Performance Metrics for Virtualized Telecommunication Environments

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Abstract—Network Function Virtualization has recently been gaining a widespread usage in the telecommunication sector and is poised to revolutionize the implementation of the next generation of telecommunication environments. The implementations led by industry are currently focused on achieving the functionality with Common-Off-The-Shelf (COTS) hardware rather than the performance of the service provided. In this paper we have studied the performance metrics that will be significant in the benchmarking of the Virtualized LTE Evolved Packet Core (EPC) Environments. Some of the most important and critical performance metrics are CPU Utilization, Memory Utilization, Disk Utilization, and Network Utilization. Each of these is further broken down into sub-categories. These performance metrics are similar to what have been used for server virtualization in the cloud architectures and datacenters but have not been studied for the LTE virtualized environments before. The metrics will play an important role in the achievement of high availability of five nines required by the telecommunication service providers.

Index Terms—Network Function Virtualization, Performance metrics, LTE, Evolved Packet Core (EPC), High Availability, telecommunication, Service Provider

I. INTRODUCTION

Virtualization has been around for several years now for the server and desktop and has been widely used for all practical purposes. Its advantages include increased efficiency of the system, flexibility, cost reduction, power reduction, and storage and backup improvement. The idle time of standalone non-virtualized server is a wasted investment. With virtual computing, increase efficiency is achieved from the existing valuable computing resources since hardware and software resource can be distributed between several host virtual machines and are shared. However, there are paramount concerns related to security and firewall of these systems especially when these are housed with Cloud Service Providers (CSP). The system can also have serious performance issues if the metrics are not optimized and the users and the services can be severely impacted.

Network Function Virtualization is a new paradigm shift in the telecommunication domain and brings in the concept of virtualization of strictly controlled domain of customized equipment. Telecommunication Vendors have for years built proprietary servers that become useless after a couple of years as the technology matures which results in higher CAPEX and OPEX values.

NFV promises to phase out the use of customized hardware in place of Common-Of-the-shelf hardware, which can be reused. The prices will be further reduced by the use of open source software.

The virtualization workload characteristics of the IT environments are very different from the telecommunication traffic environments however the similarity can be found from the standpoint of traffic which can be divided into data and control plane. We hence use this similarity to identify and experiment with the common parameters and characterize the performance metrics of the telecommunication virtualization loads.

There are several vendors with virtualizations products offering variety of services. Some of the major virtualization vendors in the market are VMware, Xen, and KVM. OpenStack & OpenContrail is one other product combo that is being widely adopted in the telecommunication industry to virtualize the traffic loads

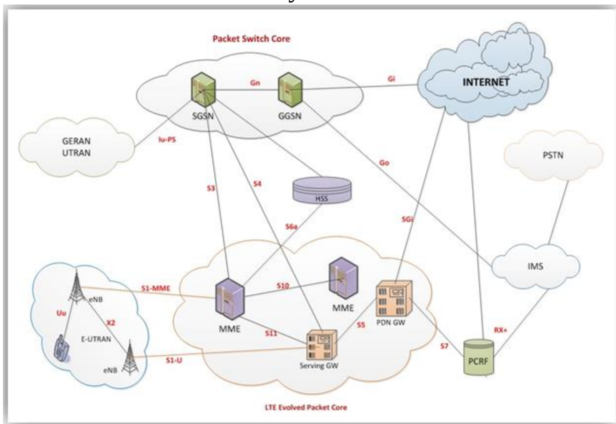

Fig. 1. LTE-Architecture

II. VIRTUALIZED LTE NODES

LTE is the latest generation of telecommunication standards released by 3GPP [1]. At this point of time several of the LTE nodes are being virtualized. Mobility Management Entity (MME), Serving Gateway (SGW), Packet Gateway (PGW), Policy and Charging Rules Function (PCRF), Home Subscriber Server (HSS), IP

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Multimedia Subsystem (IMS) Serving GPRS Support Node (SGSN) and Gateway GPRS Support Node (GGSN). This is being made possibly by the use of emerging technologies such as OpenStack, Openflow and SDN.

III. Related Work

There have been studies, which have compared the performance metrics between the different VM solutions such as KVM vs XEN [2]. [3] Has evaluated disk performance on VMware vSphere. VMmarks is a tool developed by VMware to evaluate the performance of the virtualized environments but is specific only to vSphere. [4] presents the performance metrics that can be evaluated by VMmarks. [5] setup another Testbed using VMmarks and SPECvirt_sc2010 to evaluate the performance of the virtualized environments. [6] examines the results database performance in a virtualized environment using the TPC-VMS benchmark which in turn leverages the TPC-C, TPC-E, TPC-H, and TPC-DS benchmarks

Several vendors [7] have virtual machine solutions such as VMware, Oracle's Virtual Box, Citrix Systems (earlier Xen), KVM, Microsoft Hyper-V. [8] presents a comprehensive comparison of the virtual machines. We will focus only on VMware solution for our experimentation in section 6 as these are one of the industry wide accepted solutions for Network Function virtualization.

None or little work is done on evaluating the performance of the LTE nodes which are being virtualized as put forward by the ETSI [9]. Instead most of the focus has been on the implementation of the network function virtualization functionality.

OpenStack has become an enabling technology for the deployment of NFV systems and its bundled with Ceilometer that provides monitoring functionality. Zabbix and Nagios are demonstrated in [10] as open source monitoring tools that can also be deployed after tweaking to use for monitoring NFV networks [11].

IV. Performance Metrics

The performance metrics for each of the products mentioned in section 4 remain the same from the system's administration point of view. Data is collected for the performance measurement for all aspects of the system but special focus would be on the following

a) CPU Metrics
b) Disk Metrics
c) Memory Metrics
d) Network Metrics

A. CPU Specific Metrics

The CPU Specific metrics presented in Table I column 1 are important in determining the performance of the virtual machines running on the system. The CPU load becomes intensive when there are hundreds of machines running. In our experimentation presented in section 5, we have presented several of these parameters by the use of the tool CPU-Z.

B. Memory Specific Performance Metrics

The most consumed computing resource for the virtual machine is memory. The Memory Specific Performance metrics presented in Table I column 2 can be measured in the in the vSphere clients [12], [13]

C. Storage Specific Metrics

NAS and SAN storage are common for the virtualized environments and since the virtual images reside on the disks. The performance could be seriously impacted by the virtualized solution hence [14] recommends a Checklist to troubleshooting SAN/NAS performance problems. Databases are commonly employed in the telecommunication systems to hold user information such as in HSS. The databases are demanding applications and can impact the performance. [15] presents the Experimentation and Real Metrics and Data collected for the database applications. To support higher data rate traffic Fiber channel is often employed while deploying SAN [16]. Storage Controllers provide the performance of SAN based on the following storage metrics [17]

- SP Cache Dirty Pages (%)
- SP Utilization (%)
- SP Response time (ms)
- SP Port Queue Full Count

The following parameters can be looked into to see the performances issues related to the Logical Unit Numbers (LUNS).

TABLE I. PERFORMANCE METRICS

CPU Specific metrics	Memory Specific Performance metrics	Storage Specific metrics for LUNS
cpuentitlement	Active	Utilization (%)
guaranteed	Shared	Queue Length
idle	Consumed	Average Busy Queue Length
ready	Granted	Response Time (ms)
reservedCapacity	Overhead	Service Time (ms)
system	Balloon	Total Throughput (IO/sec)
totalmhz	Swapped	Write Throughput (I/O/sec)
usage	Swapped in rate	Read Throughput (I/O/sec)
usagemhz	Swapped out rate	Total Bandwidth (MB/s)
used		Read Bandwidth (MB/s)
wait		Write Bandwidth (MB/s)
		Read Size (KB)
		Write Size (KB)

V. VMWARE SPECIFIC PERFORMANCE METRICS

In this paper we will focus on the VMware specific performance metrics due to its wide availability and yet misunderstood. Our test bed is based on VMware workstation, which is not a fully virtualized system. However all these can still be applied to the other VMware product lines. Several studies point out VMware Metrics to help pinpoint bottlenecks [18]

Table II present a list of System Parameters and their descriptions that VMware VSphere is able to record, however not all the parameters have significant impact on the performance of the telecommunication system. We observe that the most impact is found in parameters of CPU Utilization, Memory Utilization, Disk Usage and Network Metrics. Table III presents the important metrics that are available within each of these categories. For our simplistic experimental testbed, we were not able to record the values of the parameters mentioned in Table II as these are processor and disk parameters not recorded by the tool CPU-Z.

TABLE II: VMWARE VSPHERE PERFORMANCE PARAMETERS

	Parameter	Description
1.	CPU Utilization	The total CPU utilization across the system along with the average value in percentage.
2.	Memory Utilization	The total memory utilized across the system along with the average value in percentage.
3.	Disk Usage	Disk usage of ESX/ESXi server along with the average value in kilobytes per second
4.	Network Usage	Network usage of ESX/ESXi server along with the average value in (kilobytes per second)
5.	ESX Details	
6.	Host Name	Name of the ESX/ESXi server host
7.	Version	Version of the ESX/ESXi server
8.	UUID	The Universally Unique Identifier number for your distributed server
9.	Vendor Name	Name of the server vendor
10.	Hardware Model	Model name of the machine where the virtual server is installed.
11.	Hardware Vendor	Name of the vendor who provided the physical machine where the virtual server is installed.
12.	CPU Model	Overall specification of the CPU
13.	Power	Server power status (Powered On or Powered Off)
14.	Number of Virtual Machines	Number of VMs discovered in the physical machine
15.	CPU Capacity	The overall CPU capacity in Mega Hertz
16.	No of CPU Cores	Number of CPU cores present in the server

TABLE III: IMPORTANT PERFORMANCE METRICS USED IN VMWARE VSPHERE

CPU Metrics	Disk Metrics	Memory Metrics	Network Metrics
cpu.extra.summation	disk.busResets.summation	mem.active.average	net.received.average,
cpu.ready.summation	disk.commandsAborted.summation	mem.consumed.average	net.transmitted.average
cpu.usagemhz.average	disk.totalLatency.average	mem.overhead.average	net.usage.average
	disk.queueLatency.average	Memory Swapping: mem.swapin.average, mem.swapout.average and mem.swapped.average	

VI. EXPERIMENTATION

To gather data to find out how each of the 4 metrics mentioned in section 4 are measured we setup a testbed to take measurements. The test bed environment is shown in Fig. 2. We have used two tools namely CPU-Z and ManageEngine OpManager to observe the performance metrics on the VMware workstation running on a windows desktop with the base machine configurations as displayed in Table IV. The configurations of the VMs running on the system are mentioned in Table IV and hardware environment is shown in Fig. 2. It should be noted that this is not a true environment as the true telecommunication environment run on a much beefy bare-metal system such as HP C7000. However the purpose of this benchmarking was to show how the performance metrics change and the different measurements that can be taken.

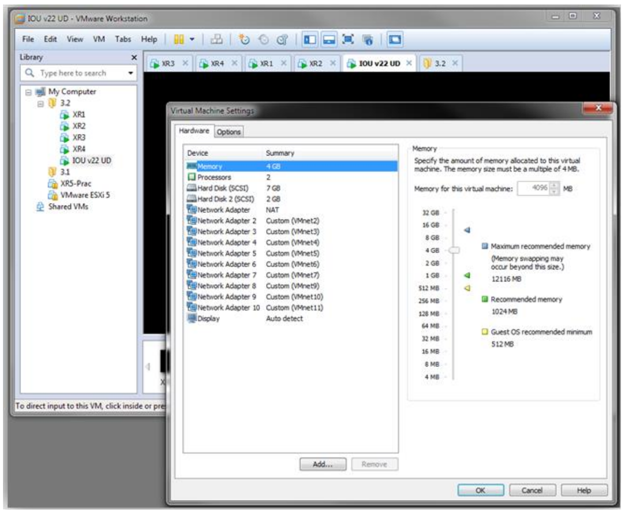

Fig. 2. Testbed VM environment

We think that the results obtained in this given environment could have been improved with the use of Solid State drive and with the use of higher level memory however the Lab inventory didn't include a SSD or higher memories. This proof will be presented in a future work.

TABLE IV: WORKSTATION CONFIGURATIONS

Machine Model	Latitude E6440
Processor	4th Generation Intel® Quad Core i5 processor
Operating System	Microsoft® Windows® 7 Professional 64 bit
Memory	DDR3L SDRAM 1600MHz; 2 slots supporting 16GB
Chipset	Mobile Intel® QM87 Express Chipset
Graphics card	Options Intel® Integrated HD Graphics 4600
Storage	Standard 320GB Hard Disk Drive

A. Load

Load running on the virtual machines was a standard cisco IOS-XR router Cisco IOS. Turning on the devices, which are emulating as routers, increased the load incrementally. The characteristics of the load are displayed in Table V.

TABLE V: CONFIGURATIONS OF VIRTUAL MACHINES RUNNING ON THE VMWARE WORKSTATION

Virtual Machines	Memory	Processors	Hard Disk allocation
VM 1 Linux based IOS	1.8 GB	1	3 GB
VM 1 Linux based IOS	1.8 GB	1	3 GB
VM 1 Linux based IOS	1.8 GB	1	3 GB
VM 1 Linux based IOS	1.8 GB	1	3 GB
VM 1 Unix machine	4GB	2	7 GB

B. Benchmarking

We used two different software for recording and measuring performance while the virtual machines are running. These software were used as they presented different set of information needed to complete the performance analysis. ManageEngine OpManager 11.4 software had an advantage of displaying information in graphical format.

a) **CPU-Z** is a freeware that gathers information on some of the main devices of your system. It is capable of recording the information presented in Table VI. The most important information that it is able to record is the memory since the virtual machines are memory hungry. Fig. 3 depicts one instance.

TABLE VI: SYSTEM PERFORMANCE PARAMETERS THAT CPU-Z CAN RECORD

CPU	Name and number, Core stepping and process, Package, Core voltage, Internal and external clocks, clock multiplier, Supported instruction sets, Cache information
Mainboard	Vendor, model and revision, BIOS model and date, Chipset (Northbridge and Southbridge) and sensor, Graphic interface.
Memory	Frequency and timings, Module(s) specification using SPD (Serial Presence Detect) : vendor, serial number, timings table.
System	Windows and DirectX version.

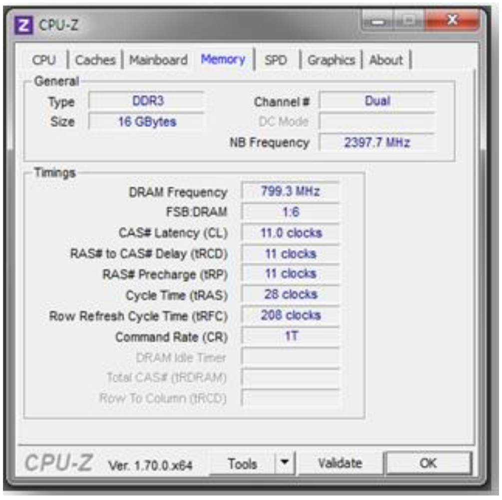

Fig. 3. Memory details of the system including latency

b) **ManageEngine OpManager 11.4** software can be used to display the statistics in a graphical manner and can monitor the alarms and other notifications generated by the system. We however noted that the software was slow to respond to the load spikes and didn't capture all the results. The graphical result for one instance is recorded in Fig. 4.

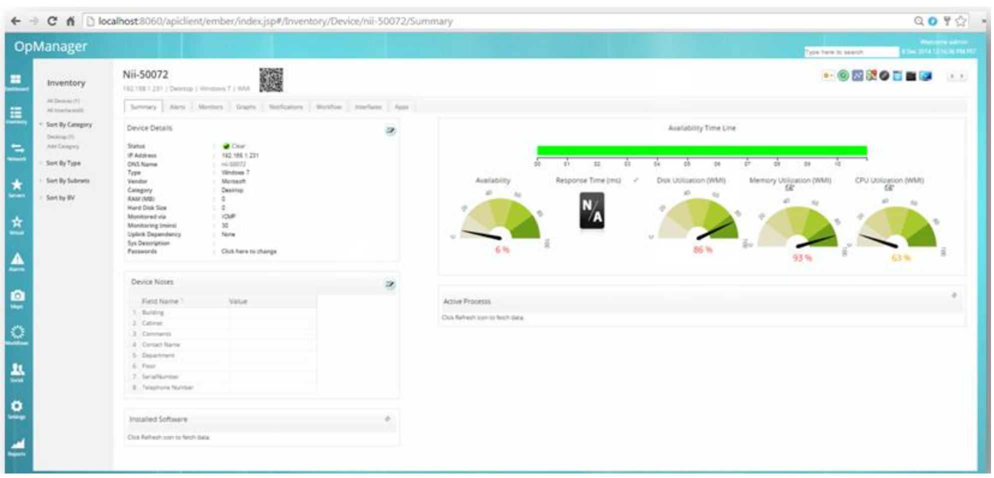

Fig. 4. Screenshot from the OpManager

VII. Conclusion and Future Work

Virtualization is a new concept for the telecommunication domain, although the virtualization techniques have been widely employed in the datacenter and cloud domains, it has not been done yet in the telecommunication. We have outlined some of the performance metrics that can be used when the Evolved Packet Core and IP Multimedia Systems are virtually deployed. The future work would include running these bench marks along with the data and control traffic.

References

[1] 3GPP, 2007. 3GPP Technical Specification 23.401 v8.

[2] Hayden, M., 2014. Performance benchmarks: KVM vs. Xen. [Online] Available: https://major.io/2014/06/22/performance-benchmarks-kvm-vs-xen/

[3] Irfan Ahmad, J. M. A. A. M. H. R. K. V, An Analysis of Disk Performance in VMware ESX Server Virtual Machines. Austin, VMware, 2003.

[4] N. D. VMmarks, VMmark 2.x - Measure Performance with the Industry's First Virtualization Platform Benchmark [Online] Available: http://www.vmware.com/products/vmmark/overview.

[5] Vikram Makhija, VMmark: A Scalable Benchmark for Virtualized Systems, 2006.

[6] D. Wayne and S. S. Smith, "Virtualization performance insights from TPC-VMS," *Transaction Processing Performance Council*, 2013.

[7] N. D. Vendors. Virtualization vendors in the market. [Online] Available: http://www.virtualizationmatrix.com/matrix.php?category_search=all&free_based=1

[8] J. P. Walters, V. Chaudhary, M. Cha, S. Guercio, and S. Gallo, "A comparison of virtualization technologies for HPC," in *Proc. IEEE 22nd International Conference on Advanced Information Networking and Applications*, 2008.

[9] N. Whitepaper, Network Functions Virtualization - An Introduction, Benefits, Enablers, Challenges & Call for Action, 2012.

[10] G. Gardikis, I. Koutras, G. Mavroudis, S. Costicoglou, G. Xilouris, C. Sakkas and A. Kourtis, "An integrating framework for efficient NFV monitoring," *IEEE NetSoft Conference and Workshops (NetSoft)*, Seoul, 2016.

[11] S. Guerassimov, E. Cordeiro, and L. Schwaighofer, "NFV and OPNFV," *Network Architectures and Services*, 2016.

[12] VMware, 2014. vSphere Monitoring and Performance. [Online] Available: http://pubs.vmware.com/vsphere-50/topic/com.vmware.ICbase/PDF/vsphere-esxi-vcenter-server-50-monitoring-performance-guide.pdf

[13] vSphere, PMI. (2014). New Performance Metrics in vSphere 5. [Online] Available: http://www.virtuallyghetto.com/2011/08/new-performance-metrics-in-vsphere-5.html

[14] G. Schulz, Checklist: Ten Steps to Troubleshooting SAN/NAS Performance Problems, 2010.

[15] Performance Study, V. (2014). Virtualizing Performance-Critical Database Applications in VMware vSphere. [Online] Available: http://www.vmware.com/pdf/Perf_ESX40_Oracle-eval.pdf

[16] A. S. Performance. (2010). The Top Ten Things to look for to avoid Fibre Channel. [Online] Available: http://www.hds.com/assets/pdf/avoiding-san-performance-problems-whitepaper.pdf

[17] S. P. Metrics. (2012). San Performance Metrics. [Online] Available: http://thesanguy.com/2012/09/25/san-performance-metrics/

[18] A. Rosemblat, The Top 20 VMware Performance Metrics You Should Care About, s.l.: VKERNEL, 2010.

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