Experimental Performance Evaluation of a Virtual Software Router

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***Abstract*—Software routers (SRs) are an alternative low-cost and moderate-performance router solutions implemented with general-purpose workstations able to host multiple network interface cards (NICs). Workstations can be programmed to forward packets between different NICs and to participate in routing functions. Virtualization can be used to model new protocols or hardware systems in software and without modifying the host's kernel. However virtualized routers are expected to suffer from performance degradation because of software execution overhead. In this paper, we investigate the performance impact of a virtual software router (VSR) in comparison to that of a SR. We present the performance of VSRs hosted by different workstations – with different number of processing cores.**

***Index Terms*—Linux, virtualization, software router, virtual router, stress testing.**

I. Introduction

Modest-performance routers can be implemented with general-purpose computers provisioned with two or more network interface cards (NICs) and software to perform packet forwarding. This software is found ubiquitously provided with Linux operating systems. These ad-hoc routers are called software routers (SR) [1]-[3]. Performance evaluation of SRs has been of recent interest, and multiple tests have shown that a modest switching performance can be achieved. Nevertheless, for some networks and applications, this performance suffices.

In machine virtualization, an operating system (e.g., Windows or Linux) can run another operating system as one or more virtual machines, each running different protocols while providing an underlying platform with simple administration and maintenance functions. A SR running in a virtual environment is then called a Virtual Software Router (VSR). A host workstation may be able to allocate a single or multiple VSRs [4], and multiple protocols. Differently from a SR, a VSR runs most of the functions on software (while a so-called SR has the interfaces running on hardware). Therefore, the performance of a VSR is expected to be lower than that of a SR. However, the magnitude of performance degradation is still unknown.

In this paper, we investigate the packet-forwarding performance of VSRs. We perform a series of experiments on a testbed under multiple flow scenarios, with packets of different sizes and rates, to estimate the actual switching performance of VSRs. The performance of VSRs hosted by personal computers with single and dual CPU cores were tested. The results suggest that multiple cores may be highly beneficial for virtualization and the new virtualization technologies implemented in modern CPUs seem to have a significant impact in machine virtualization.

II. Experimental Performance Evaluation

We performed a set of experiments on a network testbed with SRs (i.e., Linux machines) and VSRs (Linux machines on top of Windows machines) to observe a performance comparison based on the results of SRs. The SRs and VSRs were implemented on workstations with different CPU specifications using popular operating systems and virtualization software. The specifications of each workstation are summarized in Table I.

TABLE I
WORKSTATION SPECIFICATIONS

	Gateway 9510	Dell Optiplex 780
Name	Gateway	Deall
Processor	Intel(R) Xeon(TM)	Intel(R) Core 2(TM)
No. of processor	4	2
CPU speed	3 GHz	3.17 GHz
RAM	2 GB	2 GB
Interface speed	10/100 Mb/s	
Operating systems	Ubuntu 10.10 (kernel 2.6.22-35-generic) and Windows 7	
Virtualization software	VMware Workstation 7.1	

Figure 1 shows the testbed setup of our experiments consisting of two workstations, each configured and tested separately as SR with four NICs, and a traffic generator, a Spirent SmartBits 6000C Performance Analysis System. We put each workstation under a stress test, which consisted of constant-bit-rate (CBR) traffic with packets of lengths from 64 up to 1472 bytes (excluding preamble bits). The Spirent system generates traffic flows for 30 sec. for each packet size and calculates throughput upon receiving the traffic back. Throughput is referred to as the maximum data rate that the system under test can forward to the destined NICs. Basic Linux forwarding was used as routing software in both Linux and virtual Linux environments.

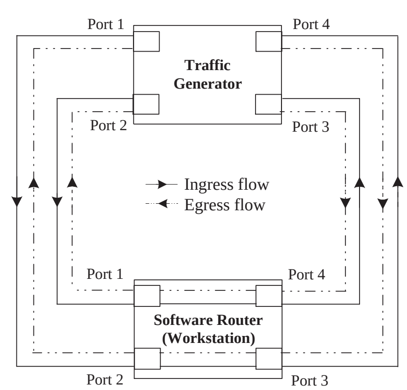

Fig. 1. Experimental setup for stress test showing four-traffic flows.

A. Forwarding of two flows

Figure 2 shows the results under two flows (each NIC has either an ingress or egress flow, as shown in Figure 1) for the Gateway and Dell workstations. The Gateway workstation, used as SR, achieves 80 Mb/s of throughput for 64-byte

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packets and 100 Mb/s for larger packets, as shown in Figure 2(a). The VSR achieves low throughput; 10 Mb/s for 576-byte packets, and the throughput increases, up to 40 Mb/s for 1472-byte packets. The VSR cannot keep up with the applied data rate with smaller packet sizes as larger processing delay to forward packets contributes to inferior throughput performances. As for the Dell workstation, the throughput achieved under 64-byte packets is 70 Mb/s and it increases to 100 Mb/s for 192-byte and larger packets, as shown in Figure 2(b). The VSR on this workstation achieves 20 Mb/s of throughput for 192-byte packets and it reaches 100 Mb/s for 1088-byte and larger packets. These results show that there are other factors to be considered in addition to the number of cores. The Gateway workstation provides similar performance compared to the Dell workstation for the implementation of a SR because of the larger number of processing cores. However, the Dell workstation achieves higher throughput than the Gateway workstation for the implementation of a VSR.

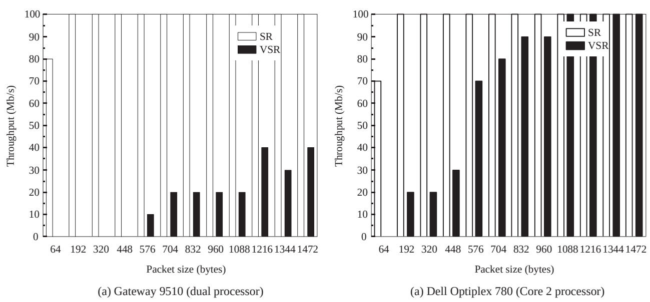

Fig. 2. Performance of a software (Linux) and virtual software (Virtual Linux) routers under two flows.

B. Forwarding of four flows

Figure 3 shows the results of stress tests under four flows (each NIC has both an ingress and egress flows, as shown in Figure 1). Figure 3(a) shows that the SR achieves a throughput of 20 Mb/s for all packet sizes, and the VSR achieves 10 Mb/s for 704-byte packets and 20 Mb/s for 1344-byte packets, using the Gateway workstation. As for the Dell workstation, the throughput for the SR is 30 Mb/s for 64-byte packets, and it increases linearly to 100 Mb/s for 576-byte and larger packets, as shown in Figure 3(b). On this workstation, the VSR achieves 10 Mb/s for 320-byte packets and the throughput slowly increases, up to 80 Mb/s for larger packet sizes, e.g., 1216-byte packets. As shown in the four-flow experiment, the Dell workstation achieves significantly higher throughput performance than the Gateway workstation because of its hardware virtualization technology and dual cores.

C. Throughput of 1472-byte packets for two and four flows

We performed another set of experiments to measure the throughput using 1472-byte packets on the Dell 780 workstation, which provided the highest performance in the previous experiments. Figure 4 shows the results obtained for the SR and VSR. The results show that the SR can support 100 Mb/s for two and four flows while the VSR can support 100 Mb/s for two flows and up to 70 Mb/s for four flows. The performance degradation under four flows is due to the increasing contention for shared resources of the VSR.

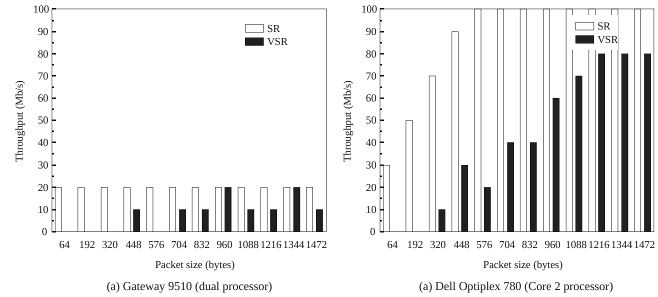

Fig. 3. Performance of a software (Linux) and virtual software (Virtual Linux) routers under two flows.

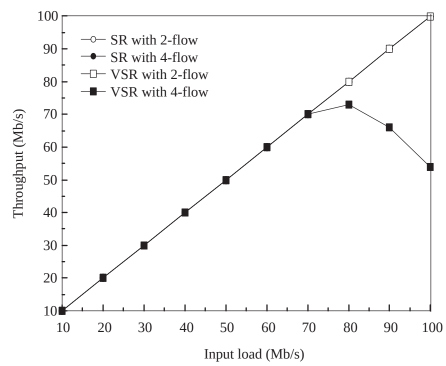

Fig. 4. Throughput of Dell Optiplex 780 workstation as software (Linux) and virtual software (Virtual Linux) routers under 1472-byte packets.

III. Conclusions

We presented a performance evaluation of VSRs and showed the performance penalty incurred by virtualization. The presented examples show the magnitude of the performance degradation without parameter tuning and how the performance is affected by the number of CPU cores. The performance penalty increases with the number of flows. However, for large packet sizes, penalty may be smaller. The obtained values suggest that virtualization has stringent requirements and the advent of multicore systems have a venue of growth in this area. A possible solution to increase the performance of VSRs can be found in peripheral processing, such as using Graphics Processing Unit (GPU) [5].

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