



Security - General

Module 4

Learning Units covered in this Module

- Lesson 1: SQL Server Services Accounts
- Lesson 2: Row Level Security
- Lesson 3: Dynamic Data Masking
- Lesson 4: SQL Server Audit

Lesson 1: SQL Server Service Accounts Best Practices

Objectives

After completing this learning, you will be able to:

- Discuss the various Microsoft SQL Server Service Accounts.
- Know the options available to better secure your environment.



SQL Server Service Accounts

Partial List

SQL Server Database Engine

SQL Server Agent

SQL Server Browser – Might be disabled

SQL Server Full-text Filter Daemon Launcher

SQL Server Launchpad – Optional

SQL Server Integration Services – Optional

SQL Server Analysis Services – Optional

SQL Server Reporting Services - Optional

Overview

Local or
Domain User
Account

Network Service
Account

Virtual Service
account
(SQL 2012)

Managed
Service account
(SQL 2012)

Which one is "right"

- Consider the principle of least privilege
- Accounts should have the level of access required and nothing further.
- Accounts should be isolated (not used by any other service)

What is the best choice?

Largely dependent on your organizations needs, but there are recommended practices:

Non-administrative Local or Domain users

- Local users **cannot** access domain resources.
- Require regular service password management

Virtual accounts (SQL 2012+)

- Auto-managed, auto-provisioned
- Ideal for non-domain joined or isolated servers

Managed accounts (SQL 2012+)

- Auto-managed, manual provisioning
- Ideal for domain joined servers that must access domain resources or used linked servers

SQL Service Identities

NT Authority Accounts

Local System

NT AUTHORITY\System

Network Service

NT AUTHORITY\NetworkService

Local Service

NT AUTHORITY\LocalService

NT Service Accounts

Virtual Accounts Service SID

NT SERVICE\MSSQLSERVER

NT SERVICE\SQLSERVERAGENT

NT SERVICE\MSSQL\$Instance

NT SERVICE\SQLAGENT\$Instance

MSA accounts and gMSA

Domain

DOMAIN\ACCOUNTNAME\$

Domain Group MSA

Domain\Global Security Group

Virtual Accounts

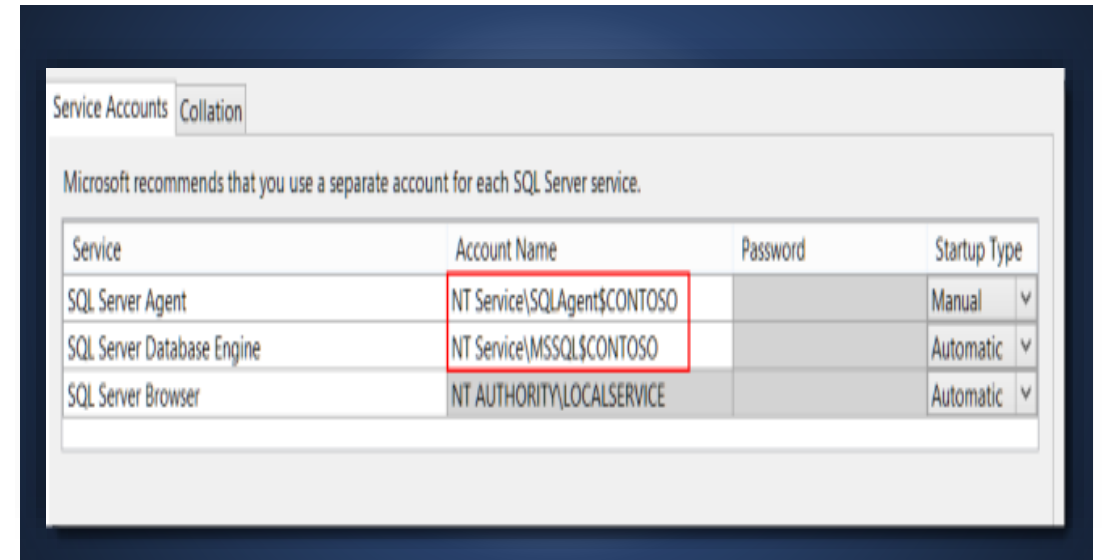
Managed local accounts

Automatically Provisioned and Managed

Default in SQL Server 2012 – specific during setup

Default instance of the Database Engine service:
NT SERVICE\MSSQLSERVER

Access network resources by using:
<domain_name>\<computer_name>\$



Managed Service Accounts

Active Directory
Domain Account

Assigned to a single
computer, used to
manage a service (not
supported in Failover
Clusters)

Provisioned by a
Domain Administrator,
then installed on local
computer

Provides automatic SPN
and (SPN and password
management) –
supports delegation

Cannot be used to log
in to an interactive
desktop session

Managed Service Accounts and gMSAs

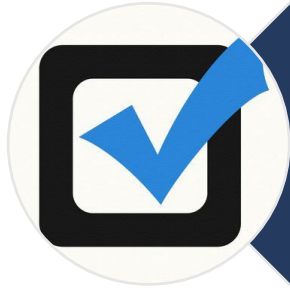
Managed Service Accounts (MSAs)

- Limited to a single server
- Remove the need to manage a service account password
- Service Principal name (SPN) registration can be done automatically

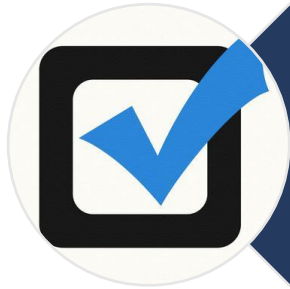
Group Managed Service Accounts (gMSAs)

- Extend MSA functionality across multiple servers
- Supported in SQL Server 2014+
- Requires Windows Server 2012+ Active Directory Domain Controller
- Requires Windows Server 2012+

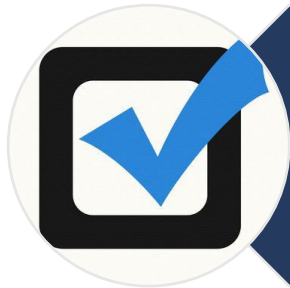
Service Account Best Practices



Separate account for each SQL Server service for each server



Use virtual service accounts, managed service accounts, or group managed service accounts



Do not grant service accounts local administrator permissions

Questions?



Knowledge Check

What are some of the best practices related to configuring SQL Server Service Accounts?

What version of SQL Server supports gMSAs?

Lesson 2: Row Level Security

Objectives

After completing this learning, you will be able to:

- Understand row-level security and how it can be used.

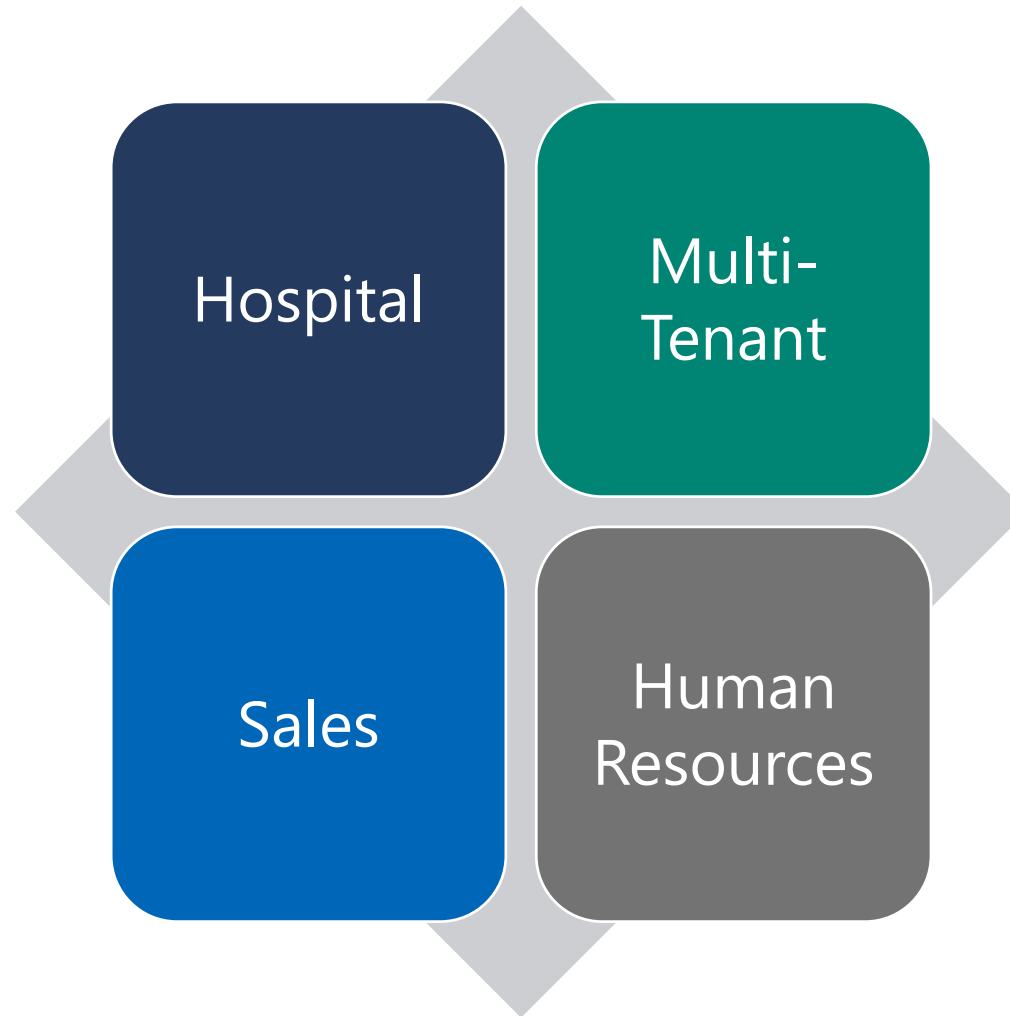


Row-Level Security Overview

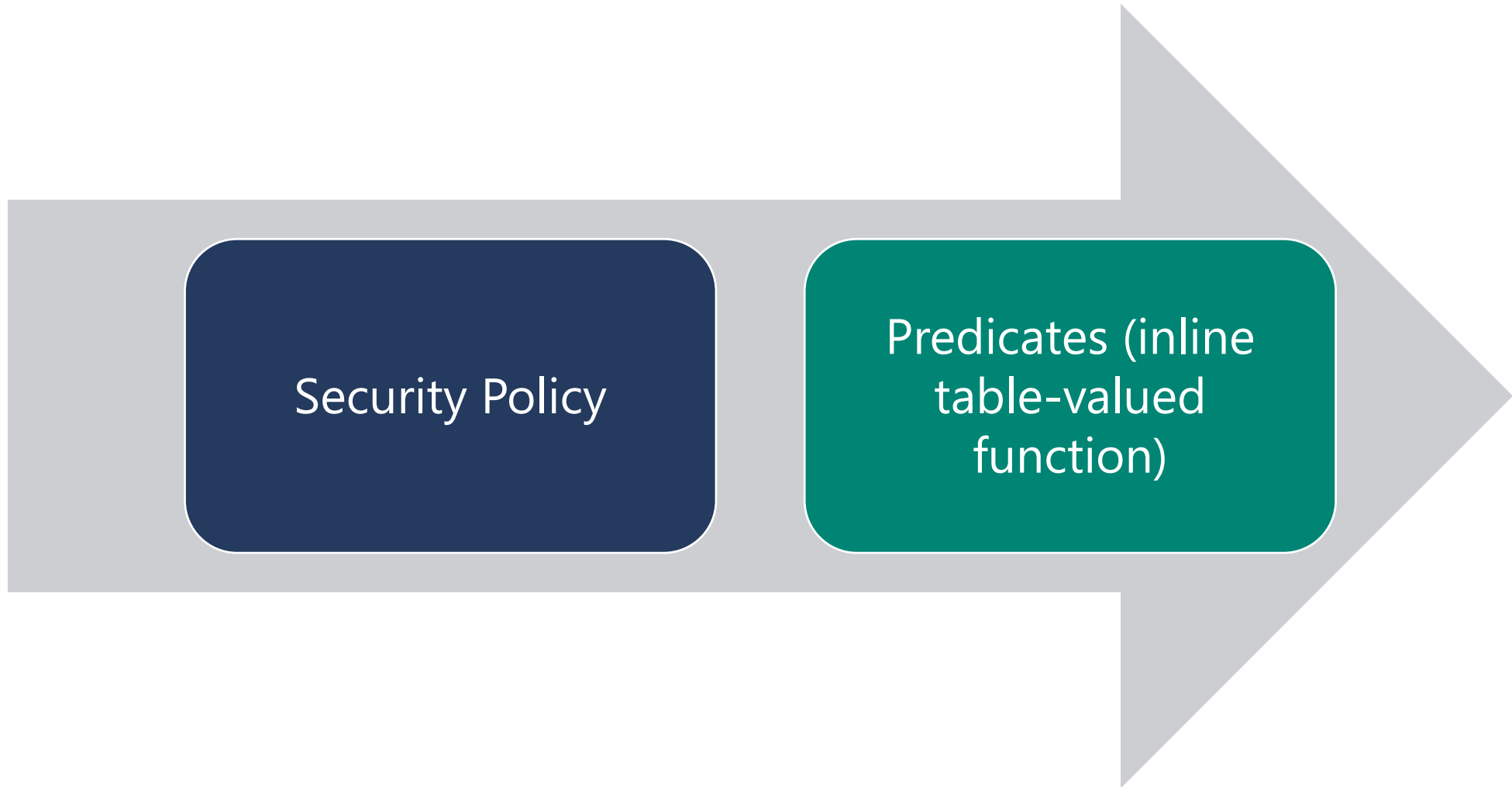
Enables fine grained access control
at the row level

Security logic is controlled at the
database tier instead of the
application tier

Row-Level Security Use Cases



Row-Level Security Components



Row-Level Security Predicates



Filter

Block

```
CREATE FUNCTION fn_RowLevelSecurity (@FilterColumnName sysname) RETURNS TABLE WITH  
SCHEMABINDING  
as  
RETURN SELECT 1 as fn_SecureCustomerData  
-- filter out records based on database user name  
where @FilterColumnName = user_name();
```

Row-Level Security Policy

Security policies are named objects, scoped to a schema that perform filtering using an inline table-valued function.

State setting determines if they are on or off.

```
CREATE SECURITY POLICY FilterCustomer  
ADD FILTER PREDICATE dbo.fn_RowLevelSecurity(SalesPersonUserName)  
ON dbo.Customer  
WITH (STATE = ON);
```

Row-Level Security Permissions

Create, alter or drop
policy

- Requires ALTER ANY SECURITY POLICY
- Creating or dropping a security policy requires the ALTER permission on the schema

For each predicate added

- SELECT and REFERENCES permissions on the function being used as a predicate
- REFERENCES on the target table
- REFERENCES on every column from the target table used as an argument

Row-Level Security Best Practices

Create a separate schema
for RLS objects

Monitor who has the ALTER
ANY SECURITY POLICY –
intended for highly
privileged users

If the security policy
managers have the ALTER
ANY SECURITY POLICY
permission, they do not
need the select permission
on the table

Keep predicate functions as
simple as possible to
prevent performance issues

Row-Level Security Limitations

Filestream – not supported

Polybase – not supported

DBCC SHOW_STATISTICS report statistics on unfiltered data (potential leak)

Memory-optimized tables – predicate must use WITH NATIVE_COMPILATION option

Indexed views cannot be created on top of tables that have a security policy

Change Data Capture (CDC) – can leak rows that should be filtered to db_owner

Demonstration

Dynamic Data Masking

Creating and Querying Masked
Tables



Row-Level Security

You will setup row level security to allow different people to see their territory without seeing data for other territories.



Questions?



Knowledge Check

What are some scenarios where row-level security would be beneficial?

Lesson 3: Dynamic Data Masking

Objectives

After completing this learning, you will be able to:

- Understand how dynamic data masking can be utilized to enhance data security.



Dynamic Data Masking Overview

Why use Dynamic Data Masking?

Limits sensitive data exposure to non-privileged users

Provides control over how much of the sensitive data is revealed

Minimal impact to the application layer

Data in the database remains unchanged

Types of Data Masks

Default (based on data
type)

Email

Custom String

Random

Dynamic Data Masking Limitations

The following columns cannot be masked

- Using Always Encrypted
- FILESTREAM
- Computed Columns*
- Column that is a key for a full-text index

Dynamic Data Masking Permissions

ALTER ANY MASK and ALTER
permission on the table

Required to add,
replace or remove the
mask of a column

UNMASK

Required to see
unmasked data*

Demonstration

Dynamic Data Masking

Creating and Querying Masked
Tables



Questions?



Knowledge Check

Which permission needs to be granted for a user to see the full data view

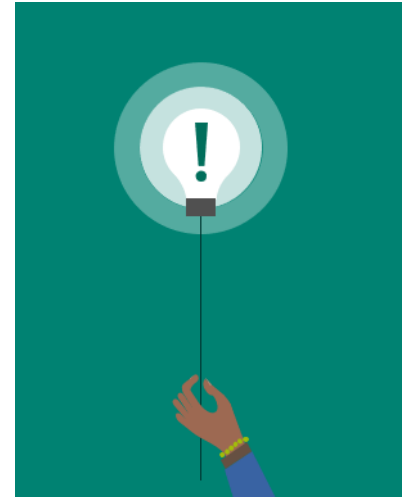
What are the four types of data masks?

Lesson 4: Introduction to SQL Server Audit

Objectives

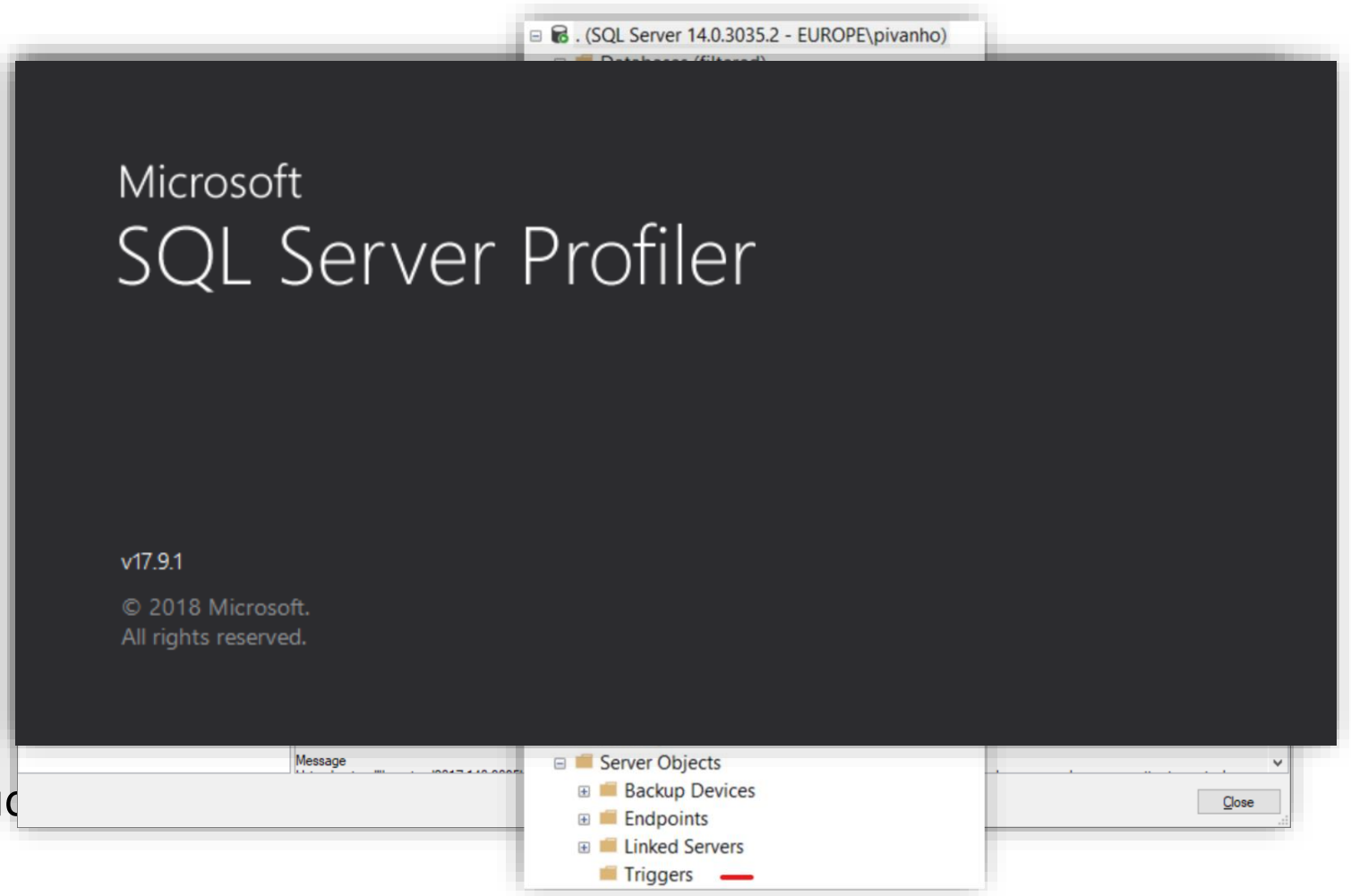
After completing this learning, you will be able to:

- Understand what SQL Server Audit is and how to configure it.

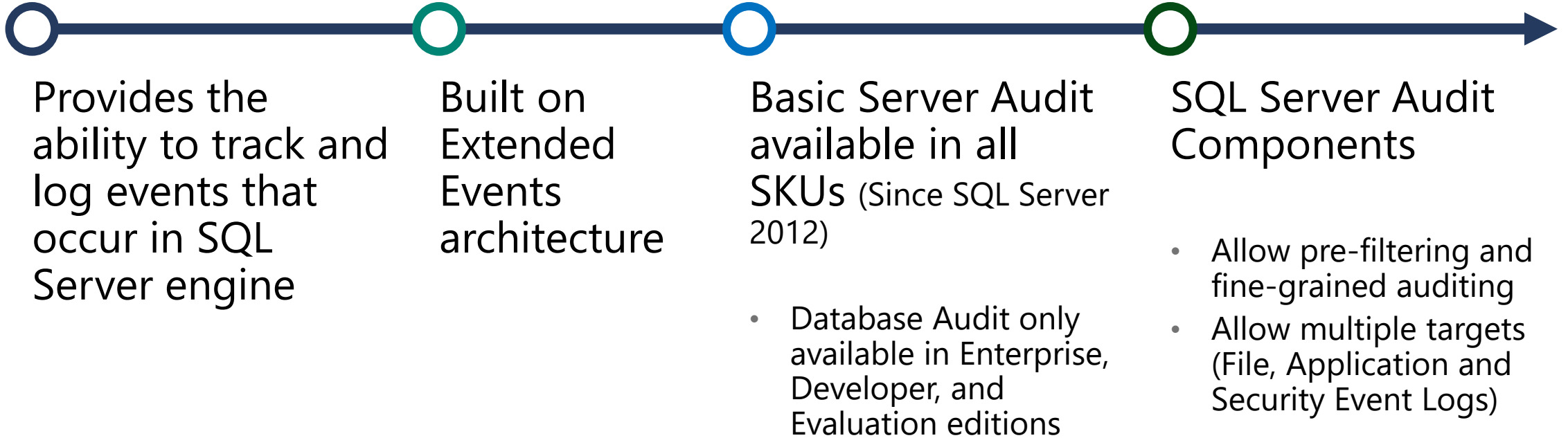


Some History...

- SQL 2005 and earlier
 - Server Level
 - Application Log
 - SQL Server Error Log
- Triggers
 - Login triggers
 - Server triggers
 - DDL triggers
- SQL Trace (Profiler)
 - Detailed activity audits
 - Individual statements, including



SQL Server Audit



Key part of security strategy

Who has accessed or attempted to access your data

Ability to detect unauthorized access attempts

Piece together the actions of malicious insiders

Robust tracking capability

Primary Goals of SQL Server Audit

Security

- The audit feature must be truly secure.

Performance

- Performance impact must be minimized

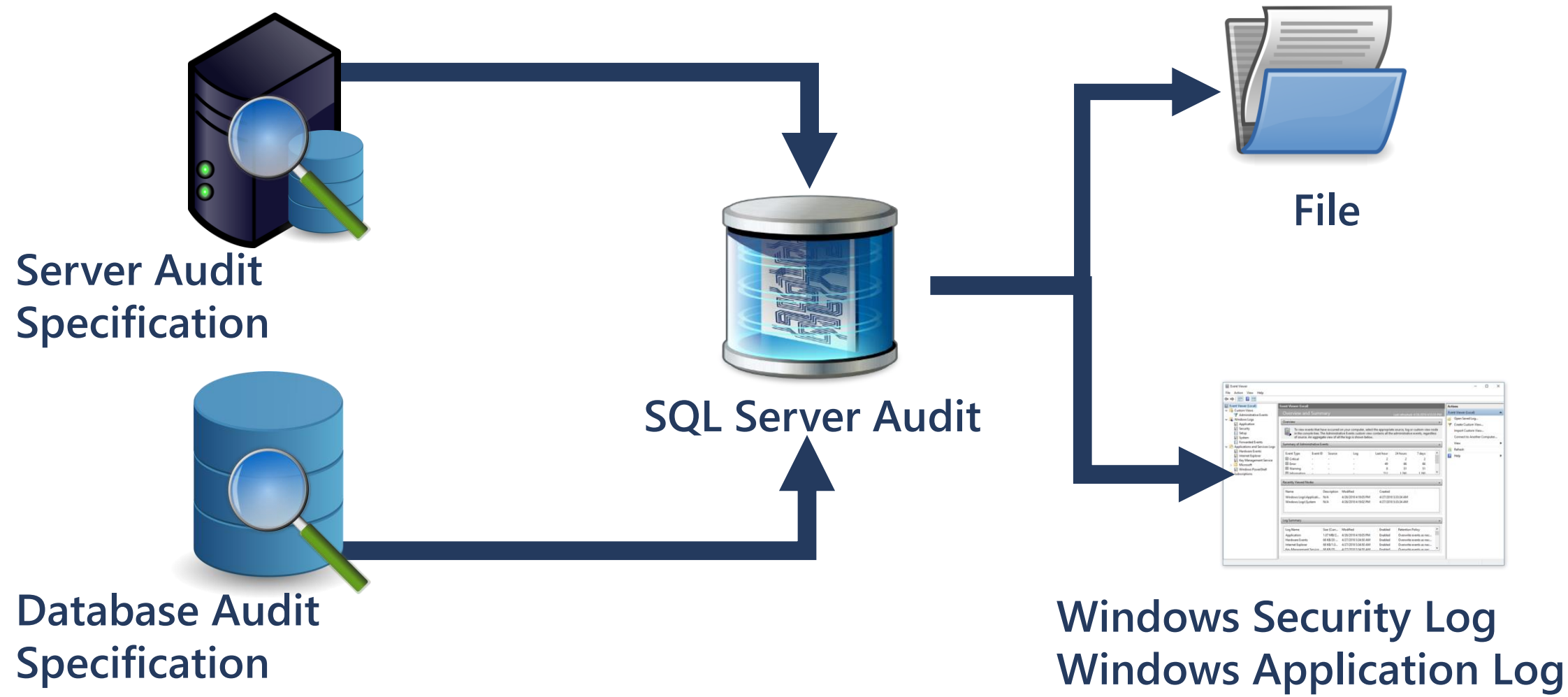
Management

- The audit feature must be easy to manage.

Discoverability

- Audit-centric questions must be easy to answer

Audit Object Layout



Working with SQL Server Audit



Create an audit and define the target



Create either a server audit specification or database audit specification



Enable the audit specification



Enable the audit



Read the audit events

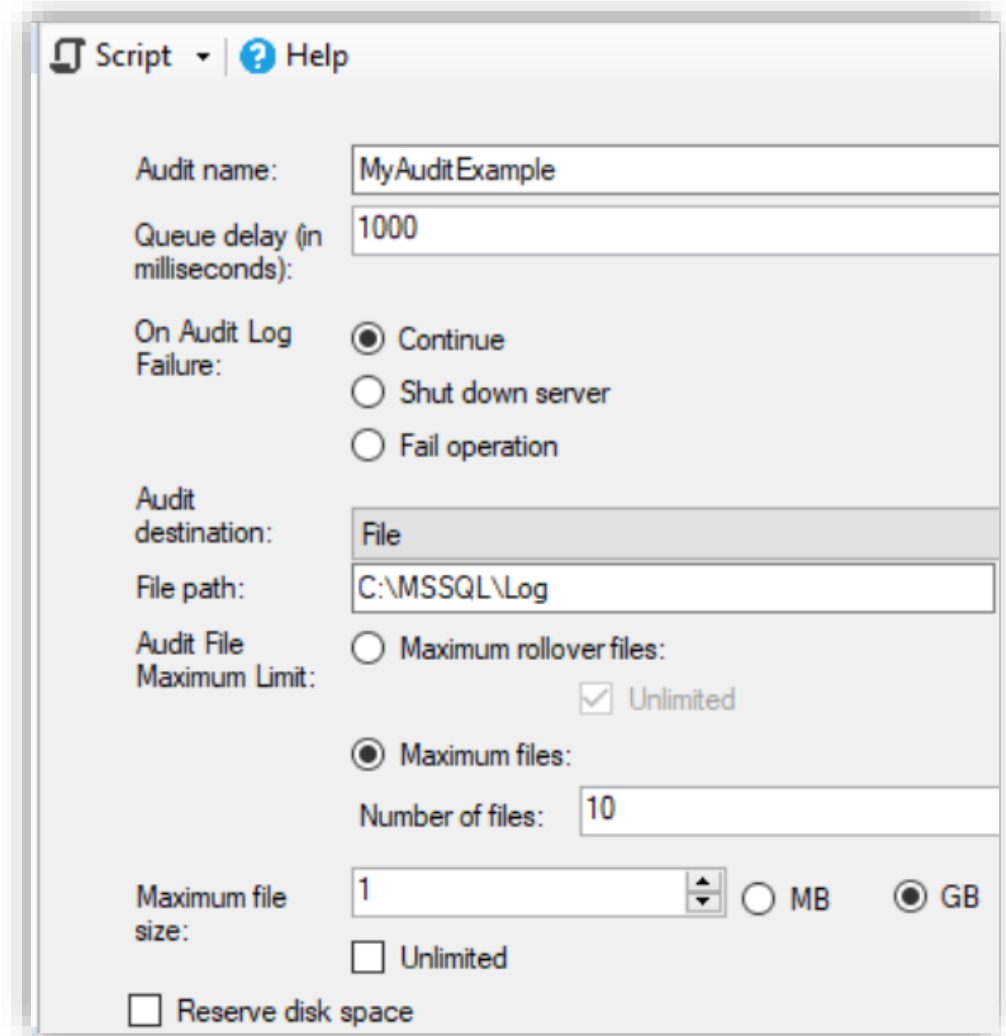
Create Audit

Queue delay (in milliseconds)

On Audit Log Failure - Continue

On Audit Log Failure - Shut down server

On Audit Log Failure - Fail operation



The screenshot shows the 'Script' window in SQL Server Enterprise Manager, used for creating an audit. The window has a menu bar with 'Script' and 'Help'. The configuration is as follows:

- Audit name:** MyAuditExample
- Queue delay (in milliseconds):** 1000
- On Audit Log Failure:** ☒ Continue, ☐ Shut down server, ☐ Fail operation
- Audit destination:** File
- File path:** C:\MSSQL\Log
- Audit File Maximum Limit:** ☐ Maximum rollover files: ☒ Unlimited, ☒ Maximum files: Number of files: 10
- Maximum file size:** 1 (with up/down arrows), ☐ MB, ☒ GB, ☐ Unlimited
- ☐ Reserve disk space

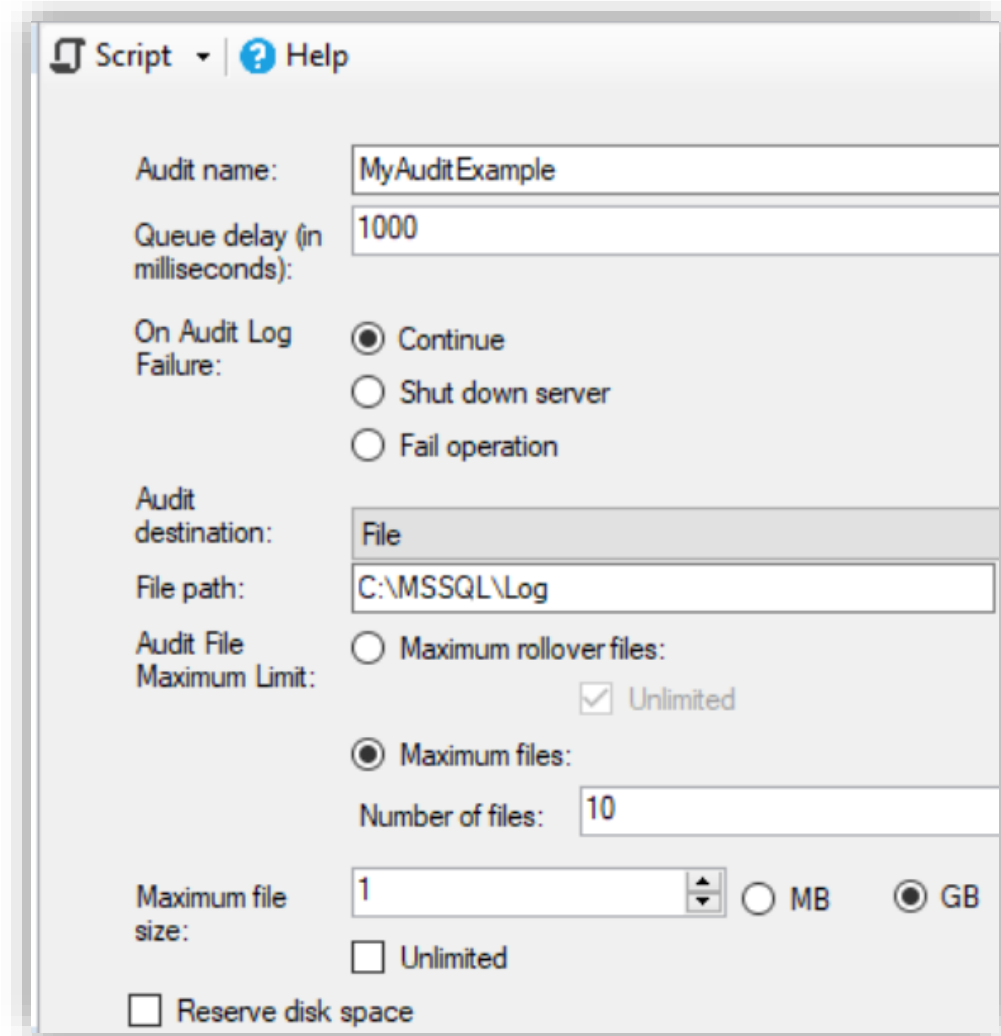
Create Audit (Continued)

Audit Destination

- Binary file
- Windows Application log
- Windows Security log

File Settings

- File Path
- Audit File Maximum Limit
- Maximum File Size
- Reserve disk space



The screenshot shows the 'Script' and 'Help' tabs at the top. The 'Audit name' field is set to 'MyAuditExample'. The 'Queue delay (in milliseconds)' is set to '1000'. Under 'On Audit Log Failure', the 'Continue' radio button is selected. The 'Audit destination' is set to 'File'. The 'File path' is 'C:\MSSQL\Log'. For 'Audit File Maximum Limit', the 'Maximum files' radio button is selected with 'Number of files' set to '10'. The 'Maximum file size' is set to '1' with 'GB' selected. The 'Reserve disk space' checkbox is unchecked.

Script | ? Help

Audit name: MyAuditExample

Queue delay (in milliseconds): 1000

On Audit Log Failure: ☒ Continue
☐ Shut down server
☐ Fail operation

Audit destination: File

File path: C:\MSSQL\Log

Audit File Maximum Limit: ☐ Maximum rollover files: ☒ Unlimited
☒ Maximum files: Number of files: 10

Maximum file size: 1 ☐ MB ☒ GB
☐ Unlimited

☐ Reserve disk space

SQL Server Audit Events to the Security Log

The Audit object

- The Audit object access setting must be configured to capture the events. The audit policy tool (auditpol.exe) exposes a variety of sub-policies settings in the audit object access category. To allow SQL Server to audit object access, configure the application generated setting.

SQL Server service Account

- The account that the SQL Server service is running under must have the generate security audits permission to write to the Windows Security log.
- secpol.msc → Generate security audits

Registry

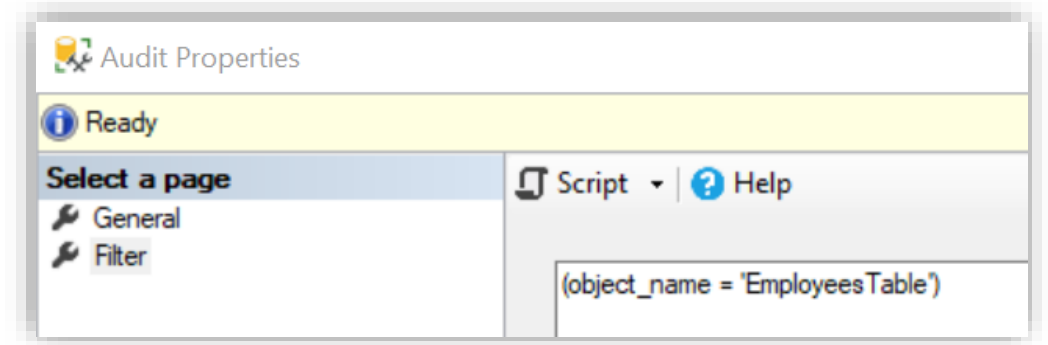
- Provide full permission for the SQL Server service account to the registry hive
- HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\EventLog\Security.

Create Audit Filter

Enter a predicate, or "WHERE clause"

Audit events are filtered before they are written to the audit log

You can filter on every element of the Audit Records



Server-Level Audit Action Groups

LOGIN_CHANGE_PASSWORD_GROUP

- Whenever a login password is changed

SERVER_OBJECT_CHANGE_GROUP

- CREATE, ALTER, or DROP operations on server objects

SERVER_PRINCIPAL_CHANGE_GROUP

- When server principals are created, altered, or dropped

SERVER_ROLE_MEMBER_CHANGE_GROUP

- Whenever a login is added or removed from a fixed server role.

SUCCESSFUL_LOGIN_GROUP

- A principal has successfully logged in to SQL Server

Database-Level Audit Action Groups

BACKUP_RESTORE_GROUP

- Whenever a backup or restore command is issued

DATABASE_CHANGE_GROUP

- When a database is created, altered, or dropped

DATABASE_OBJECT_CHANGE_GROUP

- When a CREATE, ALTER, or DROP statement is executed on database objects

DATABASE_ROLE_MEMBER_CHANGE_GROUP

- Whenever a login is added to or removed from a database role

DBCC_GROUP

- Whenever a principal issues any DBCC command

FAILED_DATABASE_AUTHENTICATION_GROUP

- A principal tried to log on to SQL Server and failed

Database Audit Specifications Actions and Groups

```
select *  
from sys.dm_audit_actions  
where class_desc = 'database'  
or parent_class_desc = 'database';
```

action_id	name	class_desc	covering_action_name
R	REVOKE	DATABASE	DATABASE_PERMISSION_CHANGE_GROUP
D	DENY	DATABASE	DATABASE_PERMISSION_CHANGE_GROUP
G	GRANT	DATABASE	DATABASE_PERMISSION_CHANGE_GROUP
GWG	GRANT WITH GRANT	DATABASE	DATABASE_PERMISSION_CHANGE_GROUP
RWG	REVOKE WITH GRANT	DATABASE	DATABASE_PERMISSION_CHANGE_GROUP
RWC	REVOKE WITH CASCADE	DATABASE	DATABASE_PERMISSION_CHANGE_GROUP
DWC	DENY WITH CASCADE	DATABASE	DATABASE_PERMISSION_CHANGE_GROUP
R	REVOKE	OBJECT	NULL
D	DENY	OBJECT	NULL
G	GRANT	OBJECT	NULL
GWG	GRANT WITH GRANT	OBJECT	NULL
RWG	REVOKE WITH GRANT	OBJECT	NULL
RWC	REVOKE WITH CASCADE	OBJECT	NULL
DWC	DENY WITH CASCADE	OBJECT	NULL
R	REVOKE	TYPE	NULL
D	DENY	TYPE	NULL
G	GRANT	TYPE	NULL
GWG	GRANT WITH GRANT	TYPE	NULL
RWG	REVOKE WITH GRANT	TYPE	NULL
RWC	REVOKE WITH CASCADE	TYPE	NULL
DWC	DENY WITH CASCADE	TYPE	NULL
R	REVOKE	SCHEMA	NULL
D	DENY	SCHEMA	NULL

List All Server and Database Action Groups

```
select name,class_desc from
sys.dm_audit_actions
where name in
(select containing_group_name
from sys.dm_audit_actions) order
by class_desc, name;
```

name	class_desc
DBCC_GROUP	DATABASE
FAILED_DATABASE_AUTHENTICATION_GROUP	DATABASE
SCHEMA_OBJECT_ACCESS_GROUP	DATABASE
SCHEMA_OBJECT_CHANGE_GROUP	DATABASE
SCHEMA_OBJECT_OWNERSHIP_CHANGE_GROUP	DATABASE
SCHEMA_OBJECT_PERMISSION_CHANGE_GROUP	DATABASE
SUCCESSFUL_DATABASE_AUTHENTICATION_GROUP	DATABASE
USER_CHANGE_PASSWORD_GROUP	DATABASE
USER_DEFINED_AUDIT_GROUP	DATABASE
APPLICATION_ROLE_CHANGE_PASSWORD_GROUP	SERVER
AUDIT_CHANGE_GROUP	SERVER
BACKUP_RESTORE_GROUP	SERVER
BROKER_LOGIN_GROUP	SERVER
DATABASE_CHANGE_GROUP	SERVER
DATABASE_LOGOUT_GROUP	SERVER
DATABASE_MIRRORING_LOGIN_GROUP	SERVER
DATABASE_OBJECT_ACCESS_GROUP	SERVER
DATABASE_OBJECT_CHANGE_GROUP	SERVER
DATABASE_OBJECT_OWNERSHIP_CHANGE_GROUP	SERVER
DATABASE_OBJECT_PERMISSION_CHANGE_GROUP	SERVER

Get Information About a Particular Group Name

```
select *  
from sys.dm_audit_actions  
where containing_group_name = 'USER_CHANGE_PASSWORD_GROUP';
```

action_id	name	class_desc	covering_action_name	parent_class_desc	covering_parent_action_name	configuration_level
PWR	RESET PASSWORD	USER	NULL	DATABASE	USER_CHANGE_PASSWORD_GROUP	NULL
PWRS	RESET OWN PASSWORD	USER	NULL	DATABASE	USER_CHANGE_PASSWORD_GROUP	NULL
PWCS	CHANGE OWN PASSWORD	USER	NULL	DATABASE	USER_CHANGE_PASSWORD_GROUP	NULL
PWC	CHANGE PASSWORD	USER	NULL	DATABASE	USER_CHANGE_PASSWORD_GROUP	NULL
USTC	COPY PASSWORD	USER	NULL	DATABASE	USER_CHANGE_PASSWORD_GROUP	NULL
UCGP	USER_CHANGE_PASSWORD_GROUP	DATABASE	NULL	SERVER	USER_CHANGE_PASSWORD_GROUP	Group
UCGP	USER_CHANGE_PASSWORD_GROUP	SERVER	NULL	NULL	NULL	Group

Database-Level Audit Actions

SELECT

UPDATE

INSERT

DELETE

EXECUTE

RECEIVE

REFERENCES

View a SQL Server Audit Log



SQL SERVER
MANAGEMENT STUDIO



SYS.FN_GET_AUDIT_FILE

sys.fn_get_audit_file

- **file_pattern**
 - Specifies the directory or path and file name for the audit file set to be read.
- **initial_file_name**
 - Specifies the path and name of a specific file in the audit file set to start reading audit records from
- **audit_record_offset**
 - Specifies a known location with the file specified for the initial_file_name

```
SELECT * FROM sys.fn_get_audit_file  
( '\\serverName\Audit\HIPAA_AUDIT.sqlaudit', default, default );
```

Considerations



In the case of a failure during audit initiation, the server will not start.



Attaching a Database with an Audit Defined



Always On Availability Groups and SQL Server Audit



Auditing Administrators

Demonstration

Demonstrate how to Create an Audit and Audit Specification within SQL Server



Questions?



SQL Server Auditing

- Exercise 1: Create a Login with PowerShell
- Exercise 2: Create a Server audit and read its results



Knowledge Check

How do you start an audit after creating the server audit specification login?

How do you stop the audit?

What are audit action groups in a server audit specification?

Lesson 5: Ledger for SQL Server

Objectives

After completing this learning, you will be able to:

- Understand what Ledger for SQL Server is and how to configure it.



Security enhancements - Ledger for SQL Server

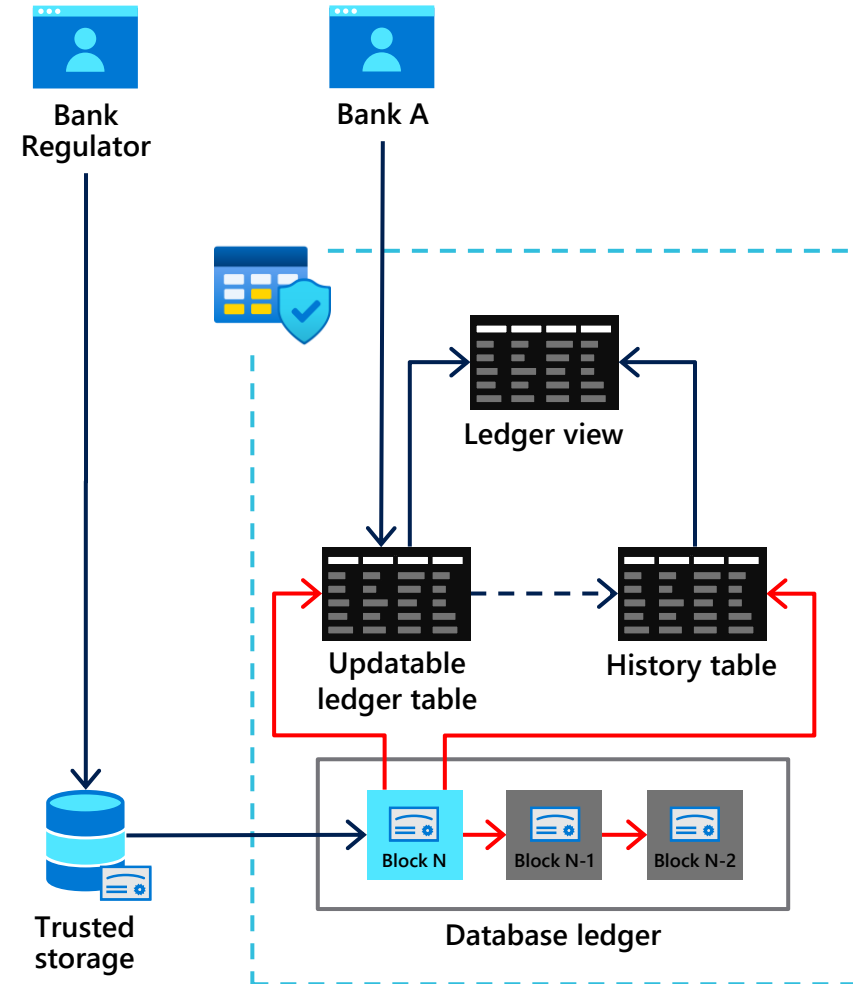
Ledger for SQL Server -The ledger feature provides tamper-evidence capabilities in your database. You can cryptographically attest to other parties, such as auditors or other business parties, that your data hasn't been tampered with.

Ledger for SQL Server

Tamper-evidence track record of data over time

Challenge: I want the power of blockchain in a centralized system like SQL Server

- ✓ Use a cryptographically hashed ledger detect tampering by malicious actors
- ✓ Built into SQL Server with T-SQL
- ✓ Establish digital trust in a centralized system using blockchain technology.
- ✓ Attest to other parties that data integrity has not been compromised
- ✓ Automatic digest storage



Ledger Tables – Updatable and Append-Only

Updatable Ledger Tables are standard SQL tables which allow updates and deletes

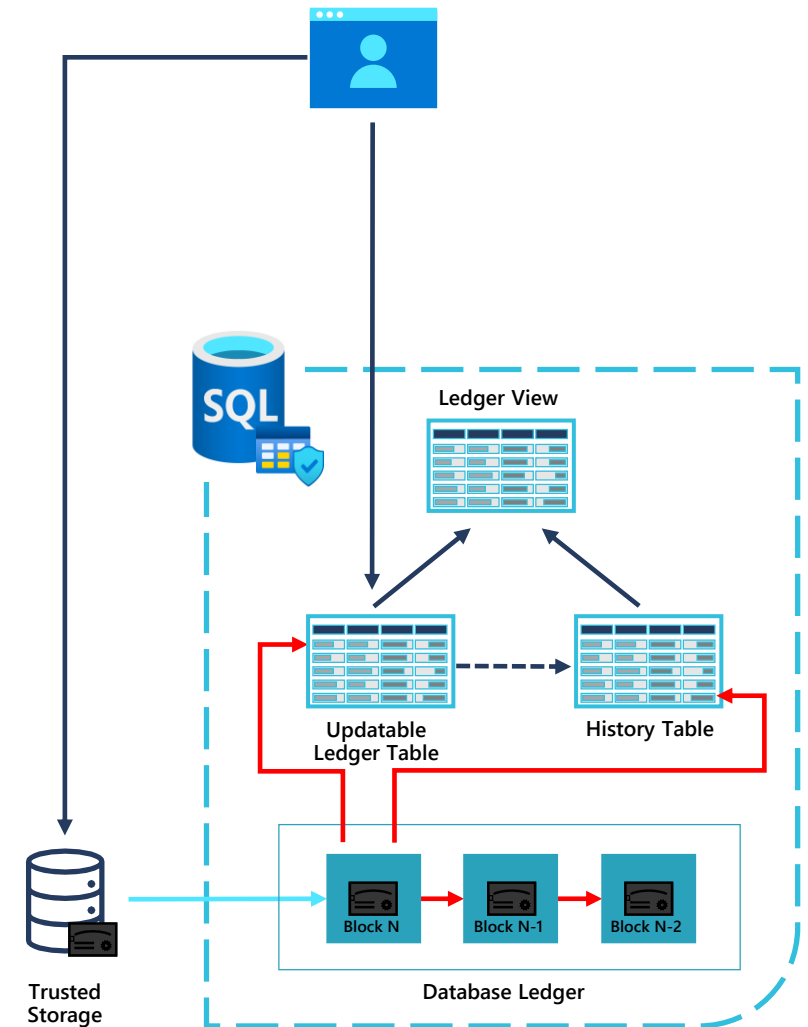
The history of rows that have been updated or deleted are preserved in the history table and easy-to-query Ledger View

Integrity of the updatable and history tables are maintained through cryptographic links from the Database Ledger

System periodically uploads digital receipts to a customer-configured trusted storage service

Customer can use digital receipts to verify the integrity of data in Ledger tables

Append-Only Ledger Tables block UPDATE/DELETE at the API and remove the need for a history table



How to use Ledger for SQL Server

Create a Ledger table

Updateable or
Append Only

Make changes

INSERT, UPDATE/ DELETE
(only updateable)

Save digest

Manual or auto

View ledger history



Verify Ledger



Creating an Account Balance Updatable Ledger Table

```
CREATE SCHEMA [Account];
GO
CREATE TABLE [Account].[Balance]
([CustomerID] INT NOT NULL PRIMARY KEY CLUSTERED,
 [LastName] VARCHAR (50) NOT NULL,
 [FirstName] VARCHAR (50) NOT NULL,
 [Balance] DECIMAL (10,2) NOT NULL)
WITH (SYSTEM_VERSIONING = ON (HISTORY_TABLE = [Account].[BalanceHistory]),
 LEDGER = ON);
```

	ledger_table_name	history_table_name	ledger_view_name
1	Account.Balance	Account.MSSQL_LedgerHistoryFor_1525580473	Account.Balance_Ledger

Viewing the Account Balance Updatable Ledger Table

```
SELECT ts.[name] + '.' + t.[name] AS [ledger_table_name]
, hs.[name] + '.' + h.[name] AS [history_table_name]
, vs.[name] + '.' + v.[name] AS [ledger_view_name]
FROM sys.tables AS t
JOIN sys.tables AS h ON (h.[object_id] = t.[history_table_id])
JOIN sys.views v ON (v.[object_id] = t.[ledger_view_id])
JOIN sys.schemas ts ON (ts.[schema_id] = t.[schema_id])
JOIN sys.schemas hs ON (hs.[schema_id] = h.[schema_id])
JOIN sys.schemas vs ON (vs.[schema_id] = v.[schema_id])
WHERE t.[name] = 'Balance';
```

	ledger_table_name	history_table_name	ledger_view_name
1	Account.Balance	Account.MSSQL_LedgerHistoryFor_1525580473	Account.Balance_Ledger

Add 4 Accounts In 2 Separate Transactions

Tx1: Add Nick with an opening balance of \$50

Tx2: Add John, Joe and Mary

- 1. Each transaction has it's own unique transaction ID
- 2. Tx2 modified 3 rows, each tracked with a ledger sequence number

Updatable ledger table

Results Messages

	CustomerID	LastName	FirstName	Balance	ledger_start_transaction_id	ledger_end_transaction_id	ledger_start_sequence_number	ledger_end_sequence_number
1	1	Jones	Nick	50.00	999	NULL	0	NULL
2	2	Smith	John	500.00	1002	NULL	0	NULL
3	3	Smith	Joe	30.00	1002	NULL	1	NULL
4	4	Michaels	Mary	200.00	1002	NULL	2	NULL

Update Nick's Balance From \$50 To \$100

Applies to: Azure SQL Database, Managed Instance preview

Updatable ledger table – Nick's balance is now \$100

	CustomerID	LastName	FirstName	Balance	ledger_start_transaction_id	ledger_end_transaction_id	ledger_start_sequence_number	ledger_end_sequence_number
1	1	Jones	Nick	100.00	1055	NULL	0	NULL
2	2	Smith	John	500.00	1002	NULL	0	NULL
3	3	Smith	Joe	30.00	1002	NULL	1	NULL
4	4	Michaels	Mary	200.00	1002	NULL	2	NULL

History Table – Shows the historical value of row containing Nick's opening balance

	CustomerID	LastName	FirstName	Balance	ledger_start_transaction_id	ledger_end_transaction_id	ledger_start_sequence_number	ledger_end_sequence_number
1	1	Jones	Nick	50.00	999	1055	0	1

Ledger View – Shows Nick's update as a delete followed but a subsequent insert

	CustomerID	LastName	FirstName	Balance	ledger_transaction_id	ledger_sequence_number	ledger_operation_type_id	ledger_operation_type_desc
1	1	Jones	Nick	50.00	999	0	1	INSERT
2	2	Smith	John	500.00	1002	0	1	INSERT
3	3	Smith	Joe	30.00	1002	1	1	INSERT
4	4	Michaels	Mary	200.00	1002	2	1	INSERT
5	1	Jones	Nick	50.00	1055	1	2	DELETE
6	1	Jones	Nick	100.00	1055	0	1	INSERT

Ledger Views

Applies to: Azure SQL Database, Managed Instance preview

Sys.database_ledger_transactions - Records the table hashes for each transaction in the database as well as the user who issued the transaction

	transaction_id	block_id	transaction_ordinal	commit_time	principal_name	table_hashes
1	999	0	0	2021-03-23 20:18:08.2700000	janders	0xB982EE5A88DFE8EF08BE7564D62273BD17306231C8E22E052644805...
2	1002	0	1	2021-03-23 20:18:12.9300000	janders	0xB982EE5AB931133CF9B8E6FCD06C9AF25C0F0C6A9A91A12C89A84AB...
3	1055	0	2	2021-03-23 20:40:08.9500000	janders	0xB982EE5A38F20FA9D8ABFC3C3523284FE65466DAA9E91166447648B...
4	1091	0	3	2021-03-23 21:36:22.2533333	janders	0x9D13BF5E345245E7456EC748BC895E0E1323379BD04EBC35638D91E...

Sys.database_ledger_blocks – Records the hash of each block created in the database, along with the # of transactions in the block

	block_id	transactions_root_hash	block_size	previous_block_hash
1	0	0x8F3C4C8ADF99EAEE24A783CB1AC282A12E9C9ECA619DDE19B2C98D8ECCA5E4A5	4	NULL

Ledger FAQ

How is this different from a temporal table?

- Built-in transaction auditing
- Append-only
- Database Ledger and digest for tamper evidence

How is this different than SQL Server Audit?

- Transaction history and audit built into database
- Digest verification

Can I disable ledger from a table?

- You cannot ALTER a table to “turn off” ledger
- You cannot turn off system versioning

Can I drop a ledger table?

- Yes, but a history of the dropped table and ledger is kept

Ledger FAQ

How often do I need to save the digest?

- As frequent as you need to ensure the ledger is tamper proof

Does Ledger require more space?

- Updateable requires similar extra space as temporal
- **Plus** database ledger requires some minimal extra space for hashes and blockchain
- Digests small and separate but you may need a long history
- You can't archive or truncate ledger tables and database ledger

Any performance impact?

- Append only should see minimal impact
- Updateable would have similar impact as temporal

Demonstration

Create and Update a Ledger
Table



