Azure Database for PostgreSQL

Prepared by WeCloudData

Welcome to PostgreSQL on Azure

1. Introduction to PostgreSQL and Azure Database for PostgreSQL
2. Background and History of PostgreSQL
3. Use Cases
4. Setting Up Azure Database for PostgreSQL
5. Security and Access Management
6. Performance Optimization
7. High Availability and Disaster Recovery
8. Monitoring and Troubleshooting
9. Cost Optimization

Agenda.

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1. Introduction to PostgreSQL and Azure Database for PostgreSQL

What is PostgreSQL?

Introduction to PostgreSQL and Azure Database for PostgreSQL

PostgreSQL is a powerful, open-source object-relational database system with over **35 years of active development** that has earned it a strong reputation for reliability, feature robustness, and performance. PostgreSQL **supports complex queries and advanced SQL features**.

Why PostgreSQL is Popular

Introduction to PostgreSQL and Azure Database for PostgreSQL

- ACID compliance ensuring data reliability and consistency
- Support of advanced features such as **JSON** support, window functions, common table expressions (**CTEs**), and geospatial queries
- Rich set of data types including arrays, **JSON**, and user-defined types
- Active open-source community with regular updates and improvements
- Enterprise-grade features without licensing costs
- Advanced indexing options (**B-tree, Hash, GiST, SP-GiST, GIN, and BRIN**)
- Extensive programming language support (**Python**, **Java**, **.NET**, etc.)

Azure Database for PostgreSQL Overview

Introduction to PostgreSQL and Azure Database for PostgreSQL

- Fully managed PostgreSQL database service
- Three deployment options:
  - **Single Server**: Simple, preconfigured database engine (ideal for smaller workloads dev/test)
  - **Flexible Server**: Full control over database engine, auto-pause, zone redundancy (prod ready)
  - **Azure Cosmos DB for PostgreSQL:** Distributed database for massive scalability
- Automatic infrastructure management and maintenance
- Built-in monitoring and alerting capabilities
- Seamless integration with Azure services
- Global presence with multiple region deployment options

Benefits of Azure Database for PostgreSQL

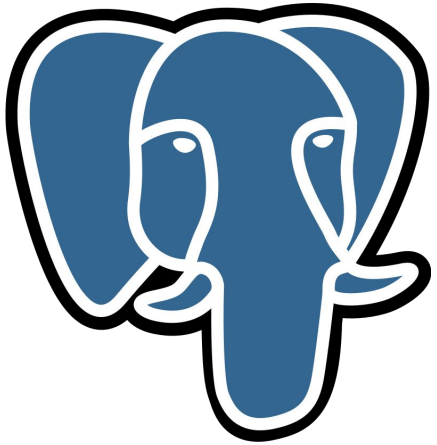
Introduction to PostgreSQL and Azure Database for PostgreSQL

- Built-in high availability (up to **99.99% SLA**)
- Automated backups and point-in-time restore capabilities
- Integrated security and compliance features
  - **Advanced Threat Protection**
  - **SSL/TLS encryption**
  - **Azure Active Directory integration**
- Automatic patching and version updates
- Scalable performance options
  - **Vertical scaling (compute and storage)**
  - **Horizontal scaling (read replicas)**
- Cost-effective pricing options
  - **Pay-as-you-go pricing**
  - **Reserved capacity discounts**
- Advanced monitoring and diagnostics
- Automated maintenance and updates
- **Over 60+** Azure regions to host your database close to your users.

Some Facts About PostgreSQL

Introduction to PostgreSQL and Azure Database for PostgreSQL

- Named after POSTGRES (**Post INGRES**) project at UC Berkeley
- Elephant logo named "**Slonik**" (which is derived from the Russian word for "little elephant") chosen for its representation of strength and reliability
- One of the most popular databases on **Stack Overflow**
- Used by major companies including; **Apple, Meta, Reddit, Spotify**
- Supported by **a global community** of contributors
- Regular **major releases** with new features
- Consistently ranked as **most loved database** by developers



Source: https://learnsql.com/blog/the-history-of-slonik-the-postgresql-elephant-logo/
Note: INGRES early project in UC Berkeley (Interactive Graphics and Retrieval System)

Demo:

- Quick Tour of Azure Database for PostgreSQL in the Azure Portal

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2. Background and History of PostgreSQL

Origins of PostgreSQL

Background and History of PostgreSQL

- **Started in 1986** as POSTGRES project at UC Berkeley
- Led by Professor **Michael Stonebraker** (Turing Award winner)
- Succeeded **INGRES** database project
- Initially focused on object-relational capabilities
- Became **PostgreSQL in 1996** with addition of SQL support
- Created to demonstrate:
  - **Complex data types**
  - **Object-relational concepts**
  - **Extensible type system**
- Active database features

Note: Michael Stonebraker Bio - https://www.britannica.com/biography/Michael-Stonebraker

Timeline of Major Releases

Background and History of PostgreSQL

- 1995: Support for SQL added (Postgres95)
- 1996: First PostgreSQL release (v6.0)
- 2005: Native Windows support added
- 2010: Built-in streaming replication
- 2012: JSON support introduced
- 2016: Parallel query execution
- 2019: Declarative partitioning
- 2020: Built-in logical replication
- 2021: Advanced performance features
- 2023: **pgvector** is an open-source vector similarity extension
- Present: Regular feature updates and improvements

PostgreSQL Community

Background and History of PostgreSQL

- Global developer community spanning continents
- Annual PostgreSQL conferences worldwide:
  - PGCon (https://www.pgcon.org/)
  - PGConf (https://2025.pgconf.dev)
  - PGDay events
- Regular local meetups and user groups
- Active mailing lists and forums for support
- Extensive documentation in multiple languages
- Commercial support available from multiple vendors
- Strong corporate sponsorship
- Regular security updates and patches

Upcoming Events: https://www.postgresql.org/about/events/

Key Differentiators

Background and History of PostgreSQL

- **Advanced indexing capabilities**
  - Multiple index types
  - Partial indexes
  - Expression indexes
- **Native JSON/JSONB support**
  - Binary storage format
  - Indexing on JSON content
- **Table inheritance and partitioning**
- **Multi-Version Concurrency Control (MVCC)**
  - No read locks required
  - Better concurrency
- **Extensible type system**
  - Custom data types
  - Custom operators
  - Custom functions
- **Foreign Data Wrappers**
  - Connect to external data sources
  - Federated database capabilities
- **Full-text search capabilities**
- **Geospatial support with PostGIS**

Demo:
- Exploring the Official PostgreSQL Documentation and Feature Timeline

- https://www.postgresql.org/docs/
- https://www.postgresql.fastware.com/hubfs/Images/Diagrams/img-dgm-postgresql-timeline-to-postgresql-15-and-beyond.svg
- https://www.postgresql.org/about/featurematrix/

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3. Use Cases

Real-World Scenarios with PostgreSQL in Azure

Use Cases

- **Enterprise Applications**
  - Complex business logic implementation
  - Large-scale data processing
  - Multi-tenant applications
- **Web Applications**
  - Content management systems
  - E-commerce platforms
  - Social media applications
- **Analytics Solutions**
  - Business intelligence
  - Real-time analytics
  - Data warehousing (RedShift is based on PostgreSQL)
- **IoT and Time-Series Data**
  - Sensor data storage
  - Time-series analysis
  - Event processing

Application Architecture Patterns

Use Cases

- **Microservices Architecture**
  - Database per service
  - Distributed transactions
  - Service isolation
  - Container-friendly, can run on Kubernetes (AKS).
- **Modern Web Applications**
  - RESTful APIs
  - GraphQL implementations
  - Real-time data updates
  - PostGIS extension for sophisticated location-based queries
- **Hybrid Solutions**
  - On-premises integration
  - Cloud migration scenarios
  - Disaster recovery configurations

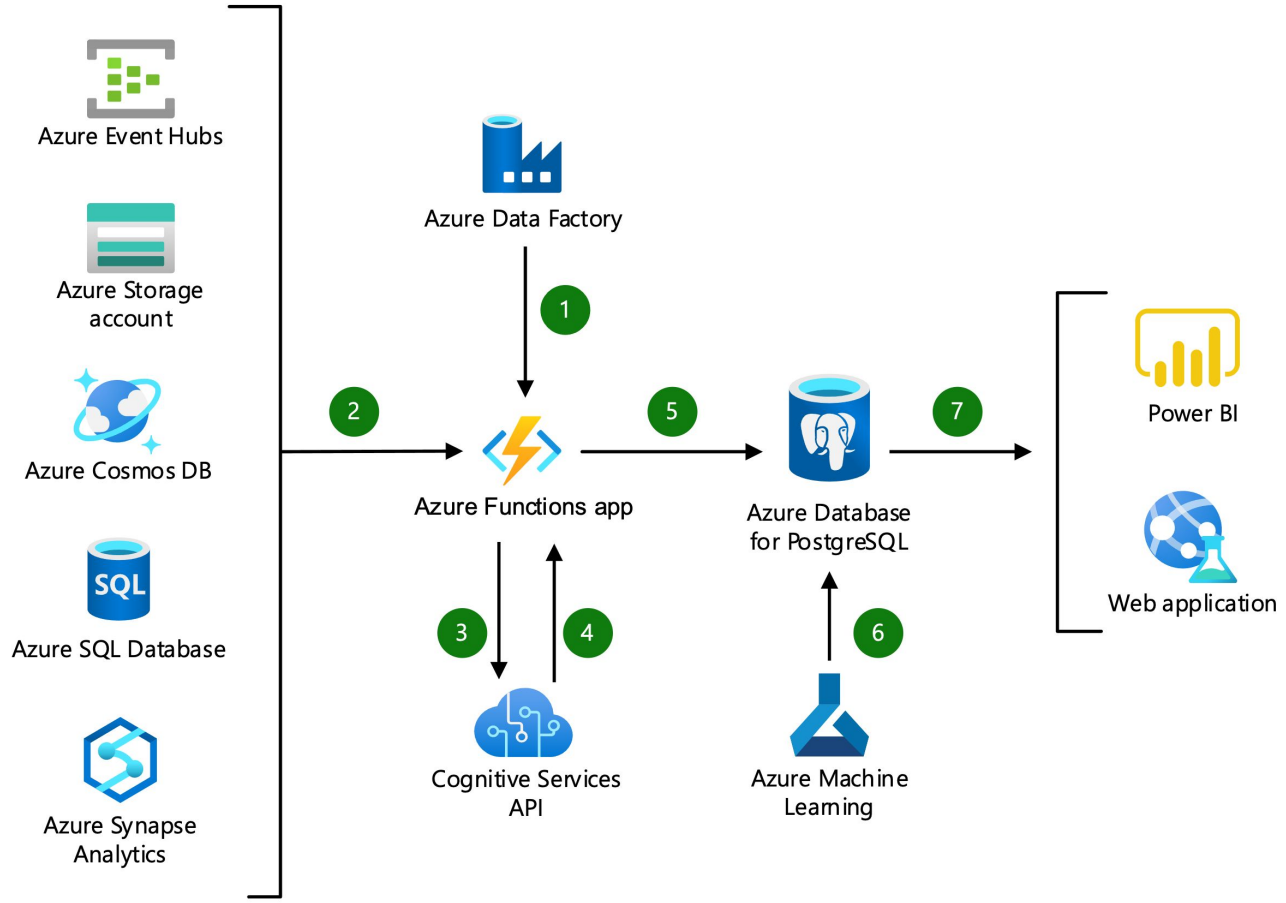
Industry-Specific Solutions

Use Cases

- **Financial Services**
  - Transaction processing
  - Risk analysis
  - Compliance reporting
- **Healthcare**
  - Patient records
  - Clinical trials data
  - Healthcare analytics
- **E-commerce**
  - Product catalogs
  - Order processing
  - Customer data management
- **Gaming**
  - Player profiles
  - Game state management
  - Leaderboards

Intelligent apps using Azure Database for PostgreSQL

Use Cases



1. An Azure function activity allows you to trigger an Azure Functions App in the Azure Data Factory pipeline.
2. Data comes from multiple sources. When the pipeline receives new data, it triggers the Azure Functions App.
3. The Azure Functions App calls the Azure AI services API to analyze the data.
4. The Azure AI services API returns the results of the analysis in JSON format to the Azure Functions App.
5. The Azure Functions App stores the data and results from the Azure AI services API in Azure Database for PostgreSQL.
6. Azure Machine Learning uses custom machine learning algorithms to provide further insights into the data.
7. The PostgreSQL connector for Power BI makes it possible to explore human-interpretable insights in Power BI or a custom web application.

Microsoft Azure

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Demo:
- Reviewing Sample Architectures Leveraging Azure Database for PostgreSQL

- https://azure.microsoft.com/blog/event-processing-with-azure-database-for-postgresql-and-azure-event-grid-integration/

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4. Setting Up Azure Database for PostgreSQL

Deployment Models

Setting Up Azure Database for PostgreSQL

- **Single Server** (Lowest complexity, suitable for smaller or dev/test workloads.)
  - Simplified management
  - Basic configuration options
  - Suitable for simple applications
- **Flexible Server**
  - Enhanced control
  - Zone-redundant high availability
  - Custom maintenance windows
  - Auto-pause for cost savings
- **Azure Cosmos DB for PostgreSQL (formerly known as Hyperscale (Citus))**
  - Distributed database capabilities (Distributed tables across multiple nodes for massive scale and parallelization.)
  - Horizontal scaling
  - Suitable for large-scale applications

Initial Configuration

Setting Up Azure Database for PostgreSQL

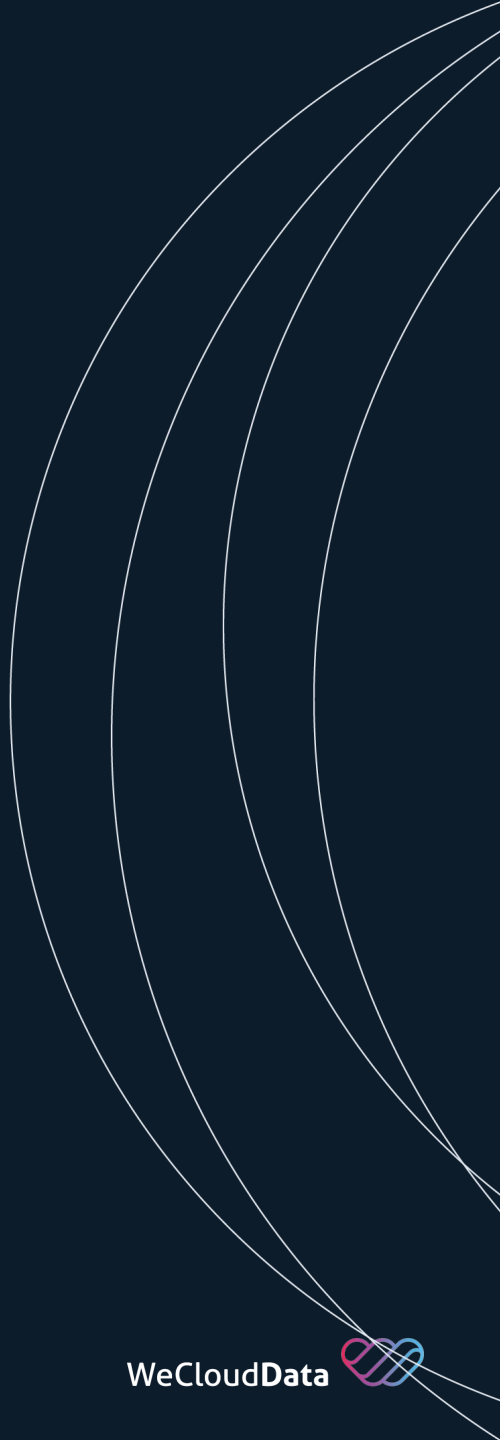
- **Compute and Memory**
  - CPU core options
  - Memory configurations
  - Burstable vs Provisioned - (B-series), General Purpose, Memory Optimized.
- **Storage Configuration**
  - Storage size selection
  - IOPS requirements - Provisioned IOPS vs. standard
  - Auto-growth settings
- **Networking Setup**
  - VNET integration for private IP addresses
  - Firewall rules
  - Private endpoints

Connection Management

Setting Up Azure Database for PostgreSQL

- **Connection Strings**
  - Format and parameters
    postgresql://[username]:[password]@[host]:[port]/[database]?sslmode=[mode]
  - Security options (Encrypted password storage in Azure Key Vault, Azure Managed Identity integration, Service Principal authentication options)
  - SSL configuration (Enforced SSL by default (**ssl=true**))
- **Client Tools**
  - **pgAdmin** - Popular GUI management tool
  - Azure Data Studio - Microsoft's cross-platform database tool
  - Command-line tools - **psql utility**, **pg_dump** and **pg_restore**
- **Connection Pooling**
  - Connection limits (*Basic: min(50, max_connections, General Purpose: min(100, max_connections), Memory Optimized: min(150, max_connections)*)
  - Pool sizing - default_pool_size = (number_of_cpus * 4)

Demo:
- Provisioning an Azure Database for PostgreSQL Instance
- Establishing a connection from a database management tool (DBeaver, no markdown file)



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5. Security and Access Management

Azure Security Features

Security and Access Management

- **Azure Entra ID Integration**
  - Single sign-on
  - Role-based access control (RBAC) - Manages access at subscription, resource group, and resource levels. Always assign only necessary permissions to each role.
  - Token-based authentication
- **Network Security**
  - Virtual Network integration
  - Private endpoints
  - Service endpoints
- **Encryption**
  - Data-at-rest encryption
  - TLS/SSL encryption
  - Key Vault integration

Managing Database Users and Permissions

Security and Access Management

- **PostgreSQL Roles**
  - LOGIN roles for actual user accounts.
  - GROUP roles to bundle privileges.
- **GRANT & REVOKE**
  - Fine-tuned access control on schemas, tables, functions.
- **Avoid Superuser**
  - Restrict superuser privileges to only essential maintenance tasks.
- **User Management**
  - Role creation
  - Permission assignment
  - Group management
- **Access Control**
  - Schema-level security
  - Row-level security
  - Column-level encryption
- **Audit Logging**
  - Query logging
  - Access logging
  - Security events

Securing Connections with SSL/TLS

Security and Access Management

- **SSL Enforcement:**
  - Usually on by default with Azure Database for PostgreSQL.
- **Certificates:**
  - Client and server verification.
- **Performance Impact:**
  - Typically, low but be aware of overhead in high throughput apps.

Integration with Microsoft Entra ID (Azure Active Directory)

Security and Access Management

- **Centralized Identity:**
  - Manage database access via Microsoft Entra ID groups/users.
- **Advantages:**
  - Single sign-on, minimal credentials management.
- **Setup:**
  - Enable Microsoft Entra ID admin in the portal, then map users to PostgreSQL roles.

Demo:
- Creating and Managing Database Users with SQL

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6. Performance Optimization

Scaling Compute and Storage

Performance Optimization

- **Vertical Scaling**: Increase or decrease vCores and memory in the Azure Portal.
  - CPU scaling
  - Memory scaling
  - Storage scaling
- **Horizontal Scaling**: Spread data across multiple nodes to handle large concurrency.
  - Read replicas
  - Sharding strategies
  - Load balancing
- **Auto-Scale (Storage)**: Avoid “out-of-disk” scenarios by letting Azure handle expansions.
  - Auto-scaling rules
  - Performance metrics
  - Threshold management

Query Performance Insights and Indexing

Performance Optimization

- **Query Store**: Tracks query performance metrics over time in Flexible Server.
- **Index Types**:
  - B-tree for equality queries.
  - GIN for full-text search.
  - BRIN for very large, naturally sorted tables.
- **EXPLAIN & EXPLAIN ANALYZE**: Tools to understand query execution plans.

Managing Connection Limits and Pooling

Performance Optimization

- **Connection Limits**: Dependent on SKU (e.g., 100, 200, etc.)
- **PgBouncer**: A lightweight connection pooler to reduce overhead
- **Idle Connections**: Clean them up to free resources.

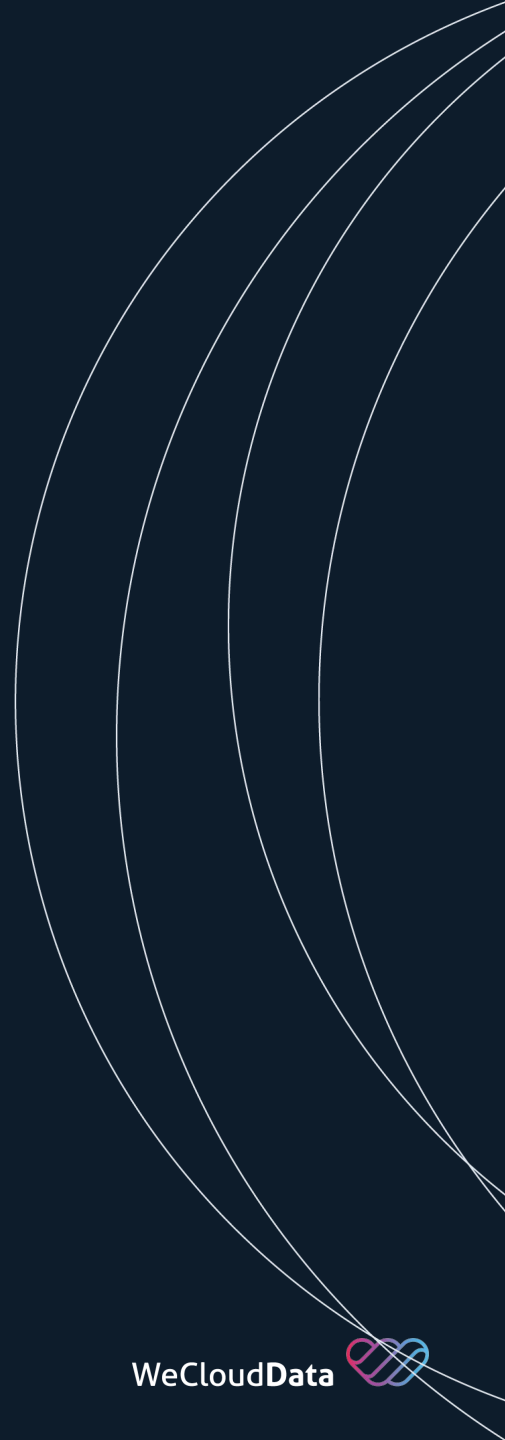
An app with many short-lived connections might benefit from pooling to reduce overhead.

Understanding Workload Profiles

Performance Optimization

- **OLTP vs. OLAP**: Different architecture and indexing strategies.
- **Short Transactions**: Minimal locking, frequent commits.
- **Long-Running Queries**: Memory and CPU planning, possibly separate from transactional workloads.
- **Analyze typical queries** before deciding on server specs.
- If an application is read-heavy, consider **read replicas or caching layers**.

Demo:
- Monitoring Query Performance and Scaling Resources



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7. High Availability and Disaster Recovery

Backup and Restore Capabilities

High Availability and Disaster Recovery

- **Automated Backup Features**
  - Built-in automated backups with configurable retention
  - Transaction log backups (5-minute intervals)
  - Geo-redundant storage for backups
  - Custom backup schedules and retention policies
- **Point-in-Time Recovery (PITR)**
  - Recovery to any point within retention period
  - Fine-grained restore capabilities
  - Cross-region restore options
- **Long-term Retention**
  - Extended backup retention up to 35 days
  - Backup archive strategies
  - Compliance and regulatory considerations

Geo-Replication for Resilience

High Availability and Disaster Recovery

- **Read Replica Architecture**
  - Support for up to 5 read replicas
  - Azure cross-region replica deployment
  - Asynchronous replication mechanism
  - Monitor and manage replication lag
- **Geographic Distribution Strategy**
  - Multi-region deployment planning
  - Network latency considerations
  - Regional compliance requirements
  - Data sovereignty management
- **Replica Management**
  - Replica promotion workflows. Automatic (in some cases) or manual to a different region if primary is down.
  - Load balancing configurations
  - Maintenance scheduling
  - Monitoring and alerting setup

Automatic Failover Strategies

High Availability and Disaster Recovery

- **High Availability Configuration**
  - Zone-redundant deployment options
  - Active-standby setup
  - Automatic failover mechanism
  - Zero RPO for committed transactions
- **Failover Process Management**
  - Automated health monitoring
  - Failover trigger conditions
  - DNS record management
  - Client connection handling
- **SLA and Reliability**
  - 99.99% availability guarantee
  - Planned maintenance windows
  - Patch management strategy
  - Performance monitoring during failover

Disaster Recovery Scenarios

High Availability and Disaster Recovery

- **Business Continuity Planning**
  - Recovery Time Objective (RTO) and Recovery Point Objective (RPO) definitions
  - Recovery procedure documentation
  - Team roles and responsibilities
  - Communication protocols
- **Recovery Scenario Types**
  - Region failure handling
  - Data corruption recovery
  - Application error mitigation
  - Infrastructure issue resolution
- **DR Testing Framework**
  - Regular disaster recovery drills
  - Failover testing procedures
  - Recovery validation processes
  - Documentation maintenance

Demo:
- Configuring Automated Backups and Performing a Point-in-Time Restore
- Setting Up Geo-Replication for High Availability

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8. Monitoring and Troubleshooting

Built-in Monitoring Tools for PostgreSQL in Azure

Monitoring and Troubleshooting

- **Azure Monitor Integration**
  - Real-time performance metrics
  - Resource utilization tracking (CPU, memory, I/O metrics for your PostgreSQL server)
  - Custom dashboard creation
  - Historical data analysis
- **Query Performance Insight**
  - Long-running query identification
  - Query pattern analysis
  - Performance recommendation engine
  - Resource usage correlation
- **Server Logs Analysis**
  - Export logs to Azure Log Analytics, Storage, or Event Hubs
  - Error log monitoring
  - Slow query logging
  - Connection tracking
  - Security event logging

Configuring Alerts and Diagnostics

Monitoring and Troubleshooting

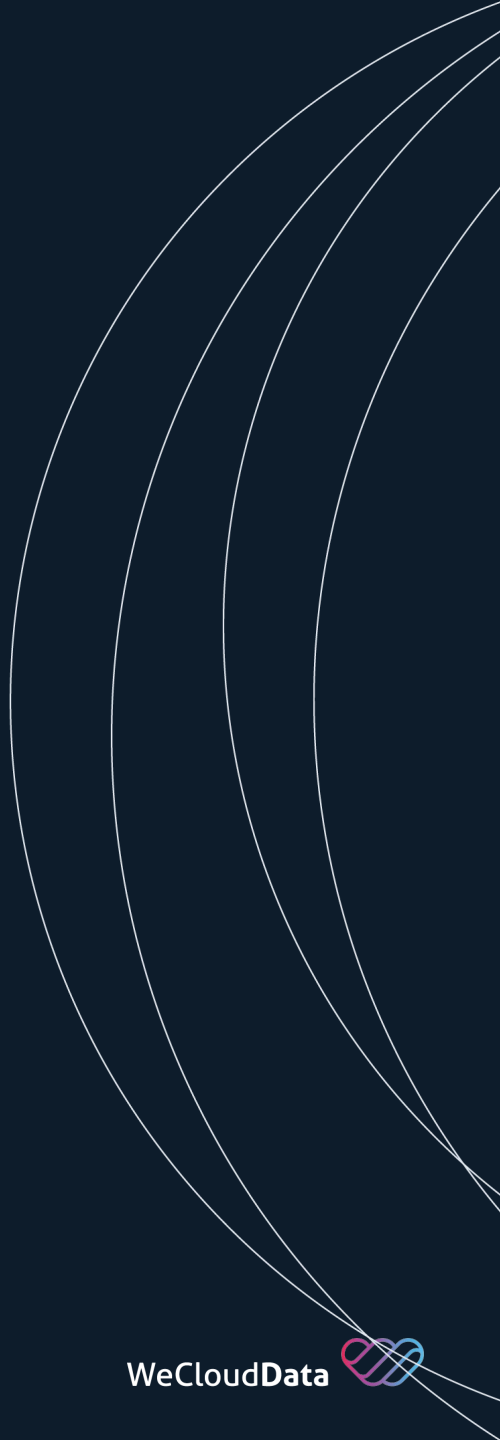
- **Alert Configuration**
  - Metric-based alerts (Trigger notifications for thresholds (e.g., CPU > 80%, storage usage))
  - Log-based alerts (Centralize logs from multiple resources for unified querying)
  - Action group integration (send emails, SMS, or call webhooks when an alert fires)
- **Monitoring Strategy**
  - Proactive monitoring setup
  - Escalation procedures
  - Alert response workflows
  - Documentation requirements

Common Issues and Solutions

Monitoring and Troubleshooting

- **Performance Problems**
  - Query performance issues
  - Resource bottlenecks
  - Connection management
  - Storage limitations
  - Check indexes
  - Missing partitioning
- **Connectivity Challenges**
  - Network configuration issues
  - Firewall rules
  - SSL/TLS problems
  - Authentication failures

Demo:
- Using Azure Monitor to Track Database Metrics



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9. Cost Optimization

Understanding Pricing Tiers

Cost Optimization

- **Service Tiers - Match CPU and memory to your workload profile**
  - Basic tier capabilities
  - General Purpose features
  - Memory Optimized options
- **Pricing Components**
  - Compute costs breakdown
  - Storage pricing models
  - Backup storage costs
  - Network traffic charges
- **Service Level Agreements**
  - SLA guarantees per tier
  - Feature availability
  - Support levels
  - Performance expectations
- **Pricing Model**
  - Pay-as-You-Go: Flexible but can be costly for always-on production.
  - Reserved Instances: Commit for 1 or 3 years to get significant discounts.

Note: It is important to review performance metrics before purchasing reserved capacity

Right-Sizing Compute and Storage

Cost Optimization

- **Monitor Utilization**: CPU usage, memory pressure, IOPS.
- **Scale Vertically**: Move to a higher-tier SKU if consistently at high load.
- **Auto-Grow Storage**: Avoid emergency scenarios or service disruptions.

Overspending occurs if you overprovision significantly, whereas underprovisioning can cause performance bottlenecks.

Start small, monitor, then scale up as usage grows.

Leveraging Reserved Instances

Cost Optimization

- **Up to 65% Savings**: vs. on-demand rates if your workload is steady.
- **Ideal for Production**: Where continuous usage is expected over a year or more.
- **Cancellation & Exchange**: Some flexibility if your needs change.

Using Azure Advisor for Cost Recommendations

Cost Optimization

- **Azure Advisor**: Analyzes your usage and offers optimization suggestions.
- **Actionable Insights**: Identifies underutilized resources or potential cost savings.
- **Budget Alerts**: Set spending thresholds for your subscription to avoid bill shock.

Discussion

Thank you

WeCloudData

180 Bloor St W #1003, Toronto, ON
www.wecloudddata.com