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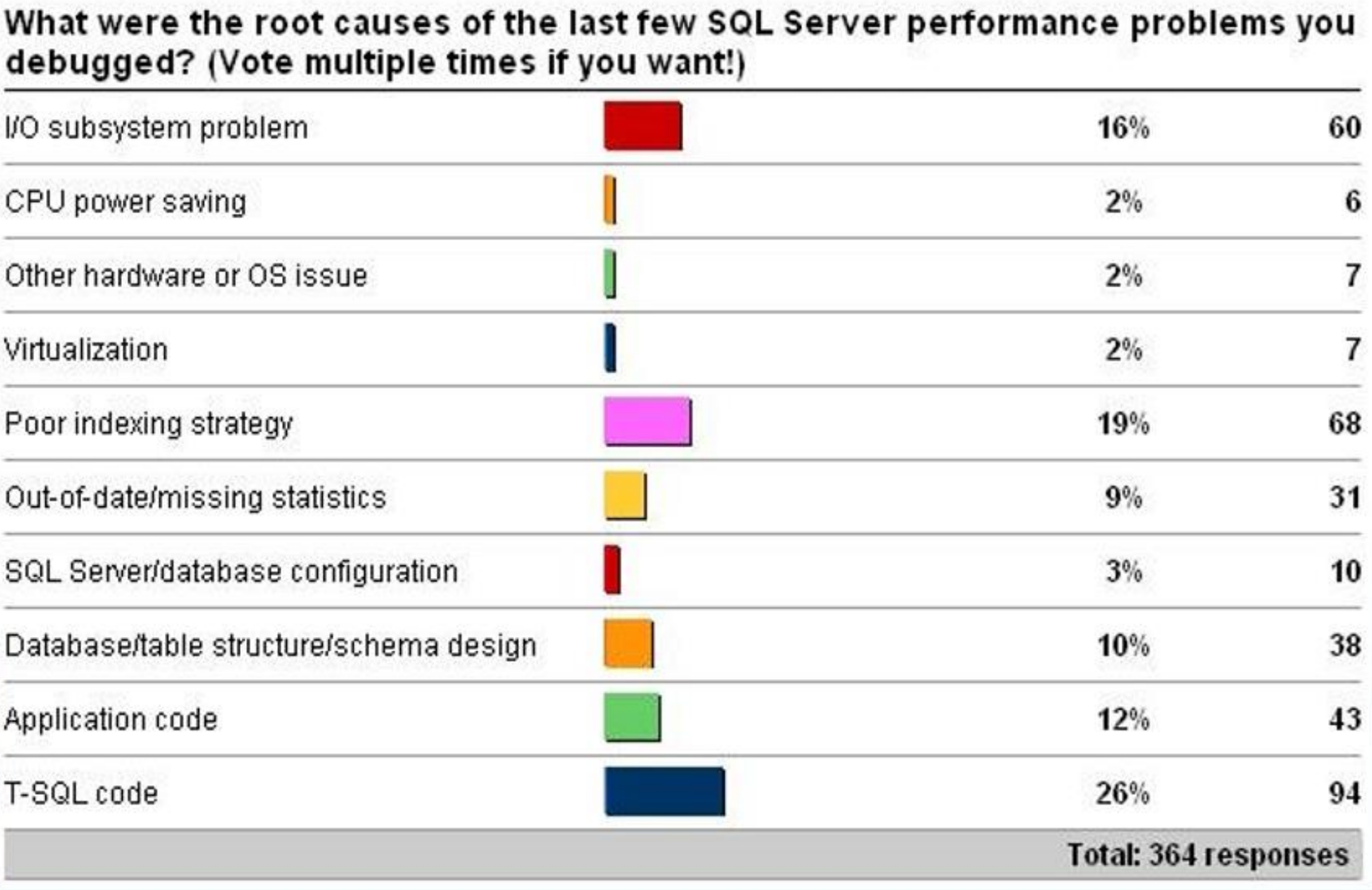
Common Cause of Performance Problems

http://www.sqlskills.com/blogs/paul/survey-results-common-causes-of-performance-problems/

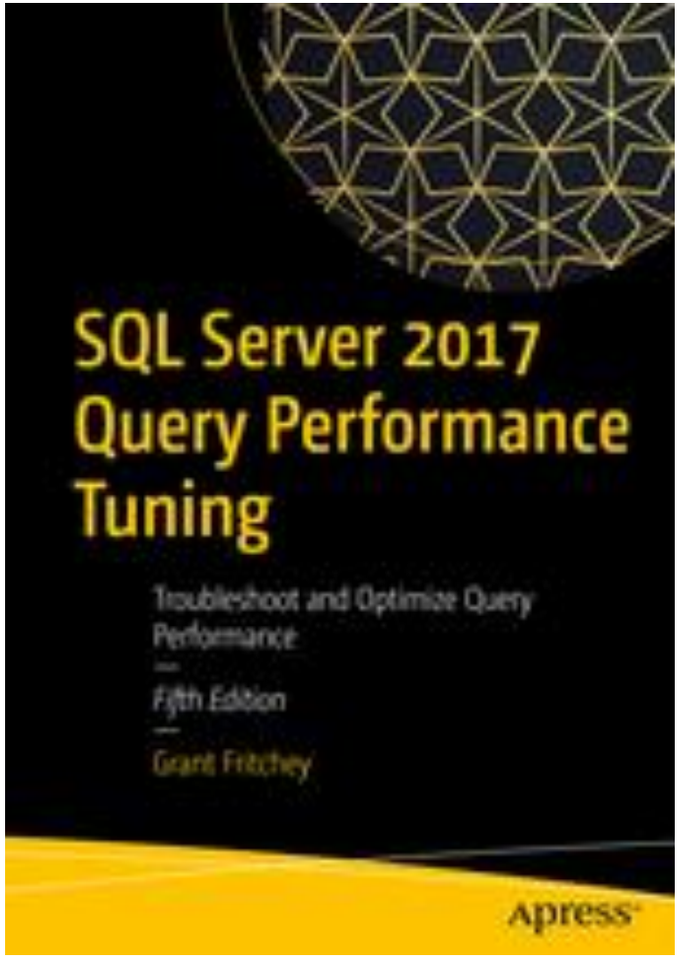
What were the root causes of the last few SQL Server performance problems you debugged? (Vote multiple times if you want!)



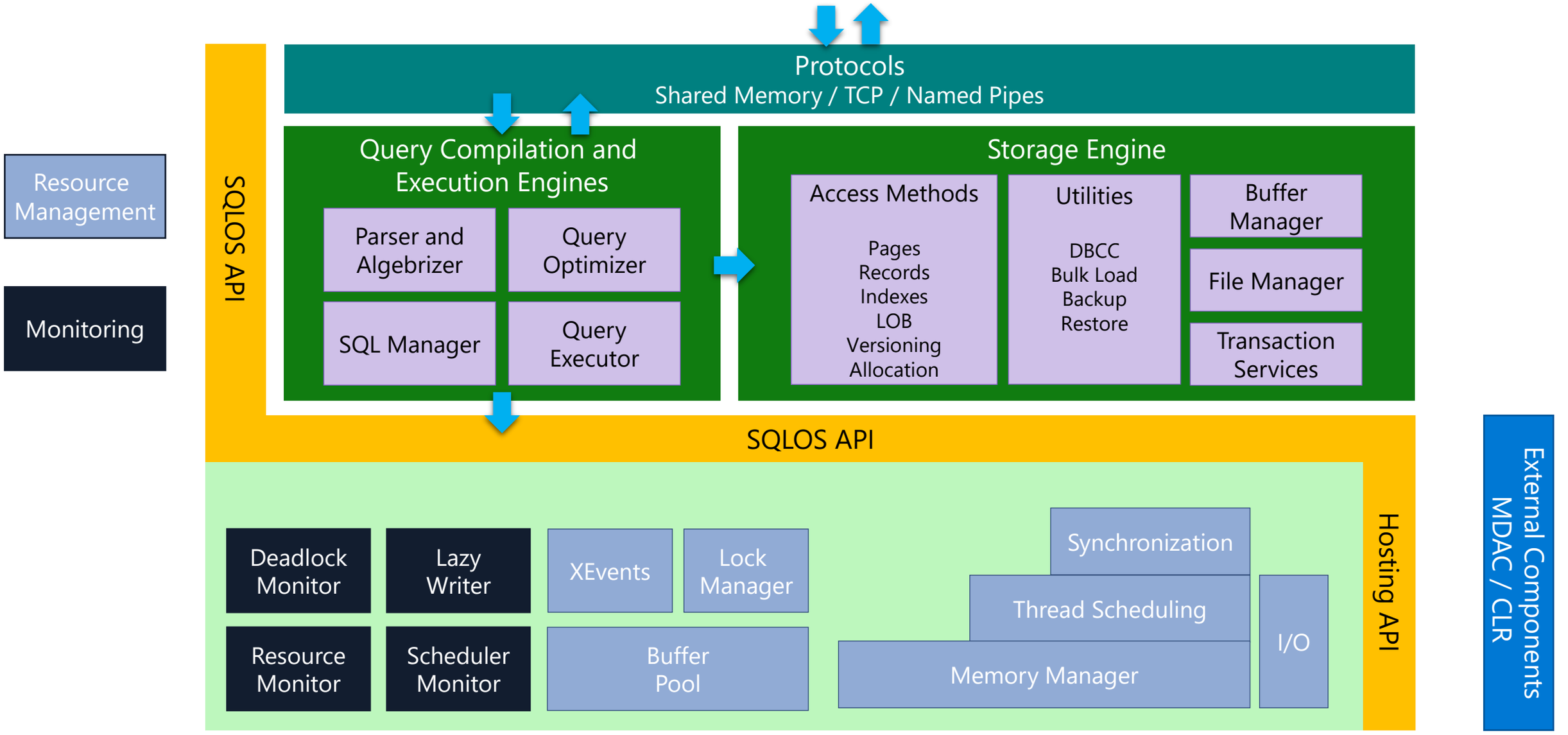
I/O subsystem problem	16%	60
CPU power saving	2%	6
Other hardware or OS issue	2%	7
Virtualization	2%	7
Poor indexing strategy	19%	68
Out-of-date/missing statistics	9%	31
SQL Server/database configuration	3%	10
Database/table structure/schema design	10%	38
Application code	12%	43
T-SQL code	26%	94
	Total: 364 responses	

SQL Server Performance Killers

Poor Indexing
Inaccurate Statistics
Poor Query Design
Poor Execution Plans
Excessive blocking and deadlocks
Non set-based operations
Poor database design
Excessive fragmentation
Non-reusable execution plans
Frequent recompilation of queries
Improper use of cursors
Improper configuration of database log
Excessive use or improper configuration of tempdb



SQL Server Operating System (SQLOS)



■ Threads, SQLOS actually does not know what these are

Two Main Functions of SQLOS

Management

- Memory Manager
- Process Scheduler
- Synchronization
- I/O
- Support for Non-Uniform Memory Access (NUMA) and Resource Governor

Monitoring

- Resource Monitor
- Deadlock Monitor
- Scheduler Monitor
- Lazy Writer (Buffer Pool management)
- Dynamic Management Views (DMVs)
- Extended Events
- Dedicated Administrator Connection (DAC)

Dynamic Management Views and Functions

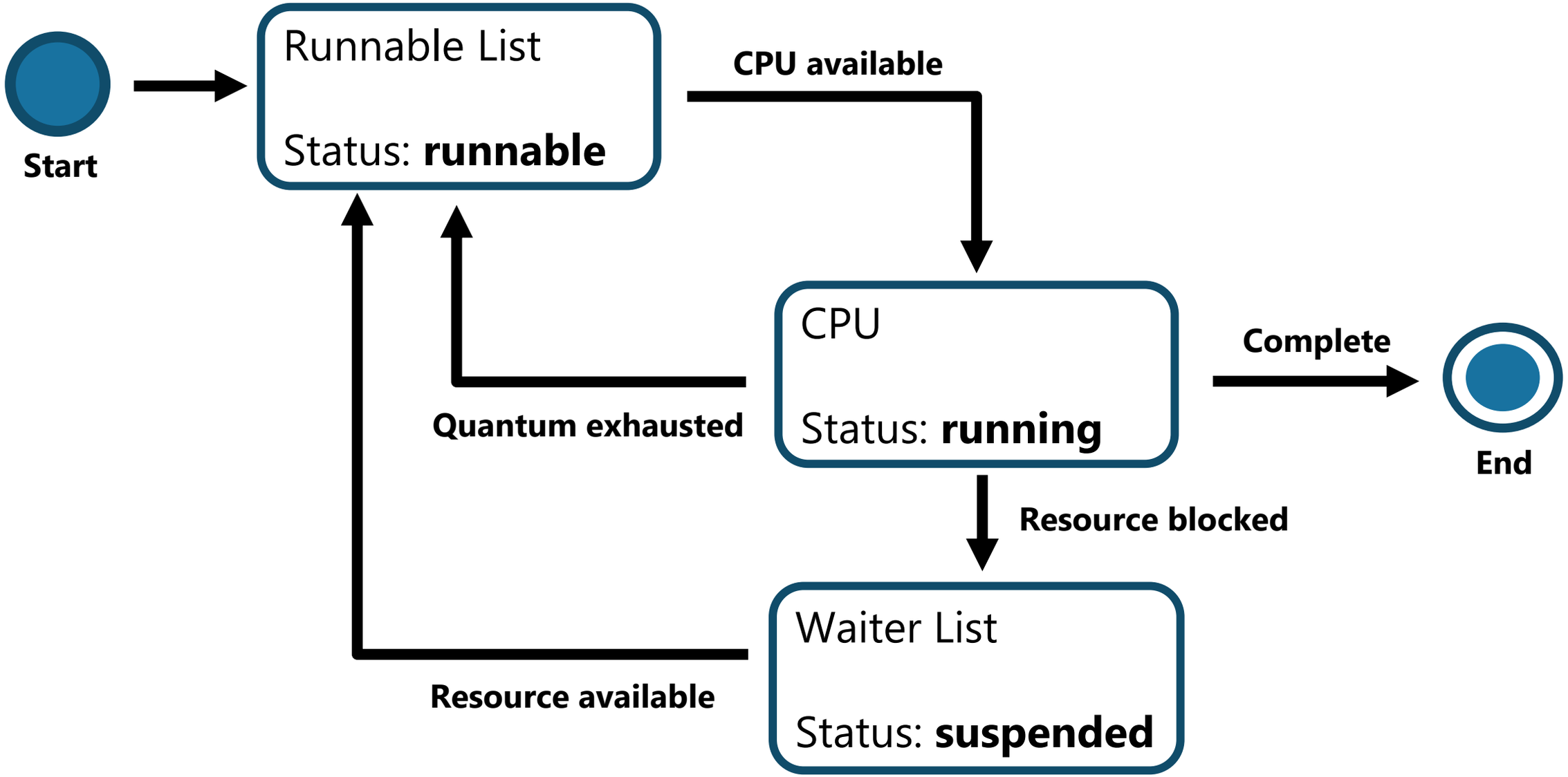
Category	Description
sys.dm_exec_%	Execution and connection information
sys.dm_os_%	Operating system related information
sys.dm_tran_%	Transaction management information
sys.dm_io_%	I/O related information
sys.dm_db_%	Database information

Using Dynamic Management Objects (DMOs)

- Must reference using the sys schema
- Two basic types:
  - Real-time state information
  - Historical information

```
SELECT cpu_count, hyperthread_ratio,
    scheduler_count, scheduler_total_count,
    affinity_type, affinity_type_desc,
    softnuma_configuration, softnuma_configuration_desc,
    socket_count, cores_per_socket, numa_node_count,
    sql_memory_model, sql_memory_model_desc
FROM sys.dm_os_sys_info
```

Yielding


Start
Runnable List
Status: runnable
CPU available
CPU
Status: running
Quantum exhausted
Complete
End
Resource blocked
Waiter List
Status: suspended
Resource available

Thread States and Queues

Runnable: The thread is currently in the Runnable Queue waiting to execute. (First In, First Out).

Running: One active thread executing on a processor.

Suspended: Placed on a Waiter List waiting for a resource other than a processor. (No specific order).

Waiting Tasks DMV

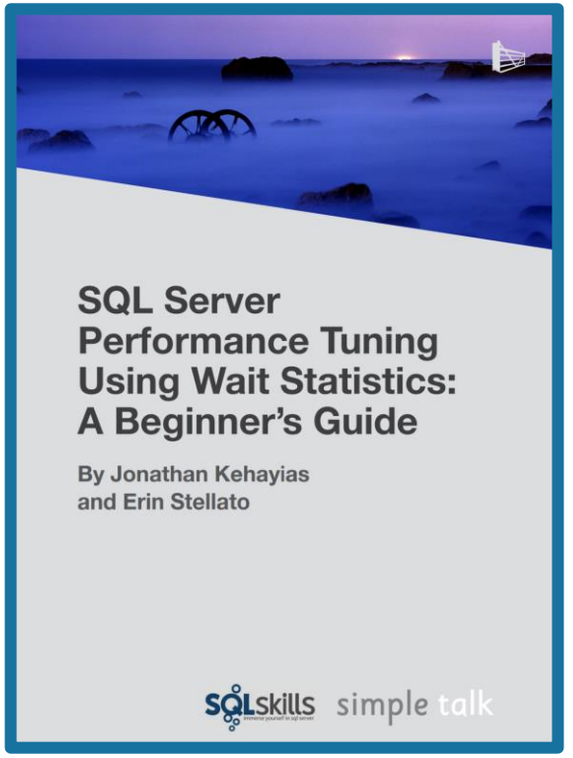
```
SELECT w.session_id, w.wait_duration_ms, w.wait_type,
       w.blocking_session_id, w.resource_description,
       s.program_name, t.text, t.dbid, s.cpu_time, s.memory_usage
 FROM sys.dm_os_waiting_tasks as w
      INNER JOIN sys.dm_exec_sessions as s
         ON w.session_id = s.session_id
      INNER JOIN sys.dm_exec_requests as r
         ON s.session_id = r.session_id
      OUTER APPLY sys.dm_exec_sql_text (r.sql_handle) as t
  WHERE s.is_user_process = 1;
```

session_id	wait_duration_ms	wait_type	blocking_session_id	resource_description
58	8563	LCK_M_S	62	keylock hobtid=72057594047365120 dbid=5 id=lock1...

Troubleshooting Wait Types

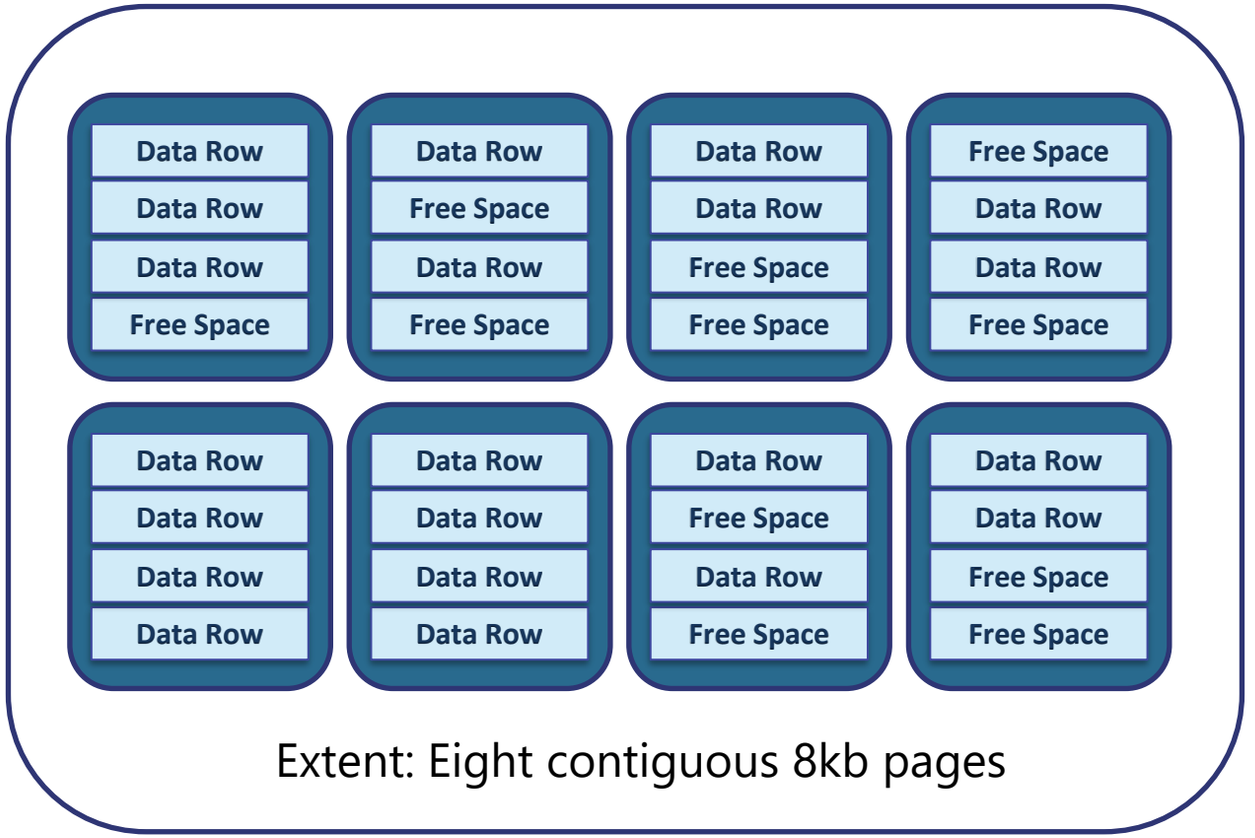
Aaron Bertrand – Top Wait Types
https://sqlperformance.com/2018/10/sql-performance/top-wait-stats

Paul Randal – SQL Skills Wait Types Library
https://www.sqlskills.com/help/waits/



SQL Server Object Allocation

Primary Data File (.mdf)
Secondary Data File (.ndf)

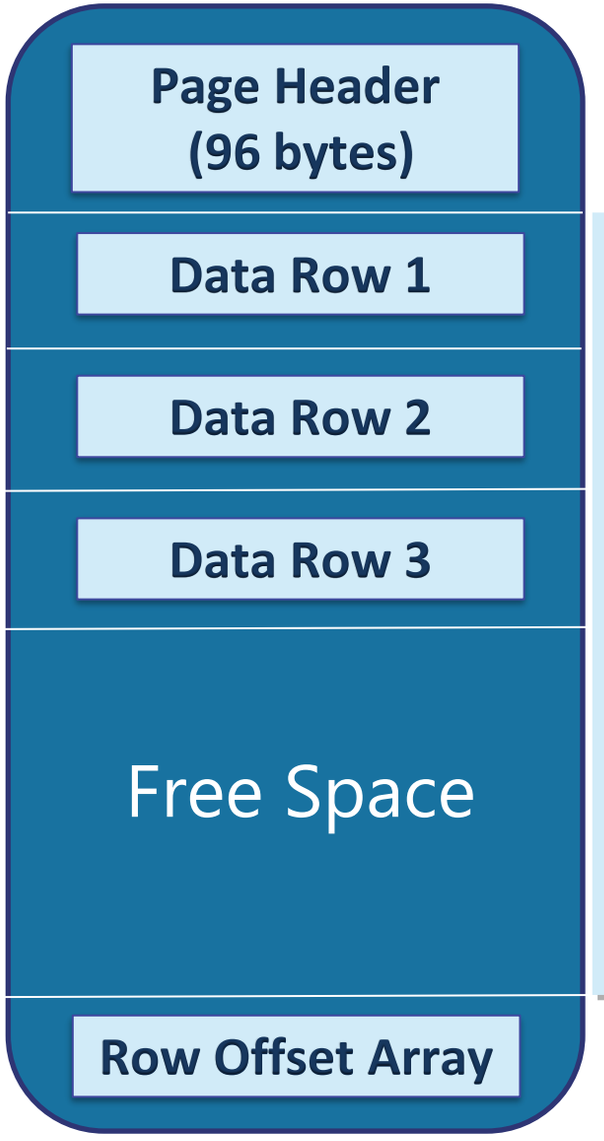


Extent: Eight contiguous 8kb pages

Uniform extents: Pages used by a single object.

Mixed extents: Pages used by different objects.

Basic Page Structure



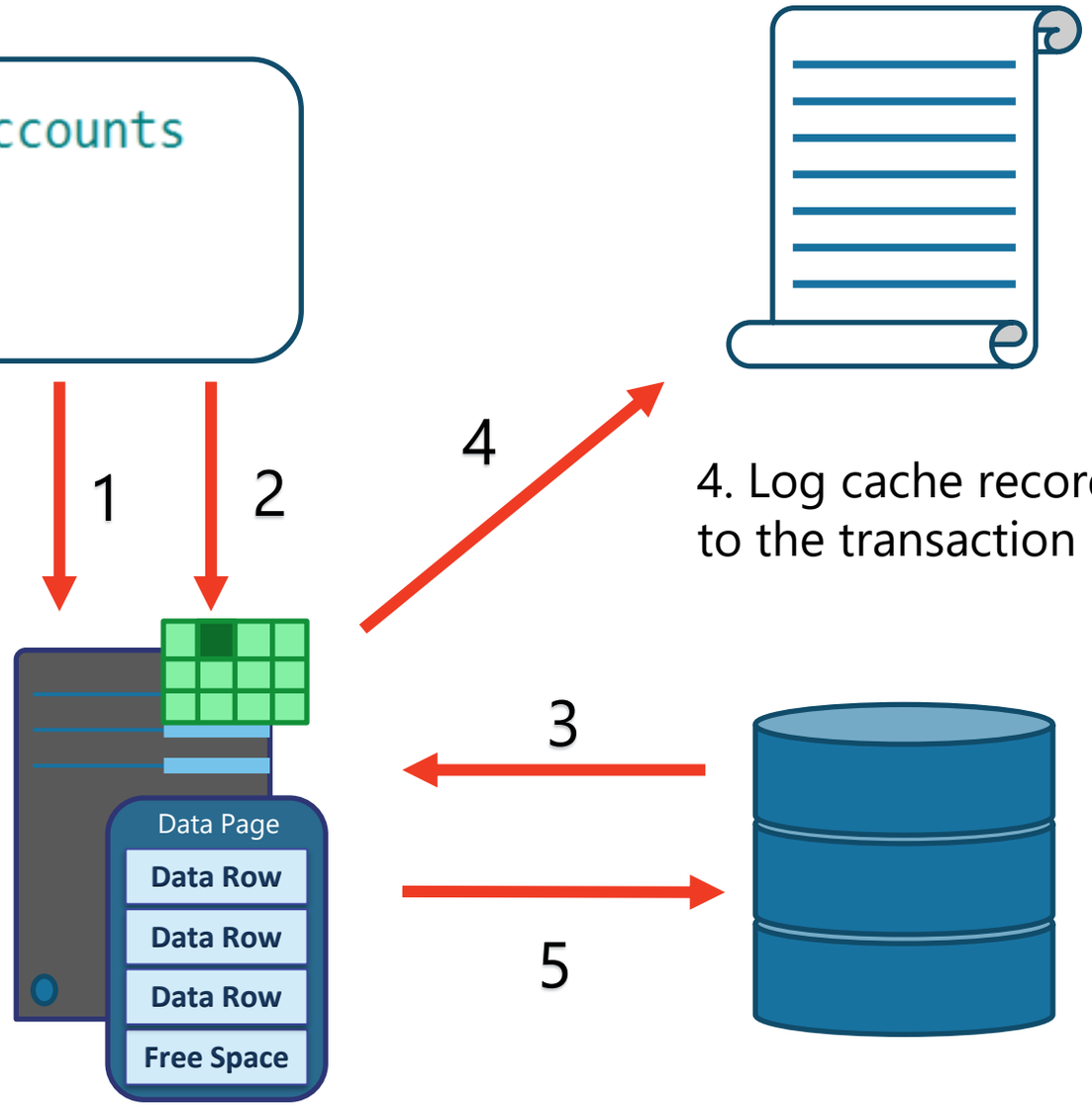
Header contains Page Information such a Page Number and Page Type

8060 bytes for Data Rows or Free Space

Displays how far from beginning of page each row is located.

SQL Server Disk I/O (Write-Ahead Logging)

```
UPDATE Accounting.BankAccounts
SET Balance -= 200
WHERE AcctID = 1
```



1. Data modification is sent to buffer cache in memory.

2. Modification is recorded in the log cache.

3. Data pages are located or read into the buffer cache and then modified.

4. Log cache record is flushed to the transaction log

5. At checkpoint, dirty data pages are written to the database file.

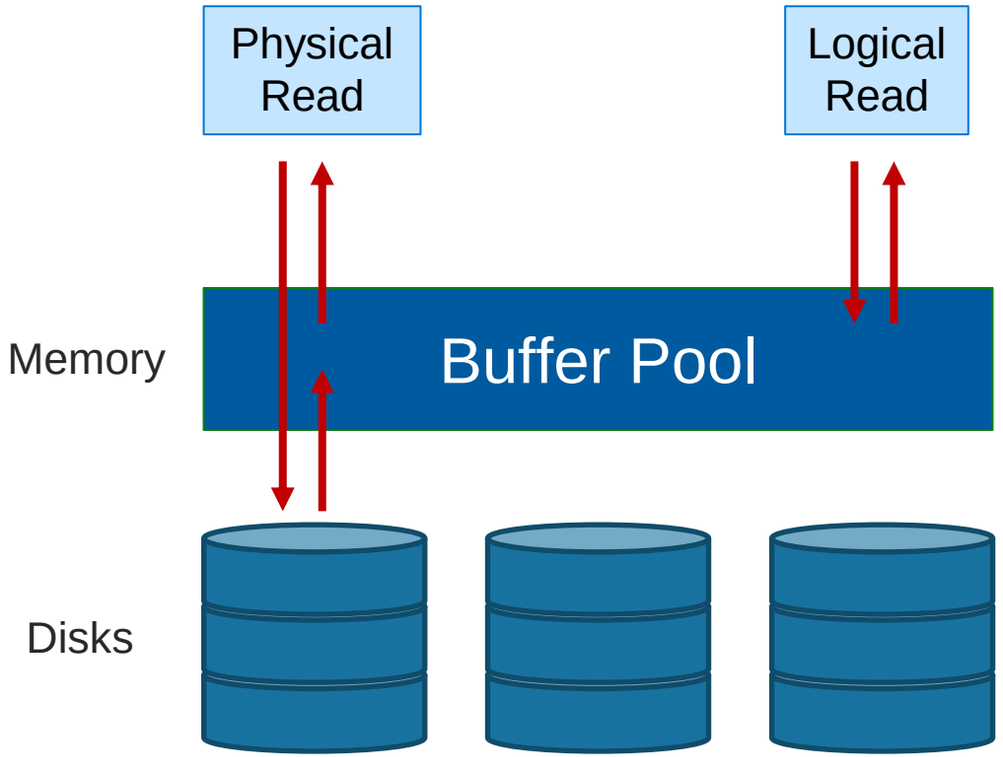
SQL Server Buffer Pool

Stores 8 kilobytes (KB) pages of data to avoid repeated disk I/O.

- Pages held in the buffer until the space is needed by something else.

Lazy Writer searches for eligible buffers.

- If the buffer is dirty, an asynchronous write (lazy write) is posted so that the buffer can later be freed.
- If the buffer is not dirty, it is freed.



SET STATISTICS IO

```
SET STATISTICS IO ON
GO
SET STATISTICS TIME ON
SELECT SOH.SalesOrderID, SOH.CustomerID,
OrderQty, UnitPrice, P.Name
FROM Sales.SalesOrderHeader AS SOH
JOIN Sales.SalesOrderDetail AS SOD
ON SOH.SalesOrderID = SOD.SalesOrderID
JOIN Production.Product AS P
ON P.ProductID = SOD.ProductID
SET STATISTICS IO, TIME OFF
```

Used to identify physical reads and logical reads for a query

```
(121317 rows affected)
Table 'Workfile'. Scan count 0, logical reads 0, physical reads 0, page server r
Table 'Worktable'. Scan count 0, logical reads 0, physical reads 0, page server
Table 'SalesOrderDetail'. Scan count 1, logical reads 428, physical reads 0, pag
Table 'Product'. Scan count 1, logical reads 15, physical reads 0, page server r
Table 'SalesOrderHeader'. Scan count 1, logical reads 57, physical reads 0, page

 SQL Server Execution Times:
   CPU time = 94 ms,  elapsed time = 1653 ms.
```

Allocation Units

IN_ROW_DATA

- Fixed length data must be store here.
- Rows cannot extend beyond pages
- Data Page is 8060 bytes

LOB_DATA (For out of row storage)

- varchar(max) / nvarchar(max) / varbinary(max)
- 16-byte point to out of row tree
- Uses text page to store a stream of data

ROW_OVERFLOW_DATA (SLOB)

- varchar(8000) / nvarchar(4000) / varbinary(8000)
- When a column can’t fit onto a page
- No control over which column overflows

Allocation Structures

Page Types
Data (1)
Index (2)
Text (3 and 4)
Boot (13)
File Header (15)
PFS (11)
GAM (8)
SGAM (9)
IAM (10)
DIFF_MAP(16)
ML_MAP (17)

Page Free Space (PFS)

- Tracks free space on a page (1 Byte/Page)
- Covers 64 megabytes (MB) worth of pages

Global Allocation Map (GAM)

- Tracks which extents have been allocated (1 Bit)
- Covers 64,000 extents (4 gigabytes (GB) worth of data)

Shared Global Allocation Map (SGAM)

- Tracks which extents are used for mixed extent allocations (1 Bit)
- Covers 64,000 extents (4 GB worth of data)

Index Allocation Map (IAM)

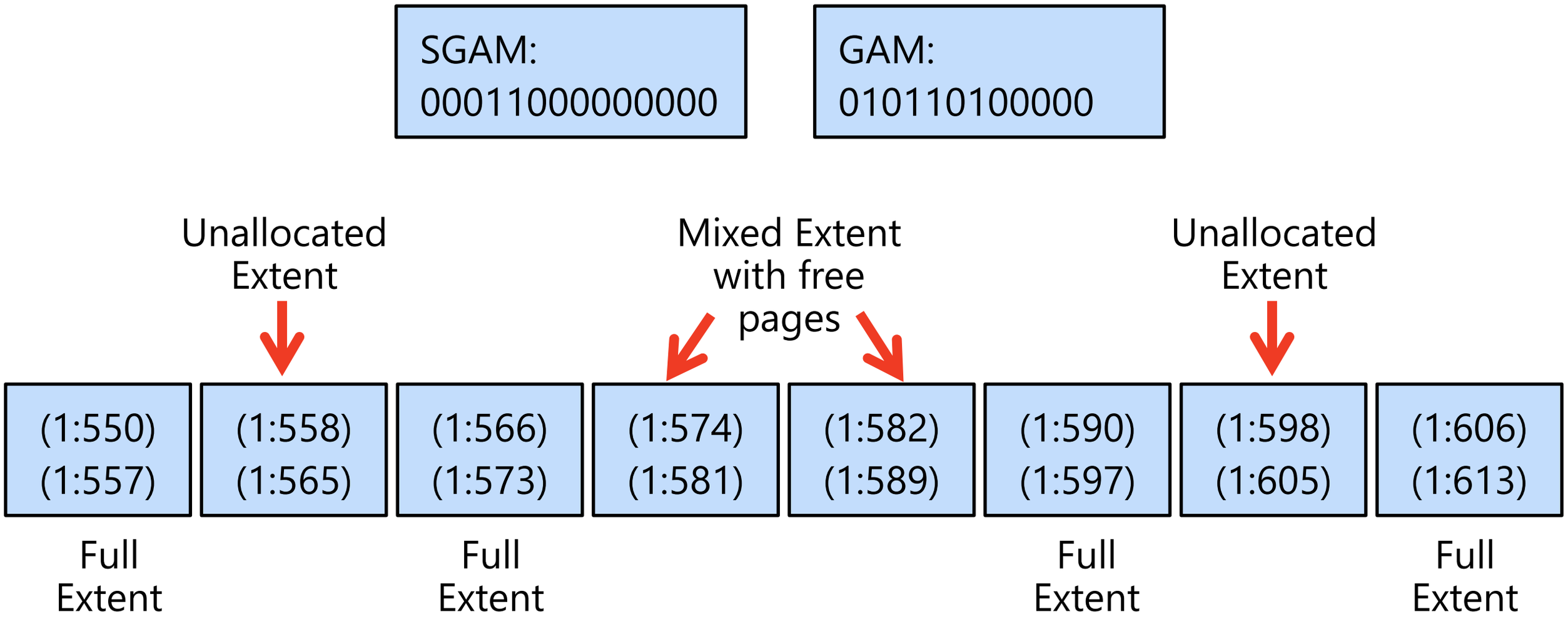
- Tracks which extents are allocated to an allocation unit
- Covers 4 GB worth of data
- One IAM chain per table, per index, per partition, per allocation unit type

The Role of Allocation Maps and PFS in Object Allocation

PFS and IAM are used to determine when an object needs a new extent allocated

GAMs and SGAMs are used to allocate the extent

Index Allocation Map Pages



DBCC IND

```
USE AdventureWorks2012
DBCC TRACEON(3604) -- Print to results pane
DBCC IND(0,'HumanResources.Employee',-1)
-- Parameter 1: Is the DatabaseName, 0 is current database
-- Parameter 2: The table name
-- Parameter 3: Index ID, -1 Shows all indexes, -2 shows only IAM Pages
```

Results | Messages

	PageFID	PagePID	IAMFID	IAMPID	ObjectID	IndexID	PartitionNumber	PartitionID	iam_chain_type	PageType	IndexLevel	NextPageFID	NextPagePID	PrevPageFID	PrevPagePID
1	1	874	NULL	NULL	1237579447	1	1	72057594045136896	In-row data	10	NULL	0	0	0	0
2	1	875	1	874	1237579447	1	1	72057594045136896	In-row data	2	1	0	0	0	0
3	1	1048	1	874	1237579447	1	1	72057594045136896	In-row data	1	0	1	1049	0	0
4	1	1049	1	874	1237579447	1	1	72057594045136896	In-row data	1	0	1	1050	1	1048
5	1	1050	1	874	1237579447	1	1	72057594045136896	In-row data	1	0	1	1051	1	1049
6	1	1051	1	874	1237579447	1	1	72057594045136896	In-row data	1	0	1	1052	1	1050
7	1	1052	1	874	1237579447	1	1	72057594045136896	In-row data	1	0	1	1053	1	1051
8	1	1053	1	874	1237579447	1	1	72057594045136896	In-row data	1	0	1	1054	1	1052
9	1	1054	1	874	1237579447	1	1	72057594045136896	In-row data	1	0	0	0	1	1053
10	1	9287	NULL	NULL	1237579447	2	1	72057594050510848	In-row data	10	NULL	0	0	0	0
11	1	9286	1	9287	1237579447	2	1	72057594050510848	In-row data	2	0	0	0	0	0
12	1	9289	NULL	NULL	1237579447	3	1	72057594050576384	In-row data	10	NULL	0	0	0	0

Query executed successfully. | STUDENTSERVER (12.0 RTM) | STUDENTSERVER\Student ... | AdventureWorks2012 | 00:00:0

DBCC PAGE

```
DBCC TRACEON(3604) -- Print to results pane
DBCC PAGE (0,1,0,3)
-- Parameter 1: Is the DatabaseName, 0 is current database
-- Parameter 2: The File ID
-- Parameter 3: The Page ID
-- Parameter 4: The print option, 3 is verbose
```

.00 %

Messages

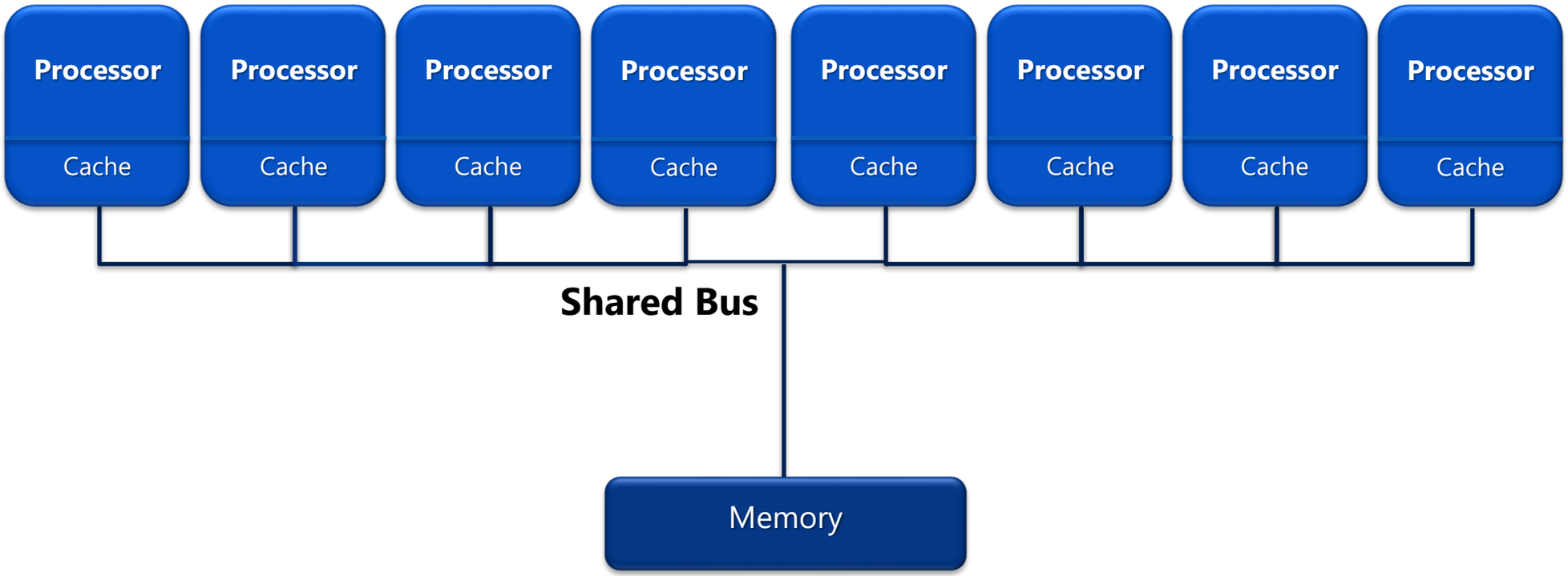
```
PAGE HEADER:


Page @0x0000000027757A000

m_pageId = (1:0)                    m_headerVersion = 1                 m_type = 15
m_typeFlagBits = 0x0                m_level = 0                         m_flagBits = 0x208
m_objId (AllocUnitId.idObj) = 99    m_indexId (AllocUnitId.idInd) = 0   Metadata: AllocUnitId = 6488064
Metadata: PartitionId = 0           Metadata: IndexId = 0               Metadata: ObjectId = 99
m_prevPage = (0:0)                  m_nextPage = (0:0)                  pminlen = 0
m_slotCnt = 1                       m_freeCnt = 6989                    m_freeData = 7831
m_reservedCnt = 0                   m_lsn = (181:50952:34)              m_xactReserved = 0
m_xdesId = (0:0)                    m_ghostRecCnt = 0                   m_tornBits = -820886669
DB Frag ID = 1
```

SQL Server 2014 VLF Growth Improvement

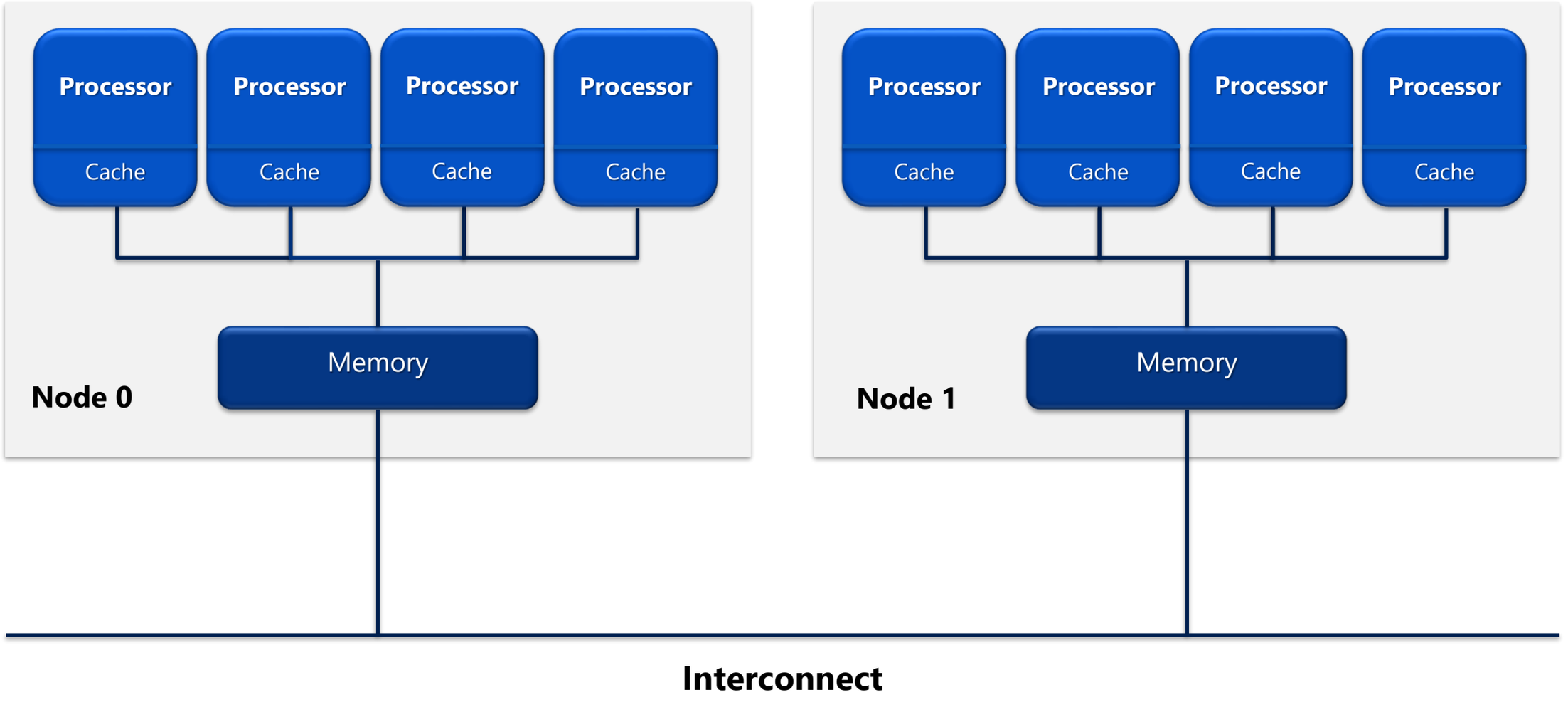
- Is the growth size less than 1/8 the size of the current log size?
  - Yes: create 1 new VLF equal to the growth size
  - No: use the previous formula
- Example of a 256 MB log file with an autogrowth setting of 5 MB
  - 2012 and earlier: 10 auto-grows of 5MB would add 4 VLFs x 10 auto-grows
  - 2014 and later: 10 auto-grows of 5MB each would only create 10 VLFs

Grow Iterations + Log size	Up to SQL Server 2012	From SQL Server 2014
0 (256 MB)	8	8
10 (306 MB)	48	18
20 (356 MB)	88	28
80 (656 MB)	328	88
250 (1.2 GB)	1008	258
3020 (15 GB)	12091	3028

Symmetric Multi-Processing (SMP)



Non-Uniform Memory Access (NUMA)



SQL Server Configuration

Processor Configuration Settings And Best Practices

Affinity Mask	• Assigns CPUs for SQL Server use • Set via sp_configure or Alter Server Configuration • Only required in specific scenarios
Max Degree of Parallelism (MAXDOP)	• Maximum worker threads available for a single given operator in a query execution plan • NOT the total worker threads available for the entire plan execution
Cost Threshold for Parallelism	• Only queries with a cost that is higher than this value will be considered for parallelism • Only required when dealing with excessive parallelism
Max Worker Threads	• Number of threads SQL Server can allocate • Recommended value is 0. SQL Server will dynamically set the Max based on CPUs and CPU architecture

SQL Server Configuration

MAXDOP Setting and Best Practices

Best Practice Recommendations (documented in KB 2806535):

Server with single NUMA node	Less than or equal to 8 logical processors	Keep MAXDOP at or below # of logical processors
Server with single NUMA node	Greater than 8 logical processors	Keep MAXDOP at 8
Server with multiple NUMA nodes	Less than or equal to 16 logical processors per NUMA node	Keep MAXDOP at or below # of logical processors per NUMA node
Server with multiple NUMA nodes	Greater than 16 logical processors per NUMA node	Keep MAXDOP at half the number of logical processors per NUMA node with a MAX value of 16

How to determine Thread Stack Memory

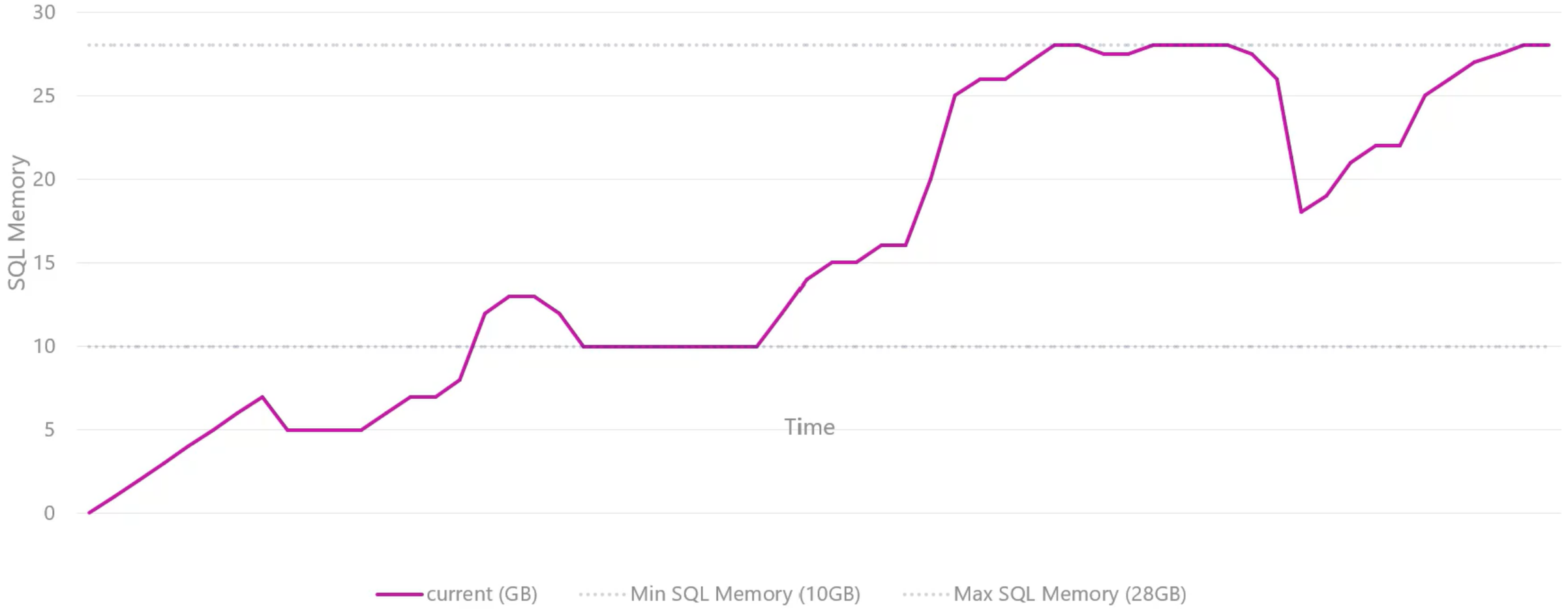
Maximum Worker Threads
512 + (Processors -4) *16

*

2mb per thread

Cores	Threads	Memory (MB)
4	512	1,024
8	576	1,152
16	704	1,408
32	960	1,920
64	1,472	2,944
80	1,728	3,456

Dynamic Memory Management

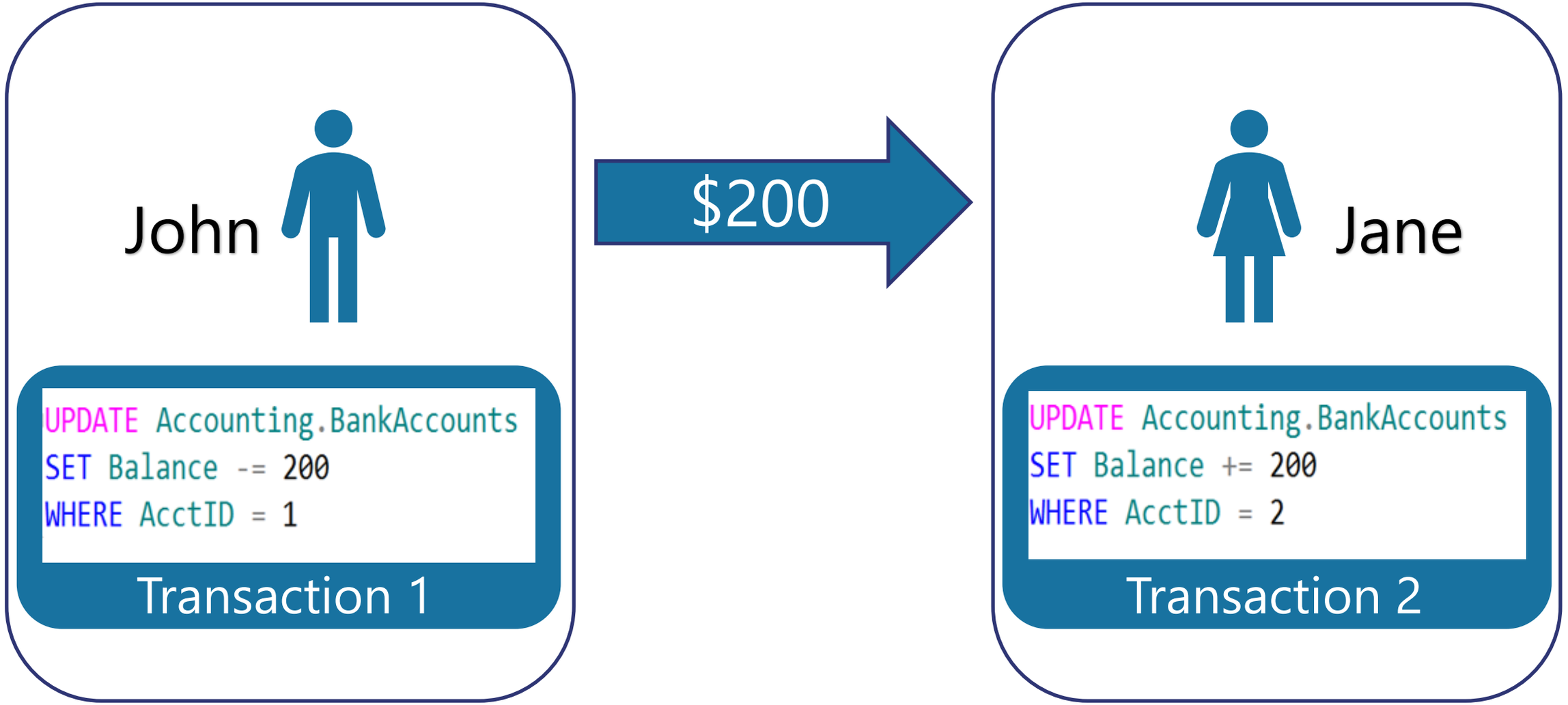


What is a Transaction?

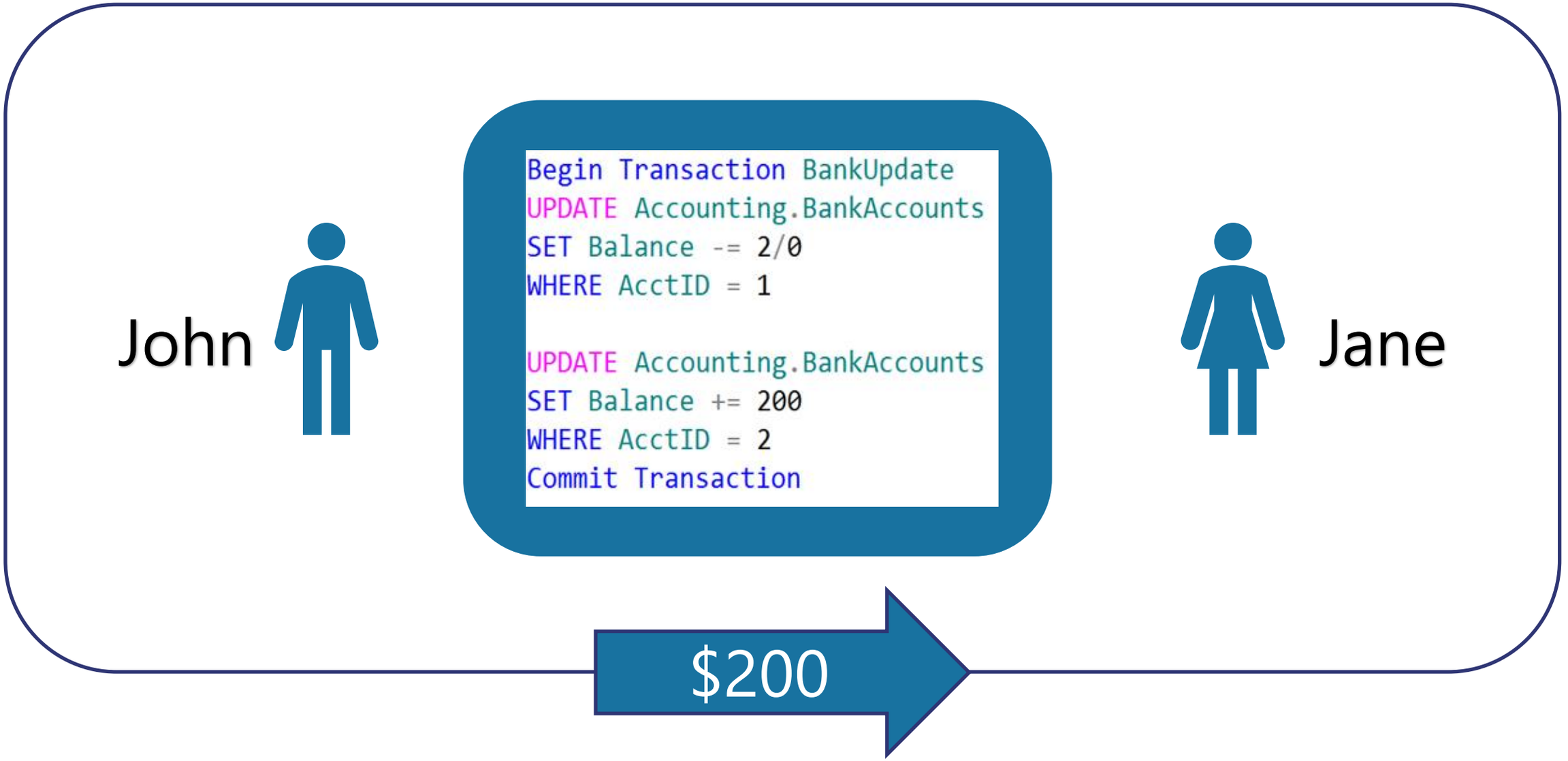
A transaction is a series of one or more statements that need to operate as a single logical unit of work.

To qualify as a transaction, the logical unit of work must possess all four of the ACID properties.

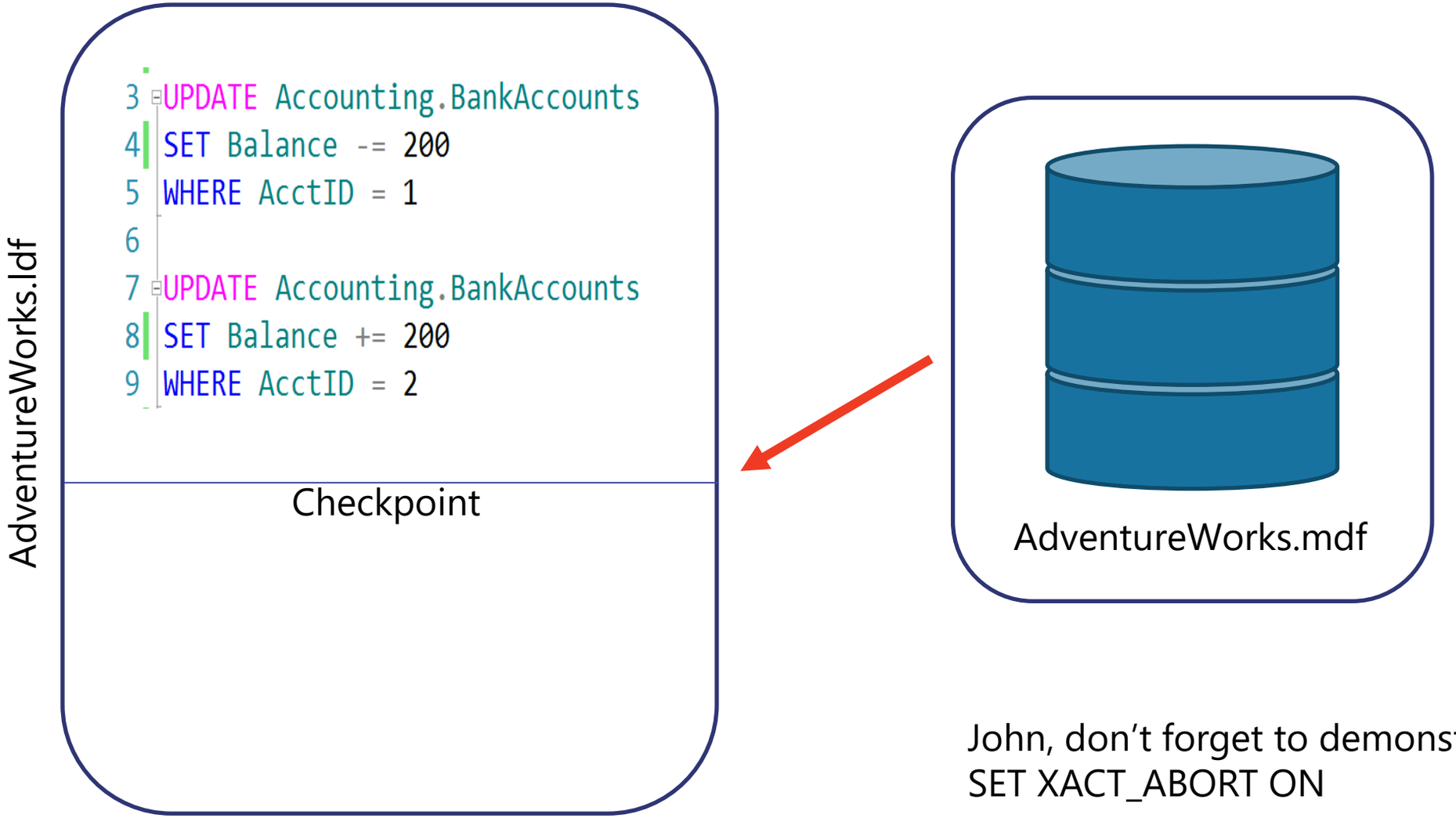
Logical Units of Work – Auto Commit Transactions



Single Logical Unit of Work – Explicit Transactions

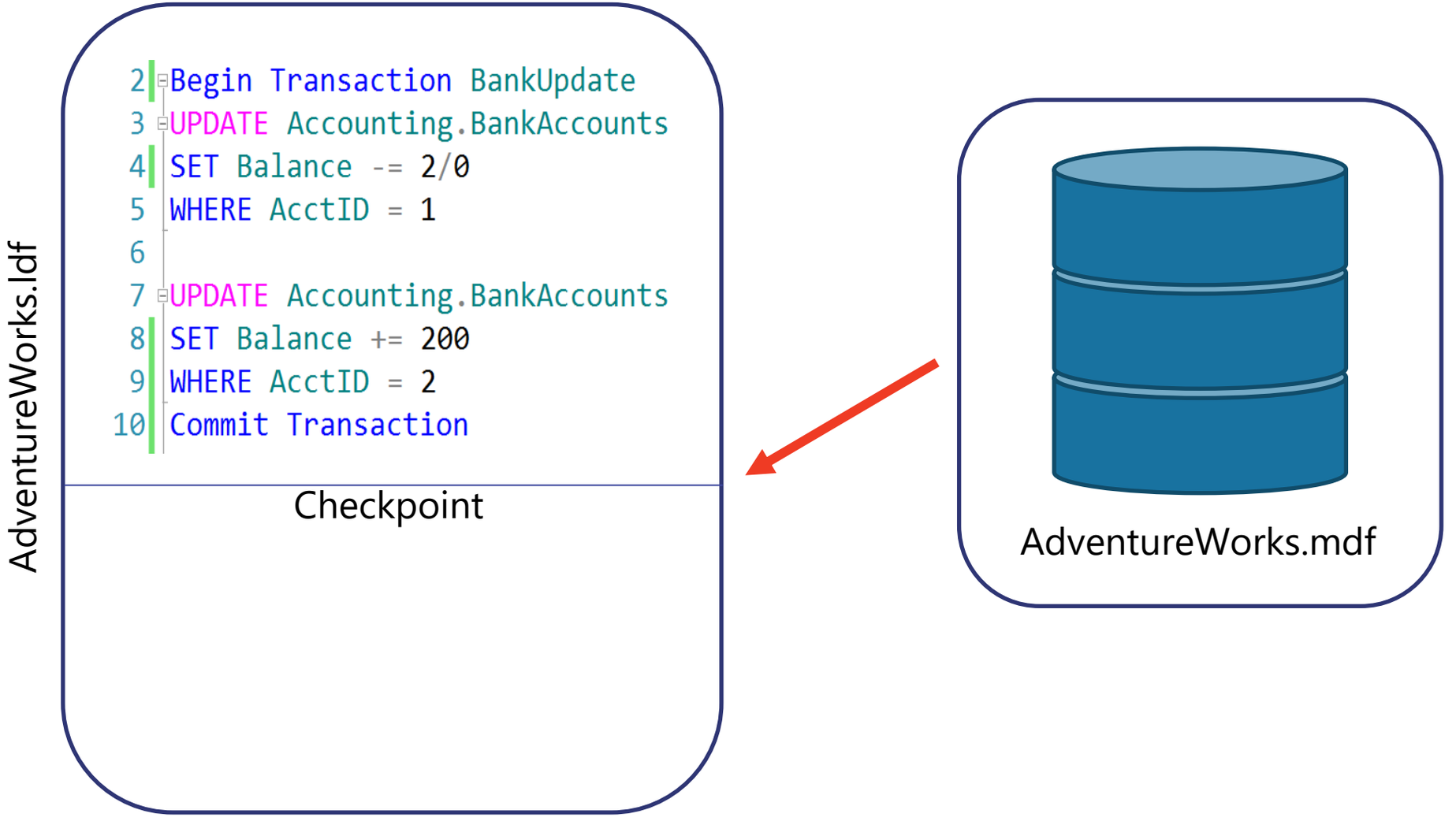


Auto-Commit Transactions without Error Handling



John, don't forget to demonstrate
SET XACT_ABORT ON

Explicit Transactions without Error Handling

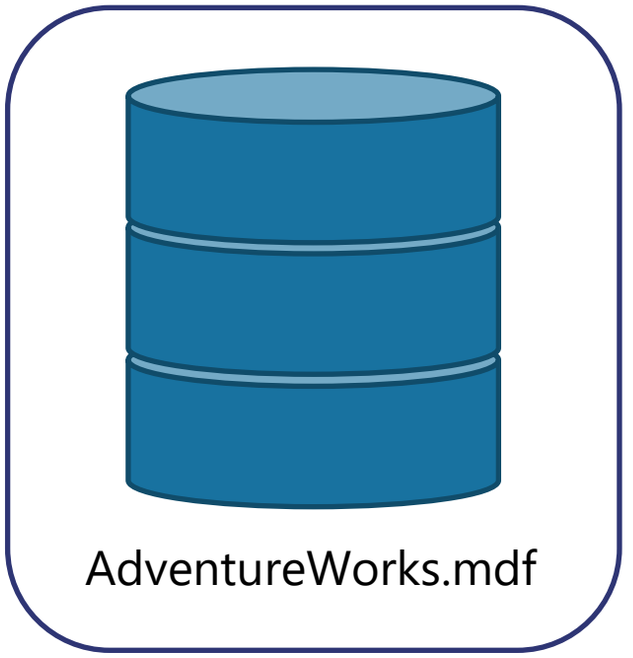


Explicit Transactions with Error Handling

AdventureWorks.ldf

```
1  Begin Try
2      Begin Transaction BankUpdate
3          UPDATE Accounting.BankAccounts
4          SET Balance -= 2/0
5          WHERE AcctID = 1
6
7          UPDATE Accounting.BankAccounts
8          SET Balance += 200
9          WHERE AcctID = 2
10     Commit Transaction
11 End Try
12 Begin Catch
13     Rollback Transaction
14     Print 'Error in code Transaction not complete.'
15 End Catch
```

Checkpoint



Transactions must pass the ACID test

Atomicity – **All or Nothing**

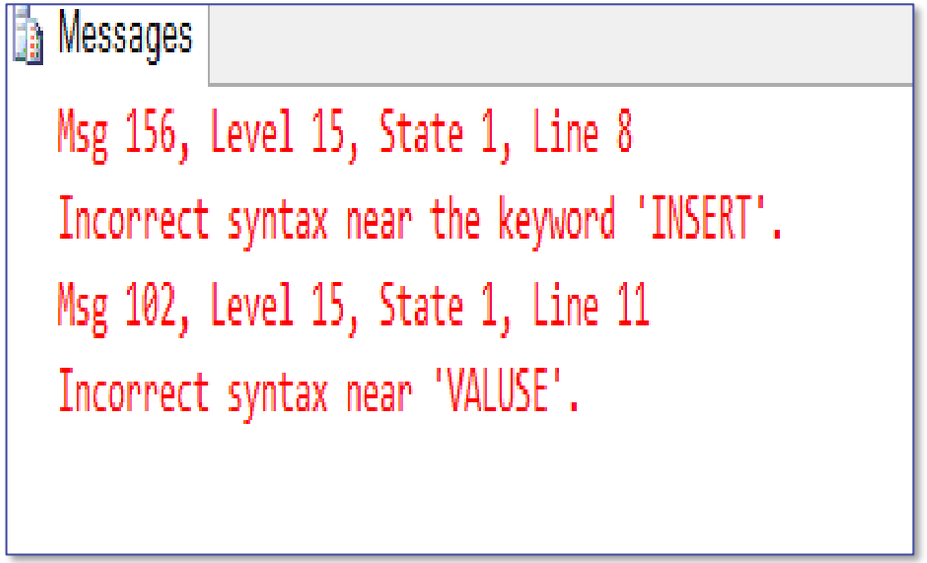
Consistent – **Only valid data**

Isolated – **No interference**

Durable – **Data is recoverable**

Working with Transactions

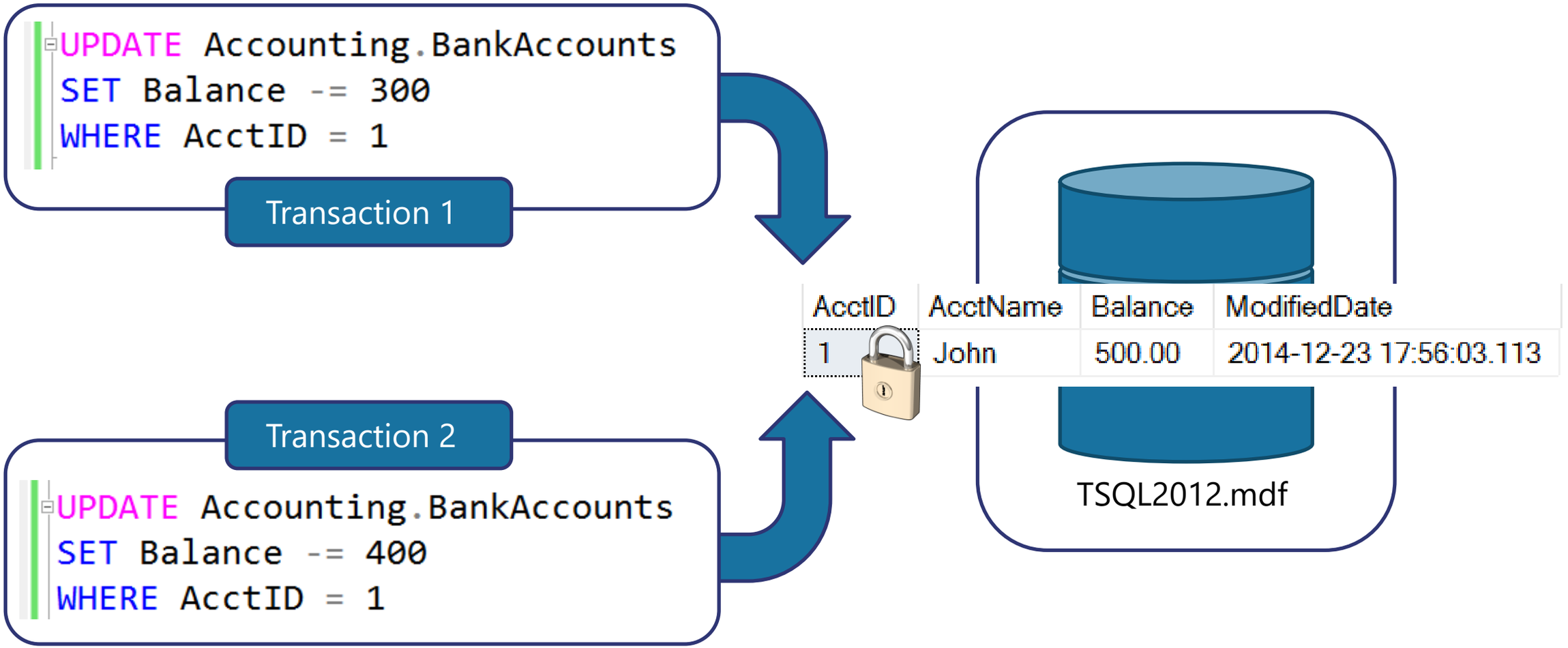
```
CREATE SCHEMA Accounting Authorization dbo
CREATE TABLE BankAccounts
 (AcctID int IDENTITY,
  AcctName char(15),
  Balance money,
  ModifiedDate date)

INSERT INTO Accounting.BankAccounts
VALUES('John',500, GETDATE())
INSERT INTO Accounting.BankAccounts
VALUSE('Jane', 750, GETDATE())
```



Creating Stored Procedures

```
ALTER PROCEDURE spAccountTransfer
(@Amount smallmoney, @a1 tinyint, @a2 tinyint)
AS
SET NOCOUNT ON

UPDATE Accounting.BankAccounts
SET Balance -= @Amount
WHERE AcctID = @a1

UPDATE Accounting.BankAccounts
SET Balance += @Amount
WHERE AcctID = @a2

PRINT 'Transfer Complete'
GO
```

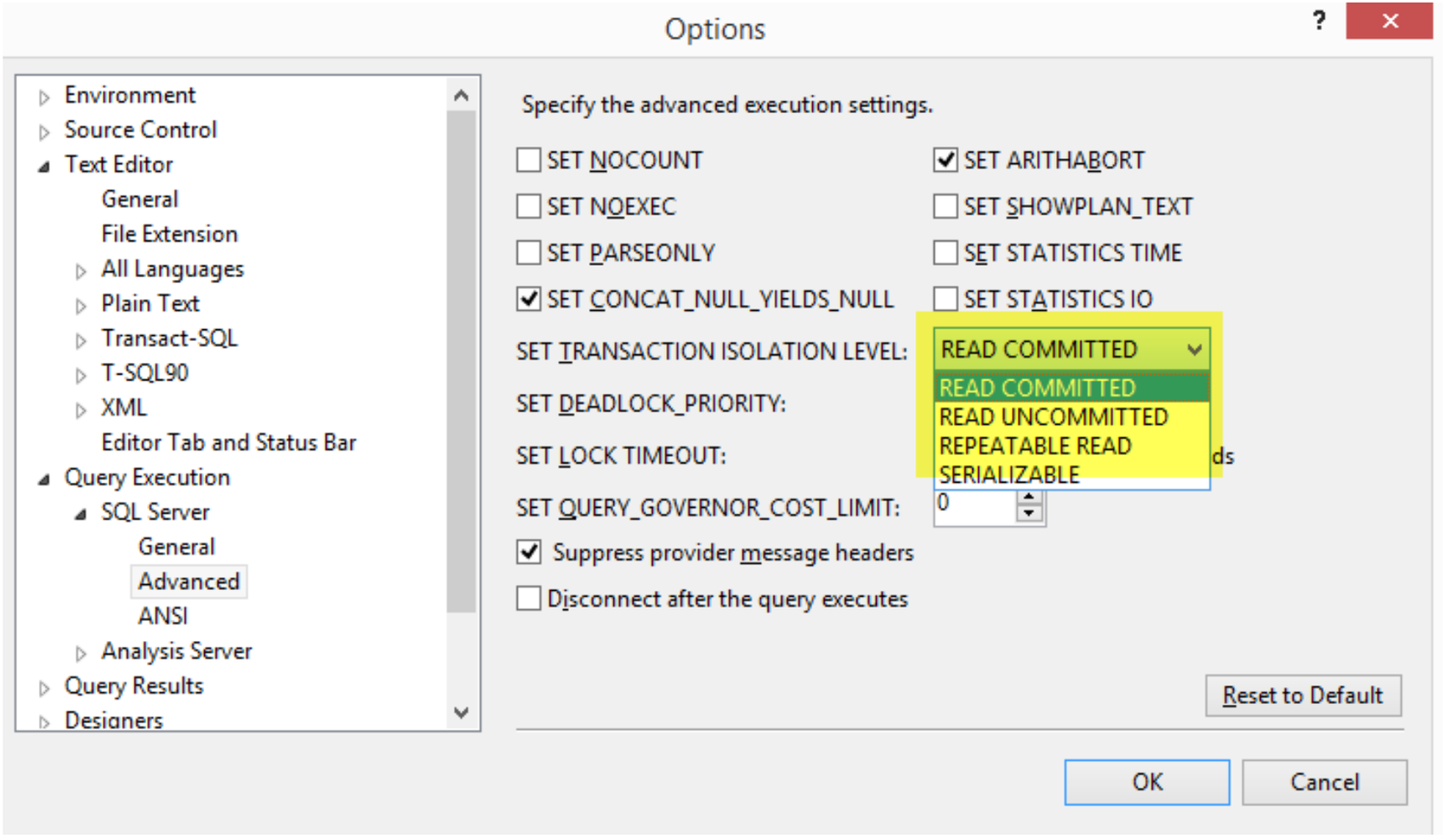
What is a Lock?



Transaction Isolation Levels

Isolation Level	Dirty Read	Lost Update	Nonrepeatable Read	Phantoms
Read uncommitted	Yes	Yes	Yes	Yes
Read committed (default)	No	Yes	Yes	Yes
Repeatable read	No	No	No	Yes
Serializable	No	No	No	No
Snapshot	No	No	No	No

Isolation Levels



Lost Updates

```sql
--  SQL Server Concurrency
-- Lost Update - Session 1
USE TSQL2012
GO
DECLARE @OldBalance int, @NewBalance int
BEGIN TRAN
    SELECT @OldBalance = Balance
    FROM Accounting.BankAccounts
    WHERE AcctID = 1
    SET @NewBalance = @OldBalance - 300
WAITFOR DELAY '00:00:30:000'
    UPDATE Accounting.BankAccounts
    SET Balance = @NewBalance
    WHERE AcctID = 1

    SELECT @OldBalance AS OldBalance,
    AcctID, AcctName, Balance
    FROM Accounting.BankAccounts
    WHERE AcctID = 1
COMMIT TRAN
```

OldBalance	AcctID	AcctName	Balance
500	1	John	200.00

```sql
--  SQL Server Concurrency
-- Lost Update - Session 2
USE TSQL2012
GO
DECLARE @OldBalance int, @NewBalance int
BEGIN TRAN
    SELECT @OldBalance = Balance
    FROM Accounting.BankAccounts
    WHERE AcctID = 1
    SET @NewBalance = @OldBalance - 400

    UPDATE Accounting.BankAccounts
    SET Balance = @NewBalance
    WHERE AcctID = 1

    SELECT @OldBalance AS OldBalance,
     AcctID, AcctName, Balance
    FROM Accounting.BankAccounts
    WHERE AcctID = 1
COMMIT TRAN
```

OldBalance	AcctID	AcctName	Balance
500	1	John	100.00

Uncommitted dependency (dirty read)

```
--  SQL Server Concurrency
-- Dirty Read - Session 1
USE TSQL2012
GO
SET TRANSACTION ISOLATION LEVEL
READ UNCOMMITTED
BEGIN TRAN
    UPDATE Accounting.BankAccounts
    SET Balance -= 300
    WHERE AcctID = 1
        WAITFOR DELAY '00:00:10:000'
    ROLLBACK TRAN
    SELECT AcctID, AcctName, Balance
    FROM Accounting.BankAccounts
    WHERE AcctID = 1
```

Clean Read

AcctID	AcctName	Balance	ModifiedDate
1	John	500.00	2013-02-16

```
--SQL Server Concurrency
--Dirty Read - Session 2
USE TSQL2012
SET TRANSACTION ISOLATION LEVEL
READ UNCOMMITTED
    SELECT * FROM Accounting.BankAccounts
    WHERE AcctID = 1
```

Dirty Read

AcctID	AcctName	Balance	ModifiedDate
1	John	200.00	2015-12-12

Inconsistent analysis (non-repeatable read)

```sql
--SQL Server Concurrency
--Repeatable Read - Session 1
USE TSQL2012
SET TRANSACTION ISOLATION LEVEL
READ COMMITTED --REPEATABLE READ
BEGIN TRAN
    SELECT AcctID, ModifiedDate
    FROM Accounting.BankAccounts
WAITFOR DELAY '00:00:30:000'
    SELECT AcctID, ModifiedDate
    FROM Accounting.BankAccounts
COMMIT TRAN
```

```sql
--SQL Server Concurrency
--Repeatable Read - Session 2
USE TSQL2012
BEGIN TRAN
    UPDATE Accounting.BankAccounts
    SET ModifiedDate = '01/05/2013'
COMMIT TRAN
```

READ COMMITTED

AcctID	ModifiedDate
1	2015-12-12
2	2015-12-12

AcctID	ModifiedDate
1	2013-01-05
2	2013-01-05

REPEATABLE READ

AcctID	ModifiedDate
1	2015-12-12
2	2015-12-12

AcctID	ModifiedDate
1	2015-12-12
2	2015-12-12

Phantom Reads

```
--SQL Server Concurrency
--Phantom Read - Session 1
USE TSQL2012
SET TRANSACTION ISOLATION LEVEL
READ COMMITTED
BEGIN TRAN
    SELECT AcctID, AcctName,
        Balance, ModifiedDate
    FROM Accounting.BankAccounts
WAITFOR DELAY '00:00:10:000'
    SELECT AcctID, AcctName,
        Balance, ModifiedDate
    FROM Accounting.BankAccounts
COMMIT TRAN
```

```
--Phantom Read - Session 2
USE TSQL2012
BEGIN TRAN
    DELETE FROM Accounting.BankAccounts
    WHERE AcctID IN(3,5,6)
COMMIT TRAN
```

Missing records

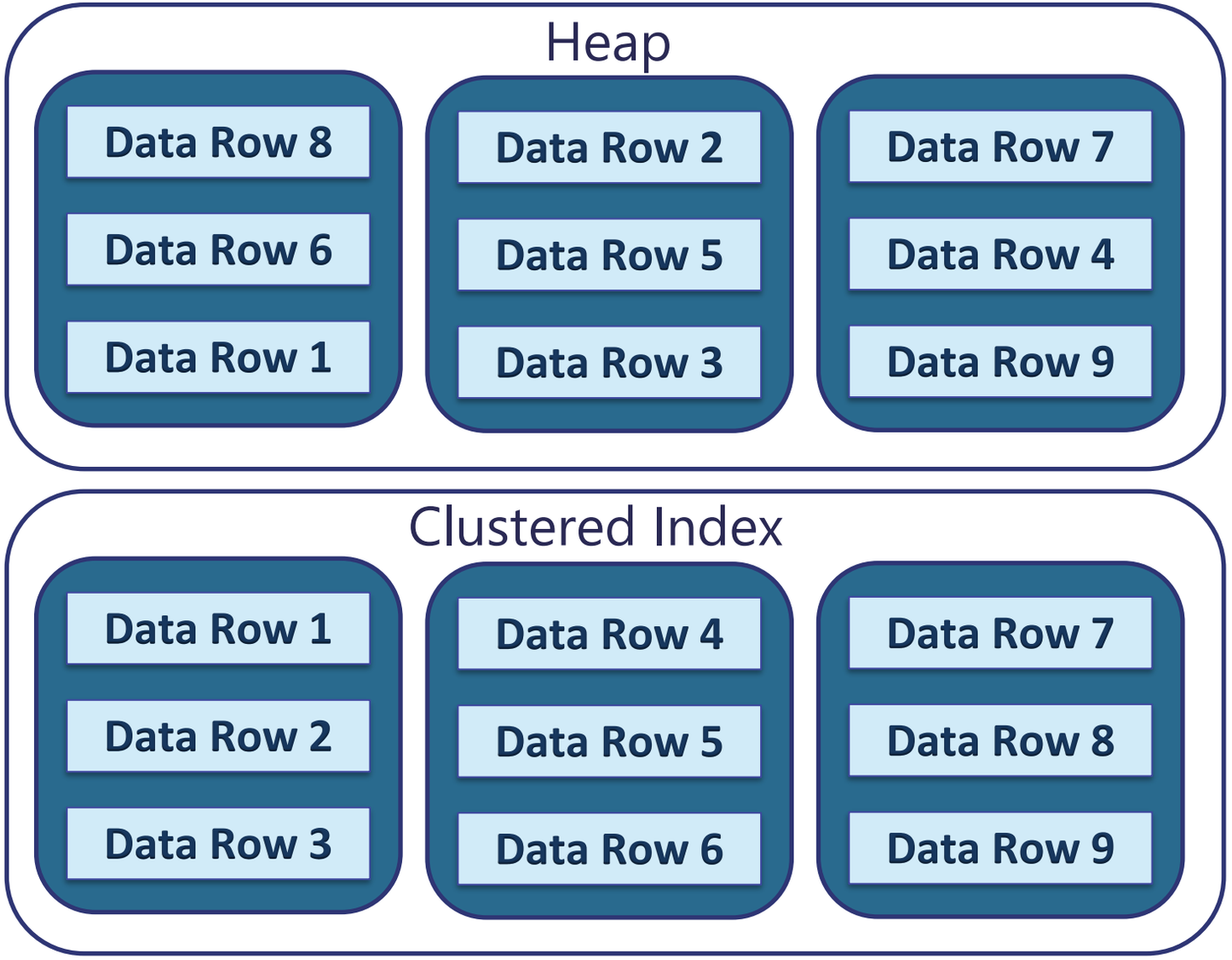
AcctID	AcctName	Balance	ModifiedDate
1	John	500.00	2016-01-02
2	Armando	750.00	2016-01-02
3	Kelli	1250.00	2016-01-02
4	Jessica	1005.00	2016-01-02
5	Maddison	745.00	2016-01-02
6	Alicen	555.00	2016-01-02
7	Molly	790.00	2016-01-02
8	Amy	650.00	2016-01-02

AcctID	AcctName	Balance	ModifiedDate
1	John	500.00	2016-01-02
2	Armando	750.00	2016-01-02
4	Jessica	1005.00	2016-01-02
7	Molly	790.00	2016-01-02
8	Amy	650.00	2016-01-02
9	Logan	1050.00	2016-01-02

How Data is Stored in Data Pages

Data stored in a Heap is not stored in any order and normally does not have a Primary Key.

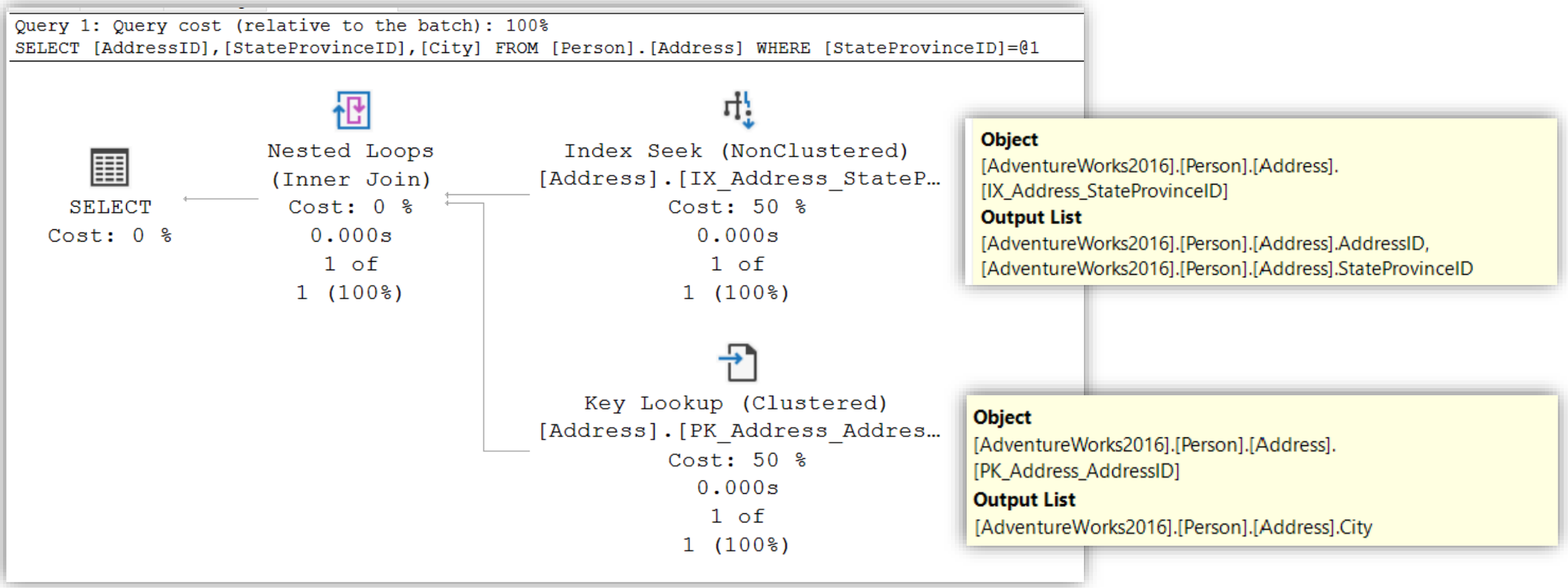
Clustered Index data is stored in sorted order by the Clustering key. In many cases, this is the same value as the Primary Key.



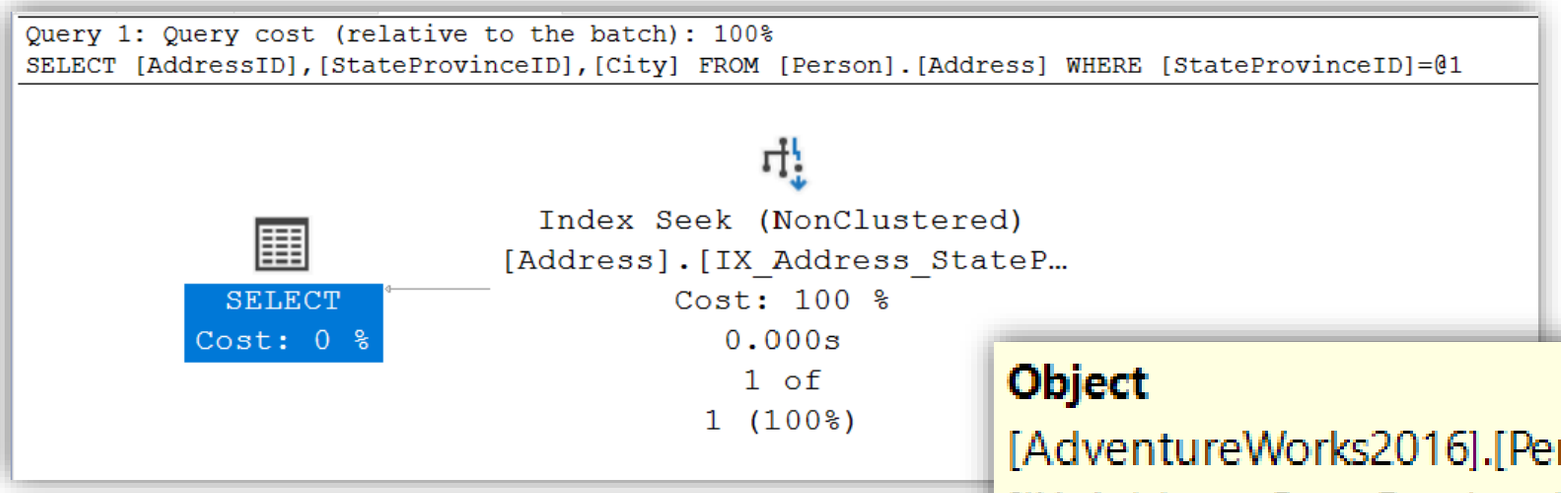
Characteristics of a Good Clustering Key

Narrow	Unique	Static	Increasing
• Use a data type with a small number of bytes to conserver space in tables and indexes	• To avoid SQL adding a 4-byte uniquifier	• Allows data to stay constant without constant changes which could lead to page splits	• Allows better write performance and reduces fragmentation issues

Key Lookup


Query 1: Query cost (relative to the batch): 100%
SELECT [AddressID],[StateProvinceID],[City] FROM [Person].[Address] WHERE [StateProvinceID]=@1
SELECT
Cost: 0 %
Nested Loops
(Inner Join)
Cost: 0 %
0.000s
1 of
1 (100%)
Index Seek (NonClustered)
[Address].[IX_Address_StateP...
Cost: 50 %
0.000s
1 of
1 (100%)
Key Lookup (Clustered)
[Address].[PK_Address_Addres...
Cost: 50 %
0.000s
1 of
1 (100%)
Object
[AdventureWorks2016].[Person].[Address].
[IX_Address_StateProvinceID]
Output List
[AdventureWorks2016].[Person].[Address].AddressID,
[AdventureWorks2016].[Person].[Address].StateProvinceID
Object
[AdventureWorks2016].[Person].[Address].
[PK_Address_AddressID]
Output List
[AdventureWorks2016].[Person].[Address].City

Non-Clustered Index with Included Column



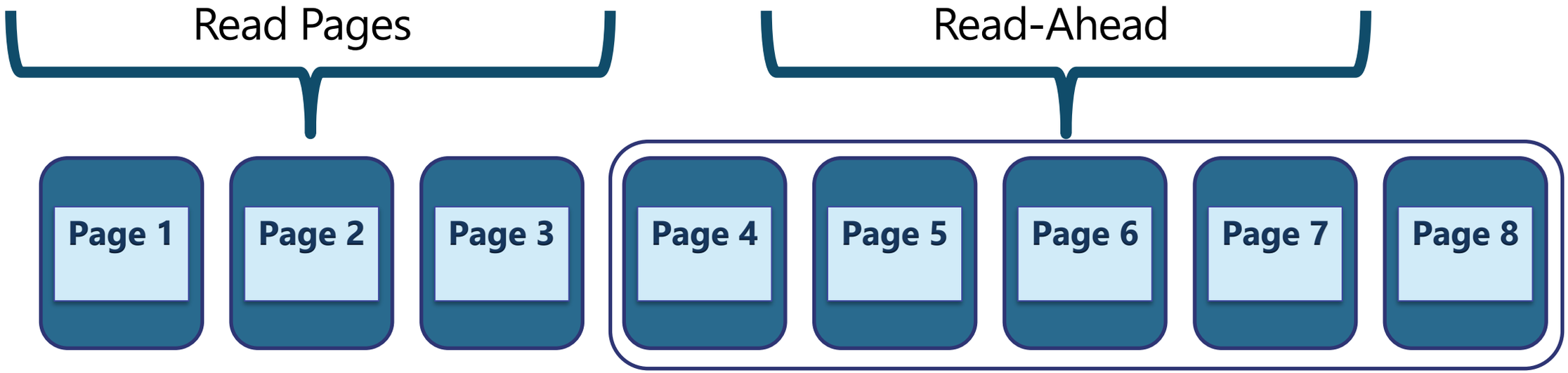
Object

[AdventureWorks2016].[Person].[Address].
[IX_Address_StateProvinceID]

Output List

[AdventureWorks2016].[Person].[Address].AddressID,
[AdventureWorks2016].[Person].[Address].City,
[AdventureWorks2016].[Person].[Address].StateProvinceID

Read-Ahead Scans



- Read-ahead anticipates the data and index pages needed to fulfill a query execution plan and brings the pages into the buffer cache before they are used by the query.
- The read-ahead mechanism allows the Database Engine to read up to 64 contiguous pages (512KB) from one file.

Columnstore Index Types

SQL Server 2012

- Only Non-Clustered, Non-Updatable Columnstore Indexes.
- Only available in Enterprise Edition.

SQL Server 2014

- Introduced Updatable, Clustered Columnstore Indexes
- Only available in Enterprise Edition.

SQL Server 2016

- Introduced Updatable, Non-Clustered Columnstore Indexes
- Available on Standard Edition. (Service Pack 1)

SQL Server 2019

- Online rebuilds for Clustered Columnstore Indexes.

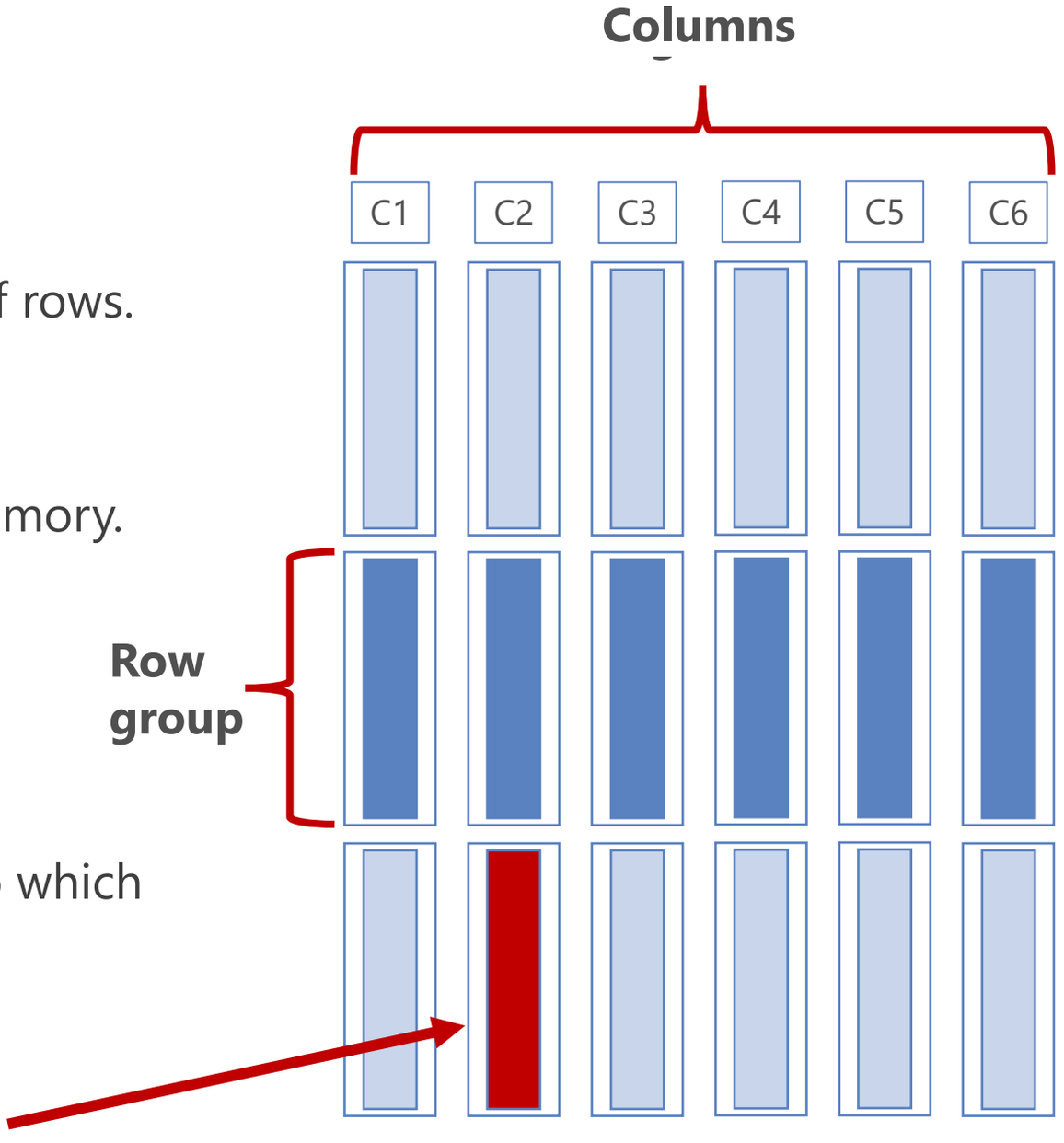
Row Groups & Segments

Segment

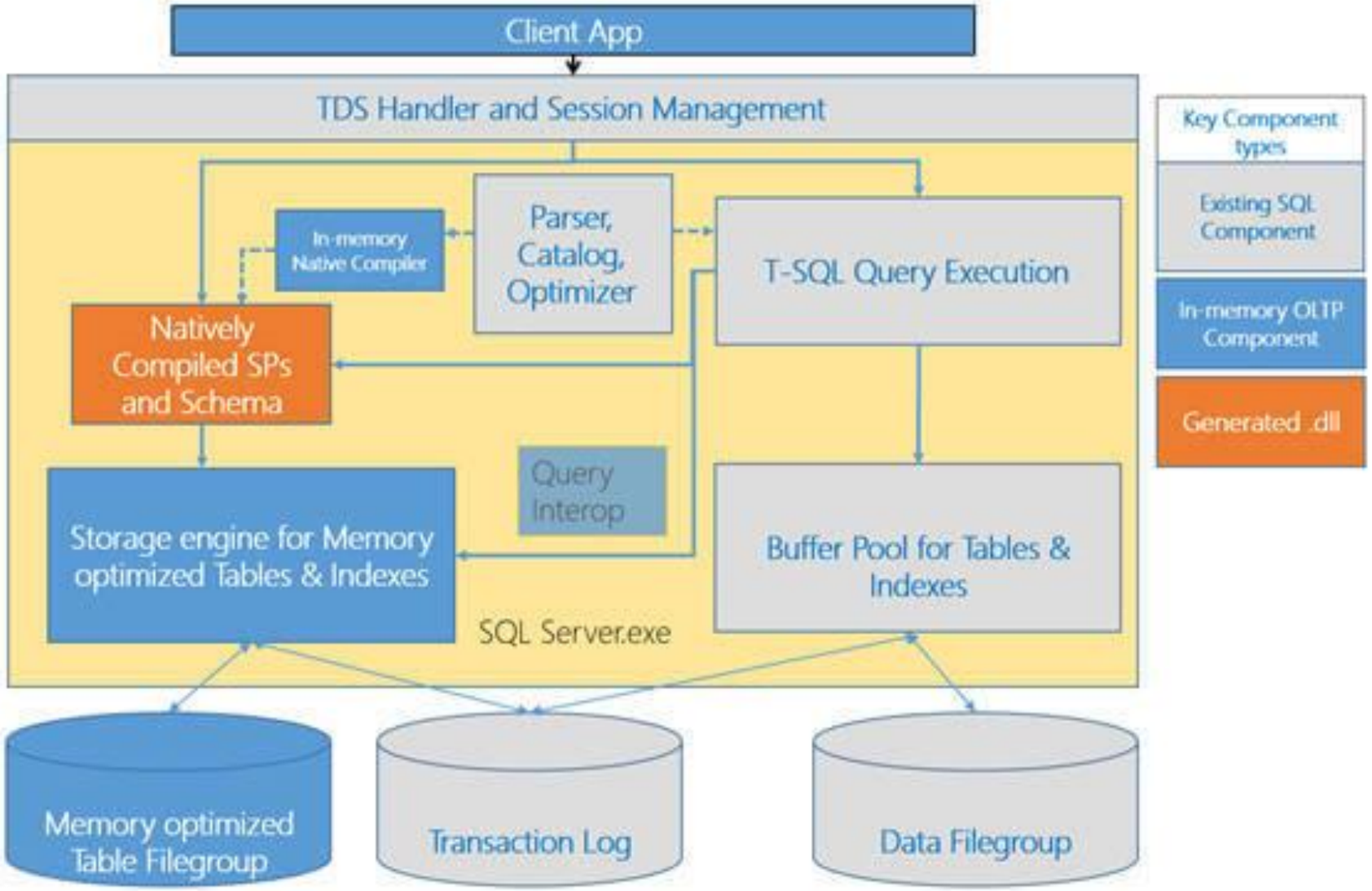
- Contains values for one column for a set of rows.
- Segments are compressed.
- Each segment is stored in a separate LOB.
- It is a unit of transfer between disk and memory.

Row Group

- Segments for the same set of rows comprise a row group.
- Position of a value in a column indicates to which row it belongs to.



Memory-Optimized Architecture



Showing Statistics

```
DBCC SHOW_STATISTICS ('Sales.SalesOrderDetail', 'IX_SalesOrderDetail_ProductID')
WITH STAT_HEADER, HISTOGRAM
```

Results | Messages

Name	Updated	Rows	Rows Sampled	Steps	Density	Average key length	String Index	Fil
IX_SalesOrderDetail_ProductID	Nov 7 2012 6:44PM	121317	121317	200	0.0078125	12	NO	N

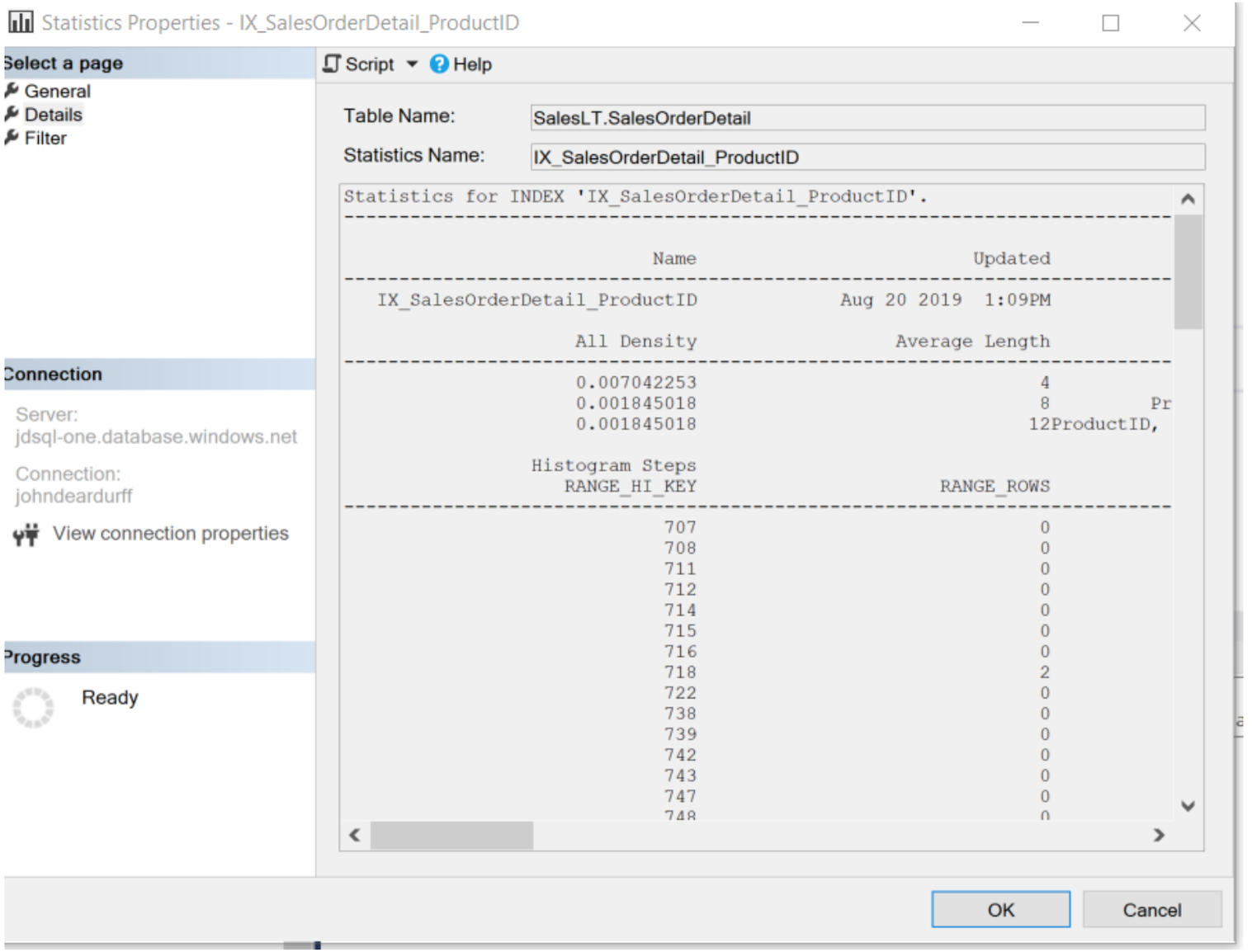
RANGE_HI_KEY	RANGE_ROWS	EQ_ROWS	DISTINCT_RANGE_ROWS	AVG_RANGE_ROWS
730	0	288	0	1
732	0	130	0	1
738	154	600	2	77
741	167	94	1	167
742	0	288	0	1

```
SELECT
    ProductID, RecordCount = COUNT(*)
FROM Sales.SalesOrderDetail
WHERE
    ProductID >= 732 AND
    ProductID <= 738
GROUP BY ProductID
```

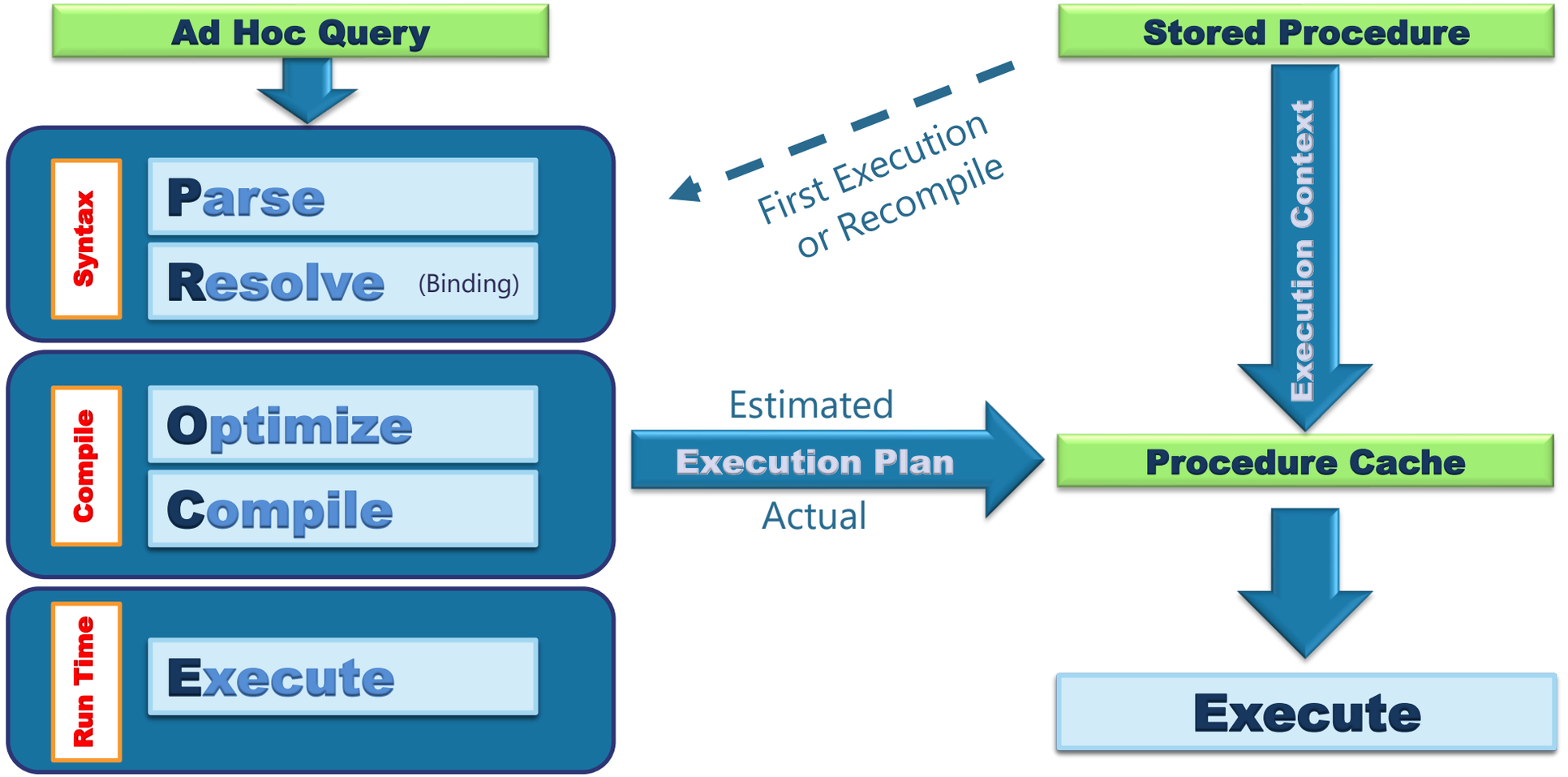
Results | Messages

ProductID	RecordCount
732	130
733	44
736	110
738	600

Cardinality Estimator and Statistics



How Queries are Processed

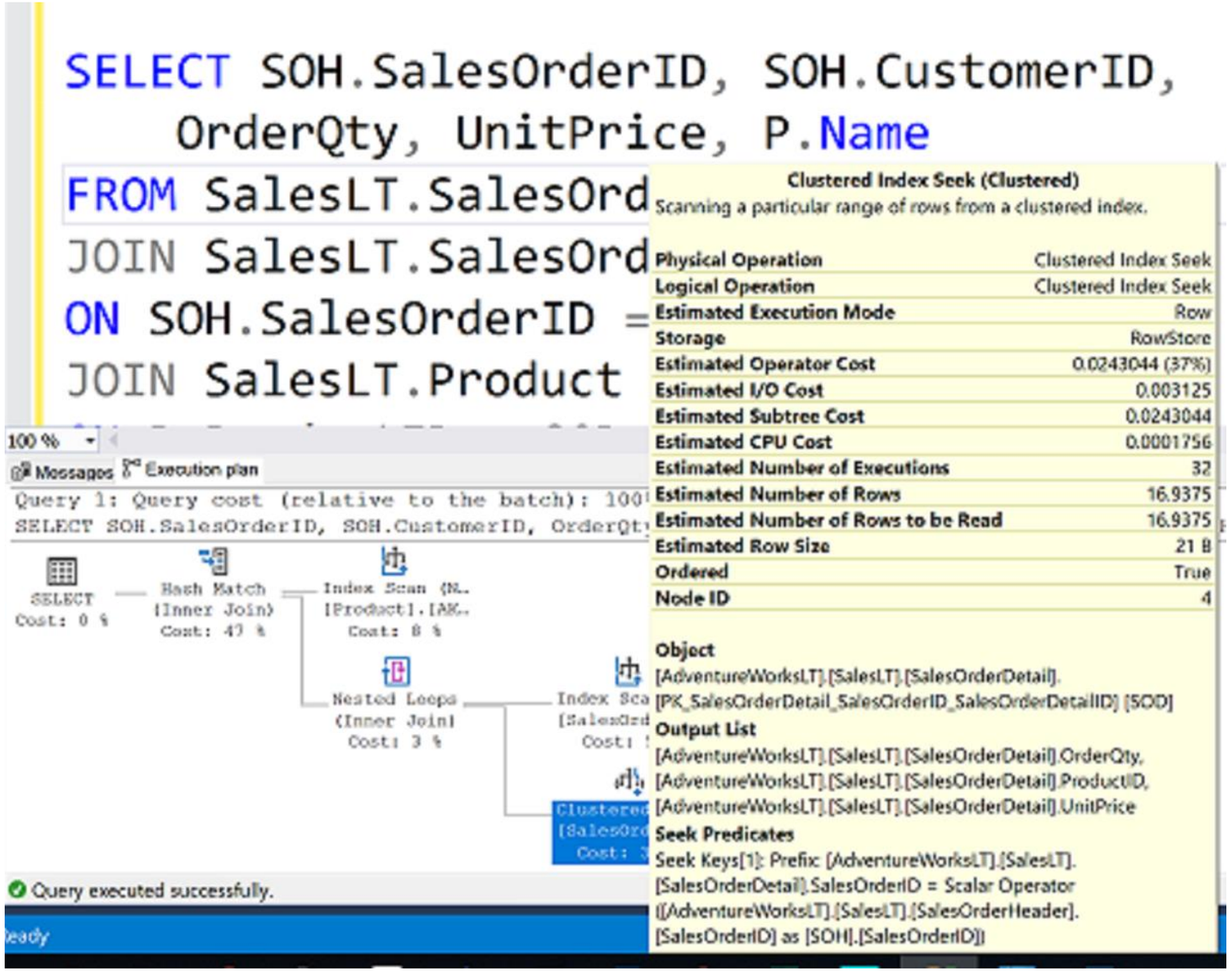


SQL

Sets

empid	lastname	firstna...	title	titleofcourt...	birthdate
1	Davis	Sara	CEO	Ms.	1958-12-08 00:00:00.000
2	Funk	Don	Vice President, Sales	Dr.	1962-02-19 00:00:00.000
3	Lew	Judy	Sales Manager	Ms.	1973-08-30 00:00:00.000
4	Peled	Yael	Sales Representative	Mrs.	1947-09-19 00:00:00.000
5	Buck	Sven	Sales Manager	Mr.	1965-03-04 00:00:00.000

What is an Execution Plan?



How to see the query plan

Text and XML

	Command	Execute query?	Include estimated row counts & stats (Estimated Query Plan)	Include actual row counts & stats (Actual Query Plan)
Text Plan	SET SHOWPLAN_TEXT ON	No	No	No
	SET SHOWPLAN_ALL ON	No	Yes	No
	SET STATISTICS PROFILE ON	Yes	Yes	Yes
XML Plan	SET SHOWPLAN_XML ON	No	Yes	No
	SET STATISTICS PROFILE XML	Yes	Yes	Yes

How to see the query plan

Graphical execution plan

Estimated Execution Plan

- The compiled plan.

Actual Execution Plan

- The same as the compiled plan plus its execution context.
- This includes runtime information available after the execution completes, such as execution warnings, or in newer versions of the Database Engine, the elapsed and CPU time used during execution.

Live Query Statistics

- The same as the compiled plan plus its execution context.
- This includes runtime information during execution progress and is updated every second. Runtime information includes for example the actual number of rows flowing through the operators.
- Enables rapid identification of potential bottlenecks.

Execution Plan Table Operators

Data stored in a Heap is not stored in any order and normally does not have a Primary Key.

Table Scan
[BankAccounts]
Cost: 100 %

Clustered Index data is stored in sorted order by the Clustering key. In many cases, this is the same value as the Primary Key.

Clustered Index Scan (Cluste…
[BankAccounts].[pk_acctID]
Cost: 100 %

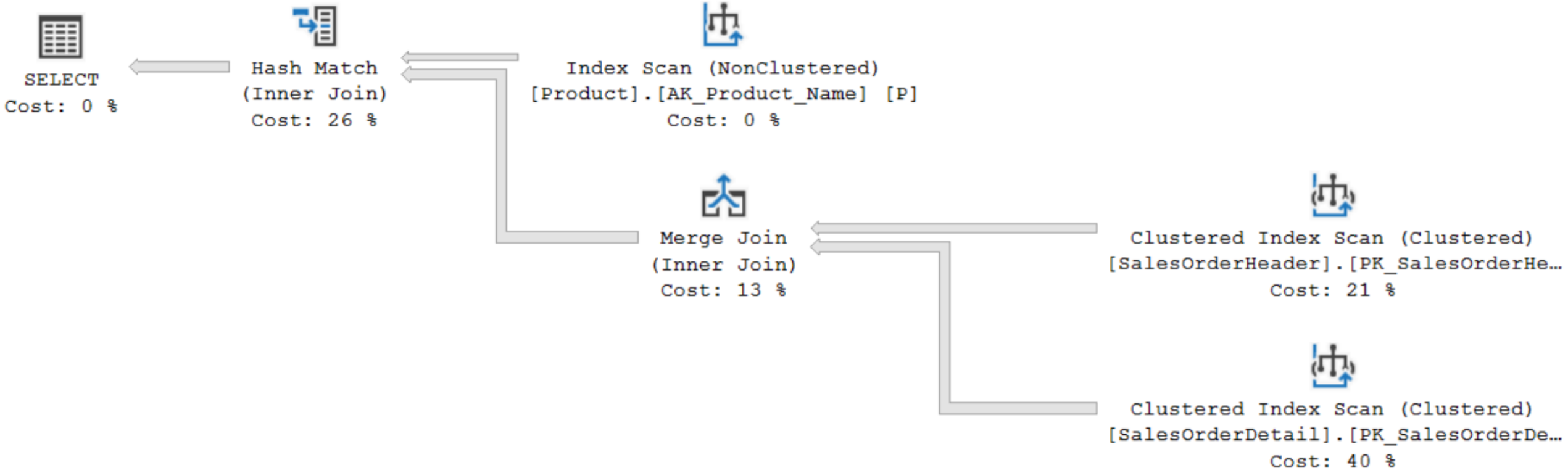
Using a WHERE statement on an Index could possibly have the Execution Plan seek the Index instead of scan.

Clustered Index Seek (Cluste…
[BankAccounts].[pk_acctID]
Cost: 100 %

Execution Plan Join Operators (Code)

```
SELECT SOH.SalesOrderID, SOH.CustomerID,
    OrderQty, UnitPrice, P.Name
FROM Sales.SalesOrderHeader AS SOH
    JOIN Sales.SalesOrderDetail AS SOD
        ON SOH.SalesOrderID = SOD.SalesOrderID
    JOIN Production.Product AS P
        ON P.ProductID = SOD.ProductID
```

Execution Plan Join Operators (Plan)



Execution Plan Join Operators

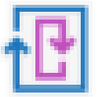
A Merge Join is useful if both table inputs are in the same sorted order on the same value.

Merge Join
(Inner Join)
Cost: 39 %

A Hash Match is used when the tables being joined are not in the same sorted order.

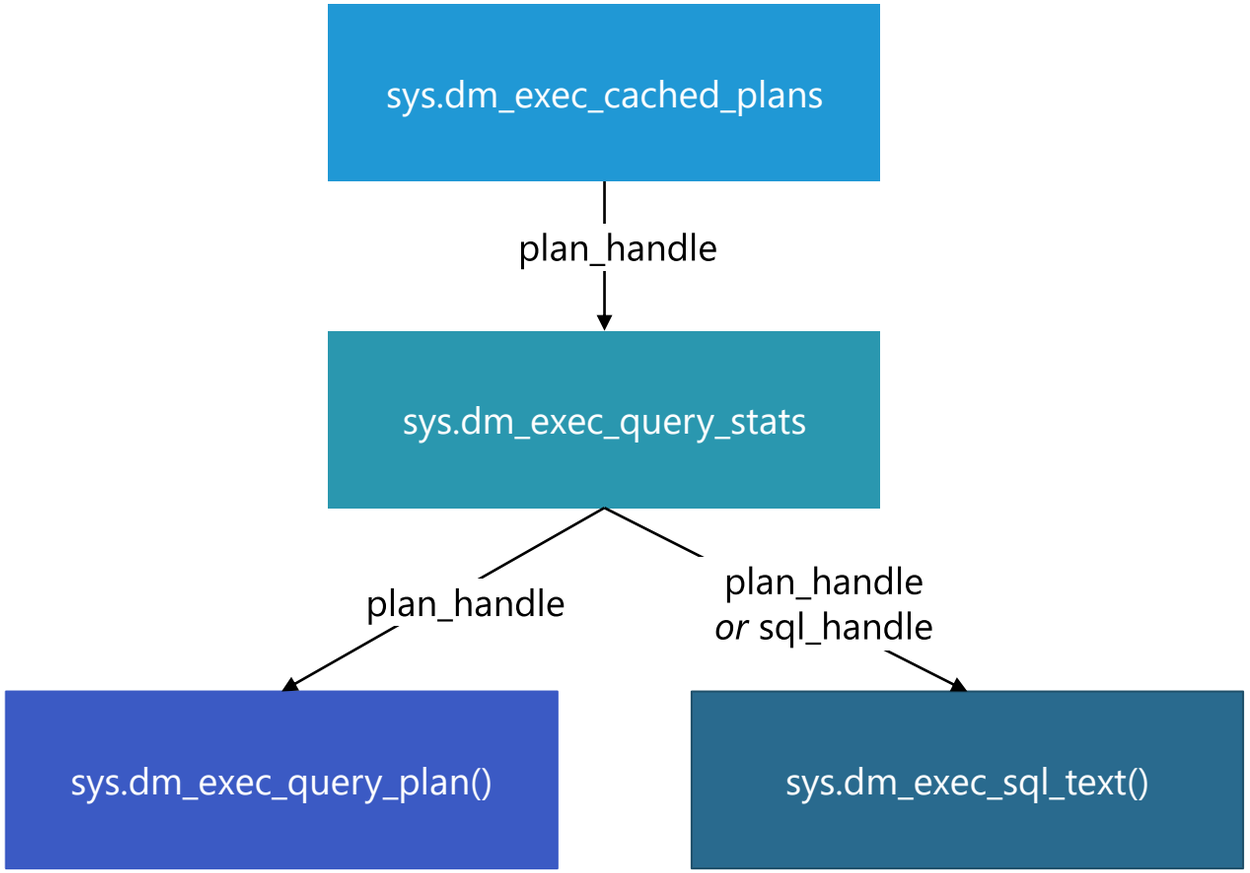
Hash Match
(Inner Join)
Cost: 47 %

A Nested Loop is use when a small (outer) table is used to lookup a value in a larger (inner) table.

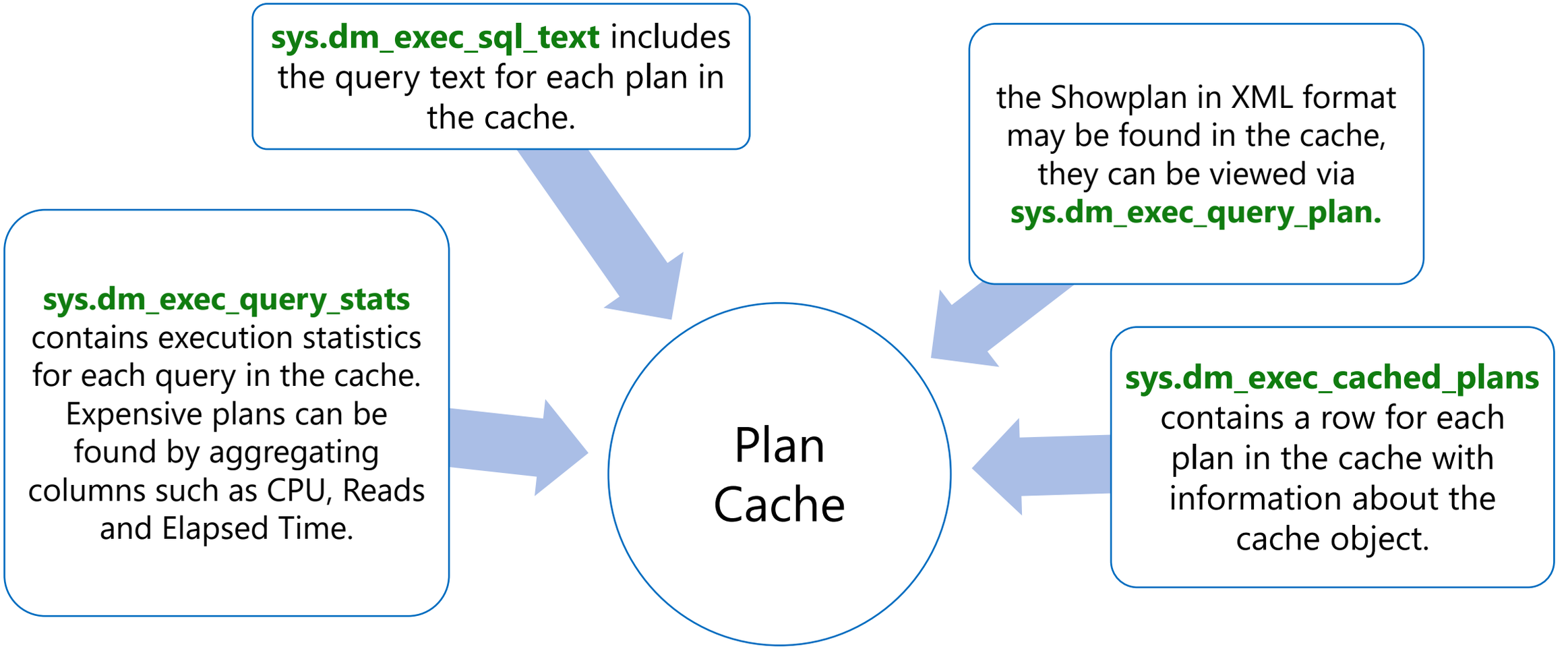


Nested Loops
(Inner Join)
Cost: 3 %

Relationships between DMOs

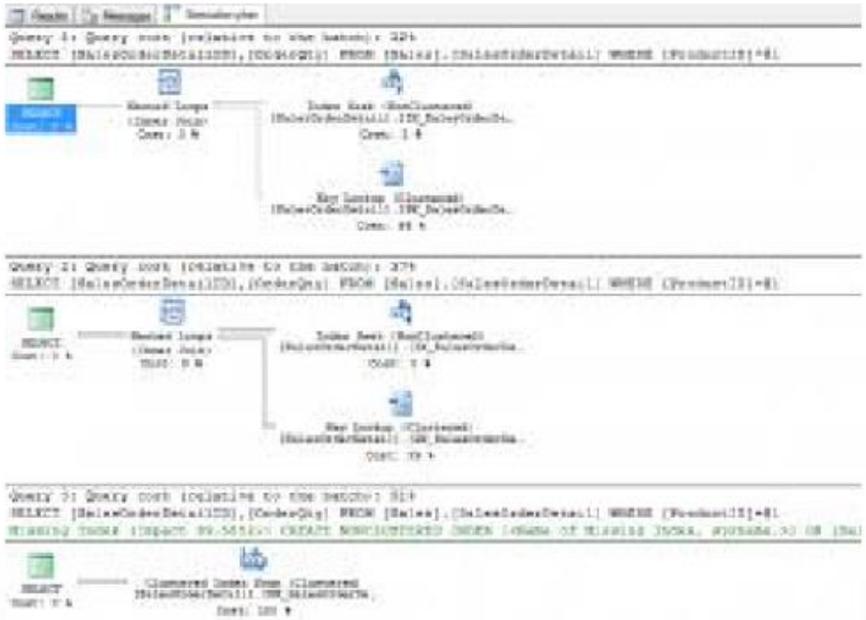


Queries in the Plan Cache

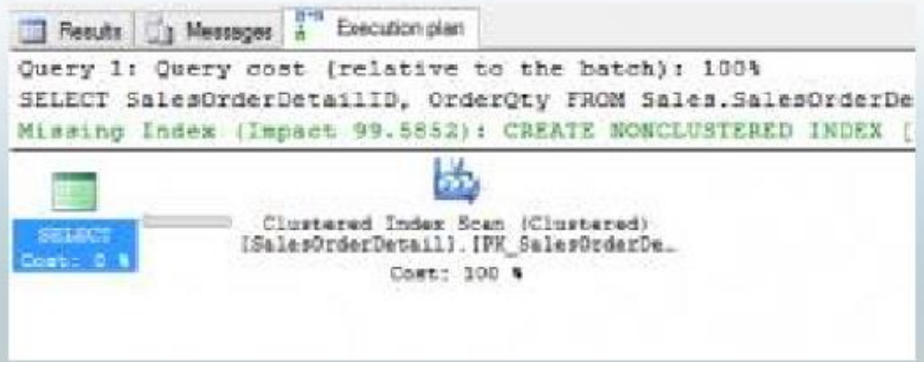


Parameter Sniffing

```
1  SELECT SalesOrderDetailID, OrderQty
2  FROM Sales.SalesOrderDetail
3  WHERE ProductID = 897
4
5  SELECT SalesOrderDetailID, OrderQty
6  FROM Sales.SalesOrderDetail
7  WHERE ProductID = 945
8
9  SELECT SalesOrderDetailID, OrderQty
10 FROM Sales.SalesOrderDetail
11 WHERE ProductID = 870
```



```
1  CREATE PROCEDURE Get_OrderQuantity
2  (@ProductID int)
3  AS
4  SELECT SalesOrderDetailID, OrderQty
5  FROM Sales.SalesOrderDetail
6  WHERE ProductID = @ProductID
```




Microsoft