A Comparative Study of Network Bandwidth Allocation protocols for DataCenter Networks in cloud.

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Abstract— ***Like CPU and memory, network is a critical and shared resource in the cloud environment. With wide application of virtualization technology, tenant's access isolated cloud services by renting the shared resources in the cloud. However, unlike other resources, network is neither shared proportionally to payment nor do cloud providers offer minimum guarantees on network bandwidth. Networks are more difficult to share because network allocation of a Virtual Machine(VM) not only depends VMs running on the same machine but also on the other VMs that communicate with & the cross traffic on each link used by machine. Hence the shared nature of the network in the cloud implies that network performance for tenants can vary significantly. Motivated by these factors, in this paper we discuss about different bandwidth allocation protocol and its performance based on key properties like scalability, flexibility, bandwidth guarantee, job completion time and network utilization. A Comparative study on these protocols is done based on the key properties and the outcome of the study reveals the best bandwidth allocation protocol.***

Keywords— Bandwidth Guarantee, Datacenter, Network Performance metrics, Bandwidth Allocation, Virtual Machine

I. INTRODUCTION

. Cloud Computing is a platform for deploying and running many of today's businesses, in which large-scale data centers are multiplexing computing, storage and network resources across multiple tenants. Each tenant consists of a collection of one or more Virtual Machine placed on one or more physical machines. Data centers are crucial to provide large volumes of compute and storage resources needed by the customers. In data centers, the scarce network bandwidth is shared across multiple tenants without any performance guarantees. Hence effective management of network bandwidth will be crucial to handle the network intensive applications. The desirable solution for sharing the cloud networks should provide to meet the practical needs of both cloud users and cloud datacenters providers.

Towards providing the predictable network performance, various bandwidth allocation protocols are measured against the key properties, that these bandwidth allocation protocols should satisfy to provide a desirable solution for sharing the cloud networks in effective way.

II. NETWORK PERFORMANCE METRICS

The key properties are:

A. Bandwidth Guarantee: The first property that the bandwidth allocation protocol should meet is to provide tenants guarantee on the minimum network bandwidth they can expect for each VM they buy. Such guarantees are common for resources like CPU and memory, and having the same for the network is key to achieving lower bounds for the worst-case performance of an application. With bandwidth guarantees for VMs, one can achieve predicable performance (means less delay for application users) for network sensitive applications running in these VMs. For Example, a web service can provide fast data delivery to users if the data transfer between the server's is guaranteed.

B. Scalability: A cloud datacenter supports thousands of physical servers hosting 10s of thousands of tenants and 10s of thousands of VMs. The VMs and tenants in the datacenter are tossed dynamically with a high rate. Each datacenter network link is potentially shared by large number of set of VMs. A solution for network performance must work with large scales and able to manage large amount of state change at high speed.

***C. Flexibility*:** Customers need deterministic guarantees ensuring expected performance independent of VM placement and migration, traffic and blend of other tenants. Due to the limited network resource in datacenters, it may not be possible to guarantee the whole of the bandwidth demand for each VM. However, deterministic guarantees can lead to overly conservative network resource allocation with severe underutilization of the physical resources. A practical approach is to guarantee a certain bandwidth considering both the tenant's budget as well as the bandwidth demand of applications. To achieve greater resource efficiency, the cloud provider should have the flexibility to offer service levels allowing tenants to exceed their minimum guarantees. That is unused bandwidth should be able share with the active sources.

D. Network Utilization: Referred to as high utilization, aims to maximize network utilization without leaving network resources underutilized when there is unsatisfied demands. For example, we would like an application to use the entire bandwidth when no other application is active. This can significantly improve the performance for applications with bursty traffic patterns. High utilization is important for throughput sensitive applications.

III. Bandwidth Allocation Techniques

A. *Netshare:* Netshare proposes a hierarchical max-min bandwidth allocation. It divides a network into slices, such that each network slice has the delusion of network all to itself with guaranteed bandwidth. Bandwidth unused by a network slice can also be shared proportionately among active network slices. Netshare uses weighted fair queuing of links to fair sharing of networks.

Netshare slices network bandwidth in 2 steps:

Step1: Ignores customer slices, and only considers the network as being shared between incoming and outgoing router. Step1 reduces the network to set of virtual links between every pair of ingress and egress points.

Step2: Divides the bandwidth of each virtual link between customer's slices.

Step1&2 combine to slice network bandwidth between customers. Customers have guaranteed minimum bandwidth as well as a probable advantage from bandwidth unused by others

Netshare algorithm [1] is being implemented by extending the existing link state routing protocol. It provides a higher-level abstraction that can provide both minimum guarantees and statistical multiplexing. Netshare can also handle adversarial sources and requires no state in the core. Netshare protocol runs well even on large networks and used to provide bandwidth and throughput guarantee. NetShare advocates network sharing through the use of per-tenant users that are constant throughout the network. The main drawback of NetShare allocation scheme is it provides resilience in the face of uncooperative sources and statistical multiplexing. This model can be used to implement a form of link proportionality.

B. *Oktopus*: Implements the virtual network abstractions that allow tenants to expose their network requirements. Oktopus [2] maps tenant virtual networks to the physical network in an online fashion, and enforces these mappings. The provider maintains a datacenter containing physical machines with slots where tenant VMs can be placed. With Oktopus, tenants requesting VMs can opt for a virtual cluster to connect their VMs. It also supports tenants who do not want a virtual network, and are satisfied with the status quo where they simply get some share of network resources. A logically centralized network manager upon receiving a tenant request performs admission control and maps the request to physical machines. NM also accounts for network resources and maintain bandwidth reservations across the physical network. Oktopus scales to large datacenter.

C. *SecondNet*: SecondNet virtualizes datacenter network for resource allocation for multiple tenants in the cloud. The resources allocated to VDC's can be rapidly adjusted to the needs of the tenants. SecondNet introduces a centralized VDC allocation algorithm [3] that provides deterministic bandwidth guarantees for traffic between each VM pair. SecondNet proposes static reservations throughout the network to implement bandwidth guarantees. The advantage of this reservation system is that they can achieve more complex virtual topologies regardless of physical location of the VMs. SecondNet achieves scalability by distributing all the virtual-to physical mapping, routing, and bandwidth reservation state in server hypervisors. The main drawback of the reservation system is that they do not achieve high utilization of datacenter networks, since the unused bandwidth is not shared between the tenants. From the tenant perspective the above protocol is not ideal one because, tenants do not understand their applications communication patterns to specify their bandwidth requirements between each pair of VMs. As well the communication pattern is dynamic and the amount of data exchanged between any pair of VM will vary significantly over time.

***D.* SEAWALL:** describes a mechanism that allocates bandwidth on every link of a datacenter network by dividing network capacity based on an administrator specified policy. Seawall's goal is to partition the bandwidth in each congested network link according to weights associated with each VMs sending traffic through that link. Seawall [4] computes and enforces allocations by tunneling through congestion controlled, point to multipoint, edge to edge tunnels. The resultant of allocations remains constant regardless of number of flows, protocols or destinations in application traffic mix. Seawall scales to large numbers of tenants by reducing the network sharing problem to an instance of distributed congestion control. Efficiency is achieved in seawall by proportionally reallocating unused shares to active sources. The design space that the seawall occupies appears well-suited to emerging hardware trends in data center and virtualization hardware.

E. GATEKEEPER: A system designed to meet the practical needs of both cloud users and cloud data center providers. Gatekeeper system provides network isolation for multi-tenant datacenters using distributed mechanisms implemented at the virtualization layer and each datacenter server. Gatekeeper [5] controls the usage of each server's network access link. It provides per-vNIC(virtual Network interface) link bandwidth guarantees in both directions of the network link at each physical server, i.e. for both I/O traffic. Minimum bandwidth guarantees are achieved using an admission control mechanism that limits the sum of guarantees to the available physical link bandwidth. Each vNIC can surpass its guaranteed allocation when extra bandwidth is available at both transmitting and receiving endpoints. To provide deterministic behavior Gatekeeper limits each vNIC bandwidth to a maximum rate thereby assuring the minimum guarantee. Gatekeeper achieves scalability using a simple point-to-point protocol and minimal datacenter-wide control state. Gatekeeper can take advantage of unused bandwidth both at the transmit and receive side up to maximum rate specified by the system administrator of each vNIC.

F. FALLOC: Towards providing predictable performance for the tenants under multiplexed infrastructure, we need to take fairness into deliberation due to the limited bandwidth resources in datacenters. The vital role of fairness is to protect each application's performance in the competition of various network aggressive applications. The fair policy adopted should be able to allocate bandwidth according to the network requirement of applications. Recent cloud applications have 2 primary requirements for datacenter networks, which can be used to form the basis of designing an allocation policy" minimum bandwidth guarantee and proportional bandwidth share. We use a Falloc[6](Fair Network Bandwidth Allocation) which is application layer bandwidth allocation protocol towards VM-based fairness across the datacenter with 2 main objectives: i) guarantee bandwidth for VMs based on their base bandwidth requirements ii) share residual bandwidth in proportion to weights of VMs. By taking the advantage of a game-theoretical approach[13], falloc first model the bandwidth allocation process in datacenters as asymmetric weighted Nash bargaining game[10], where all VMs are cooperative so as to maximize the social welfare in manner without harming others benefit. In falloc, each VM is assigned with base bandwidth and a weight. The protocol can guarantee the bandwidth of a VM when its bandwidth requirements are less than the base bandwidth and share the residual bandwidth among VMs in proportion to their weights. In the bargaining game approach, the estimation of the bandwidth allocation to each VM-pair can be executed in a distributed manner and the result achieves a weighted Nash bargaining solution.

IV. Results of Comparison

The Table 1 summarizes the comparison of few bandwidth allocation protocol for datacenter networks in cloud against the key properties which measures the network performance.

Netshare is the only mechanism that allocates the relative among tenants based on their weights instead of of sender VMs and provides constant proportionality throughout the network. It relies on a centralized bandwidth allocator which is difficult to scale to large datacenters and to deal with workload changes and the high rate of tenant and VM churn of cloud datacenters.

TABLE I

Comparison of bandwidth allocation protocol against key properties

Protocol	**Key Properties**			
	Bandwidth Guarantee	**Scala bility**	**Flexibility**	**Network Utilization**
NetShare	Based on the weights of source VMs	×	√	high
Oktopus	Deterministic	√	×	low
SecondNet	Deterministic	√	×	low
Seawall	Based on the weights of source VMs	√	√	high
Gatekeeper	Minimum	√	√	high
Falloc	Based on the base bandwidth	√	√	high

Oktopus and SecondNet focuses on providing static reservations throughout the network to implement bandwidth guarantees for the VMs. They allocate VMs into servers based on VMs bandwidth requirements, and by enforcing reservations in both hosting servers and switches, they can ensure the bandwidth of inter-VM network and achieve predictable network performance for the applications in these VMs. The main drawback of reservation policies is that they may not be able to achieve high utilization of datacenter networks, since the unused bandwidth is not shared between tenants. The advantage of the reservation policy is that they can achieve more complex virtual topologies irrespective of the physical locations of the VMs.

Seawall provides a hypervisor-based mechanism to partition the bandwidth in each congested network link according to weights associated with each VMs sending traffic through that link according to weights associated with each VMs sending traffic through that link. The advantage of this protocol, (i) since rates are enforced at the virtualization layer in the edge of the network, and tenant and rate state is distributed over the servers, design is scalable. (ii) The use of explicit feedback from receivers allows the traffic to be choked at the sources before they use network resources, and prevents a malicious VM to take over bandwidth in the network. The main drawback is that it does not satisfy the predictable service level requirement. While Seawall can provide minimum guarantees if the maximum weight associated with each link is limited to a maximum value, it cannot enforce maximum rates to support deterministic behavior. Also Seawall's bandwidth allocation does not divide the link bandwidth among tenants using the link, but among the total number of VMs sending traffic through that link.

Gatekeeper uses hypervisor-based mechanisms, which provides minimum bandwidth guarantee for VMs by shaping the traffic of VMs, but the unused bandwidth is shared based on the best-effort manner. Gatekeeper works well in simple scenarios. Still the research work is going on for the behavior of the Gatekeeper for large configuration and dynamic workloads.

Falloc, bandwidth allocation protocol, fairly share network resources at VM-level in datacenters. It guarantees the bandwidth requirement based on the base bandwidth for each VM, and shares the outstanding available bandwidth in a proportional way according to VM's weight. Falloc provides flexible fairness for VM's by balancing the tradeoff between bandwidth guarantee and proportional bandwidth share. Falloc achieves high network utilization and good job completion time in datacenter network and adapt to dynamic traffic.

V. CONCLUSION

In summary, we discussed various bandwidth allocation protocol and key properties for the network performance. Each of these protocols finds use in different applications. The outcome of the comparative study of these protocols against the key properties reveals that Falloc is the best protocol among the protocols we have considered. Falloc provides bandwidth guarantee and share the residual bandwidth in proportion and achieves high utilization and maintains fairness among VMs in datacenters. Falloc shows no advantage on providing fairness for different jobs with different bandwidth. As a part of future work we will try to do the comparative study of aggressive network application such as video delivery.

REFERENCES

[1] T. Lam and G. Varghese, *"Netshare: Virtualizing bandwidth within the cloud,"* UCSD, Tech. Rep., 2009.

[2] H. Ballani, P. Costa, T. Karagiannis, and A. Rowstron, *"Towards predictable datacenter networks,"* in ACM SIGCOMM, 2011.

[3] C. Guo, G. Lu, H. Wang, S. Yang, C. Kong, P. Sun, W. Wu, and Y. Zhang, *"Secondnet: A data center network virtualization architecture with bandwidth guarantees,"* in ACM CoNEXT, 2010.

[4]A. Shieh, S. Kandula, A. Greenberg, C. Kim, and B. Saha, *"Sharing the data center network,"* in USENIX NSDI, 2011.

[5]H. Rodrigues, J. Santos, Y. Turner, P. Soares, and D. Guedes, *"Gatekeeper: Supporting bandwidth guarantees for multi-tenant datacenter networks,"* in USENIX Workshop on I/O Virtualization, 2011.

[6] Jian Guo, F Liu, H Tang, Y Lian, Hai Jin and John C.S. Lui, *"Falloc:Fair Network Bandwidth Allocation in IaaS Datacenters Via a Bargaining Game Approach"* in IEEE, 2013

[7] J. Zhu, D. Li, J. Wu, H. Liu, Y. Zhang, and J. Zhang, *"Towards bandwidth guarantee in multi-tenancy cloud computing networks,"* in IEEE ICNP, 2012.

[8] L. Popa, G. Kumar, M. Chowdhury, A. Krishnamurthy, S. Ratnasamy, and I. Stoica, *"Faircloud: Sharing the network in cloud computing,"* in ACM SIGCOMM, 2012.

[9] J. Guo, F. Liu, D. Zeng, J. C. Lui, and H. Jin, *"A cooperative game based allocation for sharing data center networks,"* in IEEE INFOCOM2013.

[10] J. Guo, F. Liu, H. Tang, Y. Lian, H. Jin, and L. John C.S., *"Falloc: Fair network bandwidth allocation in iaas datacenters via a bargaining game approach,"* Technical report, HUST, http://grid.hust.edu.cn/fmliu/ icnp2013falloc.pdf, August 2013.

[11] H. Boche, M. Schubert, N. Vucic, and S. Naik, *"Non-symmetric nash bargaining solution for resource allocation in wireless networks and connection to interference calculus,"* in Proc. 15th European Signal Processing Conference, 2007.

[12] H. Ya ¨ iche, R. Mazumdar, and C. Rosenberg, *"A game theoretic frame-work for bandwidth allocation and pricing in broadband networks,"* IEEE/ACM Transactions on Networking (TON), vol. 8, no. 5, 2000.

[13] Z. Fang and B. Bensaou, *"Fair bandwidth sharing algorithms based on game theory frameworks for wireless ad-hoc networks,"* in IEEE INFOCOM, 2004.