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Performance Analysis of Network Virtualization Systems

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Abstract—**High-performance virtual switches are critical for supporting Quality of Service (QoS) in real-time applications. This investigation of network virtualization techniques analyzed virtual switch traffic and network interface bridging characteristics. The characterizations investigation revealed the adjustment network interface capacity that is required to yield a specified QoS level. To examine the feasibility of the developed service model in this investigation, the NetFPGA platform was utilized to emulate it and to obtain comparative results for this potential useful virtual network. The proposed virtual network model has a 50% higher system throughput in a NetFPGA-based emulator than does a traditional switching system.**

Index terms -QoS, Real-time Application, Network Virtualization, NetFPGA Platform.

I. INTRODUCTION

The migration and integration of service servers into the virtualization domain have attracted substantial attention owing to the high efficiency that is provided by this platform [1]. Clearly, the service quality of a virtual server implementation is desired to be at level a level similar to that associated with implementation on a physical server. Accordingly, designing a virtual network with favorable performance is critical. Novel hardware and software capabilities have enabled this virtualization function on physical server operations [2]. Virtual machine (VM) platforms such as VMware, Xen and KVM, have provided the virtualization function for the logical layer of virtual servers [3]. Additionally, when extended to cloud computing, the VM module enables discretionary management of the virtualization control plane in various regions. Availability platformssuch as Open vSwitch have provided new opportunities for developing virtual network capabilities [4].

Many factors must be considered in the design of a virtual switch. These include processing latency, buffer management, and the ability to collaborate with a given network interface. A virtual switch is located in the logical layer between the application layer and the network interface. The 802.1Q Virtual LAN (VLAN) protocol handles the bridging from the virtual switch to the physical adapter. The VLAN mechanism enables connectivity beyond the physical adapter.

The performance degradation that is caused by virtual switches is investigated. QoS-sensitive applications, such as high-definitionvideo streaming, are then evaluated. The queuing theory model is the model most frequently used to perform this analysis. However, the queuing model cannot accurately capture the actual conditions and is typically used to analyze the design of the network system. In contrast, network calculus is effective for evaluating network performance [5]. Therefore, such an analysis of virtual switch performance is performed by deterministic network calculus herein.

II. VIRTUAL NETWORK MODEL

A. System Model

Figure 1 demonstrates that, in a physical server, multiple VMs are implemented simultaneously. Let V be the number of VMs that run in a certain period to serve accessing users), with each flow given by $V_n(t)$. Furthermore, F is the set of flows from V that are processed logically using the virtual switch. Before process F occurs, a waiting time is assumed at the virtual buffer. The aggregate $F(t)$ assumes the arrival of a stream in the Network Adapter (NIC) processing region. In NIC, the flows are processed to push the data to the physical link. In this system model, the link between the physical server and the end user is simply denoted as R, which also represents the physical link capacity. $D(t)$ is theof the final F stream that is pushed out from the physical server system through the network adapter.

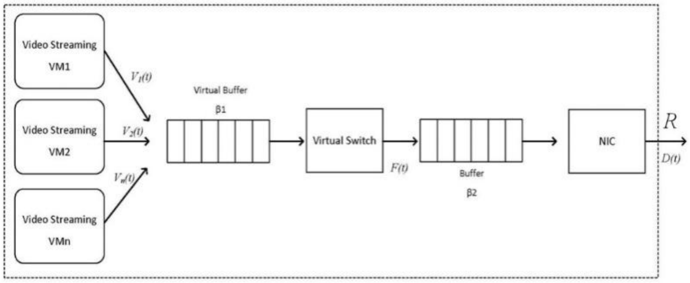

Figure 1. Virtual network system model

B. System Model

As aforementioned, $V_n(t)$ has its own traffic flow. Accordingly, F is regarded as a superposition, in which the flows are constructed modeled using the same traffic model. Suppose that F comprises two flows F_1 and F_2 , whose are represented by $V_1(t)$ and $V_2(t)$, respectively represented by F_1 and F_2. The aggregate flow is $F = (F_1 + F_2)$. The traffic that arrives from each VM is described by the fluid model:

$$F(t) - F(s) \le V(t-s); \forall_s \le t, t \ge 0 \tag{1}$$

The aggregation flow is given by:

$$\begin{aligned} F(s,t) &= F_1(s,t) + F_2(s,t) \\ &\le V_1(t-s) + V_2(t-s); \forall_s \le t, t \\ &\ge 0 \end{aligned} \tag{2}$$

F R then undergoes buffer waiting. Notably, two waiting processes occur - one in the virtual switch buffer and the other in the network adapter buffer. In the network calculus model, these processes can be regarded as backlog-bound, as verified experimentally. The backlog bound is generally represented as $B(t)$, and its deterministic formis$\beta(t)$. Based onthe experience tandem buffer experience of tandem buffers, the $D(t)$ on the edge of the network adapter in the deterministic serviceis given by

$$D(t) \ge F(t) \otimes \beta(t) \tag{3}$$

where $\beta(t)$ is given by

$$\beta(t) = \beta^{b1}(t) \otimes \beta^{b2}(t) \tag{4}$$

Therefore, for all $t \ge 0$,

$$\begin{aligned} B(t) &= F(t) - D(t) \\ &\le F(t) - \{F(t) \otimes \beta^{b1}(t) \otimes \beta^{b2}(t)\} \end{aligned} \tag{5}$$

Similarly,

$$\begin{aligned} F(t) - \inf_{0 \le s \le t} &\{F(t-s) + \beta^{b1} + \beta^{b2}\} \\ &\le \{F(t-s) + \beta^{b1} + \beta^{b2}\} \end{aligned} \tag{6}$$

After the tandem backlog periodis considered, two services toward F are each divided into two segments. For the NIC (which is NetFPGA platform used in this case), the scheduler is considered in the First Input First Output (FIFO) service discipline. Hence, the backlog β^{b2} has latency $\frac{L^{max}}{C}$ with rate C, where L^{max} is the maximum packet length. Trivially, therefore,

$$\beta^{b2}(t) = r(2) * \{t - (L^{max}/C)\}^{+} \tag{7}$$

where $r(2)$ is the service rate of β^{b2}.

C. Virtual Network Model

Based on the definition in Eq. (3), some parameters can be defined to make a similar calculation of the $F(t)$.

Lemma 1. Since the given R service rate contributes to the shape of the bound on the backlog, the β^{b1} service rate $r(1)$ must always exceed $r(2)$.

Accordingly, the service rate has a similar throughput of $D(t)$ since the buffer capacity must be consistent with the flows from the virtual server. The second important parameter that must be derived is delay on departure, $D(t)$, given by Eq. (3). It is expressed as

$$D \le h\frac{\alpha}{r} + (b_1 * b_2 * T_{acc}) \tag{8}$$

Here, α is the leaky bucket process before the server service according to the total latency by the FIFO scheduler. T_{acc} is the accumulation period of the VM operation and h is the maximum system delay, which is a scalar value.

Lemma 2. The minimum lower bound is determined by the β^{b2} H property. Accordingly, $\alpha \epsilon \beta^{b2} = 0$.

The H is commonly used as β concatenation. This condition is satisfied in the implementation to bypass the packet identification process at the physical adapter. To satisfy these assumptions, an extraordinary network adapter is required to support the adjustment of $D(t)$ toward the shape of β.

III. PERFORMANCE ANALYSES

A Virtual Network emulation environment is conducted using the NetFPGA platforms to verify the results of the performance analysis. The NetFPGA platform, which is an open platform, was developed to construct high-speed, hardware-accelerated networking systems. The high-definition TV application is tested in the emulator. The physical server uses Windows-based platforms while the virtual machines use a VMware server.

Figure 2 clearly reveals that, with β^{b1} traffic, the D(t) of NetFPGA platform yields a higher throughput and a lower delay than an ordinary NIC because NIC does not allow backlog adjustment. The throughput of F(t) tends to be higher (approximately 16Mbps) than in NIC because the buffering mechanism prevents loss in the logical layer. Linearization of the packet numbers F(t) and D(t) reveals that the D(t) achieved using the NetFPGA platform is more similar to F(t) than it is to D(t) of NIC. Additionally, F(t) causes only a slight delay on the NetFPGA platform . These results show that the NetFPGA platform canadapt to the bursty traffic from the virtual layer. Figure 3 shows a maximum throughput of approximately1.2Mbps, and 5s of bursty traffic produces a preliminary flow throughput of up to 1.8Mbps.

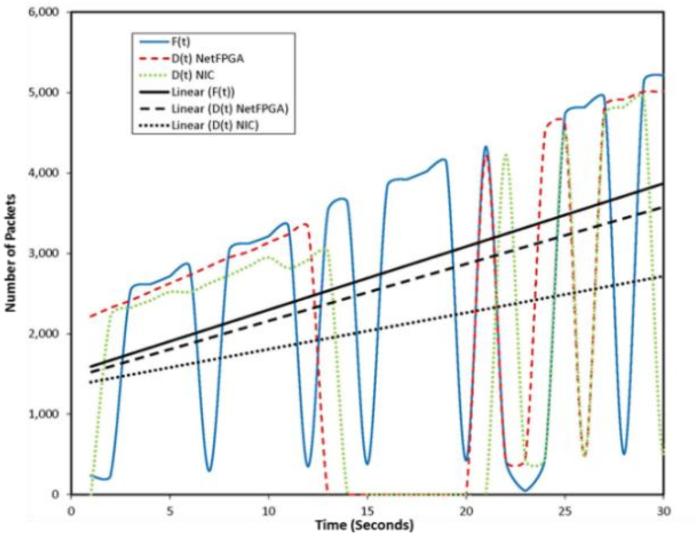

Figure 2: Performance Analysis

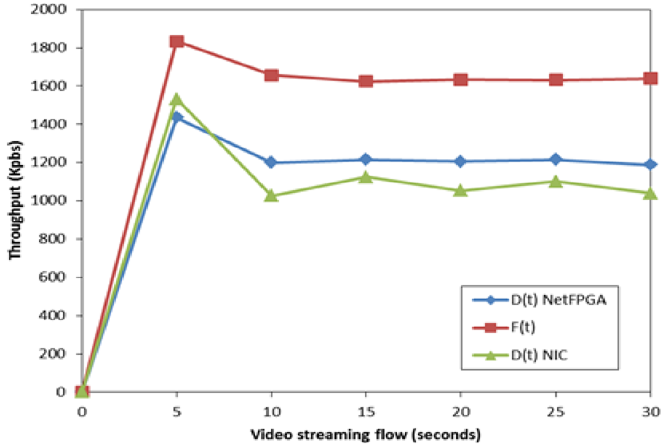

Figure 3: System Throughput

IV. CONCLUSIONS

This investigation characterizes the services that can be provided by a virtual network when a delay-sensitive application is performed using virtual machines. Analysis by deterministic network calculus yields the specific virtual switch bridging parameters that are required to optimize performance. The analysis reveals that adjusting the backlog within a particular period can reduce the effects of the delay, improving the QoS. Emulation using a promiscuous NetFPGA platform verified the results of the analysis. Based on these results, hardware designers can develop a network adapter that is aware of the layer characteristics of the virtual network in which it is used.

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