Detect and Prevent Unexpected Growth of TempDB - SQL Server

https://www.spotlightcloud.io/blog/how-to-detect-and-prevent-unexpected-growth-of-sql-server-database-tempdb

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Each SQL Server instance contains the system SQL Server database called TempDB. It is typical for all database connections, and almost every query makes usage of the TempDB database. It is like a heart for the SQL Server instance. Practically, we cannot work without the TempDB database.

Let us have a quick summary of operations in which SQL Server uses TempDB.

- Order by and Group by clause
- Index creation and online index rebuild
- Temp tables and table variables storage is in the TempDB database.
- Snapshot isolation and read committed snapshot isolation
- DBCC commands
- Hash joins static cursors, long-running transactions.
- XML queries
- Internal objects created by the SQL Server database engine.
- **Version stores**
- Multiple active record sets (MARS)

You can read more about TempDB in this article.

Few important points about TempDB

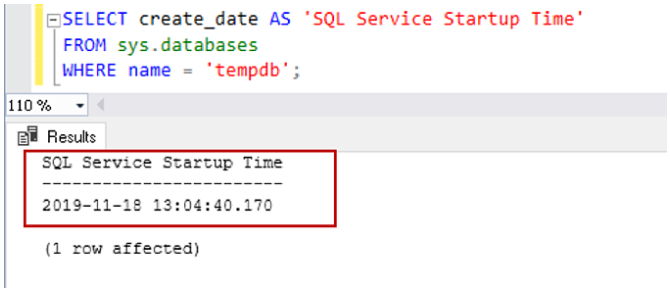
- TempDB is a global resource (available for all connected user) system database
- SQL Server recreates the TempDB database each time SQL Service restarts. During restart, it takes a copy of MDF and LDF from the model database. The size and number of MDF and LDF files reset to preconfigured size
- SQL Server does not perform recovery on the TempDB, and previous data is lost
- TempDB database is always in the Simple recovery model, and we cannot take database backup for it
- We cannot roll back transactions in the TempDB because it minimally logs the transactions

TempDB Usage Summary

- Usually, we create local temporary tables (# naming conventions) and global temporary tables (## naming conventions) to prepare intermediate tables. SQL Server creates those temporary tables in the TempDB database
- We can create or rebuild an index in TempDB using the SORT_IN_TEMPDB= ON clause. SQL Server performs all sorting calculations in the TempDB instead of the database on which the object belongs
- SQL Server uses the TempDB for the Read COMMITTED SNAPSHOT isolation level. SQL Server uses the row versioning for each record. The old version also gets an additional 14 bytes in the TempDB to track the row versioning
- Internal objects such as Cursor work tables, Spool operations, Intermediate sorts operations such as GROUP BY, ORDER BY, UNION, DBCC CHECKDB, Temporary large object storage, Service broker event notification
- In the Multiple Active Result Sets (using MultipleActiveResultSets=True), SQL Server uses the versioning and stores that in the TempDB

SQL Server recreates this TempDB database on database engine Service restart. This restart can be due to the automatic or manual restart of SQL Service. We can query sys.databases for viewing the TempDB creation date that is also a start-up time of database service:

```
SELECT create_date AS 'SQL Service Startup Time'
FROM sys.databases
WHERE name = 'tempdb';
```



TempDB SQL Server database configurations and best practices

Sometimes, we notice unexpected growth of the TempDB database. The first step of avoiding this is to configure it as per the best practices. In this section, let's view the TempDB configuration is different versions of SQL Server.

Configure TempDB for multiple DATA Files with even growth

As per best practice, we should have multiple data files with even growth of all files. The number of files depends upon the logical processors.

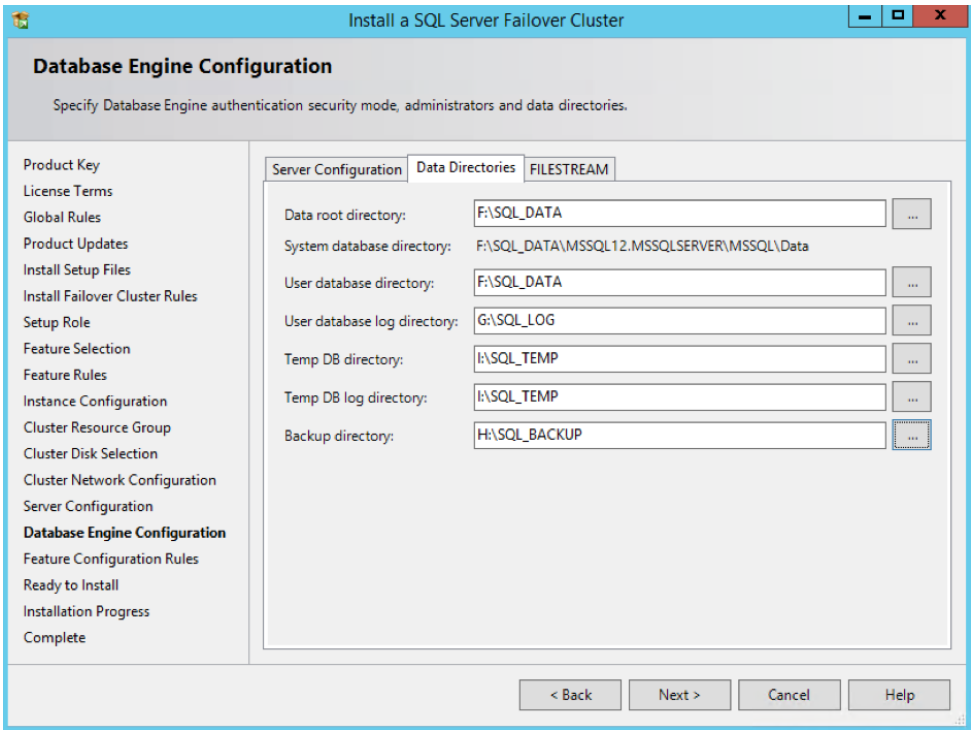
Processors	**Number of TempDB data files**
Logical processors less than or equals to eight	Eight
Logical processors greater than eight	Start with eight data files. Increase the data files in multiple of four and monitor the performance counters for TempDB contention.

For SQL Server versions before 2016, we do not have configuration available during the installation process.

By default, it creates only one data and log file with the following configurations:

TempDB Primary file	Auto grow data file by ten percent (until the disk is full)
TempDB log file	Auto grow data file by ten percent (until the disk is full or maximum log file size reaches to 2 TB)

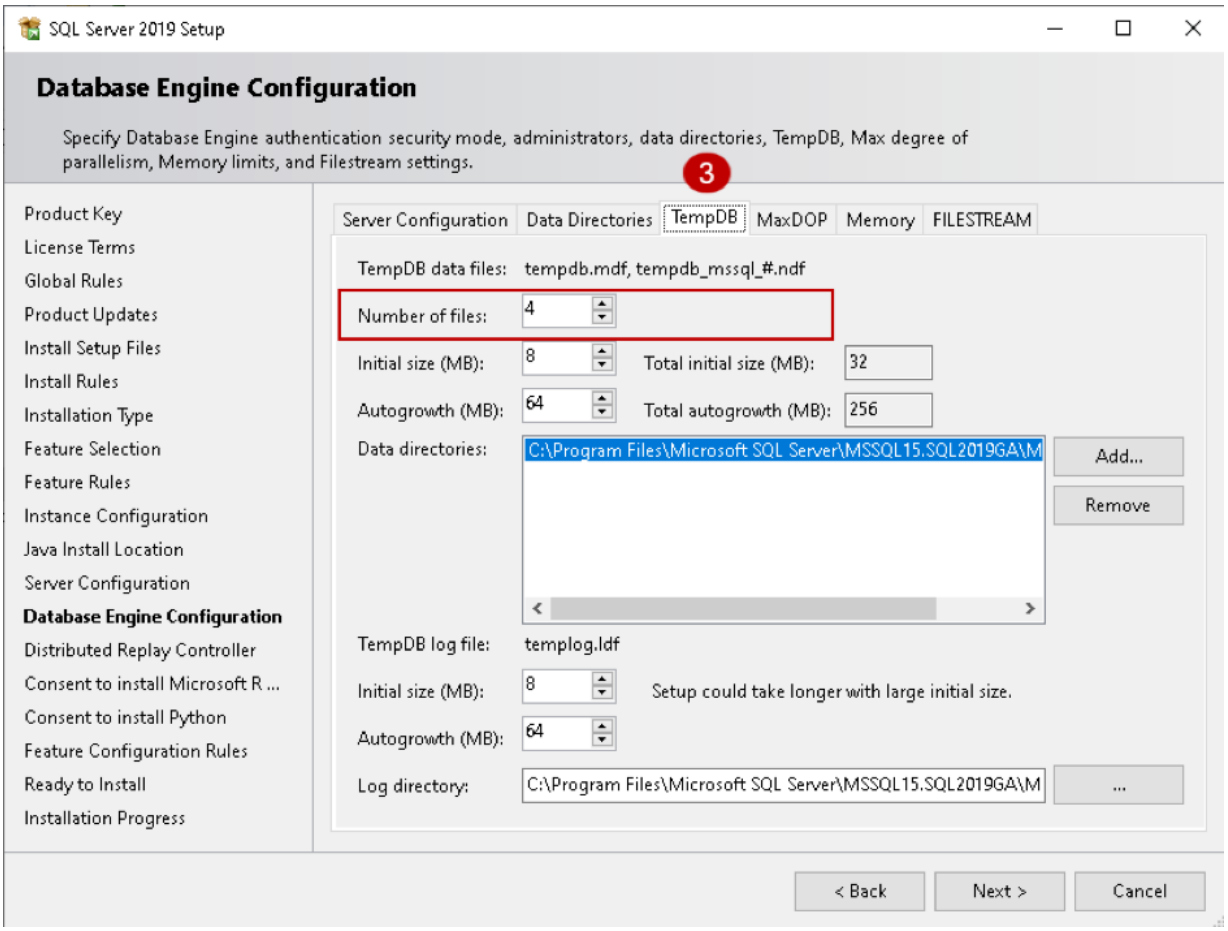
SQL Server 2014 TempDB SQL Server database configuration



SQL Server 2016 provides enhancements for TempDB configuration during the installation process as per the best practice:

TempDB Primary and secondary files	Auto grow by 64 MB (until the disk is full)
TempDB log file	Auto grow by 64 MB (until the disk is full or maximum log file size reaches to 2 TB)

SQL Server 2016 onwards TempDB configuration



Uneven auto-growth SQL Server database TempDB

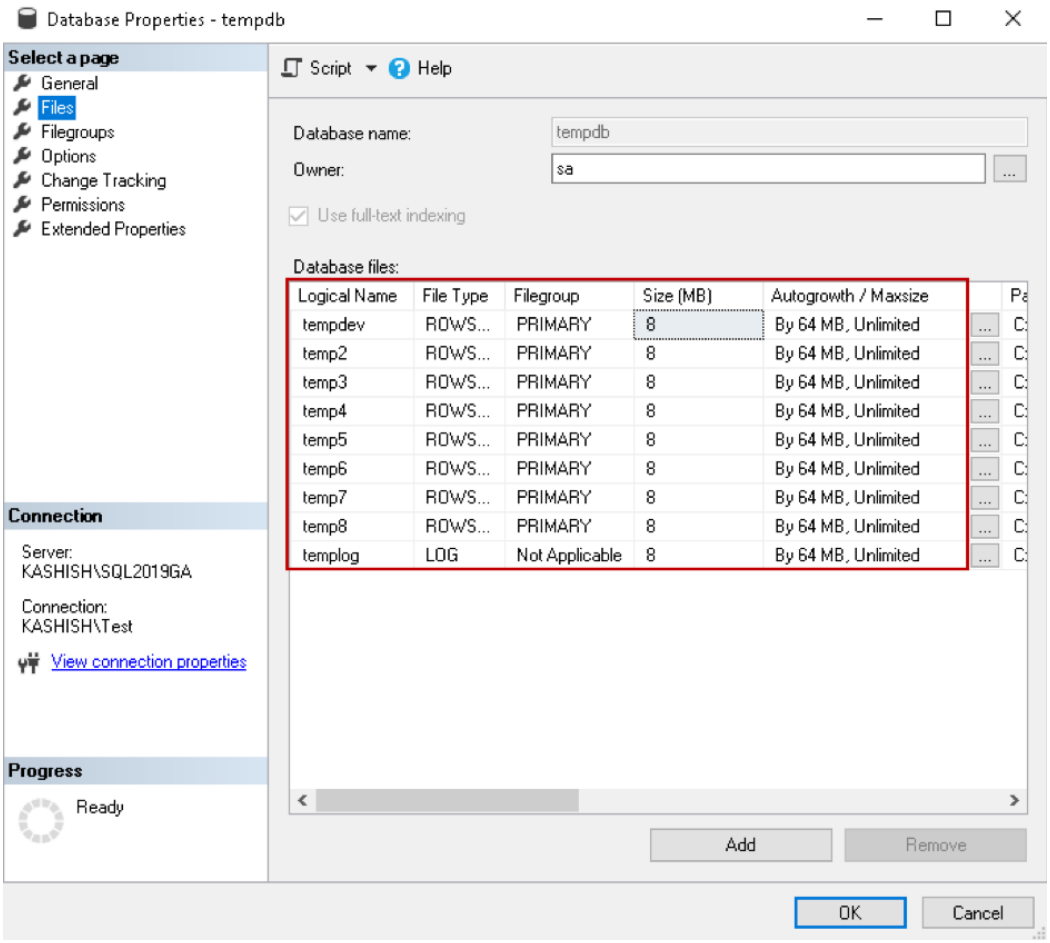
SQL Server uses a round-robin method to fill multiple data files if they do not have the same size. Sometimes, we see that one file grows huge, but other files remain minimum growth. In case of uneven files, SQL Server uses the larger file for most of the queries, and it would continue growing:

1. Use the same auto-growth of TempDB files (as discussed in the previous point).
2. Enable trace flag 1117 for growing all data files together in a database.

The second point is fixed automatically in SQL Server 2016 onwards however you should enable it in earlier versions. We do not require this trace flag in SQL Server 2016 and higher.

TempDB growth scenarios

In this section, we will see a few scenarios for SQL Server database TempDB growth. In my SQL instance, I have eight data files with the following configuration:



Now, execute the following query to create a temporary table and perform data insertion. The temporary table storage location is the TempDB database. This query uses a CROSS JOIN operator with multiple columns and further sorts the results using the ORDER BY clause.

Note: Do not run this query in the production system; I am using it for demo purpose only.

```
SELECT *
FROM sys.configurations
CROSS JOIN sys.configurations SCA
CROSS JOIN sys.configurations SCB
CROSS JOIN sys.configurations SCC
CROSS JOIN sys.configurations SCD
CROSS JOIN sys.configurations SCE
CROSS JOIN sys.configurations SCF
CROSS JOIN sys.configurations SCG
CROSS JOIN sys.configurations SCH
ORDER BY SCA.name,
SCA.value,
SCC.value_in_use DESC;
```

This query will take a long time and might result in high CPU usage as well in your system. While the query is running, open another query window and use the DMV **sys.dm_db_task_space_usage to get information of** page allocation and deallocation activity by the task. We join this DMV with other DMV's to get the required information for the SQL Server database TempDB:

```
SELECT s.session_id, dbu.database_id
, dbu.internal_objects_alloc_page_count, dbu.internal_objects_dealloc_page_count
, (dbu.internal_objects_alloc_page_count - dbu.internal_objects_dealloc_page_count) * 8192 / 1024 kbytes_used_internal
, r.total_elapsed_time
FROM sys.dm_Exec_requests r
INNER JOIN sys.dm_exec_sessions s ON r.session_id = s.session_id
LEFT JOIN sys.dm_db_task_space_usage dbu ON dbu.session_id = r.session_id
AND dbu.request_id = r.request_id
WHERE internal_objects_alloc_page_count > 0
ORDER BY kbytes_used_internal DESC;
```

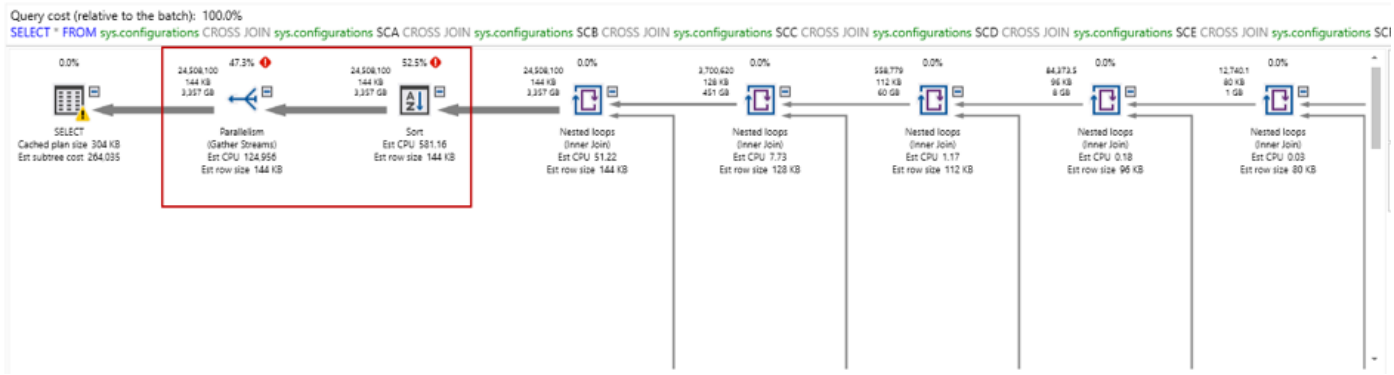
In the output, we see internal object page counts and their sizes (kbytes_used_internal) for the session ID 55.

SQL Server query optimizer executing this query in a parallel model; therefore, we can see multiple session ID 71 in the output:

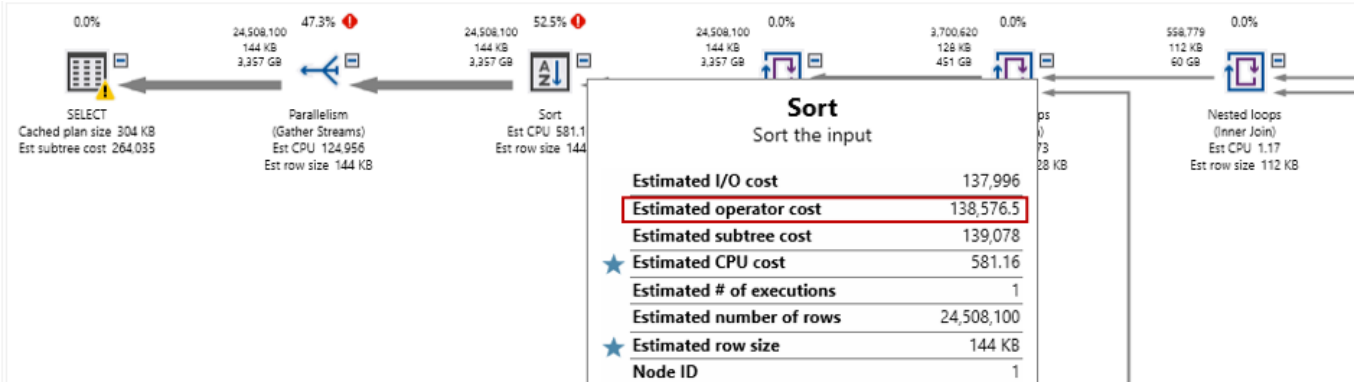
	session_id	database_id	internal_objects_alloc_page_count	internal_objects_dealloc_page_count	kbytes_used_internal	total_elapsed_time
1	71	2	296680	0	2373440	568914
2	71	2	295920	0	2367360	568914
3	71	2	294104	0	2352832	568914
4	71	2	293344	0	2346752	568914

You can also view the estimated execution plan, and as shown below, we get two costly operators:

- Parallelism: 47.3%
- Sort: 52.3%



In the sort operator, we can see high estimated operator cost 138,576.5:



The following query uses DMV **sys.dm_db_file_space_usage** and joins it with sys.master_files to check the allocated and unallocated extent page counts in the SQL Server database TempDB while the query is executing:

```
select mf.physical_name, mf.size as entire_file_page_count,
dfsu.unallocated_extent_page_count,
dfsu.user_object_reserved_page_count,
dfsu.internal_object_reserved_page_count,
dfsu.mixed_extent_page_count
from sys.dm_db_file_space_usage dfsu
join sys.master_files as mf
on mf.database_id = dfsu.database_id
and mf.file_id = dfsu.file_id
```

	physical_name	entire_file_page_count	unallocated_extent_page_count	user_object_reserved_page_count	internal_object_reserved_page_count	mixed_extent_page
1	C:\Program Files\Microsoft SQL Server\MSSQL15.SQL2019GA\MSSQL\DATA\tempdb.mdf	1024	57728	168	155912	208
2	C:\Program Files\Microsoft SQL Server\MSSQL15.SQL2019GA\MSSQL\DATA\tempdb_mssql_2.ndf	1024	57184	8	148608	24
3	C:\Program Files\Microsoft SQL Server\MSSQL15.SQL2019GA\MSSQL\DATA\tempdb_mssql_3.ndf	1024	57176	16	148600	32
4	C:\Program Files\Microsoft SQL Server\MSSQL15.SQL2019GA\MSSQL\DATA\tempdb_mssql_4.ndf	1024	57632	16	148168	8
5	C:\Program Files\Microsoft SQL Server\MSSQL15.SQL2019GA\MSSQL\DATA\temp5.ndf	1024	57712	0	148104	8
6	C:\Program Files\Microsoft SQL Server\MSSQL15.SQL2019GA\MSSQL\DATA\temp6.ndf	1024	56928	0	148888	8
7	C:\Program Files\Microsoft SQL Server\MSSQL15.SQL2019GA\MSSQL\DATA\temp7.ndf	1024	109232	0	104776	8
8	C:\Program Files\Microsoft SQL Server\MSSQL15.SQL2019GA\MSSQL\DATA\temp8.ndf	1024	92296	0	121712	8

We can monitor the query execution, its usage in the TempDB database and if required, kill the process to release the space immediately. We should also optimize the query causing massive TempDB growth.

Monitor SQL Server database TempDB usage using extended events

Extended events are useful for TempDB database monitoring. We can add the following extended events using the query:

- database_file_size_change
- databases_log_file_used_size_changed

Create extended event

```
CREATE EVENT SESSION [TempDB Usage] ON SERVER
ADD EVENT sqlserver.database_file_size_change(
```

```
ACTION(sqlserver.client_hostname,sqlserver.database_id,sqlserver.session_id,sqlserver.sql_text)),
ADD EVENT sqlserver.databases_log_file_used_size_changed(
```

```
ACTION(sqlserver.client_hostname,sqlserver.database_id,sqlserver.session_id,sqlserver.sql_text))
ADD TARGET package0.event_file(SET filename=N'TempDBUsage',max_rollover_files=(0))
WITH (STARTUP_STATE=OFF)
GO
```

Start extended event session

```
ALTER EVENT SESSION [TempDBTest] ON SERVER STATE = START;
```

Now, execute your workload to use the TempDB database and grow the data files. The extended events capture data file growth and query that caused this growth.

You can either view the extended event session file in SSMS GUI mode or use the following query to monitor TempDB growth.

Monitor TempDB Growth

```
SELECT [eventdata].[event_data].[value]('(event/action[@name="session_id"]/value)[1]', 'INT') AS [SessionID],
[eventdata].[event_data].[value]('(event/action[@name="client_hostname"]/value)[1]', 'VARCHAR(100)') AS [ClientHostName],
DB_NAME([eventdata].[event_data].[value]('(event/action[@name="database_id"]/value)[1]', 'BIGINT')) AS [GrowthDB],
[eventdata].[event_data].[value]('(event/data[@name="file_name"]/value)[1]', 'VARCHAR(200)') AS [GrowthFile],
[eventdata].[event_data].[value]('(event/data[@name="file_type"]/text)[1]', 'VARCHAR(200)') AS [DBFileType],
[eventdata].[event_data].[value]('(event/@name)[1]', 'VARCHAR(MAX)') AS [EventName],
[eventdata].[event_data].[value]('(event/data[@name="size_change_kb"]/value)[1]', 'BIGINT') AS [SizeChangedKb],
[eventdata].[event_data].[value]('(event/data[@name="total_size_kb"]/value)[1]', 'BIGINT') AS [TotalSizeKb],
[eventdata].[event_data].[value]('(event/data[@name="duration"]/value)[1]', 'BIGINT') AS [DurationInMS],
[eventdata].[event_data].[value]('(event/@timestamp)[1]', 'VARCHAR(MAX)') AS [GrowthTime],
[eventdata].[event_data].[value]('(event/action[@name="sql_text"]/value)[1]', 'VARCHAR(MAX)') AS [QueryText]
FROM
(
SELECT CAST([event_data] AS XML) AS [TargetData]
FROM [sys].[fn_xe_file_target_read_file]('C:\TEMP\TempDBusage*.xel', NULL, NULL, NULL)
) AS [eventdata]([event_data])
WHERE [eventdata].[event_data].[value]('(event/@name)[1]', 'VARCHAR(100)') = 'database_file_size_change'
OR [eventdata].[event_data].[value]('(event/@name)[1]', 'VARCHAR(100)') = 'databases_log_file_used_size_changed'
AND [eventdata].[event_data].[value]('(event/@name)[1]', 'VARCHAR(MAX)') <> 'databases_log_file_used_size_changed'
ORDER BY [GrowthTime] ASC;
```

	SessionID	ClientHostName	GrowthDB	GrowthFile	DBFileType	EventName	SizeChangedKb	TotalSizeKb	DurationInMS	GrowthTime	QueryText	
1	75	KASHISH	tempdb	temp4	Data file	database_file_size_change	65536	73728	2858000	2019-11-18T15:38:50.250Z	SELECT * FROM sys.configurations	CROSS JOIN...
2	75	KASHISH	tempdb	temp3	Data file	database_file_size_change	65536	73728	0	2019-11-18T15:38:50.251Z	SELECT * FROM sys.configurations	CROSS JOIN...
3	75	KASHISH	tempdb	temp2	Data file	database_file_size_change	65536	73728	0	2019-11-18T15:38:50.252Z	SELECT * FROM sys.configurations	CROSS JOIN...
4	75	KASHISH	tempdb	tempdev	Data file	database_file_size_change	65536	73728	0	2019-11-18T15:38:50.254Z	SELECT * FROM sys.configurations	CROSS JOIN...
5	75	KASHISH	tempdb	temp8	Data file	database_file_size_change	65536	73728	0	2019-11-18T15:38:50.255Z	SELECT * FROM sys.configurations	CROSS JOIN...
6	75	KASHISH	tempdb	temp7	Data file	database_file_size_change	65536	73728	0	2019-11-18T15:38:50.256Z	SELECT * FROM sys.configurations	CROSS JOIN...
7	75	KASHISH	tempdb	temp6	Data file	database_file_size_change	65536	73728	0	2019-11-18T15:38:50.257Z	SELECT * FROM sys.configurations	CROSS JOIN...
8	75	KASHISH	tempdb	temp5	Data file	database_file_size_change	65536	73728	0	2019-11-18T15:38:50.258Z	SELECT * FROM sys.configurations	CROSS JOIN...
9	75	KASHISH	tempdb	temp4	Data file	database_file_size_change	65536	139264	3548000	2019-11-18T15:39:23.485Z	SELECT * FROM sys.configurations	CROSS JOIN...
10	75	KASHISH	tempdb	temp3	Data file	database_file_size_change	65536	139264	190000	2019-11-18T15:39:23.675Z	SELECT * FROM sys.configurations	CROSS JOIN...
11	75	KASHISH	tempdb	temp2	Data file	database_file_size_change	65536	139264	0	2019-11-18T15:39:23.677Z	SELECT * FROM sys.configurations	CROSS JOIN...
12	75	KASHISH	tempdb	tempdev	Data file	database_file_size_change	65536	139264	0	2019-11-18T15:39:23.678Z	SELECT * FROM sys.configurations	CROSS JOIN...
13	75	KASHISH	tempdb	temp8	Data file	database_file_size_change	65536	139264	0	2019-11-18T15:39:23.680Z	SELECT * FROM sys.configurations	CROSS JOIN...
14	75	KASHISH	tempdb	temp7	Data file	database_file_size_change	65536	139264	0	2019-11-18T15:39:23.681Z	SELECT * FROM sys.configurations	CROSS JOIN...
15	75	KASHISH	tempdb	temp6	Data file	database_file_size_change	65536	139264	0	2019-11-18T15:39:23.682Z	SELECT * FROM sys.configurations	CROSS JOIN...
16	75	KASHISH	tempdb	temp5	Data file	database_file_size_change	65536	139264	0	2019-11-18T15:39:23.683Z	SELECT * FROM sys.configurations	CROSS JOIN...

Snapshot Isolation

You might use snapshot isolation for your queries. In this isolation model, SQL Server stores the updated row versions of each transaction in the TempDB. In case of a large or long-running transaction, you can see a huge TempDB database.

You can execute the transaction with the SET command and specify Snapshot isolation:

```
SET TRANSACTION ISOLATION LEVEL SNAPSHOT;
BEGIN TRAN;
UPDATE [AdventureWorks].[Person].[Person]
SET
[Title] = 'Mr.';
COMMIT TRAN;
```

You can also query **sys.databases** system view to check if any user database has snapshot isolation.

Query to enable snapshot isolation on AdventureWorks database

```
ALTER DATABASE AdventureWorks
SET ALLOW_SNAPSHOT_ISOLATION ON
GO
```

Query to check user database with snapshot isolation

```
SELECT *
FROM sys.databases
WHERE(snapshot_isolation_state = 1
OR is_read_committed_snapshot_on = 1)
AND database_id > 4;
```

In the following screenshot, you can see that the AdventureWorks database has snapshot isolation.

TempDB database also has snapshot isolation, but in the query, we have skipped database_id less than 4:

	name	database_id	source_database_id	owner_sid	create_date	compatibility_level	collation_name	user_access	user_access_desc
1	AdventureWorks	5	NULL	0x0105000000000005150000000FB430E0AADBF02070425D3...	2019-11-11 08:59:52.387	150	SQL_Latin1_General_CP1_CI_AS	0	MULTI_USER

We can use DMV sys.dm_db_file_space_usage to monitor version store in the TempDB:

```
SELECT GETDATE() AS runtime,
SUM(user_object_reserved_page_count) * 8 AS usr_obj_kb,
SUM(internal_object_reserved_page_count) * 8 AS internal_obj_kb,
SUM(version_store_reserved_page_count) * 8 AS version_store_kb,
SUM(unallocated_extent_page_count) * 8 AS freespace_kb,
SUM(mixed_extent_page_count) * 8 AS mixedextent_kb
FROM sys.dm_db_file_space_usage;
```

Here, we can see Version store size is 67968 KB. For a large or long-running transaction, you can see a huge SQL Server database TempDB size due to this version store:

	runtime	usr_obj_kb	internal_obj_kb	version_store_kb	freespace_kb	mixedextent_kb
1	2019-11-19 14:23:22.113	1600	64	67968	517632	2560

Another case that might cause a huge size of the version store is Always on read-only Secondary replica. If you execute any query on the secondary database, it automatically uses the snapshot isolation level. As you know, snapshot isolation level copies row version in the TempDB.

You should monitor the following perfmon counters:

- **SQLServer:Transactions\Longest Transaction Running Time –** It captures the most extended active transaction.
- **SQLServer:Transactions\Version Store Size (KB)** – It captures the current size of all the version stores in TempDB.
- **SQLServer:Transactions\Version Cleanup rate (KB/s**) – You can use this counter to show the rate of version cleanup in TempDB
- **SQLServer:Transactions\Version Generation rate (KB/s)** – You can capture version store capture rate using this counter.

You should monitor TempDB growth for the versioning in Always on the secondary database as well. Kill the long-running sessions so that it can clear the versioning and reclaim space in the TempDB database.

Conclusion

In this article, we learned about the SQL Server database TempDB database best practice and different methods to detect, prevent unexpected growth. You should monitor TempDB regularly and configure different alerts to be proactive.

- TempDB size monitoring
- Drive space monitoring
- Long-running transactions