Dell PowerStore with Azure Arc-enabled Data Services

Azure Arc-enabled SQL Managed Instance - Performance and Scale

June 2022

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White Paper

Abstract

This document describes how Dell PowerStore, PowerEdge and Microsoft Azure Arc-enabled SQL Managed Instance provide a performant and scalable hybrid database platform.

Dell Technologies Solutions

Contents

Executive summary....4

Azure Arc-enabled SQL Managed Instance....6

Hardware....12

Dell PowerStore integration....13

Performance study....15

Lessons learned and environment details....22

Appendix....27

References....29

Executive summary

Overview

Database as a Service – actually realized. Or, in this case, database instance as a service. Microsoft Azure Arc-enabled SQL Managed Instance delivers ease of use, is highly configurable, and seamlessly auto-manages Azure SQL Managed Instance workloads outside of Azure.

IT administrators are burdened with inflexible infrastructure, creating additional obstacles for DBAs and for themselves. Database engines often run on a wide variety of non-standardized hardware, operating systems, virtualization platforms, and container-based solutions. This leads to life cycle management chaos with many disjointed consoles and command-line tools. Database performance can also suffer because infrastructure is not configured correctly or cannot easily scale to meet spikes in demand. In our customer conversation experience here at Dell Technologies, we understand the need to be able to adopt new technologies and deploy workloads with confidence.

Here is the answer - Azure Arc-enabled data services with Dell PowerEdge, powered by Intel®, and Dell PowerStore storage solutions.

The underlying theme of this white paper, and DBaaS in general, is ease of use, time to DevOps, multi-level resiliency, and as a huge side benefit: production level performance. In this paper, we show various tests that provide proof-points for all themes listed above.

Audience

This document is for decision makers, architects, administrators, or anyone interested in modernizing their Microsoft data estate or running Microsoft Azure Arc-enabled SQL Managed Instance.

Revisions

Date	Description
June 2022	Initial version

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Note: For links to other documentation for this topic, see References at the end of this document.

Terminology

The following table provides definitions for some of the terms that are used in this document.

Table 1. Terminology

Term	Definition
Arc-enabled SQL MI	Azure Arc-enabled SQL Server Managed Instance, General Purpose or Business Critical tier
CSI	Container Storage Interface
CSM	Container Storage Module
DBaaS	Database as a Service
DevOps	The merge of Development teams and Operations teams – working with a single automated code delivery pipeline
K8s	Kubernetes
OS	Operating System
Persistent Volume Claim (PVC)	Kubernetes claim to persistent storage volumes
Persistent Volume (PV)	Kubernetes storage volume

Azure Arc-enabled SQL Managed Instance

Azure Arc-enabled SQL Managed Instance brings the benefits of a managed cloud database service to any environment outside of Azure. An Azure Arc-enabled SQL Managed Instance, or "Arc-enabled SQL MI" for short, is an Instance, or SQL engine. Being Azure based and cloud native, the Arc-enabled SQL MI is defined as "Evergreen SQL" or always current. Gone are the days of large SQL migrations to the next version because you will always be on the latest version with an Arc-enabled SQL MI. You will also benefit from no longer managing EOS for your databases.

Usability

With any solution, having the ability to use existing tools and processes can help drive adoption and minimize the learning curve for DevOps teams. Portal management, existing DBA and DevOps tools, such as Azure Data Studio and Visual Studio Code, are a few options. By incorporating dynamic scripting with Azure CLI, you then have all the benefits of a true DBaaS platform, or in this case, DB Instance as a Service.

Using these very familiar tools, entire database environments, including Always On Availability Group environments (with separate copies of each database), are deployed in two to three minutes. This keeps your DevOps teams working and delivering, with built-in out of the box resiliency.

This is the same SQL Server database engine that runs on Windows or on Linux with traditional SQL Server 2019 on premises installations. There is no difference. We reference the management tools here. You may already be very engaged with many of these tools. Others, even if new for your toolkit, are very easy to ramp-up fast and become very comfortable.

As with any solution, the importance of maintaining the solution can be referenced in the release notes. We cannot stress enough the importance of monitoring, reading, and staying up to date with the detail provided by Microsoft in the release notes located here. It is recommended that this be a part of your monthly routine to maintain cloud-speed technology.

Connection modes

Two types of connectivity modes are available for the Azure Arc-enabled data services data controller:

1. **Directly Connected Mode** – This is for organizations that maintain network connectivity to Azure. They are able to get a full Azure portal and Azure tooling experience in near real time when connected to Azure – for management of this DBaaS platform. Usage data, metrics, and logs are automatically sent to Azure. We used this connectivity mode in our lab for this paper.
2. **Indirectly Connected Mode** – This is for organizations that have limited or no connectivity to Azure. DBAs use tools such as Azure Data Studio and Azure CLI (az) with the arc data extension to manage the data controller directly. This mode requires manual uploads of usage data, metrics, and logs to Azure using the Azure CLI.

Pricing tiers

Azure Arc-enabled SQL Managed Instance enables the deployment of Azure SQL Managed Instance anywhere. Microsoft promises to deliver this service with total compatibility with Azure SQL MI and SQL Server database and integrated management capabilities. There are currently two pricing tiers available.

Azure Arc-enabled SQL Managed Instance General Purpose

Arc-enabled SQL MI General Purpose (GP) provides a single SQL instance to support a multitude of workload scenarios for SQL Server. The GP tier deploys a single pod (cluster of one) Always On Availability Group Cluster, each with four containers located within the pod. Those four containers are listed in the following table.

Azure Arc-enabled SQL Managed Instance Business Critical

Arc-enabled SQL MI Business Critical (BC) deploys a three pod (default) Contained availability group cluster, each with four containers located within the pod. These four containers are listed in the following table.

Table 2. Arc-enabled SQL MI containers

Container Name	Description
arc-sqlmi	Azure SQL Managed Instance executable
arc-monitor-collectd	Application to collect performance metrics
arc-monitor-fluentbit	Logging and metrics processing
arc-ha-supervisor	Azure SQL MI HA monitor for bridging between Arc-enabled SQL MI and and Kubernetes cluster

Applications can also benefit from read scale-out to offload read-intensive workloads to secondary replicas.

During our lab testing, a contained availability group with three replicas was deployed in minutes, which included all the internal load balancer and read-only synchronous configuration replicas, all with just a few lines of Azure CLI code. This very minimal amount of full deployment time has never been possible with any traditional Azure SQL MI deployment on any Windows or Linux full OS[1].

Microsoft does recommend a three-replica configuration to achieve near-zero data loss. Reference link.

Data resiliency

For an Arc-enabled SQL MI, there are four storage classes that can be configured. Pay special attention to the backup location. Our PowerStore environment provided us the unique opportunity to present RWX (see table below) CLI access to our Arc-enabled SQL MIs. During an Always On Group failover, the new primary replica can then continue to write to the same backup location, solving for any data loss. In addition, PowerStore provides appliance level data protection with the Dynamic Resiliency Engine (DRE). DRE is a software-based approach to data redundancy that is more distributed, automated, and efficient than traditional RAID. The burden of selecting and balancing RAID levels is a thing of the past.

[1] Based on Dell Technologies internal testing performed May 2020 and reviewed by Microsoft comparing deployment times of SQL Server Always On Availability Groups vs Azure Arc-enabled SQL Managed Instance.

The `-storage-class-x` parameters in the Azure CLI command aligned with the SQL Server files, as shown in the following table.

Table 3. Storage class

Switch	Description	CLI Access Modes
--storage-class-data	SQL data .mdf files	RWO
--storage-class-datalogs	SQL log .ldf files	RWO
--storage-class-backups	SQL Server backup files. Full, Diff, T-log	RWX
--storage-class-logs	SQL agent, errorlog, trace files, health logs, etc	RWO

Kubernetes data access modes

Table 4. Kubernetes access modes

CLI Abbreviation	Description
RWO	Read Write Once
ROX	Read Only Many
RWX	Read Write Many
RWOP	Read Write Once Pod

With PowerStore, we can have block and file storage configurations within the same appliance, which allows for NFS backup. With this option, we had the perfect location for the RWX `-storage-class-backup` requirement, all of this within a single PowerStore solution. PowerStore allows multiprotocol file access, which enables data mobility by allowing backup files from any version of SQL Server, to be accessed by NFS or SMB clients. This makes it easy to move data between traditional SQL Server instances and an Arc-enabled SQL MI.

As mentioned above, Arc-enabled SQL MI Business Critical deploys out of the box replica groups, spread across multiple Kubernetes nodes if available. This provides resiliency at many layers.

Ease of deployment

It is easy to deploy an Azure SQL MI, as in the following examples. The benefit of using Azure CLI is the repeatable and scripted nature of a deployment. You can now include the data layer into the DevOps pipe.

Example of an Arc-enabled SQL MI General Purpose deployment:

```
az sql mi-arc create --name sqlmi-01 --resource-group
PowerStoreAzureArc-RG   --location "East US" --custom-location
"edenprairienm"  --dev --replicas 1 `
    --cores-request "2" --cores-limit "8" --memory-request "8Gi" -
-memory-limit "16Gi" `
    --storage-class-backups "nfs-csi" --storage-class-data
"powerstore-xfs" --storage-class-logs "powerstore-xfs" --storage-
class-datalogs "powerstore-xfs" `
```

```
    --volume-size-backups "500Gi" --volume-size-data "950Gi" --
volume-size-logs "100Gi"--volume-size-datalogs "500Gi"
```

Example of an Arc-enabled SQL MI Business Critical deployment (two minutes to deploy a fully enabled Always On Group):

```
az sql mi-arc create --name bizcrtcl-02 --resource-group
PowerStoreAzureArc-RG  --tier BusinessCritical --location "East
US" --custom-location "edenprairienm"   --replicas 3 `
    --cores-request "4" --cores-limit "4" --memory-request "8Gi" -
-memory-limit "10Gi" `
    --storage-class-backups "nfs-csi" --storage-class-data
"powerstore-xfs" --storage-class-logs "powerstore-xfs" --storage-
class-datalogs "powerstore-xfs" `
    --volume-size-backups "500Gi"  --volume-size-data "950Gi" --
volume-size-logs "100Gi"--volume-size-datalogs "500Gi"
```

The following is an example of how simple it is to ramp up and ramp down pod resources. This example represents an Arc-enabled SQL MI memory reconfiguration that ramps down from 8GB to 4GB. (For more information, see az sql mi-arc update.)

```
# this is for Direct mode
az sql mi-arc update --name sqlmi-01  --memory-request "4Gi"  --
k8s-namespace arc-services-ns --use-k8s
```

As storage capacity requirements change, the Dell CSI driver for PowerStore allows storage to be expanded from the Kubernetes control plane. For more details, see the section Dell Container Storage Interface.

Performance

The Arc-enabled SQL MI DBaaS platform continued to deliver substantial ease of use, all while addressing database management challenges. Our functional and performance testing revealed that an Arc-enabled SQL MI with PowerStore enables rapid deployment, ease of management, and elastic scale – all while ensuring database Transaction Per Minute (TPM) are aligned with SLAs.

For all of our testing scenarios, the –retention-days switch was set to 0. This setting disables automatic backups for the Arc-enabled SQL MI.

```
az sql mi-arc update --name sqlmi-01  --retention-days 0 --k8s-
namespace arc-services-ns --use-k8s
```

MI features and benefits

You can leverage your existing SQL Server experience because this is the same SQL engine, which can be fully deployed in minutes.

An Arc-enabled SQL MI is the same evergreen Azure SQL MI engine that is compatible with any production release of SQL Server database engine in your on-premises environment. An Arc-enabled SQL MI combines the best and most widely used RDBMS, SQL Server, with the declarative power of Kubernetes. Many features and services that you already use with SQL Server are ready and available. A few features are still being enabled, but this is a very short list, anticipating the support of these features being enabled over time.

For more information, see Features and Capabilities of Azure Arc-enabled SQL Managed Instance.

No tuning required

Historically, database environments would require configuration tuning to achieve predictable, consistent performance. However, cloud-native architectures such as Kubernetes discourage this approach from an application standpoint. This is because manual tuning can become unmanageable at large scale. The idea is that components should be as simple as possible and used in a commodity fashion. The Kubernetes design principle “cattle, not pets” is used to describe this. The PowerEdge, PowerStore, and Arc-enabled SQL MI stack has exceptional performance with no tuning required.

PowerEdge servers enable this with System Profiles, allowing you to select the best settings by choosing a profile for performance, power savings, and others, without the need to tune individual settings.

PowerStore storage appliances utilize machine learning to tune storage resources based on appliance usage, either on a single appliance or across multiple appliances in a cluster. This allows for optimal performance without manual configuration for individual storage volumes and hosts. For mixed workload environments, PowerStore performance policies can be used to set relative performance priority of high, medium, or low that take effect only if resources become constrained.

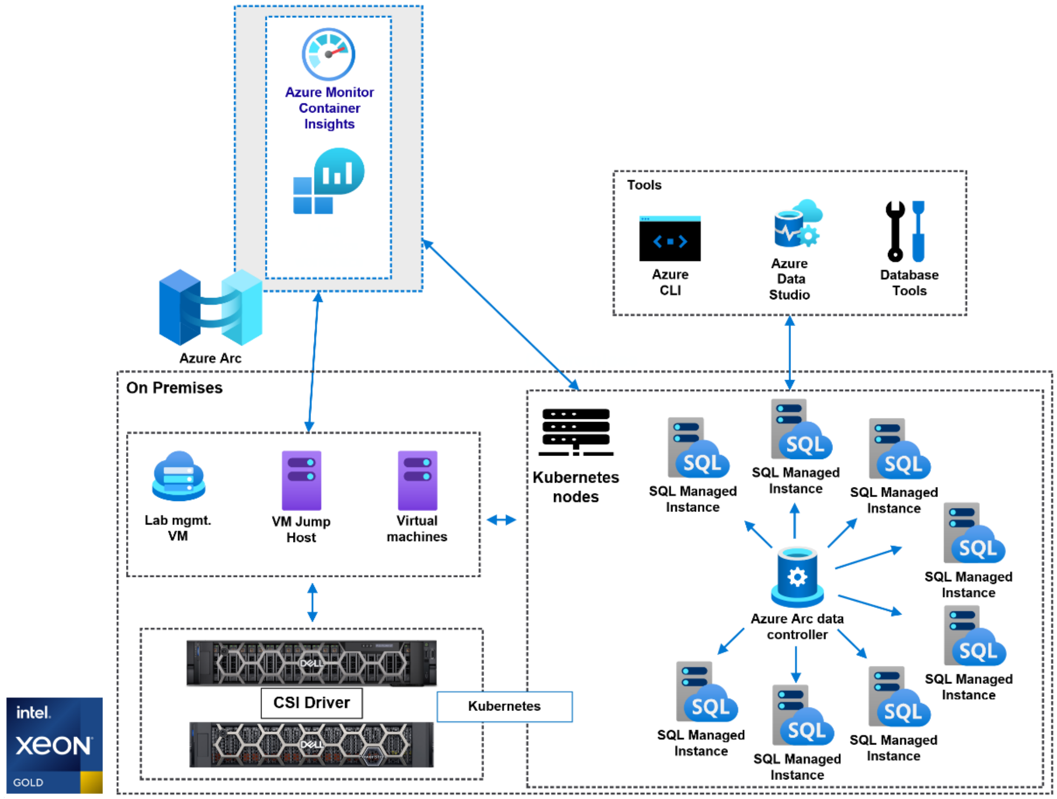
Dell Container Storage Interface (CSI) drivers for PowerStore allow storage to be provisioned dynamically and allow the storage to follow container workloads as they move between nodes in the cluster for load balancing or availability. Therefore, all common storage management tasks are performed by the Kubernetes control plane and Arc-enabled SQL MI configuration.

Arc-enabled SQL MI adapts to the workload by scaling within the deployment limits and utilizing the proven SQL Server core database engine. Compute and memory are managed with requests and limits upon deployment, and Arc-enabled SQL MI will scale within those boundaries to accommodate varying workloads.

Lab Architecture

The following figure represents our lab architecture.

Figure 1. Lab architecture



Management toolsets

Table 5. Tools and versions used

Tool	Purpose	Version
Azure Arc-enabled Kubernetes	Provides rich monitoring, GitOps-based configuration management, policy enforcement, and a target for Azure Arc-enabled data services.	1.6.16
PowerShell	Performed various operational, deployment and monitoring tasks.	7.2.3
kubectl	Used for various management and maintenance activities in Kubernetes.	Client 1.23.0 Server 1.23.5

Tool	Purpose	Version
az cli	Used to interact with Azure Arc-enabled Kubernetes resources. Including Extensions	"azure-cli": "2.36.0", "azure-cli-core": "2.36.0", "azure-cli-telemetry": "1.0.6", "extensions": { "arcdata": "1.4.0", "connectedk8s": "1.2.8", "customlocation": "0.1.3", "k8s-configuration": "1.5.1", "k8s-extension": "1.2.0"
Azure portal	Used to interact with Azure Arc-enabled Kubernetes resources.	N/A
Azure Monitor Container Insights	Used for monitoring performance and capacity in the Kubernetes environment through the Azure portal.	2.9.2
Azure Data Studio	Deployment and management of Azure Arc-enabled data services. Database development	1.35.1
SQL Server Management Studio	T-SQL and DBA standard management for SQL Server	18.11.1
VSCode	PowerShell, Azure CLI, SQL Database Projects, GitHub	1.67.1
Windows Terminal	PowerShell, Command Prompt, SSH, Azure Cloud Shell, Kubectl	1.12

Hardware

Dell PowerStore

PowerStore is an outstanding choice for Arc-enabled SQL MI because it fills all the performance and feature requirements of Arc-enabled SQL MI. Most important is performance. PowerStore all-flash design provides high-speed and sub-millisecond response times which are crucial for Arc-enabled SQL MI performance. Arc-enabled SQL MI deploys as a contained availability group and a shared backup target is a recommended best practice. File storage is a great option for this. PowerStore and its combined block and file capabilities make it one of the few storage appliances that can fulfill this requirement with a single system. Therefore, you can either use a single PowerStore appliance for both high performance block and file or add up to four PowerStore appliances to a single cluster for even greater scalability, capacity, and performance.

The Dynamic Resiliency Engine (DRE) is a software-based approach to data redundancy that is more distributed, automated, and efficient than traditional RAID. DRE ensures that storage is resilient to component failures within the storage appliance and therefore increases availability in mission-critical environments.

Thin provisioning and data reduction features ensure that data is stored in the most efficient manner to optimize space efficiency and make provisioning easier. This allows storage to be generously provisioned at deployment without concern for wasting space.

Dell PowerEdge

PowerEdge R650xs and R750xs servers are 1U dual-socket and 2U dual-socket servers, respectively. These servers are designed for virtualization, VDI, and performance sensitive workloads such as databases. They come with full stack management integration with Microsoft, VMware, ServiceNow, Ansible, and many other tools for multiple operating environments, from on-premises to cloud to edge.

For more information, visit the Dell PowerEdge website.

Intel®

3rd Generation Intel® Xeon® Scalable processors are “optimized for cloud, enterprise, HPC, network, security, and IoT workloads with 8 to 40 powerful cores and a wide range of frequency, feature, and power levels.” Intel® continues to offer many models from the Platinum, Gold, Silver, and Bronze processor lines, which are aimed at “the most common workload requirements”.

PowerStore also leverages Intel® Xeon ®processors and QuickAssist technology acceleration for scalability and performance.

For more information, visit the Intel® Xeon® website.

Dell PowerStore integration

In addition to the performance and scale required for demanding workloads, PowerStore offers several features and integrations for Kubernetes. These integrations enable and enhance the Kubernetes storage experience, providing automation, management, and insights to the Kubernetes control plane. These enhanced capabilities allow day to day storage management to be performed from Kubernetes.

Dell Container Storage Modules

In addition to implementing core persistent storage functionality, PowerStore Container Storage Modules (CSM) provide additional capabilities, such as snapshotting, replication, observability, authorization, and resiliency to Kubernetes. This allows PowerStore storage visibility and management from the Kubernetes control plane.

During our testing, the CSM Observability module was used to gain insights into storage performance. The CSM Observability module allows Kubernetes developers and administrators to view storage metrics using the Kubernetes control plane and popular data collection and monitoring tools such as Prometheus and Grafana. These storage metrics can easily be viewed in a Grafana dashboard along with other Kubernetes metrics for single pane of glass monitoring.

Dell Container Storage Interface

Arc-enabled SQL MI requires two types of Kubernetes persistent storage: RWO and RWX. PowerStore Container Storage Interface Driver (CSI) provides these storage provisioning capabilities to Kubernetes, allowing the Arc-enabled SQL MI deployment to dynamically provision storage volumes. As data requirements grow, the volumes can also be expanded through the Kubernetes control plane by modifying the Persistent Volume Claim (PVC), eliminating the need for storage administrator involvement.

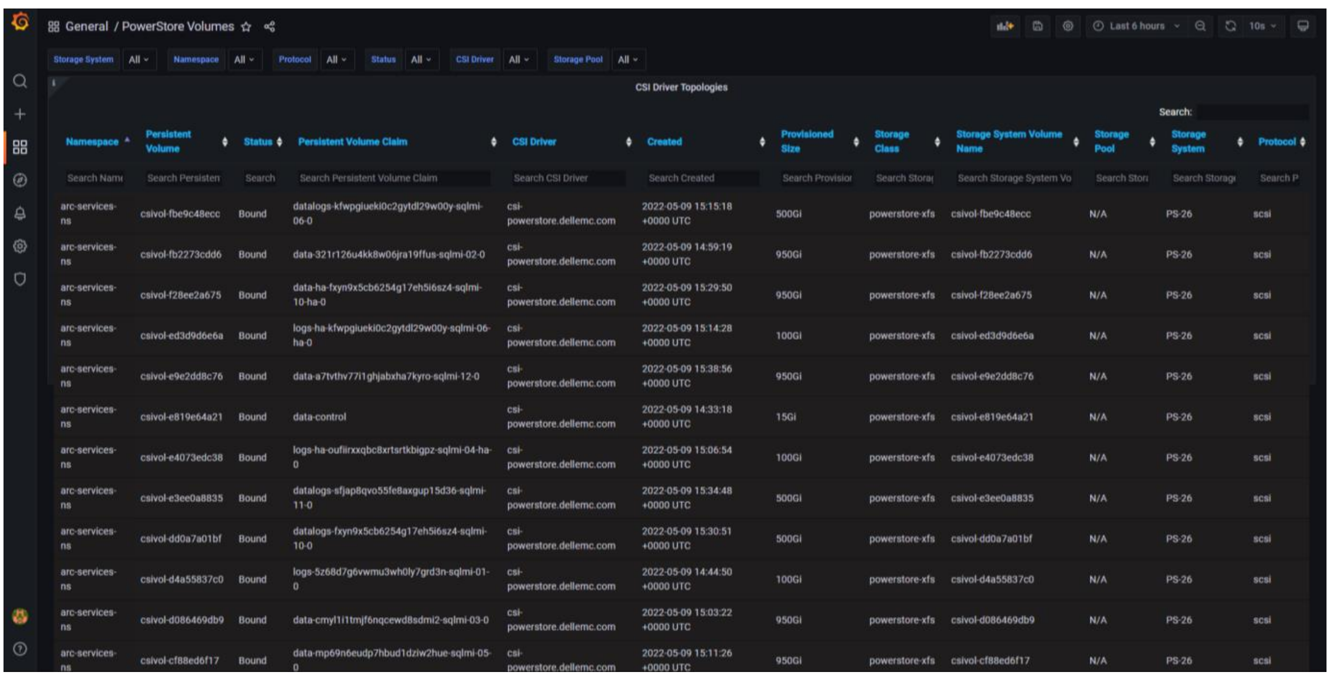
The CSI driver for PowerStore is the fundamental component that communicates with the PowerStore appliance to provide storage provisioning and insights. The CSI driver implements standard Kubernetes functionality for PowerStore, such as volume creation, mapping, expansion, replication, and deletion, which are the most common storage provisioning tasks. This allows Kubernetes deployments such as Arc-enabled SQL MI to request storage volumes at deployment time and then automatically create and map volumes to the appropriate Kubernetes node. As the workload moves around the cluster, the CSI driver will perform the necessary storage mapping changes to ensure that the storage follows the workload.

When Arc-enabled SQL MI instances are provisioned, storage sizes are specified for data, log, and backup storage. Initial sizing in some environments can be a difficult decision. PowerStore makes this decision easier by thin-provisioning storage volumes. Storage is only provisioned on the array as it is consumed, so unused space is not wasted. Additionally, PowerStore CSI allows volumes to be expanded by simply editing the Kubernetes Persistent Volume Claim (PVC) and increasing the size. This provides flexibility and manageability of storage consumption, all managed without touching the PowerStore appliance.

Dell CSM Observability module

Below is an example of the CSM Observability module for PowerStore providing storage volume insights into a Grafana dashboard. This allows Kubernetes administrators to correlate storage volumes in Kubernetes to their respective PowerStore volume.

PowerStore CSM volume information



Namespace	Persistent Volume	Status	Persistent Volume Claim	CSI Driver	Created	Provisioned Size	Storage Class	Storage System Volume Name	Storage Pool	Storage System	Protocol
arc-services-ns	csivol-fbe9c48ecc	Bound	datalogs-kfwpgiueki0c2gytdl29w00y-sqlmi-06-0	csi-powerstore.dellemc.com	2022-05-09 15:15:18 +0000 UTC	500Gi	powerstore-xfs	csivol-fbe9c48ecc	N/A	PS-26	scsi
arc-services-ns	csivol-fb2273cdd6	Bound	data-321r126u4kk8w06jra19ffus-sqlmi-02-0	csi-powerstore.dellemc.com	2022-05-09 14:59:19 +0000 UTC	950Gi	powerstore-xfs	csivol-fb2273cdd6	N/A	PS-26	scsi
arc-services-ns	csivol-f28ee2a675	Bound	data-ha-fxyn9x5cb6254g17eh5i6sz4-sqlmi-10-ha-0	csi-powerstore.dellemc.com	2022-05-09 15:29:50 +0000 UTC	950Gi	powerstore-xfs	csivol-f28ee2a675	N/A	PS-26	scsi
arc-services-ns	csivol-ed3d9d6e6a	Bound	logs-ha-kfwpgiueki0c2gytdl29w00y-sqlmi-06-ha-0	csi-powerstore.dellemc.com	2022-05-09 15:14:28 +0000 UTC	100Gi	powerstore-xfs	csivol-ed3d9d6e6a	N/A	PS-26	scsi
arc-services-ns	csivol-e9e2dd8c76	Bound	data-a7tvthv77i1ghjabxha7kyro-sqlmi-12-0	csi-powerstore.dellemc.com	2022-05-09 15:38:56 +0000 UTC	950Gi	powerstore-xfs	csivol-e9e2dd8c76	N/A	PS-26	scsi
arc-services-ns	csivol-e819e64a21	Bound	data-control	csi-powerstore.dellemc.com	2022-05-09 14:33:18 +0000 UTC	15Gi	powerstore-xfs	csivol-e819e64a21	N/A	PS-26	scsi
arc-services-ns	csivol-e4073edc38	Bound	logs-ha-oufiirxxqbc8xrtsrtkbigpz-sqlmi-04-ha-0	csi-powerstore.dellemc.com	2022-05-09 15:06:54 +0000 UTC	100Gi	powerstore-xfs	csivol-e4073edc38	N/A	PS-26	scsi
arc-services-ns	csivol-e3ee0a8835	Bound	datalogs-sfjap8qvo55fe8axgup15d36-sqlmi-11-0	csi-powerstore.dellemc.com	2022-05-09 15:34:48 +0000 UTC	500Gi	powerstore-xfs	csivol-e3ee0a8835	N/A	PS-26	scsi
arc-services-ns	csivol-dd0a7a01bf	Bound	datalogs-fxyn9x5cb6254g17eh5i6sz4-sqlmi-10-0	csi-powerstore.dellemc.com	2022-05-09 15:30:51 +0000 UTC	500Gi	powerstore-xfs	csivol-dd0a7a01bf	N/A	PS-26	scsi
arc-services-ns	csivol-d4a55837c0	Bound	logs-5z68d7g6vwmu3wh0ly7grd3n-sqlmi-01-0	csi-powerstore.dellemc.com	2022-05-09 14:44:50 +0000 UTC	100Gi	powerstore-xfs	csivol-d4a55837c0	N/A	PS-26	scsi
arc-services-ns	csivol-d086469db9	Bound	data-cmyl1i1tmjf6nqcewd8sdmi2-sqlmi-03-0	csi-powerstore.dellemc.com	2022-05-09 15:03:22 +0000 UTC	950Gi	powerstore-xfs	csivol-d086469db9	N/A	PS-26	scsi
arc-services-ns	csivol-cf88ed6f17	Bound	data-mp69n6eudp7hbud1dziw2hue-sqlmi-05-0	csi-powerstore.dellemc.com	2022-05-09 15:11:26 +0000 UTC	950Gi	powerstore-xfs	csivol-cf88ed6f17	N/A	PS-26	scsi

Figure 2. PowerStore volume information displayed in Grafana

Storage array metrics have eluded database professionals for a long time. Typically, these metrics were only available in storage tools and access was often limited to storage administrators. The CSM Observability module for PowerStore collects key storage performance metrics such as input/output operations per second (IOPS), latency, and bandwidth so application owners and administrators can finally have an end-to-end view of storage performance, from the application to the PowerStore appliance.

PowerStore CSM volume performance

Figure 3. PowerStore volume performance displayed in Grafana

Performance study

Testing and environment

Mission critical workloads require high performance to maximize throughput and minimize response time. SQL Server on Windows has proven over the years to be able to deliver both. As organizations begin to run their workloads on container platforms such as Kubernetes, they need to be confident in performance and scale. Therefore, Dell Technologies and Microsoft partnered to test the performance and scale Arc-enabled SQL MI to demonstrate power and scale.

Performance test

The first test demonstrated how Arc-enabled SQL MI would perform relative to how customers run SQL Server today. Therefore, SQL Server running on Windows virtual machine on VMware was used as the performance baseline to compare SQL Managed Instance. Architecturally, these environments are similar in that there is an operating system and hardware abstraction layer on both. In this case, a single instance was running on both environments to keep the test as simple as possible. The MSOLTPE[1] workload was used to compare the performance between these two different environments.

[1] The MSOLTPE workload is derived from the TPC-E Benchmark and is not comparable to published TPC-E Benchmark results, because this implementation does not comply with all requirements of the TPC-E Benchmark.

Scalability test

The second type of test demonstrated Arc-enabled SQL MI scale, specifically the linear scale of multiple Arc-enabled SQL MIs running under two scenarios:

1. Run an increasing workload across 12 Arc-enabled SQL MIs to demonstrate an application load increasing.
2. Run a fixed user workload and ramp up the number of running Arc-enabled SQL MIs from one to 12 and then back down to one. This demonstrates what happens when additional workloads or applications are added or running a larger distributed or sharded data application.

Both test two scenarios were run using HammerDB to run the TPROC-C workload.

Performance test detail

SQL Server / Windows / VMware vs Azure Arc-enabled SQL Managed Instance General Purpose

Microsoft SQL Server 2019, Microsoft Windows, and VMware ESXi is a popular combined platform for running SQL Server workloads. Therefore, we wanted to compare the performance between the SQL Server 2019, Windows, VMware stack vs. Arc-enabled SQL MI to demonstrate what customers can expect as they begin to run workloads on this platform.

Arc-enabled SQL MI is available in two versions, General Purpose (GP) and Business Critical (BC). The first test compared a single SQL Server VM vs. a single Arc-enabled SQL MI GP running the MSOLTPE like workload using the Microsoft BenchCraft transaction driver. The results of this test showed nearly identical performance between the two.

Workload comparison

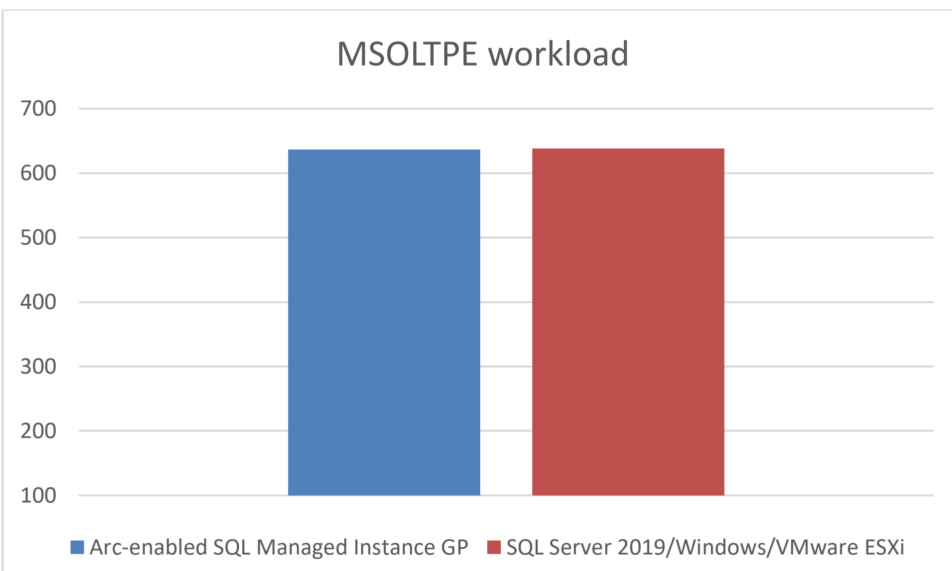


Figure 4. MSOLTPE[1] workload with nearly identical performance

This test result aligns with what Microsoft has done to run SQL Server on Linux and in containers by porting the Platform Abstraction Layer (PAL) to different operating systems. The same SQL Server engine code is running on multiple platforms. Therefore, it makes sense that the workload performance should be very similar. More information about the PAL can be found in this Microsoft blog post.

SQL Server/Windows/VMware vs Azure Arc-enabled SQL Managed Instance Business Critical

Many SQL Server customers rely on Always On Availability Groups for protecting their SQL Server workloads. This protection is built into Arc-enabled SQL MI and one to three replicas are deployed in the Business Critical tier. Therefore, we wanted to assess the performance difference by comparing a SQL Server 2019, Windows, and VMware ESXi instance configured for Always On with two replicas vs. Arc-enabled SQL MI BC with two replicas. This workload is the same MSOLTPE[1] workload and toolset that was used in the General Purpose test.

Workload comparison

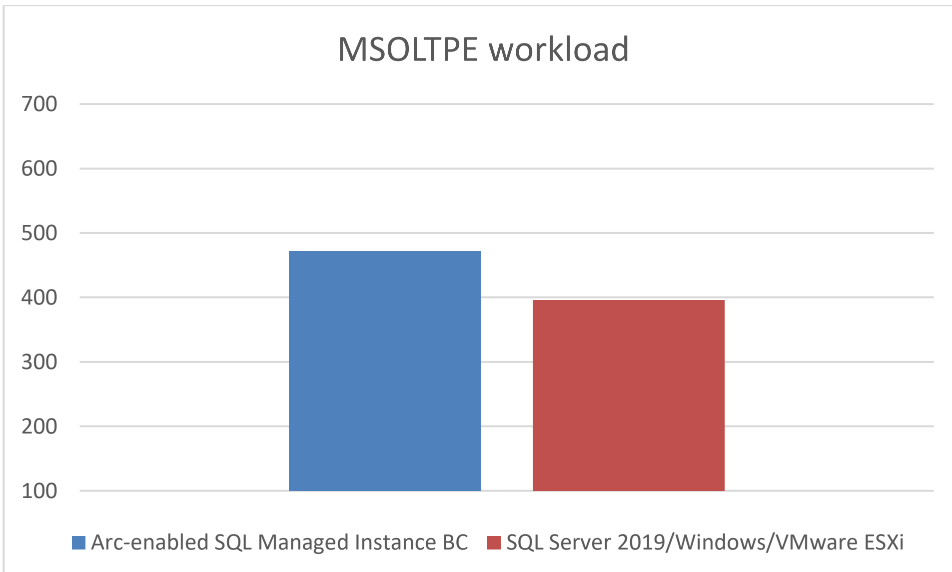


Figure 5. MSOLTPE[1] workload with Always On Availability Group protection

This test showed a 15% performance improvement when comparing an Arc-enabled SQL MI BC vs. a SQL Server 2019, Windows, and VMware ESXi configuration.

Scalability test detail

HammerDB TPROC-C Ramped users

For as long as databases have been in existence, performance tests have been used to assess performance of a single instance under ideal circumstances. While these tests are valuable to demonstrate what is possible, they are not a typical use case, especially on a container, cloud-enabled platform such as Kubernetes. By default, Kubernetes is a multi-node deployment built and designed for mixed workload and massive scale. Therefore, we wanted to assess PowerStore and PowerEdge, running multiple instances of Arc-enabled SQL Managed Instance GP.

To demonstrate this, a scale up and scale out test was performed on our test environment, consisting of Arc-enabled SQL MIs running on a single PowerStore 9000T and a single PowerEdge R650xs worker node.

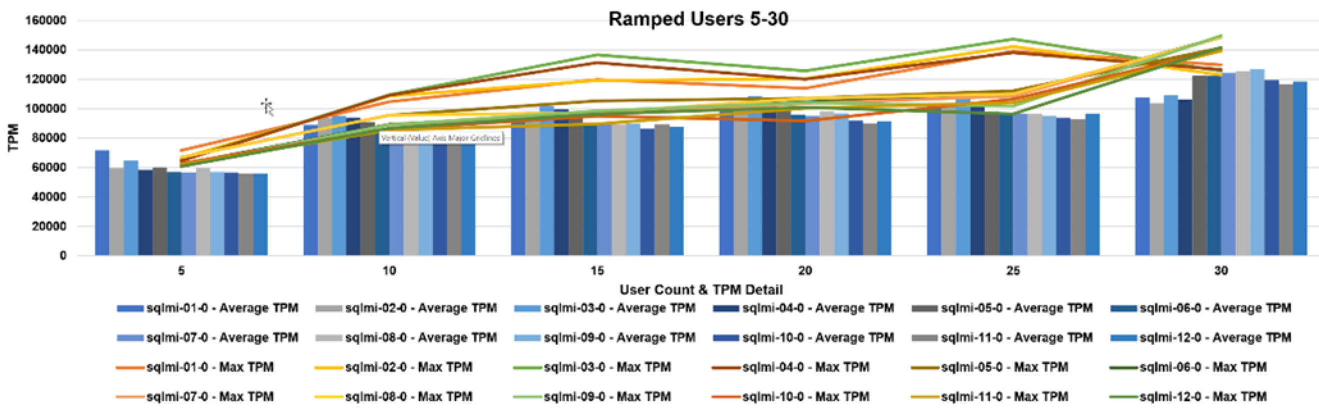
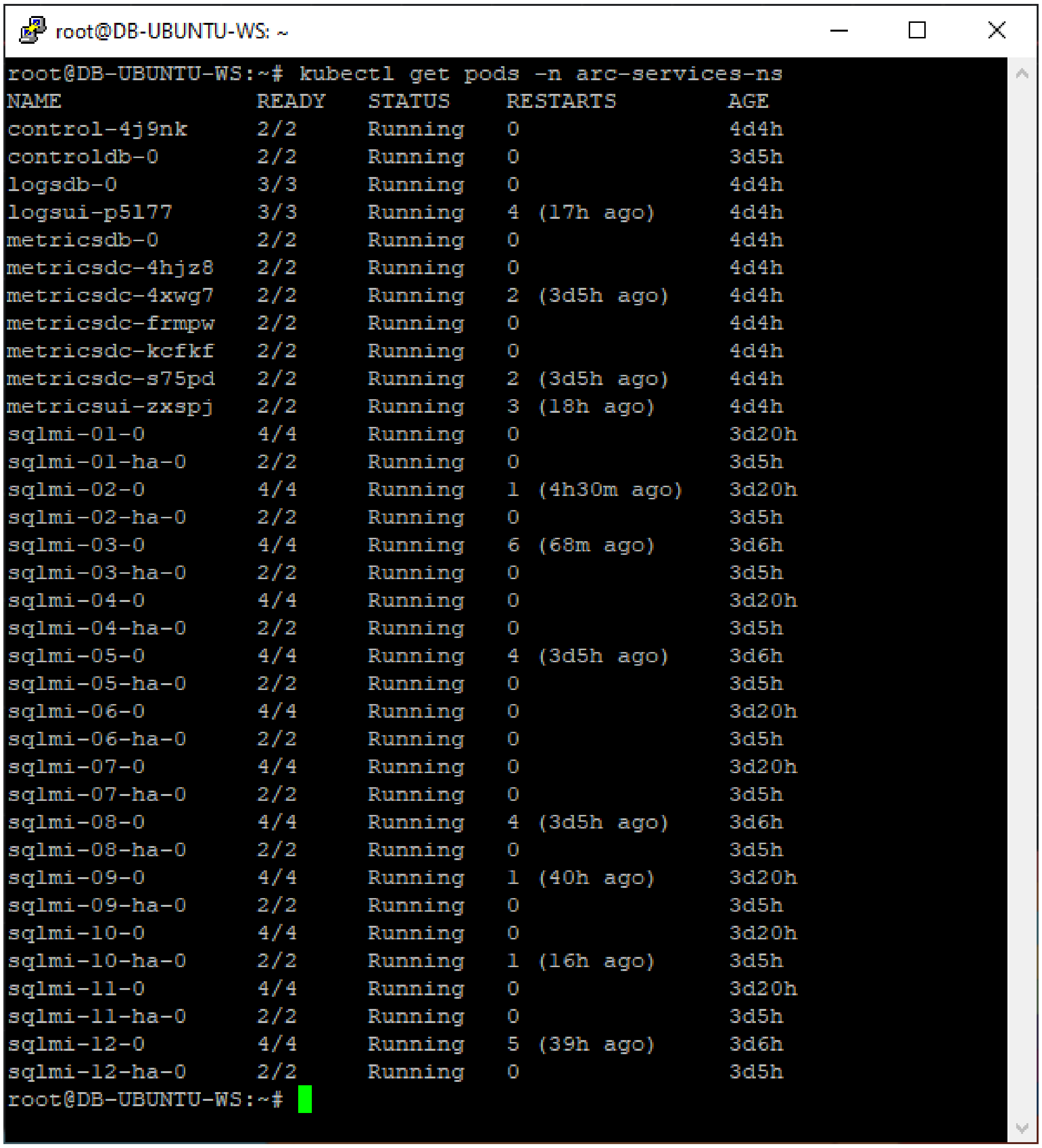


Figure 6. Arc-enabled SQL MI – Ramped up users

Scale-up user workload

As businesses grow, the amount of data and data transactions grows as well. Therefore, data infrastructure needs to be able to handle this growth, ideally in a predictable fashion. To assess this, a test was run using the HammerDB TPROC-C workload on 12 Arc-enabled SQL MI GP instances simultaneously. The workload ramped up the number of users over time, increasing the workload in a controlled fashion to demonstrate business growth.

Azure Arc-enabled SQL Managed Instance General Purpose deployment



root@DB-UBUNTU-WS: ~

```
root@DB-UBUNTU-WS:~# kubectl get pods -n arc-services-ns
NAME               READY   STATUS    RESTARTS         AGE
control-4j9nk      2/2     Running   0                4d4h
controldb-0        2/2     Running   0                3d5h
logsdb-0           3/3     Running   0                4d4h
logsui-p5177       3/3     Running   4 (17h ago)      4d4h
metricsdb-0        2/2     Running   0                4d4h
metricsdc-4hjz8    2/2     Running   0                4d4h
metricsdc-4xwg7    2/2     Running   2 (3d5h ago)     4d4h
metricsdc-frmpw    2/2     Running   0                4d4h
metricsdc-kcfkf    2/2     Running   0                4d4h
metricsdc-s75pd    2/2     Running   2 (3d5h ago)     4d4h
metricsui-zxspj    2/2     Running   3 (18h ago)      4d4h
sqlmi-01-0         4/4     Running   0                3d20h
sqlmi-01-ha-0      2/2     Running   0                3d5h
sqlmi-02-0         4/4     Running   1 (4h30m ago)    3d20h
sqlmi-02-ha-0      2/2     Running   0                3d5h
sqlmi-03-0         4/4     Running   6 (68m ago)      3d6h
sqlmi-03-ha-0      2/2     Running   0                3d5h
sqlmi-04-0         4/4     Running   0                3d20h
sqlmi-04-ha-0      2/2     Running   0                3d5h
sqlmi-05-0         4/4     Running   4 (3d5h ago)     3d6h
sqlmi-05-ha-0      2/2     Running   0                3d5h
sqlmi-06-0         4/4     Running   0                3d20h
sqlmi-06-ha-0      2/2     Running   0                3d5h
sqlmi-07-0         4/4     Running   0                3d20h
sqlmi-07-ha-0      2/2     Running   0                3d5h
sqlmi-08-0         4/4     Running   4 (3d5h ago)     3d6h
sqlmi-08-ha-0      2/2     Running   0                3d5h
sqlmi-09-0         4/4     Running   1 (40h ago)      3d20h
sqlmi-09-ha-0      2/2     Running   0                3d5h
sqlmi-10-0         4/4     Running   0                3d20h
sqlmi-10-ha-0      2/2     Running   1 (16h ago)      3d5h
sqlmi-11-0         4/4     Running   0                3d20h
sqlmi-11-ha-0      2/2     Running   0                3d5h
sqlmi-12-0         4/4     Running   5 (39h ago)      3d6h
sqlmi-12-ha-0      2/2     Running   0                3d5h
root@DB-UBUNTU-WS:~#
```

Figure 7. K8s pods deployed via Azure CLI

The following Grafana chart demonstrates the scalability of the environment. Each layer in the chart represents the compute resources consumed by each Arc-enabled SQL MI GP instance. The instances are balanced, consuming roughly the same amount of compute resources.

CPU usage while increasing user workload

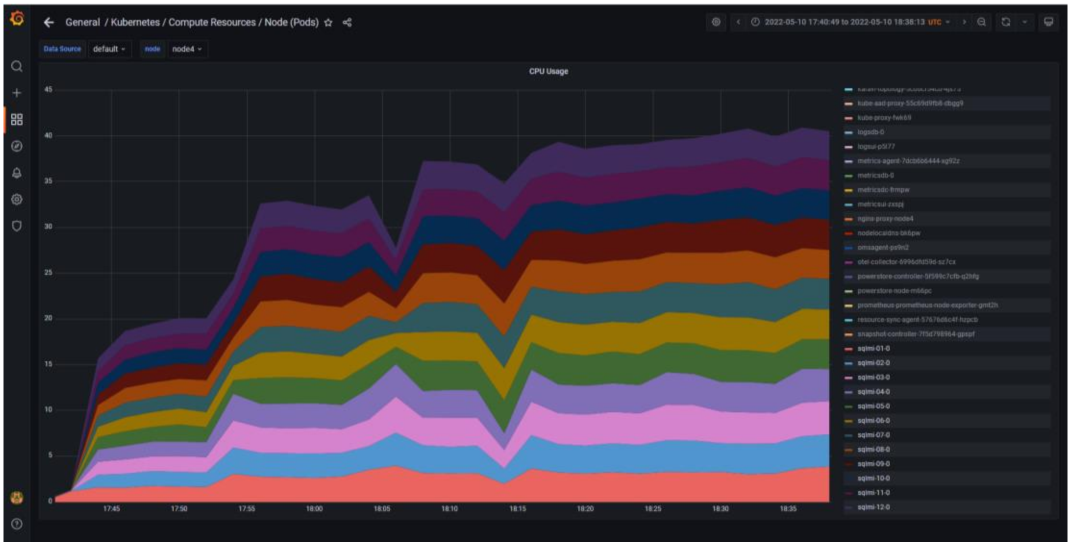


Figure 8. Equal CPU resources consumed by each of the 12 Azure Arc-enabled SQL Managed Instances

Scale-out instances

Another common method of accommodating business growth in data architectures is to deploy a scale-out architecture where the number of instances can be increased over time for additional power and capacity. These architectures are becoming increasingly popular as cloud-enabled architectures, such as this one, allow workloads to be “spun up” and “spun down” easily. To demonstrate this, a fixed workload was deployed using the same HammerDB TPROC-C test to start or “spin-up” the same user workload (15 users) every 10 minutes on a new Arc-enabled SQL MI GP Instance, up to 12 instances. Each workload executed for 150 minutes and completed or “spun-down”.

Again, the following Grafana chart demonstrates the scalability of the environment. Each layer in the chart represents the compute resources consumed by each Arc-enabled SQL MI GP instance. The instances are balanced, consuming roughly the same amount of compute resources, and starting and stopping in a non-disruptive fashion.

We also monitored with the Azure portal using the Azure Monitor for Containers extension. This extension was deployed into an Azure Arc namespace within our Kubernetes cluster.

CPU usage while increasing Azure Arc-enabled SQL Managed Instances

Figure 9. Equal CPU resources consumed by each of the 12 Azure Arc-enabled SQL MIs

Node CPU Utilization – Azure Arc for Kubernetes | Insights

There are robust options for full observability into the environment. In Figure 9 we have Grafana from the data controller; in Figure 10 we have Azure Monitor from the Azure portal. Both observe the same workload at the same time, node CPU, through two different perspectives.

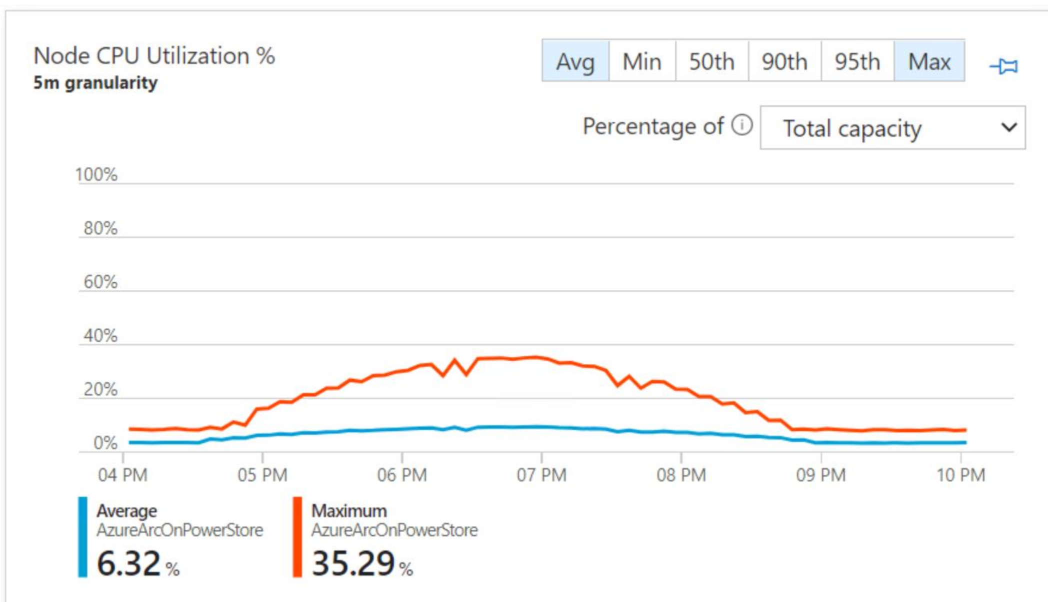


Figure 10. Azure Monitor

The following graph for the staggered start metrics displays a ramp-up and ramp-down performance test. This demonstrates predictive performance and scale which would be required to support stringent SLAs, when the workload was at its most dense, in the middle of the graph.

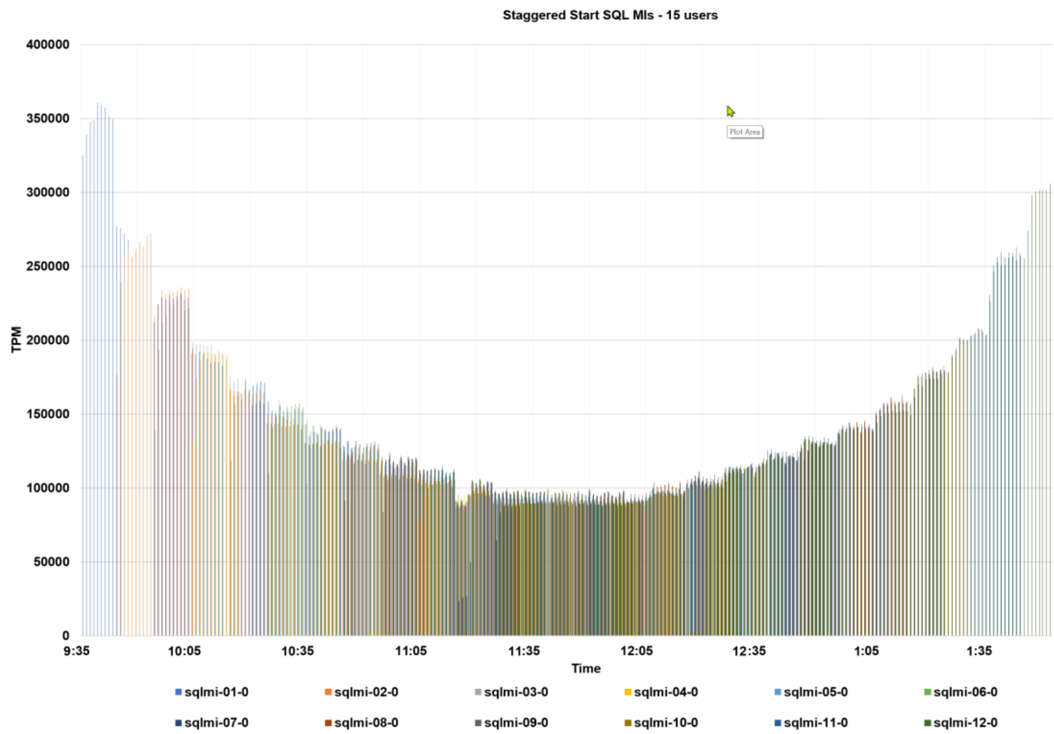


Figure 11. Staggered start Arc-enabled SQL MIs

Throughout all of our tests there was ample performance headroom on the PowerStore and PowerEdge hardware.

Lessons learned and environment details

As part of the testing that was performed there were several interesting items and lessons learned.

Hybrid cluster environment

As mentioned above, a Kubernetes deployment requires several server nodes to accommodate the master and worker roles and redundancy for each. By default, it might be assumed that these nodes are equal in platform and hardware specifications. However, Kubernetes can accommodate a mixed or hybrid environment and that was leveraged in a couple of different ways in this study.

In this environment, the control-plane/master nodes were run as virtual machines running on VMware ESXi 7.0u3, some worker nodes were also virtual machines, and the worker nodes used for our test workload were running on physical PowerEdge servers. Because the control-plane is not resource intensive, especially on smaller clusters, this enabled efficient use of resources by allowing the control plane to run in a shared environment rather than dedicating physical machines.

To direct our test workload to run on physical hosts, we leveraged the capabilities of Kubernetes and PowerStore CSI. Kubernetes architecture uses labels and selectors for controlling orchestration and objects within the environment. The PowerStore CSI driver leverages this architecture, allowing a node selector label to be used. This was employed by first labeling our cluster nodes that were physical and configured for Fibre Channel storage connections to PowerStore with the label “fc=true”.

Next, the PowerStore CSI driver configuration is configured with the following:

```
nodeSelector:
     fc: “true”
```

This configuration ensures that the CSI driver will only run on nodes with the specified label. Because the Storage Class that references this will only be available on those nodes, Kubernetes will only consider these nodes for scheduling workloads that require the PowerStore storage classes. In this manner we have selectively marked specific nodes in our mixed cluster for the Arc-enabled SQL MI workload. The output from `kubectl get nodes --show-labels` is shown in the following table, with the additional labels shown in **bold** on node4, node5, and node6.

Table 6. Kubernetes nodes and labels

Name	Status	Roles	Age	Version	Labels
node1	Ready	control-plane, master	37d	v1.23.5	beta.kubernetes.io/arch=amd64,beta.kubernetes.io/os=linux,kubernetes.io/arch=amd64,kubernetes.io/hostname=node1,kubernetes.io/os=linux,node-role.kubernetes.io/control-plane=,node-role.kubernetes.io/master=,node.kubernetes.io/exclude-from-external-load-balancers=
node2	Ready	control-plane, master	37d	v1.23.5	beta.kubernetes.io/arch=amd64,beta.kubernetes.io/os=linux,kubernetes.io/arch=amd64,kubernetes.io/hostname=node2,kubernetes.io/os=linux,node-role.kubernetes.io/control-plane=,node-role.kubernetes.io/master=,node.kubernetes.io/exclude-from-external-load-balancers=
node3	Ready	<none>	37d	v1.23.5	beta.kubernetes.io/arch=amd64,beta.kubernetes.io/os=linux,kubernetes.io/arch=amd64,kubernetes.io/hostname=node3,kubernetes.io/os=linux
node4	Ready	<none>	37d	v1.23.5	beta.kubernetes.io/arch=amd64,beta.kubernetes.io/os=linux,csi-powerstore.dellemc.com/xxx.xxx.xxx.xxx-nfs=true,csi-powerstore.dellemc.com/xxx.xxx.xxx.xxx-fc=true,csi-powerstore.dellemc.com/xxx.xxx.xxx.xxx-nfs=true,**fc=true**,kubernetes.io/arch=amd64,kubernetes.io/hostname=node4,kubernetes.io/os=linux
node5	Ready	<none>	36d	v1.23.5	beta.kubernetes.io/arch=amd64,beta.kubernetes.io/os=linux,csi-powerstore.dellemc.com/xxx.xxx.xxx.xxx-nfs=true,csi-powerstore.dellemc.com/xxx.xxx.xxx.xxx-fc=true,csi-powerstore.dellemc.com/xxx.xxx.xxx.xxx-nfs=true,**fc=true**,kubernetes.io/arch=amd64,kubernetes.io/hostname=node5,kubernetes.io/os=linux

Name	Status	Roles	Age	Version	Labels
node6	Ready	<none>	36d	v1.23.5	beta.kubernetes.io/arch=amd64,beta.kubernetes.io/os=linux, csi-powerstore.dellemc.com/xxx.xxx.xxx.xxx-nfs=true,csi-powerstore.dellemc.com/xxx.xxx.xxx.xxx-fc=true,csi-powerstore.dellemc.com/xxx.xxx.xxx.xxx-nfs=true,**fc=true**,kubernetes.io/arch=amd64,kubernetes.io/hostname=node6,kubernetes.io/os=linux

Azure Arc-enabled SQL Managed Instance pod placement

Arc-enabled SQL MI and Kubernetes work together such that a standard deployment will distribute the instances across the worker nodes in the cluster, and that the replicas for a given instance will run on different workers where possible. However, to demonstrate the power of a single worker node to run all pods in the workload, we took the other nodes offline, so Kubernetes was forced to run all of the workload on our PowerEdge R650xs server. This is not typical and was done for illustration purposes of power and scale of a single server.

Environment details

The following table provides the details of the hardware environment used in the testing.

Table 7. Environment details

	Windows environment	Azure Arc-enabled SQL Managed Instance environment
Workload Server	Dell PowerEdge R650xs 2x Intel® Xeon® Gold 6330 CPU @ 2.00 GHz (28 physical cores, hyperthreading enabled) 256GB DDR-4 DRAM @2933MT/s QLogic QLE2662 16gb FC Adapter – dual port Embedded Broadcom Gigabit Ethernet BCM5720 1000Mbps BIOS version 1.5.4	Dell PowerEdge R750xs 2x Intel® Xeon® Gold 6330 CPU @ 2.00 GHz (28 physical cores, hyperthreading enabled) 256GB DDR-4 DRAM @2933MT/s QLogic QLE2662 16gb FC Adapter – dual port Embedded Broadcom Gigabit Ethernet BCM5720 1000Mbps BIOS version 1.5.4
Availability Group Replicas	2 x Dell PowerEdge R640 2 x 2x Intel® Xeon® Gold 5217 CPU @ 3.00 GHz (8 physical cores) 256GB DDR-4 DRAM @ 2933 MT/s QLogic QLE2662 16gb FC Adapter – dual port Embedded Broadcom Gigabit Ethernet BCM5720 1000Mbps BIOS version 2.12.2	2 x Dell PowerEdge R640 2 x 2x Intel® Xeon® Gold 5217 CPU @ 3.00 GHz (8 physical cores) 256GB DDR-4 DRAM @ 2933 MT/s QLogic QLE2662 16gb FC Adapter – dual port Embedded Broadcom Gigabit Ethernet BCM5720 1000Mbps BIOS version 2.12.2
Storage	Dell PowerStore 9000T Version: 2.1.0.1 (Release, Build 1602345, 2022-02-24 04:48:04, Retail). Dell CSI modules version 2.2.0. Dell CSM modules version 1.1	

<table>
<tr><th></th><th>Windows environment</th><th>Azure Arc-enabled SQL Managed Instance environment</th></tr>
<tr><td>OS</td><td>Windows Server 2022, ESXi 7.0u3</td><td>K8s Upstream (https://kubernetes.io/) 1.23.5, Red Hat Enterprise Linux 8.5</td></tr>
<tr><td>SQL Server Version</td><td>Microsoft SQL Server 2019 (RTM-CU15) (KB5008996) - 15.0.4198.2 (X64) Jan 12 2022 22:30:08 Copyright (C) 2019 Microsoft Corporation Developer Edition (64-bit) on Windows Server 2022 Standard 10.0 <X64> (Build 20348:) (Hypervisor)</td><td>
<table>
<tr><th>Product</th><th>Version</th></tr>
<tr><td>Azure Arc Data Controller</td><td>v1.6.0_2022-05-02
(Direct mode configuration)</td></tr>
<tr><td>Arc-enabled SQL MI General Purpose</td><td>Microsoft Azure SQL Managed Instance - Azure Arc - 15.0.2327.117 (X64) Mar 10 2022 12:24:25 Copyright (C) 2019 Microsoft Corporation General Purpose (64-bit) on Linux (Ubuntu 20.04.4 LTS) <X64></td></tr>
<tr><td>Arc-enabled SQL MI Business Critical</td><td>Microsoft Azure SQL Managed Instance - Azure Arc - 15.0.2327.117 (X64) Mar 10 2022 12:24:25 Copyright (C) 2019 Microsoft Corporation Business Critical (64-bit) on Linux (Ubuntu 20.04.4 LTS) <X64></td></tr>
</table>
</td></tr>
</table>

Conclusion

Microsoft Azure Arc-enabled SQL Managed Instance makes it easier for database administrators to manage on-premises SQL Server workloads in a hybrid and multicloud deployment model. This paper demonstrates the power and capability of the Dell PowerStore and PowerEdge products, combined with Arc-enabled SQL MI including contained availability group, to deliver a high availability DBaaS solution.

Unlike many performance studies, this workload was run on a very common hardware configuration. The PowerEdge servers with Intel® Xeon® Gold processors and 256GB DD4-DRAM are an affordable configuration with room to grow.

Throughout this study we have demonstrated exceptional performance, simplified and accelerated deployment, and predictable scale. Benefits include:

- Deploy entire database environments, including Always On Group environments (with separate copies of each database), in as little as two to three minutes.

- 15% performance improvement when comparing an Arc-enabled SQL Managed Instance Business Critical vs. a SQL Server 2019, Windows, and VMware ESXi configuration.
- 60 Seconds to deploy an Arc-enabled SQL Managed Instance Business Critical environment with HA capability.
- Leverage existing SQL Server skill experience, as this is the same SQL engine.
- Remove the burden of selecting and balancing RAID levels with the data redundancy feature provided by the PowerStore Dynamic Resiliency Engine.
- Easily move data between traditional SQL Server instances and an Arc-enabled SQL MI with PowerStore's multiprotocol file access capabilities.
- Flexible storage system that provides a single architecture unified (block and file) or block optimized workloads to support a wide variety of traditional and modern workloads.
- No tuning required. Performant "out of the box" with default settings.

The combination of Arc-enabled SQL MI and a Dell Technologies infrastructure foundation helps ease and accelerate SQL Server data estate modernization strategies in a hybrid and multicloud world.

Appendix

SQL test harness details for HammerDB TPROC-C workload

Deployment steps for the multi-instance Arc-enabled SQL MI test harness:

Note: We authored and managed all work with VS Code.

We deployed a SQL MI with Azure Arc-enabled data services in direct mode.

We pre-built the TPROC-C database on the first Arc-enabled SQL MI. We pre-sized the SQL Server data and log files.

We retrieved the Arc-enabled SQL MI endpoint IP for the instance we were restoring the database into.

We restored the database backup to the arc-sqlmi container in the appropriate Arc-enabled SQL MI pod.

We deployed the T-SQL Stored Procedure test harness. A custom T-SQL procedure was created and deployed to the Master database on the instance. Results were inserted into a reporting table:

```
CREATE TABLE dbo.TPSvalues
    (
    RowID_TPSvalues INT IDENTITY (1,1)
    ,ServerName VARCHAR(20)
    ,ValueReportTime SMALLDATETIME
    ,TPSvalue BIGINT
    ,TPSvaluePerMinute BIGINT
    ,TPSvaluePerSecond AS (TPSvaluePerMinute / 60) PERSISTED
    ,UserCount INT
    ,CPUCount INT
    ,[CommittedMemory(MB)] BIGINT
    ,[TargetMemoryGoal(MB)] BIGINT
    ,BatchID UNIQUEIDENTIFIER
    ,CpuRank NVARCHAR(MAX)
    ) ;
```

We ran a timed HammerDB workload with an incrementing user count. We used the autorundrive.tcl file and updated it with the IP address of the Arc-enabled SQL MI endpoint. We ran the batch file using the integrated terminal from the HammerDB root directory in *C:\Program Files\HammerDB-4.4*.

The multi-instance test batch file included two execution statements per instance:

1. Ran a small piece of dynamic SQL in a .sql file that resided in the HammerDB root execution directory.
2. Started the Arc-enabled SQL MI specific HammerDB drive CLI - each containing the specific IP for each instance endpoint.

The process ran for the duration configured in the HammerDB autorundrive.tcl file.

We deployed a master reporting SQL instance. We used a Linked Server connection to each of the Arc-enabled SQL MIs to retrieve the records by batch ID.

We grouped the TPM results by batch ID on the reporting host.

Finally, we pulled the aggregated data to Excel and used pivot tables to display our results in charts.

References

Dell Technologies documentation

The following Dell Technologies documentation provides other information related to this document. Access to these documents depends on your login credentials. If you do not have access to a document, contact your Dell Technologies representative.

- *Dell PowerStore Storage Resources on InfoHub*
- *Dell PowerEdge Server resources on InfoHub*
- *Dell InfoHub resources for SQL Server*
- *Dell Container Storage Modules*

Microsoft documentation

The following Microsoft documentation provides more detail on Azure Arc-enabled SQL Managed Instance:

- *Azure Arc-enabled SQL Managed Instance Overview*