IBM® Storage

IBM FlashSystem max configuration with SAP HANA

Version 1.0

IBM Storage Team

Contents

About this document

This paper is intended as an IBM solution reference for using IBM FlashSystem with SAP HANA in an SAP HANA tailored data center integration (SAP HANA TDI) environment. SAP HANA TDI allows the SAP customer to attach external storage to the SAP HANA server. This paper demonstrates the storage configuration to run the maximum number of HANA nodes on one IBM FlashSystem. This document also provides recommended configuration steps for the storage system and the Power server to improve performance.

This document is written for system integrators, system or storage administrators, customers and business partners with knowledge about SAP HANA and IBM System Storage.

Scope

This document was developed using the following software tools:

- SAP HANA 2.0 database
- IBM Storage Insights
- SAP HANA Hardware and Cloud Measurement Tools (HCMT)
- IBM Storage Modeller (STORM)

This technical report does not:

- Replace any official manuals and documents issued by IBM
- Explain installation and configuration of SAP HANA

Prerequisites

For a list of all IBM storage systems certified for SAP HANA production please refer to:

- Certified and supported SAP HANA hardware

It is assumed that you are familiar with and have basic knowledge of the following products:

- IBM FlashSystem
- SAP HANA database
- IBM Power server

IBM FlashSystem

The IBM FlashSystem family combines the performance of flash and end-to-end Non-Volatile Memory Express (NVMe) with the reliability and innovation of IBM FlashCore technology, the ultra-low latency of Storage Class Memory (SCM), the rich features of IBM Spectrum Virtualize and AI predictive storage management and proactive support by Storage Insights. Built in a powerful 2U enterprise-class, blazing fast storage all-flash array, as shown in Figure 1.

NVMe protocol inside FlashSystem
NVM Express (NVMe) is an optimized, high-performance scalable host controller interface designed to address the needs of systems that utilize PCI Express-based solid-state storage. The NVMe protocol is an interface specification for communicating with storage devices. It is functionally analogous to other protocols, such as SAS. However, the NVMe interface was designed for extremely fast storage media, such as flash-based solid-state drives (SSDs) and low-latency non-volatile storage technologies.

NVMe storage devices are typically directly attached to a host system over a PCI Express (PCIe) bus. That is, the NVMe controller is contained in the storage device itself, alleviating the need for an additional I/O controller between the CPU and the storage device. The architecture results in lower latency, throughput scalability, and simpler system designs. NVMe protocol supports multiple I/O queues, versus legacy SAS and SATA protocols that use only a single queue.

These all-flash systems include IBM Spectrum Virtualize software and introduce remarkable new features in comparison to the predecessor models:

- End-to-end **NVMe** support: NVMe is a logical device interface standard from 2011 for accessing non-volatile storage media that is attached via a PCI Express bus.
- **Lower latencies** through RDMA: Direct memory access from the memory of one node into that of another without involving either one's operating system.
- **Data reduction pools** (DRP) represent a significant enhancement to the storage pool concept. Now with the introduction of data reduction technology, compression, and deduplication, it has become more of a requirement to have an uncomplicated way to stay “thin”.
- **FlashCore Modules** (FCMs) or industry standard NVMe drives can be used for the IBM FlashSystems. If the FCM option is chosen, then the user can take advantage of the built-in hardware compression, which will automatically try to compress the stored data when written to the drives.
- Thin-provisioned **IBM FlashCopy** uses disk space only when updates are made to the source or target data, and not for the entire capacity of a volume copy.
- **HyperSwap** capability enables each volume to be presented by two IBM FlashSystems. This high-availability configuration tolerates combinations of node and site failures, using host multipathing driver, based on the one that is available for the regular IBM FlashSystem.

- The IBM FlashSystem supports the new low latency, high speed Storage Class Memory (SCM). SCM is a non-volatile memory device that performs faster (~10µs) than traditional NAND SSDs(100µs), but slower than DRAM (100ns).
- ***IBM Storage Insights is an additional part of the monitoring capability of the IBM FlashSystem 9200 system and supplements the views available in the GUI.***
- 

Figure 1: IBM FlashSystem control enclosure

For more information about the IBM FlashSystem family see the following resources:

- IBM FlashSystem 9200 and 9100 Best Practices and Performance Guidelines: http://www.redbooks.ibm.com/abstracts/sg248448.html?Open

- SAP HANA certified and supported IBM storage systems https://www.sap.com/dmc/exp/2014-09-02-hana-hardware/enEN/enterprise-storage.html#categories=certified%23International%20Business%20Machines%20Corporation

IBM Storage Insights

IBM Storage Insights is offered free of charge to customers who own IBM block storage systems. It is a secured IBM Cloud storage service that monitors IBM block storage and provides advanced functionality for alerting.

It provides single-pane views of IBM block storage systems, such as the Operations dashboard and the Notifications dashboard. With the information that is provided, such as the diagnostic event information, key capacity and performance information, and the streamlined support experience, you can quickly assess the health of your storage environment and get help with resolving issues. And, on the Advisor page, IBM Storage Insights provides recommendations on the remedial steps that can be taken to manage risks and resolve issues that might impact your storage services.

All IBM FlashSystem performance graphs in this paper where created with IBM Storage Insights.

For more information about IBM Storage Insights see the following resources:

- https://www.ibm.com/products/analytics-driven-data-management

IBM Storage Modeller

Storage Modeller (StorM) is an IBM sales process tool that is designed to model Storage Solutions for client applications. This tool is for use by IBM and Business Partner technical sellers. The mathematics and algorithms of this tool are considerably more accurate than older estimators and reflect the latest technologies used in modern storage systems.

By specifying the FlashSystem 7200 and the HANA workloads in StorM, we aim to prove, that our performance test results in a live environment match with the performance output predictions from StorM. Our ambition is to give planners confidence that using StorM they can accurately 'right-size' their planned SAP HANA Storage environment

IBM SAP HANA Setup

For the testing covered by this document the following setup was used, as shown in Figure 2 . The hardware setup consists of:

- IBM FlashSystem 7200 with:
  - 768 GB System Memory per I/O Group
  - 24 x 4.8 terabytes usable (TBu) / 21.99 terabytes effective (TBe) NVMe IBM FlashCore Modules (FCM) 2.0
  - 2 x 32Gb FC 4 Port Adapter Pair per node

- IBM Power System H922, 2TB Memory
- 32Gb SAN infrastructure
- 28 LPARS
  - 8 vCPUs per LPAR
  - 32GB memory
  - Operating System: SLES 15 SP2
  - HANA 2.0 SPS05

28 Power LPARs were used for the SAP HANA database. The LPARs were attached to an IBM FlashSystem 7200 volumes from two DRAID 6 pools. Each DRAID 6 pool contains 12 FCM drives.

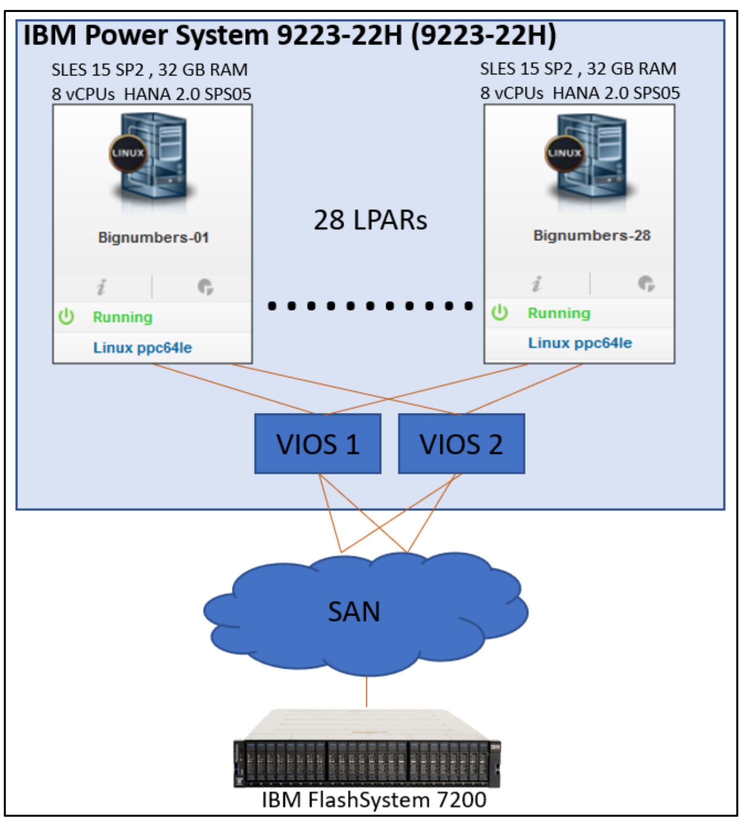

Figure 2: Hardware setup for HANA max configuration testing

To validate the performance, we used the official SAP HANA hardware and cloud measurement tool (HCMT). It allows customers and partners to collect information on the infrastructure intended for SAP HANA deployment. The tool measures whether the planned hardware complies with the requirements defined by SAP. Furthermore, it gauges whether the storage system planned for SAP HANA deployment can achieve satisfactory performance by meeting the minimum Key Performance Indicators (KPIs) requirements as well as satisfactory overall performance given the intended SAP HANA usage. The measurement results are saved into a file, which can be uploaded to the SAP HANA hardware and cloud measurement analysis for further analysis and reporting.

HCMT runs parallel on all involved LPARs controlled by a single host, to ensure each system is performing the same kind of workload in a given time.

For further information about the SAP HANA HCMT tool, please refer to:
https://help.sap.com/doc/af47cce52aaa4ed4992d42d3cf319d62/2.0/en-US/How_to_Use_the_SAP_HANA_Hardware_and_Cloud_Measurement_Tools_en.pdf

Performance considerations

This stress test is designed to push the involved systems to their limits. Therefore, configuring everything for optimized performance is a central requirement. Optimizations can be applied to the IBM FlashSystem, the VIO server and the host operating system.

Storage:

The utilization of several components of the IBM FlashSystem is partially near the capacity limit, so tuning the system is an important part of the overall setup. During the tests, we observed for example a high CPU load of nearly 80%, as shown in Figure 3. The reason for this is the required high bandwidth of the test workload. High saturation of the FCM drives was also seen by read operations with large block sizes (16Mb and 64Mb). Configuring the system with an optimized setup reduces the overutilization of the affected components and prevents the system from becoming overloaded.

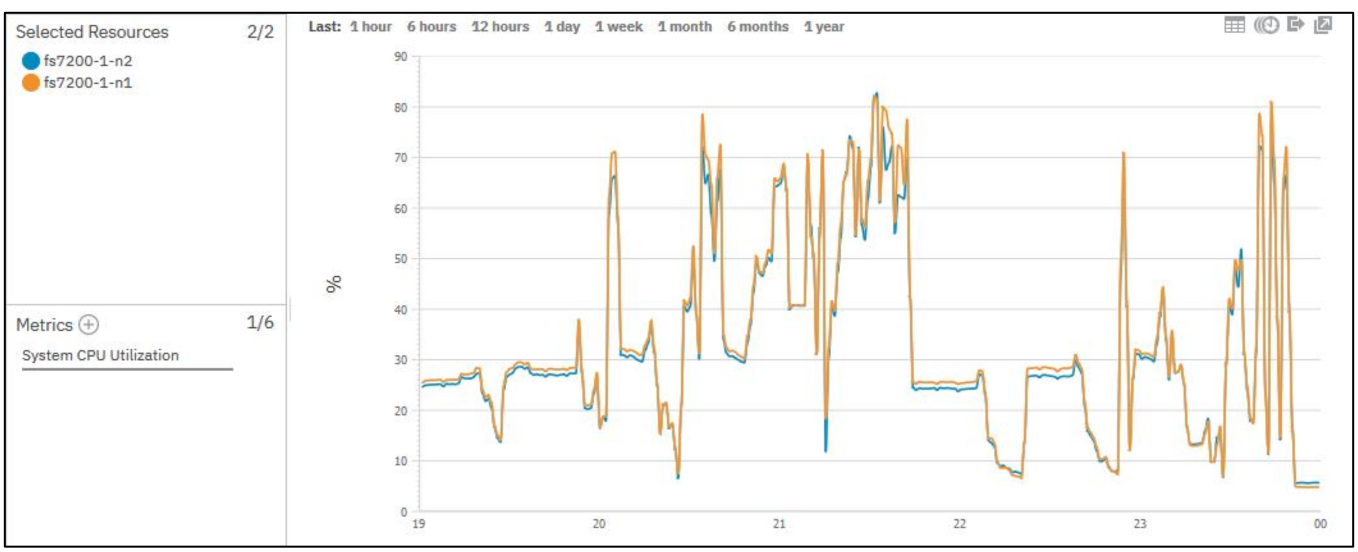

Figure 3: FlashSystem CPU utilization per node during the test

To reduce the CPU overhead, any kind of CPU intensive configuration should be avoided. Data Reduction Pools, for example, are known to require a lot of CPU power. Therefore, no DRP pools are allowed here. This means that data deduplication and compression will not work. However, the inline compression of the FCMs is not affected – this feature is transparent for the storage system and does not impact the CPU performance.

It’s also important to balance the workload of the FCM drives. As we have 24 drives available in our setup, the following configuration gave us the best results:

- We created DRAID6 arrays with a 9 +P +Q distribution of 12 drives each.
- Two storage pools (each one containing exactly one DRAID6 array mdisk) were used.
- The VDisks were equally distributed across those pools, and they were all formed by a single VDisk copy.

There is no need to create fully allocated volumes – thin provisioning does not seem to have a negative effect in our tests. However, there is one last aspect which should be taken into consideration. The workload is really high, and there is not always a guarantee that it will be distributed fairly across all 28 hosts. One possibility to recover from this situation is to implement a set of throttles in the IBM FlashSystem. Throttles can be set for both IO/s and bandwidth on a per VDisk, per Mdisk Group or per Host basis. So, throttling the max. bandwidth of data a single host can read, avoids that this particular host will consume to much bandwidth – which is then not available for other hosts (avoiding the noisy neighbour problem).

VIO Server:

In a PowerVM environment, all virtualized IO is handled by one or more Virtual IO Servers. Fibre channel (FC) adapters are virtualized via N_Port ID virtualization (NPIV), and VIO servers can be used to create one or more virtual FC adapter slots for each LPAR. This means that the underlying physical FC adapters may have to deal with a very high workload. Additionally, the FC virtualization stack of the VIO servers needs to be tuned so that it does not add too much additional latency. Considering that SAP HANA workload depends on low latencies, especially while writing the log journal it is recommended to address the following:

The first and most important step to do is to increase the number of IO queues on the involved physical FC adapters on each VIOs.
For more information, please refer to:
https://www.ibm.com/developerworks/aix/library/au-aix-performance-improvements-fc-fcoe-trs/index.html

The latest release of VIOs (3.1.2) implements NPIV Multiple-Queue, which might give additional benefit in terms of NPIV performance. For more information about this new feature, please take a look at the current Power9 documentation at IBM Knowledge Center:
https://www.ibm.com/support/knowledgecenter/POWER9/p9hb1/p9hb1_npiv_multi_queue_support.htm

Next, adjust the processor and memory assignments for each VIO server, so that it does not suffer from a shortfall of resources. A good starting point for resource planning is still the IBM Power Systems Performance Guide. This document suggests adding additional 140MB memory for each virtual Fibre Channel adapter. We increased that value to 512MB, since the backing devices are of type EN1B (PCIe3 LP 32Gb 2-port Fibre Channel Adapter), while the calculation in IBM Power Systems Performance Guide is still based on 8Gb Fibre Channel adapters.

Finally, use the Virtual I/O Server Performance Advisor to determine any kind of possible bottlenecks in the Virtual I/O Server configuration. The output of the VIOS performance advisor tool can be displayed in a web browser, as shown in Figure 4. For further information please refer to:
https://www.ibm.com/support/knowledgecenter/POWER9/p9hb1/p9hb1_vios_perf_adv.htm?pos=10

VIOS - Processor *Risk/Impact 1=lowest 5=highest*

	Name	Measured Value	Suggested Value	First Observed	Last Observed	Risk	Impact
	CPU Capacity	1.0 ent		11/25/2020 04:57 AM			
	CPU consumption	avg:16.2% high:21.0%		11/25/2020 04:57 AM	11/25/2020 05:43 AM		
	Processing Mode	Dedicated CPU		11/25/2020 04:57 AM			
	Processor Donation	off		11/25/2020 04:57 AM	11/25/2020 05:43 AM		
	SMT Mode	SMT8		11/25/2020 04:57 AM			

Figure 4: VIOS performance advisor output

Host:

The host configuration also has an impact on the overall I/O performance. Though most of the SAP HANA related settings described by various SAP Notes are related to CPU, memory or network performance configuration, the host's storage stack is another considerable component for optimization.
Before starting to implement specific settings, install the *saptune* package from SuSE and use it to configure the system for SAP HANA optimization. Most of the relevant settings are covered by *saptune*, which makes life much easier for HANA host administrators.

Saptune does not modify any of the relevant storage settings, so this is something which must be done afterwards. IBM has released the IBM System Storage Architecture and Configuration Guide for SAP HANA TDI which gives detailed instructions how to set up a SAP HANA host for use with IBM FlashSystem.
Furthermore, the common host attachment guide for Linux on IBM FlashSystem is found here:
https://www.ibm.com/support/knowledgecenter/ST3FR7_8.3.1/com.ibm.fs7200_831.doc/svc_FChostslinux_cover.html

As a deviation from this host attachment guide, we're using a modified multipath configuration. The value of the "*rr_min_io_rq*" parameter has been set to "8", while the host attachment guide's recommendation is "1". This defines the number of IO requests to route to a path before switching to the next in the same path group. SAP HANA runs lots of small I/O block sizes (4KB) and switching before at least 32KB have been written decreases the write performance significantly.

SAP HANA database server storage configuration

In the SAP HANA test environment, the filesystems for storing SAP HANA data volumes and SAP HANA transaction logs are located on LVM logical volumes. For log and for data dedicated LVM volume groups exist. The LVM physical volumes of these volume groups are provided by an IBM FlashSystem 7200.
We measured the IO behavior of the disks from the HANA data and log volume group.

Here is a quick overview of the /hana/data and /hana/log filesystem structure down to the corresponding IBM FlashSystem VDisks:

1) Filesystem on LVM logical volume /dev/VG_B10_DATA/LV_B10_DATA mounted as /hana/data/B10 and LVM logical volume /dev/VG_B10_LOG/LV_B10_LOG mounted as /hana/log/B10.
2) Each logical volume consumes 100% space of LVM volume group "VG_B10_DATA" and "VG_B10_LOG".
3) The following multipath devices are used as LVM physical volumes, as shown in Figure 5:

```
bignumbers-10:~ # pvs
  PV                  VG             Fmt  Attr PSize   PFree
  /dev/mapper/mpathb VG_B10_LOG     lvm2 a--   64.00g     0
  /dev/mapper/mpathc VG_B10_LOG     lvm2 a--   64.00g     0
  /dev/mapper/mpathd VG_B10_LOG     lvm2 a--   64.00g     0
  /dev/mapper/mpathe VG_B10_LOG     lvm2 a--   64.00g     0
  /dev/mapper/mpathf VG_B10_DATA    lvm2 a--  128.00g     0
  /dev/mapper/mpathg VG_B10_DATA    lvm2 a--  128.00g     0
  /dev/mapper/mpathh VG_B10_DATA    lvm2 a--  128.00g     0
  /dev/mapper/mpathi VG_B10_DATA    lvm2 a--  128.00g     0
  /dev/mapper/mpathj VG_B10_SHARED lvm2 a--   64.00g     0
```

Figure 5: LVM Physical Volumes

4) The “multipath -ll” command lists the UUID of these devices, as shown in Figure 6:

```
bignumbers-10:~ # multipath -ll | grep dm-
mpathe (360050768108002733800000000000028) dm-7 IBM,2145
mpathd (360050768108002733800000000000021) dm-6 IBM,2145
mpathc (36005076810800273380000000000001a) dm-5 IBM,2145
mpathb (360050768108002733800000000000013) dm-1 IBM,2145
mpatha (36005076802a580ada0000000000006e) dm-0 AIX,VDASD
mpathj (36005076810800273380000000000004b) dm-12 IBM,2145
mpathi (36005076810800273380000000000003c) dm-11 IBM,2145
mpathh (360050768108002733800000000000035) dm-10 IBM,2145
mpathg (360050768108002733800000000000030) dm-9 IBM,2145
mpathf (36005076810800273380000000000002f) dm-8 IBM,2145
```

Figure 6: Multipath devices

5) The corresponding data and log VDisks are listed in the IBM FlashSystem Web GUI, as shown in Figure 7.

Name	UID ↑	Capacity
Bignumbers-10-log1	600507681080027338000000000000013	64.00 GiB
Bignumbers-10-log2	60050768108002733800000000000001A	64.00 GiB
Bignumbers-10-log3	600507681080027338000000000000021	64.00 GiB
Bignumbers-10-log4	600507681080027338000000000000028	64.00 GiB
Bignumbers-10-data1	60050768108002733800000000000002F	128.00 GiB
Bignumbers-10-data2	600507681080027338000000000000030	128.00 GiB
Bignumbers-10-data3	600507681080027338000000000000035	128.00 GiB
Bignumbers-10-data4	60050768108002733800000000000003C	128.00 GiB
Bignumbers-10-shared	60050768108002733800000000000004B	64.00 GiB

Figure 7: List of IBM FlashSystem mapped VDisks

Results

By using the official SAP HANA HCMT measurement tool, it could be proven that all storage related key performance indicator targets have been met on IBM FlashSystem 7200 configured for running 28 instances of SAP HANA. This has been measured by using a single I/O group of the IBM FlashSystem 7200.
From the physics involved and our engineering experience we state that this quantity will scale linearly with increasing I/O groups given that the compute resources are correctly balanced and zoned. Therefore, the maximum configuration of the IBM FlashSystem 7200 is capable of running 112 SAP HANA instances, as shown in Table 1.

Table 1: FlashSystem 7200 scalability

IBM FlashSystem	Number of I/O groups	Number of SAP HANA worker nodes
7200	1	28
	2	56
	3	84
	4	112

With HCMT we performed many different workloads and we will show some examples in the following section.

- 4KB block log volume overwrite
  This is a typical database transaction log write pattern
- 16MB block data volume overwrite
  This is a typical database data volume write pattern

4KB block log volume overwrite

According to STORM the IBM FlashSystem 7200 can perform up to 120.000 IO/s before reaching the critical threshold of 80% CPU utilization with the given workload. In our test environment we see the following performance results. With our test environment we reached around 46.000 IO/s over all running LPARs. The limiting factor was the virtualization through virtual IO server where all LPARs share the same four physical fiber channel ports.

For a single HANA system, we see the following 4k write I/O rate per HANA log volume, as shown in Figure 8.

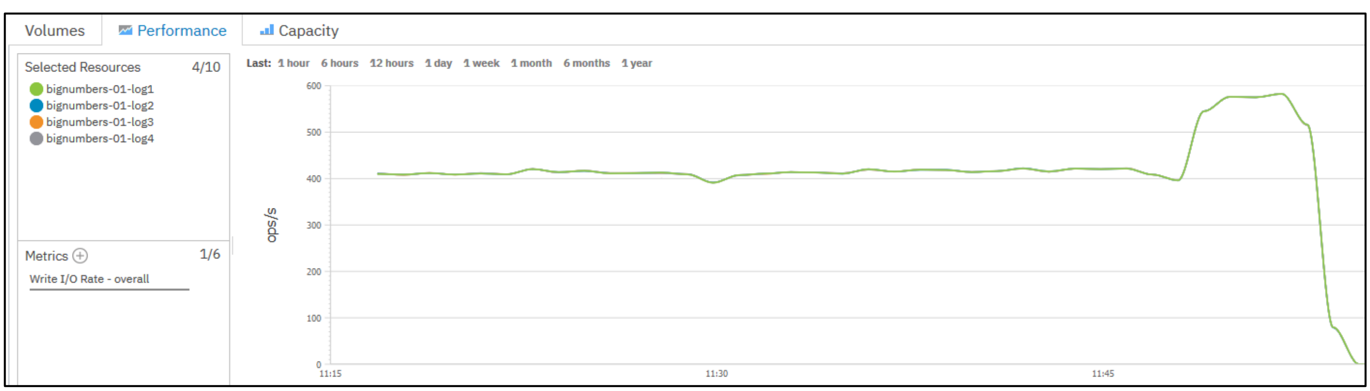

Figure 8: HANA log volumes "Write I/O Rate" of one HANA system

STorM calculates for that IO rate (400 IO x 28 LPARs x 4 volumes = 44800 IO/s) and a CPU utilization rate of ~ 30%. In our test environment we measured a CPU utilization of ~ 26% as shown in Figure 9.

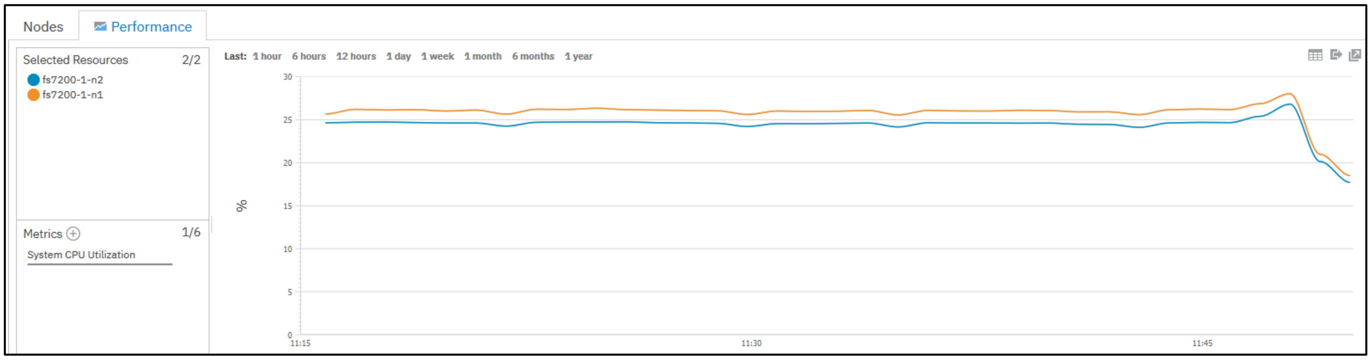

Figure 9:System CPU utilization for small block(4kb) writes

When writing small blocks, I/O latency is a critical factor and must be low. E.g. SAP requires less than 1ms write latency for 4kb blocks. StorM calculates 0,4ms for our workload and our measured results show 0,3ms, as shown in Figure 10.

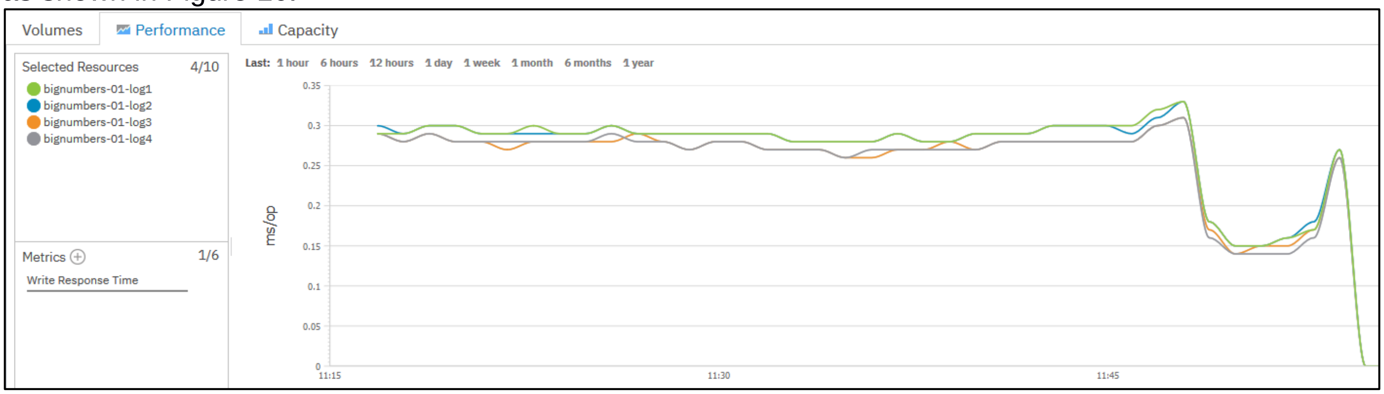

Figure 10: HANA log volumes "Write Response Time"

16MB block data volume overwrite

For a single HANA system, we see the following results for 16MB block writes on the HANA data volumes, as shown in Figure 11. The IBM FlashSystem handles ~ 7GB/s write performance in total for all HANA LPARs and the attached data volumes.

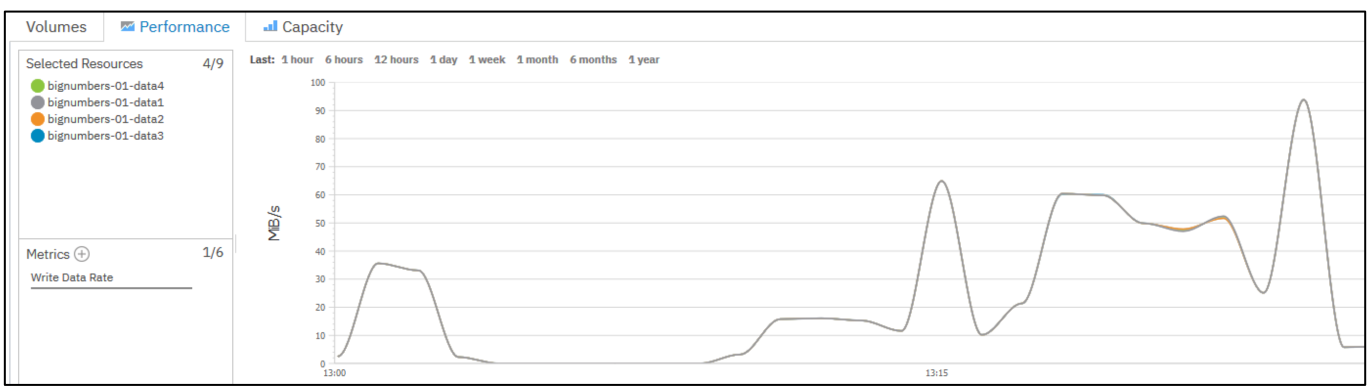

Figure 11: HANA data volumes “Write Data Rate for 16MB blocks

With 28 HANA LPARs we reached a CPU utilization of ~80%, as shown in Figure 12. This indicates a high utilization of the IBM FlashSystem 7200. So, we reached the maximum number of SAP HANA instances. If more HANA instances were required, we could add additional FlashSystem I/O groups or consider using a more performant IBM FlashSystem 9200.

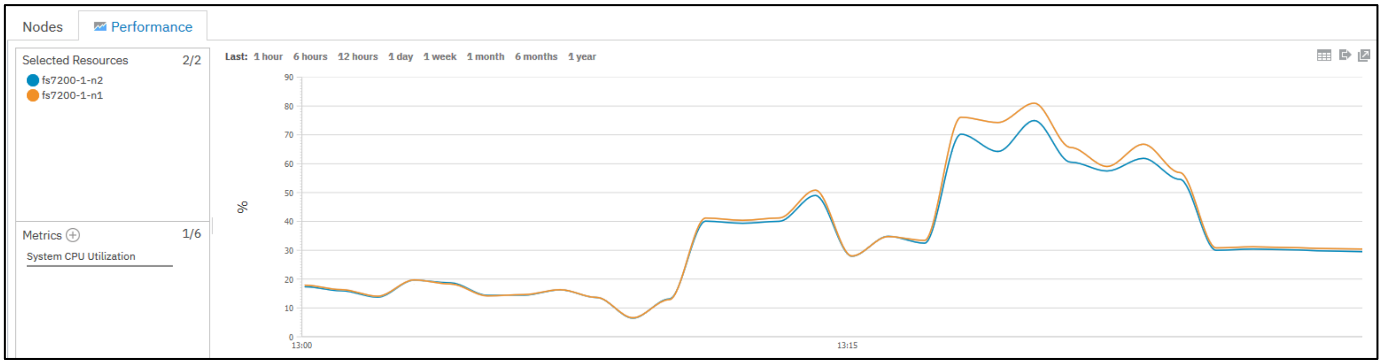

Figure 12: System CPU utilization for large block(16MB) writes

For the majority of customers, the high-performance IBM Flash System 9200 is probably not required for SAP HANA Workloads. However, as some customers may need the higher hosting capacity the following scaling guide by I/O Group for FS9200 as calculated using StorM is provided, as shown in Table 2.

Table 2: IBM FlashSystem 9200 scalability

IBM FlashSystem	Number of I/O groups	Number of SAP HANA worker nodes
9200	1	41
	2	82
	3	123
	4	164

At the lower performance end of the IBM FlashSystem portfolio, the FlashSystem 5000 family can also be used to provide storage to SAP HANA. Again using StorM the calculated sizing by I/O Group is shown in Table 3.

Table 3: IBM FlashSystem 5000 family scalability

IBM FlashSystem	Number of I/O groups	Number of SAP HANA worker nodes
5010/H	1	8
5030/H	1	9
	2	18
5100	1	14
	2	28

Summary

Running SAP HANA in TDI environments on IBM FlashSystem provides many benefits like reduced hardware and operational costs, improved availability and performance. It could be shown that the test results match the maximum configurations which are described in the IBM HANA TDI guide. It could also be shown that StorM accurately predicts the behavior of the IBM FlashSystem storage for such workloads. One IO group of the IBM FlashSystem 7200 is capable of running 28 SAP HANA production instances concurrently.

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