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While we are waiting….

- **This session will be delivered in English only**
  - But I have colleagues from the local office who speak Chinese and can help with questions.
- **Target audience is intermediate level SQL Server professionals**
  - SQL Server experts should feel free to attend other sessions

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Performance tuning for non-beginners but not yet experts

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Before we begin

- **Goals**
  - Understand key performance influencers
  - Review common performance monitoring tools and techniques
  - How to interpret the data and determine what best practices are relevant to your environment
  - Review actual customer performance tuning mistakes
- **Non-goals**
  - Make you a SQL Server performance monitoring/tuning expert
  - Deep dive on features or tools
    - But feel free to ask questions
  - Provide performance troubleshooting magic bullets
  - Flashy demos

Intermediate level session on performance?

- **Plenty of content for beginners**
- **Plenty of content for expert level**
- **Not everybody can jump from A to Z in one step**
- **A lot of the content in this space is too cryptic and confusing for the average Joe**
- **This Joe does not believe you need to be an expert to find performance problems**
  - Though you might need help fixing them
    - But at least you know what needs to be fixed
      - And you'll learn to spot real experts vs. those who read a lot of blogs and repeat what they read

Agenda

- Understanding performance
- Measuring and tracking
- Interpreting the data
- Practical solutions

Agenda

- **Understanding performance**
  - **What is performance**
  - Performance influencers
- **Measuring and tracking**
- **Interpreting the data**
- **Practical solutions**

What is performance

- **Fulfilling workload demands within a period deemed acceptable or agreed upon by the user[1]**
  - Guaranteed < 2s business transaction response time
  - 130,000 database transactions per second
  - Loading >1 billion rows an hour
  - 18G**B**/s storage subsystem
  - 75seconds RTO for SQL Server in a Failover Cluster
  - Backup 2TB per hour over the network
  - Restore 1.3TB database in under 30 minutes
  - DBCC DBREINDEX on a 3 billion row table (ok, probably not a good idea)

[1] DBAs are just another class of user

Performance and scalability

- **Scalability is the level of performance maintained as workload influencers increase**
  - ✓ ERP application
    - 5 users: 2 seconds query response time
    - 700 users: 2.3 seconds query response time
  - × Generate year end report for
    - 300GB database: 85seconds
    - 1.5TB database: 30 minutes

Agenda

- **Understanding performance**
  - What is performance
  - **Performance influencers**
- **Measuring and tracking**
- **Interpreting the data**
- **Practical solutions**

Performance influencers

- **User workload**
  - DBAs are a special class of users
- **System & infrastructure resources**
  - Server, storage, interconnects, networks
- **Optimization**
  - Workload and resources sized and configured appropriately for your performance requirements at your require level (scale)
- **Contention**
  - A performance blocker that highlights a system's ability to scale (or not)
- **Environment**
  - Mostly stuff beyond your control like data center, ISP, workload source (e.g. end-user PC)

Agenda

- Understanding performance
- **Measuring and tracking**
- Interpreting the data
- Practical solutions

Measuring and tracking

- **Measures will vary depending on user workload**
  - Accounting will have very different performance metrics from an online trading – financial analyzer metrics are nothing like either of those
- **Different perspective of the same workload will have different measures**
  - Retail POS system
    - Cashier cares about items being scanned and registered quickly
    - Store manager cares about sales totals at any time
    - Loss prevention specialist wants to know quickly if items registered in POS equals to decrease in automated inventory manager

Measuring and tracking

- **Workload: measures will vary depending on the workload type**
  - Accounting will have very different performance metrics from online trading – financial analyzer metrics are nothing like either of those
- **User: different perspective of the same application will have different measures**
  - Library information system
    - Image recording/scanning clerk cares about fast BLOB inserts
    - Researcher needs fast searches on large data sets across multiple formats
  - Retail POS system
    - Cashier cares about items being scanned and registered quickly
    - Store manager cares about sales totals at any time
    - Loss prevention specialist wants to know quickly if items registered in POS equals to decrease in automated inventory manager

What to measure and track

- **Different application admins/owners track different performance metrics**
  - Not always aligned with what users care about
- **DBAs have some basic metrics that are "almost" universally helpful**
  - Resource utilization
  - Workload response time
  - Contention and waits
- **Important: performance metrics taken at any point in time without a baseline reference is often not useful**

Baseline

- **Establishes "known behavior"**
  - Resource utilization levels for a given workload and scale
    - Order entry system with 500 concurrent users consumes x GB RAM, y% sustained average CPU utilization – certified by ISV to scale almost linearly up to 11,000 concurrent users
  - User workload query response times
    - Monday 8am-11am: 2-5 seconds
    - Friday 12pm-4pm: 5-12 seconds
    - Other times: 1-3 seconds
- **Documents acceptable performance – your performance SLA**

Without a baseline

- **Networks never have problems**
  - We use multiple redundant 10Gb/s switches and average reliability is around 99.98%, what network problem?
- **Storage is never the problem**
  - We have two 2Gb/s ports from your server to the SAN, you are only using 400MB/s, go back and tune your SQL queries
- **End users can “instinctively” tell if performance is bad**
  - Why is it very slow today? It is usually a lot faster. You must have done something wrong during the upgrade.
- **End users’ PCs/laptops are always working fine and nothing has changed (or ever changes)**

Without a baseline

- Databases are guilty until proven innocent
- Without documented performance metrics and baselines you just can't win
- Especially if you have just performed a major operation (e.g. just upgraded to SQL Server 2008 R2)
- Difficult to convince other parties to investigate their areas (see previous slide)

Case study 1 – blame the upgrade

- **Major medical health care provider**
- **3 months upgrade planning and testing**
- **Successful upgrade over weekend**
- **Normal operations Monday morning; 6 phone calls and multiple emails starting 130pm**
  - Complaints about very slow queries, timeouts, etc…
  - Blames DBAs for botching the upgrade
  - Managers and senior managers put on CC

Case study 1 – blame the upgrade

- **DBA team reviews database server load and resource utilization**
  - Server not breaking a sweat
  - Network operations center (NOC) says network is healthy
  - Storage monitor shows light loads
  - DBAs run tests from local clients and verified performance metrics very close to baseline
    - Blocker scripts, long running queries, etc… all show nothing suspicious
- **Eliminated database, server, storage – focus on network**
- **2.5 hours later, faulty switch at Mexico office discovered**
  - NOC still says network is ok (apparently local network equipment problems don't count)
  - Other local US user problems not related

Basic measures independent of applications

- Storage
- Memory
- CPU
- Network

Storage

- **This is the physical foundation of your database**
- **80% deployments (that I've seen or worked on) have sub-optimal or incorrectly configured storage**
  - Including those certified by a storage vendor
- **Always test (SQLIO tool) before deployment**
- **Many counters and waitstats data available to monitor**
- **Start with the basics**
  - IOPS
  - Throughput
  - Latency
  - Queuing

Storage

Metric	Data source	Considerations
IOPS	Performance Monitor • Average disk read/write per second	• Number of I/O requests per second • Type of disk and size can affect this greatly • E.g. 2.5” SAS can sustain ~180 IOPS, 3.5” 15k rpm SCSI sustains ~130 IOPS

Throughput	Performance Monitor
	• Disk read/write bytes per second
		• Bytes throughput per second
		• Beware of B vs b
		  • 1Gb/s ~ 125MB/s
		  • 3Gb/s ~ 300MB/s

Latency	Performance Monitor
	• Average disk sec per read/write
		• Latency of I/O operations
		• Typically[1]
		  • Log: 1-5ms (ideally <1ms)
		  • Data (OLTP): 5-20ms (ideally <10ms)
		  • Data (DSS): 20-30ms

Queuing	Performance Monitor • Logical/Physical disk: Average disk queue length	• Number of I/O requests that cannot be serviced immediately • Value is measured across all disks for direct attached storage

[1] SQL Server Pre-deployment IO Best Practices

Memory

- **Next in-line in the list of common performance bottlenecks**
- **Difficult to really determine how much is enough given SQL Server's memory management approach**
  - Measure in reverse; look for pressure
- **Further complicated with NUMA servers**
  - One or more nodes may have severe memory pressure while other nodes are idle
- **Often result in performance problem symptoms in other areas**
- **Start with the basics**
  - Available free memory
  - Memory pressure hints

Memory

Metric	Data source	Considerations
Available free memory	Performance Monitor • Memory:Available Mbytes • SQLServer:BufferManager\Free Pages	• Tracks available system memory for use • Total number of pages on the free list
Memory pressure hints	Performance Monitor • SQLServer:BufferManager\Free list stalls /sec • SQLServer:Memory Manager\Target Server Memory (KB) and SQLServer:Memory Manager\Total Server Memory (KB) DMV • Sys.dm_os_wait_stats	• Tracks potential memory pressure by measuring number of free page requests that are not granted immediately • Track what SQL Server thinks it could use vs what it current is able to use • Track memory grants pending

Be careful with these commonly "recommended" counters

- **Often recommended in public forums, blogs, events as counters to determine if memory is adequate**
  - Cache hit ratio >90%
    - Highly workload dependent – if the queries do not touch the same data, hit ratio will be low but this is not a clear indicator of where the performance problem might be
  - Page life expectancy >300
    - Can be workload dependent and behavior is similar to cache hit ratios
  - Memory grants pending <2
    - Theoretically tracks memory requests pending but this can be caused by contention (e.g. blocking), not just lack of memory
- **Correlate multiple data point; don't just measure one**

CPU

- **Sustained high activity may or may not indicate bottlenecks or problems**
- **Hardware faults can sometimes result in high CPU utilization and/or context switches**
- **Start with the basics**
  - Overall utilization
  - CPU pressure hints

CPU

Metric	Data source	Considerations
Overall utilization	Performance Monitor • Processor:%Processor Time	• Amount of time the CPUs are actually doing work across the entire system • Value is for all CPUs in the system
CPU pressure hints	Performance Monitor • System:Processor Queue Length	• Total number of threads awaiting CPU resource • Value is for all CPUs in the system

Network

- **Usually one of the easiest resources to manage for performance**
- **Start with the basics**
  - Overall utilization
  - Device errors
- **Be careful with some commonly recommended counters**
  - Output queue length
    - Dependent on operating system implementation (E.g. always zero in Vista)

Network

Metric	Data source	Considerations
Overall utilization	Performance Monitor • Network Interface: Bytes Total /sec	• Measures volume of data sent and received by each network adapter or cumulative for all NICs in the system
Device errors	Windows Event Log • System Logs: network device errors	• Non-critical hardware faults are logged here • Critical hardware faults can result in blue-screen

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Interpreting the data: storage*

Data	Considerations

• Average disk read/write per second
• Disk read/write bytes per second
	• Ensure system requirements are less than storage capacity
	• If using SAN, ensure SAN cache can flush to disk faster then workload requests fills up SAN cache
	• Beware of B vs b for bytes/second
	  • 1Gb/s ~ 125MB/s
	  • 3Gb/s ~ 300MB/s

• Average disk sec per read/write	• Hardware and configuration can affect values
	• Log: 1-5ms (ideally <1ms)
	  • Minimal tolerance for exceeding 5ms
	• Data (OLTP): 5-20ms (ideally <10ms)
	  • Moderate tolerance levels dependent on application
	• Data (DSS): 20-30ms
	  • Higher values are not uncommon and may not be a performance issue but try to keep <50ms

• Logical/Physical disk: Average disk queue length	• Use logical value for SAN devices and corroborate with SAN data

***Beware of polling intervals**

Interpreting the data: storage

- **Problems with storage can result in many different symptoms across the system**
- **General statements like**

  "…storage performance problem…"

  "…query timed out…"

  is not helpful in most modern systems – get the specifics
  - HBA
  - Switch
  - SAN
    - Ports
    - Cache
    - Disks

Case study 2 – blame SQL Server scalability

- **Top 10 largest banks in the US**
- **Commercial customers system upgrade SQL Server & hardware**
- **Phase 1 (SQL Server) stable – tens of millions transacted daily**
- **Phase 2 (new hardware) nearing rollout; expecting 200% increase in customer base within 6-12 months then stable**
- **Second largest possible server in the market (at the time) – sized to handle ~10x growth**
- **Top of the line SAN – sized to handle at least 12x growth**
- **POC stress test consistently collapses at 3x ~ 4x load**
  - Blamed SQL Server scalability; suggestions to use ***O***ther database
  - All other parties claim no-fault

Case study 2 – blame SQL Server scalability

- **POC background**
  - Realistic workload capture/replay
  - Server burn-in tests onsite (memory, CPU, peripherals)
  - Theoretical maximum throughput & capacity for SAN calculated
    - Alerted sponsor and vendor that SAN is significantly under configured – dismissed by vendor citing POC team lacks knowledge on brand new SAN
  - Actual SAN capacity tests onsite (IOPS, MB/s, latency)
    - Basic tests support POC team's calculations
- **Full POC tests fails with multiple indicators pointing to SAN overload**
  - 1.5 days before SAN team finally concede they had erred in their data collection and interpretation (neglected to mention original design error)
  - This was with detailed documentation and extensive data
- **Re-designed SAN with POC team guidance supported new stress tests up to 7x workload – load generators exhausted**

Case study 2 – blame SQL Server scalability

- **Chasing symptoms**
  - Query timeouts
  - CXPacket waits – someone read on a blog that this was bad
  - Context switching
  - Compilation & re-compilations – apparently this is bad too
  - Load generators' CPUs constantly ~90%
  - Application's history of performance issues – send developers for ~~flogging~~ training
- **Root cause**
  - Storage unable to keep up
    - Overlapping stripes – same HDDs striped twice to create LUN
    - Over estimated SAN cache capacities – not enough HDDs to flush cache quickly

Interpreting the data: memory

Data	Considerations

• Memory:Available Mbytes
• SQLServer:BufferManager\Free Pages
• SQLServer:BufferManager\Free list stalls /sec
• SQLServer:Memory Manager\Target Server Memory (KB) and SQLServer:Memory Manager\Total Server Memory (KB)
	• Appropriate values dependent on type of application and volatility of query activity
	• Reasonable starting points
	  • Available Mbytes: >50
	  • Free pages: >640
	  • Free list stalls: <2
	  • Target/total memory: dependent on total physical memory on server and number/type of workloads active

• SQLServer:Buffer Node\Free pages • SQLServer:Buffer Node\Foreign pages • SQLServer:Buffer Node\Remote node page lookups /sec	• Additional counters to monitor for NUMA based servers • Local node memory usage and cross-node usage dependent on application behavior • SQL Server tries to work efficiently within local node but application design and/or behavior can prevent this

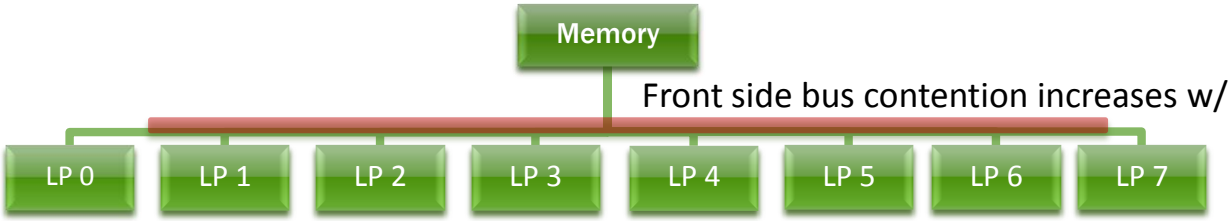
Case study 3 – blame SQL Server scalability

- **Major retail chain running sales monitoring and inventory tracking application**
- **Regular performance degradation but non-discernable pattern or root causes**
- **System review indicates storage IO bottlenecks**
  - CPU utilization low to moderate
  - Overall memory utilization low to moderate
- **Upgraded SAN; storage IO bottlenecks removed**
- **Performance issues persist**

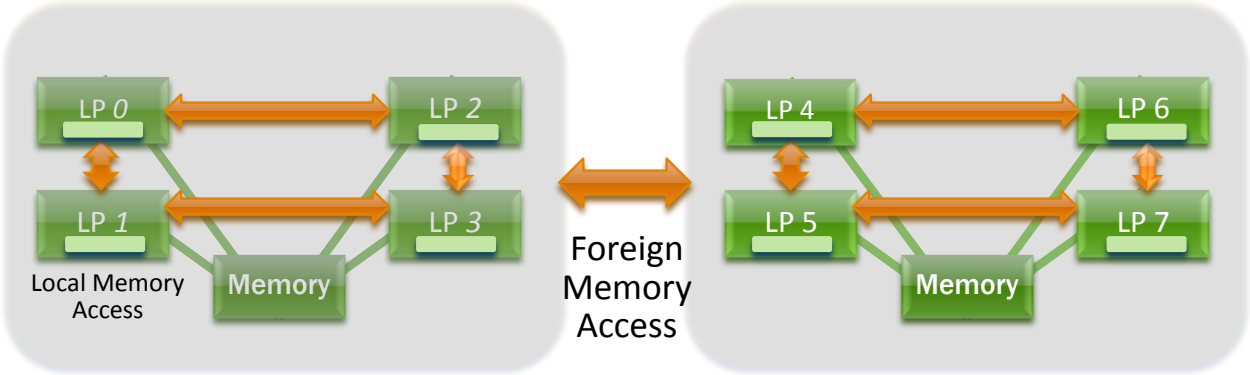
Case study 3 – blame SQL Server scalability

- **Engaged specialists for detailed system review**
  - Occasional storage bottlenecks still exist
  - 1-2 out of 4 NUMA nodes experiences memory pressure routinely
    - Induced by application design and data patterns
      - Manually managed workload/worker threads
      - Long running transactions
      - Vastly different data volume from hundreds of sources – from few MB to few GB

NUMA



Symmetric Multiprocessing Architecture (SMP)



Non-Uniform Memory Access (NUMA)

Foreign memory access >> local memory access

Interpreting the data: CPU

Data	Considerations
• Processor:%Processor Time	• Reasonable starting point • <80% but highly dependent on nature of application and spike values
• System:Processor Queue Length	• Reasonable starting point • <10 per logical CPU

Interpreting the data: network

Data	Considerations
• Network Interface: Bytes Total /sec	• Compare values to NIC capacity • Again, beware of B vs b
• System Logs: network device errors	• Device errors are bad news

What about other counters/waitstats?

- **There are many more you can monitoring and analyze**
  - Queries and query plans
  - Filestats
  - Waitstats
  - Index usage
  - Statistics
  - Extended events
- **These will help you identify the root cause of the problems**
  - Always use both resource utilization data with waitstats data in the context of the specific application

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Non-expert solutions

- **Default reports**
  - Build your own once you're familiar with it
  - Don't run this too frequently
- **Profiler (or SQL Trace) + Performance Monitor**
  - Correlate data from these tools
- **Performance data warehouse or scheduled DMV snapshots**

Dynamic Management Views (DMVs)

- Really useful once you get past the basics; for example:
- Top 50 statements by IO

Top 50 queries by IO

```
SELECT TOP 50
        (qs.total_logical_reads + qs.total_logical_writes)
   /qs.execution_count
   as [Avg IO]
      , substring (qt.text,qs.statement_start_offset/2
      , (case when qs.statement_end_offset = -1
            then len(convert(nvarchar(max), qt.text)) * 2
       else qs.statement_end_offset end -
   qs.statement_start_offset)/2) as query_text
      , qt.dbid
      , qt.objectid
FROM sys.dm_exec_query_stats qs
CROSS APPLY sys.dm_exec_sql_text (qs.sql_handle) as qt
ORDER BY [Avg IO] DESC
```

IO waits per file

```
select database_id
       , file_id
       , io_stall,io_pending_ms_ticks
       , scheduler_address
from sys.dm_io_virtual_file_stats (NULL, NULL) as t1,
     sys.dm_io_pending_io_requests as t2
where t1.file_handle = t2.io_handle
```

TempDB usage tasks and SQL

```
SELECT t1.session_id,
(t1.internal_objects_alloc_page_count + task_alloc) as allocated,
(t1.internal_objects_dealloc_page_count + task_dealloc) as
 deallocated, t3.sql_handle
from sys.dm_db_session_space_usage as t1,
        sys.dm_exec_requests t3,
(select session_id,
   sum(internal_objects_alloc_page_count)
                       as task_alloc,
   sum (internal_objects_dealloc_page_count) as
        task_dealloc
      from sys.dm_db_task_space_usage group by session_id) as t2
where t1.session_id = t2.session_id and t1.session_id >50
and t1.database_id = 2    --- tempdb is database_id=2
and t1.session_id = t3.session_id
order by allocated DESC
```

Indexes that are not used

```
SELECT object_name(i.object_id), i.name
FROM sys.indexes i, sys.objects o
WHERE  i.index_id NOT IN
       (select s.index_id
        FROM sys.dm_db_index_usage_stats s
        WHERE s.object_id=i.object_id
        AND i.index_id=s.index_id
        AND database_id = <dbid> )
AND o.type = 'U'
AND o.object_id = i.object_id
ORDER BY object_name(i.object_id) ASC
```

Hardware setup

- Hardware vendors have built-in tests for most environments
- More thorough testing can be performed by vendor or certified partners

Case study 4 – blame unproven technologies

- **Global bank with extensive SQL Server and other database deployments**
- **Major SQL Server infrastructure overhaul and consolidation preparation**
  - Largest x64 server in the market – fully loaded
  - Latest enterprise SAN – almost fully loaded
  - Windows Server 2008 R2 and SQL Server 2008
- **HA and DR by design**
  - Large multi-node failover cluster
  - SAN replication for DR

Case study 4 – blame unproven technologies

- **System design reviewed and approved by specialists from MS**
  - Secondary review and approval by independent SQL Server experts
- **Servers & storage setup and configured by specialists from hardware principal and SI partner**
  - All the latest & greatest from server DIMM to physical HDD
- **Never ending problems with performance (right from the start)**
  - Unable to complete even one full cycle of performance testing
  - Intermittent cluster failures, occasional system dumps, several bluescreens
  - Some failures require full system rebuild – 2 days each time
- **Unable to even hand-over to QA team after 2 months**

Case study 4 – blame unproven technologies

- **Chasing symptoms**
  - Software setup taking a really long time – blamed storage performance
  - Bluescreens – blamed hardware, Windows
  - Intermittent cluster failures – blamed use of latest and greatest of everything
  - Never before seen such high level of instability/problems – blamed everybody (including performance test team for system overload)
- **Root cause**
  - Poorly seated components in server discovered with hardware diagnostic tools ~ 2 days work
    - Strip, rebuild, burn-in, full-test – handover to QA in < 2 weeks

Summary

- **Performance monitoring and troubleshooting can be done by the average Joe**
- **Baseline data is critical**
- **Start with the basics**
  - Capture everything including the kitchen sink approach is very intrusive and usually not helpful
    - If you must capture everything (sometimes it's right), analyze in layers
- **Do not draw conclusions based on singular data points or using raw data by itself**
- **Leverage what already exists before creating**
- **What and how are easy questions, why and why not are the tough questions**

Resources

- **Troubleshooting performance problems in**
  - SQL Server 2008
    http://msdn.microsoft.com/en-us/library/dd672789.aspx
  - SQL Server 2005
    http://technet.microsoft.com/en-us/library/cc966540.aspx
- **SQL Server Pre-deployment IO Best Practices**
  - http://sqlcat.com/whitepapers/archive/2008/10/03/running-sql-server-2008-in-a-hyper-v-environment-best-practices-and-performance-recommendations.aspx
- **SQL Server waits and queues**
  - http://sqlcat.com/whitepapers/archive/2007/11/19/sql-server-2005-waits-and-queues.aspx
- **SQLCAT best practices and high watermark customer experiences**
  - http://sqlcat.com/Default.aspx

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Questions?

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