Analyzing SAP Performance with VMware vRealize® Operations™

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Contents

List of Figures

1. Overview

This document outlines some use cases for monitoring and analyzing SAP deployments with VMware vRealize® Operations™ and the Blue Medora Management Packs.

The scope of the content is based upon testing with the following SAP systems:

- SAP Netweaver 7.4 Business Warehouse on HANA
- SAP Netweaver 7.4 ABAP stack on Oracle.

The following is covered:

- Overview of the Blue Medora SAP, SAP HANA, and Oracle Database Management Packs.
- Memory management use case based on SAP HANA.
- Super metric example based on the Netweaver ABAP stack memory counters.
- SAP on Oracle troubleshooting example covering Oracle and SAP counters.
- Example custom dashboard – Blue Medora provides “out-of-the-box” dashboards that provide a holistic view of all chosen SAP systems and components within the SAP architecture. Meanwhile, it may be useful to create some custom dashboards to provide a drill-down on specific user-defined SAP scenarios.

Note At least vRealize Operations Advanced edition is needed for customizable dashboards and reports. Refer to **Compare** at http://www.vmware.com/products/vrealize-operations.html.

2. Introduction

2.1 vRealize Operations

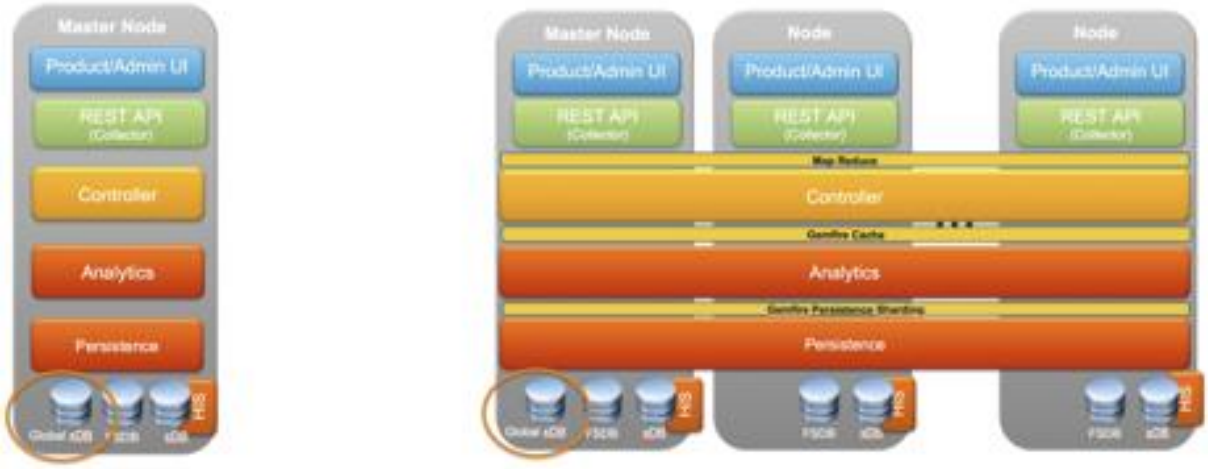
vRealize Operations provides a complete view of health and performance across the Software-Defined Data Center (SDDC), including VMware vSphere® and VMware vSAN™. vRealize Operations enables proactive remediation of performance problems through predictive analytics and alerts. vRealize Operations can provide actionable explanations of underlying problems and recommended corrective actions. Administrators can access the data required to make informed, intelligent, operational, and capacity management decisions through out-of-the-box and customizable dashboards, views, and reports.

vRealize Operations is provided as a virtual appliance that is installed from an OVF file.

VMware vRealize Operations Manager™ v6.x has been completely redesigned since the 5.x version. It uses Gemfire cluster technology, and as such can also scale-out for additional capacity. In addition, the Advanced and Enterprise editions have vRealize Operations specific High Availability functionality (not related to VMware vSphere High Availability).

The following figure shows examples of vRealize Operations architectures.

Figure 1. vRealize Operations Deployment Architecture Examples



Single Node Cluster Multi-Node Cluster

The cluster nodes participate in the VMware vRealize Operations Manager™ cluster. There are three node types:

- Master node – The first node assigned to the cluster, responsible for managing all the other nodes in the cluster.
- Data nodes – Make up the remaining nodes of a non-HA cluster.
- Replica node – A backup to the master node should the master node fail. This assumes vRealize Operations Manager HA is enabled.

For more information see vRealize Operations Manager Reference Architecture.

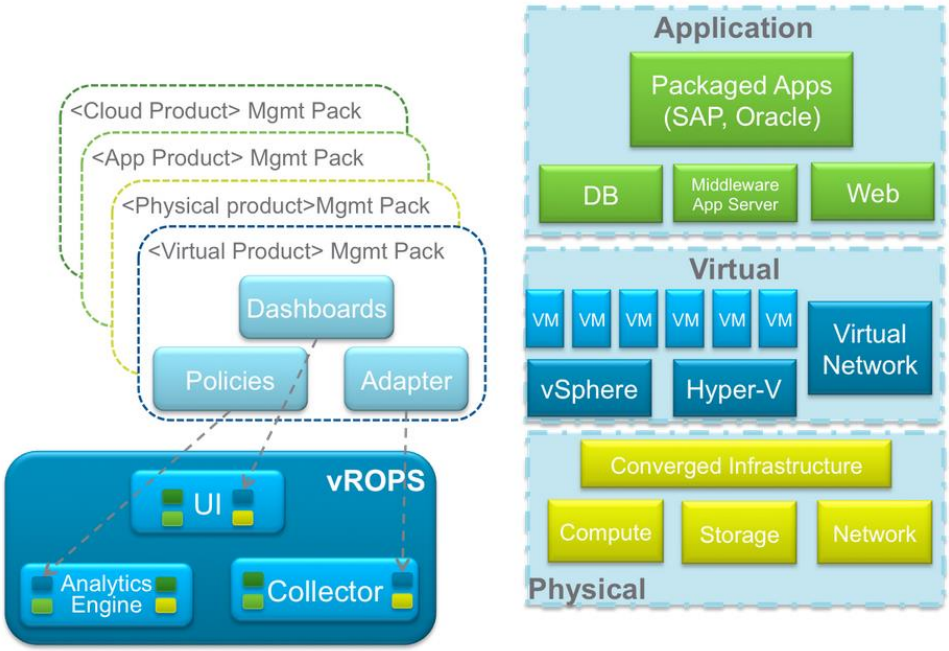
2.1.1 VMware vRealize Operations Management Packs

The VMware vRealize Operations Management Pack™ extends vRealize Operations Manager capabilities to monitor other technology domains such as storage, network, compute, or application. vRealize Operations Management Packs include several components, for example:

- Adapter – one of more Java files implementing vRealize Operations Management APIs and providing the data pipe for time series data in events.
- Pre-built dashboards – set of user interface definition files that is built by configuring vRealize Operations Management widgets around the domain specific information.

For more information see https://developercenter.vmware.com/vmware-ready-programs/management/vrealize-operations . The following diagram from this source describes the overall architecture of the management packs.

Figure 2. vRealize Operations Management Pack Design



2.2 Blue Medora

Blue Medora is a VMware partner that provides VMware-enabled management packs that aggregate individual resource data from cloud, storage arrays, databases, and applications such as Amazon, Cisco, Citrix, Mongo, Microsoft, NetApp, Oracle, and SAP. The management packs are installed into vRealize Operations, and make it possible for administrators to identify performance issues in these applications from vRealize Operations dashboards. The management packs include out-of-the-box dashboards, and enable correlation of performance metrics in software like SAP, SAP HANA, and Oracle databases with vSphere level performance data.

2.3 SAP

SAP creates enterprise software to manage business operations and customer relations. The company's best-known software products are its Business Suite of solutions (such as SRM, CRM, SCM, PLM, and ERP), its Enterprise Data Warehouse solution (SAP Business Warehouse - SAP BW), SAP Business Objects, and the Sybase and SAP HANA data platform. For further information on SAP solutions, see http://go.sap.com/solution.html#productcategories.

SAP NetWeaver is the technical foundation for many SAP applications. It is a solution stack of SAP's technology products. The SAP Web Application Server is the runtime environment for SAP applications on which all of the Business Suite solutions run.

Production support for SAP NetWeaver and the Business Suite of SAP solutions on vSphere has existed since 2008, and this support now includes Business Objects and the Sybase and SAP HANA database platform.

2.3.1 SAP Architecture

This section summarizes SAP architecture concepts and terminology used in this document.

SAP uses the term *system landscape*, which contains all the SAP systems that have been installed. It can consist of several system groups where SAP systems are linked by transport routes. *Transport routes* refers to the paths of code migration between SAP systems, for example from Development (DEV) to Quality Assurance (QAS) to Production (PRD) (https://help.sap.com/saphelp_nw74/helpdata/en/63/a30a4ac00811d2851c0000e8a57770/content.htm).

The architecture of a single SAP system is multitier and consists of the following components:

- Application Servers (SAP Web Application Servers) – These are ABAP and/or Java (J2EE) based, depending on the specific SAP product or module. Two types exist:
    - Primary Application Server (PAS) – An application server instance that is installed with SAP Central Services in newer NetWeaver releases and is part of the base installation.
    - Additional Application Servers (AAS) – Application servers installed as required for horizontal scalability. These can also be referred to as dialog instances.
- SAP Message Service – The SAP Message Service is used to exchange and regulate messages between SAP instances in a SAP system. It manages functions such as determining which instance a user logs onto during client connect, and scheduling batch jobs on instances configured for batch.
- SAP Enqueue Service – The SAP Enqueue Service manages the locking of business objects at the SAP transaction level. Locks are set in a lock table stored in the shared memory of the host on which the SAP Enqueue Service runs.
- Database Server – SAP supports several databases. The most common databases include Oracle, SAP HANA, Microsoft SQL Server, Sybase, and IBM DB2.

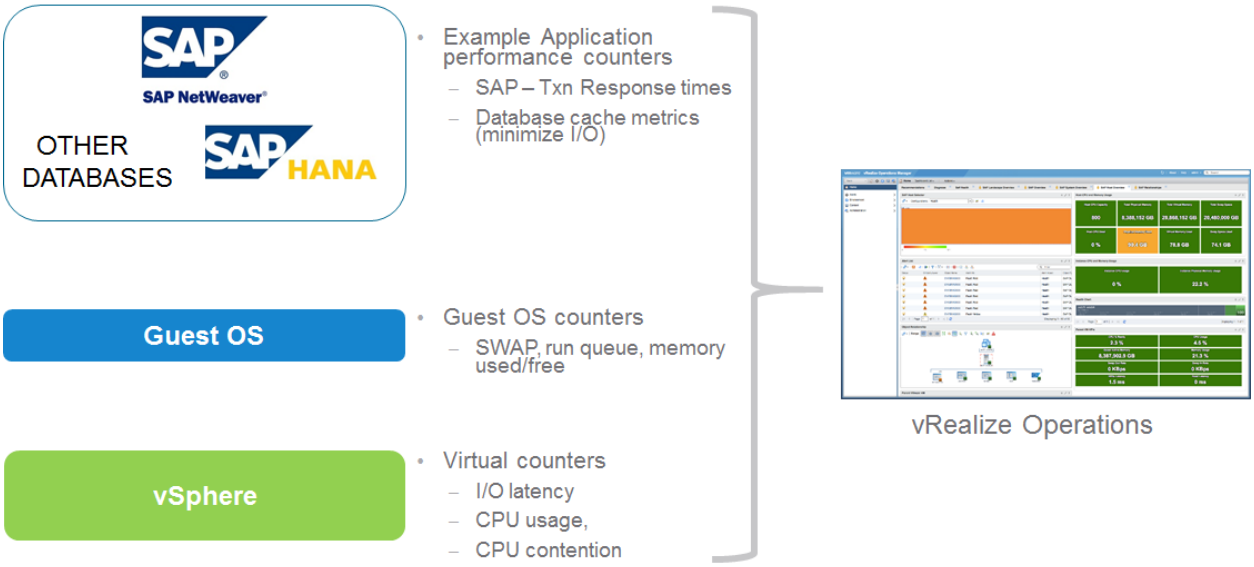
The following SAP services are defined based on the Message and Enqueue Services:

- Central Instance (CI) – Comprised of the Message and Enqueue Services and other SAP work processes that allow the execution of online and batch workloads. In newer NetWeaver releases, the CI is replaced with SAP Central Services and the Primary Application Server.
- SAP Central Services – In newer versions of SAP, the Message and Enqueue Services have been grouped into a standalone service. Separate Central Services exist for ABAP- and Java-based application servers. For ABAP variants, it is called ABAP SAP Central Services (ASCS), and for J2EE variants is called SAP Central Services (SCS).

3. Monitoring the Virtual SAP Stack

A virtualized SAP environment has multiple layers of technology that require monitoring, including SAP Netweaver (ABAP and/or JAVA stack), database, guest operating system (Guest OS), and vSphere hypervisor. Each layer typically has its own administrator (in a traditionally siloed organization) and its own set of metrics to track and measure performance, and typically the administrator is more familiar with the metrics of his/her respective layer. Troubleshooting such a scenario can be challenging because visibility of metrics across all the layers can be limited, and this is required for effective resolution of performance problems. vRealize Operations can help here by providing the complete view across the different layers. The following diagram demonstrates this concept.

Figure 3. Performance Metrics Across Some of the Layers



Correlating the performance metrics across the layers enables better understanding for all the administrators, for example:

- SAP administrators need to see impact of heavy SQL workloads on memory utilization of the database. (Databases cache data in its own memory areas, and utilization of this cache is dependent on the SQL code. Undersized database memory can result in unnecessary I/O to disk, which can reduce performance).
- SAP and database administrators concerned with I/O performance need to see the I/O latency counters in vSphere, not the Guest OS.
- SAP and database administrators concerned about over-commit of CPU resources need to access the vSphere counter that measures CPU contention between virtual machines.
- vSphere administrators need a realistic view of memory used by SAP and/or database within the virtual machine. The Guest OS memory counters or the application-specific counters in SAP and the database can provide an accurate indication of memory usage.
- I/O performance is critical for mission-critical SAP systems, hence vSphere administrators monitor the vSphere I/O latency counters and certain threshold values. It would be more effective to correlate these thresholds with the actual response time experienced by the SAP users (which is available in the SAP layer). There may be cases where the I/O latency values could be higher than the threshold,

but meanwhile users are not experiencing a noticeable slowdown in performance as measured by the SAP response time metrics.

Some of the performance metrics for each of the layers (SAP, database, and vSphere) are described in this document. The next section covers the vSphere layer metrics.

3.1 vSphere Performance Metrics

vSphere performance metrics can be accessed and analyzed with different tools from VMware, including vRealize Operations. These tools include:

- VMware vCenter Server® system – collects statistical data that captures CPU, memory, disk, network, system, and virtual machine operations metrics. Performance charts are available to view the metrics via the vSphere Web Client.
- vRealize Operations – a vCenter Server adapter enables vRealize Operations to monitor the VMware virtual infrastructure, you configure the vCenter Server adapter for each of your vCenter Server instances. The VMware vSphere solution is provided with vRealize Operations Manager by default – no separate download or management pack installation is required. This vCenter Server adapter collects the vSphere performance data and makes it available inside of vRealize Operations.
- rexstop/esxtop – command-line utilities that provide a detailed look at how VMware ESXi™ uses resources in real time. These can be started in one of three modes: interactive (default), batch, or replay. rexstop is used remotely, whereas esxtop is started through the ESXi Shell of a local ESXi host.

The following table summarizes some of the vSphere counters useful for SAP environments.

Counter	Description
Virtual Machine CPU Usage (%)	CPU usage is the average CPU utilization over all available virtual CPUs in the virtual machine. This is the host's view of the CPU usage, not the guest operating system view. At high workloads the vSphere CPU counter can provide more accurate measurement of CPU utilization versus the guest OS counter (https://kb.vmware.com/kb/2031).
Virtual Machine Ready (%)	Percentage of time that the virtual machine was ready, but could not get scheduled to run on the physical CPU, for example due to other virtual machines causing CPU resource constraint on the ESXi host.
Virtual Machine Consumed Memory	Amount of machine memory allocated to the virtual machine, accounting for savings from shared memory. The counter increases when memory is used by the virtual machine, but does not decrease if the application gives up the memory inside the Guest OS.
Virtual Machine Memory Reservation	Memory reserved for the virtual machine. A best practice for mission-critical production SAP systems as an insurance policy against potential degraded performance due to memory over-commit scenarios.
Balloon Memory	Amount of guest physical memory reclaimed from the virtual machine by the balloon driver. This is part of VMware's memory reclamation technique. Counter should be zero if there is no memory over-commit/memory pressure on the ESXi host.

Counter	Description
Swapped	The amount of guest physical memory swapped out to the disk by the VMkernel. This data counter measures VMkernel swapping and is part of VMware's memory reclamation techniques (this is not Guest OS swapping). Counter should be zero if there is no memory over-commit/memory pressure on the ESXi host.
Kernel Latency (ms)	Measures the average amount of time, in milliseconds, that the VMkernel spends processing each SCSI command. For best performance, the value should be 0-1 milliseconds. If the value is greater than 4ms, the virtual machines on the host are trying to send more throughput to the storage system than the configuration supports.
Device Latency (ms)	Measures the average amount of time, in milliseconds, to complete a SCSI command from the physical device. Depending on your hardware, a number greater than 15ms indicates probable problems with the storage array.
Queue Latency (ms)	Measures the average amount of time taken per SCSI command in the VMkernel queue. This value must always be zero. If not, the workload is too high and the array cannot process the data fast enough.
Receive/Transmit Packets Dropped	Dropped network packets indicate a bottleneck in the network.

For a complete list of performance counters see the Performance Monitoring guide listed in the Resources section.

4. Lab Environment

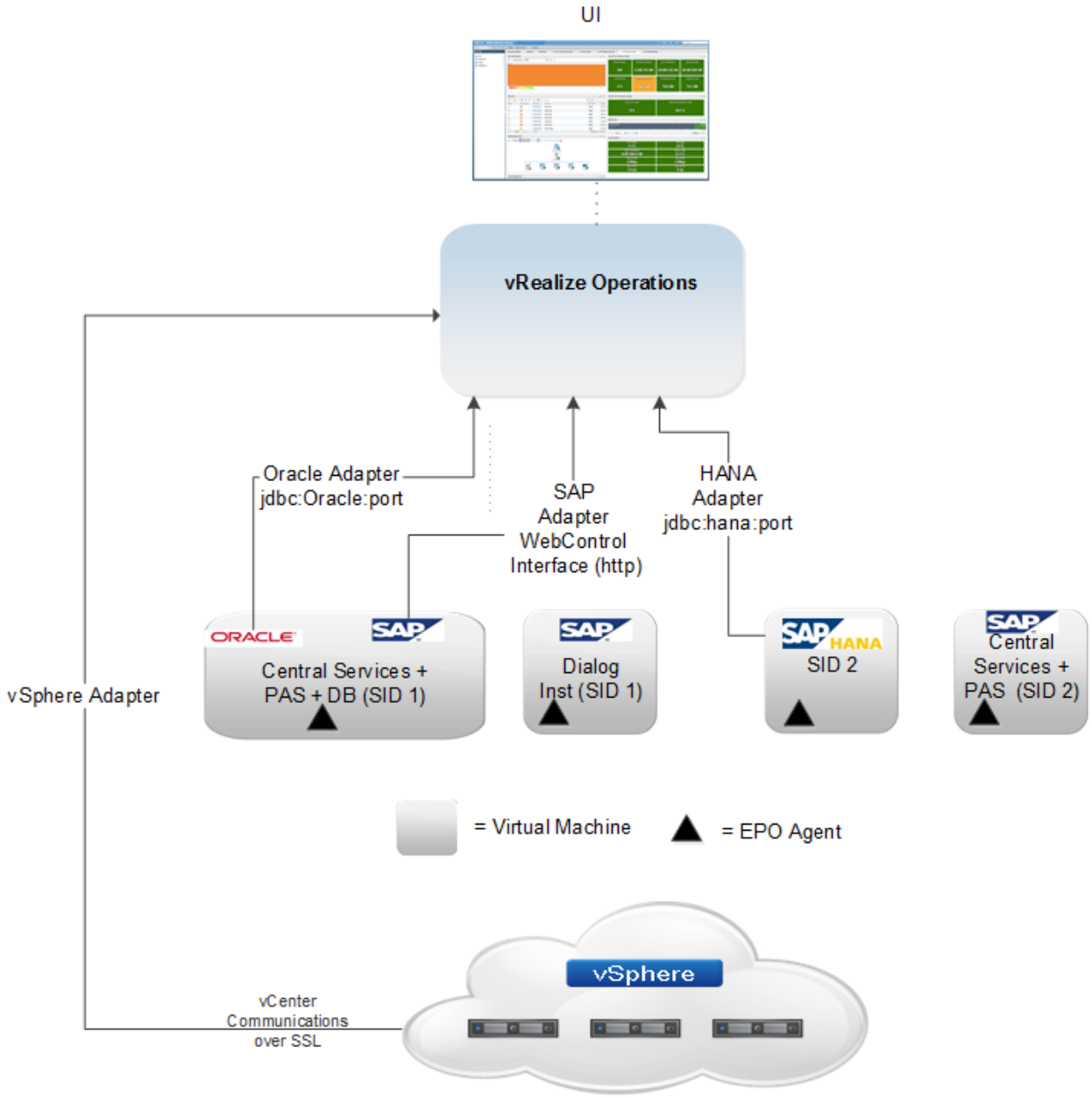
The use cases described in this document are based on a lab setup of a small virtual SAP landscape: SAP ECC on Oracle; SAP BW on SAP HANA. The lab setup is described in this section. The following table lists the virtual machines and software instances running inside them.

Table 1. Overview of Virtual Machines and SAP Applications

Virtual Machine Name	Hostname	Application Instances
SAP_DB	dbcitst	NetWeaver 7.4, SAP ECC Oracle 11.2 Instance, SID = “TST” Primary Application Server (PAS) ABAP Central Services (ASCS)
sap_app	apptst	Dialog Instance (AAS) for SID = “TST”
BW_HANA3	bwhana3	NetWeaver 7.4, SAP BW HANA Instance, SID = “HAN”
bwhanaapp3	bwhanaapp3	Primary Application Server (PAS) for SID = “HAN” ABAP Central Services (ASCS)

The following diagram shows the Blue Medora management packs/adapters that were installed. The Blue Medora documentation provides steps for installation.

Figure 4. Overview of Lab Setup



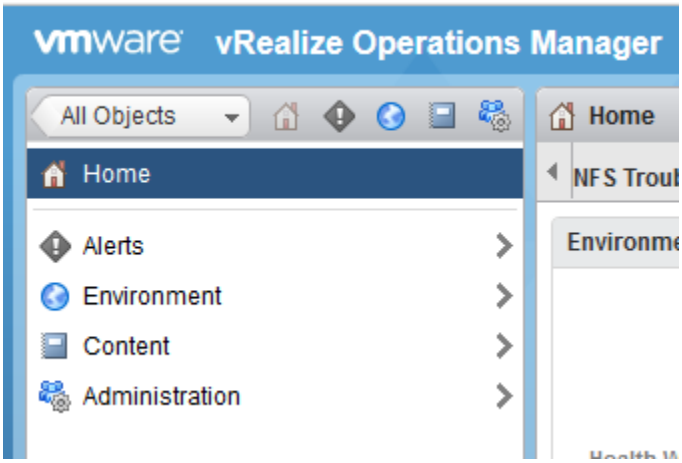
The SAP systems are deployed as sandbox environments for testing vRealize Operations functionality and are not configured and sized for performance and scale.

In the setup shown in Figure 4, the SAP adapter was configured to connect to the Central Services of one of the SAP systems (SID 1). Once connected, it discovers all the other instances configured for the SAP system.

EPO in the diagram above refers to the End Point Operations agent to access Guest OS metrics – see next section for details.

The home page after initial logon to vRealize Operations shows the following in the top left.

Figure 5. vRealize Operations Home Page

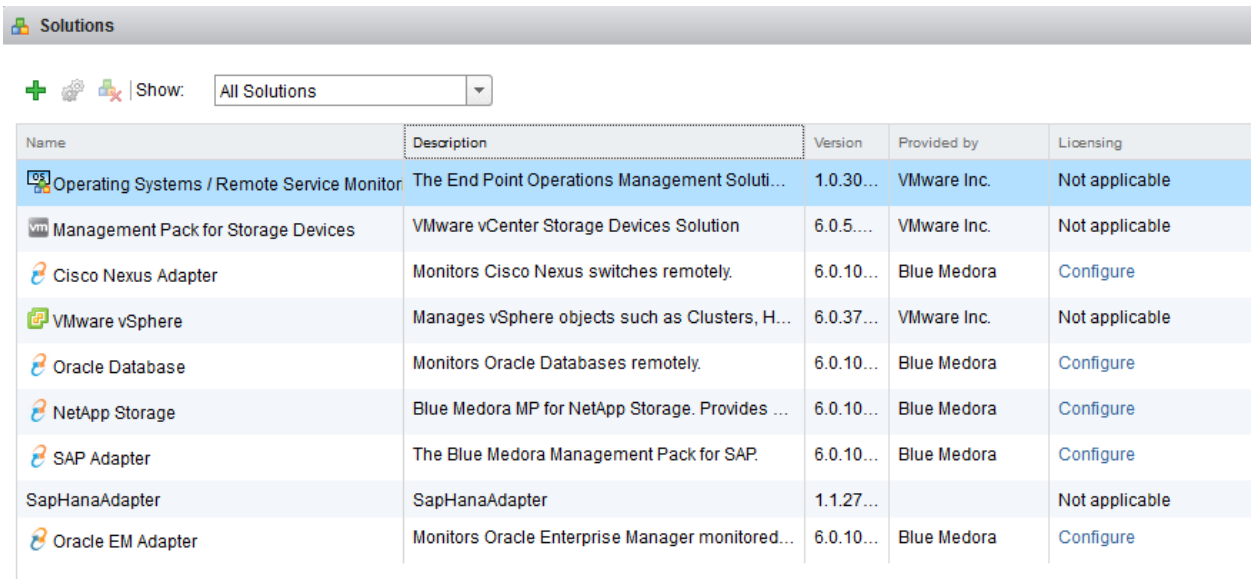


Screenshots of vRealize Operations shown in this document were accessed through menu paths that originated from the home page in Figure 5.

An overview of installed management packs can be seen in vRealize Operations.

Menu: Home > Administration > Solutions

Figure 6. Overview of Installed Adapters

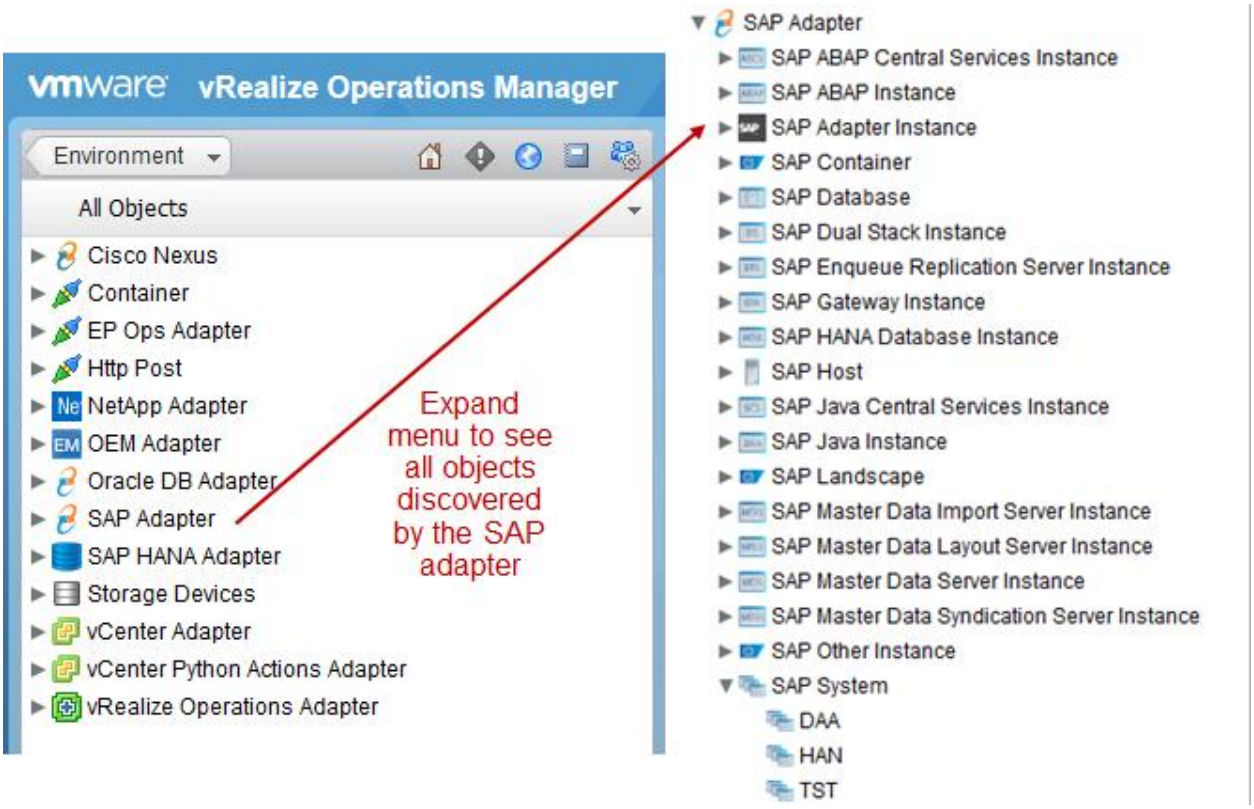


Name	Description	Version	Provided by	Licensing
Operating Systems / Remote Service Monitor	The End Point Operations Management Soluti...	1.0.30...	VMware Inc.	Not applicable
Management Pack for Storage Devices	VMware vCenter Storage Devices Solution	6.0.5....	VMware Inc.	Not applicable
Cisco Nexus Adapter	Monitors Cisco Nexus switches remotely.	6.0.10...	Blue Medora	Configure
VMware vSphere	Manages vSphere objects such as Clusters, H...	6.0.37...	VMware Inc.	Not applicable
Oracle Database	Monitors Oracle Databases remotely.	6.0.10...	Blue Medora	Configure
NetApp Storage	Blue Medora MP for NetApp Storage. Provides ...	6.0.10...	Blue Medora	Configure
SAP Adapter	The Blue Medora Management Pack for SAP.	6.0.10...	Blue Medora	Configure
SapHanaAdapter	SapHanaAdapter	1.1.27...		Not applicable
Oracle EM Adapter	Monitors Oracle Enterprise Manager monitored...	6.0.10...	Blue Medora	Configure

Once all the adapters are installed and configured to collect data from their source systems (for instance, SAP, HANA, and Oracle), vRealize Operations generates objects for all the discovered applications. Access to the application metrics require navigating to these objects.

Menu: Home > Environment > All Objects

Figure 7. Overview of Objects After Configuration of Adapters



4.1 End Point Operations

As of the 6.1 release of vRealize Operations, VMware merged the Hyperic Monitoring solutions into vRealize Operations. This is referred to as End Point Operations and allows data collection of Guest OS level metrics inside of vRealize Operations. This requires installation of an End Point Operations agent in the Guest OS. Guest OS data has advantages for SAP applications because it enables access to the Guest OS memory counters, which provides a clearer picture of how memory is being used by SAP.

Installation details of the End Point Operations agent is available at https://pubs.vmware.com/vrealizeoperationsmanager-64/index.jsp?topic=%2Fcom.vmware.vcom.core.doc%2FGUID-44080717-078F-401A-B99C-F220D03D144C.html.

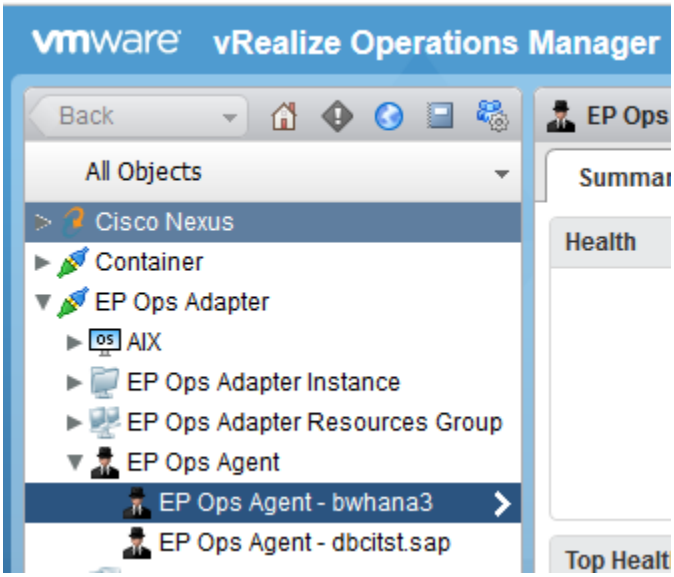
Once the agent is installed, connection parameters are required to access the vRealize Operations server. For example, on Linux the following parameters need to be set in the file `/opt/vmware/epops-agent/conf/agent.properties`:

```
agent.setup.serverIP=NNN.NNN.NNN.NNN

agent.setup.serverSSLPort=443

agent.setup.serverLogin=xxxxxx

agent.setup.serverPword=xxxxxxxx
```

Once configured, the Guest OS data can be viewed inside of vRealize Operations. In this example, the installation was implemented on Guest OS host name bwhana3, which runs the SAP HANA instance.

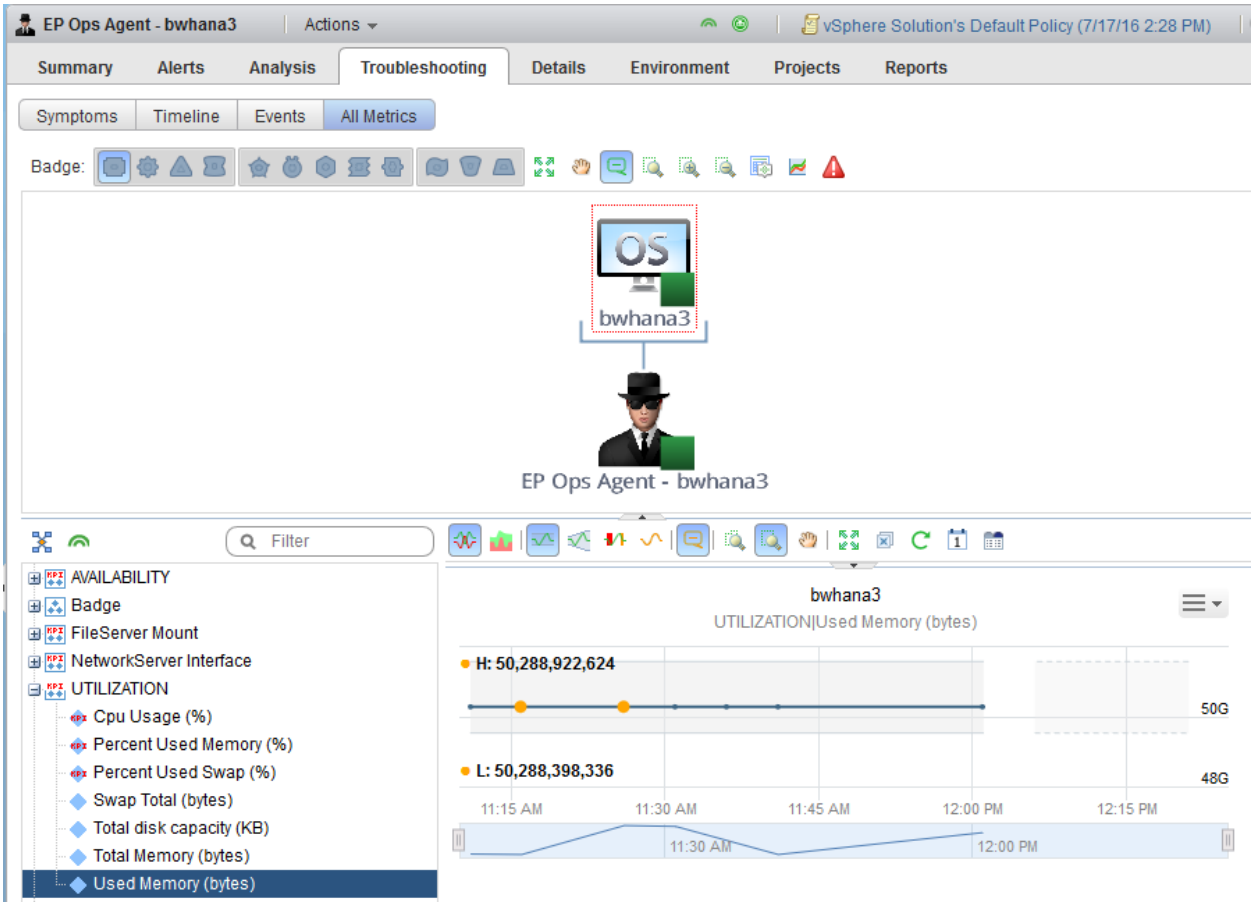
Menu: Home > Environment > All Objects > Expand menu to show EP Ops Adapter

Figure 8. EP Ops Adapter Objects After Agent Successfully Installed in Guest OS



Menu: Select EP Ops Agent – bwhana3 > Troubleshooting > All Metrics

Figure 9. Guest OS Metrics Collected through EP Ops Agent



The previous screenshot shows some of the Guest OS metrics, for example used memory, which can be useful for monitoring SAP.

5. Blue Medora Management Packs

This section covers the Blue Medora Management Packs for SAP, SAP HANA, and Oracle.

5.1 SAP Management Pack

Details of the Blue Medora SAP Management Pack are available at
http://www.bluemedora.com/products/vRealize Operations-management-pack-for-SAP/

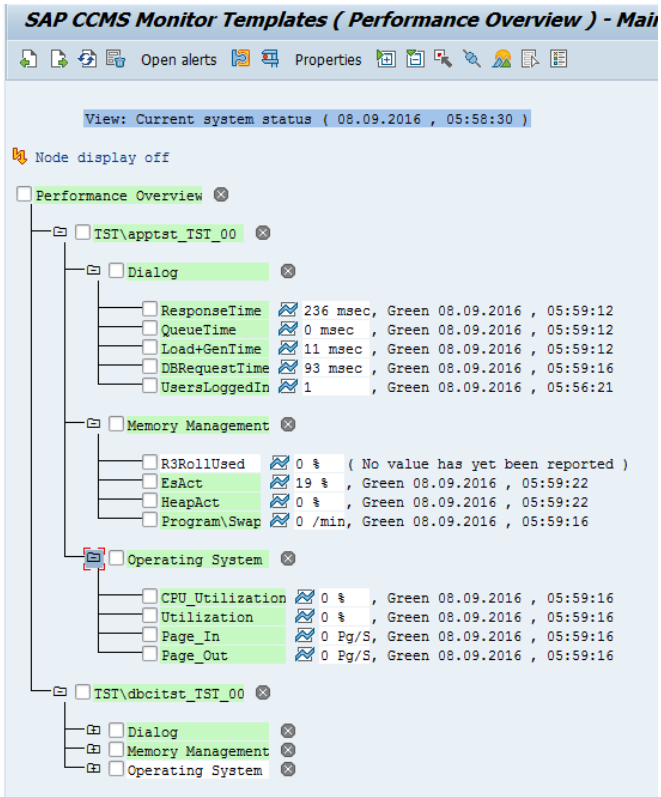
5.1.1 SAP Counters

The Management Pack for SAP connects with the SAPControl Web Service Interface to retrieve data.

The data retrieved by the pack is the same performance data that SAP administrators can access in SAP's Computer Center Management System. SAP has a monitoring component called Computer Center Management System (CCMS), which provides a range of monitors for monitoring SAP environments. These monitors include performance counters for understanding and evaluating the behavior of the SAP processing environment. If performance values are poor, the monitors provide information to fine-tune the SAP system.

The performance data in CCMS can be accessed by SAP administrators through the SAP client (SAP GUI). The CCMS monitors are available in SAP transaction code RZ20. The following figure shows RZ20 and some performance counters.

Figure 10. Basis Transaction RZ20 Screenshot



Some of the counters are documented in the following table. Consult SAP documentation for the complete list of performance counters.

Table 2. Some Useful SAP Metrics

Counter	Description
Dialog Response Time	Period of time from the request of the dialog to the dispatcher through processing to the end of the dialog in the dispatcher and the transfer of the data to the presentation layer.
Database Request Time	Average time for processing logical database requests (calls to the SAP database interface).
Background Utilization	Percentage of the background processing capacity currently utilized. The value is averaged over the background work processes and, by default, averaged over the last hour.
Users Logged On	Number of users logged in to an application server or dialog instance.
Extended Memory utilization	Percentage usage of extended memory. Extended memory contains the largest part of the user context. The page management of this memory is performed not by the operating system, but directly by the SAP system.
Heap Memory Utilization	Percentage usage of private memory. A work process is only assigned private memory if the roll area and extended memory are occupied. The work process is then reserved for the current user context until the end of the transaction.

For a complete list of SAP performance counters consult the SAP documentation.

5.1.2 Installation and Configuration

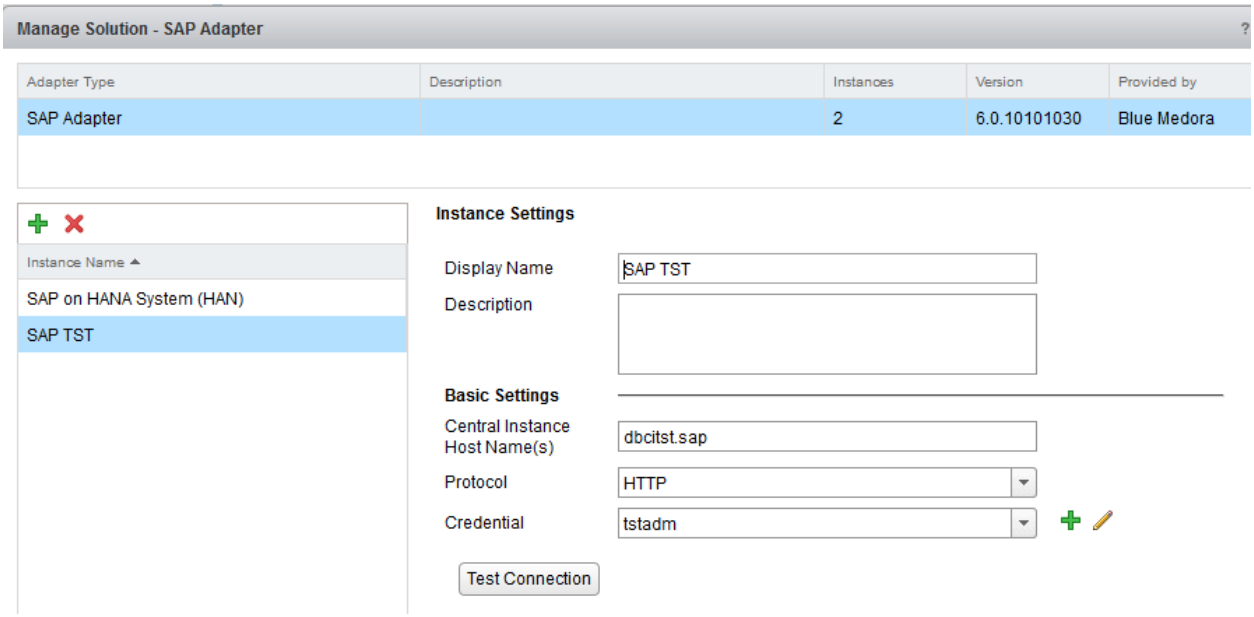
Installation guidelines for the SAP Management Pack are available here: http://www.bluemedora.com/wp-content/uploads/2015/05/Blue-Medora-vRealize-Operations-Management-Pack-for-SAP-CCMS-Installation-Guide.pdf.

After installation, configuration is required to connect to an individual SAP system.

Menu: Home > Administration > Solutions

Select SAP Adapter > Configure

Figure 11. Connect to SAP System

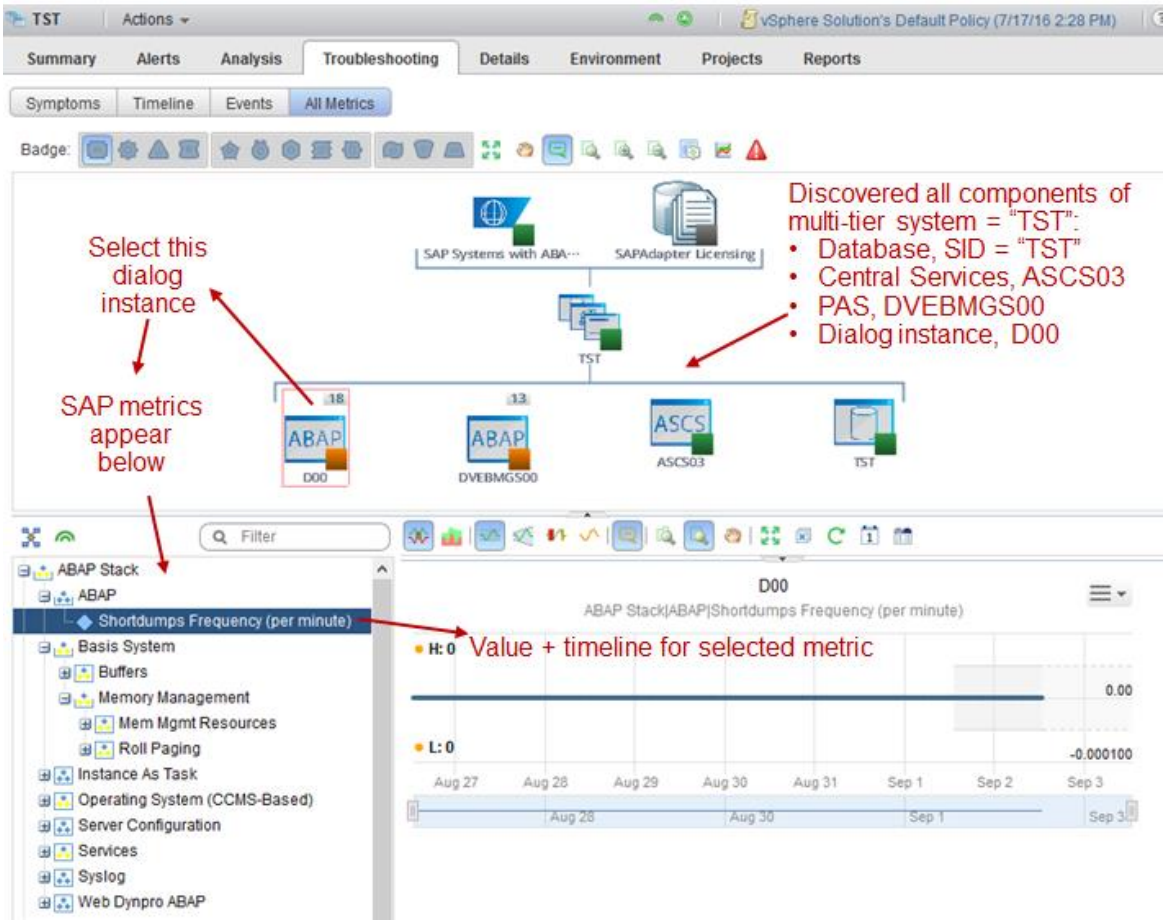


Once configured, vRealize Operations discovers the instance architecture of the complete SAP system.

Menu: Environment > All Objects

Expand the menu tree on the left, Select SAP system TST > Select Troubleshooting Tab > Select All Metrics

Figure 12**. SAP System Discovery**



5.2 SAP HANA Management Pack

Details of the Blue Medora SAP HANA Management Pack are available at http://www.bluemedora.com/products/vRealize Operations-management-pack-for-sap-hana/
The Management connects to any SAP HANA instance running on a dedicated appliance or on VMware through a JDBC connection. It extracts a large number of SAP HANA health, performance, and availability metrics.

As SAP HANA is an in-memory database, memory is a key resource that needs to be monitored. The following table defines some of the HANA memory metrics.

Table 3. HANA Metric Examples (source: SAP HANA Memory Usage Explained)

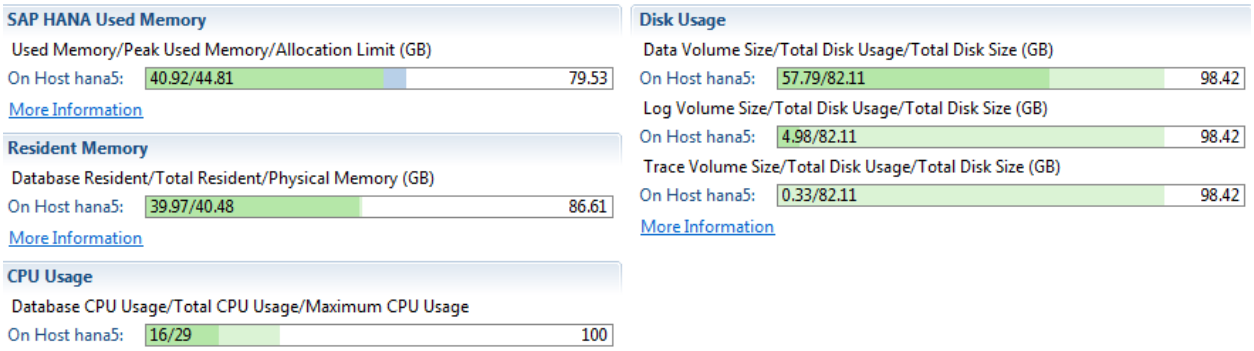
Counter	Description
Used Memory	Total amount of memory currently in use by SAP HANA – indicates the amount of memory that SAP HANA requires at any time.

Counter	Description
Allocation Limit	Maximum amount of memory HANA can use. Set at a percentage of total physical memory available to the OS, that is, configured RAM size of the virtual machine (see SAP documentation for percentage values).
Resident Memory	Physical memory in operational use by all the HANA processes.

For a complete list of SAP HANA performance counters, consult the SAP documentation.

The SAP HANA studio is a client tool that enables system administrators / technical users to manage the SAP HANA database. The following is a screenshot of HANA studio showing some performance metrics.

Figure 13. HANA Studio Example Metrics



The Blue Medora SAP HANA Management Pack can pull these counters as well as many others into vRealize Operations

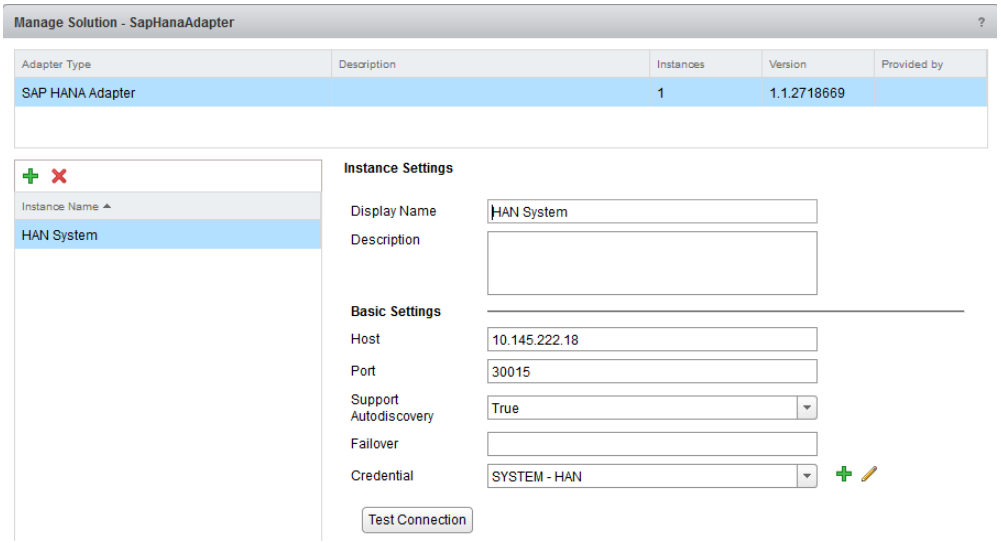
5.2.1 Installation and Configuration

Installation guidelines for the SAP HANA Management Pack are available at http://www.bluemedora.com/wp-content/uploads/2016/06/vCenter_SAP_HANA_Guide-2.pdf
After installation, configuration is required to connect to an individual SAP HANA system.

Menu: Home > Administration > Solutions

Select SapHanaAdapter > Configure

Figure 14. Connect to SAP HANA Database

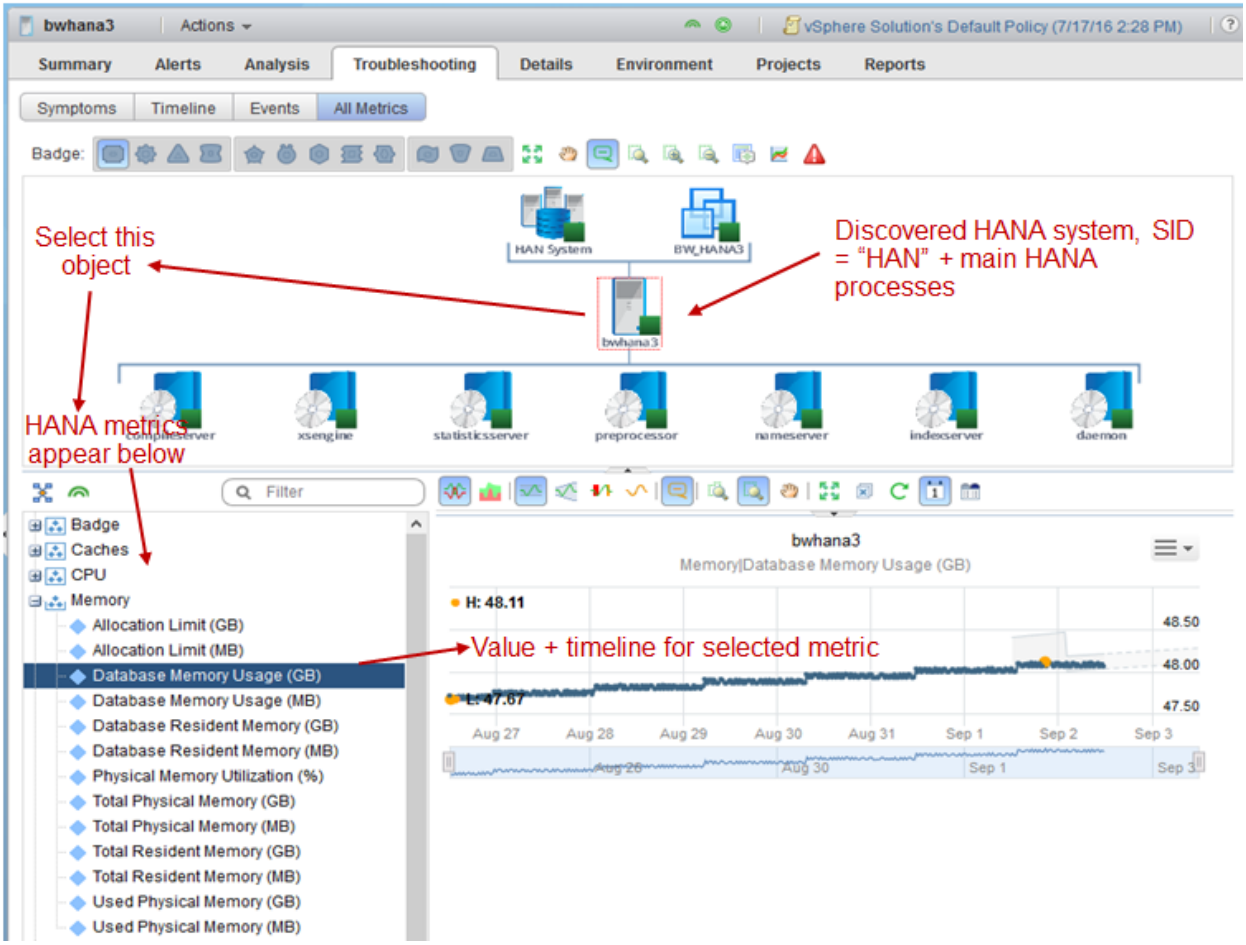


Once configured, vRealize Operations discovers the SAP HANA system.

Menu: Environment > All Objects

Expand the menu tree on the left,
Select SAP HANA host bwhana3 > Select Troubleshooting Tab > select All Metrics

Figure 15. HANA Database Discovery



5.3 Oracle Management Pack

Details of the Blue Medora Oracle Management Pack are available at http://www.bluemedora.com/products/vRealize Operations-management-pack-for-oracle-database/. The Management Pack for Oracle Database monitors Oracle Database systems remotely with a direct connection through JBDC to retrieve performance data from the Oracle database.

The following table defines some of the Oracle metrics.

Table 4. Oracle Metric Examples

Counter	Description
Logical Reads per User Call	Average Oracle blocks read from the buffer cache (part of Oracle's System Global Area)
Physical Reads per Txn	Physical reads from disk if blocks not in memory
DBWR Checkpoints per Second	Frequency of DB writer writing some/all dirty blocks to disk

Counter	Description
Database Wait Time Ratio	Percentage of time spent by the database in waiting for resource

For a complete list of Oracle performance counters, consult the Oracle documentation.

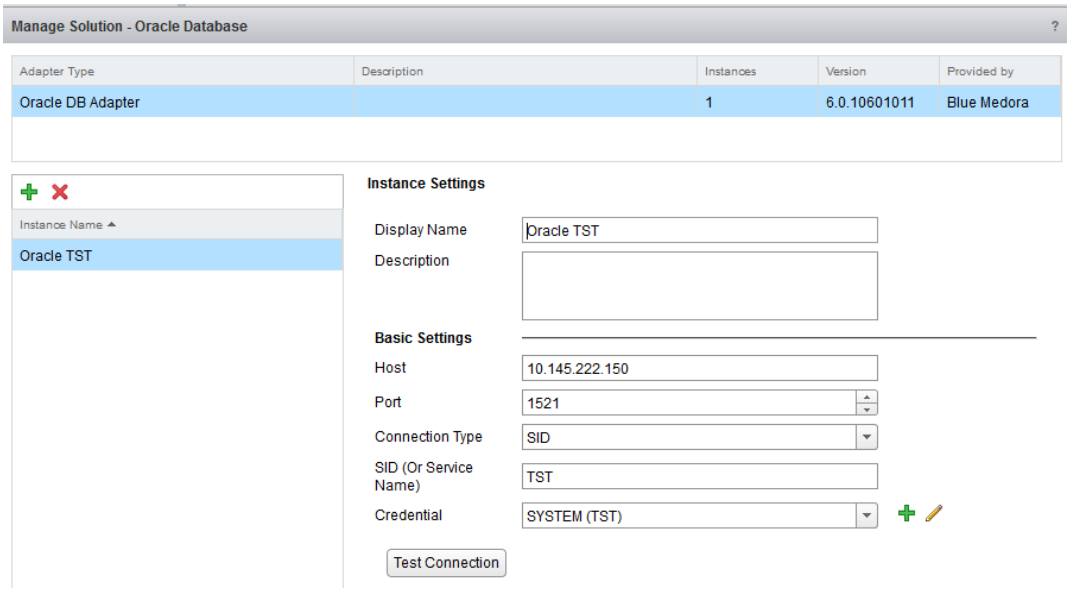
5.3.1 Installation and Configuration

Installation guidelines for the Oracle Management Pack are available at http://www.bluemedora.com/wp-content/uploads/2016/04/Blue-Medora-vRealize-Operations-Management-Pack-for-Oracle-Database-Installation-Guide.pdf. After installation, configuration is required to connect to an individual Oracle system.

Menu: Home > Administration > Solutions

Select Oracle Database > Configure

Figure 16. Connect to Oracle Database

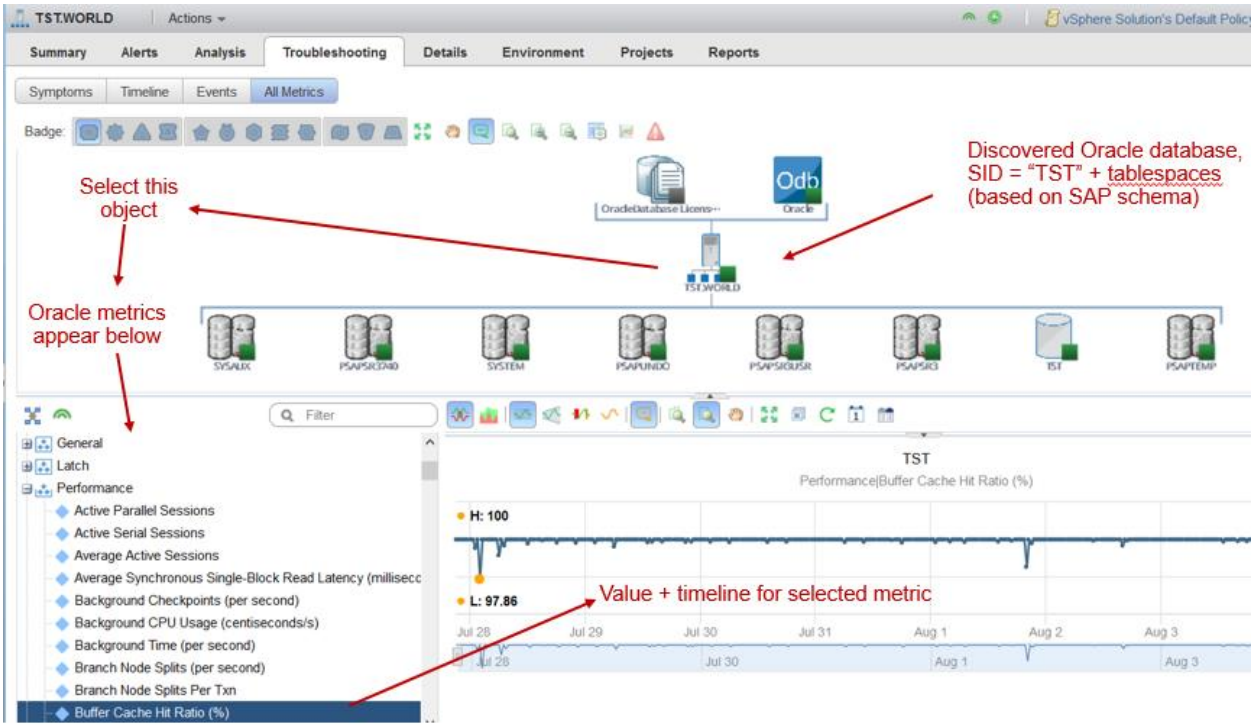


Once configured, vRealize Operations discovers the Oracle database.

Menu: Environment > All Objects

Expand the menu tree on the left, Select Oracle DB Database > Select Troubleshooting Tab > Select All Metrics

Figure 17. Oracle Database Discovery



6. SAP HANA Memory Analysis Example

This section describes a memory management use case based on SAP HANA.

Monitoring and analyzing memory usage of SAP virtual machines can be an important operational activity for the following reasons:

- SAP HANA by nature is memory intensive and it is mandatory to set memory reservations, which can reduce consolidation.
- Sizing of SAP HANA (and SAP NetWeaver) can result in oversized virtual machines from a RAM perspective because sizing is based upon estimate of maximum peak usage, which drives up memory requirements.

Hence monitoring memory usage after go-live can help with right-sizing with the potential of increasing resource utilization and consolidation ratios.

6.1 Memory Counters

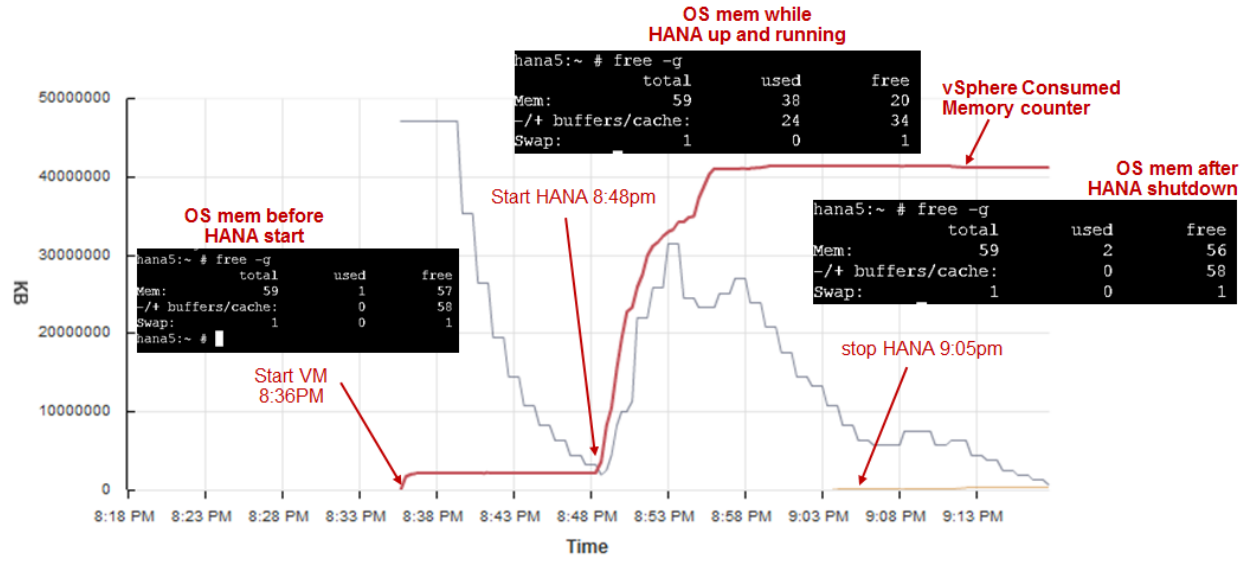
The following table summarizes the different memory counters that can be used for monitoring the memory usage of SAP HANA in a virtual machine.

Table 5. Counters to Measure HANA Memory Usage

Layer	Memory Counter	Description	Source
SAP HANA	Used Memory	Total amount of memory currently in use by SAP HANA – indicates the amount of memory that SAP HANA requires at any time	vRealize Operations HANA Adapter
Guest OS	Used	Memory used as measured by Guest OS, for example, Linux “free –g” command	vRealize Operations EP Ops Agent
vSphere	Consumed	Amount of machine memory allocated to the virtual machine, accounting for savings from shared memory	vRealize Operations default
vSphere	Active	Amount of memory that is actively used, as estimated by VMkernel based on recently touched memory pages	vRealize Operations default

To demonstrate the differences between the vSphere memory counters, the following performance chart, obtained from the VMware vSphere Web Client, shows a timeline of memory counter values based on the following activity: start virtual machine and Linux OS; start SAP HANA instance; stop SAP HANA instance. The diagram also includes the Linux Guest OS memory usage based on the “free –g” command (note this has been added to the diagram manually and is not available via the vSphere Web Client). The virtual machine is configured with 60 GB RAM.

Figure 18. vSphere Consumed versus Active Memory (vSphere Web Client Performance Chart)



Performance Chart Legend

Key	Object	Measurement	Units	Maximum 1 ▼	Latest
	BW_HANA3	Active	KB	47185920	629144
	BW_HANA3	Consumed	KB	41434356	41218988

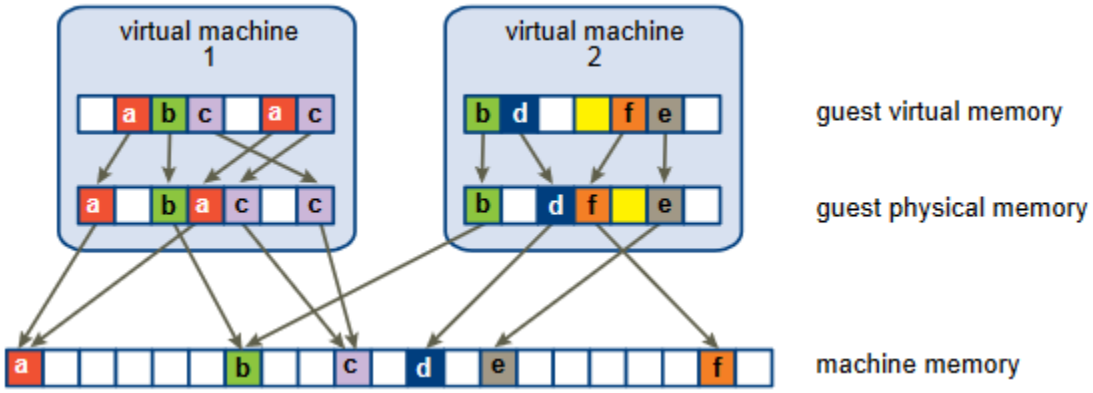
As shown in Figure 18, the active memory counter can provide a much different estimate of memory usage from the consumed memory metric. This is expected, because active memory is calculated by the vSphere hypervisor and its purpose is to assist in making memory scheduler allocation decisions. The active memory counter should not be used for capacity planning estimates of applications like SAP NetWeaver and SAP HANA. For more details see this blog post, Understanding vSphere Active Memory. The consumed memory counter can be used from the vSphere side to provide a more realistic indicator of memory usage of SAP HANA (and NetWeaver). Note that the consumed memory value does not drop after the SAP HANA instance is shut down. Meanwhile, the Linux memory command shows the expected release of memory by the application. The consumed memory counter is described in more detail next.

6.1.1 Consumed Memory

The VMware vSphere Resource Management ESXi 6.0 vCenter Server 6.0 guide provides a comprehensive explanation of the consumed memory counter. The content here is taken from this document and will help explain the observations described in the next section.

The VMkernel maps guest physical memory to machine memory, but they are not always mapped one-to-one. Multiple regions of guest physical memory might be mapped to the same region of machine memory (in the case of memory sharing) or specific regions of guest physical memory might not be mapped to machine memory (when the VMkernel swaps out or balloons guest physical memory). In these situations, calculations of guest physical memory usage and machine memory usage for an individual virtual machine or a host differ. The concept is shown in the following diagram, which shows two virtual machines running on a host. Each block represents 4 KB of memory and each color/letter represents a different set of data on a block.

Figure 19. Memory Usage Example

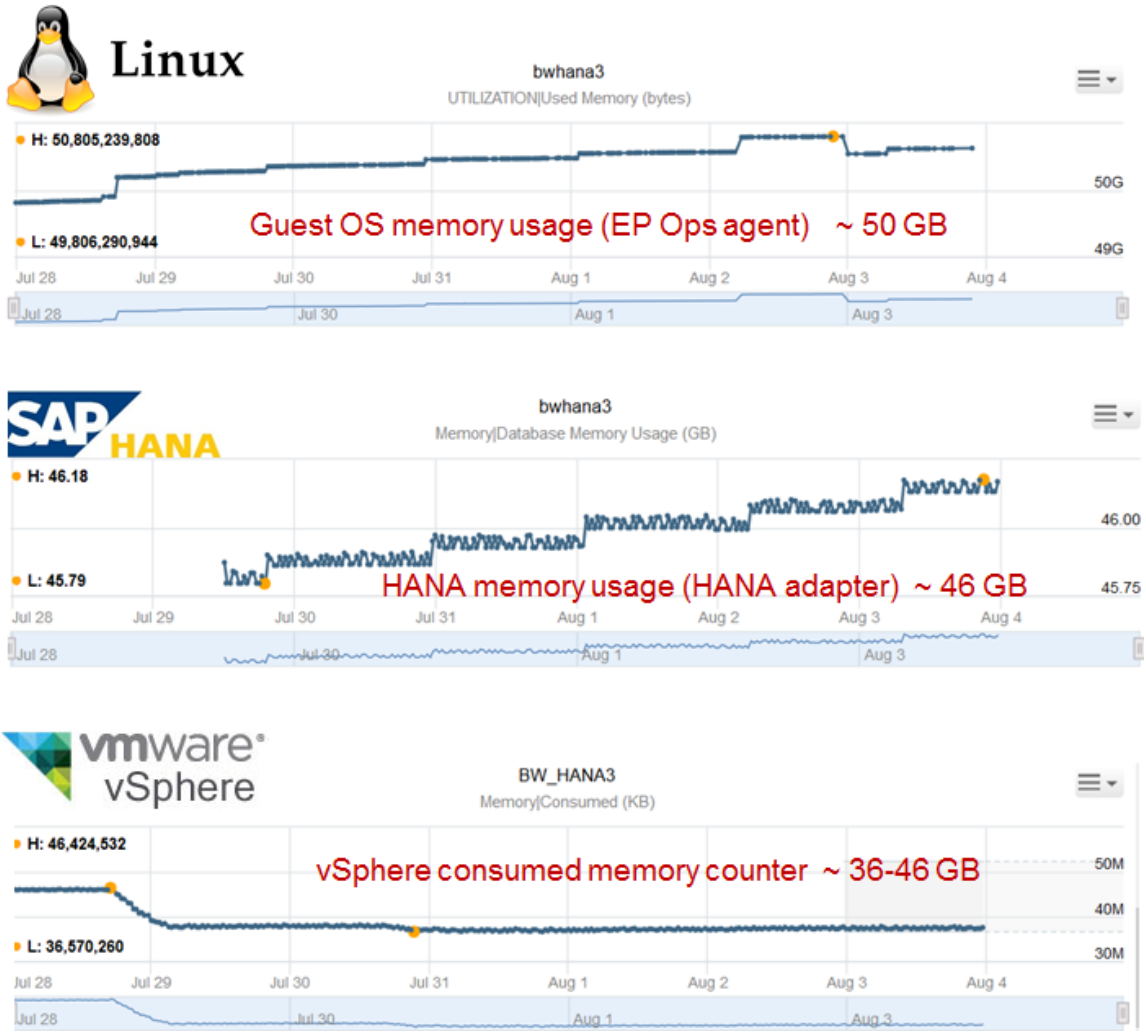


Memory Consumed is the amount of machine memory allocated to the virtual machine, accounting for savings from shared memory. First, count the number of blocks in machine memory that have arrows from virtual machine 1's guest physical memory. There are three such blocks, but one block is shared with virtual machine 2. So count two full blocks plus half of the third and multiply by 4 KB for a total of 10 KB Memory Consumed.

6.1.2 Correlating Memory Counters in vRealize Operations

How does the vSphere consumed memory counter compare with the counters in the Guest OS and SAP HANA? This is shown next in a series of screenshots obtained from vRealize Operations. The following charts compare the consumed memory counter with the Linux and SAP HANA memory counters for the SAP HANA instance while it is up and running.

Figure 20. vRealize Operations Charts Comparing Memory Counters for HANA in a 60 GB Virtual Machine



From Figure 20:

- Guest OS memory usage is higher than the SAP HANA memory usage metric, which defines how much memory the in-memory database is actually using as measured by SAP HANA. This is expected, because SAP HANA pre-allocates memory in advance of using it.
- The consumed memory metric starts in the same ball park but has dropped below the other two counters. This can be expected based on the definition of consumed memory described in the previous section. That is, consumed memory can be below Guest OS memory usage because any duplicate blocks of memory are only counted once, and there is a downward adjustment based on memory sharing between virtual machines.

6.2 Capacity Planning

vRealize Operations has two consumption models that can be used for capacity planning of resources: consumed, and demand. For the memory resource, the consumed model is based on the vSphere consumed memory counter, and the demand model is based on the vSphere active memory counter. The reason for different consumption models is that different data centers might approach capacity

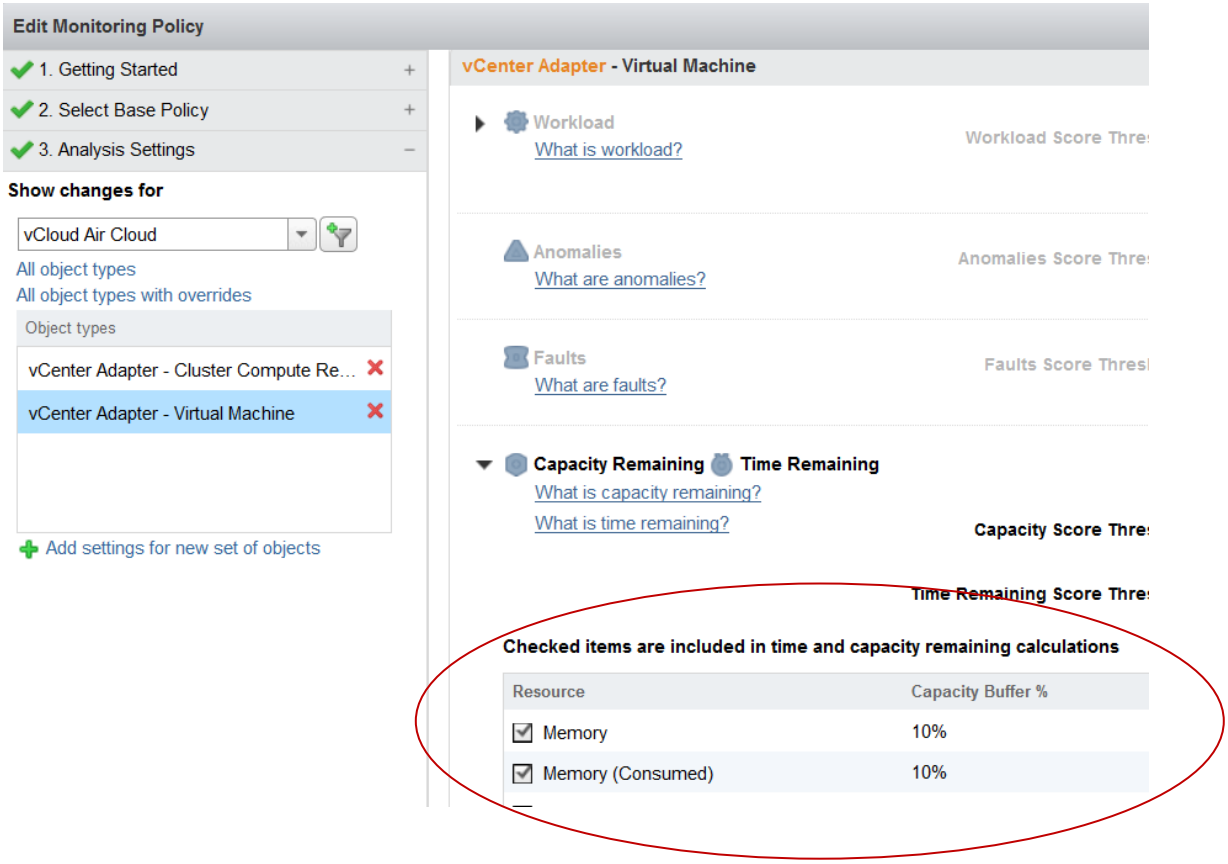
management in different ways for their different workloads. This is addressed in vRealize Operations with policies that determine how vRealize Operations monitors and provides alerts on the objects. vRealize Operations administrators assign policies to object groups and applications to support different Service Level Agreements (SLAs) and business priorities. For example:

- Critical Production: Production environment ready, optimized for performance with sensitive alerting.
- Development, Test, and QA: Less critical settings, fewer alerts.

The capacity consumption model can be configured for a policy to allow it to analyze capacity based on either demand or consumed consumption models. This is set in vRealize Operations, for example:

Menu: Home > Administration > Policies > Policy Library > expand menu and select <policy name> > Edit Selected Policy > Analysis Settings

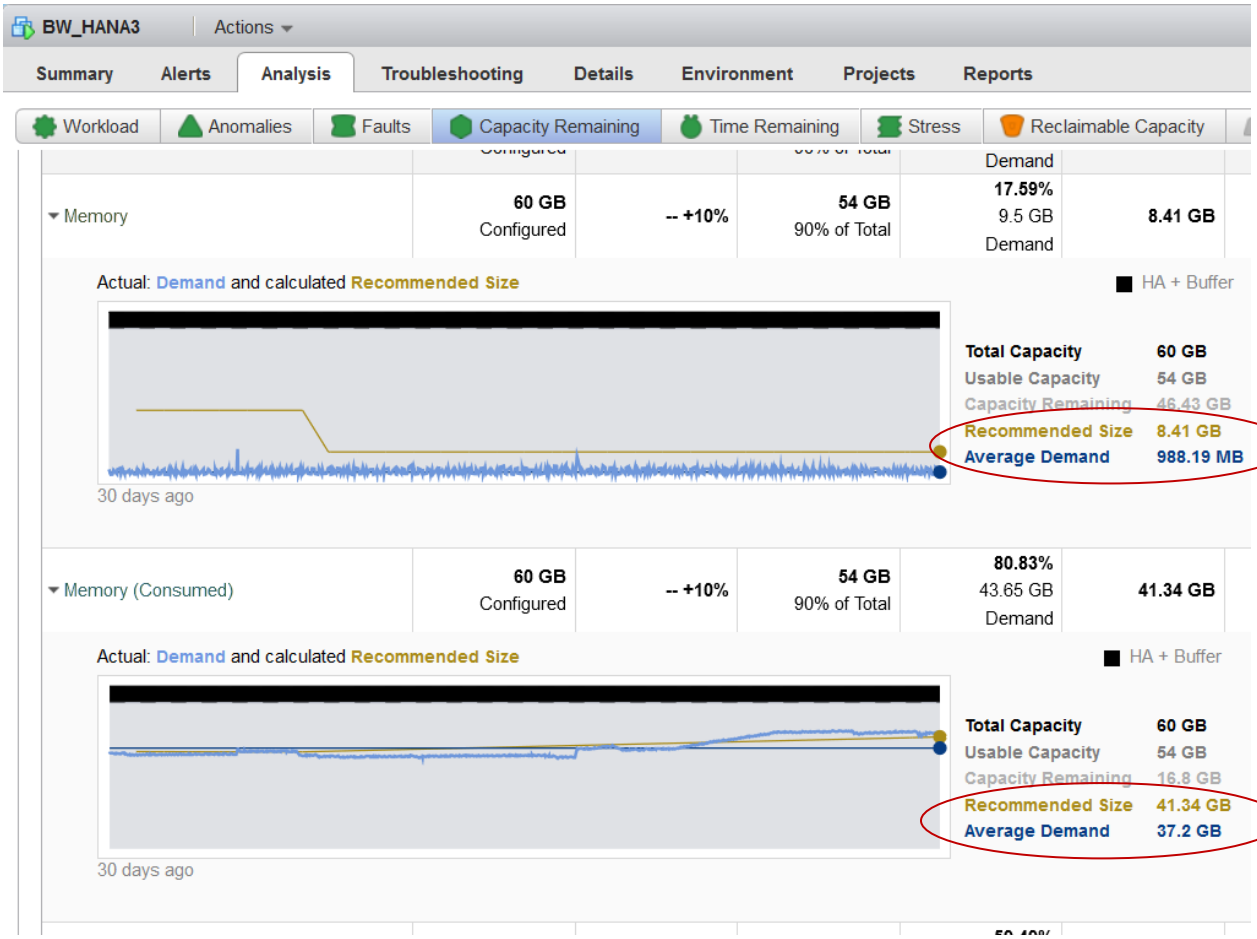
Figure 21. Select Demand and Consumed Consumption Model



After this is done (and the virtual machine is assigned to the object group associated with the policy), it is possible to then view the capacity analysis calculated by vRealize Operations for the virtual machine.

Menu: Home > Environment > All Objects > filter and select virtual machine BW_HANA3 > Analysis > Capacity Remaining > expand the Memory section

Figure 22. Capacity Analysis for Memory Demand and Consumed for the HANA Virtual Machine



In the preceding figure, there are two demands calculated: based on active memory the recommended size is ~8 GB; based on consumed memory the recommended size is ~41 GB. At a minimum, the consumed-based demand should be used for SAP. A more conservative result can be obtained by rounding upward based on the Guest OS memory usage values. This is not calculated automatically by vRealize Operations as of version 6.3, and must be done manually.

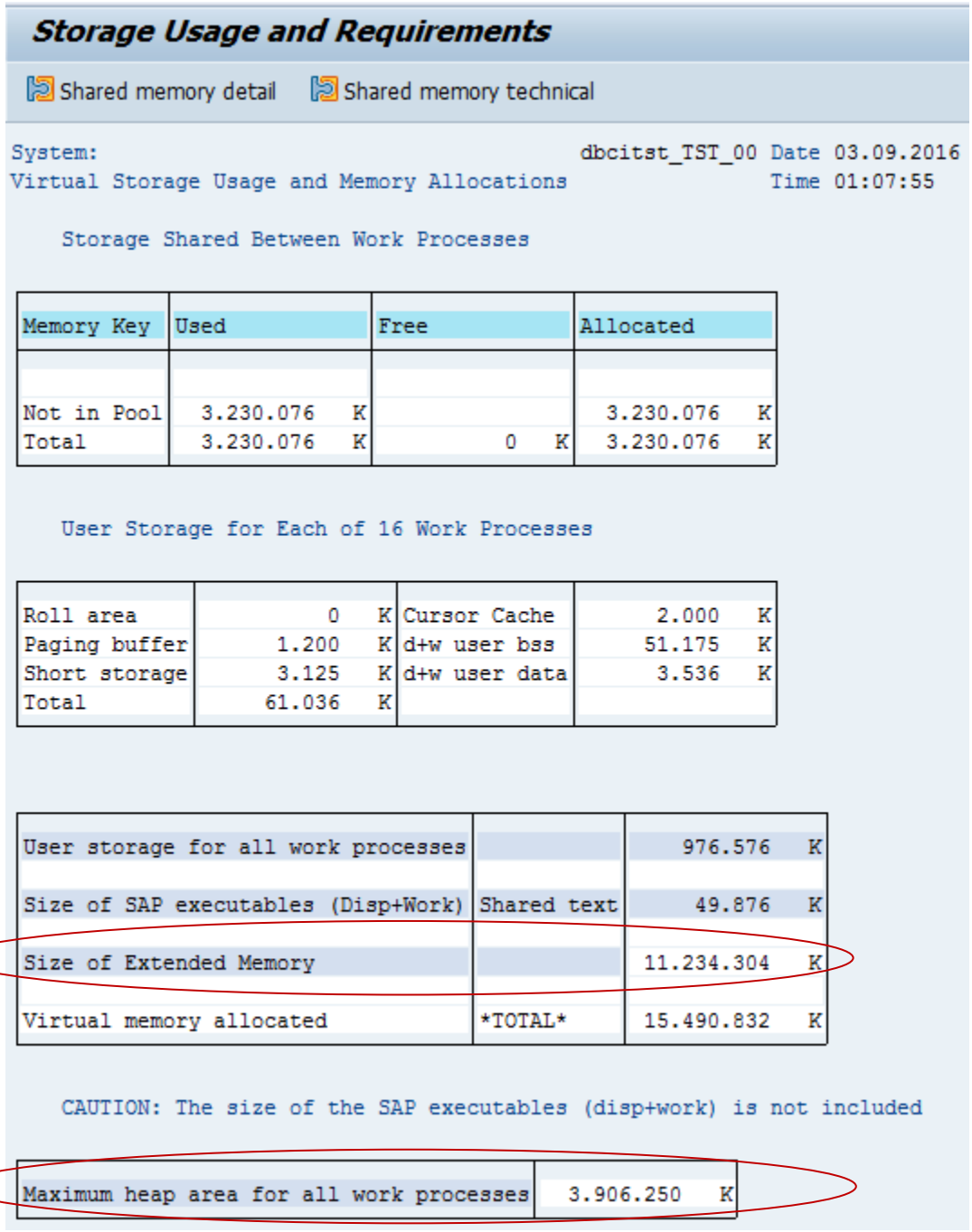
7. Super Metric Example with ABAP Memory Counters

This section describes a memory use case based on the SAP NetWeaver ABAP stack and the super metric functionality in vRealize Operations. A super metric is a mathematical formula that contains a combination of one or more metrics for one or more objects.

As mentioned in the previous sections, HANA has a memory counter that defines the total amount of memory SAP HANA is using at a specific moment in time. Having an application-level counter that defines how much memory an application is actually using (as defined by the application vendor) can help to simplify memory monitoring and management. However, such a counter is not always available for many applications like the NetWeaver ABAP stack (Oracle is similar). Rather, memory utilization is composed of different areas each with its own counter, and the total usage is a mathematical formula based on these different counters. This is where the vRealize Operations super metric with the SAP Blue Medora Management Pack can help.

The following figure shows a screenshot of a SAP Basis transaction that provides an overview of the different memory areas in an ABAP-based application server.

Figure 23. SAP Transaction Showing ABAP Stack Memory



Storage Usage and Requirements

Shared memory detail | Shared memory technical

System: dbcitst_TST_00 Date 03.09.2016
Virtual Storage Usage and Memory Allocations Time 01:07:55

Storage Shared Between Work Processes

Memory Key	Used	Free	Allocated
Not in Pool	3.230.076 K		3.230.076 K
Total	3.230.076 K	0 K	3.230.076 K

User Storage for Each of 16 Work Processes

Roll area	0 K	Cursor Cache	2.000 K
Paging buffer	1.200 K	d+w user bss	51.175 K
Short storage	3.125 K	d+w user data	3.536 K
Total	61.036 K		

User storage for all work processes		976.576 K
Size of SAP executables (Disp+Work)	Shared text	49.876 K
Size of Extended Memory		11.234.304 K
Virtual memory allocated	*TOTAL*	15.490.832 K

CAUTION: The size of the SAP executables (disp+work) is not included

Maximum heap area for all work processes	3.906.250 K

The different memory areas shown in Figure 23 are described in detail in the SAP note 941735 - SAP memory management system for 64-bit Linux. Most of the memory for online users and batch jobs as they run their workload is allocated to the Extended Memory and Heap area. SAP counters measure the utilization of these memory areas and are available inside of vRealize Operations with the Blue Medora SAP Management pack. The example in Figure 24 shows how vRealize Operations can monitor the combined actual usage of the Extended Memory and Heap area.

7.1 Create Super Metric

The following example will show a super metric that totals the extended and heap memory usage. Note that the complete memory usage of an ABAP stack requires additional memory areas (for instance, Roll area, buffers, and so forth) – these other components can be added to the super metric but it is not shown in this example.

The following SAP metrics are extracted by the SAP adapter and are relevant for the Extended and Heap memory usage:

- Extended Memory Actual – current usage expressed as a percentage of total Extended memory available
- Extended Memory Total – Total Extended memory available (= 11234304 KB in this example)
- Heap Actual – Current usage expressed as a percentage of total Heap available
- Heap Total – Total Heap area available (= 3906250 KB in this example)

Based on the above counters, the total Extended and Heap memory currently in use is based on the equation:

(Extended Memory Actual / 100) * Extended Memory Total

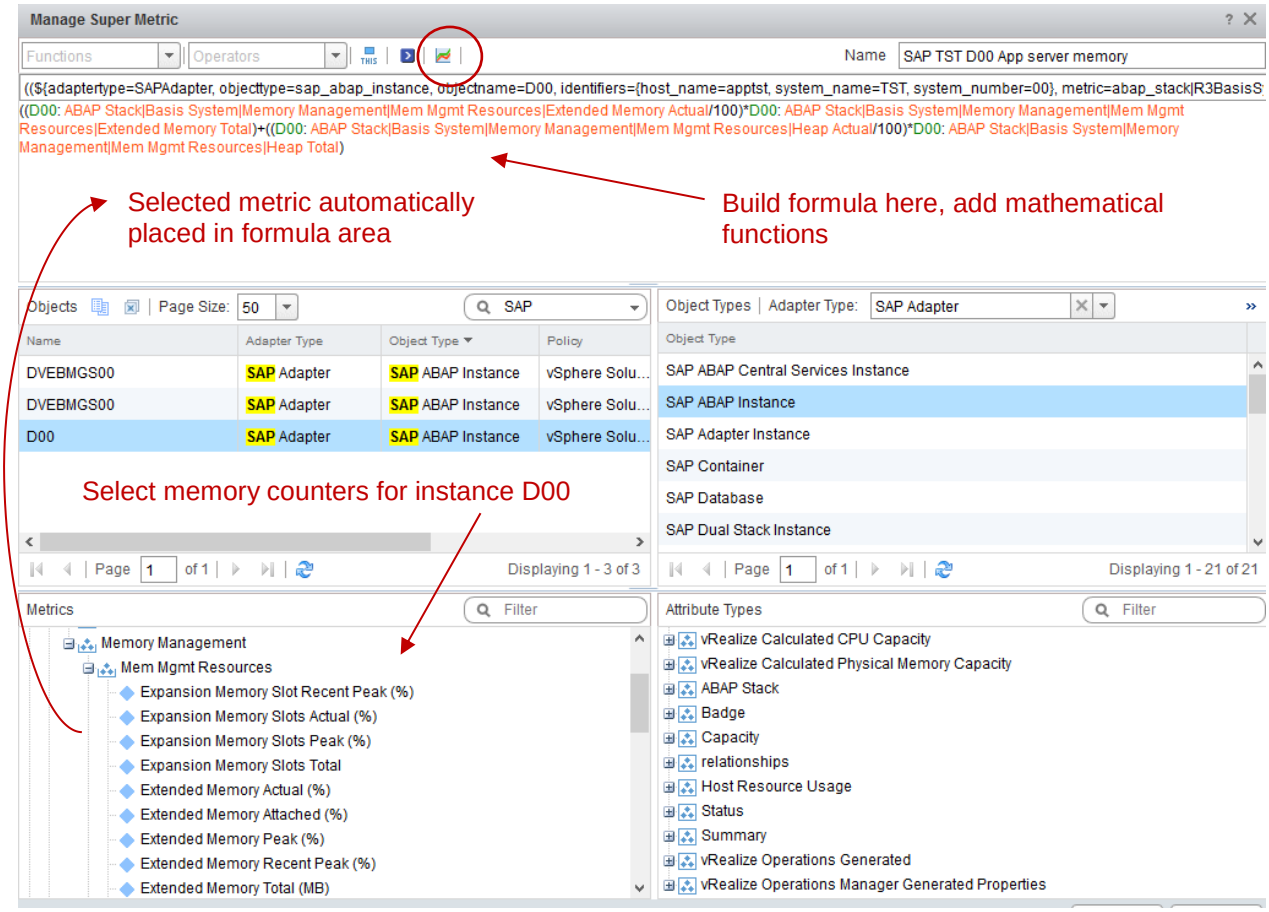
+

(Heap Actual /100) * Heap Total

This equation is created in vRealize Operations as a super metric.

Menu: Home > Content > Super Metrics

Figure 24. Define Memory Super Metric for Dialog Instance D00 (Extended + Heap in Use)



Menu: Click on Visualize Super Metric ICON at top

A timeline of values for the super metric appears in the same window.

Figure 25. Show Super Metric Values Based on the Formula

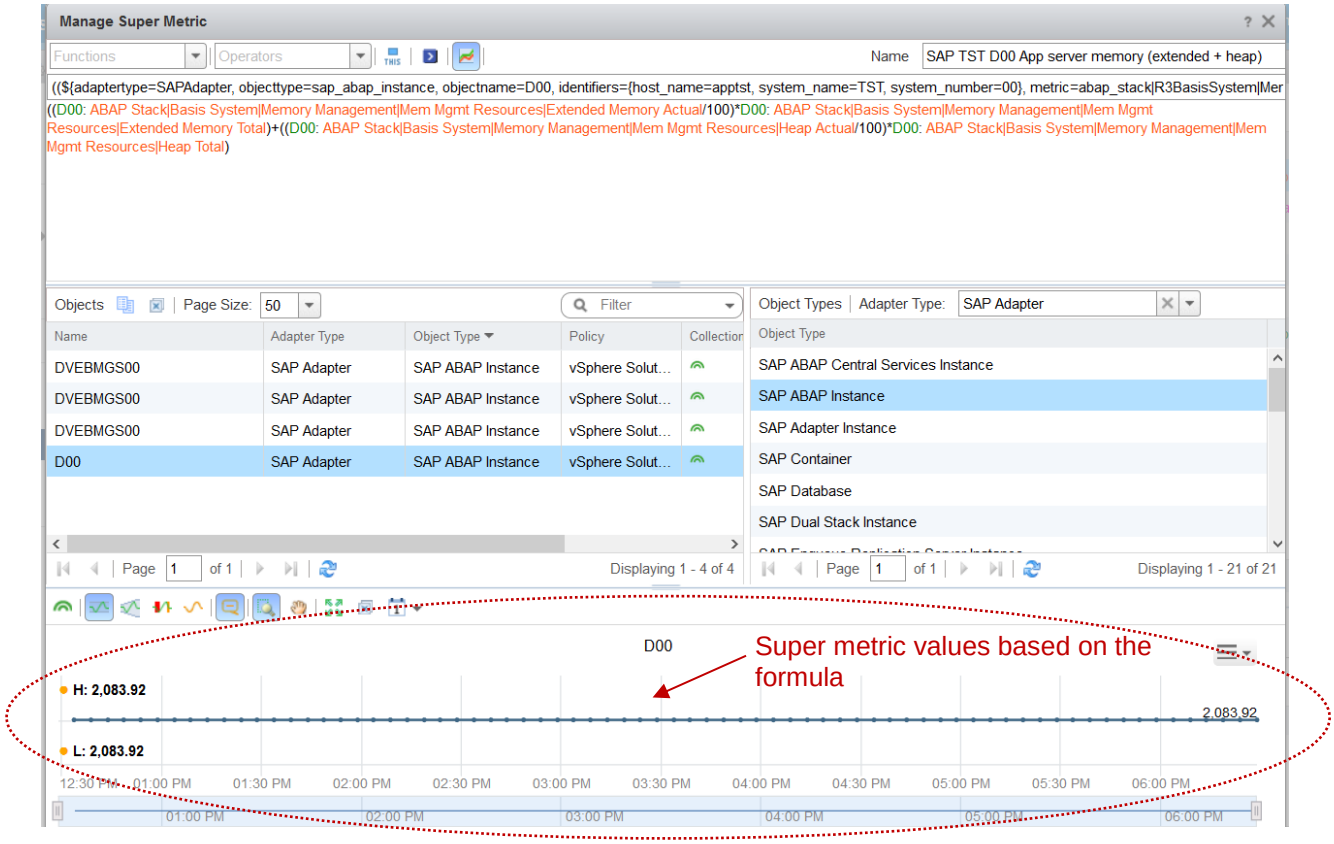


Figure 25 shows that the current value of the super metric is 2083.93 MB, that is, the sum of the currently used Extended and Heap memory areas.

Once saved, the super metric is available to be assigned to an object.

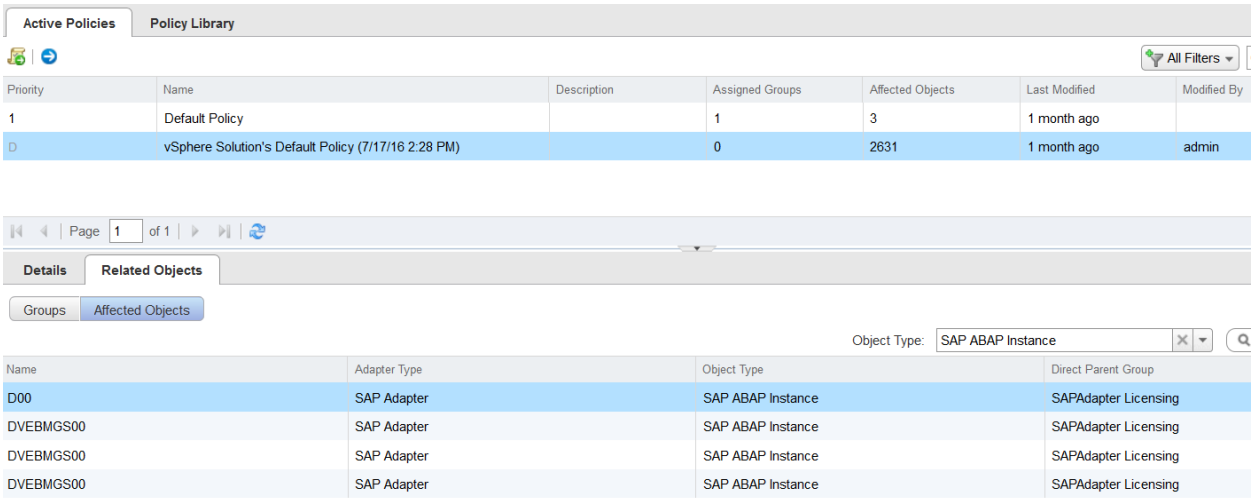
7.2 Assign Super Metric to Object

Once the super metric has been created and defined, it can be assigned to an object type. Then vRealize Operations calculates the super metric for the target objects and displays it as a metric for the object type. This involves editing the policy in vRealize Operations.

Menu: Administration > Policies

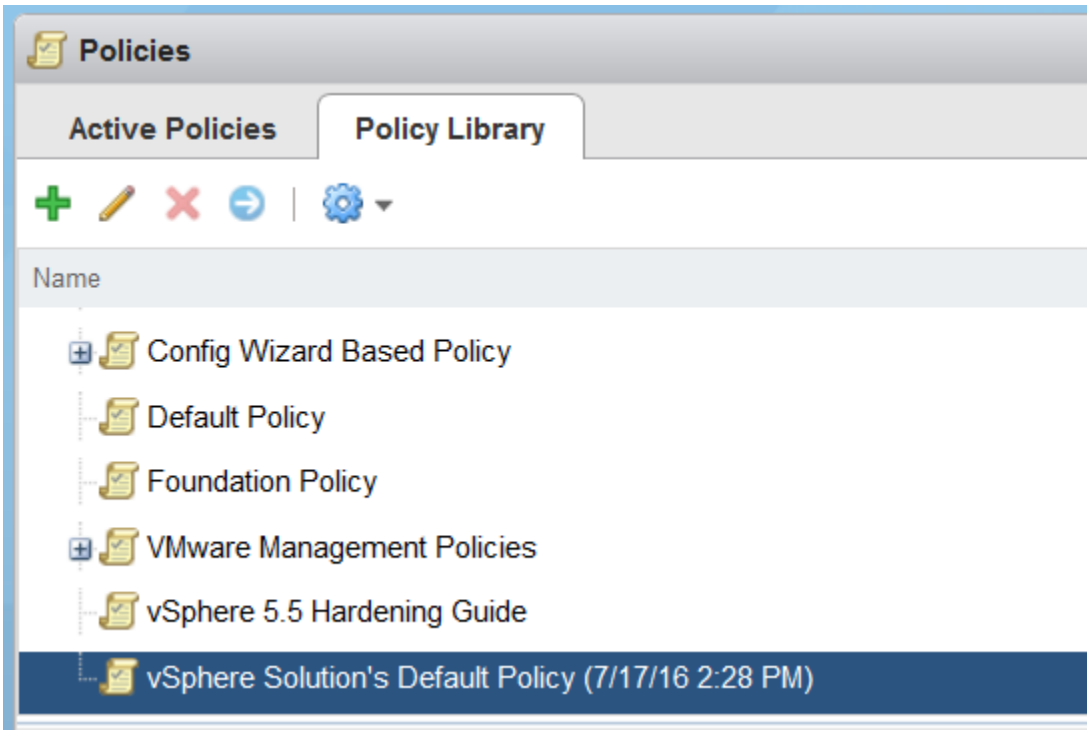
Select the default policy to find related objects below, filter on “SAP ABAP Instance” object type to help with the search. (The default policy is predefined in vRealize Operations and is a set of rules that applies to the majority of the objects).

Figure 26. Confirm SAP Objects Are Part of the Default Policy



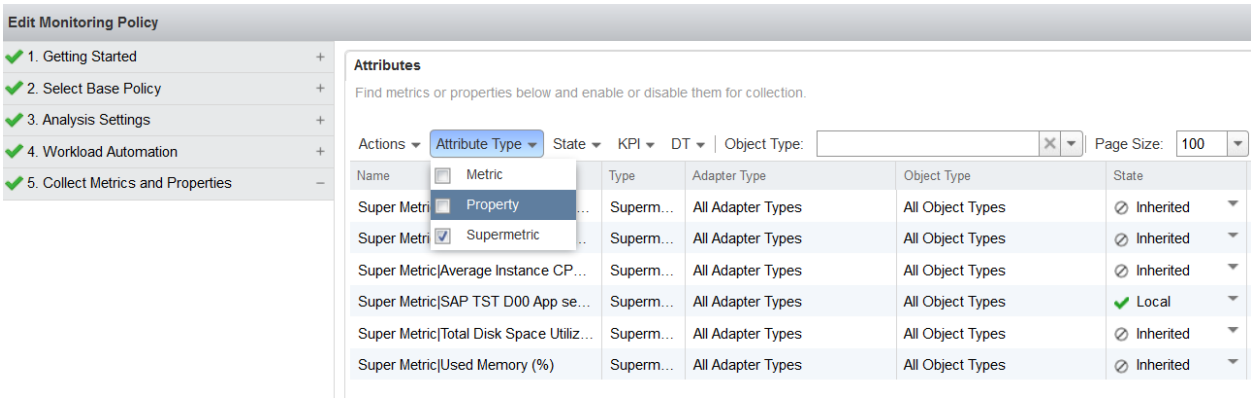
Menu: select Policy Library > Click on the edit icon

Figure 27. Edit Default Policy



Menu: Select vSphere Solution's Default policy > Click on edit > under 5 Collect Metrics and Properties, select attribute type Supermetric to filter out all the other objects > select super metric SAP TST D00 > change state to Local to activate super metric

Figure 28. Activate Super Metric



Navigate to the SAP object for the SAP dialog instance D00.

Menu: Home > Environment > All Objects > Expand menu SAP Adapter

Figure 29. View Super Metric in Troubleshooting Tab of Dialog Instance D00 Object

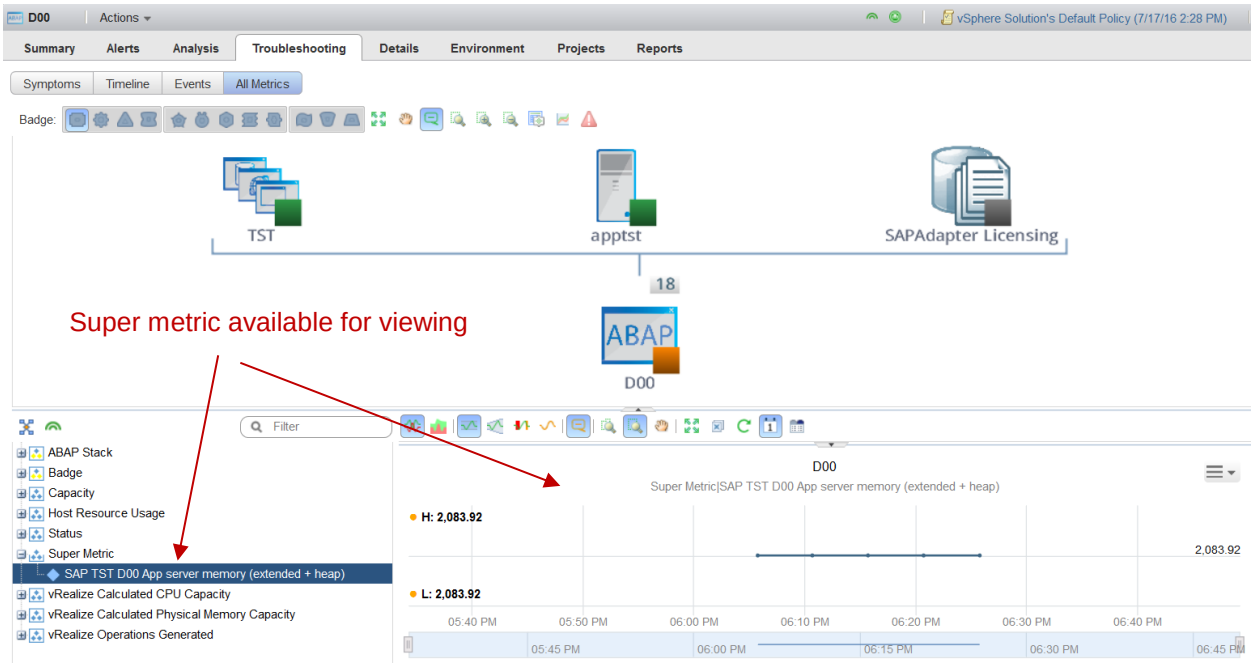
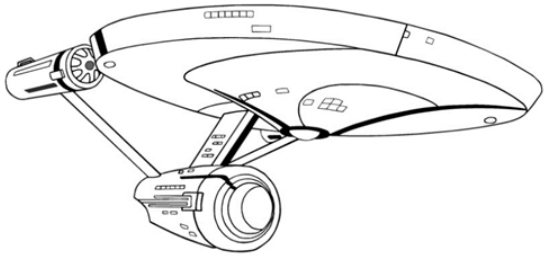


Figure 29 confirms the association of the super metric with the object type SAP ABAP Instance. It is now available for selection in the Troubleshooting > All Metrics tab.

8. SAP on Oracle Troubleshooting Example



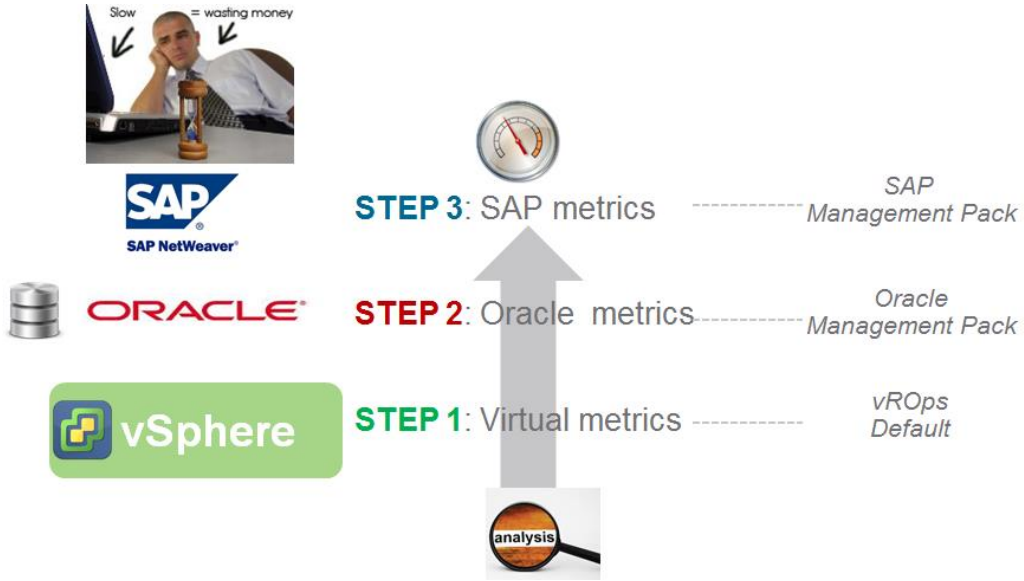
http://www.sketchite.com/starship-enterprise-coloring-pages-sketch-templates/

"I could tell you the speed that we were traveling by the feel of the deckplates"
(Star Trek Nxt Gen, S6E4)

This section describes a performance troubleshooting example based on a workload running on the SAP on Oracle system described previously in the Lab section, and will show how it can be monitored with vRealize Operations and the Blue Medora Management Packs. The workload is causing a slow online response time as experienced by end-users.

The SAP on Oracle stack in this example involves monitoring three technology layers. The analysis in this scenario starts at the virtual layer, then moves up to the database, and finally to the SAP layer, as shown in the following diagram.

Figure 30. Troubleshooting Example – Order of Analysis



Problem

SAP end users are complaining of slow response times on the SAP system. Some users are claiming it is taking a long time to log in to SAP.

Where to Start

As shown in Figure 30, in this troubleshooting scenario, we start at the vSphere layer. In SAP environments, it is very possible that after multiple calls to the help desk about poor performance, the requests are initially routed to the infrastructure administrators, because problems at this level can have a wider impact on the SAP system. Ideally, with a virtual SAP on Oracle stack, it would be beneficial to have all the different administrators troubleshooting together from the start. SAP and database administrators are more likely to have an understanding of the workload that is running on the SAP system (compared to the infrastructure team), which can greatly help with troubleshooting. An anecdote here based on the science fiction show Star Trek: the fictional engineer of the vessel says, “I could tell you the speed that we were traveling by the feel of the deckplates.” This is analogous to SAP administrators who might be able to quickly pinpoint a source of performance problem from their knowledge (“feel”) of the workload schedules, such as batch job schedules that can add a sudden surge of activity. However, the SAP administrator might not be available during the initial analysis, and this is where vRealize Operations can assist by providing complete visibility, from the application stack down to infrastructure.

Access to the different objects and metrics in this example is through the menu:

Menu: Home > Environment > All Objects > <Select Adapter> > <select adapter object> > Troubleshooting > All Metrics > <select object> > <select counter>

8.1 Step 1: Virtual Metrics

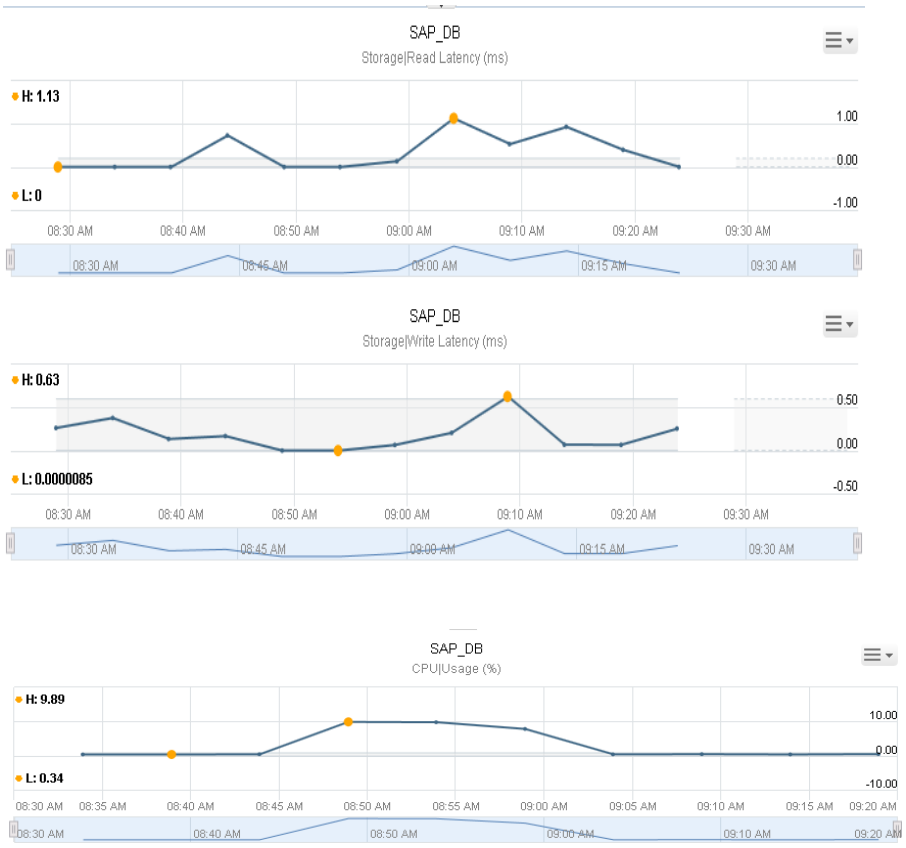
The following table shows the key virtual metrics for this example.

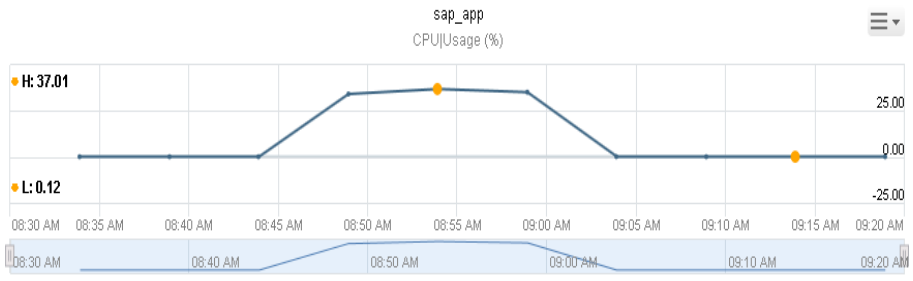
Table 6. SAP on Oracle Troubleshooting Example – Virtual Metrics

<table>
<tr>
<td>Database virtual machine Read Latency < 2 ms

Database virtual machine Write latency < 1 ms

The I/O latency values do not indicate any issues

Database virtual machine CPU usage < 10%</td>
<td> 
</td>
</tr>
<tr>
<td>SAP application server virtual machine CPU usage < 30%

Some workload has caused CPU to increase and plateau during the period of user complaints</td>
<td> 
</td>
</tr>
<tr>
<td colspan="2">Other metrics:

% Ready for database and app server virtual machines: ~ 0.

No vCPU or memory overcommit

Memory reservations set for all SAP virtual machines</td>
</tr>
</table>

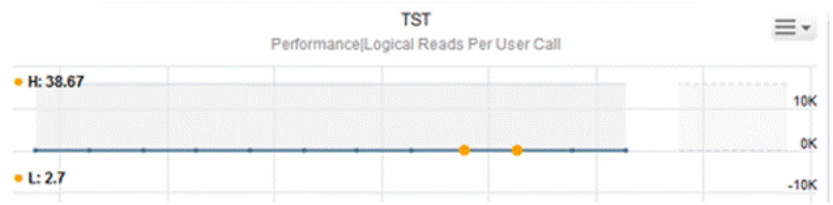
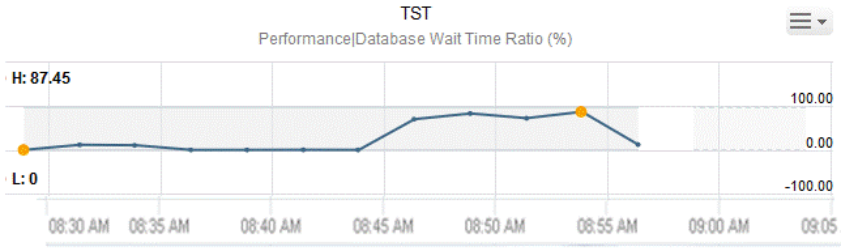
From the preceding figure, we can see that there does not appear to be any resource bottleneck at the infrastructure layer. Now we progress to the application layer.

8.2 Step 2: Oracle Metrics

From the previous step, we see that the Oracle database is not experiencing any I/O or CPU issues.

The following table shows two Oracle metrics for this example (note there are other Oracle metrics that also must be considered for an in-depth analysis).

Table 7. SAP on Oracle Troubleshooting Example – Oracle Metrics

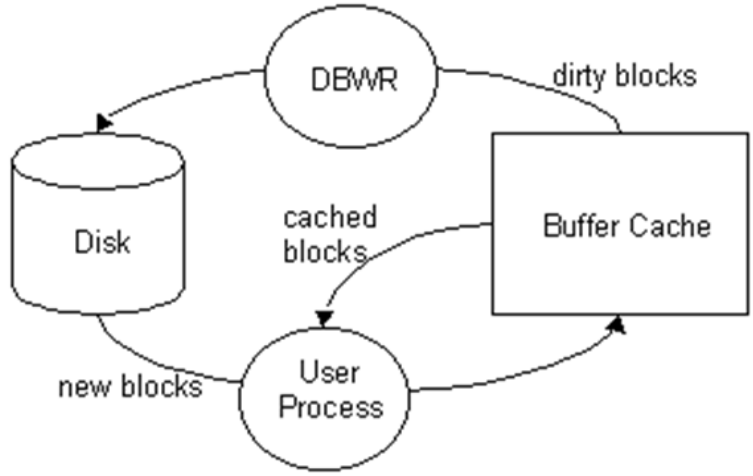
Oracle logical reads per user call peaks at 38	
Oracle database wait ratio is near 100%	
Other metrics: Guest OS shows no indication of swapping in the Oracle database virtual machine. No Oracle Archive Redo Log file system full situation.	

Let us take a look at the preceding two Oracle metrics.

Logical Reads per User Call

Oracle Logical Reads per User Call corresponds to the average Oracle blocks read from the buffer cache (part of Oracle's System Global Area) to service queries from the application server. If the block is not available in the cache, it is serviced from disk. Oracle manages storage in units called data blocks, which is the smallest unit of data used by a database. Oracle requests data in multiples of Oracle data blocks, not operating system blocks. The following diagram shows some of the operations Oracle has to perform on the blocks when it services SQL statements from user queries.

Figure 31. Oracle Architecture (Simplified)



Source: http://www.toadworld.com/platforms/oracle/w/wiki/551.buffer-cache-overview

The more blocks Oracle has to process, the more system resources Oracle will need. Hence in SAP systems that have thousands of different tables and many queries from enterprise users, monitoring and managing the block operations can greatly help to fine-tune database performance. The buffer cache is important for performance, and in many SAP systems this would be sized with a large amount of memory and memory reservations would be set to protect this from overcommit scenarios.

A large number of logical reads per user call may be due to expensive SQL statements. Too many expensive SQL statements (or a few very expensive statements) can flood the buffer cache and impact performance, because it can force more physical reads from disk. Expensive SQL statements can be addressed by SQL tuning. Threshold value and guidelines for the logical reads per user call counter (and other key Oracle metrics) are documented in SAP Knowledgebase article 618868 - FAQ: Oracle performance (user ID and password required).

Database Wait Ratio

The Oracle database wait ratio counter is used together with another counter database, CPU wait ratio (together these two add to 100 percent). This helps to determine if the database is currently experiencing a high percentage of waits/bottlenecks.

Database wait time ratio – Amount of elapsed time spent performing database user-level calls divided by total time of the interval. This does not include the elapsed time spent on instance background processes.

Database CPU time – Amount of CPU time spent on database user-level calls divided by total time of the interval. This does not include the elapsed time spent on instance background processes.

Significantly higher values of database wait time ratio indicate that system performance can be improved using "wait event tuning", which requires more in-depth analysis of Oracle wait events. These wait event counters can be accessed within Oracle by the database administrator or can be available in vRealize Operations through the Blue Medora management pack for Oracle Enterprise Manager (http://www.bluemedora.com/products/vRealize Operations-management-pack-oracle-em/), which is not part of scope of this document.

Threshold values for the database wait ratio and guidelines for further action are documented in SAP Knowledge Base article 618868 - FAQ: Oracle performance. For details on Oracle wait events, see SAP Knowledge Base article 619188 - FAQ: Oracle wait events.

Conclusion

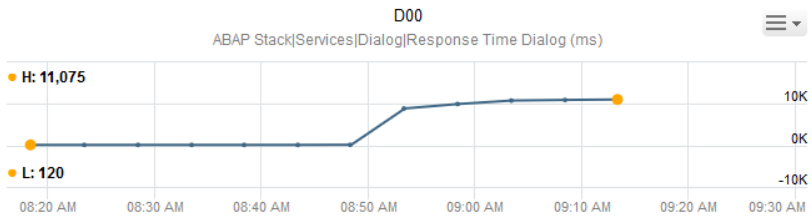
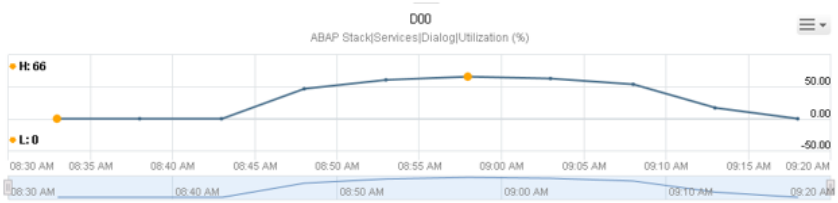
In this example both the logical reads per user call and the database wait ratio have increased to levels that require more in-depth analysis to determine if Oracle or bad SQL statements are the cause of the performance problem. However, it is possible that Oracle is performing as expected to process the SQL

statements as submitted by the application server. We now need to move to the SAP layer, because ultimately all workload originates from the application tier.

8.3 Step 3: SAP Metrics

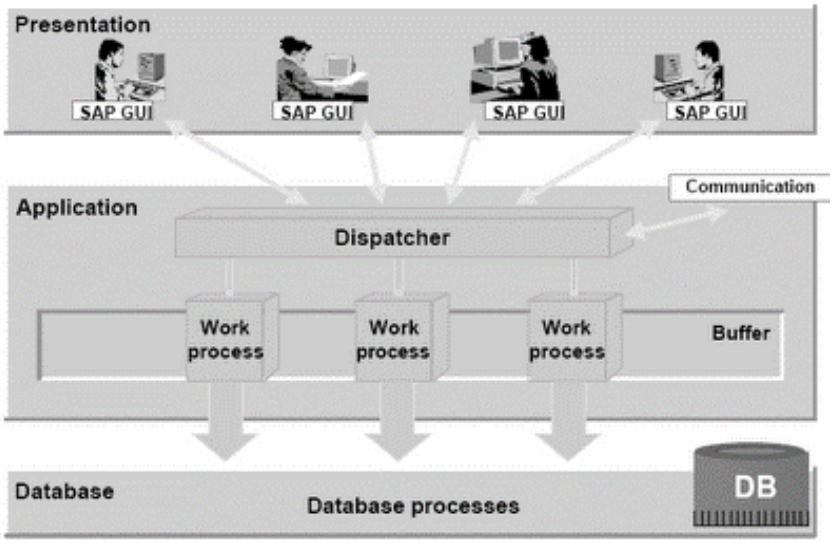
In the third and final step, we look at the SAP counters, which can help explain the workload running on the application server. The following table shows some SAP metrics for this example (note there are other relevant metrics).

Table 8. SAP on Oracle Troubleshooting Example – SAP Metrics

SAP user response time is above 10 seconds – confirms that user complaints are valid. Typical average response times are within 1-2 seconds.	
The SAP dialog work process utilization has increased during the time of the performance escalation. Data collection is every 5 minutes, so it is possible there are higher spikes between the data points.	
Other metrics: Guest OS shows no indication of swapping in the application server virtual machine.	

The SAP dialog work process utilization shows the percentage of work processes allocated for online user activity that is currently being utilized on the SAP application server. The following diagram shows the SAP architecture of an ABAP-based application server.

Figure 32. SAP ABAP Stack Architecture (Source: SAP Documentation)



If all of the work processes are utilized, then a user request to the application server waits until one is free.

In this example, the increase in work process utilization is suspect and requires further inspection by the SAP administrator. The SAP administrator can use SAP Basis transactions like “SM50” to investigate further and reveal exactly what workload is running.

Root cause: In this performance troubleshooting example the root cause is at the SAP application layer, where a batch job was scheduled on the application server competing with the online users. The batch job utilized many of the available work processes, thus minimizing the number of free work processes available for the online users.

Potential resolution: Reschedule batch job on other application servers or at different time; increase the number of work processes.

8.4 Summary

In this section, we have shown a troubleshooting scenario of an SAP on Oracle system using vRealize Operations to analyze metrics from the vSphere, Oracle, and SAP layers. vRealize Operations with the Blue Medora Management Packs has enabled the required visibility across these layers to expedite root cause analysis. In this example we have accessed the required metrics directly through the menu Home > Environment > All Objects > <Select Adapter> > and so forth. Alternatively, you can navigate to the relevant metrics through the dashboards provided by the SAP management pack. An example of this is described at http://www.bluemedora.com/blog/advanced-troubleshooting-of-virtualized-sap-environments-with-vrealize-operations/. A big advantage of these dashboards is that the stack dependencies are automatically linked, making traversal and navigation between the objects much easier.

9. Create Custom Dashboard Example

The Blue Medora Management Packs include out-of-the-box dashboards that provide a single console with visibility into the complete SAP stack. Meanwhile, there might be situations when a customized dashboard can be used:

- VMware/SAP/database administrator might have some tribal knowledge that he/she would like to incorporate into a custom dashboard.
- SAP and SAP database vendors have knowledge base articles (which are regularly updated by the vendors) that describe metrics and threshold values. These can be incorporated into a custom dashboard.
- To address certain workload scenarios that are critical to the business: for example, a major data load into the SAP system. This might require specific components to be monitored and specific set of metrics that have been preselected by the administrators. A dashboard can be temporarily created for this event.

A custom dashboard can be easily created in vRealize Operations. An example is shown in this section. The dashboard created here is for the following scenario:

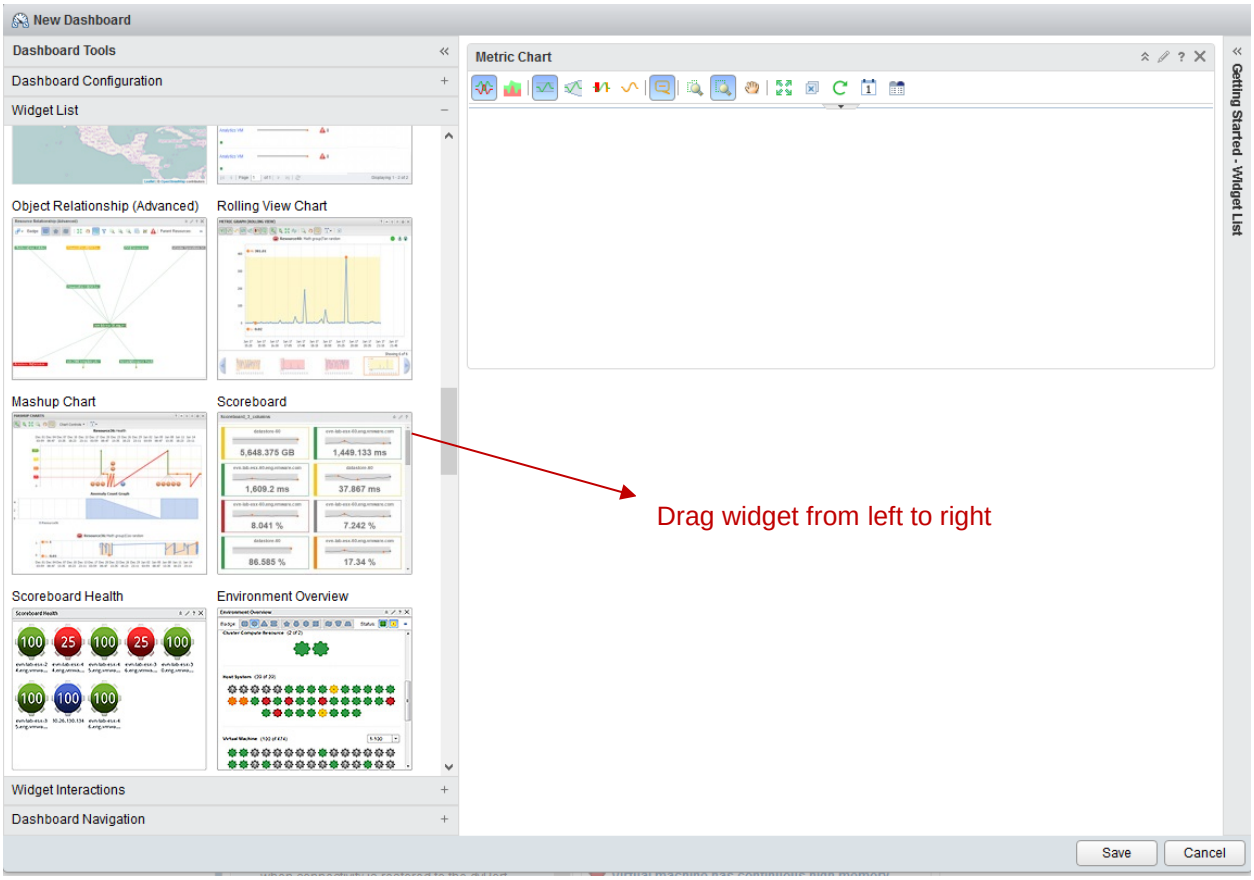
- A large data load is expected to run and insert/update data in SAP and must complete in a certain time window.
- Administrators are concerned about performance of the SAP database during this event, and therefore must focus on the metrics relevant to the database.
- Note: the custom dashboard shown in the following figures is based on a workload run on the SAP system that has been deliberately provisioned on slow storage to show the impact on the metrics.

To start the dashboard creation process:

Menu: Home > Actions > Create Dashboard

Enter name of dashboard SAP Database TST > Widget List

Figure 33. Create Dashboard and Select Widgets

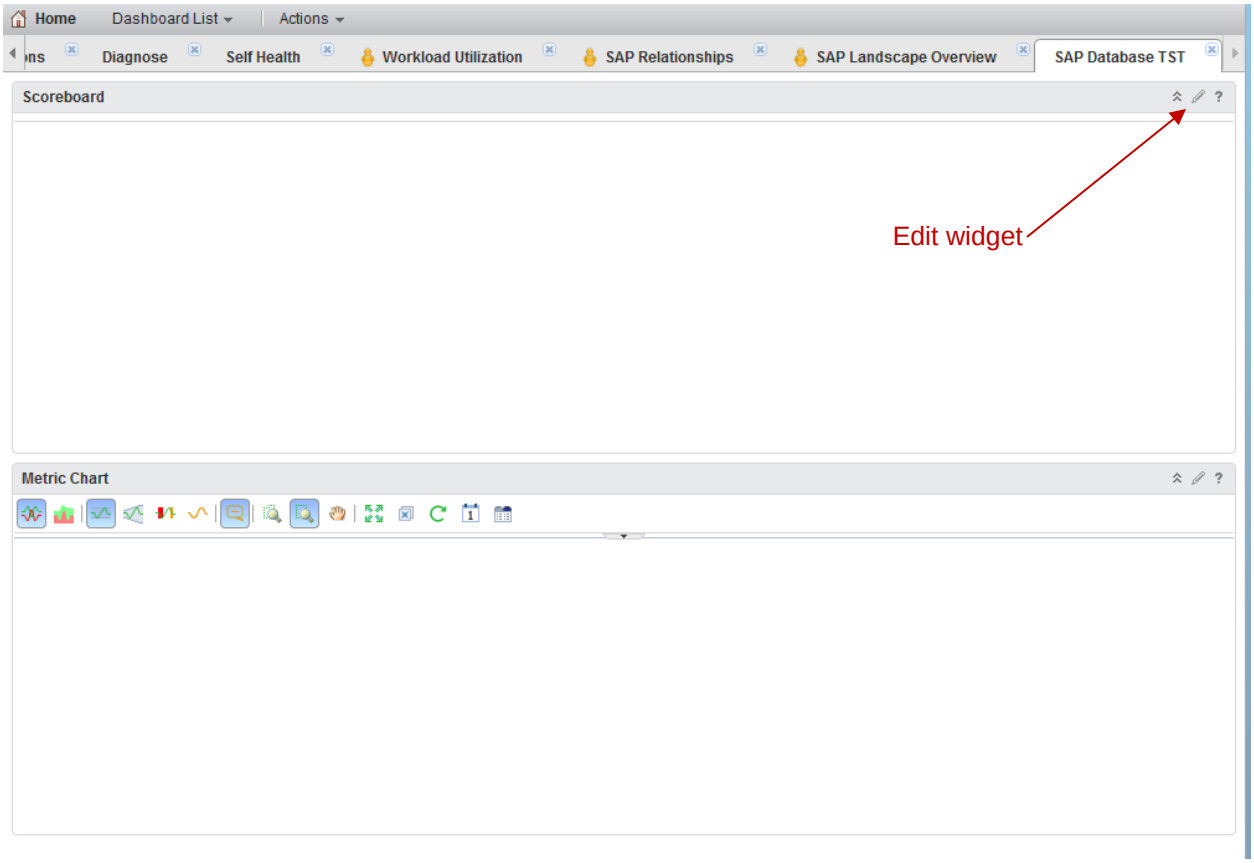


In this example, we chose the Scoreboard and Metric Chart widget.

Click on Save.

Dashboard is created with two widgets, but has no data because the metrics have not yet been assigned to the widgets.

Figure 34. Custom Dashboard with Two Widgets – No Metrics Assigned



Click on the edit widget icon to add metrics. This must be done separately for each widget.

Figure 35. Scoreboard Widget – Add Metrics

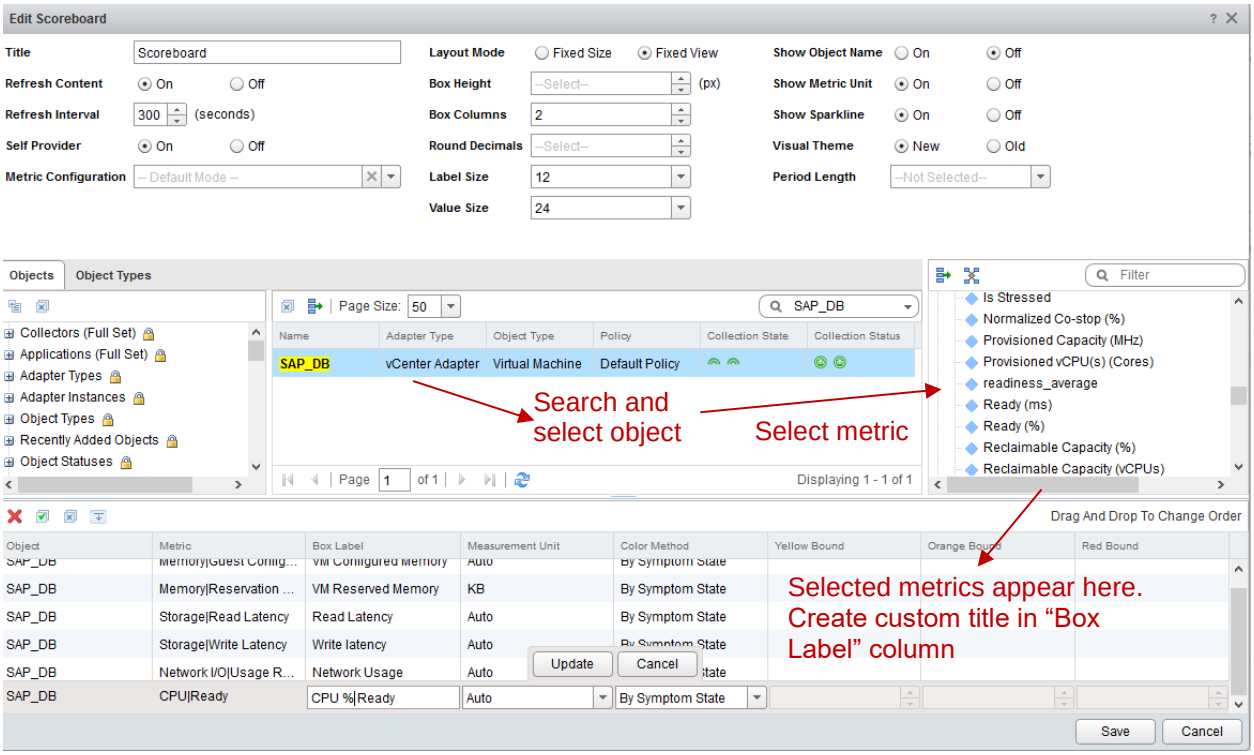
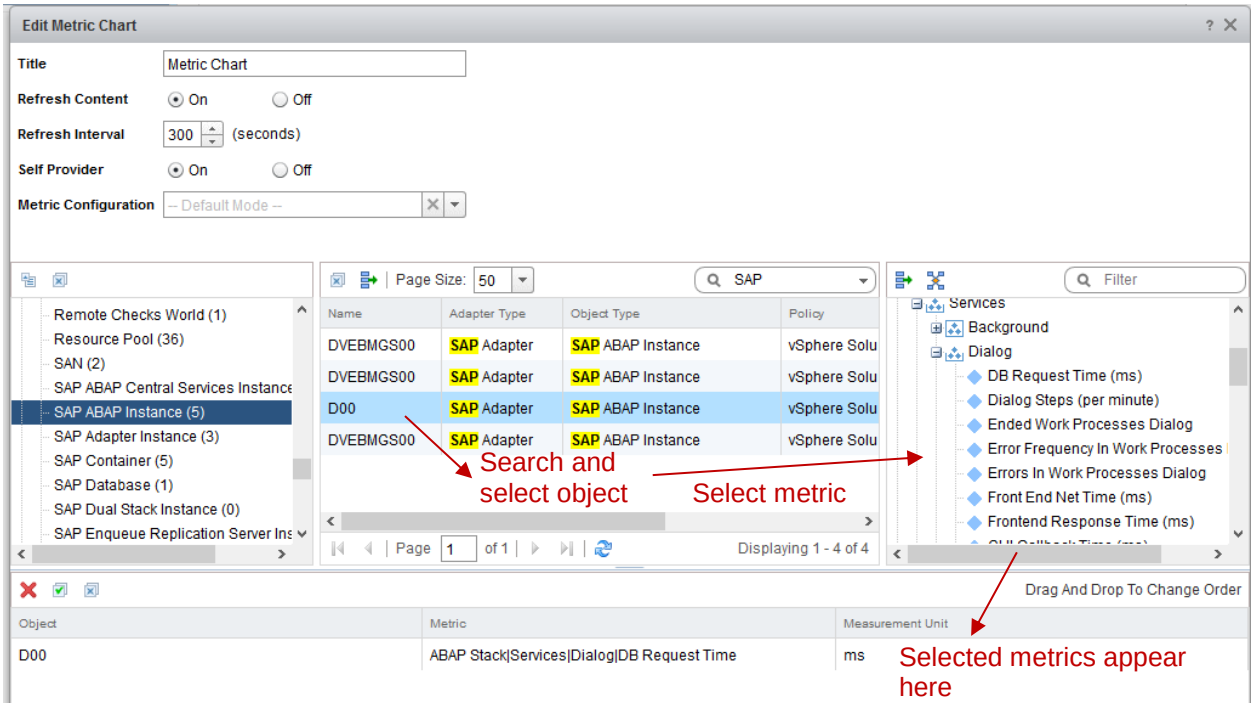
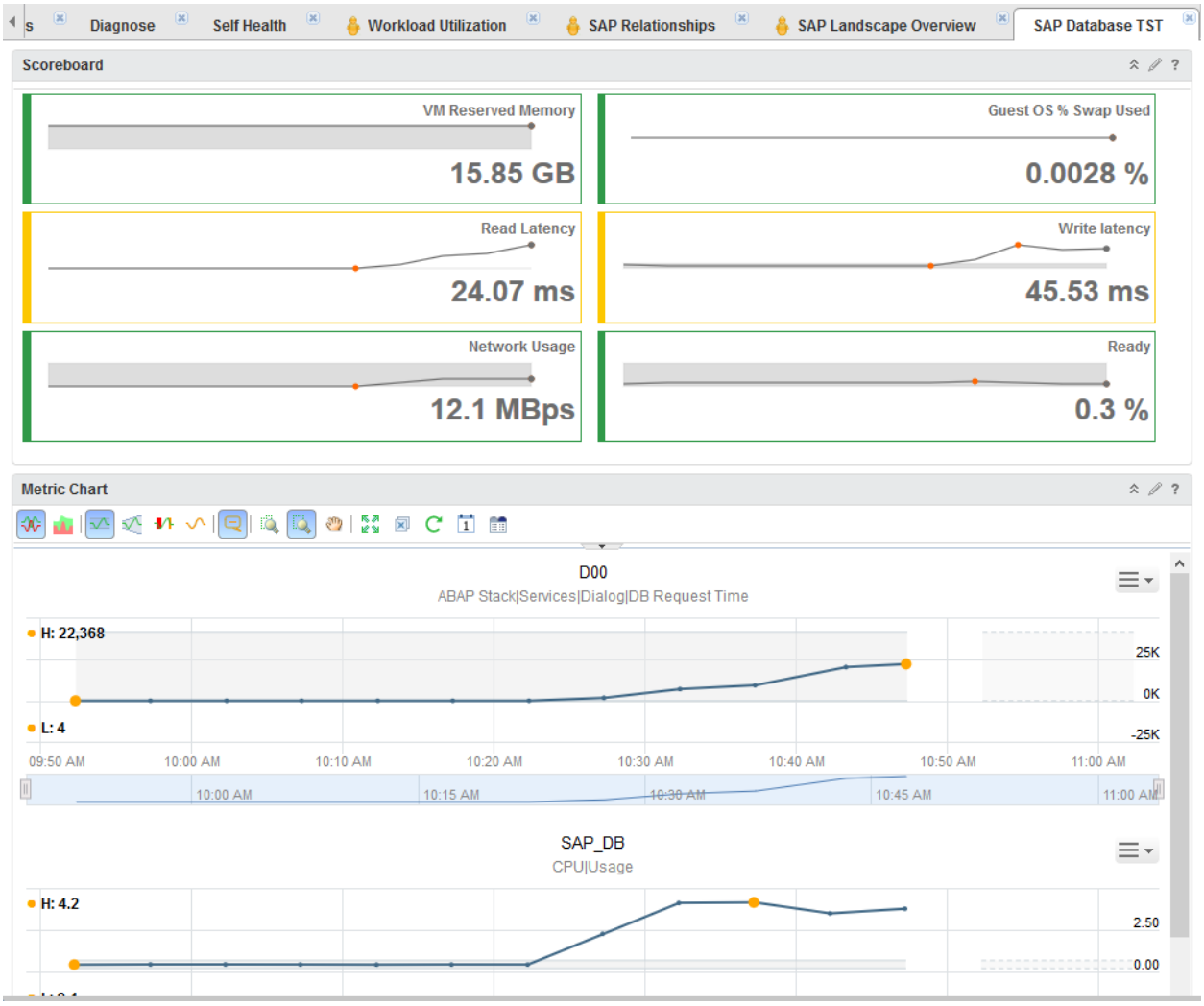


Figure 36. Metric Chart Widget – Add Metrics



The following figure shows the custom dashboard under load. The virtual machine is placed on storage deliberately configured for bad performance*, so I/O latency is expected to be high.*

Figure 37. Custom Dashboard for SAP Oracle Database Virtual Machine Under Load (on Deliberately Slow Storage to Demonstrate Impact on Metrics)



The chosen metrics in the preceding figure are explained.

- VM Reserved Memory – Shows the memory reservation for the database virtual machine. Setting this to the configured size of the virtual machine means administrators do not have to worry about memory over commit issues.
- Guest OS % Swap Used – This is from the EPO Guest OS agent and can help to determine if there are any memory issues within the Guest OS.
- Read Latency/Write Latency – The average amount of time taken for a read/write from the perspective of the Guest OS. The values should be within 10-15ms approximately, but in this example, they are much higher as expected, due to the slow storage.
    - For large databases spread across multiple virtual disks, the database administrator may be interested in the I/O latency of certain filesystems on certain virtual disks for example the Oracle redo log files which would be heavily utilized in database load operations. It is possible to select the specific virtual disk to monitor.

- Network Usage – The network activity to/from the database virtual machine. This is a good indicator of workload activity on the application server as more workload on the application server tends to generate more SQL traffic to/from the database.
- Ready – This is the VMware %ready metric which measures CPU contention. This should be less than 5% (see https://kb.vmware.com/kb/2001003).
- Metric Chart D00 DB Request Time – This metric is from the SAP adapter and measures the database component of the average SAP online response time experienced by the user. The values in this example are way too high and is due to the I/O bottleneck being experienced by the database.
- Metric Chart SAP_DB CPU Usage – Measures the CPU utilization of the database virtual machine. The value is very low because database processes are blocked waiting on I/O.

The preceding metrics chosen are not a complete list, and administrators might require others; for example:

- Oracle metric that measures log writer performance.
- File system utilization of the archive redo log file directory (can be obtained from the EPO agent). If this filesystem reaches 100% the Oracle database will freeze due to archive log destination being full.

10. Summary and Guidelines

- vRealize Operations with the Blue Medora Management Packs provides the required visibility across multiple layers of a multitier SAP system and can help to expedite root cause analysis. You can navigate to the relevant metrics via the dashboards provided by the SAP management pack. An example of this is described at http://www.bluemedora.com/blog/advanced-troubleshooting-of-virtualized-sap-environments-with-vrealize-operations/ .
- The installation steps for the Blue Medora Management Packs are available in guides at the Blue Medora website at http://www.bluemedora.com/true-visibility-suite-for-vmware/.
- End Point Operations (EPO) allows data collection of Guest OS level metrics inside of vRealize Operations. Make sure the EPO agent version matches the version of vRealize Operations. Guest OS data may not be collected when combining an earlier version of the EPO agent with a later release of vRealize Operations.
- The application counters considered in this document are examples, actual implementations will vary and the specific set of counters will be based on customer-specific requirements of the database and SAP administrators.
- The SAP and database administrators can help to define thresholds for critical application counters. For example key Oracle metrics for SAP is defined in the SAP knowledge base article 618868 - FAQ: Oracle performance .
- There may be situations where a custom dashboard can be created to satisfy specific requirements of SAP and database administrators. These custom dashboards can be easily created in vRealize Operations by choosing pre-defined widgets.
- Any errors in data collection or gaps in the data consult the vRealize Operations logs for any connection issues to SAP and/or the database. Access to logs from the vRealize Operations home screen is: Administration -> solutions -> Support -> Logs.
- The vSphere consumed memory counter is a good starting point from which to determine memory usage of SAP. The Guest OS memory counters can provide a more accurate indication. Alternative methods include using the application level counters - HANA has a counter for this. For SAP NetWeaver and Oracle multiple metrics and calculations are required to determine the actual memory used as measured by the application. vRealize Operations super metrics can be helpful for this type of analysis.
- Note that the consumed memory counter may provide a lower estimate of memory usage than the guest OS counters as it makes a deduction for shared memory pages within a virtual machine and shared pages with other virtual machines. The latter should be minimal as production guidelines typically require deactivation of inter-virtual machine transparent memory sharing to maximize security (https://kb.vmware.com/kb/2097593)
- For memory capacity analysis, use the consumption model based on the consumed memory counter. A more conservative result can be obtained by rounding upwards based on the Guest OS memory usage values – the latter is not calculated automatically by vRealize Operations and will need to be done manually.
- When monitoring SAP and database systems in NSX micro segmentation configurations, traffic flows will need to be unblocked to allow vRealize Operations to connect via the services required by the Blue Medora application management packs.

11. References

11.1 VMware References

- *Monitoring Business Critical Applications with VMware vCenter Operations Manager*
  http://www.vmware.com/files/pdf/solutions/Monitoring-Business-Critical-Applications-VMware-vCenter-Operations-Manager-white-paper.pdf
- *vRealize Operations Manager Reference Architecture*
  https://pubs.vmware.com/vrealizeoperationsmanager-62/topic/com.vmware.ICbase/PDF/vrealize-operations-manager-62-reference-architecture-guide.pdf
- *vSphere Monitoring and Performance Update 1 vSphere 6.0 vCenter Server 6.0 ESXi 6.0*
  http://pubs.vmware.com/vsphere-60/topic/com.vmware.ICbase/PDF/vsphere-esxi-vcenter-server-601-monitoring-performance-guide.pdf
- *vRealize Operations Definitions for Metrics, Properties, and Alerts*
  http://pubs.vmware.com/vrealizeoperationsmanager-63/topic/com.vmware.ICbase/PDF/vrealize-operations-manager-63-reference-guide.pdf
- *Troubleshooting ESX/ESXi virtual machine performance issues*
  https://kb.vmware.com/kb/2001003
- *Using esxtop to identify storage performance issues for ESX / ESXi (multiple versions)*
  https://kb.vmware.com/kb/1008205
- *vSphere Resource Management ESXi 6.0 vCenter Server 6.0*
  https://pubs.vmware.com/vsphere-60/topic/com.vmware.ICbase/PDF/vsphere-esxi-vcenter-server-60-resource-management-guide.pdf
- *vRealize Operations Manager Customization and Administration Guide*
  http://pubs.vmware.com/vrealizeoperationsmanager-64/topic/com.vmware.ICbase/PDF/vrealize-operations-manager-64-cust-admin-guide.pdf
- *Getting More Out of vRealize Operations 6.x: Optimizing Your Existing Capacity*
  http://blogs.vmware.com/management/2016/05/getting-more-out-of-vmware-vRealize Operations-optimizing-capacity.html

11.2 External References

The following third-party Web sites are not under the control of VMware and the content available at these sites might change.

11.2.1 SAP

- SAP Knowledge Base Article 941735 *SAP memory management system for 64-bit Linux Systems*
  http://service.sap.com/sap/support/notes/941735
- *SAP HANA Troubleshooting and Performance Analysis Guide*
  http://help.sap.com/hana/SAP_HANA_Troubleshooting_and_Performance_Analysis_Guide_en.pdf

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