Network Optimization in the Open Stack Cloud

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ABSTRACT
Cloud systems software requires a VM placement engine that decides where to place the virtual machine in the environment. The placement engine in the cloud platform such as OpenStack considers multiple constraints when launching a new instance, including required compute and memory resources. This placement mechanism does not consider network requirements of VM. In this paper, we propose the solution to optimize the network resources which is easily integrated in the OpenStack placement engine. Our solution keeps the track of the traffic flow within the physical network devices and the appropriate action is taken to optimize the network resources including migration of existing VM.

General Terms
VM- Virtual Machine
OpenStack- Open Stack cloud software
CPU- Central Processing Unit
RAM- Random Access Memory
CN- Cloud Network

Keywords
Cloud, Network optimization, Virtual Machine, Container, Placement, Migration

1. INTRODUCTION
The OpenStack[1] cloud computing platform has sophisticated mechanisms for managing the CPU, memory, and storage resources. However, Openstack lacks behind managing the network resources. The OpenStack uses the logic that launch instances such as Virtual Machines (VMs) to the physical server is called scheduler or placement engine. The default placement engine only considers CPU and memory resources. It does not consider network requirements. Other cloud computing platforms e.g. Eucalyptus have similar limitations regarding network awareness. A lack of network optimization in the cloud management platforms risks performance issues in the data plane and a violation of the Quality of Service (QoS) [2]. For example, there could be a congestion in shared resources on servers, which leads to increase the job queue and results into QoS violation. In the past there has been substantial progress regarding theoretical solutions and designs for addressing the network optimization. But none of them are practically implemented in the existing cloud platforms. In this paper we analyzes the network optimization problem and design a solution that can easily integrated in the existing cloud computing platform. Openstack. Section 2 explains the exiting work to address network optimization problem. In Section 3 captures the mathematical model. Section 4 introduces the Openstack architecture and reviews the functionalities of its existing default scheduler. In Section 5, we analyze the solutions for optimizing network resources during VM placement. Later, we propose the design of our prototype implementation network optimization in OpenStack. Section 6 Finally, concludes this paper.

2. RELATED WORK
This section briefly describes the efferent techniques already designed for cloud network optimization.

2.1 NETDEO
The NetDeo[3] is designed for improving the better utilization of the existing network resources and infrastructure. Without changing existing network architecture and routing protocol intact, it aims at reducing network bandwidth requirement by optimizing placement of VMs in the cloud. This mechanism has lower up-front cost and immediate effect.

2.1.1 Advantages
- Applicable in the dynamic environment where the servers are getting added and removed from the environment very frequently
- Continuous and incremental optimization of the cloud network

2.1.2 Disadvantages
- The traffic agent needs to be installed on the all servers that keep on sending the traffic information for given server. Its very difficult to install and maintain the traffic agent software if the number of server in the environment are very huge
- Does not perform well in Bcube [9] topology
- Performance degrades when number of hosts are increased

2.2 MAPLE
A MAPLE[4] is a network-aware Virtual Machine placement technique that uses estimate of the effective bandwidth required for compute hosts to ensure that the cloud network performs within targets specified in the SLA for the customer application. It allocates network resources to make perfect balance between efficiency of resource utilization and the performance requirement. The MAPLE is designed to provide a network-aware VM placement policy used to launch the set of VMS on different servers. The MAPLE does require the a prior reservation of bandwidth.

2.2.1 Advantages
- Good performance in case of deploying multiple VM at a time
Less QoS violation compared to NetDEO[3] and Oktupus[5]

2.2.2 Disadvantages
- Not applicable in dynamic environment where the server are upgraded very frequently
- Applicable only for tree topology.

2.3 Oktupus
This Oktupus[5] is designed for multi-tenant cloud provider that accepts the network bandwidth requirement from the tenant and try to reserve the required network bandwidth while deploying the tenant application in the cloud. The user specifies the network bandwidth requirement as Virtual Network. It provides the abstraction of the virtual network by which it determines the trade-off between the network bandwidth guarantees offered to customer and the cloud provider's profit.

2.3.1 Advantages
- Virtual Network profiles allows to mentions the QoS requirement
- Physical Network sharing ratio is increased in multi-tenant environment

2.3.2 Disadvantages
- Not applicable for dynamic environment where the infrastructure is frequently upgraded
- Does not perform VM migration

2.4 Traffic Aware Virtual Machine Placement Problem (TVMPP)
The TVMPP[6] is a network performance problem. The traffic matrix among the virtual machines and the cost matrix among the compute host machines is considered as the input for this algorithm. The output of this algorithm is the optimal solution that suggests which compute host the VMs should be placed in order to improve the cloud network. The aggregate traffic rates dictated by every network devices like switches and routers. The TVMPP is NP-hard problem and propose a heuristic approach to solve the TVMPP efficiently for large environment. The algorithm follows a novel two-step approach: it first makes partitions of VMs and compute hosts in the clusters. Then it finds matching VMs and compute hosts within the cluster and subsequently at individual level.

2.4.1 Advantages
- Good performance in varying and heterogeneous traffic condition
- Bcube topology is benefited more with TVMPP

2.4.2 Disadvantages
- Not applicable for dynamic environment where the infrastructure compute and network devices get upgraded continuously. The NetDeo[3] is designed for improving the better utilization of the existing network resources and infrastructure. Without changing existing network architecture and routing protocol intact, it aims at reducing network bandwidth requirement by optimizing placement of VMs in the cloud. This mechanism has lower up-front cost and immediate effect.

3. PROBLEM DEFINITION AND FORMULATION
The network optimization problem is defined as a set of service nodes \( \{n_1, n_2, ..., n_N\} \) on a collection of network server systems \( \{s_1, s_2, ..., s_M\} \), where \( N \) and \( M \) are respectively the total number of nodes and servers in the system.

The traffic load between two servers \( n_x \) and \( n_y \) is defined as the product of their traffic, path length, and inverse path reliability:

\[
TLoad(n_x, n_y) = D_{xy} \times L_{ij} \times R_{ij}^{-1}
\]

The traffic load of a service node is defined as the quadratic mean of the traffic loads between the service/node and all its communicating pairs:

\[
NodeLoad(n_x) = \frac{1}{N_x} \sum_{y=1}^{N_x} TLoad(n_x, n_y)^2
\]

where \( N_x \) is the number of service nodes communicating with node \( n_x \).

4. OPENSTACK ARCHITECTURE
4.1 Overview
A cloud computing platform manages pools of compute, storage, and networking resources to offer them on demand, e.g., as Infrastructure-as-a-Service[9] (IaaS). This paper focuses on the OpenStack [1], which is widely used cloud platform by cloud service providers. It is an open source cloud platform that comprises of a set of interconnected development projects. The main components are implemented in Python, and they are accessible through REST API. The web interface is also used to manage different components. The OpenStack architecture is extensible and flexible. Figure 1 shows a simplified overview on the OpenStack software architecture.

![Open Stack Architecture Overview](image-url)
A cloud computing environment can be built by a subset of these components, and systems can also be extended by other components that are not officially part of the OpenStack platform.

### 4.2 VM Placement

"Nova" is the component of OpenStack that manages the hypervisors on the physical server and controls the execution of VM. The "scheduler" controls the compute resources on the hypervisors of the available hosts. If a new VM instance is launched, the scheduling logic/placement engine selects the most suitable physical server to host the new instance. The default placement policy in OpenStack is the "filter" scheduler [8][11]. It uses a 2-step process of "filtering" and "weighting" to make decision on which server a new VM should be launched.

### 4.3 Existing drawbacks and Challenges

The existing filter scheduler determines a set of acceptable compute hosts by filtering and weighting. Each time it selects a host to launch a new instance, the scheduler consumes some resources so that subsequent evaluations can adjust accordingly. It suffers from few limitations as below:

- **No Network-aware filter [10]**: There is no filter to select the host based on the available network bandwidth on the host.
- **Static data structure**: The VM scheduler maintains the static own view of the resource allocation on each nodes, This view is not frequently updated dynamically.

### 5. Proposed Design

Figure 2 shows the proposed architecture of the systems that could add network awareness in the VM placement.

![Fig. 2: Proposed Design](image)

5.1 **sFlow collector**

The slow collector is the process running on the cloud server that keeps listening the UDP packets form the sFlow agent. The collector keeps records of the most recent traffic information and make analysis of the traffic identifying top N talkers. The list of top N talker is sent to VM placement engine to run a VM placement algorithm.

### 5.2 Algorithm

Algorithm 1 is the main algorithm used for network aware virtual machine placement in the cloud. It contains following steps.

- **Step 1**: It collects traffic information using `GetTrafficInfo()` function.
- **Step 2**: Find the list of target physical machine to accommodate new VM. The function `FindTargetPM()` is used.
- **Step 3**: Select the VM to be migrated using function `SelectVMNode()`.
- **Step 3.1**: If the move is not accepted, continue step 3.1.
- **Step 3.2**: Explores neighborhoods by exchanging different server on the candidate server to the original server.

### Algorithm 1: The Network-Aware VM Placement Algorithm

![Algorithm 1](image)

### 5.1 sFlow collector

The sFlow collector runs on the cloud server that keeps listening the UDP packets form the sFlow agent.

- **Step 1**: It collects traffic information.
- **Step 2**: Find the list of target physical machine to accommodate new VM.
- **Step 3**: Select the VM to be migrated.
- **Step 3.1**: If the move is not accepted, continue step 3.1.
- **Step 3.2**: Explores neighborhoods by exchanging different server on the candidate server to the original server.

### Algorithm 2: Collect traffic information using packet sampling

![Algorithm 2](image)
6. TEST ENVIRONMENT AND RESULTS

![Open Stack Cloud Test Environment](image)

**Fig. 3: Open Stack Cloud Test Environment**

Figure 3 shows the test environment for open stack cloud. It contains 1 controller and 2 compute servers, each one has 16 CPU and 64 Gb memory. Each compute host is capable of hosting 20 VMs. The server are connected to the 1 Gbps switch. The following graphs shows the bandwidth utilization with and without Network aware VM placement.

![Network Bandwidth Utilization](image)

**Fig. 4: Graph Network Bandwidth utilization – NetworkAware vs Without network Aware VM placement**

If the number of VMs less them 40, the Network-aware placement does not make any difference. If the no. of VMs are greater than 40 and less the 150, the network aware placement makes difference. The VM migration can be performed to save the bandwidth. If no. of VMs are more than 150. The environment becomes more congested; hence there is much less opportunity to migrate the VM.

7. CONCLUSIONS AND FUTURE WORK

Adding the network awareness in the VM placement significantly optimizes the cloud network. The proposed design is easily integrated in the OpenStack cloud platform. The proposed solution eliminates the drawback of existing solutions covered in section 2. At the writing of this paper, the full implementation and the result testing is not complete.

8. REFERENCES


