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Rational Network Bandwidth Distribution in IaaS

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Abstract:
The shared resources in Infrastructure-as-a-Service (IaaS) datacenters. Unlike resources such as CPU and memory, datacenter network, which relies on traditional transport-layer protocols, suffers unfairness due to a lack of virtual machine (VM)-level bandwidth guarantees. In this paper, we model the datacenter bandwidth allocation as a cooperative game, toward VM-based fairness across the data enter with two main objectives: guarantee bandwidth for VMs based on their base bandwidth requirements, and share residual bandwidth in proportion to the weights of VMs. Through a bargaining game approach, we propose a bandwidth allocation algorithm, Falloc, to achieve the asymmetric Nash bargaining solution (NBS) in datacenter networks, which exactly meets our objectives. The cooperative structure of the algorithm is exploited to develop an online algorithm for practical real-world implementation. We validate Falloc with experiments under diverse scenarios and show that by adapting to different network requirements of VMs, Falloc can achieve fairness among VMs and balance the tradeoff between bandwidth guarantee and proportional bandwidth sharing.

I.INTRODUCTION

INFRASRUCTURE-AS-A SERVICE (IaaS) cloud services, such as Amazon EC2[1], have become an attractive choice for today's business, in which large-scale datacenters are multiplexing computing, storage, and network resources across multiple tenants. With a simple pay-as-you-go charging model, tenants are able to rent their respective sets of virtual machines (VMs) with performance isolation on CPU and memory resources [2]. However, in current datacenters, the scarce network bandwidth is shared across many tenants without any performance guarantees [2], [3]. The bandwidth between VMs can fluctuate significantly due to the competition of network intensive applications, and their performance may become unpredictable. The uncertainty in the execution times of jobs increases the risk of revenue loss for tenants, which is against the provider's incentive to attract more tenants. As the rapid development in IaaS cloud, it is critical to reason about how to properly share networks in IaaS datacenters. Toward providing predictable performance for the tenants under multiplexed infrastructure, we need to take fairness into consideration due to the limited bandwidth resources in data- centers. The essential of fairness is to guarantee each application's performance in the competition of various network aggressive applications. Current cloud applications have two primary requirements for fairness [4], which can be used to form the basis of designing an allocation policy: minimum bandwidth guarantee and proportional bandwidth share. Minimum bandwidth guarantee can provide strong isolation among VMs or tenants since it ensures a lower bound of band- width allocation independent of the communication patterns of other VMs. With the ability of guaranteeing bandwidth for each VM, providers agreements (SLAs) on network performance with the tenants, which may be attractive to tenants deploying network intensive applications in the cloud. Proportional share, on the other hand, is to share band- width in proportion to certain associated weights among VMs, where each VM can obtain apportion of the physical bandwidth regardless of the competition at the flow level. By slicing the network bandwidth, proportional share makes efficient use of the network resource and maintains weighted fairness among the VMs, which can be useful to differentiate the service level for applications with different priorities. For cloud providers, we need to achieve high network utilization throughout the datacenter. The network resources should be fully allocated among VMs if there exist unsatisfied demands. If a VM is able to utilize the residual bandwidth left by other idle VMs, the increase in throughput will shorten the completion times of jobs that are bottlenecked by network resources. In this way, more applications or VMs can be deployed on the same infrastructure, which will further increase the providers' revenues. In existing networks, such as Internet, the TCP-friendly sharing naturally provides applications with max- min fairness, which meets the requirements for flow-level fairness and work-conserving sharing. However, in IaaS datacenters that require fairness among VMs, the tenants may suffer unpredictable performance, as the bandwidth is shared in proportion to the number of TCP flows in VMs without guarantee. Due to the lack of VM-level rate-control protocols, the bandwidth allocation in IaaS datacenters raises great challenges in simultaneously guaranteeing VM network performance and achieving high network utilization under unpredictable traffic demand. For example, existing reservation policy (e.g., [5]) leads to bandwidth wastage if the reserved bandwidth is not fully utilized.Moreover, there is a tradeoff between guaranteeing bandwidth and sharing bandwidth proportionally [4]. For instance, proportional sharing (e.g., [6]) ensures a certain portion of the shared bandwidth for each VM. However, the VM can hardly get a minimum bandwidth, because the shared portion reduces as more VMs are competing for the same physical link. Consequently, the bandwidth allocation should offer mechanisms to balance such a tradeoff while achieving the fairness requirements. While existing works focus on providing bandwidth isolation technologies for VMs, they fail to take a theoretical in sight into such a fair resource sharing problem. In this paper, we view the bandwidth allocation as a basic resource sharing problem involving consideration of fairness and utilization. By taking advantage of a game-theoretical approach, this paper takes the first step to model the bandwidth allocation process in datacenters as a Nash bargaining game, where all VMs are cooperative so as to maximize the social welfare, i.e., the network utilization, with fairness among VMs being guaranteed. In summary, we make the following contributions in this work. We apply rigorous game-theoretic techniques to model and solve datacenter network resource sharing problem by considering both efficiency and fairness. For the key network requirements of applications in the cloud, bandwidth guarantee and proportional bandwidth sharing, we consider them in a cooperative game-theoretic framework by defining the base bandwidth and the weight for each VM, and show how to achieve the Nash bargaining solution for bandwidth sharing. Based on a bargaining game approach, we present the de- sign of Falloc, an application-layer bandwidth allocation algorithm to achieve fairness among VMs in datacenters, which corresponds to the weighted Nash bargaining solution. Our offline algorithm of Falloc can guarantee the bandwidth of a VM when its bandwidth requirement is less than the base bandwidth and share the residual bandwidth among VMs in proportion to their weights. To realize Falloc in datacenter networks, we develop a distributed online algorithm using the cooperative structure of the offline algorithm. The online algorithm can theoretically achieve the same solution as the offline algorithm, and we experimentally show that the online algorithm can control the relative error ofratewithin6% as compared to the offline algorithm.We implement the Falloc prototype and evaluate it on a test be under diverse scenarios. By characterizing the impact of both the base bandwidth and the weight on band- width allocation, we validate Falloc's ability to enforce bandwidth guarantee and proportional network sharing, and show that Falloc can balance the tradeoff by adjusting the base bandwidth of VMs. We carryout trace-driven simulations using Map reduce work loads and show that Falloc can adapt to dynamic traffic. It can achieve a utilization approximate to the best effort manner while providing performance guarantees for VMs by enforcing a fair bandwidth allocation. The rest of this paper is organized as follows. In Section II, we present the motivation and the objectives of our work. In Section III, we formulate the datacenter network model and the optimization for fair bandwidth allocation. Section IV presents the solution to the optimization problem via a bargaining game approach. Based on an offline algorithm for the optimal solution, we complement our preliminary work [7] and develop a practical online algorithm in Section V. We evaluate our proposed algorithms in Section VI with comprehensive experiments and simulations. Related work is presented in Section VII, and Section VIII concludes.

II. LITERATURE SERVEY

In this project we are using network concept for sharing data from source to destination and use the IaaS service in cloud computing for the sharing data to be secured. The guarantee bandwidth allocated to each node for identifying where the data to be lose. The Nash bargaining service (NBS) is a game approach used for achieving the goal of reaching data to destination without lose of data.

In paper [1] On efficient bandwidth allocation for traffic variability in datacenters, The effects of large numbers of short flows and massive burst traffic in the datacenter. Design a novel distributed rate allocation algorithm.

In paper [2] A Cooperative Game based allocation for sharing datacenter networks Guarantee bandwidth for those VM's lower network rate than their base bandwidth , while maintaining fairness among other VMs with higher network than their base bandwidth.

In paper [3] Managing Performance Overhead of VM in cloud computing IaaS cloud computing offers customers(tenants) a scalable and economical way to provision VM's. IaaS cloud ranging from the single server virtualization, a single mega datacenter, to multiple datacenters.

In paper [4] Sharing the network in cloud computing The network is a critical and shared resource in the cloud. However, unlike other resource it is neither shared proportionally to payment, nor do cloud provides offer min guarantees on network bandwidth.

III. BLOCK DIAGRAM

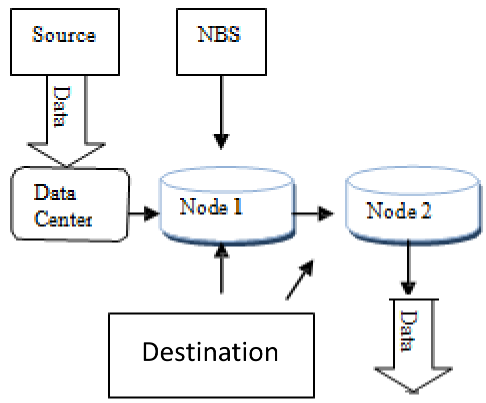


Figure 1: Block Diagram

BANDWIDTH ALLOCATION

In our model, we choose to allocate bandwidth for each VM-pair, which provides more fine-grained guarantees compared to the solution of allocating bandwidth to the aggregated traffic of each VM. For example, a reduce task of a Map Reduce job on VM needs to shuffle data from multiple map tasks on different VMs. If we only guarantee the aggregated traffic of, and the bandwidth between and each VM with map tasks is not guaranteed, then the job may be delayed by one or more slow tasks on network congested VMs. Hence, the pair wise bandwidth allocation can guarantee the performance of applications when a VM communicates with multiple VM's Fairness.

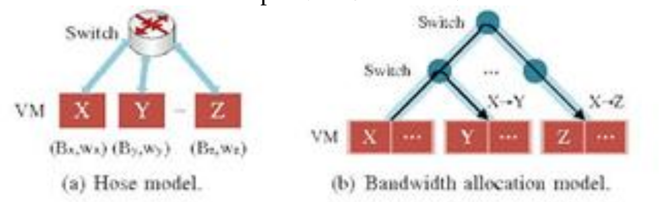


Fig. 1. System model: use hose model for bandwidth requirements of VMs, and allocate bandwidth for VM-pairs on each link based on the requirements

bandwidth and weight of existing VM-pairs should be changed accordingly. The updating process is shown in Algorithm 1. The function is triggered by the change of connections to a VM: When it connects to or disconnects from another VM , it obtains the weight and base bandwidth of VM , and then updates the weight and base bandwidth of all its VM-pairs. To reduce the overhead of recalculation, each VM-pair can be managed by its source VM. The outputs of Algorithm 1, i.e., the base bandwidth and weight, are used as input for calculating the optimal rate allocation for VM-pairs.

A. Offline Cooperative Algorithm

Based on the game-theoretical framework, we present the bandwidth allocation algorithm for datacenter networks in this section. We focus on two interesting results in the bargaining game approach: 1) the dual variables (and) of each server can be updated independently with local information in (19); 2) the iteration of each rate in (11)only requires the bandwidth information of the server hosting VM and the server hosting VM. This motivates the design of Falloc, which can obtain the optimal distributed cooperative manner. Update Weight and Base Bandwidth: We first Đonsider how to update the ďase ďandwidth and weight of each VM-pair. As (1) and (2) show, when a VM establishes a connection or disconnects with another VM, the number of its connected VMs changes. Thus, the base

Algorithm1: Bandwidth Allocation on Server

Input: The step-size: £

Server bandwidth capacity:C_m, □m € M

Bandwidth demand matrix: $[D_{i,j}]_{N\times N}$,□ i € N

VM placement:$[\omega_{m,i}]_{M\times N}$,□ m€ M ,□ i€ N

The total number of iteration rounds: **S**

The gap between two consecutive iterations: Δ

Output

1: while s<S or $r^{(s)}_{ij}-r^{(s-i)}_{I,j}>\Delta$ do

2: Update allocated bandwidth $r^B_p - \sum_i \omega_{m,i} r^B_i r^I_{pm} - \sum_i \omega_{m,i} r^I_i$

3: Update dual variables as (16) $\lambda^B_m = \max(0, \lambda^B_m - \varepsilon(C_m - r^B_{pm}))$ $\lambda^I_m = \max(0, \lambda^I_m - \varepsilon(C_m - r^I_{pm}))$

4: for all $r_{i,j}$, i € V_m do

5: Update $\lambda^B = \lambda^B_m$

6:Obtain $\lambda^I = \lambda^I$ from server i,j €$V_{i,j}$

7: if $K_{i,j}/\lambda^R+\lambda^I > U_{i,j}-L_{i,j}$ then

8: $r^{(s)}_{i,j} - U_{i,j}$

9: else

10: $r^{(s)}_{i,j} - L_{i,j} + K_{i,j}/\lambda^R + \lambda^I$

11: end if

12: end for

13: Update step size ε

14: Update iteration round s=s+1

15: end while

server and . Since the step-size and residual bandwidth are both maximal initially and decrease as the algorithm performs, the dual variables will quickly converge to approximate optimal values and then slowly approach the optimal values. Hence, the algorithm can finish within a Case the rate exceeds the upper-bound bandwidth. The step size is chosen according to the step-size rules in Proposition 1 and updated locally within each iteration. Stopping Rules: Note that the convergence speed of depends on the step-size and the gradient of the dual variables, which are exactly the residual bandwidth of

Infrastructure –As -A- Service (Iaas) Datacenter

Infrastructure as a Service datacenters. Unlike resources such as CPU and memory, datacenter network, which relies on traditional transport-layer protocols, suffers unfairness due to a lack of virtual machine level bandwidth guarantees. In this paper, we model the datacenter bandwidth allocation as a cooperative game, toward VM B.Online Algorithm and Message Exchange In the offline algorithm, the bandwidth demand of each VM is assumed given. However, existing works(e.g.,[12]and[22]) have shown that datacenter traffic is highly dynamic, making it acceptable number of steps if we do not need strict optimal rates for all VM-pairs. We can define two stopping rules in Falloc to balance the tradeoff between algorithm overhead and precision. • Step-based mechanism: Use as the total iteration steps in the convergence process. As the execution time of the algorithm is in proportion to the iteration rounds, one can manage the cost of the algorithm by adjusting the iteration rounds. For example, if the cloud provider cares much about the algorithm's overhead, he can choose a small (e.g.,) in this mechanism to reduce the execution time. • Precision-based mechanism: Stop the convergence process if the variation of each is less than within two consecutive iterations. For example, if the cloud provider has based fairness across the datacenter with two main objectives: 1) guarantee bandwidth for VMs based on their base bandwidth requirements, and 2) share residual bandwidth in proportion to the weights of VMs. Through a bargaining game approach, we propose a bandwidth allocation algorithm, Falloc to achieve the asymmetric Nash bargaining solution in datacenter networks, which exactly meets our objectives. a rd to accurately predict the bandwidth demand between VMs. As a consequence, the allocated bandwidth may not be fully utilized, and the residual bandwidth (and) and the design consists of two components: the bandwidth communication protocols (Fig.3) between servers. allocation algorithm on each server(Algorithm 3)and the

Algorithm 2: Online bandwidth allocation

Input:

The step-size:ε

Server bandwidth capacity: C_m,□ €M

Bandwidth demand matrix: $[D_{i,j}]_{N\times N}$,□i€N,

VM placement:$[\omega_{m,i}]_{M\times N}$,□m€M,□ i€N

Output:

1:Obtain the dual variable of server m:λ^r_m 2:Update the local dual variable as(16) $\lambda^B_m = \max[0, \lambda^B_m - \varepsilon(C_m - r^B_m))$

3:for all $r_{i,j}$,i ε V_m do

4: Obtain the actual rate $r_{i,j}$ 5: if $r_{i,j}<B_{i,j}$ then

6: $r_{i,j}=B_{i,j}$

7: else

8:Update $\lambda^{B}=\lambda^{B}_{m}$

9: Obtain $\lambda^{I}_{i}=\lambda^{I}_{i}$ from server I,j€V

10:ri,j=Bi,j+Ki,j/$\lambda^{B}+\lambda^{I}$

11: Enforce rate-limit $r_{i,j}$ of VM-pair i to j

12:end

13:end for

NASH BARGAINING SOLUTION

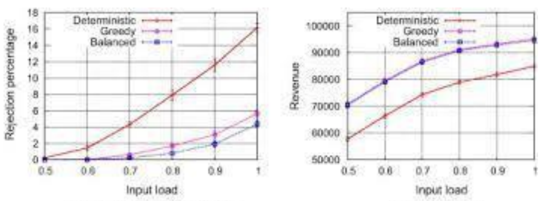
Based on a bargaining game approach, we present the design of Falloc, an application-layer bandwidth allocation algorithm to achieve fairness among VMs in datacenters, which corresponds to the weighted Nash bargaining solution. Our offline algorithm of Falloc can guarantee the bandwidth of a VM when its bandwidth requirement is less than the base bandwidth and share the residual bandwidth among VMs in proportion to their weights.

FAIRNETWORK

As applications are run by VMs in IaaS datacenters, providers can reserve certain bandwidth for different VMs, or allocate a certain portion of the bandwidth on congested links to VMs based on the bandwidth requirements of these applications. However, it is not easy to achieve fairness relying on traditional Transmission Control Protocol (TCP). The challenge comes from the fact that the TCP maintains flow-level fairness, and one cannot change this protocol if he wants to run any TCP-based applications in the cloud. Hence, to fairly share the intra-datacenter networks, we need to design a VM-level bandwidth sharing policy with the ability to fulfill the bandwidth requirements of VMs running different applications. The following important objectives should be taken into consideration.

• Bandwidth guarantee. With bandwidth guarantee for VMs, tenants can achieve predictable performance for network sensitive applications running in these VMs. For example, a Web service can provide fast and stable data delivery to users if the data transfer between the server's front and back ends is guaranteed. By deploying bandwidth guarantee for the VM instance, cloud providers area bleto provide quantitative network performance for cloud applications, thus to attract more tenants.

• Weight assignment. Since jobs in the cloud have different priorities, the policy should have the ability to assign differentiate weights to VMs running different applications. For example, an important job calculating stock prices and a less urgent data-backup job are sharing the same congested link, the cloud provider may want to allocate more bandwidth for the important job. With the weights of VMs, the policy should share the bandwidth in proportion to their respective weights.



(a) Rejection percentage (b) Revenue

VIII. CONCLUSION

To summarize, we have applied the game-theoretic framework to the bandwidth allocation problem in IaaS datacenters. Through a cooperative approach, we present the design of Falloc with a both offline and online algorithm that solves the optimization of Nash bargaining solution. Falloc guarantees the bandwidth requirement based on the base bandwidth for each VM and shares the residual available bandwidth in a proportional way according to VM's weight. The experiment with prototype implementation shows that Falloc can provide flexible fairness for VMs by balancing the tradeoff between bandwidth guarantee and proportional bandwidth share. Our trace-driven simulations show that Falloc can achieve high network utilization and good job completion time in datacenter networks.

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