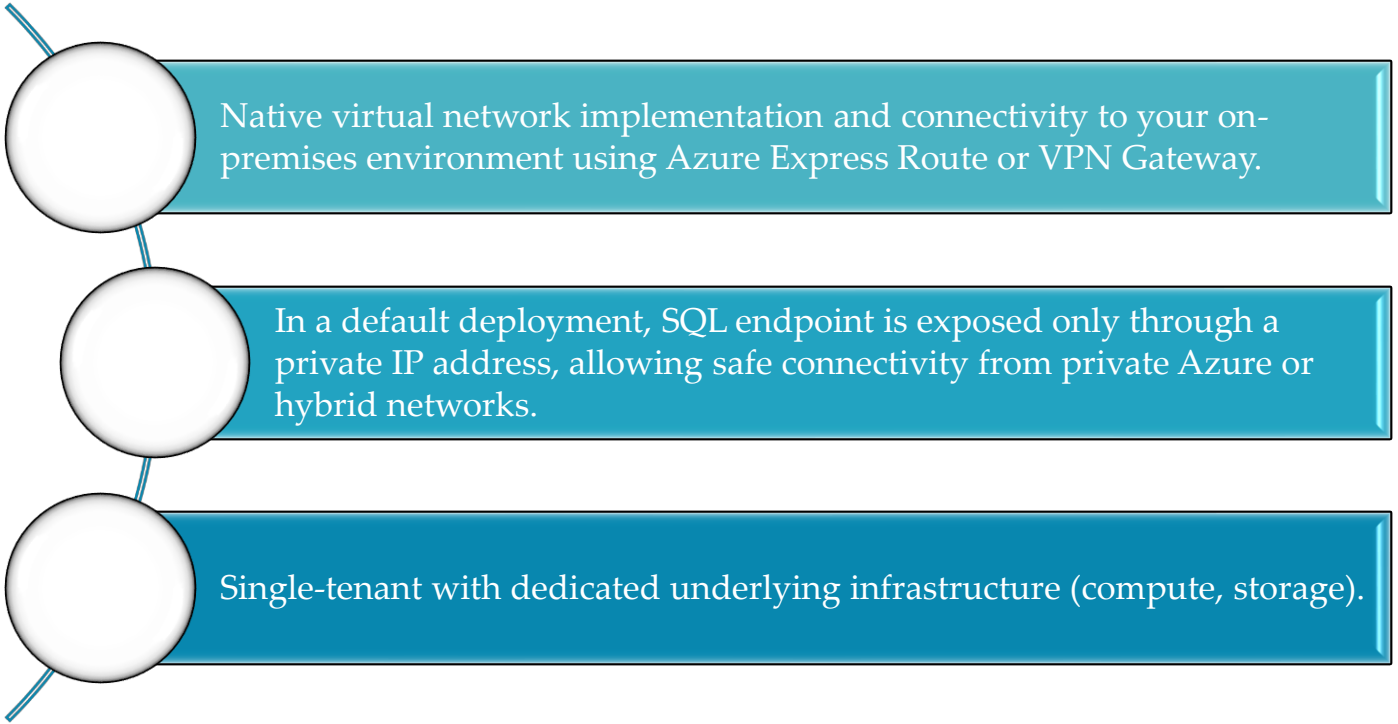
Information Protection



Security Management



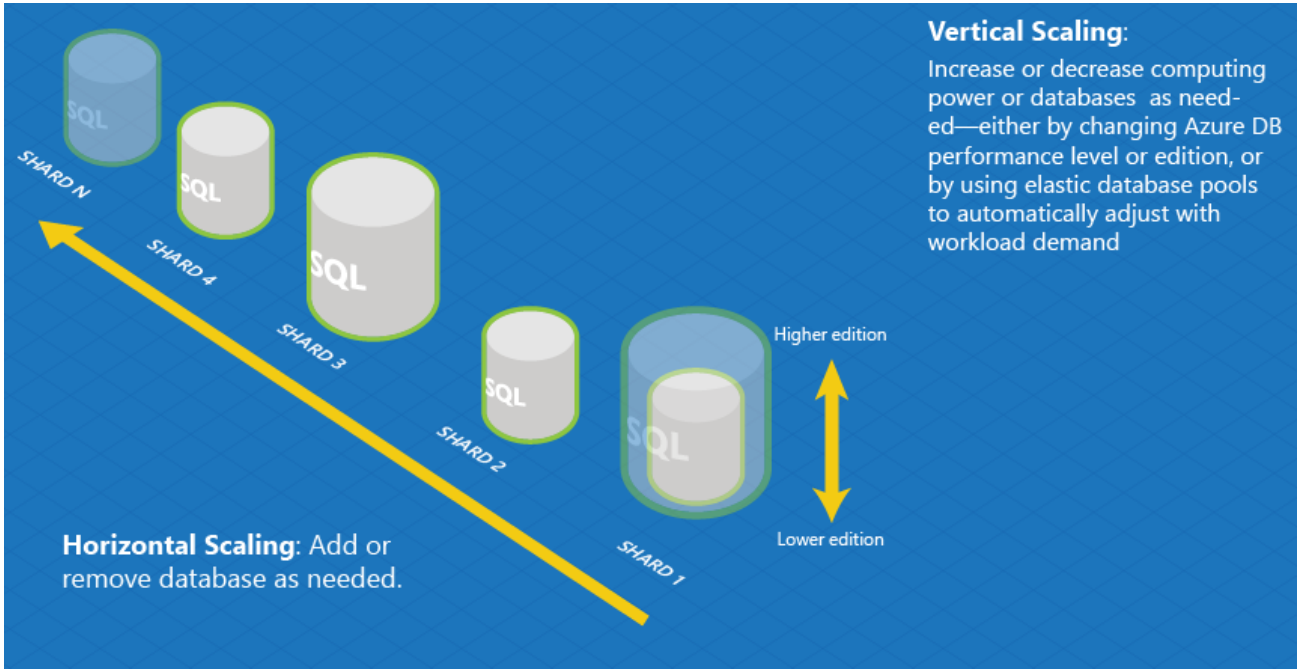
Managed Instance Advance Security



Azure SQL Database Scaling

Azure SQL Database supports two types of scaling:

- **Vertical scaling:** Scale up or down the database by adding more compute power.
- **Horizontal scaling:** Scale out or Add more databases and to shard your data into multiple database nodes.



Vertical vs Horizontal Scaling

Azure SQL Database supports two types of scaling:

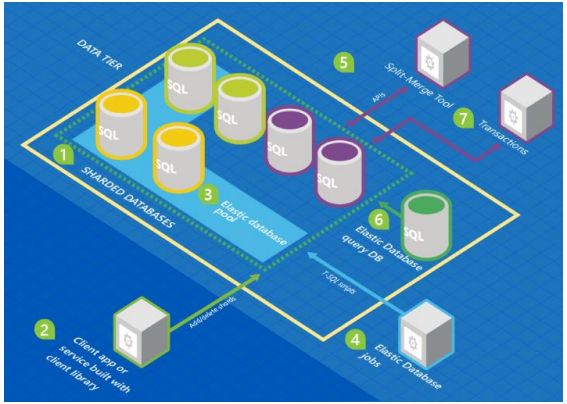
- **Vertical scaling:**
  - Scale up or down the database by adding more compute power.
  - CPU Power, Memory, IO throughput, and storage
  - DTU and vCore models to scale
  - Dynamic Scalability (Note: this is not auto-scale)
  - Any change that you made will be almost instant .

- **Horizontal scaling:** Scale out or Add more databases and to shard your data into multiple database nodes.

Azure SQL Database Scaling

Read Scale Out

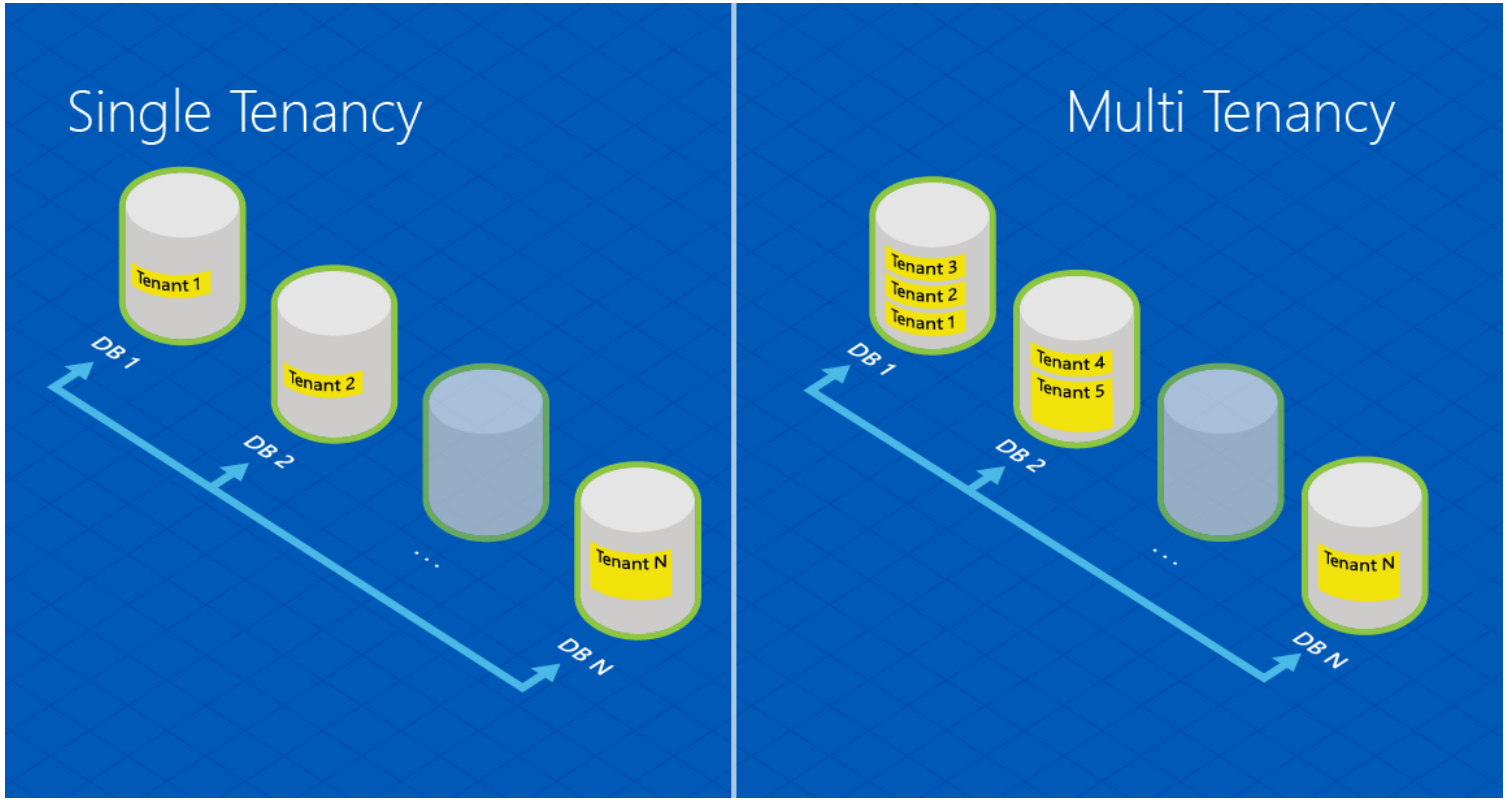
- Allows you to use the capacity of the read-only replicas for read-only queries.
- Feature is intended for the applications that include logically separated read-only workloads, such as analytics
- Benefit: When Secondary nodes handles heavy reports and analytical queries, primary writable node saved resources that might be used to improve the performance
- Secondary nodes is asynchronous
- Premium (DTU-based model) or in the Business Critical (vCore-based model)
- Also available in Hyperscale with secondary replica creation



Global Scale-out/Sharding

- Split your data into multiple database nodes.
- Every database shard is an independent database where you can add or remove resources as needed.
- Application may access only the shard associated to that region without affecting other shards.
- Why?
    - Data or transaction throughput exceed the capabilities of individual database
    - Tenants may require physical isolation
    - Different sections of a database may need to reside in different geographies for compliance, performance, or geopolitical reasons.

Single Tenancy vs Multi Tenancy

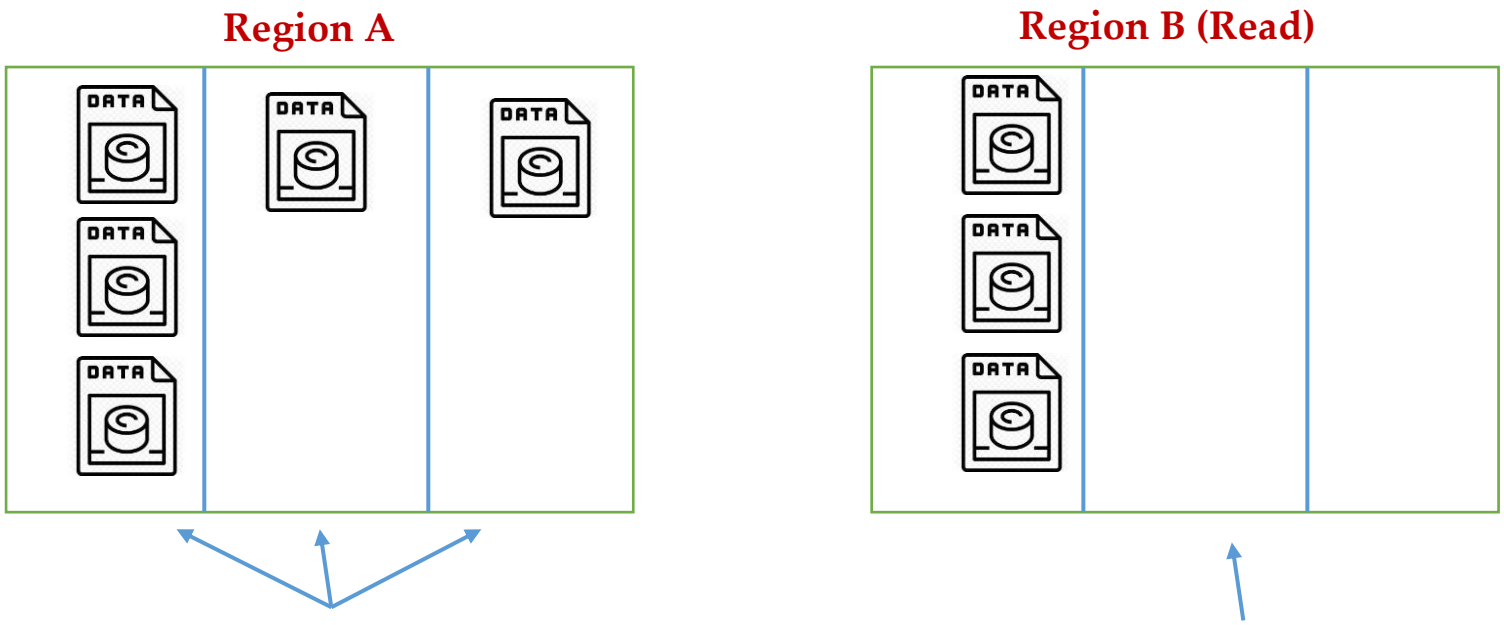


Azure SQL Database Scaling

Change Service Tier

- From Standard/General Purpose to Premium/Business Critical.
- In Standard/General Purpose - Data stored on Azure premium disks
- In Premium/Business Critical - Data stored on local SSD

Azure SQL DB – HA and DR Options



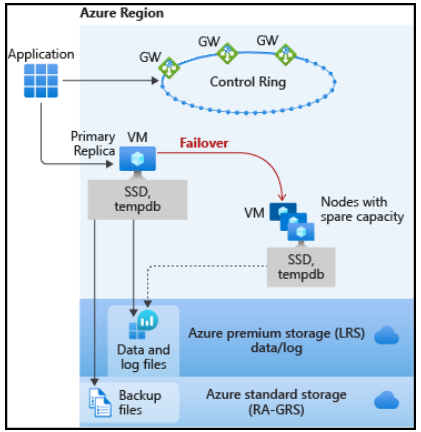
Storage Clusters

Each cluster is physically separate in what's called an availability zone, with its own separate utilities and networking.

Region B

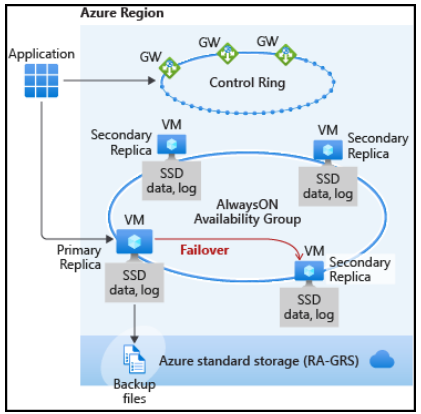
Hundreds of miles away from the primary region to prevent data loss in the event of a natural disaster.

Azure SQL DB – High Availability Architecture



Standard availability model

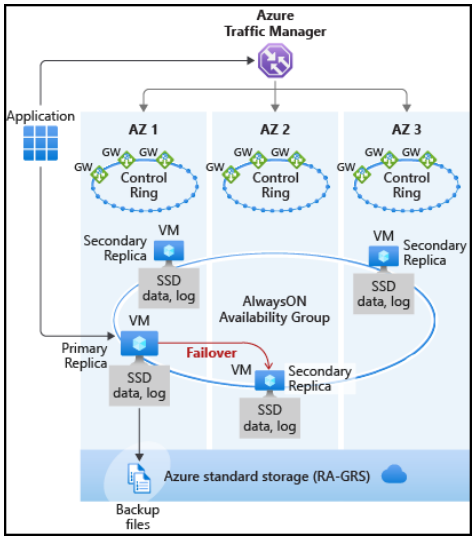
- Separation of compute and storage
- Performance degradation during maintenance activities
- Budget-oriented business applications
- Basic, Standard, and General Purpose service tier availability



Premium availability model

- Integrates compute resources and storage (locally attached SSD) on a single node
- Replicating both compute and storage to additional nodes creating a three to four-node cluster.
- Data is synchronized to at least one secondary replica before committing each transaction.
- Targets mission critical applications with high IO performance and high transaction rate
- Guarantees minimal performance impact during maintenance activities.
- Premium and Business Critical service tier availability
- Read Scale-Out feature

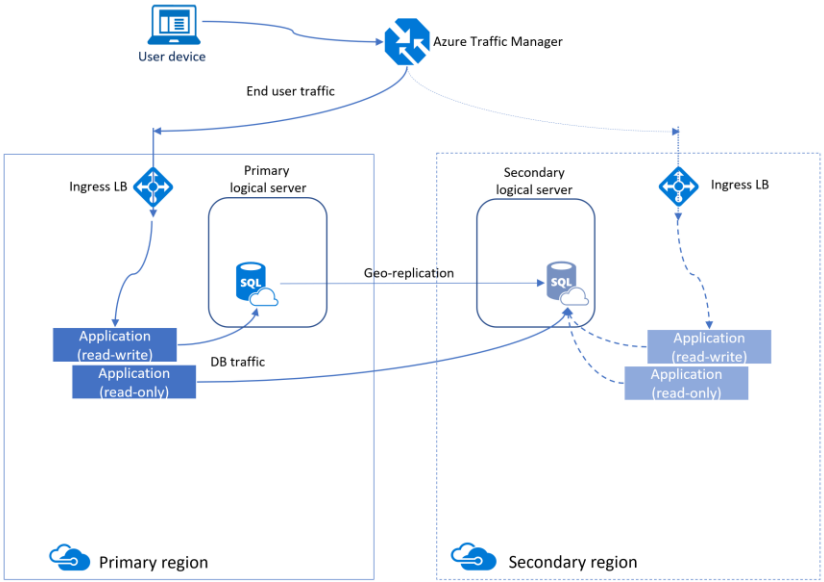
Azure SQL DB –Zone Redundancy



Zone redundant configuration

- Place different replicas of the Business Critical database to different availability zones in the same region
- Does not create additional database redundancy
- Enable it at no extra cost
- Supported in the Premium and Business Critical service tiers
- Not available in SQL Managed Instance.
- Increased network latency may increase the commit time and thus impact the performance of some OLTP workloads.

Azure SQL DB – Geo Replication



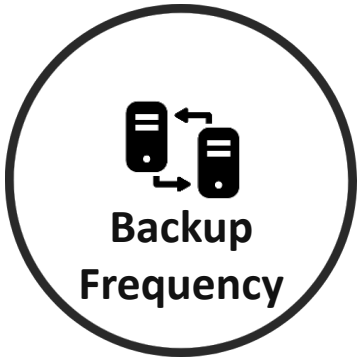
- **Create a readable secondary database in the same region or cross-region**
- **Use cases:**
  - Can failover to the secondary database in case of an outage
  - Migrate a database from one server to another server in the same or cross region with minimal downtime.
- We can create up to four secondaries for each primary database.
- **Data Loss:**
  - Uses the Always-on feature to replicate committed transactions to the secondary database asynchronously.
  - May lag the primary database at any point in time.
- **Manual - Forced Failover**
  - This will make your secondary database immediately online and start accepting connections. Forced failover may result in data loss.

- **Issues**:
  - Supports only manual failover
  - End-point connection must be changed in the application after the failover
  - Must have the same firewall rules and the logins to run applications successfully without any discrepancies

Compare geo-replication with failover groups

Auto-failover groups simplify the deployment and usage of geo-replication and add the additional capabilities as described in the following table:

	Geo-replication	Failover groups
Automatic failover	No	Yes
Fail over multiple databases simultaneously	No	Yes
User must update connection string after failover	Yes	No
SQL Managed Instance support	No	Yes
Can be in same region as primary	Yes	No
Multiple replicas	Yes	No
Supports read-scale	Yes	Yes



1

Full Backup

- Backs up the whole database
- Taken every week

2

Differential backup

- Captures only the data that has changed since the last full backup
- Taken every 12 hours

3

Transaction log backup

- Records of all the committed and uncommitted transactions
- Taken every 5-10 mins

Storage cost and Security of Backup files

Storage Cost

Backup files are copied to RA-GRS standard blob storage by default to paired region

Security

Backup are automatically encrypted at rest using TDE, blob storage is also protected

Backup Retention Period

Backup storage redundancy

- Point in time restore (PITR) - 7-35 days
- Long-term retention - Up to 10 years

Long term retention (LTR)

- One or more long term retention periods to your database to meet regulatory, compliance or other business purposes
- Full backups can be taken up to 10 years
- Stored in RA-GRS blob storage
- Any change of the LTR policy applies to the future backups

LTR and Managed Instance

- LTR is not yet available for databases in Managed Instances
- You can use SQL Agent jobs to schedule copy only database backups as an alternative to LTR beyond 35 days
- These backups can be kept in the Azure blob storage

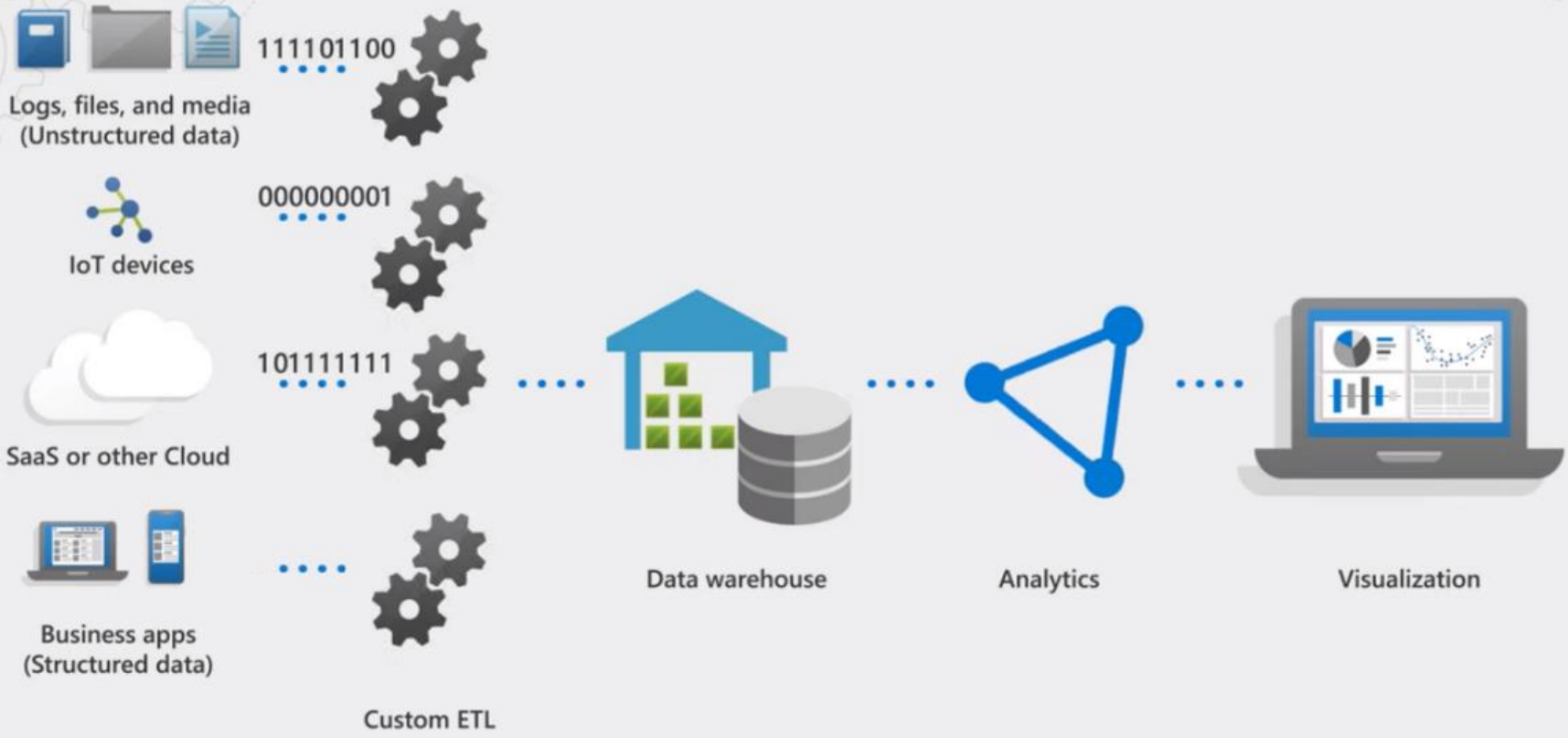
Backup Restore

Backup usage

- Point-in-time restore of existing database
- Point-in-time restore of deleted database
- Geo-restore
- Restore from long-term backup
- *If you delete an Azure Logical SQL Server, all elastic pools and databases that belong to that logical server are also deleted and cannot be restored*

Restore Time is impacted By

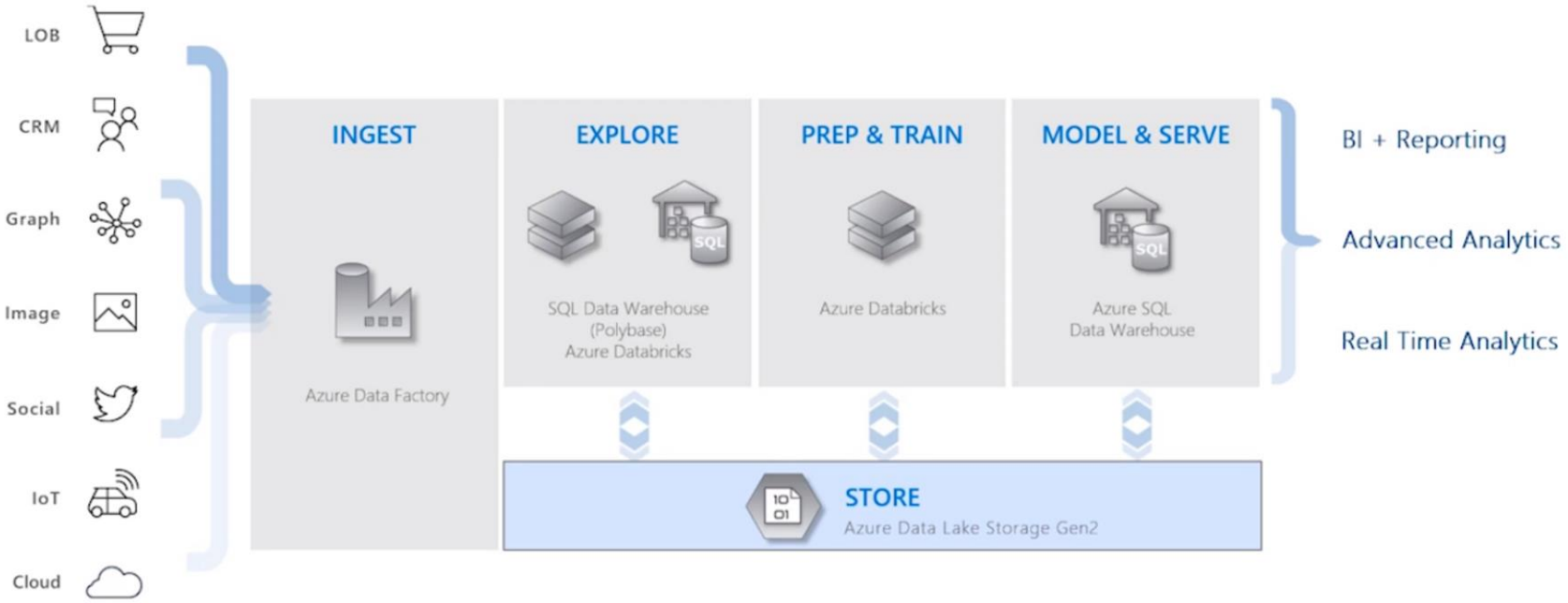
- Size of database & Compute size of the database
- Number of transaction logs and Amount of activity
- Network bandwidth if the restore is to a different region
- Concurrent restore requests being processed region



Old data warehouse

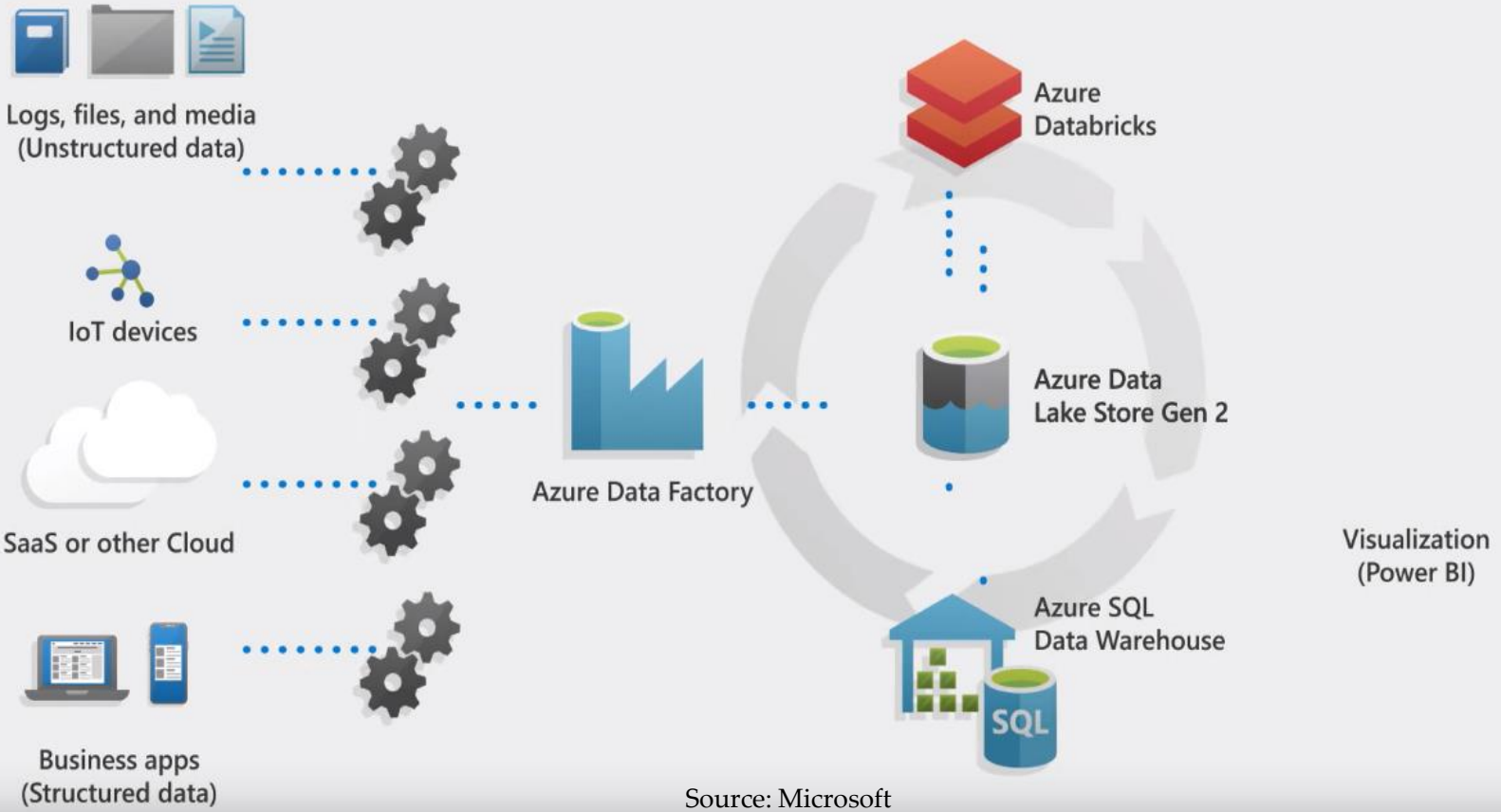
Source: Microsoft

Modern Data Warehousing



Source: Microsoft

Modern Data Warehouse

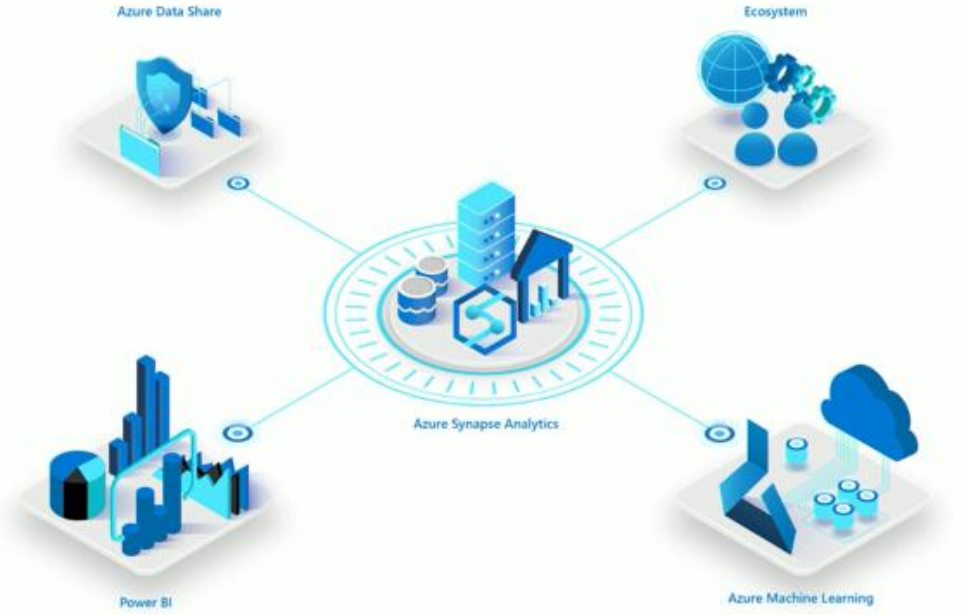


Source: Microsoft

Azure Synapse Analytics

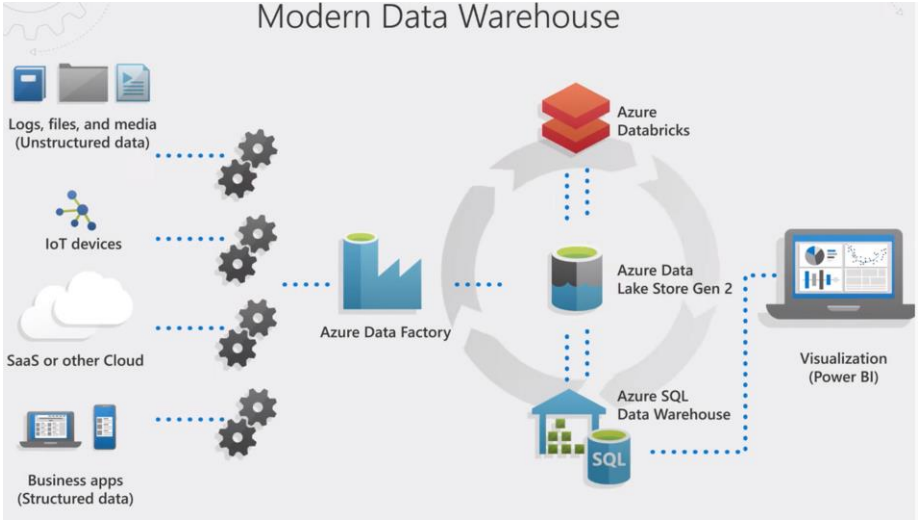
"Synapse is the next generation of Azure SQL Data Warehouse, blending big data analytics, data warehousing, and data integration into a single unified service that provides end-to-end analytics with limitless scale."

Azure Synapse Analytics

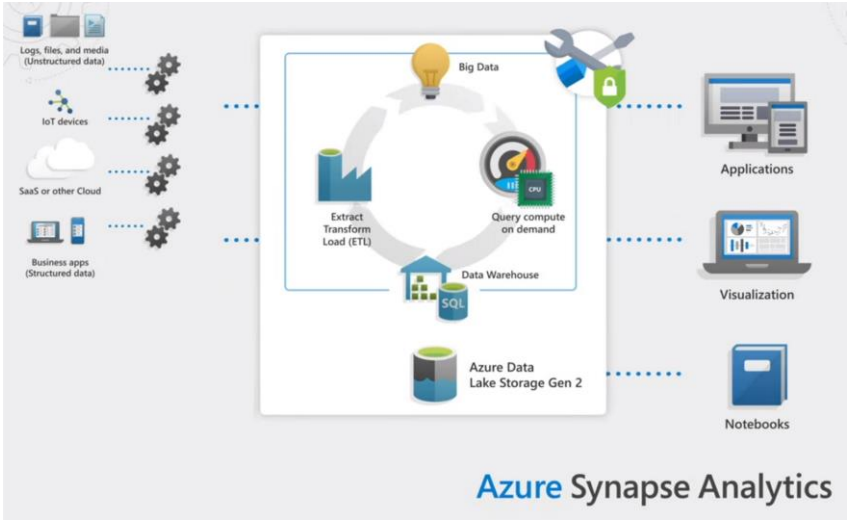


Source: Microsoft

Modern vs Synapse Architecture

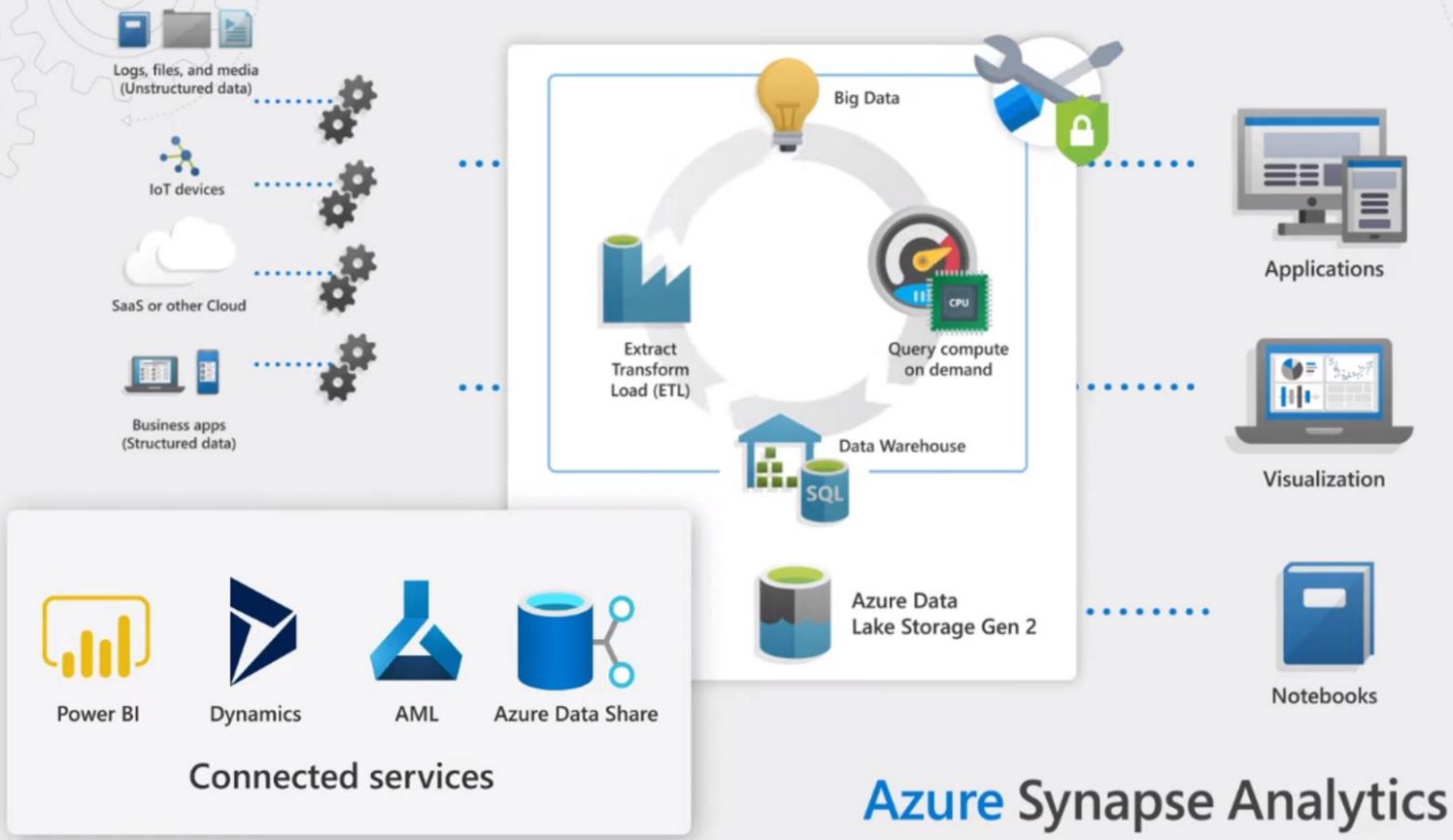


Modern Data Warehouse Architecture



Synapse Analytics Architecture

Source: Microsoft



Source: Microsoft

Azure Synapse Analytics

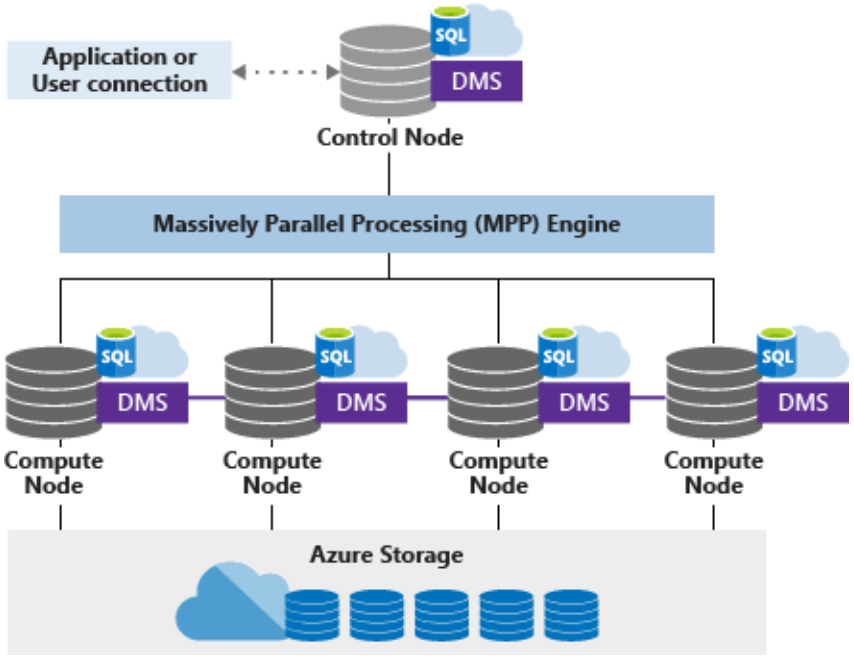
Source: Microsoft

Demo – Provision Azure Synapse Service

1. Create SQL Server
2. Create Synapse SQL Pool (Azure SQL Data Warehouse)
3. Pause/Resume Compute Node
4. Create Firewall Rule
5. Connect with Microsoft SQL Server Management Studio

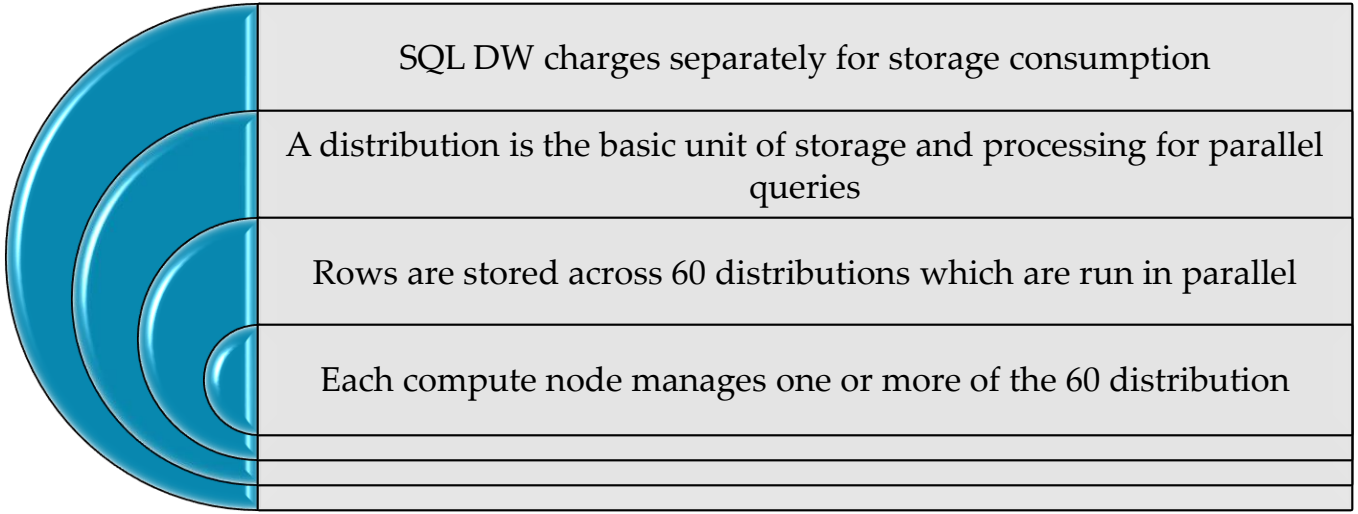
Azure Synapse MPP Architecture

DWU	Loading 3 Tables	Ran Report
100	15	20
500	3	4

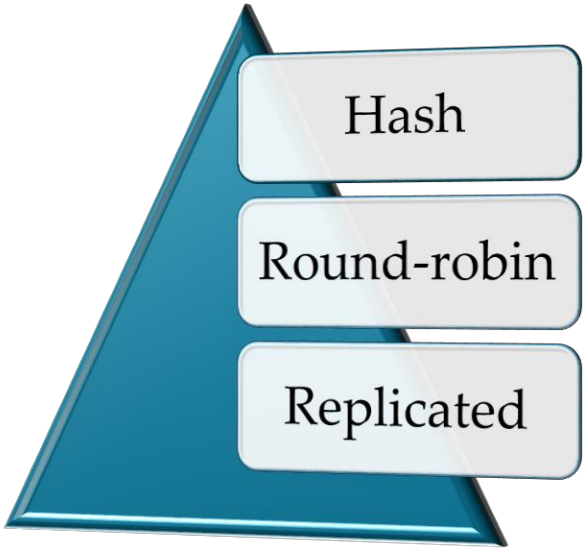


Source: Microsoft

Azure Storage and Distribution



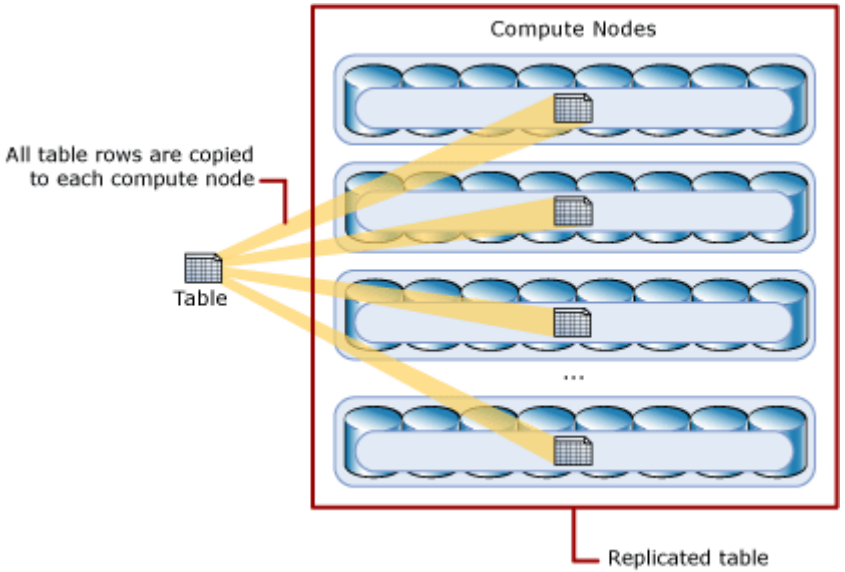
Sharding Patterns



Replicated Tables

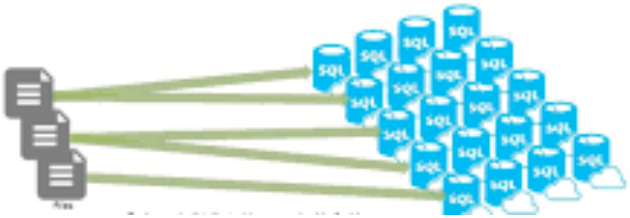
- Caches a full copy on each compute node.
- Used for small tables

```
CREATE TABLE [dbo].[BusinessHierarchies](
    [BookId] [nvarchar](250)  ,
    [Division] [nvarchar](100) ,
    [Cluster] [nvarchar](100) ,
    [Desk] [nvarchar](100) ,
    [Book] [nvarchar](100) ,
    [Volcker] [nvarchar](100) ,
    [Region] [nvarchar](100)
)
WITH
(
    CLUSTERED COLUMNSTORE INDEX
,    DISTRIBUTION = REPLICATE
)
;
```



Source: Microsoft

Round Robin tables



- Generally use to load staging tables
- Distribute data evenly across the table without additional optimization
- Joins are slow, because it requires to reshuffle data
- Default distribution type

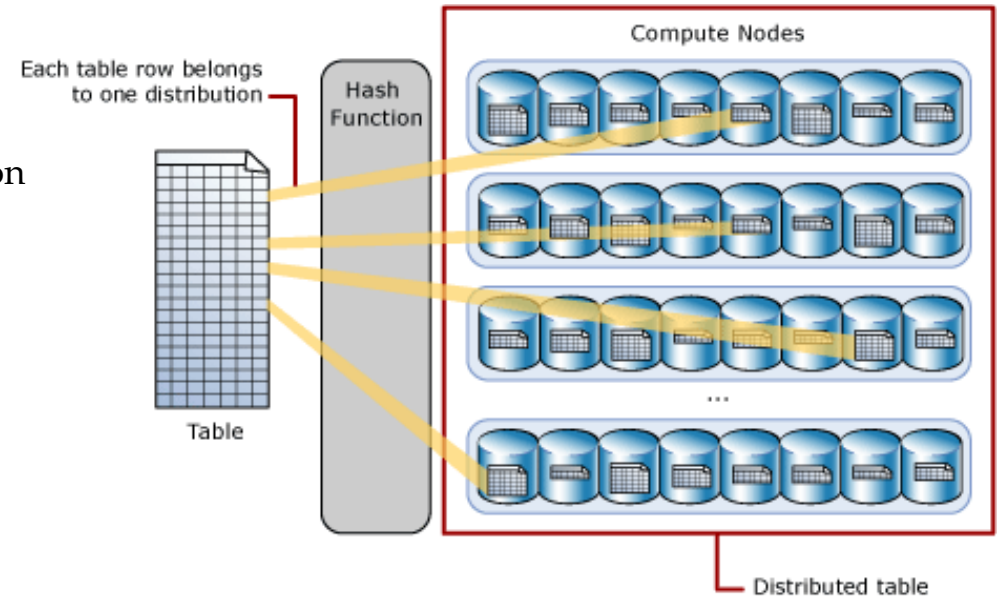
```
CREATE TABLE [dbo].[Dates](
    [Date] [datetime2](3) ,
    [DateKey] [decimal](38, 0) ,
    ..
    ..
    [WeekDay] [nvarchar](100) ,
    [Day Of Month] [decimal](38, 0)
)

WITH
(
    CLUSTERED COLUMNSTORE INDEX
,    DISTRIBUTION = ROUND_ROBIN
)
;
```

Source: Microsoft

Hash Distribution Tables

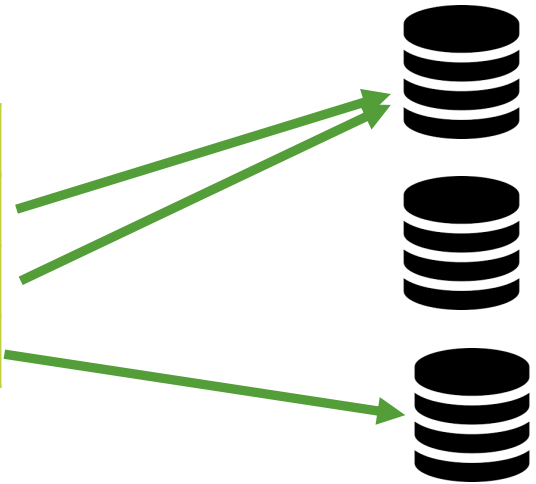
- Highest performance for large tables
- Each row belong to one particular distribution
- It is used mostly for larger tables



Source: Microsoft

Hash Distribution Tables

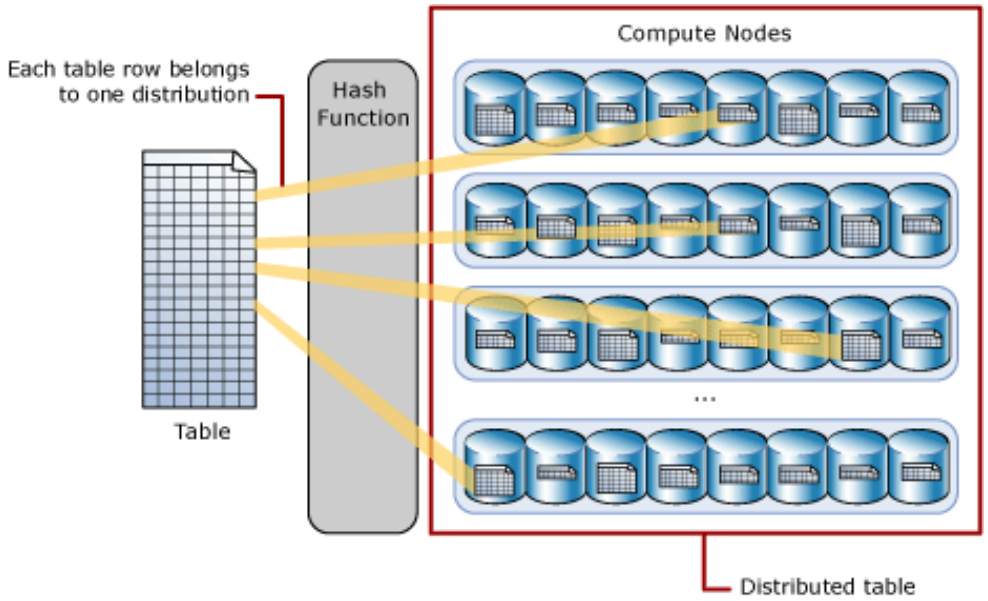
Record	Product	Store
1	Soccer	New York
2	Soccer	Los Angeles
3	Football	Phoenix



Hash Distribution Tables

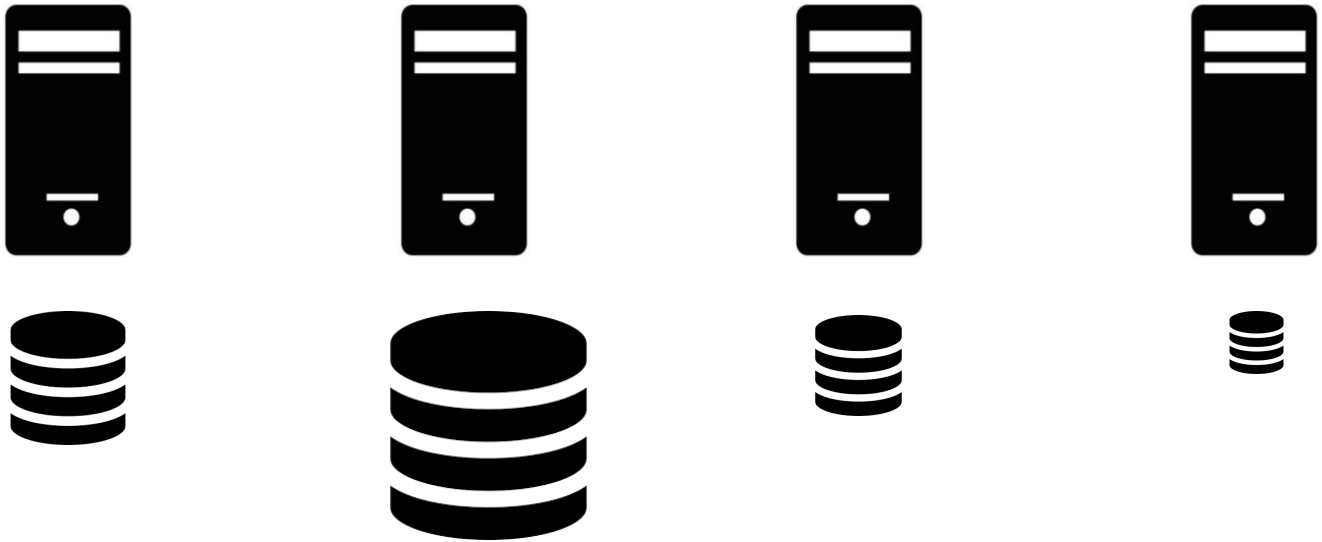
- Highest performance for large tables
- Each row belong to one particular distribution
- It is used mostly for larger tables

```
CREATE TABLE [dbo].[EquityTimeSeriesData](
   [Date] [varchar](30) ,
   [BookId] [decimal](38, 0) ,
   [P&L] [decimal](31, 7) ,
   [VaRLower] [decimal](31, 7)
)
WITH
(
   CLUSTERED COLUMNSTORE INDEX
,   DISTRIBUTION = HASH([P&L])
)
;
```

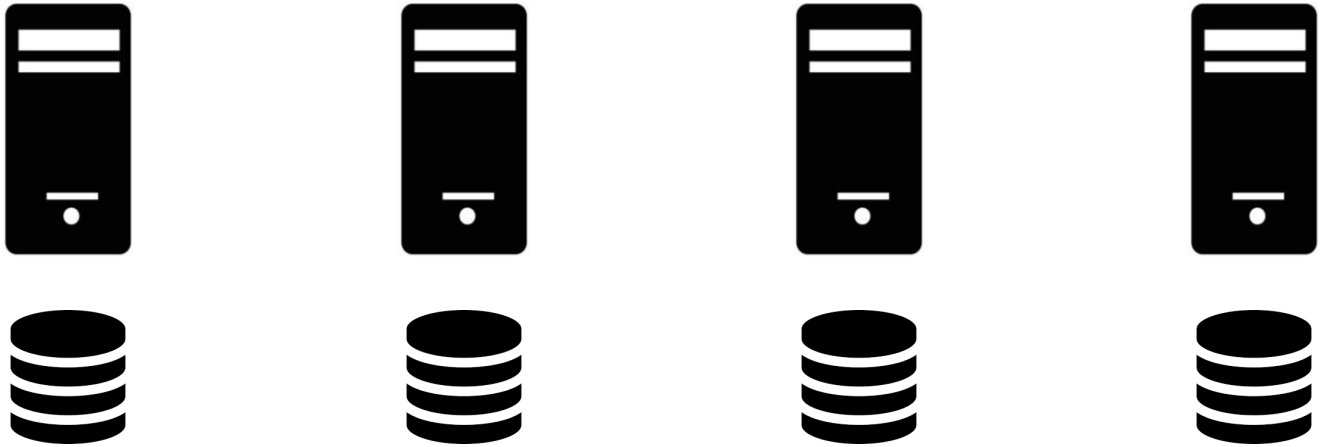


Source: Microsoft

Avoid Data Skew



Even Distribution

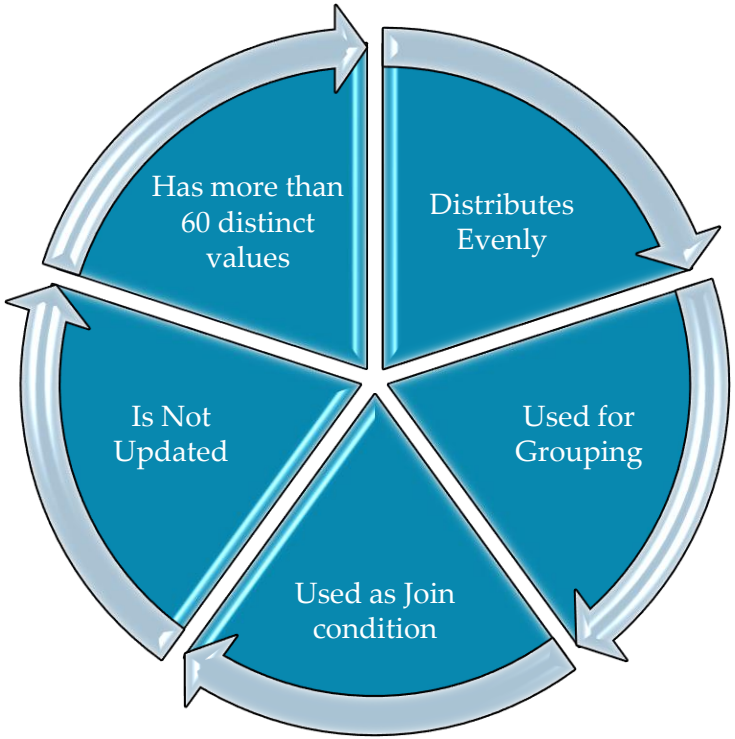


Distribution key

Determines the method in which Azure SQL Data Warehouse spreads the data across multiple nodes.

Azure SQL Data Warehouse uses up to 60 distributions when loading data into the system.

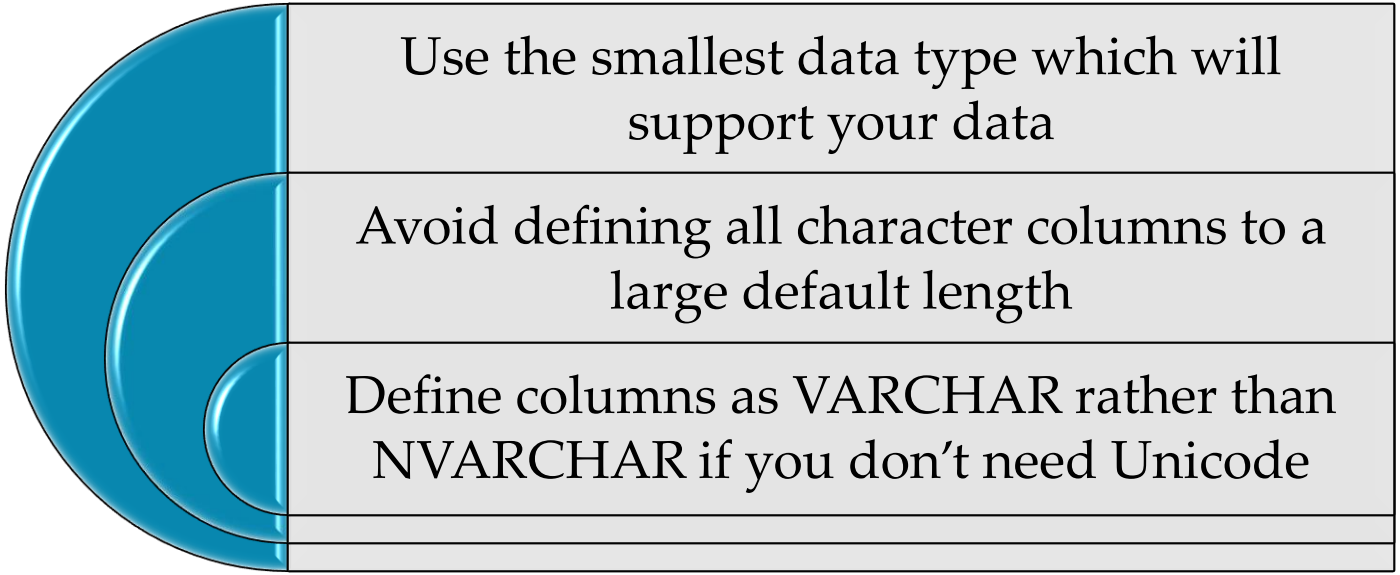
Good Hash Key



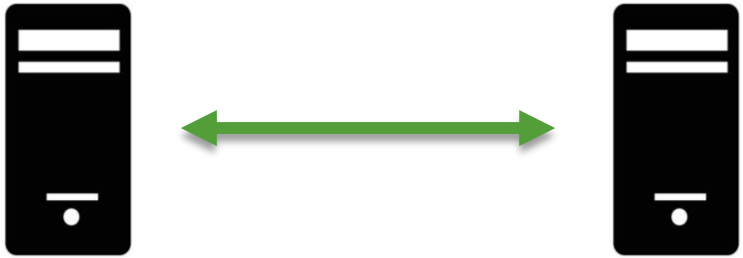
What Data Distribution to Use?

Type	Great fit for	Watch out if…
Replicated	Small-dimension tables in a star schema with less than 2GB of storage after compression	• Many write transaction are on the table (insert/update/delete) • You change DWU provisioning frequently • You use only 2-3 columns, but your table has many columns • You index a replicated table
Round-robin (default)	• Temporary/Staging table • No obvious joining key or good candidate column.	Performance is slow due to data movement
hash	• Fact tables • Large dimension tables	The distribution key can't be updated

Data types


Use the smallest data type which will support your data
Avoid defining all character columns to a large default length
Define columns as VARCHAR rather than NVARCHAR if you don't need Unicode

Data types



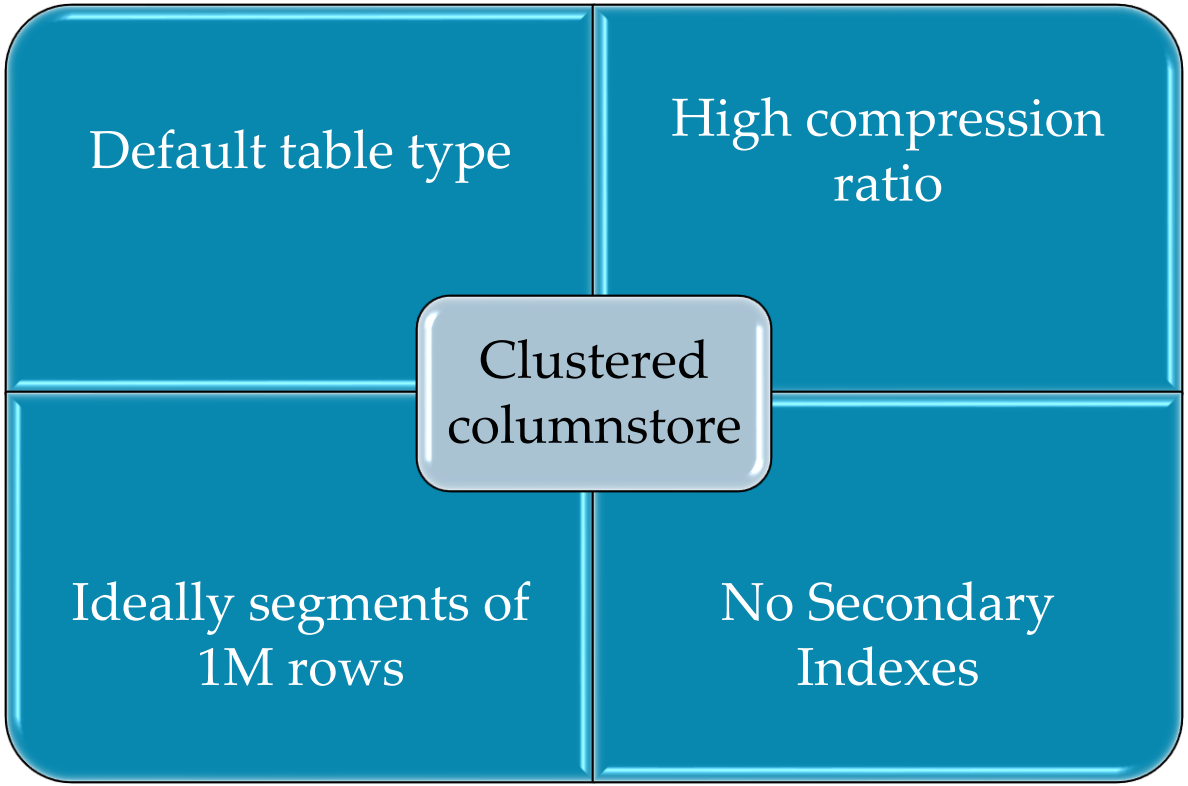
The goal is to not only save space but also move data as efficiently as possible.

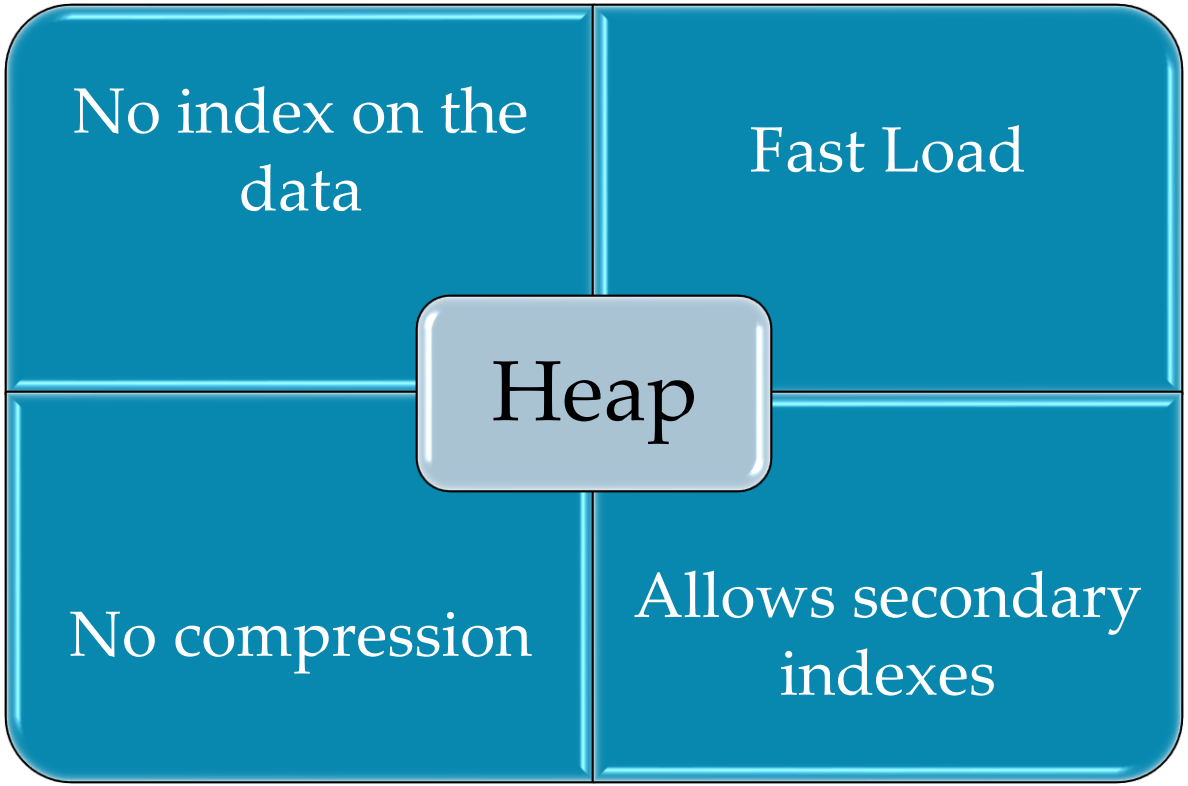
Data types

Some complex data types (XML, geography, etc) are not supported on Azure SQL Data Warehouse yet.

Table types

Clustered columnstore	• Updateable primary storage method • Great for read-only
Heap	• Data is not in any particular order. • Use when data has no natural order.
Clustered Index	• An index that is physically stored in the same order as the data being indexed


Default table type
High compression ratio
Clustered columnstore
Ideally segments of 1M rows
No Secondary Indexes


No index on the data
Fast Load
Heap
No compression
Allows secondary indexes

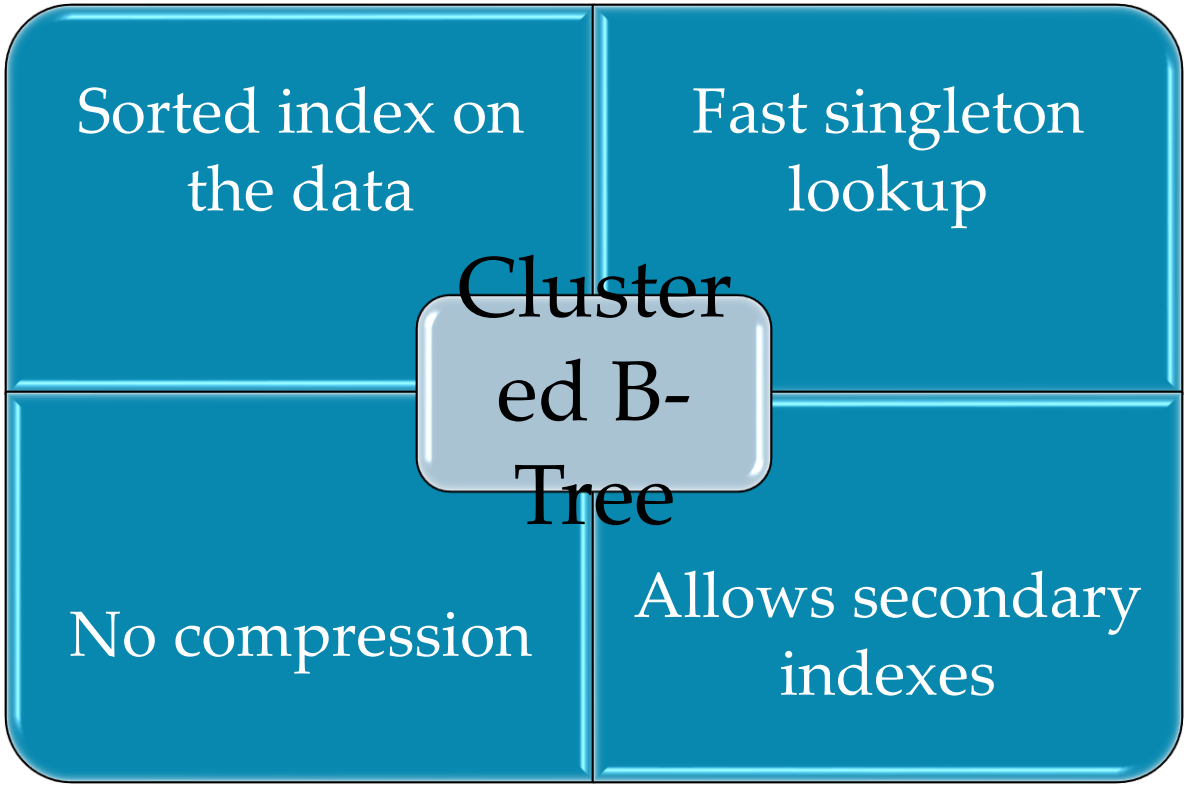
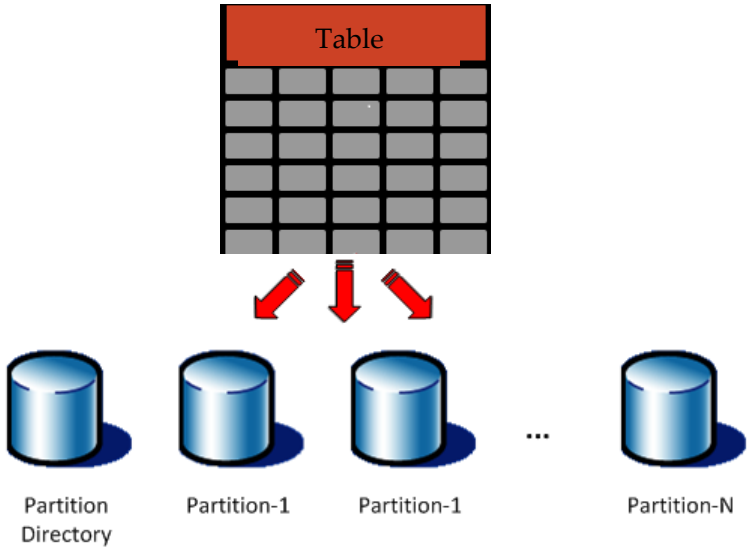
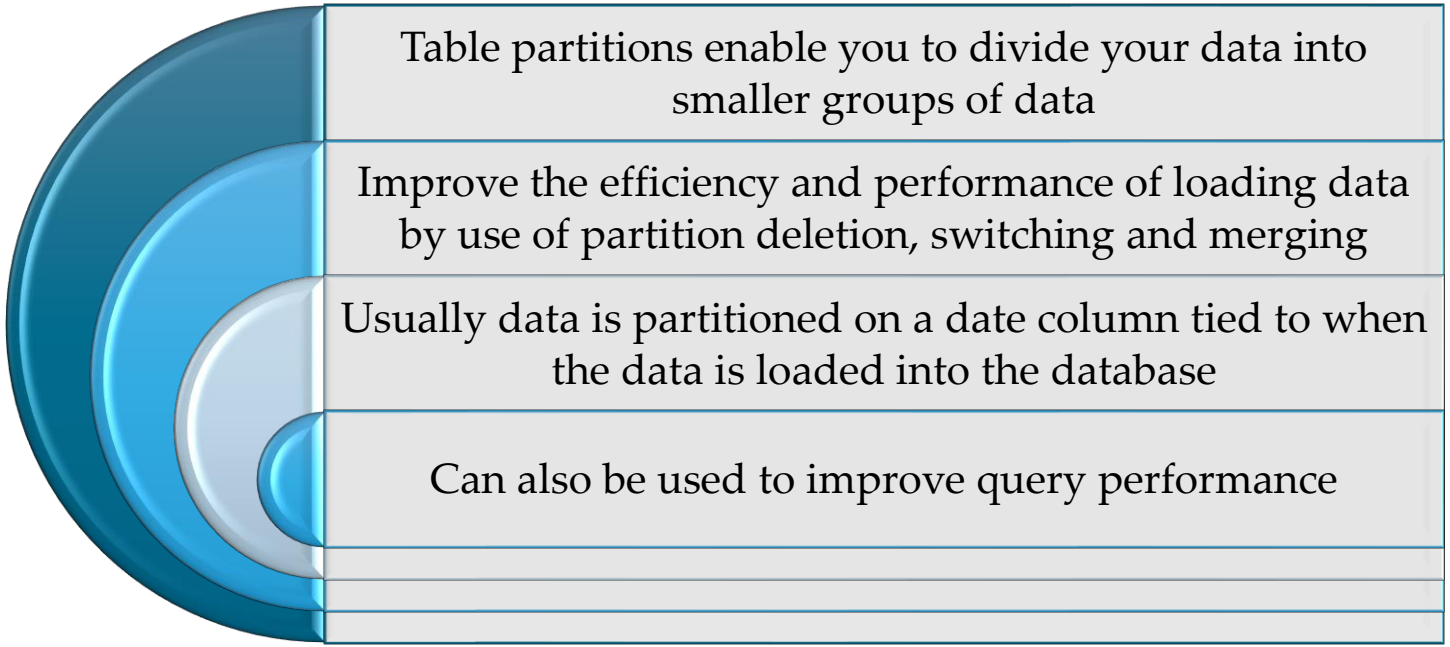

Sorted index on the data
Fast singleton lookup
Clustered B-Tree
No compression
Allows secondary indexes

Table Partitioning

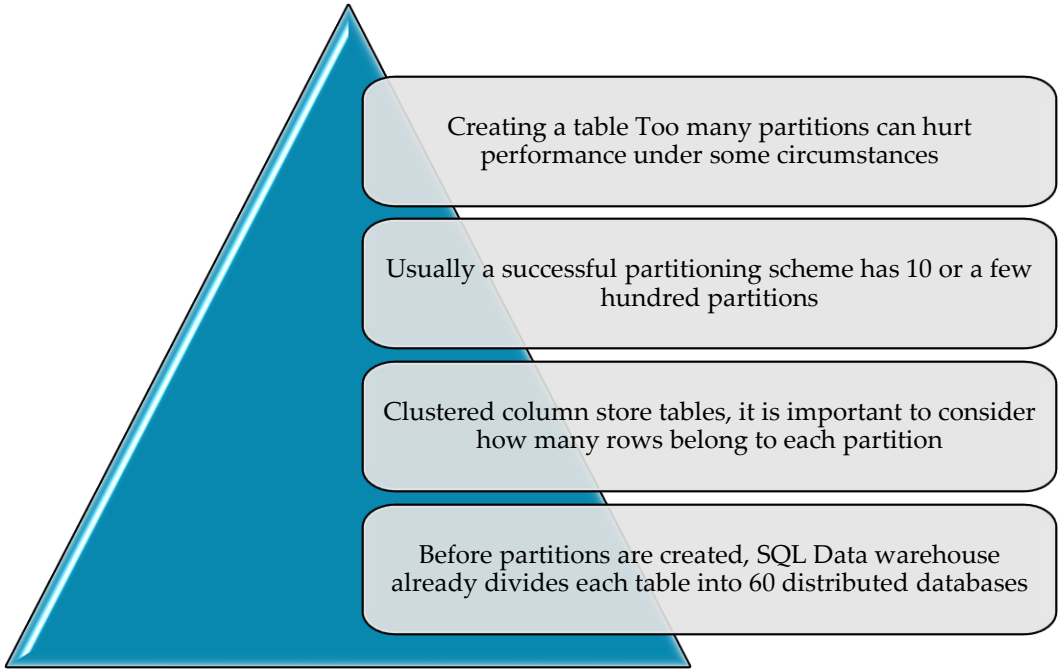


Partitioning



Why Partitioning?

Partitions best practices



A highly granular partitioning scheme can work in SQL Server but hurt performance in Azure SQL Data Warehouse.

Example

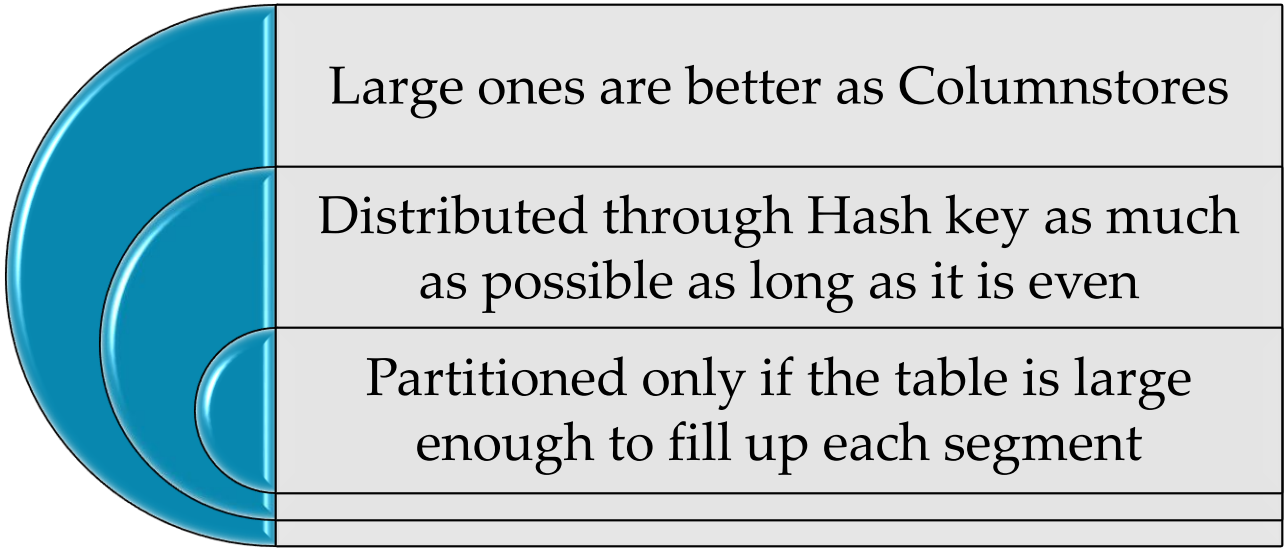
60 Distributions  365 Partitions  21900 Data Buckets

21900 Data Buckets  Ideal Segment Size (1M Rows)  21 900 000 000 Rows

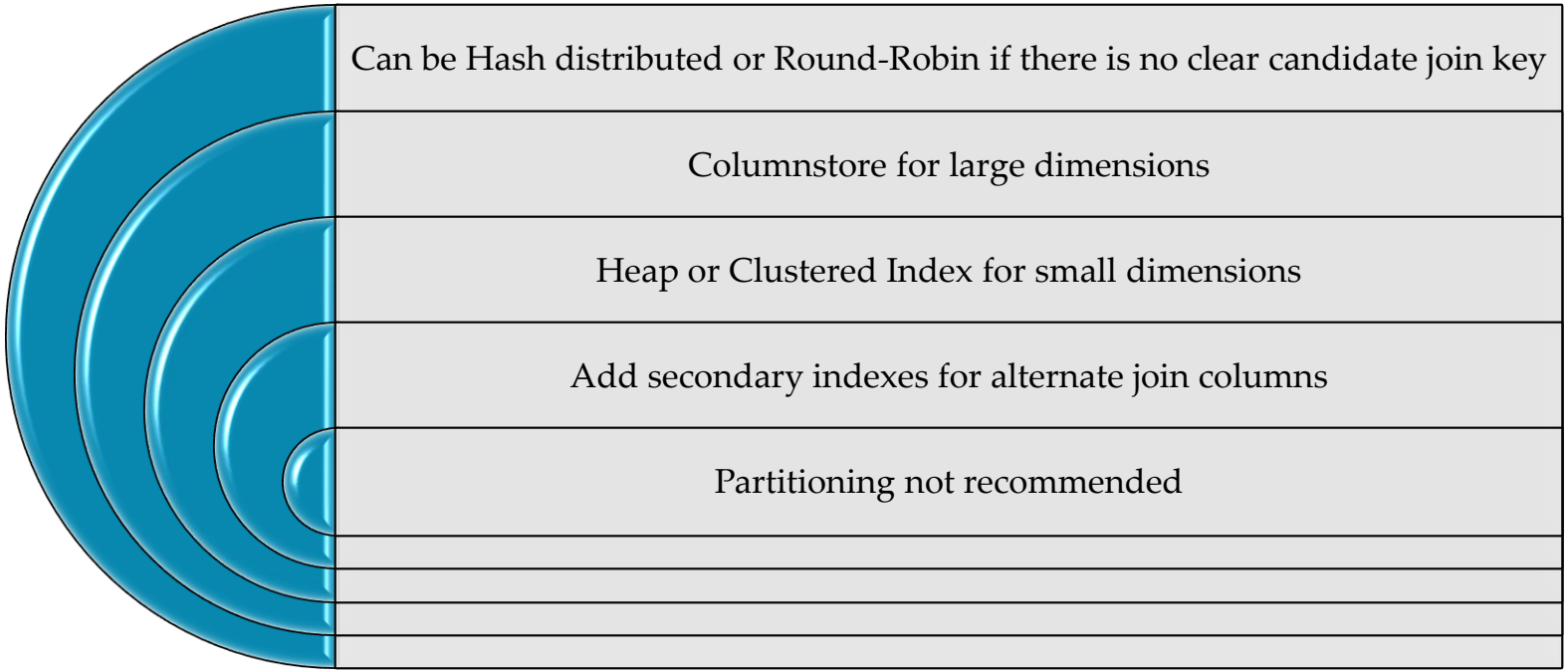
Lower Granularity (week, month) can perform better depending on how much data you have.

How do we apply these principles to a Dimensional model?

Fact Tables


Large ones are better as Columnstores
Distributed through Hash key as much as possible as long as it is even
Partitioned only if the table is large enough to fill up each segment

Dimension Tables



Best Practices for Data Laod

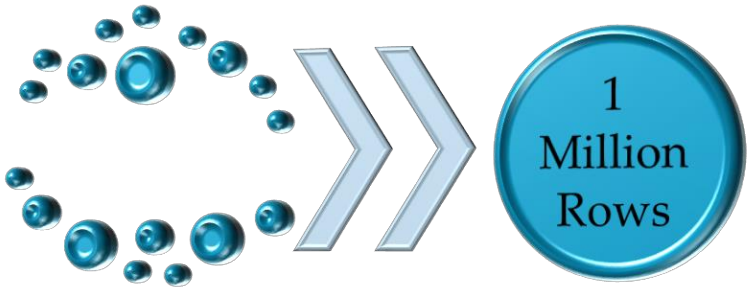
Data Warehouse Readers

Your DWUs have a direct impact on how fast you can load data in parallel

No of DWU	**100**	**200**	**300**	**400**	**500**	**600**	**1000**	**1500**	**2000**
Readers	8	16	24	32	40	48	60	60	60
Writers	60	60	60	60	60	60	60	60	60

Optimize Insert Batch Size

Avoid trickle insert pattern. Ideal batch size is 1 million or more direct or in a file

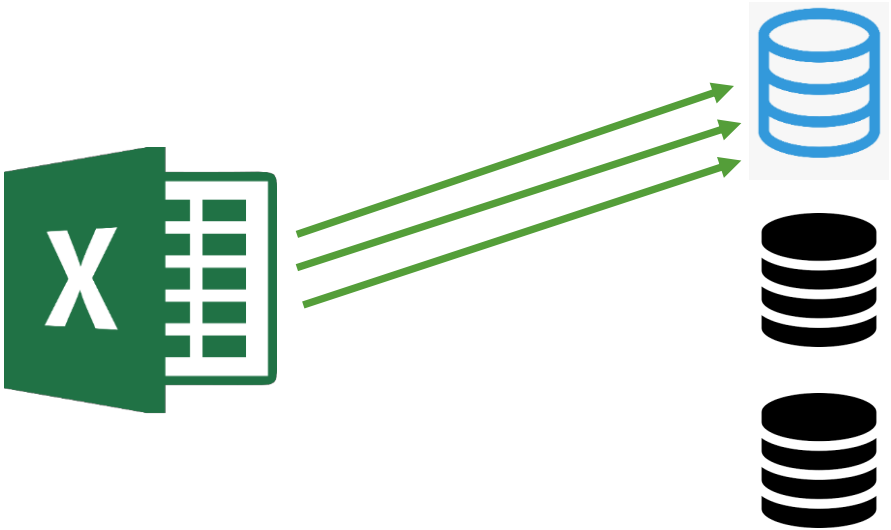


Combine rows to make it a batch of 1 million

Ideal batch size

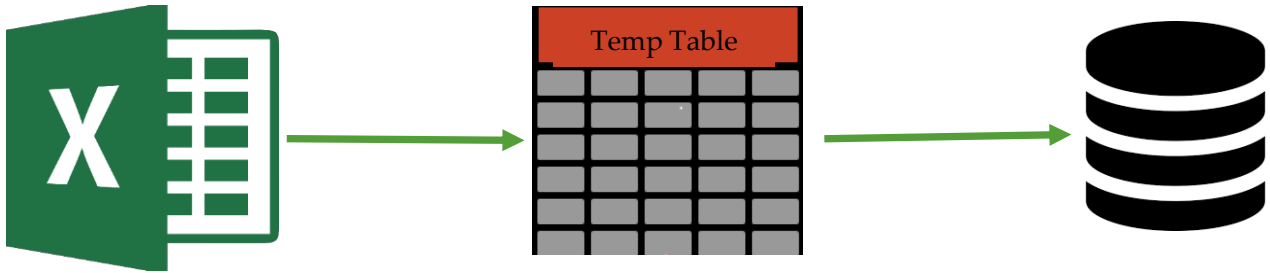
Avoid ordered data

Data ordered by distribution key can introduce hot spots that slow down the load operation



Using temporary tables

Stage and transform on a Temp Heap table before moving to permanent storage.



CREATE TABLE AS

```
CREATE TABLE #tmp_fct
WITH
(
DISTRIBUTION = ROUND_ROBIN
)
AS
SELECT *
FROM
[dbo].[FactInternetSales];
```

- Fully Parallel operation
- It is minimally logged
- It can change: distribution, table type, partitioning

Loading Methods

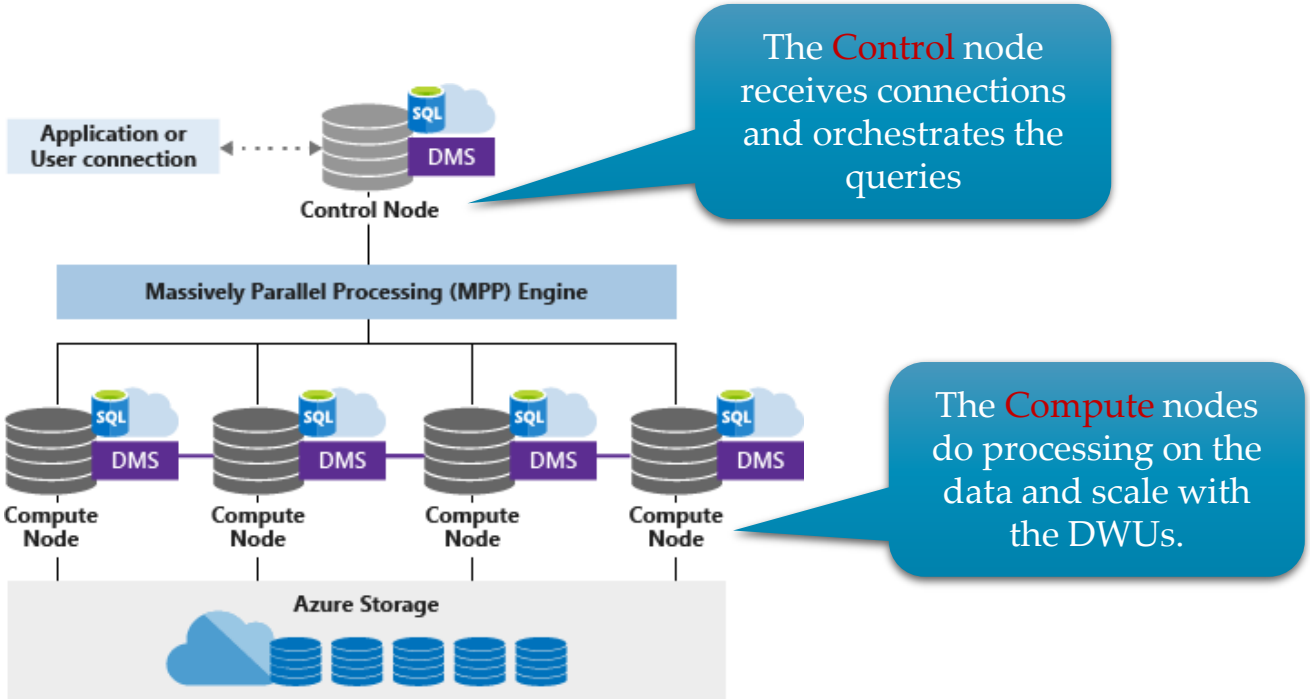
Single client loading methods

- SSIS
- Azure Data Factory
- BCP
- Can add some parallel capabilities but are bottlenecked at the control node

Parallel readers loading methods

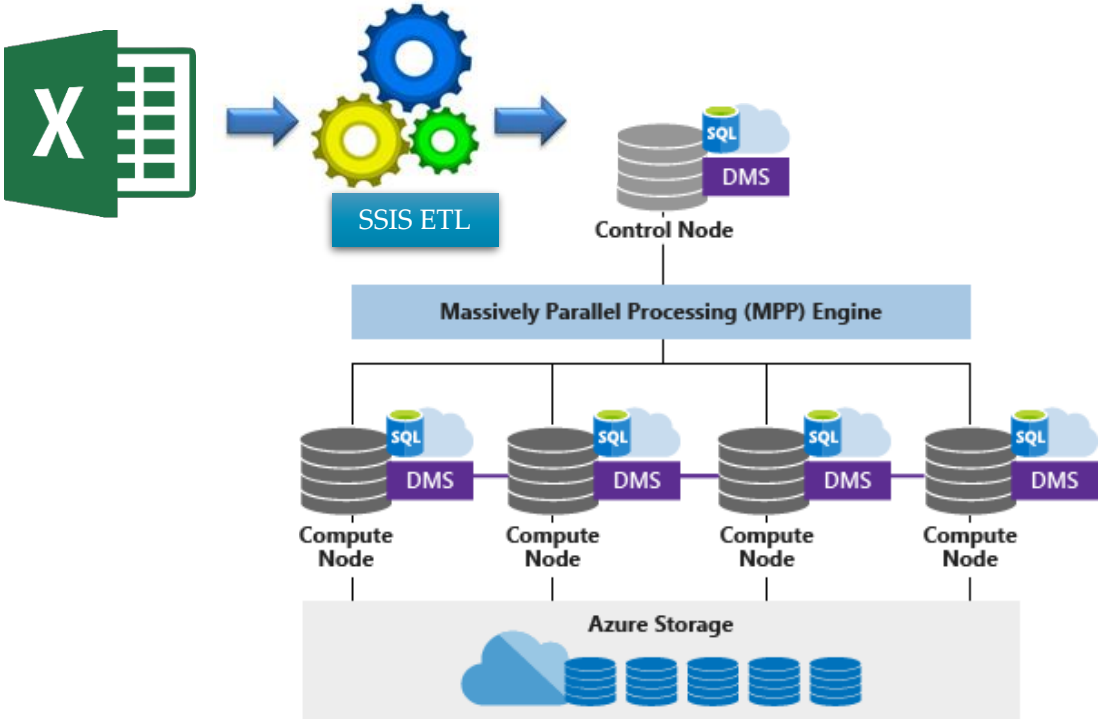
- PolyBase
- Reads from Azure blob Storage and loads the contents into Azure SQL DW
- Bypasses the Control Node and loads directly into the Compute Nodes

Control Node



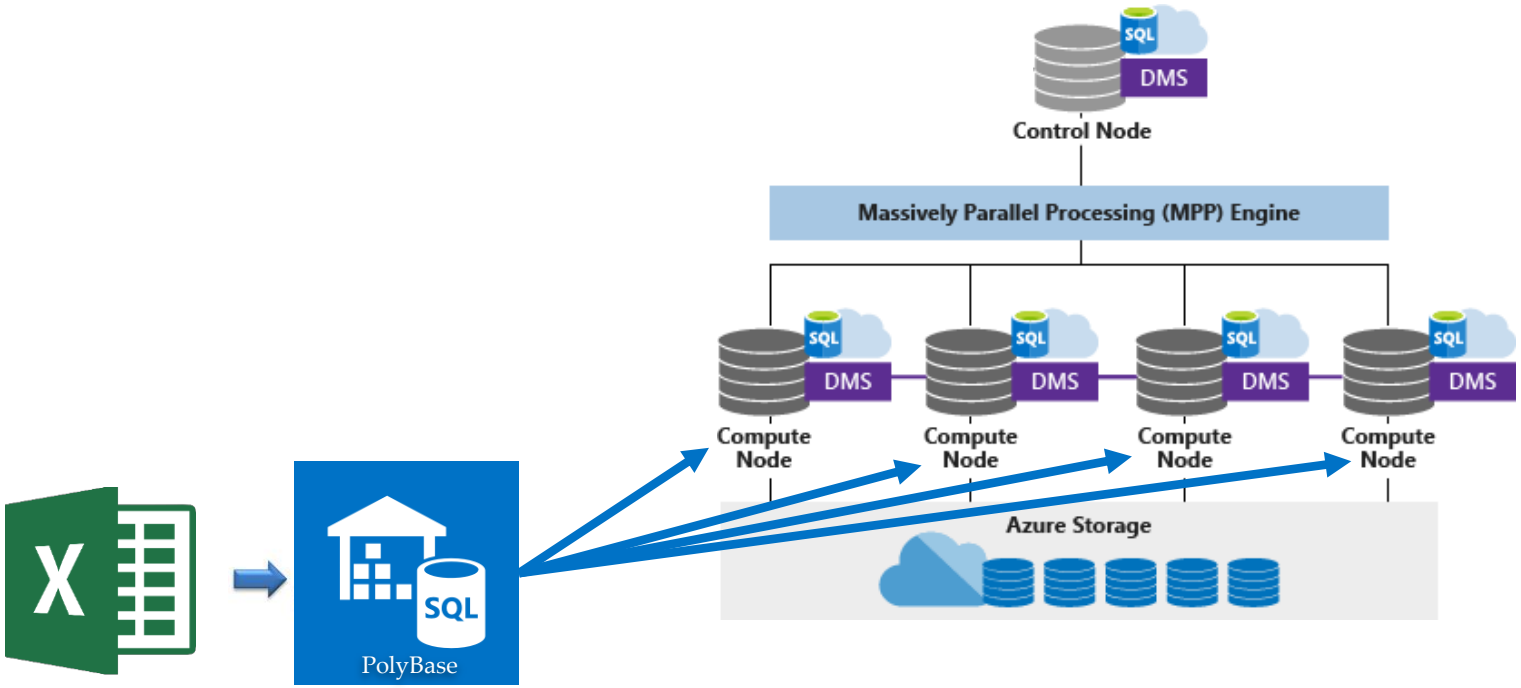
Source: Microsoft

Loading with SSIS



Source: Microsoft

Loading with PolyBase

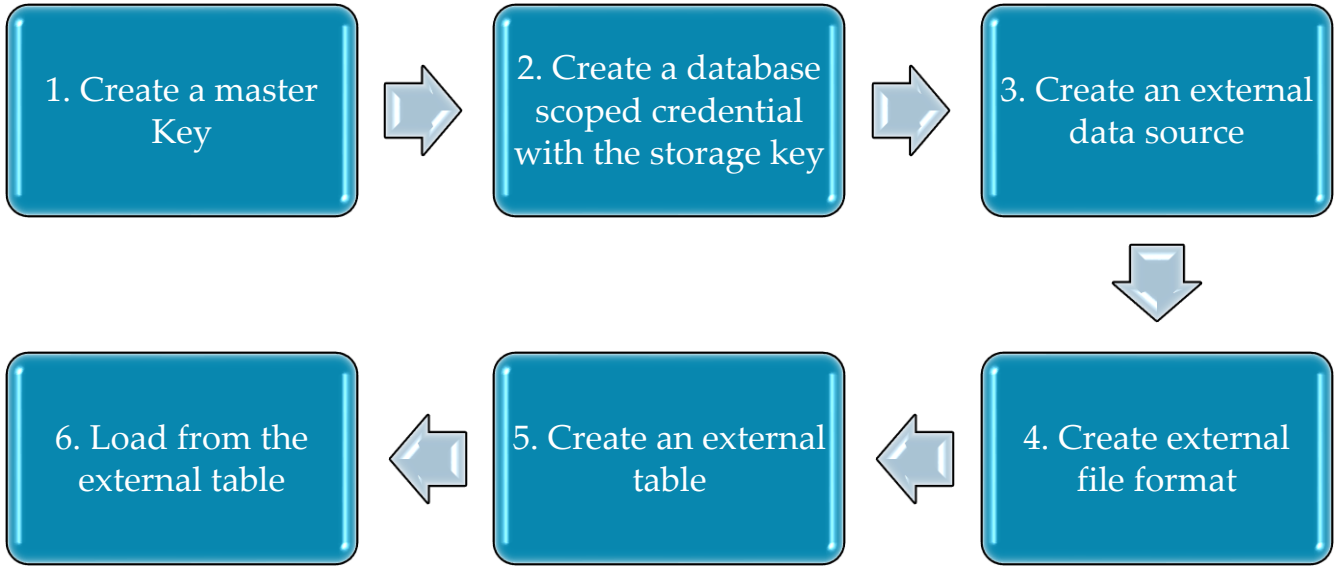


Source: Microsoft

PolyBase can load data from UTF-8 delimited text files and popular Hadoop file formats like RC File, ORC, and Parquet

Multiple readers will not work against a compressed file

PolyBase Setup



Demo – PolyBase

1. Export table to flat file
2. Create blob storage account
3. Upload flat file to blob storage
4. Run PolyBase 6 steps process
5. Monitor and confirm successful migration
6. Confirm 60 distributions in destination table

Azure Synapse Analytics

Azure SQL Warehouse Scaling

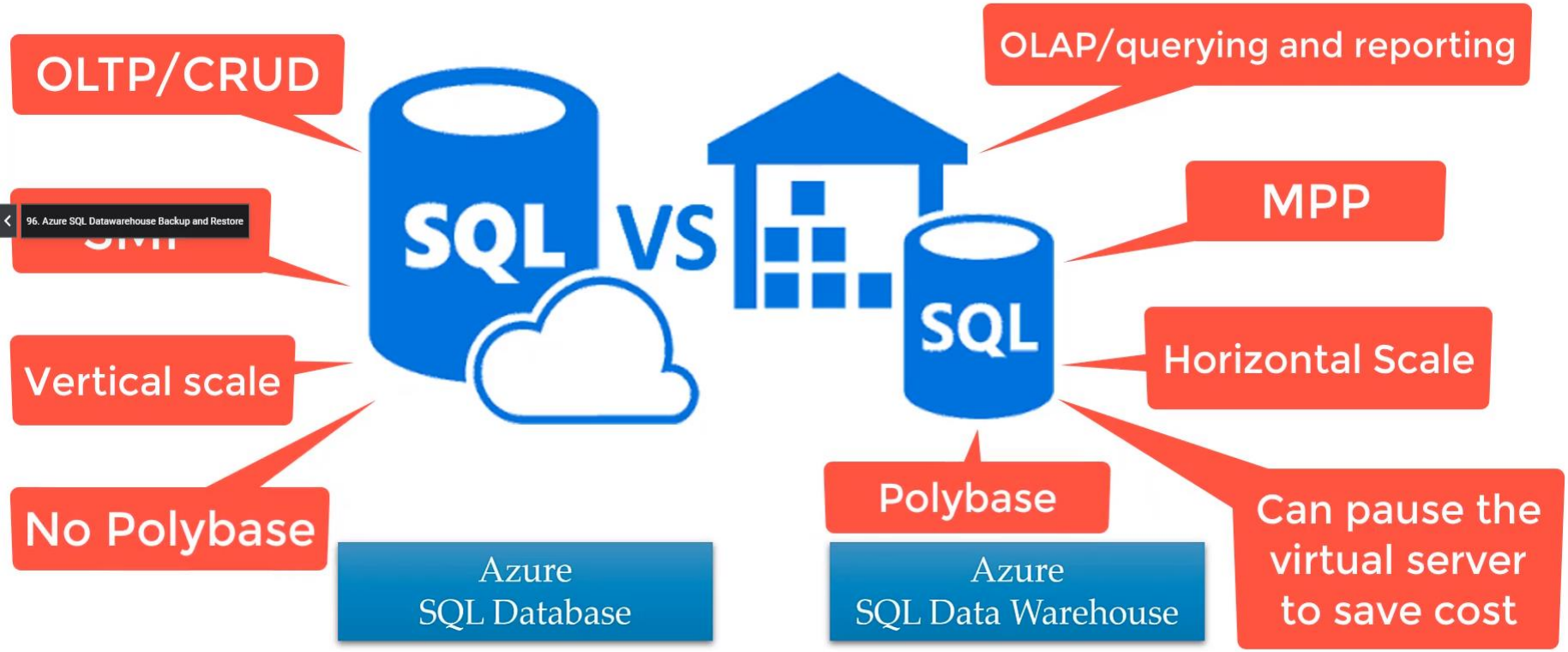
Scaling in SQL Data Warehouse

- SQL DW allows us to scale or pause at will
- Scale up during heavy demand
- Pause to cut cost
- DWUs are CPU, memory, and I/O bundled into units of compute scale
- Increasing DWU's
  - increase query performance
  - Also increase maximum number of concurrent queries and concurrent sl
- Modify with GUI, PowerShell, or TSQL

Azure SQL DW Backup and Restore

- Snapshots of your data warehouse are taken throughout the day creating restore points
- These restore points are available for 7 days
  - Retention period of 7 days cannot be changed
- SQL pool supports an 8 hour recovery point objective (RPO)
- Replicated to paired region once a day
- You can also take user-defined snapshots
  - Retention period 7 days cannot be changed
  - 42 max restore point possible
  - Can be created using PowerShell or portal
- When you drop a SQL pool, a final snapshot is created and saved for seven days
  - SQL Pool should not be in paused state

Azure SQL DB vs. Azure SQL DW



96. Azure SQL Datawarehouse Backup and Restore

Dynamic Data Masking

ID	PersonName	EmailAddress	CreditCardNumber	SocialSecurityNumber
1	Anoop Kumar	abcdefgh@hotmail.com	1234-5678-4321-8765	123-45-6789
1	Rahul Gupta	amitguptaabcdefg@hotmail.com	8765-1234-5678-4321	231-45-6787
1	Amit Goel	amitgoelabcdefgh@hotmail.com	4321-1234-5678-4321	321-45-6700

ID	PersonName	EmailAddress	CreditCardNumber	SocialSecurityNumber
9590	AXXXr	aXXX@XXXX.com	xxxx-xxxx-xxxx-8765	xxxx
7604	RXXXa	aXXX@XXXX.com	xxxx-xxxx-xxxx-4321	xxxx
8453	AXXXl	aXXX@XXXX.com	xxxx-xxxx-xxxx-4321	xxxx

Random Number function – generates random number based on selected boundaries and actual data type. Can be applied only numbers, not string

Email function – Exposes the first letter and replace the domain with xxx.com

Custom String function – You can define the exposed prefix, the padding string and exposed suffix

Credit Card function - Only the last four digits of Credit card are shown

Default function – Full masking of data.
For numeric – 0
For String – XXXX characters

Dynamic Data Masking

- **Limit the exposure of sensitive data to non-privileged users**
  - You can decide the level of exposure of data
- **No change in physical layer**
  - Data in the database is not changed
  - Not the same as data encryption
- **No additional development effort needed at application level**
- **Security: Should not be used as a primary security layer**
  - Dynamic Data Masking should not be used as an isolated measure to fully secure sensitive data
  - ad-hoc query permissions can apply techniques to gain access to the actual data.
- **Other considerations**
  - Masked columns can be updated if user has permission
  - Export masked from source data results in masked data in target table

Dynamic Data Masking

- **How to Enable DDM?**
  - Portal
  - Powershell
    - Get-AzSqlDatabaseDataMaskingRule
    - New-AzSqlDatabaseDataMaskingRule
    - Remove-AzSqlDatabaseDataMaskingRule
    - Set-AzSqlDatabaseDataMaskingRule
  - Rest API

1

Data at Rest

Inactive data that is not currently being transmitted across a network

2

Data in motion

Data that is currently travelling across a network

3

Data in Use

Data currently in the process of being generated, updated, appended or erased

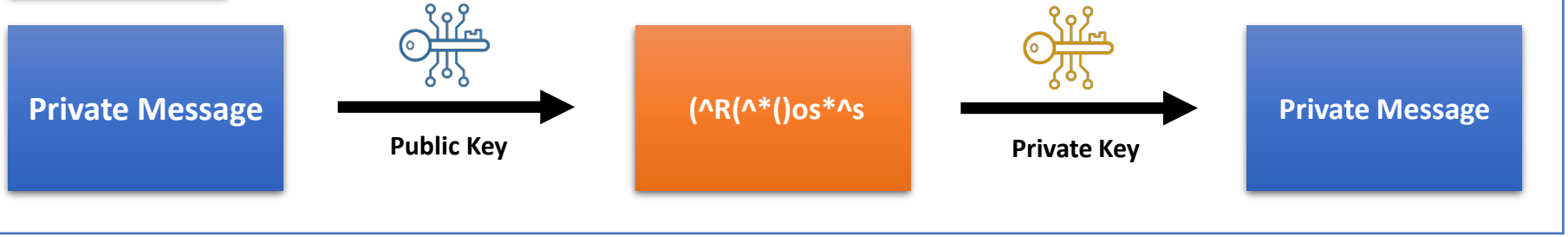
Types of Encryption

Symmetric

- Highly performant
- Secure key handling is difficult

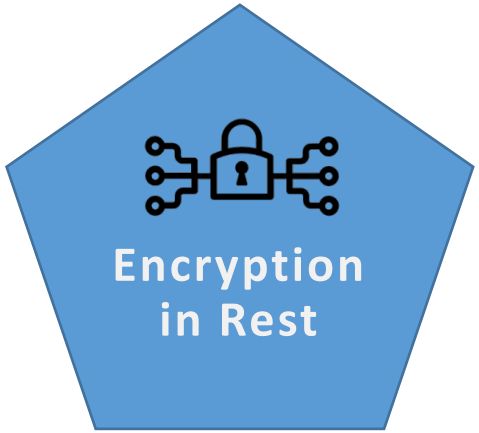
Types of Encryption

Asymmetric



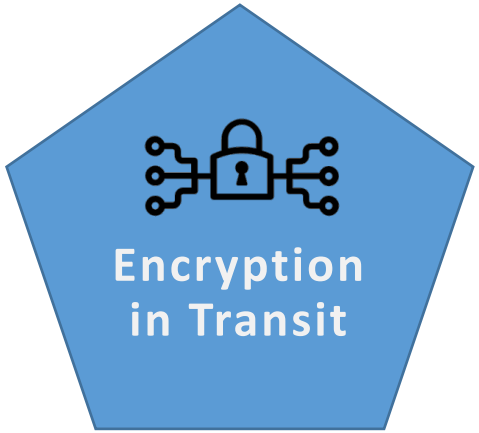
- Set of keys (Public and Private) where one is use to encrypt and other to decrypt
- Computationally more expensive, but solves the key handling problem

Encryption in Rest



- By default all storage services encrypted data at rest
- 256-bit AES encryption
- Keys are stored in Azure Key Vault

Encryption in transit



- Any communication over the internet to Azure services is typically encrypted via SSL/TLS protocols
- Utilize site-to-site VPN or point-to-site VPN connections
- Or utilize ExpressRoute
- ExpressRoute communication is a private connection and not encrypted but workloads can be encrypted via SSL/TLS
- Storage services can be configured to require secure transfer

Types of Encryption

Deterministic encryption:

- This will always generate the same encrypted value for any plain text value.
- You can perform point lookups, equality joins, grouping and indexing on encrypted columns.

Randomized encryption:

- This is more secure than deterministic encryption because the encrypted value is generated in a less predictable manner.
- But you can’t perform searching, grouping, indexing or joins on encrypted columns.

Types of Encryption

Column Encryption Key (CEK)

- Used to encrypt values in specific columns
- Encrypted versions of each CEK is stored in the database.

Column Master Key (CMK)

- Used to encrypt all the CEKs
- Must be stored externally in a secure key store
- Key store providers: Azure key vault, certificate store, HSM