

# Implementation of L3 Function on Virtualization Environment using Virtual Machine Approach: Case of University XYZ Computer Laboratory

Marcel

Faculty of Engineering and Computer Science  
Krida Wacana Christian University / UKRIDA  
Jakarta, Indonesia  
marcel@ukrida.ac.id

**Abstract** — There are 2 approaches to implement layer 3 network function on virtualization platforms, the first approach uses the conventional physical devices; while the second is software-based. Several previous studies have been carried out to test the performance of L3 function on virtualization using software-based and obtained positive result for the performance over the physical-based. While the previous studies were limited only within the scope of testing environment, this paper tries to extend the study not only limited to the performance test based-on RFC 2544 standard, but also implementation in the production environment using virtual machine (VM) approach. Mikrotik CHR (Cloud Hosted Router) designed specifically for virtualization environment will be used as the L3 platform on the VM. Implementation in the production environment was conducted at University computer laboratory that has 207 desktops (190 in the form of virtual desktops, 17 in the form of PCs) not including user' devices that connected via WiFi networks. VM-based approach for routing functions (Layer 3) using Mikrotik CHR has proven to be stable and sufficient for use in the computer laboratory after 6 months of usage. Performance test also shown that VM-based L3 function had higher transfer rates; physical-based router was about 23,4% slower for 1 routing load and 4,25% slower for 2 routings load. The characteristic of VM itself also add some benefits like VM snapshot and migration for recovery. The test also revealed that VM-based L3 function prone to performance penalties when more than one routing load performed compared with physical-based.

**Keywords** — *implementation, L3 function, virtualization, case, university, computer laboratory*

## I. INTRODUCTION

Server virtualization is a computational approach that allows a physical server to run multiple virtual servers logically. This virtual server in the form of a VM (Virtual Machine) has its own virtual computing resources (virtual CPU - virtual RAM - virtual storage - virtual graphics and virtual NIC), where in the upper layer resides operating systems and applications. Each virtual server in the form of VM shares the physical computing resources that available on the physical server on which they reside. [1][2] Figure 1 shows the concept of a conventional computing approach compared with virtualization-based computing platform. These virtual machines (VM) similar like the conventional approach required to be connected to the data network. Big players of virtualization platforms such as VMware vSphere, Microsoft Hyper-V, and XenServer were provide built-in network connectivity on their hypervisor platform, called as a virtual switch but limited only for L2 function (Layer 2

OSI) [4][5][6]. L2 function means only VMs that reside on the same network address that can be connected with each other, connectivity between VMs with different network addresses requires layer 3 OSI devices (routing functions). There are 2 approaches to implement layer 3 function on virtualization platforms, the first approach uses physical devices such as layer 3 switches or router devices; while the second approach is software-based. For software-based can be divided into 2 options, first option using integrated approach through hypervisor's API (Application Programming Interface) like VMware NSX, Cisco Nexus, or open-source based like OVN (Open Virtual Network) [7], while the second options is using VM to perform the L3 function. The first option of software-based has offered more advanced features for enterprise or cloud environment and integrates well with the hypervisor, while the second option is more adequate for small-scale environment that require simple and quick-steps of implementation with basic L3 function.

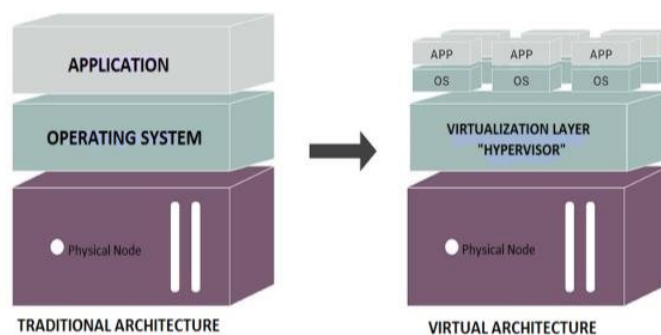


Fig. 1. Conventional VS. Virtualization Approach. [3]

Some previous studies have been conducted and showed positive results of performances when using software-based approach to perform the L3 function compared with the hardware-based approach [8][9][10][11][12]. Our previous studies using VM-based approach using Mikrotik RouterOS x86 platform also justified the positive results [13], but all of those studies were limited within the scope of testing environment. From layering perspective (Figure 1), the first option of software-based was implemented at the hypervisor level, while the second option (VM-based) was at the VM level which reside on top of the hypervisor. There are advantages and disadvantages of each layer where the L3 function is implemented, but the VM-based approach has some benefits as result of its VM form, in terms of quick VM recovery (through VM snapshot features) and VM migration to different physical servers through a hypervisor.

Furthermore, Mikrotik also introduce their new product, named CHR (Cloud Hoster Router) for L3 functions, designed specifically for virtualization environment [14]. This paper then tried to explore how reliable the VM-based L3 function using Mikrotik CHR platform on production environment at University XYZ computer laboratory.

University XYZ is one of the private university in Jakarta that already implemented desktop virtualization using VMware platform for their computer laboratory environment. Their current environment for desktop virtualization connectivity was using hardware-based approach for the L3 function. But some problems arise with the use of this physical approach (Based-on initial interview with computer laboratory' network administrator):

- The increasing number of installed physical devices has an impact with physical space, power consumption, some complexity with cables, and somehow introduce some difficulties during maintenance and troubleshoot processes because the amount of the devices.
- When technical-related problems occur, the worst-case is when the main device (with L3 function) was failed, and has a serious impact with the operational because of the downtime duration; that condition was happened in the absence of a backup device, with consideration of physical devices with L3 function that require significant amount of investment.

Based-on the identified problem, implementation of VM-based L3 function was extended and conducted to replace the main L3 physical' devices on the production environment. All of the activities performed on the production environment was remain same like the previous when still using hardware-based approach for the L3 function. Some performance and load test was performed to see how reliably it can run in the production environment. And at the same time, field observation and discussion with the network engineers was conducted to get some feedback how this approach perform at least for 6 months of running period.

## II. VM-BASED APPROACH FOR L3 FUNCTION

The software-based approach was actually replace the resource required for core-process of L3 function from hardware to the software (in the form of VM). Since it run as a VM, the process within will consume computing resources of the physical server. Performance of the VM will be depend on the specification of the physical server. There are 2 options for software-based approach of L3 function, the first one is API-based integration with the hypervisor, and the second-one is more loose using VM-based. Within the scope of VMware platform, there are VMware NSX, Cisco Nexus or using Open Flow-based protocol solutions (Open vSwitch) offered for the first option. The first option offered more advanced features, targeted for enterprise or cloud solution; vendor-based solution like VMware NSX and Cisco Nexus also require some significant investment for the license; while the open-based protocol basically is free to use but requires additional technical capabilities to configure the CLI (Command Line Interface). The second-one (using VM-based approach) is more flexible to implement, as a VM, it's independent from the hypervisor platform, L3 function was performed on the VM, so all traffic from other VMs that require routing was redirected to this VM first. The VM functioned as a routing device, replacing the physical routing

device. Figure 2 shows abstract view of interconnection for each VM for network connectivity on VMware virtualization platform. Each VM must connect to the L2 vSwitch (Virtual Switch) that bridge the VM with the pNIC (Physical Network Interface Card). All VMs within the same network address connect to the same virtual switch. In case where one VM want to transmit data to other VM with different network address will require external L3 device. Figure 3 shows abstract view of interconnection for L3 function using VM. On figure 3, there is a VM with L3 function that connected to every vSwitch that available on the hypervisor where the L3-VM reside, each of the vSwitch represent different network address. When a VM want to communicate with other VM that reside on different vSwitch, then the traffic will be redirected to the L3-VM first for routing process, before going to the destination VM.

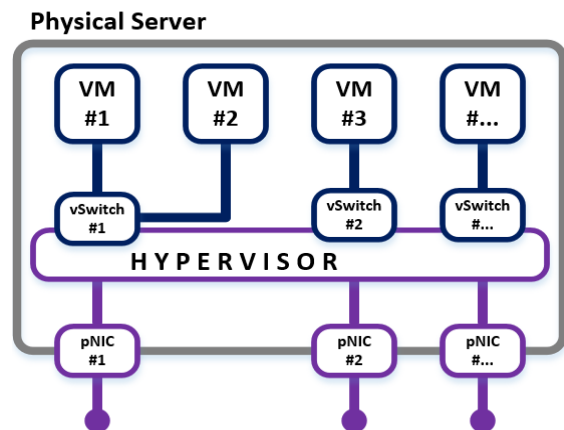


Fig. 2. Standard network connectivity for L2 virtual switch.

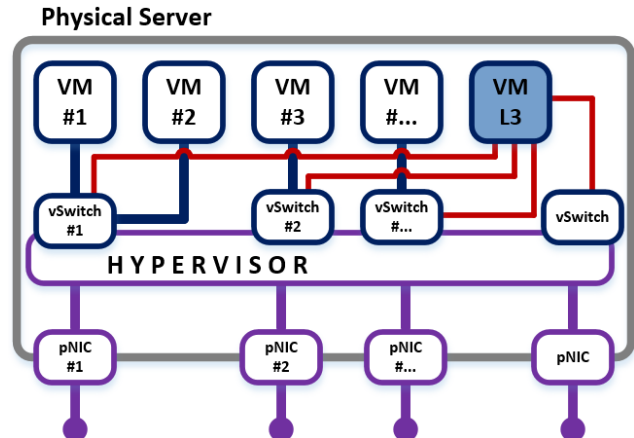


Fig. 3. Network connectivity with VM-based for L3 function.

VM-based approaches are more targeted to small-scale networks because of the hypervisor limitation for maximum numbers of virtual NICs supported per VM, also this approach is like a conventional physical approach in terms of admin management for device configuration, where each of virtual device in the form of VM must be configured in one-by-one basis (Silo model). Within the context of the implementation performed on university XYZ, 3 (three) VM-based L3 devices will be made to replace the routing function of the main physical devices (cores) in the university's computer laboratory infrastructure environment. Virtual machines that perform L3 function within the scope of our test and implementation will use Mikrotik platform. Currently, there are 2 versions of Mikrotik platform that can

be used as a VM: The RouterOS x86 version and CHR (Cloud Hosted Router). The RouterOS x86 version is basically the OS that being used on Mikrotik physical board (x86 -based machine) that also can be installed as a VM, while CHR is the newer version designed specifically for virtualization environment, installed as a VM.

### III. METHODOLOGY

#### A. Environmental Setup

The following main hardware components are used in the scope of this experimental, which are the existing hardware used in the operating environment of a computer laboratory:

- HP Proliant ML350p Gen8 server with specifications: 2x Intel Xeon E5-2609 CPU (total 8 physical cores), ECC-DDR3 128GB RAM, 7.2x 2TB RAID10 HDD-SATA storage, 4x Gigabit Ethernet NIC (@ 4 ports, total 16 ports). The ML350p Gen8 server is existing server - used for the operational of several VMs that are used for lab management, servers are based on virtualization with the VMware platform. In case of computational resource optimization, it is still sufficient to be optimized through the addition of VMs for L3 functions.
- Layer 2 physical switches for connecting network devices that are in the same network address.
- A PC (Personal Computer) with Intel i3 specifications and 4GB RAM. The PC will be used as configuration management related to virtualization on the server.

Apart from the 2 hardware main components (servers and L2 switches) with a PC for management and configuration, there are several other existing devices that are also connected with these two main components:

- 5 units of the HP Proliant DL380p Gen8 server that functioned as host of desktop virtualization servers that cover 6 classrooms in the lab area, for total of 190 desktop or VMs (Windows 7 Professional 64bit based). Those servers did not play any direct role to the L3 function using VM, but represent functions on the end-user side, consist of 7 different network addresses, where 6 network addresses represent 6 lab' classrooms, and 1 network address for server management.
- 1 unit of NAS device (Network Attached Storage) used for storage functions. This NAS device is on a different network address than the previous 7 network addresses used by 5 units of the HP Proliant DL380p Gen8 server.
- Wireless access point for WiFi facilities in the lab area with separate network address allocations.

The software components used in the scope of this case study are as follows:

- VMware vSphere 6 U3 consisting of VMware ESXi as the hypervisor installed on the server, and VMware vSphere Client for management installed on the PC.
- Mikrotik CHR (Cloud Hosted Router) that is implemented in the form of a VM. This VM with the CHR Mikrotik will be used for virtualization-based routing functions to replace the physical devices.
- Passmark network advanced test version 9 was installed on Windows 7 -based VM as a benchmark tool.

The implemented interconnection using VM-based L3 function will replace 3 main hardware components that being used previously on computer laboratory, they are:

- 1 Mikrotik RB750 unit, is a small-size router that is used specifically only for DHCP server functions.
- 1 unit of Mikrotik CCR (Cloud Core Router), as a physical core router that performs firewall functions, NAT (Network Address Translation), bandwidth management and web proxies.
- 1 unit of HP switch 4800-48G as a core switch for the routing function (layer 3 OSI).

#### B. Test Scenarios

Table 1 summarize all the tests performed on VM-based and physical-based router within the scope of this experimental test based-on RFC 2544 [15].

TABLE 1. Scenarios for performance benchmark based-on RFC 2544.

Scenario (Load)	Routing Devices	Scope of Test	Test Performed
L2 Traffic	Physical Ethernet-switch	16 packet-sizes: 64, 128, 256, 512, 768, 1024, 1280, 1518, 1522, 1600, 1728, 2496, 3584, 4016, 9104, and 9136 bytes (based-on RFC 2544)	Throughput of one-way data transmission; each packet-size run 3 times, each for 60 seconds
	MikroTik CHR in VM		
L3 Traffic: Single routing	Physical Ethernet-switch	16 packet-sizes: 64, 128, 256, 512, 768, 1024, 1280, 1518, 1522, 1600, 1728, 2496, 3584, 4016, 9104, and 9136 bytes (based-on RFC 2544)	Throughput of one-way data transmission; each packet-size run 3 times, each for 60 seconds
L3 Traffic: Dual routing	Physical Ethernet-switch	16 packet-sizes: 64, 128, 256, 512, 768, 1024, 1280, 1518, 1522, 1600, 1728, 2496, 3584, 4016, 9104, and 9136 bytes (based-on RFC 2544)	Throughput of one-way data transmission; each packet-size run 3 times, each for 60 seconds
	MikroTik CHR in VM		

### IV. IMPLEMENTATION

#### A. Implementation Framework

The implementation of the L3 virtual machine consists of several stages, figure 4 show 6 stages that becoming framework for the implementation of VM-based L3 function on University XYZ computer laboratory.

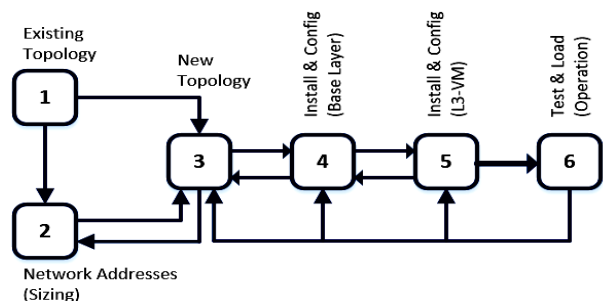


Fig. 4. Implementation Framework for VM-based Virtualization.

- The first stage focuses on the existing physical topology, maps the physical interconnection of the current existing configuration. Output at this stage is the existing physical interconnection topology. For cases of new implementations (not migration), this stage focuses on

the general topology description of the physical interconnection plan that will be held.

- The second stage focuses on collecting network addresses from existing interconnection configurations or new interconnection plans. Output at this stage is the list of required network addresses. From the number of network addresses recorded can be a reference to determine the number of L3 VMs that need to be prepared as well as the number of required physical Ethernet ports. The number of required physical Ethernet ports determine the type of physical server.
- The third stage focuses on the design of new topologies on a virtual basis. This stage also identified physical components which can be eliminated by the new topology model (in the case of migration from the existing conventional infrastructure). For the case of a new implementation, this stage focuses on the topology where the virtual component is used, so that this topology is more mature than the previous topology version (Output first stage).
- The fourth stage focuses on installing and configuring the virtualization platform (hypervisor) and management client, including the IP addresses configuration.
- The fifth stage focuses on installing and configuring the VM (Mikrotik CHR), the number of VMs is adjusted to the needs based on information from the previous stages. The administrator also configures the virtual networks that interconnects the Mikrotik VM with other VMs and with physical interfaces (via physical Ethernet ports).
- The sixth stage focuses on traffic test and load for the interconnection configurations that have been made.

**B. Existing and New Topology**

Figure 5 shows existing / old topology installed and run on the infrastructure of university’ computer laboratory. L3 function was performed externally by physical devices, where core router was dedicated for internet connection gateway and management, and core switch was dedicated for local area network / LAN’ L3 function. The core switch covering all of VLANs (Virtual LAN) that resides on the computer laboratory, the routing process between the VLANs was processed inside the core switch. This topology was covering 6 classrooms area inside the university’ computer laboratory and 2 work areas, consist of 190 units of thin client (for virtual desktop), 17 units of PC, not including user’s owned devices that connected to wireless access point. Using physical-device approach for core devices require us to have investment for physical backup unit also, which is one of challenging factor for small-scale organization with limited resource. Another consideration is a downtime and effort required when the core device fail and the backup unit is different type or series, which require full reconfiguration.

Table 2 shows list of identified network addresses captured from the existing operational environment (Total 15 network addresses / VLAN). This captured network address was useful to determine the new topology using VM-based routing. Figure 6 shows new topology based-on previous information (existing topology) and list of network addresses. We created 3 L3-VMs to accommodate all of the identified network addresses. The VM #1 was functioned as internet gateway and management (core router) while the other 2 VMs (VM #2 and VM #3) were functioned for LAN’ L3 function (core switch).

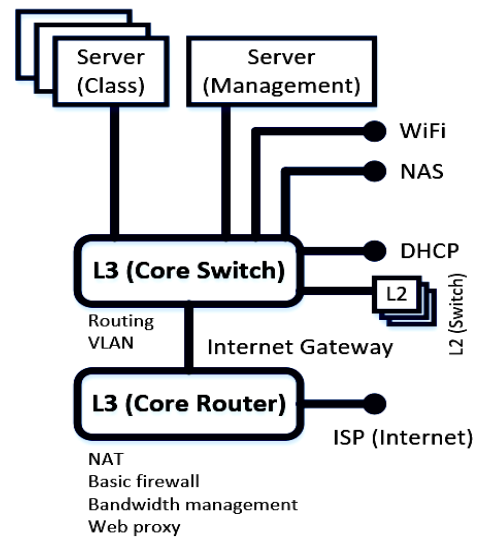


Fig. 5. Existing / old topology.

TABLE 2. List of existing network addresses.

QTY	Description
6	Classroom (Lab area)
2	Server and storage
1	Management for VMware ESXi
1	CCTV camera
1	WiFi (Access point)
2	Work area
2	Others

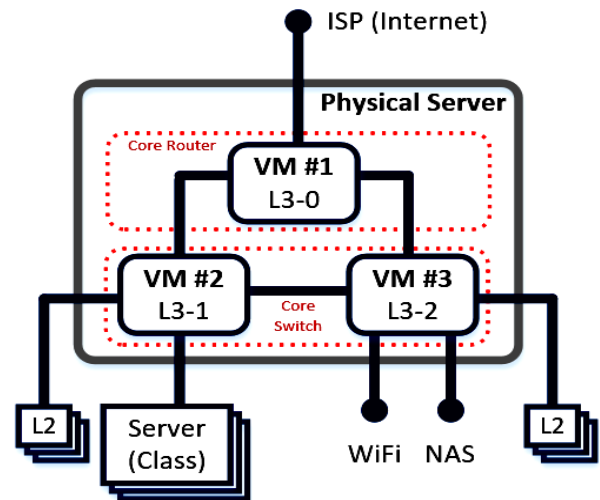


Fig. 6. New topology with L3 VM.

This new topology with L3 VM remove and replace the 2 core physical devices (core router and core switch). We used 2 L3-VMs to functioned as a core switch because of virtual NIC amount limitation on VMware ESXi as hypervisor, where each of VM was limited only up to 10 vNIC(s) or 10 network addresses. Here are the technical specifications for the L3 VMs: **VM #1 (L3-0)** specification: 4 cores vCPU, 8GB vRAM, 4 vNIC, 8.5GB vStorage (Thin provisioning); **VM #2 (L3-1)** specification: 8 cores vCPU, 8GB vRAM, 8 vNIC, 8.5GB vStorage (Thin provisioning); **VM #3 (L3-2)** specification: 8 cores vCPU, 8GB vRAM, 9 vNIC, 8.5GB vStorage (Thin provisioning).

**C. Reliability and Performance Evaluation**

At first, the L3-VM’ platform for core switch function was using Mikrotik RouterOS x86 version, but we found that

this Mikrotik OS version is keep crashing randomly after running for couple days. We also found that CPU activities of this VM was very high, average at 93% (rounded) before it crash. Then we continue to replace the platform with Mikrotik CHR (Cloud Hosted Router), and found it was stable and only consume about 19% average (rounded) of CPU usage during peak hour for core switch function. This is interesting because that condition (very high CPU utilization) did not appear during the trial phase and the first phase of implementation (limited implementation only for 3 small classrooms, covering 77 desktops), this happened because in full production environment, the traffic was massive and unpredictable (covering 6 classrooms, 2 work areas, about 207 desktops, not including user' devices that connected via wireless area network). This condition also justifies the recommendation of using CHR platform over the previous x86 version for virtualization environment [14].

Refer to figure 6, VM #1 was performing 4 functions as an internet gateway: NAT (Network Address Translation), basic firewall based on TCP ports, bandwidth management, and web proxy for web caching. While VM #2 and VM #3 not only performing a routing function (using static route), but also basic firewall. Previously, basic firewall configuration based-on TCP/UDP ports only can be performed on the physical core switch through the CLI, and this condition becoming a limitation for configuration management' flexibility. The rules created for basic firewall under CLI must follow a certain sequence. Moving rule above or below any other rules was not allowed. Any changing means a reconfiguration for all of the rules. While Mikrotik is more flexible to configure the basic firewall (through the GUI), allowing to reorder the firewall rules. Table 3 shows transfer rate results (in megabits per second) for each of blocksize (in bytes), based-on RFC 2544 benchmarking specification, for peer-to-peer connection that reside on the same network address through virtual L2 switch. Comparing with table 4, also peer-to-peer connection using existing physical L2 switch.

TABLE 3. Transfer rate for peer-to-peer within single network address (virtual L2 switch).

Blocksize (B)	64	128	256	512	768	1024	1280	1518
Average (Mb)	158,32	207,2	248,7	279,3	309,4	363,3	363,5	370,2
Blocksize (B)	1522	1600	1728	2496	3584	4016	9104	9136
Average (Mb)	375,1	394,7	382,6	475,9	526,9	609,7	697,2	700,4

TABLE 4. Transfer rate for peer-to-peer within single network address (physical L2 switch).

Blocksize (B)	64	128	256	512	768	1024	1280	1518
Average (Mb)	116,9	152,4	178	192,6	208,5	210,3	227,6	236,2
Blocksize (B)	1522	1600	1728	2496	3584	4016	9104	9136
Average (Mb)	243,8	246,4	227,5	273,3	315,7	332,9	378,2	377,1



Fig. 7. Scenario of peer-to-peer transfer within single network address.

It's interesting to see that physical switch was about 37% lower in average for transfer rate when compared with virtual switch. But this's not surprising because in virtual switch scenario, all components (nodes, connection and L2 switch) are virtual; where in physical switch, even though the nodes are virtual (using VM), but it also involves the physical components like cables, connectors and electronic board are all contributes to the quality of the transfer rates. The results

on table 3 and 4 will be used as a baseline score for further comparison that preview a condition when there is no routing process performed within. Continuing the test, we have table 5 that shows transfer rates for peer-to-peer connection that involved 1 routing process within a single VM-router (Figure 8). The performance impact for this 1 routing process (table 5) compared with the baseline condition (table 3, without any routing) was about 0,5% average, which is very slight.

TABLE 5. Transfer rate for peer-to-peer connection with 1 routing process on a single VM-based router.

Blocksize (B)	64	128	256	512	768	1024	1280	1518
Average (Mb)	157,6	205,63	247,5	277,24	308,8	362,1	360,8	368,86
Blocksize (B)	1522	1600	1728	2496	3584	4016	9104	9136
Average (Mb)	373,2	392,4	381,3	473,2	524,5	604,3	694,4	697,8



Fig. 8. Scenario of 1 routing process on a single VM-based router.

Another results as shown on table 6 for peer-to-peer transmission that involve 1 routing process using physical L3-switch. When compare it with table 4 (using physical L2-switch, a condition without any routing process), the performance impact because of this 1 routing process was about 0,6% average, which is also very slight difference.

TABLE 6. Transfer rate for peer-to-peer connection with 1 routing process on a single physical-based router.

Blocksize (B)	64	128	256	512	768	1024	1280	1518
Average (Mb)	116,8	152,1	177,3	192,6	208,3	210,2	225,4	233,9
Blocksize (B)	1522	1600	1728	2496	3584	4016	9104	9136
Average (Mb)	239,5	246	227,3	273,2	313,5	332,8	369,3	370,2

Comparing table 5 with table 6, we found that physical-based router was about 23,4% slower when compared with virtual-based router. Continuing the test, by adding 1 more routing load (figure 9) on a single router (table 7, 8). Table 8 for physical-based router overall had about 4,25% slower transfer rate compared with table 7 (software-based router).

TABLE 7. Transfer rate for peer-to-peer connection with 2 routing process on a single VM-based router.

Blocksize (B)	64	128	256	512	768	1024	1280	1518
Average (Mb)	123,31	127,45	124,72	129,55	136,11	136,96	281,42	287,71
Blocksize (B)	1522	1600	1728	2496	3584	4016	9104	9136
Average (Mb)	291,1	306,1	297,41	369,09	409,11	471,35	542,3	593,6

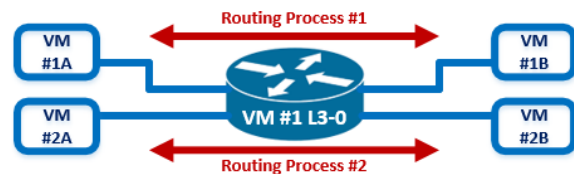


Fig. 9. Scenario of 2 routing process on a single VM-based router.

TABLE 8. Transfer rate for peer-to-peer connection with 2 routing process on a single physical-based router.

Blocksize (B)	64	128	256	512	768	1024	1280	1518
Average (Mb)	118,3	149,6	173,7	190	196,7	203,4	222,3	234,3
Blocksize (B)	1522	1600	1728	2496	3584	4016	9104	9136
Average (Mb)	232,3	243,7	225,7	271,6	305,2	324,9	364,6	353,9

Comparing table 5 (1 routing process) with table 7 (2 routing process) for VM-based router, we found that the addition of 1 routing process was impacting the transfer rate about 30,8%. While comparing table 6 (1 routing process) with table 8 (2 routing process) for physical-based router, we found that 2-routing process scenario was about 1,8% slower

when compared with 1 routing process scenario. It's interesting because performance impact of additional routing process is quite significant on VM-based approach.

Table 9 shows transfer rate of peer-to-peer connection during peak-hours (around 11.00AM – 15.00PM) at computer laboratory. During peak-hours, about 200 desktops are actively used, and most of the routing traffic activities was intended for internet connection. Table 9 also shows performance impact on transfer-rate during the peak-hours, which is quite significant but still adequate for the computer laboratory case. Comparing with table 5, a synthetic condition with 1 routing load, the impact (performance penalty on transfer-rate) was about 78,6% (the highest impact within 6 months running observation period). Table 10 shows transfer-rate per week for total 24 weeks or 6 months' period (4 weeks per month). Test was performed on a single day, randomly between Monday-to-Friday for each week (when all of the available desktops were used for teaching activities) during peak-hours. The impact (performance penalty on percentage) was come after comparing the test results with table 5' results.

TABLE 9. Transfer rate for peer-to-peer connection during operational on VM-based router.

Blocksize (B)	64	128	256	512	768	1024	1280	1518
Average (Mb)	43,92	50,13	58,36	59,42	52,6	61,21	87,44	75,03
Blocksize (B)	1522	1600	1728	2496	3584	4016	9104	9136
Average (Mb)	76,17	85,97	79,78	112,2	107,3	120,1	139,8	131,2

TABLE 10. Transfer rate per week for peer-to-peer connection during peak-hour (operational) on VM-based router.

Week #	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12
Impact (%)	70,1	72,2	68	78,6	65,4	75,5	59,6	63,3	77,2	73,8	75	78,2
Week #	W13	W14	W15	W16	W17	W18	W19	W20	W21	W22	W23	W24
Impact (%)	74,2	69,7	70,3	63,3	66,5	71,2	73,4	75,6	78	78,5	76,5	73

#### D. Design Limitation

There are several limitation related to the usage of VM-based L3 function using Mikrotik CHR. VMware platform only allow us to have up to 10 vNIC per VM. In-case we need more than 10 vNIC to support more interconnection, then we also need to create more L3 VM. This condition of creating several L3 VMs also add additional complexity related to devices' configuration and management because Mikrotik platform did not have central management feature. Another consideration, since this approach was software-based where the core device for network function was performed by VM, then the performance will be influenced by the server's hardware configuration where the VM reside.

#### V. CONCLUSION

VM-based L3 function offer some flexibility as a result of virtualization platform. Since the layer of VMs and the hardware were separated and independent with each other, then it's easier to migrate the VM from one to another hardware (server) without the risk of hardware compatibility problem. This flexibility was very useful during hardware failure, and at the same time, the usage of virtualization platform allow us to optimize the utilization of hardware resources. Another benefit of using VM-based L3 function is snapshot feature that usable for VM quick restore when a failure occurs on the system that run inside the VM. The experimental test using synthetic scenarios also reveal that

VM-based routing approach using Mikrotik CHR platform was adequate in performance and reliable to replace the previous physical-based core devices. Physical-based router was about 23,4% slower for 1 routing load and 4,25% slower for 2 routings load in transfer-rate when compared with VM-based approach. To justify the test, the Mikrotik CHR -based VMs also implemented on production environment at University XYZ computer laboratory, the implementation was referred to 6 stages of implementation framework and monitored at least for 6 months' period without problem. Furthermore, we also found that VM-based approach was more prone to performance impact compared with physical-based when more routing traffic was involved.

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