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Masterarbeit

Design and implementation of an SDN based authentication and separation mechanism for WiFi users

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Abstract

The ever-increasing use of data services on mobile devices, places increased demands on existing networks. Especially in busy areas, such as shopping centers, office buildings or in event centers, the existing network coverage by UMTS and LTE is no longer sufficient. It is, therefore, obvious to direct some traffic through other radio standards. In this case, WLAN is particularly suitable because those frequencies are free to use without any license restrictions and since most mobile devices have long since supported this. However, an uncontrolled number of WLAN access points can interfere with each other. It is, therefore, desirable to install only one set of access points at these locations and manage them centrally. The research project BIC-IRAP (Business Indoor Coverage Integrated Radio Access Points) is a project aimed at providing a seamless coupling between LTE and WLAN.

The separation of data traffic is an important aspect when using shared hardware. No direct data exchange between the networks of different mobile radio providers should be possible. Likewise, the networks of different businesses or companies should be kept strictly separate from each other. Classic VLANs would be used for this purpose. Within the scope of the BIC-IRAP project, however, there were considerations to control parts of the network using SDN. Therefore, the goal of this master thesis is to operate an access point (AP) on an Open Flow-controlled switch. Users can be authenticated against a RADIUS server. The AP should supply at least two separate networks. If possible, the separation of data traffic should already take place in the AP. Optionally the AP should provide Hotspot 2.0 functionality.

The conceptualization and implementation must be documented in detail. The optional components are carried out in consultation with the supervisor. The successful completion of the work is a test set-up. The achievable performance characteristics must be recorded.

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1 Introduction

The penetration of mobile internet users has increased many fold from a few thousands to millions over a short span of time. Due to the increasing demand for data among subscribers, mobile operators are pushed to go beyond boundaries to provide efficient and reliable data service to their customers. Although, the existing network services such as UMTS and LTE can handle larger data capacity, their coverage is not always sufficient in crowded places such as office buildings, convention centers, shopping malls etc. There is an urgent need to find a solution on how to offload the mobile data traffic over to other radio standards.

In such case, WLAN is an existing radio standard that has already been deployed in large numbers and has been supported by millions of devices lately. One unique advantage of using WLAN over other radio standards would be its license free usage of its radio frequency for commercial purposes. This WLAN standard, when deployed in a controlled manner can support data traffic routed from the mobile services. The IEEE 802.11 WLAN has already been widely used for commercial enterprises ranging from office networks, shopping malls to educational institutions etc. The deployment rages from a few dozens to hundreds of access points (APs), which serve many users through multitude of devices ranging from mobile devices, laptops to printers and other connected hardware. These networks also provide varied set of services that includes authentication, authorization and accounting (AAA), dynamic channel reconfiguration, interference management, security such as intrusion detection and prevention and providing quality of service.

These enterprise WLAN AP's are usually centrally managed through a controller. The task now is to find a solution to seamlessly direct traffic between LTE and WLAN. The research project BIC-IRAP (Business Indoor Coverage Integrated Radio Access Point) is currently aimed at providing a solution for the seamless coupling between LTE and WLAN.

The growing adoption of Software Defined Networking in the recent years has given rise to providing unique solutions without depending too much on hardware. The advantage of using SDN is that, it separates the network control pane from the physical network topology and uses software control flow to define how traffic is forwarded in the network. For example, the routing table and the flow control of a switch can be easily controlled remotely through a software controller. The capabilities of SDN is possible due to the use of OpenFlow protocol which is a standardized protocol that is used by the SDN based controller to manipulate the flow tables of network switches. This provides more flexibility to programmatically control the behavior of network switches by building network applications that talk to the network controller. Any OpenFlow enabled switch from any vendor provides a common interface to be manipulated via a controller, thus providing flexibility and simplified network management.

1.1 Contribution

This thesis provides a novel approach towards separating the data traffic between the different network providers within an access point. This is made possible through the simple, yet effective use of OpenFlow protocol that enables the development of different enterprise WLAN services as applications such as, using software defined network controllers. The performance benefits achieved though this system is possible without any changes to the existing 802.11 client. The proposed system is compatible with the existing enterprise WLAN security protocols like WPA2 enterprise.

1.2 Results

The expected outcome of this thesis is to demonstrate a prototype system that runs an AP on an OpenFLow controlled switch. The AP also provides enterprise grade authentication system WPA2 enterprise alongside a RADIUS server, and host two separate networks. The separation of data traffic between the two networks will take place within the same AP and provide Hotspot 2.0 functionality.

1.3 Research Context[1]

The research described in this thesis was done based on the BIC-IRAP project which is focused on combining the strengths of LTE and Wireless-LAN seamlessly. Through the integration of small and micro cells of LTE with WLAN in the BIC-IRAP system, the two radio technologies are available through a single dynamically configurable hardware configuration.

1.4 Thesis Structure

This thesis report is organized as follows, Chapter 2 describes the background for this thesis. Chapter 3 describes in detail about SDN and the different types in use today. Chapter 4 talks about the control and authentication mechanism such as the protocols and technologies used. Chapter 5 talks about the environment required to build the system such as the tools and software's. Chapter 6 describes in detail how the application is developed, from conceptualization to coding in python. Chapter 7 shows how the system is being implemented. Chapter 8 presents the results obtained from the system after series of testing and enhancement. Chapter 9 concludes the thesis and describes further improvements and drawbacks of this method.

2 Background

This chapter discusses about the topics relevant this thesis, it includes an introduction to software defined networking, 802.11 protocol, Hotspot 2.0 and BIC-IRAP project.

2.1 Software Defined Networking [2]

SDN is nothing but the physical separation of the network control plane from the forwarding plane. The control plane consists of all the logic that the switch requires to correctly setup a forwarding plane, that is, the signaling associated with the switch.

Traditionally, the vendor has the control over the logic necessary for signaling since they run a proprietary firmware. This makes the devices non-interoperable with other vendors which hampers flexibility. Though most of these switches provide SNMP based management solution via CLI, they still do not allow the introduction of custom control plane function or protocol into the switch. This makes experimenting with new protocols cumbersome. Software Defines Networking aims to alleviate these problems by making the switched control plane be easily accessible remotely and be modifiable using the OpenFlow protocol. Any third-party software can than take advantage of this open protocol to manage and orchestrate an entire network.

SDN architecture generally has three components or groups of functionality as shown in the figure 2.1 below.

- **Application Layer:** Consists of programs that communicate the behaviors and needed resources with the SDN controller via the application protocol interfaces (API's). It can also build an abstracted view of the network by collecting information from the controller.
- **Control Layer:** This logical layer functions as a relay that sends the instructions or resources sent by the application layer to the networking components.
- **Infrastructure Layer:** This holds the SDN networking devices that control the forwarding and data processing capabilities of the network including the function to forward and process the data paths.

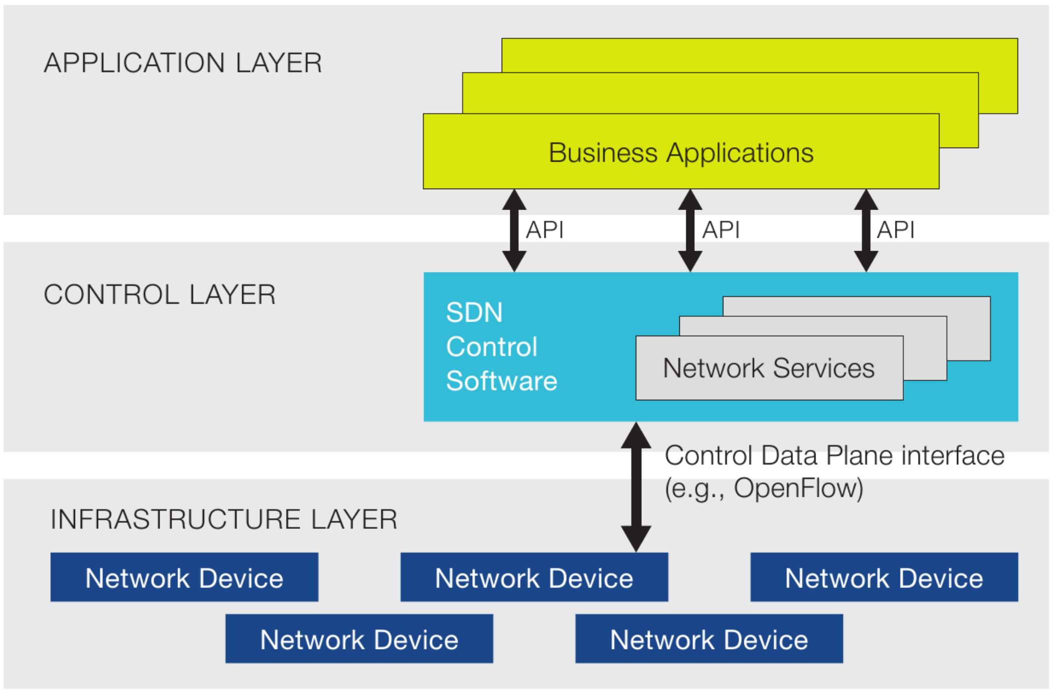


Figure 2.1: SDN architecture diagram[12]

2.2 IEEE 802.11 MAC [3]

The IEEE 802.11 Media Access Control Layer (MAC) [3] defines the protocol for stations to establish connections with each other and transmit data frames. Medium access in 802.11 is performed by a distributed coordination function (DCF), which uses carrier sense multiple access with collision avoidance (CSMA/CA) to enable random medium access among all contending stations (STAs). Hence, it reduces the amount of collisions. Logically, the MAC is divided into two parts, an upper MAC, and a lower MAC. The upper MAC handles management frames, which include probe, authentication, association requests and their corresponding responses. The lower MAC handles control frames, which includes acknowledgement (ACK) frames, along with request-to-send (RTS) and clear-to-send (CTS) frames. The frames handled by the lower MAC have real-time constraints. For instance, ACK frame timeouts are within the order of micro-seconds. For this reason, control frames are handled and generated within hardware. Management frames, however, have softer time constraints, and can be handled in software locally (as is the case in Linux systems that use hostapd [30]), or remotely (as is the case when using a centralized WLAN controller [31]).

An 802.11 based wireless interface can operate under the following operating modes: STA (client), access point (AP), mesh, ad-hoc and item Monitor mode. The most common mode of operation is the infrastructure mode (which includes enterprise WLAN environments). In this mode of operation, clients connect to the AP using a series of message exchanges in a process called “association”. The decision on which AP to associate with is left entirely to the client. Clients learn about APs either passively through beacon frames that are periodically broadcasted by the access points, or actively by performing a probe scan.

In a probe scan, clients first send out probe request frames over all channels. APs that receive these frames and are willing to accept a connection from a client respond with a probe response frame. All APs from which the client receives probe responses are candidates for the client to associate with. Next, the client sends an authentication frame, and waits for an authentication response from the AP. This is followed by the client sending an association request, and receiving an association response from the AP. If the network is operating in open authentication mode, the client is considered to be associated at this point, and can now transmit data frames to be forwarded by the AP. If the AP is configured to use WPA, WPA2, or WPA2 Enterprise, the corresponding 802.1X [30] handshake is performed after the association phase before clients can forward data frames through the AP.

2.3 Hotspot 2.0 [4]

It is a new wireless network standard that is designed to make connection to public Wi-Fi hotspots more easy and secure. They are already supported on many mobile devices running some of the popular operating systems such as Windows 10, Mac OS 10.9 or newer, Android 6.0 or newer, and iOS 7 or newer.

The main purpose of Hotspot 2.0 is to provide seamless mobility like cellular style “roaming” for Wi-Fi networks. The device will automatically connect to the available networks based on the networks partners on the home networks while roaming globally. This is made possible using the latest 802.11u [32] protocol designed for the same purpose. Some organizations also call this as Passpoint [33].

3 Software Defined Networking

The Open Network foundation, a non-profit organization, has been undertaking an extensive research for the past couple of years in designing and standardizing open network components such as OpenFlow, SDN etc. which, after being rolled out on to a variety of network devices and software's from different vendors has been delivering substantial benefits to both enterprises and carriers include: [34]

- **Directly Programable:**Network directly programmable because the control functions are decoupled from forwarding functions, which enable the network to be programmatically configured by proprietary or open source automation tools.
- **Centralized Management:** Network intelligence is logically centralized in SDN controller software that maintains a global view of the network, which appears to applications and policy engines as a single, logical switch.
- **Reduce CapEx:** Software Defined Networking potentially limits the need to purchase purpose-built, ASIC-based networking hardware, and instead supports pay-as-you-grow models
- **Reduce OpEX:** SDN enables algorithmic control of the network of network elements (such as hardware or software switches/routers that are increasingly programmable, making it easier to design, deploy, manage, and scale networks. The ability to automate provisioning and orchestration optimizes service availability and reliability by reducing overall management time and the chance for human error.
- **Deliver Agility and Flexibility:** Software Defined Networking helps organizations rapidly deploy new applications, services, and infrastructure to quickly meet changing business goals and objectives.
- **Enable Innovation:** SDN enables organizations to create new types of applications, services, and business models that can offer new revenue streams and more value from the network.

3.1 Existing SDN Controllers

For this Master thesis, a few available SDN controllers are first studied for its functionality that can be manipulated for data path segregation. A brief overview on each controller is discussed in the following sections.

3.1.1 Ryu Controller [5]

Ryu is a component-based software defined networking framework. It provides software components with well-defined API that make it easy to create new network management and control applications. The component that is of particular interest for this master thesis is the switching hub by using OpenFlow.

Switching hubs have a variety of functions, some of which are discussed below.

- Learns the MAC address of the host connected to a port and retains it in the MAC address table.
- When receiving, packets addressed to a host already learned, transfers them to the port connected to the host.
- When receiving, packets addressed to an unknown host, performs flooding.

The main reason to choose RYU over other controllers is due to its customizability and easy to create core applications using Python. RYU allows users to modify core functions or use these functions to create custom applications that suits specific needs, in this case, it was used to create a switching application that can segregate users within the OpenVswitch, instead of being controlled each time by the controller.

The software components provided by RYU with well-defined Application Programming Interface (API's), makes it easy for developers to create custom network management or control applications. The existing components can be quickly and easily modified or implement a custom component so that the underlying network can meet the changing demands of the application. RYU is designed to increase the agility of network by being more easily manageable and adapt how traffic is handled.

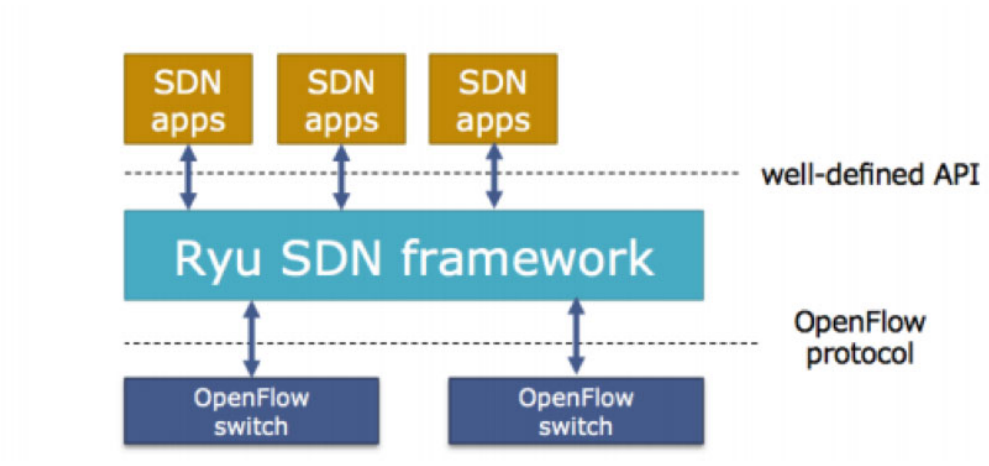


Figure 3.1: RYU SDN Controller Framework [13]

RYU Controller is supported by NTT of Japan and has a strong open source RYU community that maintain and manage the code which is hosted at GitHub. OpenStack also supports deployment of RYU as network controller in its cloud operating systems.

3.1.2 Floodlight Controller [6]

It is yet another open source SDN controller similar to RYU. The benefit of using this controller is the ability to easily develop applications using Java, which is widely used for high level programming by developers and to adapt the software as per requirement. Flood Light offers Representational state transfer application program interface (REST API's) which help developers to easily program interfaces with the product.

Floodlight is used to run as the network backend for OpenStack. When used with the Neutron plugin with OpenStack, the Floodlight controller functions as a network-as-a-service model with the help of REST API offered by Floodlight. The following diagram below shows the architecture of Floodlight controller.

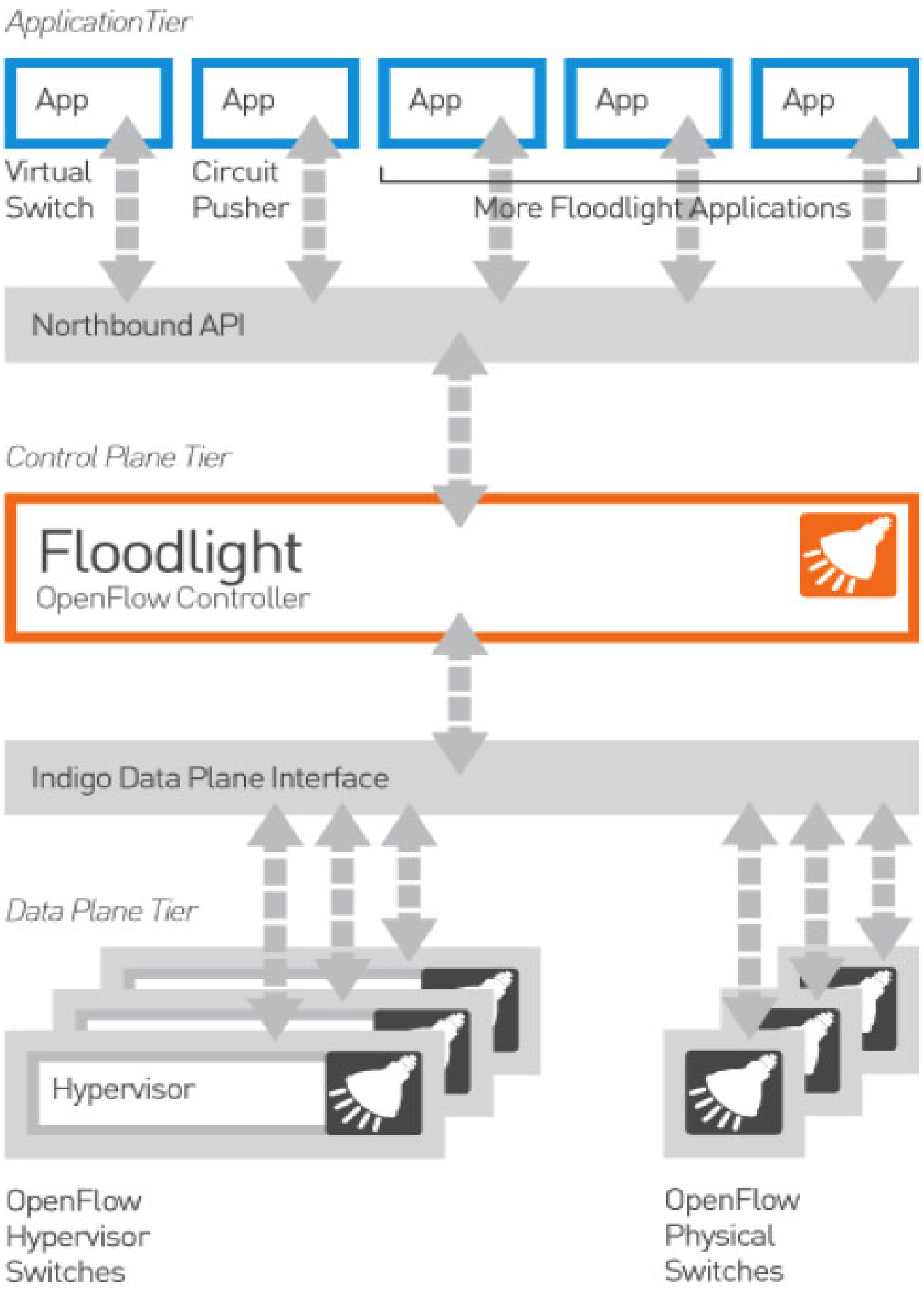


Figure 3.2: Floodlight Controller architecture [14]

3.1.3 OpenDaylight

OpenDaylight controller is based on JVM, similar to Floodlight, which was a derivative of OpenDaylight that can be deployed on any systems that supports Java. OpenDaylight controller uses the following tools as its framework:

- **Maven:** OpenDaylight uses Maven, which uses Project Object Model to script the dependencies between the bundles for easier build automation.
- **OSGi:** It works as the back-end for OpenDaylight as it loads bundles dynamically and packages JAR files and binding them together for exchange of information.
- **JAVA interfaces:** They are used for event listening, specifications, and forming patterns.
- **REST APIs:** These are the northbound APIs that manage the topology, flow program, host tracking, static routing and so on.

The following figure shows the framework of OpenDaylight with the above tools mentioned:

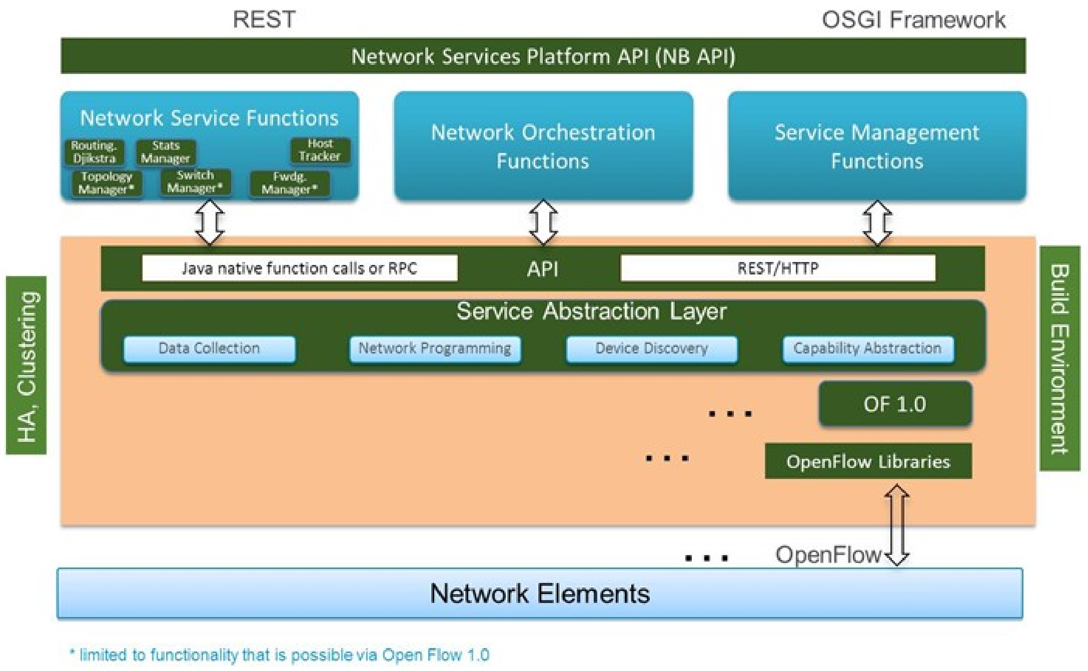


Figure 3.3: OpenDaylight Architecture Framework [15]

3.2 Applications of SDN

Many research efforts has been done till now in writing SDN applications. Jose et. al. [35] propose using commodity OpenFlow enabled switches for traffic measurement. The authors propose a framework where a collection of rules are installed on OpenFlow switches, and having a controller track the corresponding flow match counters. The controller can then draw inferences from the counters and dynamically tune the rules as required in order to identify different traffic aggregates.

Resonance [36] is another application uses programmable switches to enforce access control in the network. The authors try to prove that today's enterprise networks rely on different combinations of middle boxes, intrusion detection systems, and network configurations in order to enforce access control policies, whilst placing a burden on end-hosts in the system to remain patched and secure. The proposed system uses an SDN approach comprising programmable switches and a controller, which together implement a network monitoring framework, a policy specification framework, and the ability to trigger specific actions at the switch level.

OpenSAFE [37] is a framework that enables network monitoring using OpenFlow. It addresses the problem of routing traffic for network analysis in a reliable manner without affecting normal traffic.

Hedera [38] is an adaptive flow scheduling system for data center networks. The premise for Hedera is that existing IP multipathing techniques used in data centers usually rely on per-flow static hashing, which can lead to under-utilisation of some network paths over time due to hash collisions. The system works by detecting large flows at the edge switches of a data center, and using placement algorithms to find good paths for the flows in the network. Experiments performed using simulations indicate significant improvements over static load balancing techniques.

In the paper *OpenFlow based server load balancing gone wild* [39], the authors address the problem of server load balancing using OpenFlow switches. The number of flow entries that can be saved on an OpenFlow switch is much less than the number of unique flows that a switch might need to handle in data center workloads. Thus, micro flow management using per-flow rules is not practical for performing distributing flows between different servers using a switch. The authors thus take advantage of OpenFlow's wildcard based rules capability, and propose algorithms to compute concise wildcard rules that achieve a specific distribution of traffic.

These are some of the applications that have been written for SDN controllers but none of them address the challenge to dynamically redirect packets in real time, based on different clients and their credentials used for authentication. This thesis proposed to build one such application that can segregate packets coming from different clients in such a way that there is no possible connection between multiple clients associated within the same access point.

3.3 Open vSwitch [7]

It is a production quality multilayer virtual switch, designed to enable massive automation through programmatic extension. It also supports standard management interfaces and protocols such as NetFlow, sFlow, CLI, port mirroring, VLAN's, LACP etc. In addition to this, it is also designed to support distribution across multiple physical servers similar to VMWare's vNetwork distributed vswitch. Open vSwitch was developed by the Linux foundation and is licensed under Apache 2.0.

The virtual switch is a software layer that resides in a server that is hosting virtual machines. VM's and also now, containers such as Docker have logical and virtual Ethernet ports. These logical ports connect to a virtual switch. The diagram below shows the features of an Open vSwitch. [40]

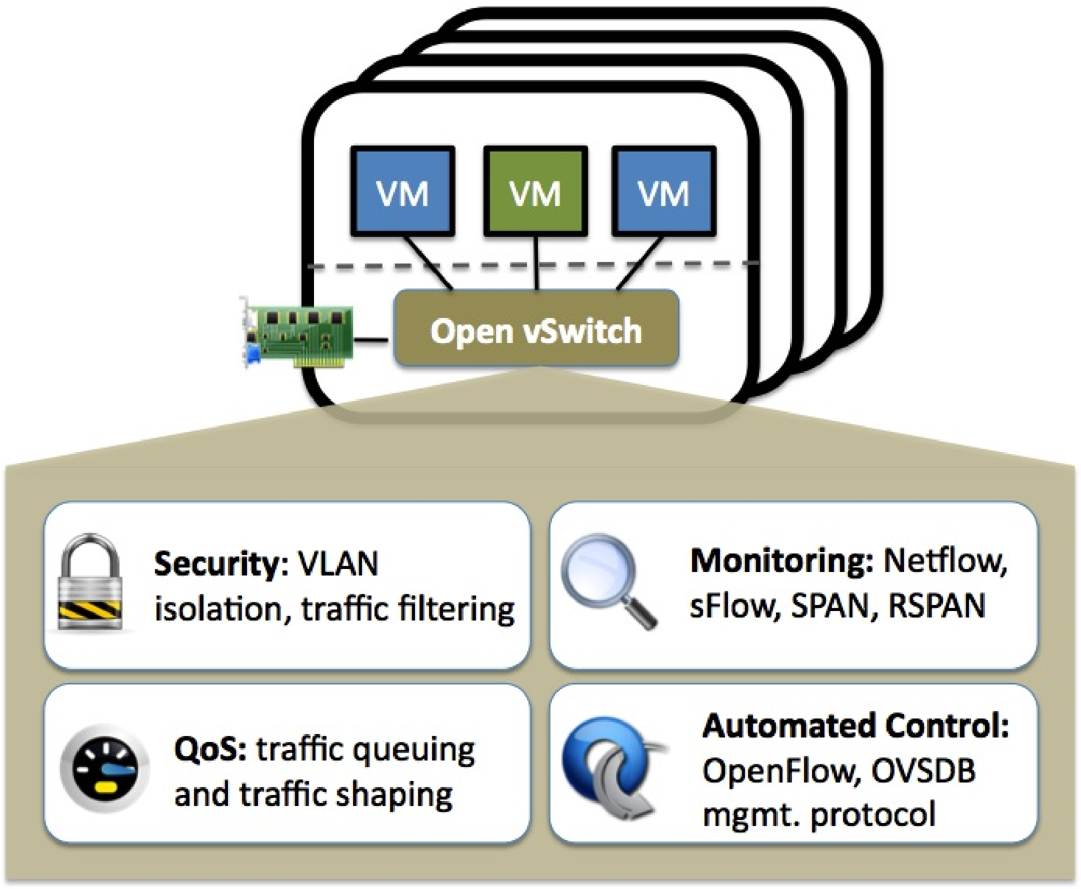

VM
VM
VM
Open vSwitch
Security: VLAN isolation, traffic filtering
Monitoring: Netflow, sFlow, SPAN, RSPAN
QoS: traffic queuing and traffic shaping
Automated Control: OpenFlow, OVSDB mgmt. protocol

Figure 3.4: Open vSwitch features [16]

From the management and control perspective, Open vSwitch leverages on the OpenFlow and the Open vSwitch Database (OVSDB) management protocol, which means it can work as both a soft switch running within the hypervisor and as the control stack for switching operations on the physical switches. Other ways in which OVS is used in Software Defined Networking include:

- SDN's deployed in data centers use OVS because it connects all the virtual machines (VMs) within a hypervisor instance on a sever.
- It is the ingress point in overlay networks running on top of the physical networks in the data center and it is the first point of entry for all the VM's sending traffic to the network.
- In datacenter SDN deployments, using OVS for virtual networking is considered the core element since its main use case is a multi-tenant network virtualization.

- In some service chaining use cases, OVS is sometimes used to direct traffic between network functions.

Open vSwitch is designed in such a way that it is meant to be managed and controlled by a third-party controllers and managers. OVS can also directly work with OpenStack using a plugin or directly from an SDN controller, such as OpenDaylight. It is also possible to deploy OVS on all servers in an environment and let it operate with the MAC learning functionality.

4 Control and Authentication Mechanism

In this chapter, the softwares and protocols used for providing authentication and for controlling the access point is discussed. A brief introduction to OpenWrt and the different protocols such as OpenFlow, RADIUS is described in the flowing topics.

4.1 OpenWrt [8]

OpenWrt is a Linux distribution that works like any other Linux distro designed for embedded devices. OpenWrt offers bult-in package manager that allows to install packages from its repository or manually build your own firmware file using your custom-built package. The packages range anything from an SSH server, VPN, traffic-shaping, enterprise wireless solutions, BitTorrent client, or even as a hotspot manager.

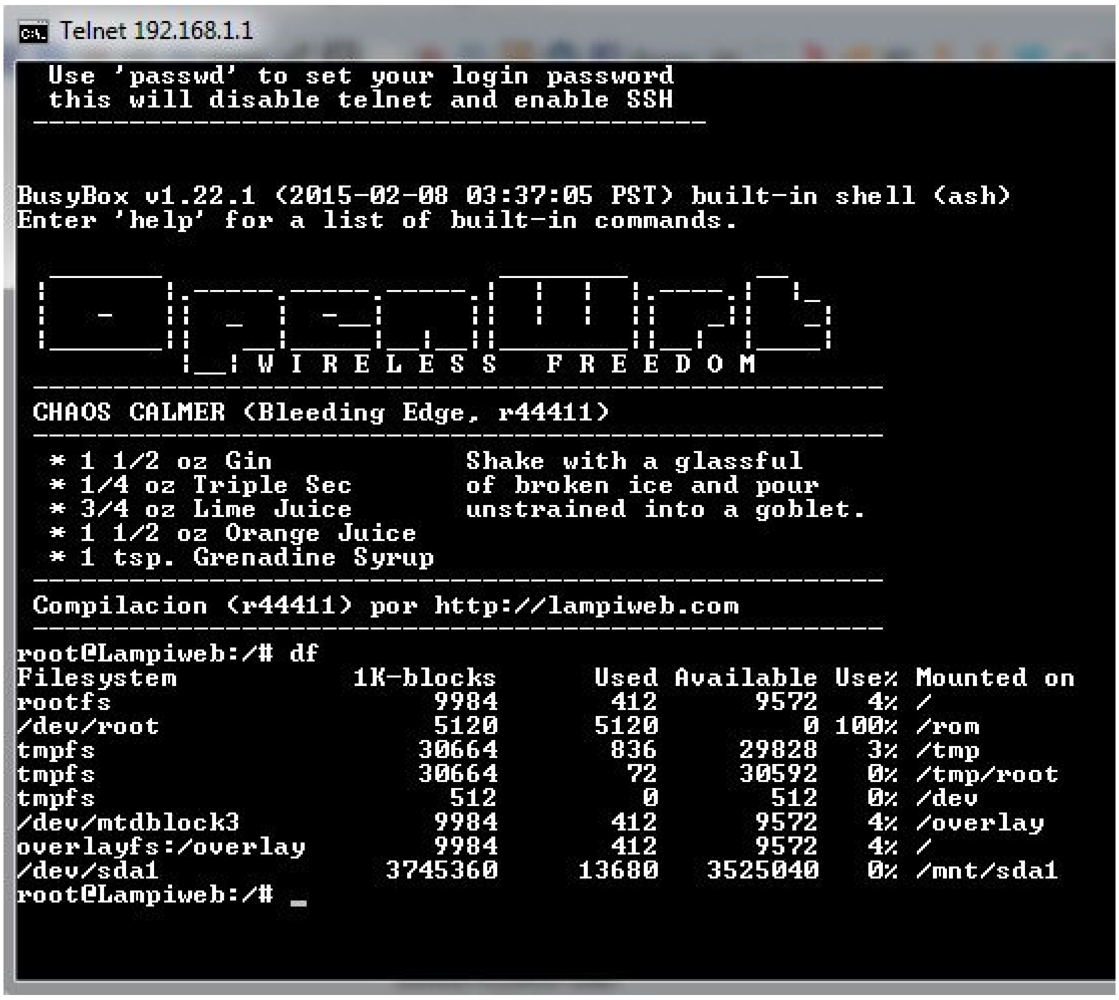
OpenWrt is designed for power users that wants customizability to the stock firmware provided by the manufacturer. There are many custom firmware's such as DD-WRT available for most popular routers, for this thesis, OpenWrt is chosen because of its flexibility and more stable than most custom firmware's or sometimes even the stock firmware.

OpenWrt has many features that can be mentioned but out of scope for this thesis, a run-down version of the most relevant features are listed below that are related to this thesis.

- **SSH server for terminal access:** Provides SSH server, which allows to connect directly to the routers terminal via SSH and when the router is configured to the internet, allows to remotely configure the router.
- **Capture and Analyse network Traffic:** Tcpdump tool is included in the build to analyze the packets that are traversing thru the router. The tool can also be used to create packet logs that can be open in packet analyzer tools such as Wireshark.
- **GUI Interface:** OpenWrt also includes a GUI interface for managing most of the router's configuration, the built in one is named as LuCi.

- **OpenvSwitch:** The virtual switch is also available as a package on OpenWrt repository that is used in this thesis to be installed in the router for creating a virtual switch within the router that can also work along with the physical switched present.
- **Wireless Utilities:** OpenWrt provides many different packages for managing wireless sockets in the router, for this thesis, Hostapd package is chosen because of its fully featured support for a wide range of authentication mechanisms such as IEEE 802.1x/WPA/EAP/RADIUS with EAP protocols. It can be configured in the file located at /etc/hostapd.conf in the routers folder.
- **Freeradius:** The open source RADIUS server is also available as a package for the OpenWrt build but is not used in the firmware for this thesis because of memory unavailability of the TP Link WR-4300 router.
- **MySQL:** The is a fully featured MySql server also available as the packages that can be installed on the router but again could not be used in this thesis due to memory restrictions of the router.

The following figures below shows the SSH interface of OpenWrt terminal and the LuCi web interface.

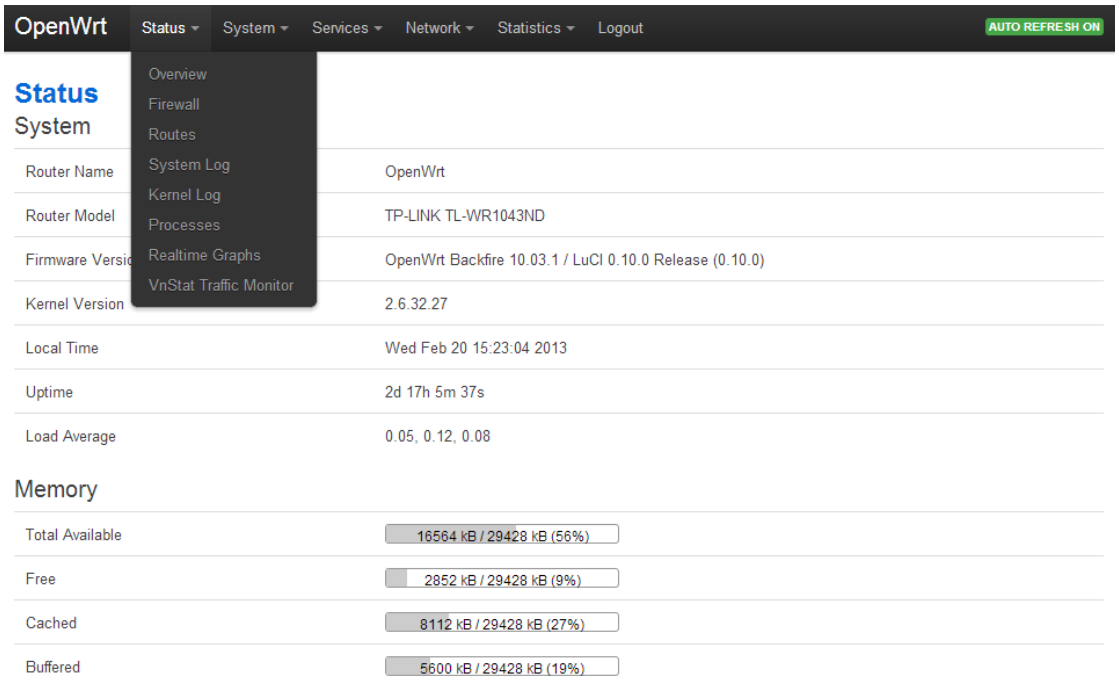

Telnet 192.168.1.1

```
  Use 'passwd' to set your login password
  this will disable telnet and enable SSH
 ------------------------------------------


BusyBox v1.22.1 (2015-02-08 03:37:05 PST) built-in shell (ash)
Enter 'help' for a list of built-in commands.

  _______                     ________        __
 |       |.-----.-----.-----.|  |  |  |.----.|  |_
 |   -   ||  _  |  -__|     ||  |  |  ||   _||   _|
 |_______||   __|_____|__|__||________||__|  |____|
          |__| W I R E L E S S   F R E E D O M
 -----------------------------------------------------
 CHAOS CALMER (Bleeding Edge, r44411)
 -----------------------------------------------------
  * 1 1/2 oz Gin            Shake with a glassful
  * 1/4 oz Triple Sec       of broken ice and pour
  * 3/4 oz Lime Juice       unstrained into a goblet.
  * 1 1/2 oz Orange Juice
  * 1 tsp. Grenadine Syrup
 -----------------------------------------------------
 Compilacion (r44411) por http://lampiweb.com
 -----------------------------------------------------
root@Lampiweb:/# df
Filesystem           1K-blocks      Used Available Use% Mounted on
rootfs                    9984       412      9572   4% /
/dev/root                 5120      5120         0 100% /rom
tmpfs                    30664       836     29828   3% /tmp
tmpfs                    30664        72     30592   0% /tmp/root
tmpfs                      512         0       512   0% /dev
/dev/mtdblock3            9984       412      9572   4% /overlay
overlayfs:/overlay        9984       412      9572   4% /
/dev/sda1              3745360     13680   3525040   0% /mnt/sda1
root@Lampiweb:/# _
```

Figure 4.1: OpenWrt Terminal View [17]



Status

System

Router Name	OpenWrt
Router Model	TP-LINK TL-WR1043ND
Firmware Versi	OpenWrt Backfire 10.03.1 / LuCI 0.10.0 Release (0.10.0)
Kernel Version	2.6.32.27
Local Time	Wed Feb 20 15:23:04 2013
Uptime	2d 17h 5m 37s
Load Average	0.05, 0.12, 0.08

Memory

Total Available	16564 kB / 29428 kB (56%)
Free	2852 kB / 29428 kB (9%)
Cached	8112 kB / 29428 kB (27%)
Buffered	5600 kB / 29428 kB (19%)

Figure 4.2: OpenWrt GUI Interface [18]

4.2 Protocols

For this thesis, protocols such as OpenFlow, RADIUS and 802.1x security are used extensively and are discussed in detail below, explaining their use cases and features.

4.2.1 OpenFlow [9]

It is a standard communication interface defined between the control and forwarding layers of the SDN architecture, allowing direct access for manipulating the forwarding plane of the network devices such as switches and routers, both physical and virtual (hypervisor based).

OpenFlow, along with SDN technologies have helped IT to manage and address the high-bandwidth, and dynamic nature of today's applications. It also has helped adapt the network to ever-changing business needs, and significantly reduce the complexity in maintenance and operations.

Some of the best features of OpenFlow is explained in the following figure.

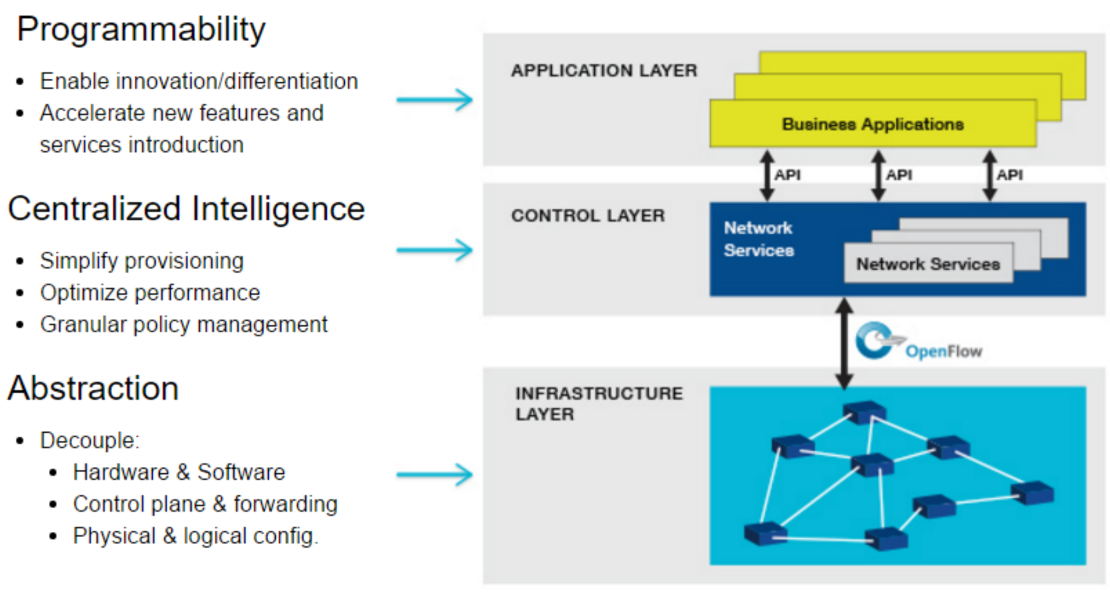


Figure 4.3: OpenFlow features [19]

How does OpenFlow Work? [41]

In a traditional switch or a router, the packet forwarding and high level routing decisions occur on the same device. In an OpenFlow switch, the routing and forwarding functions are separated. The data path portion is still on the switch and the routing decisions are handled by a separate controller, typically it's a standard server. The OpenFlow switch and controller communicate using the OpenFlow protocol, which defines messages such as packet-in, packet-out modify-forwarding path and get stats.

OpenFlow Specification [42]

The protocol can be split into 4 components namely: message layer, state machine, system interface and configuration.

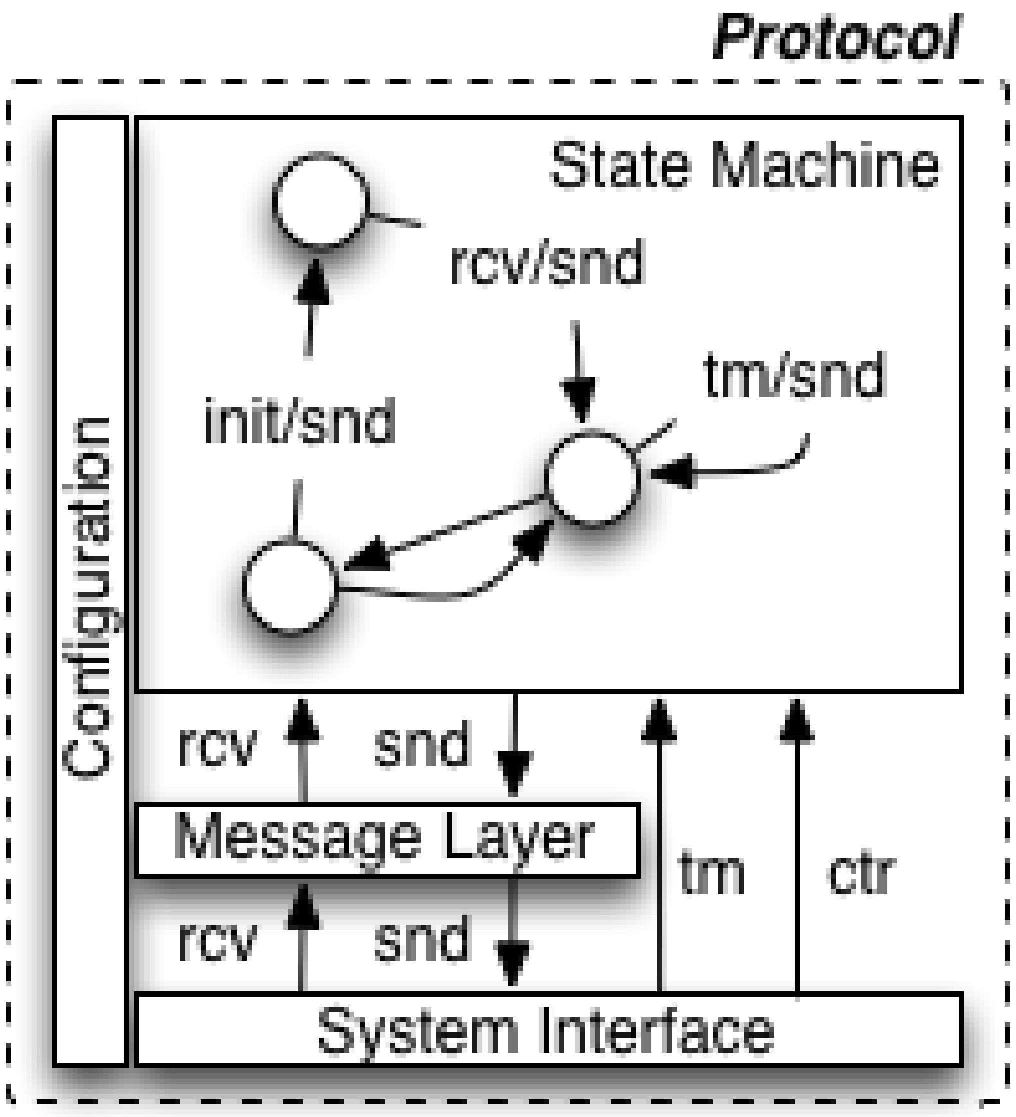


Figure 4.4: OpenFlow Protocol [20]

- **Message Layer:**
  It is the core of the protocol stack. It also supports the ability to construct, copy, compare, manipulate and print the messages. The message layer defines the valid structure and semantics for all messages.
- **State Machine:**
  It defines the core level behaviour of the protocol. It is typically used to describe

the actions such as: flow control, negotiations, delivery, capability discovery etc.

- **System Interface:**
  It typically defines how the protocol interacts with the other protocols in the outside world. The system interface identifies the necessary and optional interfaces along with its intended use such as TLS and TCP as transport channels.
- **Configuration:**
  Almost every protocol has its own configuration or initial values. It can cover anything from buffer size, reply intervals to X.509 certificates.
- **Data Model:**
  Each switch maintains the attributes of each OpenFlow abstration in a relational data model. The attributes either describe its configuration state, or some set of current statistics or the abstraction capability.

OpenFlow Switch [43]

An OpenFlow switch is made up of two components namely the switch agent and the data plane. The switch agent takes care of the communication between two or more controllers and also with the data plane using the requisite internal protocol. The switch agent translates the commands into low-level instructions to send to the data plane and the data plane notifications to the OpenFlow messages that are forwarded to the controller. The data plane takes care of the packet manipulation and forwarding and sometimes sends packets to the switch agent for further handling based on its configuration.

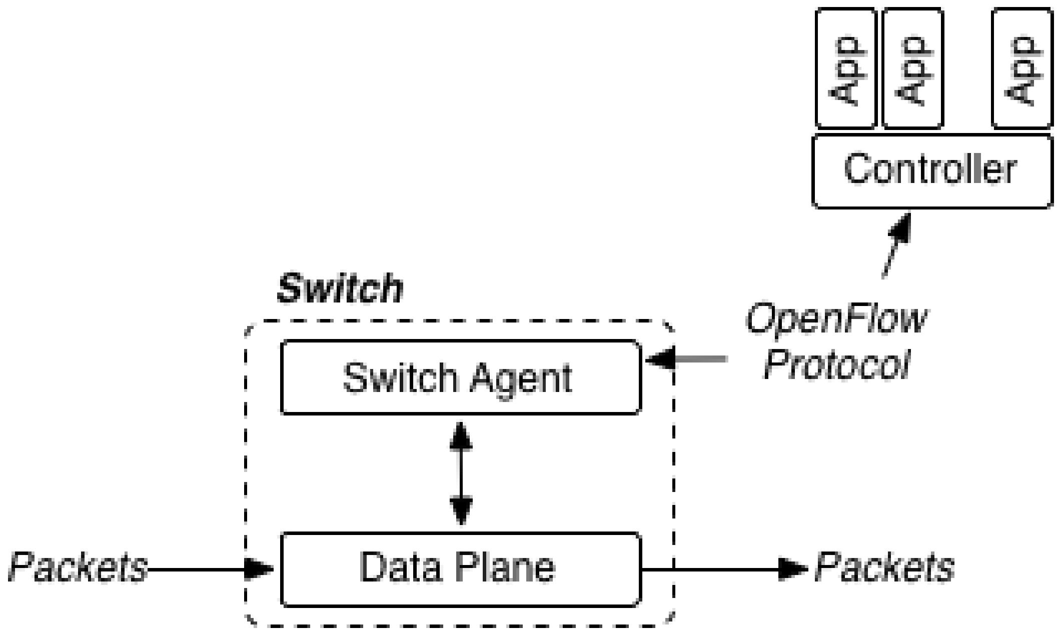


Figure 4.5: OpenFlow Switch Anatomy [21]

OpenFlow Switch Agent [43]

The following figure shows how the switch agent works, its components are explained the table following the figure.

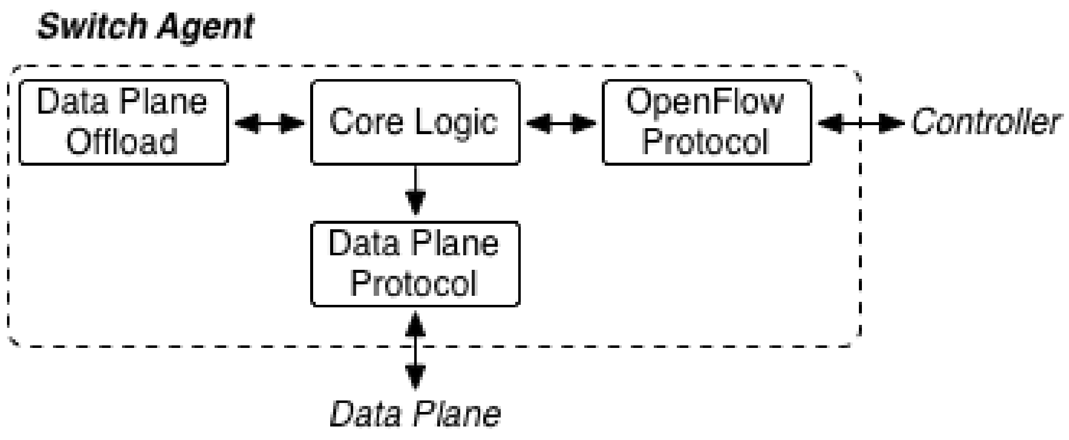


Figure 4.6: OpenFlow Switch Agent [22]

- **OpenFlow protocol:** This instance is on the switch side

- **Core Logic:** Switch management, command execution to the data plane and manage the data plane offload etc.
- **Data Plane Offload:** Some functionality present in the OpenFlow will be offloaded by the control plane which is not provided in the existing data plane implementation.
- **Data Plane protocol:** This protocol is internal which is mostly used for configuring the data plane state.

Data Plane [43]

The data plane consists of the ports, flow tables, flows, classifiers and actions. Packets traverse through the system on ports. When each packet arrives, it is matched with the flows in the flow table using classifiers. The flows contain the set of actions that are applied to each packet that matches.

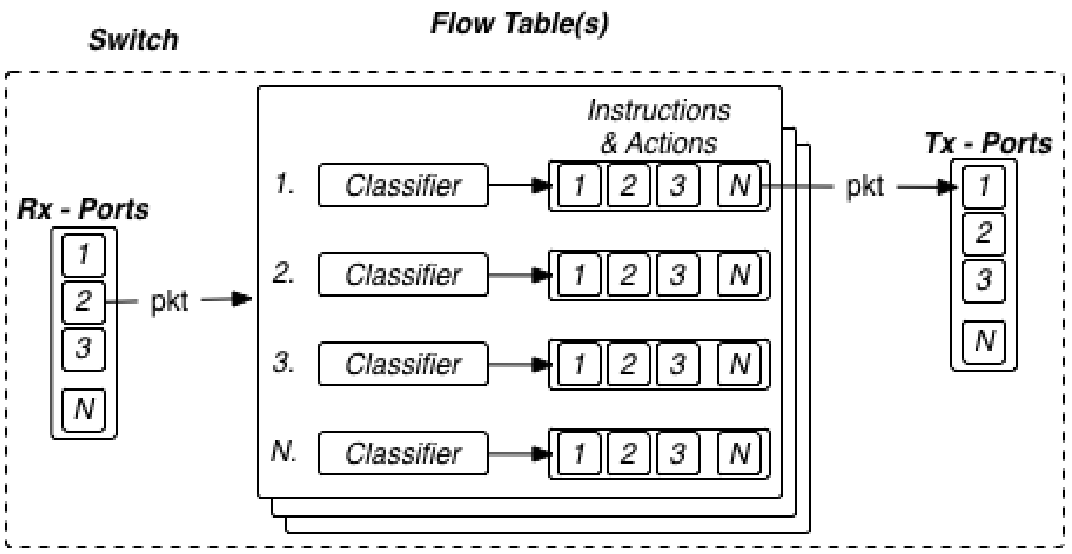


Figure 4.7: OpenFlow Data Plane Schematic [23]

Data Plane - Packet Lifecycle [43]

Each packet is processed in the following sequence as explained in the table below.

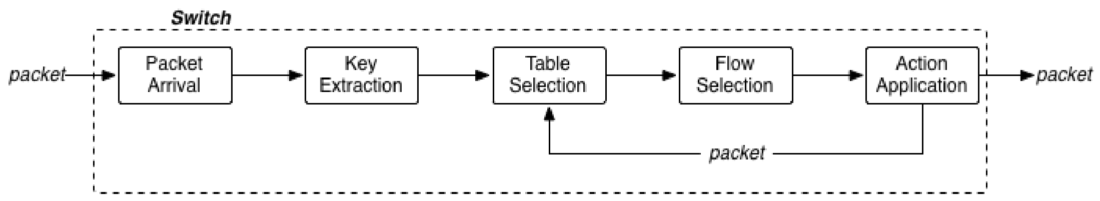


Figure 4.8: Packet Lifecycle [24]

- **Step 1: Packet Arrival**
  Packets arrive in either a physical or virtual port, it is necessary to make note of the arrival port for source-based processing later.
- **Step 2: Key Extraction**
  When each packet arrive on the port, a small meta data is built called the key. This key contains information about the packet such as header values, buffered packet, arrival port, arrival time etc.
- **Step 3: Table Selection**
  When a packet goes through the pipeline, the packet is matched with the first table by default and if multiple tables exist then subsequent tables will be selected through hit or miss actions.
- **Step 4: Flow Selection**
  The Key extracted in the initial step is used for selecting the flow from the table. The first flow where the classifier subsumes the key become the selected flow.
- **Step 5: Application Selection**
  Each flow contains a set of actions, which is applied to the packet when a flow is matched. The actions can modify the state of the packet or change how the packet is treated.

4.2.2 RADIUS [10]

RADIUS stands for Remote Authentication Dial-In User Service, which is an access server for authentication and accounting protocol. RADIUS is an AAA protocol used for network access applications.

What is AAA Protocol? [44]

AAA stands for Authentication, Authorization and Accounting.

- **Authentication:** It is the confirmation to the validation of the user who is requesting a service. It is normally done by providing some credentials such as username and password.
- **Authorization:** Providing specific services based on the user's authentication such as physical location restrictions, multiple login access restrictions etc.
- **Accounting:** keeping track of all the users and their network resource consumption is provided by the accounting service, it's like a log for every user who gained access to the network. Typical information includes user identity, nature of service delivered etc. This information may probably be used for billing, management purposes.

Key Features of RADIUS: [10]

- **Client / Server Model:**
  The network server acts as the client of RADIUS, which passes the user information to designated RADIUS server. The responsibilities of the radius server include receiving connection requests, authenticating users, providing all the configuration details necessary for the client to deliver service to the user.
- **Network Security:**
  The communication between the client and the RADIUS server is encrypted so, any user password sent is encrypted. In addition, the client and the RADIUS server transactions are authenticated over a shared secret which is never sent over the network.
- **Flexible Authentication Mechanisms:**
  The RADIUS server supports several method's for a user to authenticate such as PPP, PAP or CHAP etc.
- **Extensible Protocol:**
  All transactions are of variable length Attribute-value-length 3 tuples. Supports addition of new attribute values without disturbing the existing implementation of the protocol.

RADIUS Components [45]

The following components are part of the RADIUS infrastructure.

- Access Clients
- Access Servers (RADIUS clients)

- RADIUS servers
- RADIUS proxies
- User account databases (Active Directory, any database such as MySQL)

The components are showing in the following figure.

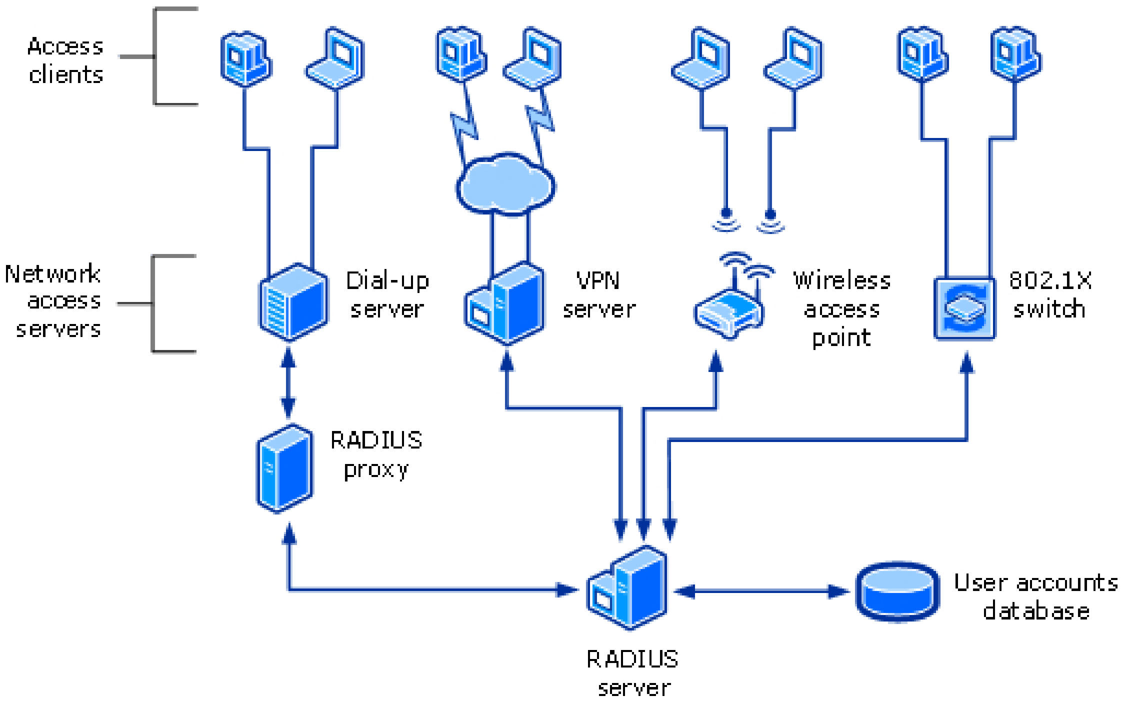


Figure 4.9: RADIUS Components [25]

RADIUS Operation [45]

RADIUS messages are sent as UDP messages using the port 1812 for authentication and port 1813 for accounting messages. Some network access servers (NAS) use 1645 and 1646 for authentication and accounting respectively.

A RADIUS data format looks as shown below where the fields are transmitted from left to right.

```
0                   1                   2                   3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Code      |  Identifier   |            Length             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                         Authenticator                         |
|                                                               |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Attributes ...                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The code field as shown in the data frame above uses one octet which help identify the type of RADIUS packet.

- **Access-Request:** Sent by the RADIUS client requesting authentication and authorization for a connection.
- **Access-Accept:** It's the response from the RADIUS server to the client stating that the connection was authenticated and authorized.
- **Access-Reject:** It's a response from the RADIUS server to the client that the connection attempt failed in authentication.
- **Access-Challenge:** Sometimes the RADIUS server requires more information from the client and sends a challenge as a response the Access-Request message.
- **Accounting-Request:** Sent by the RADIUS client to specify accounting information for an accepted connection.
- **Accounting-Response:** The RADIUS server sends the acknowledgement for the successful receipt and processing of the Accounting-Request message.

RADIUS Authentication Mechanism

RADIUS uses the following message codes when communicating between the RADIUS client and server as shown in the figure below.

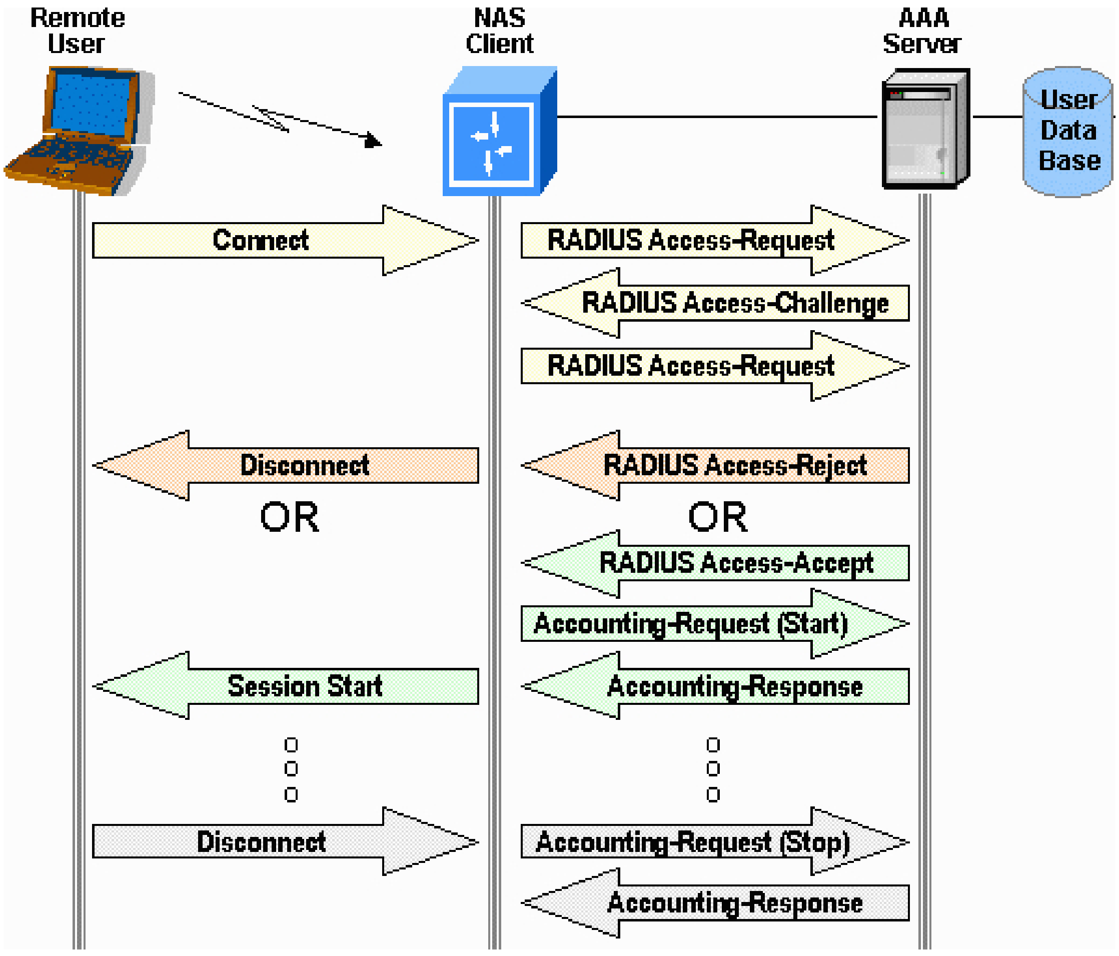


Figure 4.10: RADIUS Architecture [26]

- **STEP 1:**When a user makes a connection request, the NAS client sends an Access-Request message to the AAA server, in this case a RADIUS server.
- **STEP 2:**The RADIUS sever responds by sending an Access-Challenge message requesting more information from the user.
- **STEP 3:**The client responds with an Access-Request message with the requested information back to the RADIUS server. The response is typically a username and password information in the form of PPP, PAP or CHAP authentication mechanisms.
- **STEP 4:**The RADIUS server once after validating the received information sends back an Access-Accept information. If not validated, then it sends a Access-Reject message back to the client.

- **STEP 5:**Upon successfully establishing a connection, the client sends an Accounting-Request message to request to start accounting the user.
- **STEP 6:**The RADIUS server responds by sending an Accounting-Response message after successfully starting an accounting session for the connection. Thus, concludes the connection process of the user to the network.

4.2.3 WLAN 802.1x Security [11]

Wi-Fi or Wireless Local Area Networks (WLAN's) have become increasingly more popular in the recent years. The wireless standard IEEE 802.11 has become the most widely adopted standards for wireless broadband internet access. The security considerations however are more complicated in the wireless environment compared to the wired ones. IEEE 802.11 has defined the following two basic security mechanisms for secure access to wireless network.

- Entity authentication including shared key and open-system.
- Wired Equivalent Privacy (WEP)

Both these mechanisms are proven to be severely vulnerable. To enhance the security in wireless networks, 802.11i standard was proposed. This 802.11i standard defines encryption and authentication improvements in addition to introducing protocols for key management and establishment. 802.11i also incorporates the IEEE 802.1x standard as its authentication enhancement. The IEEE 802.1x is a port based network access control used for authenticating and authorizing devices connected by various LAN's.

The IEEE 802.1x standard is based upon the Extensible Authentication Protocol (EAP), and can use a number of authentication mechanisms which is beyond the scope of the IEEE 802.1x standard. Many authentication mechanisms such as MD5, TLS, TTLS, and PEAP can be used. The IEEE 802.1x uses EAP over LAN (EAPoL) for encapsulating EAP messages between the authenticator and the supplicant.

There are three main components in the IEEE 802.1x system namely, the supplicant, authenticator and the authentication server. In case of WLAN, the supplicant is usually the mobile device or node, the Access Point (AP) serves as the authenticator and the RADIUS server as the authentication server. The Port Access Entity (PAE) authenticator relays all the messages between the authentication server and the supplicant. 802.1x is used in this place to enforce the specific authentication mechanism.

802.1x Authentication Process

Authentication methods of 802.1x include PEAP, MD5 etc. Each method has its own authentication process. The following figure shows the basic EAP based authentication process in Eduroam networks.

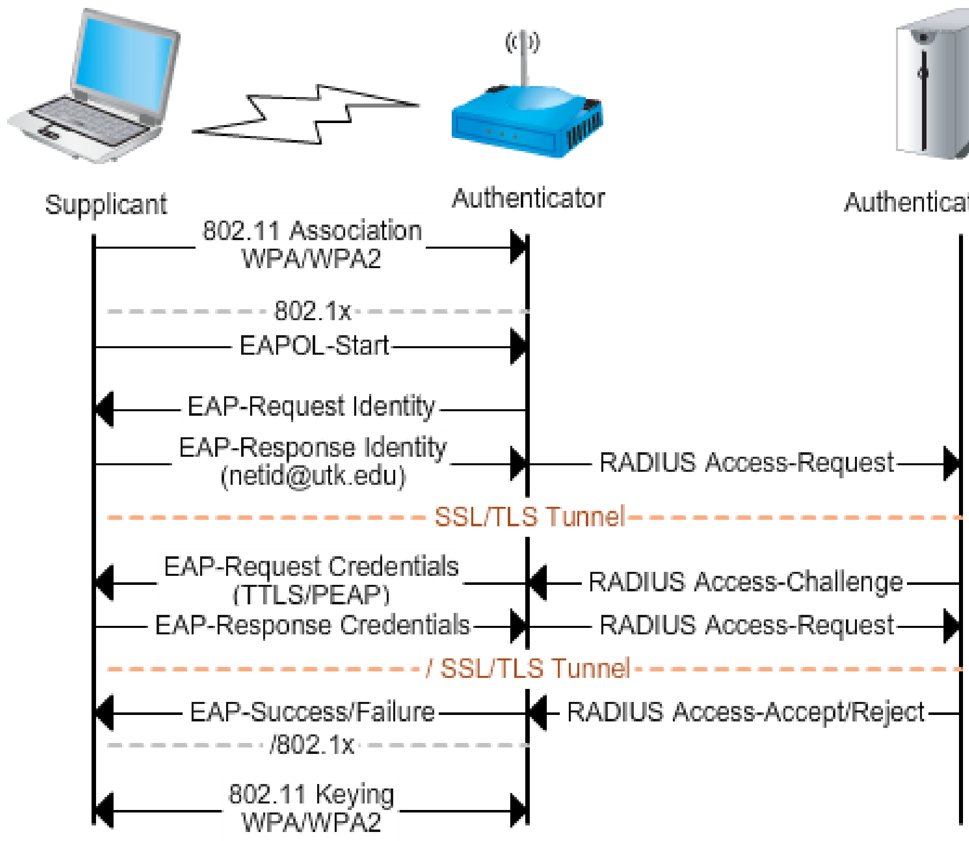


Figure 4.11: IEEE 802.1x WLAN authentication process [27]

- **Step 1:**
  After the association of the supplicant with the authenticator or AP via WPA or WPA2 enterprise, the 802.1x application initiates the EAPOL start message with the authenticator.
- **Step 2:**
  The authenticator responds by send a EAP-Request identity message from the supplicant.
- **Step 3:**
  Once receiving the username as a EAP response from the supplicant, the authen-

ticator then initiates a RADIUS Access-request message with the authentication server.

- **Step 4:**
  The authenticator receives the RADIUS access challenge from the authentication server and forwards that via a secure SSL/TLS tunnel to the supplicant by encapsulating the EAP-Request credentials message with TTLS/PEAP.
- **Step 5:**
  The supplicant responds with a EAP-Response Credentials message which is typically a username and password to the authenticator via the same secure tunnel, the authenticator forwards the received information as a RADIUS Access-Request message with encapsulation to the authentication server.
- **Step 6:**
  The authentication server responds with a RADIUS Access-Accept/Reject message to the authenticator. The Authenticator sends this information as a EAP Success/Failure message to the supplicant.
- **Step 7:**
  The supplicant is now fully associated with the network.

5 Implementation of Cplex based Nova Scheduler

After the iterations of debugging the OpenStack Scheduler Python module, the key parameters which contribute in the calculation of the placement decisions of virtual instances are identified. The key parameters that would be required in computation of placements decision are:

- Available RAM capacity on each of the Compute node and
- Available Hard Disk capacity on each of the Compute node

The number of CPU cores are not taken into consideration. As the Compute nodes support the hardware acceleration for virtual machines using the KVM mode, the CPU cores can be over utilised. The default `cpu_allocation_ratio` is set to 16 which allows the over creation of virtual CPU cores, due to which the available CPU cores do not play a major role in determining the creation of virtual instances.

In this chapter, the formulation of the new cPlex based Mathematical model is explained, and also the implemented code is provided with an explanation.

5.1 Mathematical Formulation

The idea behind the mathematical formulation is to implement the energy efficient scheduler mechanism, where the placement decisions are made to utilise maximum capacity of the Compute node before a new placement decision is requested on the other Compute nodes. This was conceptualised with an idea to extend the algorithm with an ability to perform live migration of the existing virtual machines to re-order the placement decisions.

As the live migration is still a work in progress, the mathematical model is formulated with only the essential parameters into considerations.

Parameters for the mathematical model are defined as follows:
n_s is the host number in the set of nodes.
N_s is the set of all the host nodes.

n_v is the virtual instance number in the requested virtual instances list.
N_v is the set of all the requested virtual instances to be placed.
x_{n_s} is the each individual host node.
$x_{n_s}^{n_v}$ is the unique combination of requested virtual instance from the set of N_v and host node from the set of N_s.
$suit_{n_s}^{n_v}$ is the suitable host entry for the requested virtual instance.
$d_{n_v}^{RAM}$ is the required demand of RAM for the given virtual instance.
$c_{n_s}^{RAM}$ is the available capacity of RAM in the given host node.
$d_{n_v}^{HDD}$ is the required demand of hard disk for the given virtual instance.
$c_{n_s}^{HDD}$ is the available capacity of hard disk in the given host node.

The objective function is to minimize the host nodes for placing the requested virtual instances. This objective function can be given as:

$$\min \sum_{n_s \in N_s} x_{n_s} \tag{5.1}$$

For each virtual instance, the placement request of the virtual instance is done on one and only one host node. This can be given by the equation:

$$\sum_{n_s \in N_s} x_{n_s}^{n_v} suit_{n_s}^{n_v} = 1, \forall n_v \in N_v \tag{5.2}$$

The equation to determine if the host is suitable or not suitable for a given combination of virtual instance and host is given by:

$$x_{n_s}^{n_v} \leq suit_{n_s}^{n_v}, \forall n_s \in N_s, n_v \in N_v \tag{5.3}$$

The equation which evaluates if the placement decision can be made on the given host node or not for a given virtual instance is given by:

$$x_{n_s} \geq x_{n_s}^{n_v}, \forall n_s \in N_s, n_v \in N_v \tag{5.4}$$

The RAM capacity constraints are given as follows:

$$\sum_{n_v \in N_v} x_{ns}^{n_v} d_{n_v}^{RAM} \leq c_{n_s}^{RAM}, \forall n_s \in N_s \tag{5.5}$$

The hard disk(HDD) capacity constraints are given as follows:

$$\sum_{n_v \in N_v} x_{ns}^{n_v} d_{n_v}^{HDD} \leq c_{n_s}^{HDD}, \forall n_s \in N_s \tag{5.6}$$

These equations provide the boundary conditions to determine the possible placement decision of the virtual instances in the host nodes.

5.2 The overview of implementation

IBM ILOG CPLEX® Optimizer is a mathematical programming technology that enables decision of mathematical optimization for improving efficiency, reducing costs, and increasing profitability[46]. This software is used to provide the solution for placement decision of the virtual instances on the host nodes. For the purpose of this Thesis, the version 12.6 of the IBM Cplex is used.

To implement the mathematical formulation described in the section Mathematical Formulation, a new scheduler file is created with a name "`tuc_ccn_scheduler.py`".

The `tuc_ccn_scheduler.py` has the class and function definition similar to the default `FilterScheduler`. There are few changes in the implementation of the `_schedule` function and a new function named as `solve_TUC_Cplex` has been added to implement the new cPlex based mathematical scheduling model.

The `_schedule` function for the new `tuc_ccn_scheduler` is given as:

```
def _schedule(self, context, request_spec, filter_properties):
    """Returns a list of hosts that meet the required specs,
    ordered by their fitness.
    """
    elevated = context.elevated()
    instance_properties = request_spec['instance_properties']

    # NOTE(danms): Instance here is still a dict, which is converted from
    # an object. The pci_requests are a dict as well. Convert this when
    # we get an object all the way to this path.
    # TODO(sbauza): Will be fixed later by the RequestSpec object
    pci_requests = instance_properties.get('pci_requests')
    if pci_requests:
        pci_requests = (
            objects.InstancePCIRequests.from_request_spec_instance_props(
                pci_requests))
        instance_properties['pci_requests'] = pci_requests

    instance_type = request_spec.get("instance_type", None)

    update_group_hosts = filter_properties.get('group_updated', False)

    config_options = self._get_configuration_options()

    filter_properties.update({'context': context,
                              'request_spec': request_spec,
                              'config_options': config_options,
                              'instance_type': instance_type})

    # Find our local list of acceptable hosts by repeatedly
    # filtering and weighing our options. Each time we choose a
    # host, we virtually consume resources on it so subsequent
    # selections can adjust accordingly.

    # Note: remember, we are using an iterator here. So only
    # traverse this list once. This can bite you if the hosts
    # are being scanned in a filter or weighing function.
    hosts = self._get_all_host_states(elevated)
    selected_hosts = []
    num_instances = request_spec.get('num_instances', 1)

    # the function get_filtered_hosts is called only once
    # before the for loop unlike the default scheduler's
    # _schedule function
    hosts = self.host_manager.get_filtered_hosts(hosts,
            filter_properties, index=0)

    weighed_hosts = self.weight_handler.get_weighed_objects(self.
    weighers,
            hosts, filter_properties)

    vi_hosts = {}
    start_time = rtime.time()
    # implementation of cPlex based mathematical solver
    try:
        vi_hosts = self.solve_TUC_Cplex(hosts, filter_properties,
    num_instances)
    except CplexError as exc:
        LOG.error('%s', exc)
        reason = _(exc)
        raise exception.NoValidHost(reason=reason)
    #end of the function call within try and exception

    for num in range(num_instances):
        weighed_hosts = vi_hosts[num]

        scheduler_host_subset_size = CONF.scheduler_host_subset_size

        if scheduler_host_subset_size > len(weighed_hosts):
            scheduler_host_subset_size = len(weighed_hosts)
        if scheduler_host_subset_size < 1:
            scheduler_host_subset_size = 1

```

```
72          chosen_host = weighed_hosts[0]
73          LOG.debug("Selected host: %(host)s", {'host': chosen_host})
74
75          # append the selected hosts  to the array mapping
76          selected_hosts.append(chosen_host)
77
78          # Now consume the resources so the filter/weights
79          # will change for the next instance.
80          chosen_host.obj.consume_from_instance(instance_properties)
81          if update_group_hosts is True:
82              # NOTE(sbauza): Group details are serialized into a list now
83              # that they are populated by the conductor, we need to
84              # deserialize them
85              if isinstance(filter_properties['group_hosts'], list):
86                  filter_properties['group_hosts'] = set(
87                      filter_properties['group_hosts'])
88              filter_properties['group_hosts'].add(chosen_host.obj.host)
89      LOG.info('%s number of instances scheduled with tuc scheduler in %s seconds' % (num_instances, (rtime.time() - start_time)))
90      return selected_hosts
```

Listing 5.1: The cPlex based TUC_scheduler's _schedule function

In the above code listing 5.1, the `get_filtered_hosts` at line number 45 is called before the for loop and called only once to provide an input to cPlex solver, unlike the default scheduler which filters the hosts for each request of an instance.

The cPlex based solver funtion is called at line number 55. The hosts, filter_properties and num_instances are passed as parameters to the function in the listing 5.2.

```
def solve_TUC_Cplex(self, hosts, filter_properties, num_instances):
    weighedHosts     = []
    #available RAM capacity on each compute (host) node
    ns_rams          = []
    #available HDD capacity on each compute (host) node
    ns_hdds          = []
    for host in hosts:
        weighedHost = []
        weighedHost.append(host)
        weighedHost = self.host_manager.get_weighed_hosts(weighedHost,
                    filter_properties)
        weighedHosts.append(weighedHost)
        ns_rams.append(host.free_ram_mb)
        ns_hdds.append(host.free_disk_mb)

    instance_type = filter_properties['instance_type']
    root_gb       = instance_type['root_gb']
    memory_mb     = instance_type['memory_mb']
    nvram         = 1.0*memory_mb
    nvhdd         = 1024.0*root_gb
    my_prob       = cplex.Cplex()

    #Number of hosts available to cater the requested instances
    host_count    = len(hosts)
    vis           = num_instances

    # cPlex input parameters
    # objective function parameters
    my_obj        = []
    # upper bound values
    my_ub         = []
    # lower bound values
    my_lb         = []
    # parameter type
    my_ctype      = ''
    # names of all the mathematical parameters
    my_colnames = []
    # the values on the right hand side
    my_rhs        = []
    # unique name for each row
    my_rownames = []
    my_sense      = ''

    rows          =   []

    # translate the mathematical formulations into cPlex input
    for i in range(host_count):
        my_obj.append(1.0)
        my_colnames.append("x_"+str(i))
        my_ub.append(1.0)
        my_lb.append(0.0)
        my_ctype = my_ctype+'B'
        vvar  = []
        vvalr = []
        vvalh = []
        for j in range(vis):
            my_obj.append(0.0)
            my_colnames.append("x_"+str(i)+"_"+str(j))
            my_ub.append(1.0)
            my_rhs.append(0.0)
            my_ctype = my_ctype+'B'
            my_lb.append(0.0)
            row = []
            var = []
            val = []
            var.append("x_"+str(i))
            var.append("x_"+str(i)+"_"+str(j))
            val.append(1.0)
            val.append(-1.0)
            row.append(var)
            row.append(val)
            rows.append(row)
            my_rownames.append('rsv_'+str(i)+'_'+str(j))
            my_sense = my_sense+'G'
            vvar.append("x_"+str(i)+"_"+str(j))
            vvalr.append(nvram)
            vvalh.append(nvhdd)
        row = []
        row.append(vvar)
        row.append(vvalr)
        rows.append(row)
        my_rhs.append(ns_rams[i])
        my_sense = my_sense+'L'
        my_rownames.append('rsram_'+str(i))
        row = []
        row.append(vvar)
        row.append(vvalh)
        rows.append(row)
        my_rhs.append(ns_hdds[i])
        my_sense = my_sense+'L'
        my_rownames.append('rshdd_'+str(i))

    for i in range(vis):
        row = []
        var = []
        val = []
        for j in range(host_count):
            var.append("x_"+str(j)+"_"+str(i))
            val.append(1.0)
        my_sense = my_sense+'E'
        row.append(var)
        row.append(val)
        rows.append(row)
        my_rhs.append(1.0)
        my_rownames.append('rnv_'+str(i))

    my_prob.objective.set_sense(my_prob.objective.sense.minimize)

    my_prob.variables.add(obj=my_obj, lb=my_lb, ub=my_ub,
        types=my_ctype, names=my_colnames)

    # pass all parameters to cPlex to solve the equation
    my_prob.linear_constraints.add(lin_expr=rows, senses=my_sense,
        rhs=my_rhs, names=my_rownames)
    # solve the mathematical model
    my_prob.solve()

    numcols = my_prob.variables.get_num()
    numrows = my_prob.linear_constraints.get_num()

    slack = my_prob.solution.get_linear_slacks()
    # get the solution values
    x = my_prob.solution.get_values()

    vi_hosts = {}
    for i in range(vis):
        for j in range(host_count):
            vi_host = (j*vis+1+j)+i
            if x[vi_host] == 1.0:
                vi_hosts[i] = weighedHosts[j]

    #LOG.info('VI Hosts: %(vih)s', {'vih': vi_hosts})
    return vi_hosts
```

Listing 5.2: The cPlex based TUC_scheduler's solve_TUC_Cplex function

The above code listing 5.2 is a cPlex based approach to perform scheduling of virtual instances.

The comparisions of both the schedulers and their performances are provided in the chapter Comparision of performance evaluation.

6 Comparision of performance evaluation

In this chapter, observations are made based on both the schedulers. The data based on default nova scheduler driver and the data based on tuc_scheduler driver are evaluated for different iterations of scheduling of virtual instances. A data set of different number of virtual instance creation is performed on both of the scheduler drivers.

6.1 Observations of standard Nova scheduler

Observing the listing ??, at the line ?? it can be seen that the `get_filtered_hosts` is performed for each virtual instance scheduling rather than once for the whole of the request. This is also followed by line ?? to get weighed hosts for each virtual instance scheduling instead of once for the whole of the request.

In the log trace listing B.2 at the line number 185, it can be observed that, the placement decision of the 10 virtual instances is spread across all the host systems. This creates the need to keep the hosts powered up for all the time.

The log trace listing B.2 provided in the Appendix Logs in chapter FilterScheduler log trace for creation of 10 virtual instances shows the number of times the `get_filtered-_hosts` and `get_weighed_hosts` is called to calculate the placement decision of 10 virtual instances.

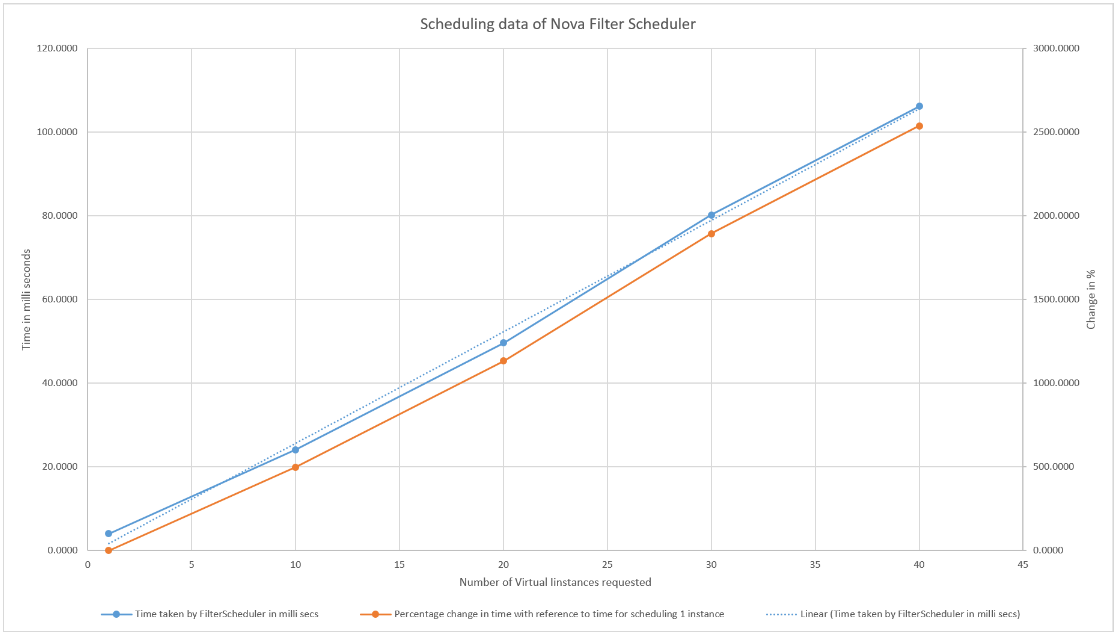


Figure 6.1: Placement decision time for Standard Nova Scheduler from the data C.1

The above table C.1 is the time logs recorded for different requested number of virtual instances. Here in the table, for providing a placement decision of 10 virtual instances, the standard nova scheduler takes around 24.10ms. The percentage change in time is given by the change in time with reference to time for scheduling 1 instance.

6.2 Observations of cPlex based scheduler

Observing the listing 5.1, at the line 45 it can be seen that the `get_filtered_hosts` is executed only once for all the bulk requests of virtual instance scheduling. This is followed by line 55 `solve_TUC_Cplex` to solve the scheduling problem for all the bulk requests.

In the log trace listing B.3 at the line number 39, it can be observed that, the placement decision of all the 10 virtual instances is concentrated on one host system "`compute03`".

The log trace listing B.3 provided in the Appendix Logs in chapter cPlex based Scheduler log trace for creation of 10 virtual instances shows that only one instance of the `get_filtered_hosts` is called to calculate the placement decision of 10 virtual instances.

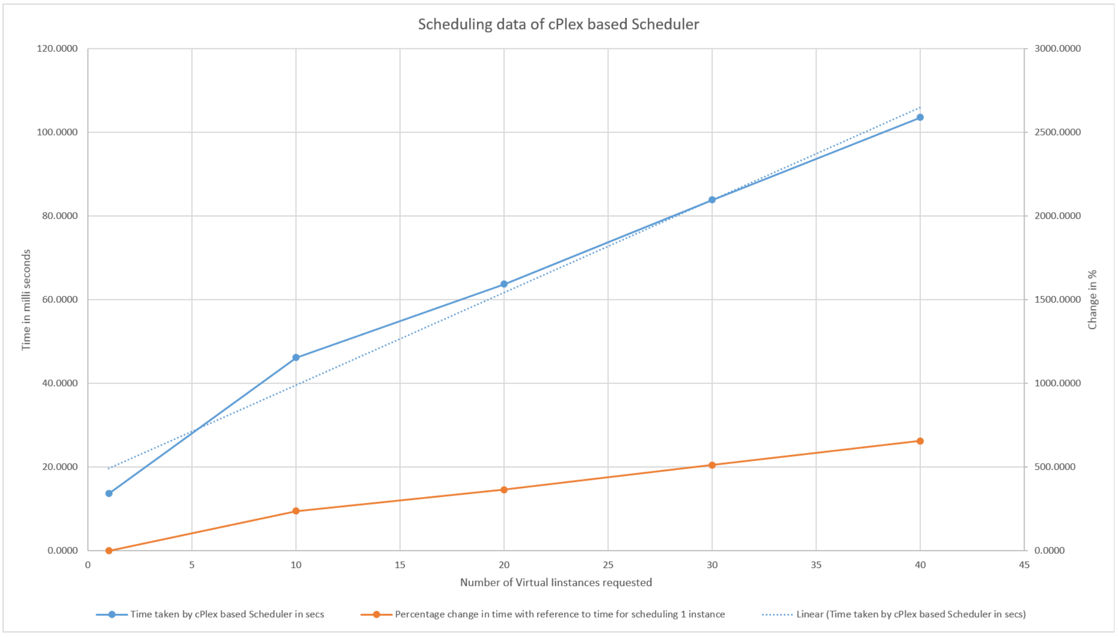


Figure 6.2: Placement decision time for cPlex based Scheduler from the data C.2

If the total requested capacity of RAM or HDD of virtual instances are more than the total available capacities, then the cPlex throws an exception as "unsolvable problem error". This exception is caught by the code and displayed as an error message on the screen.

6.3 Comparision

As stated in sections Observations of standard Nova scheduler and Observations of cPlex based scheduler, the default Filter scheduler places the virtual instances across the hosts, whereas the `tuc_ccn_scheduler` aggregates the creation of virtual instances on minimum possible host systems. As the virtual instances on the new `tuc_ccn_scheduler` are not spread across the multiple machines and aggregated on the few machines, the rest of the machines can be powered down which reduces the operating power costs.

On the other hand, combining the above two charts 6.1 and 6.2, it can be observed that the slope of the cplex based scheduler is lesser than the slope of the standard nova filter scheduler. Which means that, for a larger requests of virtual instances, the cPlex based scheduler would be more efficient in providing the placement decisions for all the requested virtual instances. The initial offset time for execution of cPlex to solve the mathematical problem is higher compared to the standard nova filter scheduler.

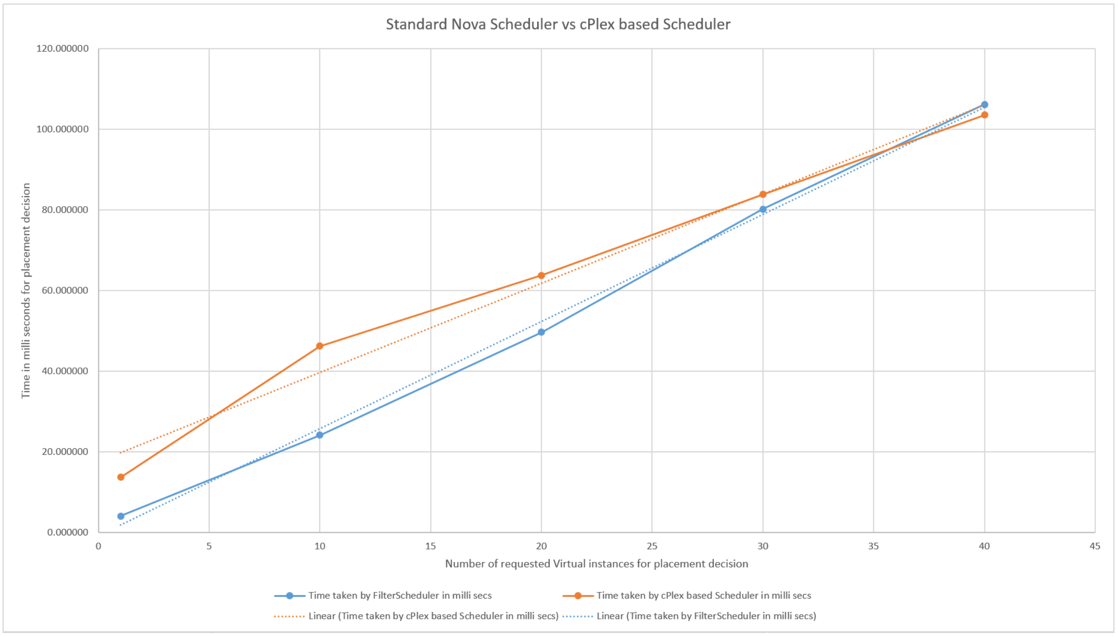


Figure 6.3: Comparision of placement decision time between Standard Nova FilterScheduler and cPlex based Scheduler

From the above chart 6.3, it can be concluded that, the higher the number of requests to schedule the virtual instances the lesser the solving time for scheduling compared to the nova filter scheduler.

6.4 Space for further improvements

As an example, let there be three host machines with a RAM capacity of 16GB each. Let there be 9 virtual machines which consume 4GB of RAM each and shared equally among three host machines. The available capacity of RAM is limited to 4GB on each machine whereas the total available capacity of RAM across all the machines is 12GB. When there is a request for a virtual machine which requires the RAM of 8GB, both the schedulers would fail to make a placement decision for the requested virtual instance as there is no host with an available capacity of 8GB.

"Live Migration" is a functionality which would move the running virtual machine from one physical host machine to another physical host machine with minimum or no downtime. Currently, the OpenStack Liberty has an ongoing issue with "Live Migration". The live migration functionality fails to migrate the virtual instance from the source host machine to requested destination host machine and turns off the virtual instance scheduled for migration. This "Live Migration" functionlity could mitigate the above mentioned issue with runtime reallocation of live(running) virtual machines to free the space by migrating it to any other possible hosts, freeing the space on the host and make a placement decision to allocate a new request of 8GB.

An idea for future could also be to have a shared resource pooling with a high speed dedicated networking bus on the hardware, to make the large clusters of compute servers into a single shared entity.

7 Further possible extensions in OpenStack

Being one of the key open source software platform for Cloud Computing in Infrastructure-as-a-Service model, it has various possible implementations and extensions. As far as networking is concerned, there are modules in and out of OpenStack which provides the Network Functions Virtualization (NFV) for global telecom providers.

Network Functions Virtualization (NFV) allows telecom and enterprise network operators to control their networking functions: physical, virtual and functional domains—using commercial off-the-shelf hardware, and open source software as a single control pane for management and orchestration. Here, OpenStack can provide a platform for the development and evolution of NFV components across the virtual systems. With robust system level integration and deployment a reference NFV platform can be created to accelerate the transformation of enterprise and service provider networks.

Early on, the telecommunications industries and the networking vendors have recognised the potential for OpenStack as a platform for NFV, which triggered investigations and work in development of OpenStack compatible modules to optimize for NFV.

"Network Functions Virtualization (NFV) is now synonymous with OpenStack. When people say NFV, there is an implication that they are talking about OpenStack."[28]

Both the European Telecommunications Standards Institute and Linux Foundation collaboration project OPNFV have defined specifications and released reference platforms for NFV that select OpenStack as the Virtualization Infrastructure Manager. Additionally, OpenStack is the dominant choice for additional management and orchestration functions.[47]

The interoperability between OpenStack and virtualized network functions is still an ongoing development.

So, what does Network Functions Virtualization (NFV) define? To answer in a simple way, it is a new way to define, create, and manage networks by replacing dedicated network appliances with software and automation. It is the idea of replacing the physical network devices which are dedicated and expensive by the virtual software devices.

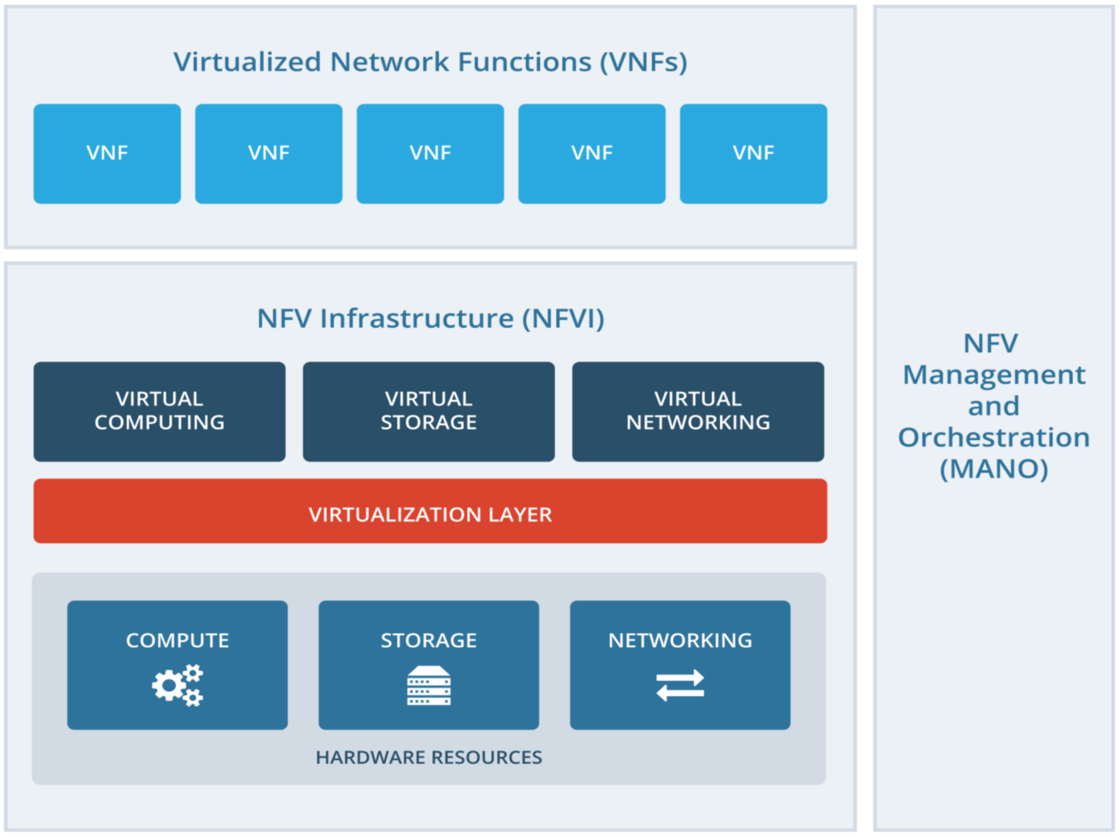


Figure 7.1: NFV functional overview[28]

In an NFV environment, a virtual network function (VNF) takes on the responsibility of handling specific network functions that run on one or more virtual machines (VMs), on bare metal, or in containers, on top of the physical networking infrastructure. A VNF can be an instance of any virtual hardware, for example: message router, CDN, DPI, Firewall, DNS...

The benefits of NFV stem from the fact that it runs on general purpose servers and switches in virtual machines or containers and is built with standard open APIs.

There are many ongoing NFV implementations. To keep it short, two of the NFV projects will be discussed.

- Open Baton
- Tacker

7.1 Open Baton - NFV Orchestrator

Open Baton is an European Telecommunications Standards Institute's (ETSI) NFV compliant Management and Orchestration (MANO) Framework. It enables virtual Network Services deployments on top of the NFV infrastructure.

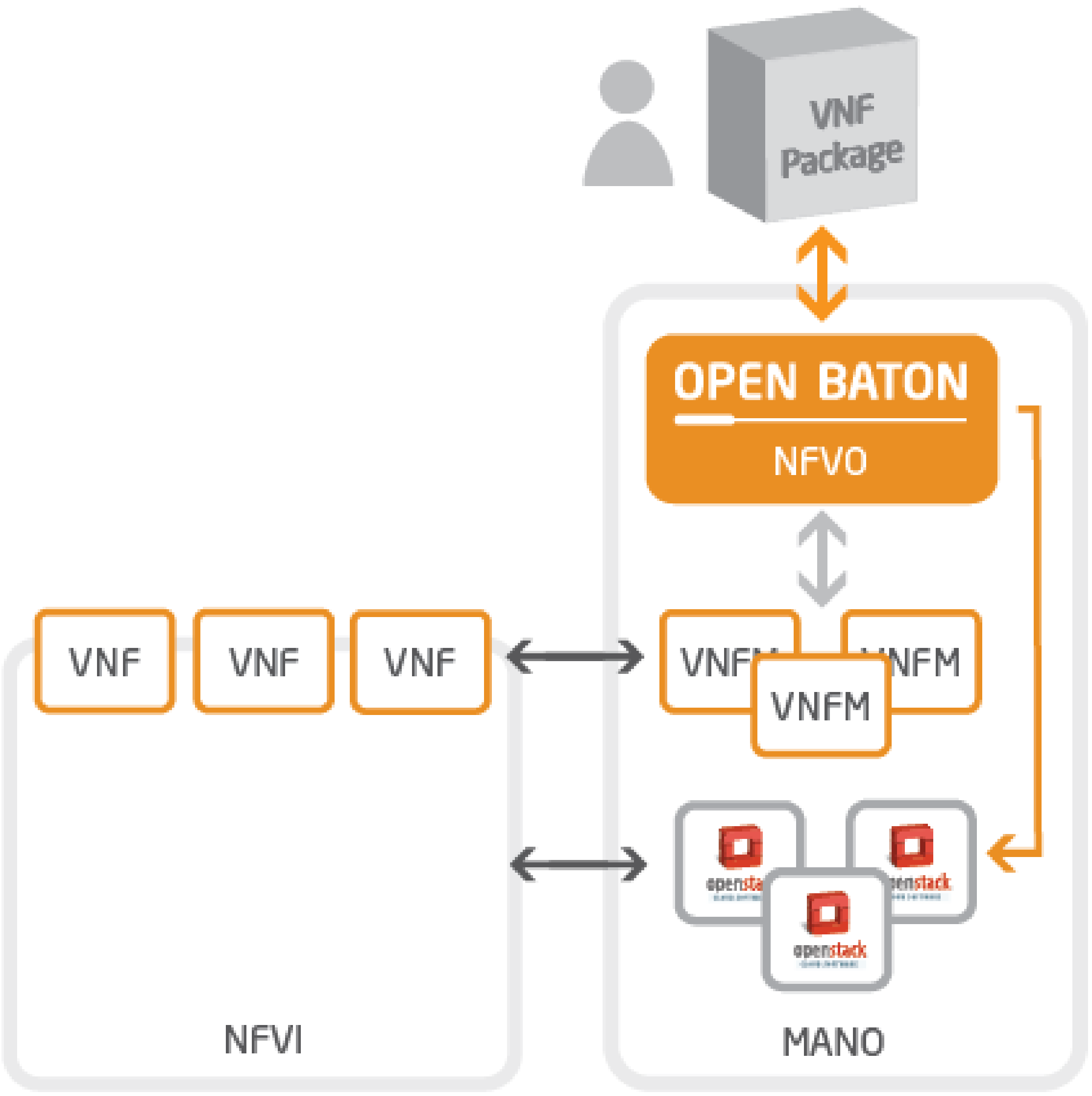


Figure 7.2: Placement of VNFM and VNF over the OpenStack Vitual Machines[29]

The Open Baton software is deployed over OpenStack with its own dashboard which would provide an easy to use web based VNF management console. The VNF is configured on the virtual machine in the OpenStack IaaS.

7.2 Tacker - OpenStack NFV Orchestration

Tacker is an official OpenStack project building a Generic VNF Manager (VNFM) and a NFV Orchestrator (NFVO) to deploy and operate Network Services and Virtual Network Functions (VNFs) on an NFV infrastructure platform like OpenStack. It is based on ETSI MANO Architectural Framework and provides a functional stack to Orchestrate Network Services end-to-end using VNFs.

8 Conclusion

OpenStack is an emerging and stable open source Cloud Infrastructure-as-a-Service operating solution. OpenStack, with it's usage as Compute service- to create cloud based computing or Storage service- for cloud based storage solutions or both combined, is an easily deployable cloud operating solution with minimum infrastructure to start hosting the Cloud service.

As this thesis is focussed on scheduling algorithm of requested virtual instances, it can be observed from the logs in Appendix B.2 that, with the standard nova FilterScheduler, when a large number of virtual instance creation is requested, it iterates for that number of times to provide a placement decision one after the another. There is an opportunity for improvement to solve a large requests with minimum time and better mathematical modelling.

In the section Comparision of the chapter Comparision of performance evaluation, it can be observed that the cPlex based scheduling algorithm is effective in providing a placement decision which would reduce the operating power expense of the OpenStack cloud cluster by minimising the active(powered on) number of hosts.

This is also effective in timely creation of large quantity of virtual instances compared to the existing standard nova scheduler.

This thesis is an approach to have a different possible solution in the scheduling algorithm which could be helpful to have constraint dependant scheduling.

This thesis can also be extended to have two different scheduling solutions depending on the number of requests for creation of the virtual instances. With a condition based on quantity of instance creation, the selection of the scheduler driver can be switched at runtime.

If the "Live Migration" could work effectively, the scheduling algorithm could also include the migration of existing instances to re-arrange itself which would increase the available capacity on the hosts and place new instances with larger configuration requirements. This could also be helpful for live migration of multiple virtual instances when the compute nodes needs a maintenance downtime.

The cloud computing is the growing field of interest which creates lots of opportunities for research and as well as the ideas for business.

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Appendix

Appendix A

Configuration Content

In this Appendix Configuration Content, the reader can find the specifically mentioned configuration.

A.1 RabbitMQ configuration

The RabbitMQ configuration parameters set in the [oslo_messaging_rabbit] are:

```
[oslo_messaging_rabbit]
rabbit_host = controller
rabbit_port = 5672 #define ports
rabbit_hosts = controller:5672
rabbit_userid = openstack
rabbit_password = user
rabbit_use_ssl = false
```

Appendix B

Logs

In this Appendix, the logs from the `scheduler.log` file have been provided for different log purpose.

B.1 FilterScheduler log trace

```
2016-10-23 22:04:46.471 14886 INFO nova.scheduler.filter_scheduler [
    req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: does it come here twice?
2016-10-23 22:04:46.472 14886 INFO nova.scheduler.filter_scheduler [
    req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: select_destinations FilterScheduler: for number of
    instances: 1
2016-10-23 22:04:46.481 14886 INFO nova.scheduler.host_manager [req-6
    f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: get_all_host_states
2016-10-23 22:04:46.499 14886 INFO nova.scheduler.host_manager [req-6
    f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: __init__: HostState
2016-10-23 22:04:46.501 14886 INFO nova.scheduler.host_manager [req-6
    f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _add_instance_info, host_manager = compute01
2016-10-23 22:04:46.519 14886 INFO nova.scheduler.host_manager [req-6
    f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: __init__: HostState
2016-10-23 22:04:46.520 14886 INFO nova.scheduler.host_manager [req-6
    f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _add_instance_info, host_manager = compute03
```

```
2016-10-23 22:04:46.521 14886 INFO nova.scheduler.host_manager [req-6
    f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: __init__: HostState
2016-10-23 22:04:46.521 14886 INFO nova.scheduler.host_manager [req-6
    f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _add_instance_info, host_manager = compute02
2016-10-23 22:04:46.550 14886 INFO nova.scheduler.host_manager [req-6
    f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: __init__: HostState
2016-10-23 22:04:46.551 14886 INFO nova.scheduler.host_manager [req-6
    f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _add_instance_info, host_manager = compute04
2016-10-23 22:04:46.552 14886 INFO nova.scheduler.host_manager [req-6
    f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: __init__: HostState
2016-10-23 22:04:46.552 14886 INFO nova.scheduler.host_manager [req-6
    f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _add_instance_info, host_manager = compute05
2016-10-23 22:04:46.553 14886 INFO nova.scheduler.filter_scheduler [
    req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _schedule FilterScheduler:
2016-10-23 22:04:46.554 14886 INFO nova.scheduler.host_manager [req-6
    f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: get_filtered_hosts: <dictionary-valueiterator object
    at 0x7f9578245fc8>
2016-10-23 22:04:46.554 14886 INFO nova.scheduler.filters.ram_filter
    [req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 11598.0
2016-10-23 22:04:46.555 14886 INFO nova.scheduler.filters.ram_filter
    [req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 48187.5
2016-10-23 22:04:46.555 14886 INFO nova.scheduler.filters.ram_filter
    [req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 48081.0
2016-10-23 22:04:46.556 14886 INFO nova.scheduler.filters.ram_filter
    [req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 23287.5
```

```
2016-10-23 22:04:46.556 14886 INFO nova.scheduler.filters.ram_filter
    [req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 23946.0
2016-10-23 22:04:46.557 14886 INFO nova.scheduler.filters.disk_filter
     [req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 911.0
2016-10-23 22:04:46.557 14886 INFO nova.scheduler.filters.disk_filter
     [req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 219.0
2016-10-23 22:04:46.558 14886 INFO nova.scheduler.filters.disk_filter
     [req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 884.0
2016-10-23 22:04:46.558 14886 INFO nova.scheduler.filters.disk_filter
     [req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 229.0
2016-10-23 22:04:46.559 14886 INFO nova.scheduler.filters.disk_filter
     [req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 458.0
2016-10-23 22:04:46.559 14886 INFO nova.scheduler.filters.
    compute_filter [req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: ComputeFilter
2016-10-23 22:04:46.560 14886 INFO nova.scheduler.filters.
    compute_filter [req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: ComputeFilter
2016-10-23 22:04:46.560 14886 INFO nova.scheduler.filters.
    compute_filter [req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: ComputeFilter
2016-10-23 22:04:46.561 14886 INFO nova.scheduler.filters.
    compute_filter [req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: ComputeFilter
2016-10-23 22:04:46.561 14886 INFO nova.scheduler.filters.
    compute_filter [req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: ComputeFilter
2016-10-23 22:04:46.562 14886 INFO nova.scheduler.weights.metrics [
    req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute04
```

```
2016-10-23 22:04:46.562 14886 INFO nova.scheduler.weights.metrics [
    req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute05
2016-10-23 22:04:46.563 14886 INFO nova.scheduler.weights.metrics [
    req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute02
2016-10-23 22:04:46.563 14886 INFO nova.scheduler.weights.metrics [
    req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute01
2016-10-23 22:04:46.564 14886 INFO nova.scheduler.weights.metrics [
    req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute03
2016-10-23 22:04:46.564 14886 INFO nova.scheduler.host_manager [req-6
    f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: consume_from_instance host_manager.py
2016-10-23 22:04:46.566 14886 INFO nova.scheduler.filter_scheduler [
    req-6f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] 1 number of instances scheduled with filter scheduler in
    0.0127098560333 seconds
2016-10-23 22:04:46.568 14886 INFO nova.scheduler.manager [req-6
    f237d8e-24c6-42ab-b996-ba9e7203601c 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: select_destinations SchedulerManager [{'host': u'
    compute05', 'nodename': u'compute05', 'limits': {'memory_mb':
    48187.5, 'disk_gb': 219.0}}]
```

Listing B.1: The filter scheduler code trace log

The trace starts with date and time of the logs, type of the log like, INFO for information, DEBUG for debug, WARN for warning and ERROR for error types of logs. The path of the python file is mentioned in the next column. At the end, the custom logs are printed with a message.

B.2 FilterScheduler log trace for creation of 10 virtual instances

```
2016-11-23 04:30:00.948 14886 INFO nova.scheduler.filter_scheduler [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    – –] Hanif: select_destinations FilterScheduler: for number of
    instances: 10
2016–11–23 04:30:00.963 14886 INFO nova.scheduler.host_manager [req–
    a2449432–6b13–444f–941c–0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 –
    – –] Hanif: get_all_host_states
2016–11–23 04:30:00.984 14886 INFO nova.scheduler.host_manager [req–
    a2449432–6b13–444f–941c–0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 –
    – –] Hanif: _add_instance_info, host_manager = compute01
2016–11–23 04:30:00.990 14886 INFO nova.scheduler.host_manager [req–
    a2449432–6b13–444f–941c–0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 –
    – –] Hanif: _add_instance_info, host_manager = compute03
2016–11–23 04:30:00.993 14886 INFO nova.scheduler.host_manager [req–
    a2449432–6b13–444f–941c–0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 –
    – –] Hanif: _add_instance_info, host_manager = compute02
2016–11–23 04:30:00.994 14886 INFO nova.scheduler.host_manager [req–
    a2449432–6b13–444f–941c–0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 –
    – –] Hanif: _add_instance_info, host_manager = compute04
2016–11–23 04:30:00.995 14886 INFO nova.scheduler.host_manager [req–
    a2449432–6b13–444f–941c–0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 –
    – –] Hanif: _add_instance_info, host_manager = compute05
2016–11–23 04:30:00.996 14886 INFO nova.scheduler.filter_scheduler [
    req–a2449432–6b13–444f–941c–0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 –
    – –] Hanif: _schedule FilterScheduler:
2016–11–23 04:30:00.997 14886 INFO nova.scheduler.host_manager [req–
    a2449432–6b13–444f–941c–0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 –
    – –] Hanif: get_filtered_hosts: <dictionary–valueiterator object
    at 0x7f957819d838>
2016–11–23 04:30:00.998 14886 INFO nova.scheduler.filters.ram_filter
    [req–a2449432–6b13–444f–941c–0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 –
    – –] Hanif: host_passes: BaseRamFilter: 11598.0
2016–11–23 04:30:00.998 14886 INFO nova.scheduler.filters.ram_filter
    [req–a2449432–6b13–444f–941c–0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 –
    – –] Hanif: host_passes: BaseRamFilter: 48187.5
2016–11–23 04:30:00.998 14886 INFO nova.scheduler.filters.ram_filter
    [req–a2449432–6b13–444f–941c–0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 –
    – –] Hanif: host_passes: BaseRamFilter: 48081.0
2016–11–23 04:30:00.999 14886 INFO nova.scheduler.filters.ram_filter
    [req–a2449432–6b13–444f–941c–0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 23287.5
2016-11-23 04:30:00.999 14886 INFO nova.scheduler.filters.ram_filter
    [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 23946.0
2016-11-23 04:30:00.999 14886 INFO nova.scheduler.filters.disk_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 911.0
2016-11-23 04:30:01.000 14886 INFO nova.scheduler.filters.disk_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 219.0
2016-11-23 04:30:01.000 14886 INFO nova.scheduler.filters.disk_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 884.0
2016-11-23 04:30:01.001 14886 INFO nova.scheduler.filters.disk_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 229.0
2016-11-23 04:30:01.001 14886 INFO nova.scheduler.filters.disk_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 458.0
2016-11-23 04:30:01.001 14886 INFO nova.scheduler.filters.
    compute_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: ComputeFilter
2016-11-23 04:30:01.002 14886 INFO nova.scheduler.filters.
    compute_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: ComputeFilter
2016-11-23 04:30:01.002 14886 INFO nova.scheduler.filters.
    compute_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: ComputeFilter
2016-11-23 04:30:01.003 14886 INFO nova.scheduler.filters.
    compute_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: ComputeFilter
2016-11-23 04:30:01.003 14886 INFO nova.scheduler.filters.
    compute_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: ComputeFilter
2016-11-23 04:30:01.004 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute04
2016-11-23 04:30:01.005 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute05
2016-11-23 04:30:01.006 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute02
2016-11-23 04:30:01.007 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute01
2016-11-23 04:30:01.007 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute03
2016-11-23 04:30:01.007 14886 INFO nova.scheduler.host_manager [req-
    a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: consume_from_instance host_manager.py
2016-11-23 04:30:01.009 14886 INFO nova.scheduler.host_manager [req-
    a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: get_filtered_hosts: [(compute04, compute04) ram:7220
    disk:880640 io_ops:0 instances:0, (compute05, compute05) ram:31101
     disk:207872 io_ops:1 instances:1, (compute02, compute02) ram
    :31542 disk:855040 io_ops:0 instances:0, (compute01, compute01)
    ram:15013 disk:217088 io_ops:0 instances:0, (compute03, compute03)
     ram:15452 disk:440320 io_ops:0 instances:0]
2016-11-23 04:30:01.010 14886 INFO nova.scheduler.filters.ram_filter
    [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 11598.0
2016-11-23 04:30:01.011 14886 INFO nova.scheduler.filters.ram_filter
    [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 48187.5
2016-11-23 04:30:01.011 14886 INFO nova.scheduler.filters.ram_filter
    [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 48081.0
2016-11-23 04:30:01.011 14886 INFO nova.scheduler.filters.ram_filter
    [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 23287.5
2016-11-23 04:30:01.012 14886 INFO nova.scheduler.filters.ram_filter
    [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 23946.0
2016-11-23 04:30:01.012 14886 INFO nova.scheduler.filters.disk_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 911.0
2016-11-23 04:30:01.013 14886 INFO nova.scheduler.filters.disk_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 219.0
2016-11-23 04:30:01.013 14886 INFO nova.scheduler.filters.disk_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 884.0
2016-11-23 04:30:01.015 14886 INFO nova.scheduler.filters.disk_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 229.0
2016-11-23 04:30:01.015 14886 INFO nova.scheduler.filters.disk_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 458.0
2016-11-23 04:30:01.016 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute04
2016-11-23 04:30:01.017 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute05
2016-11-23 04:30:01.017 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute02
2016-11-23 04:30:01.017 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute01
2016-11-23 04:30:01.018 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute03
2016-11-23 04:30:01.018 14886 INFO nova.scheduler.host_manager [req-
    a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: consume_from_instance host_manager.py
2016-11-23 04:30:01.021 14886 INFO nova.scheduler.host_manager [req-
    a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: get_filtered_hosts: [(compute04, compute04) ram:7220
    disk:880640 io_ops:0 instances:0, (compute05, compute05) ram:31101
     disk:207872 io_ops:1 instances:1, (compute02, compute02) ram
    :31030 disk:854016 io_ops:1 instances:1, (compute01, compute01)
    ram:15013 disk:217088 io_ops:0 instances:0, (compute03, compute03)
     ram:15452 disk:440320 io_ops:0 instances:0]
2016-11-23 04:30:01.022 14886 INFO nova.scheduler.filters.ram_filter
    [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 11598.0
2016-11-23 04:30:01.022 14886 INFO nova.scheduler.filters.ram_filter
    [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 48187.5
2016-11-23 04:30:01.023 14886 INFO nova.scheduler.filters.ram_filter
    [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 48081.0
2016-11-23 04:30:01.023 14886 INFO nova.scheduler.filters.ram_filter
    [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 23287.5
2016-11-23 04:30:01.024 14886 INFO nova.scheduler.filters.ram_filter
    [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 23946.0
2016-11-23 04:30:01.024 14886 INFO nova.scheduler.filters.disk_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 911.0
2016-11-23 04:30:01.025 14886 INFO nova.scheduler.filters.disk_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 219.0
2016-11-23 04:30:01.025 14886 INFO nova.scheduler.filters.disk_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 884.0
2016-11-23 04:30:01.026 14886 INFO nova.scheduler.filters.disk_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 229.0
2016-11-23 04:30:01.026 14886 INFO nova.scheduler.filters.disk_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 458.0
2016-11-23 04:30:01.027 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute04
```

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2016-11-23 04:30:01.027 14886 INFO nova.scheduler.weights.metrics [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: _weigh_object: value: 0.0, for host: compute05
2016-11-23 04:30:01.028 14886 INFO nova.scheduler.weights.metrics [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: _weigh_object: value: 0.0, for host: compute02
2016-11-23 04:30:01.028 14886 INFO nova.scheduler.weights.metrics [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: _weigh_object: value: 0.0, for host: compute01
2016-11-23 04:30:01.028 14886 INFO nova.scheduler.weights.metrics [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: _weigh_object: value: 0.0, for host: compute03
2016-11-23 04:30:01.029 14886 INFO nova.scheduler.host_manager [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: consume_from_instance host_manager.py
2016-11-23 04:30:01.031 14886 INFO nova.scheduler.host_manager [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: get_filtered_hosts: [(compute04, compute04) ram:7220 disk:880640 io_ops:0 instances:0, (compute05, compute05) ram:31101 disk:207872 io_ops:1 instances:1, (compute02, compute02) ram:31030 disk:854016 io_ops:1 instances:1, (compute01, compute01) ram:15013 disk:217088 io_ops:0 instances:0, (compute03, compute03) ram:14940 disk:439296 io_ops:1 instances:1]
2016-11-23 04:30:01.032 14886 INFO nova.scheduler.filters.ram_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes: BaseRamFilter: 11598.0
2016-11-23 04:30:01.032 14886 INFO nova.scheduler.filters.ram_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes: BaseRamFilter: 48187.5
2016-11-23 04:30:01.033 14886 INFO nova.scheduler.filters.ram_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes: BaseRamFilter: 48081.0
2016-11-23 04:30:01.033 14886 INFO nova.scheduler.filters.ram_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes: BaseRamFilter: 23287.5
2016-11-23 04:30:01.034 14886 INFO nova.scheduler.filters.ram_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes: BaseRamFilter: 23946.0
```

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2016-11-23 04:30:01.035 14886 INFO nova.scheduler.filters.disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes disk_filter: 911.0
2016-11-23 04:30:01.036 14886 INFO nova.scheduler.filters.disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes disk_filter: 219.0
2016-11-23 04:30:01.036 14886 INFO nova.scheduler.filters.disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes disk_filter: 884.0
2016-11-23 04:30:01.037 14886 INFO nova.scheduler.filters.disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes disk_filter: 229.0
2016-11-23 04:30:01.037 14886 INFO nova.scheduler.filters.disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes disk_filter: 458.0
2016-11-23 04:30:01.037 14886 INFO nova.scheduler.weights.metrics [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: _weigh_object: value: 0.0, for host: compute04
2016-11-23 04:30:01.038 14886 INFO nova.scheduler.weights.metrics [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: _weigh_object: value: 0.0, for host: compute05
%2016-11-23 04:30:01.038 14886 INFO nova.scheduler.weights.metrics [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: _weigh_object: value: 0.0, for host: compute02
%2016-11-23 04:30:01.039 14886 INFO nova.scheduler.weights.metrics [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: _weigh_object: value: 0.0, for host: compute01
%2016-11-23 04:30:01.039 14886 INFO nova.scheduler.weights.metrics [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: _weigh_object: value: 0.0, for host: compute03
%2016-11-23 04:30:01.040 14886 INFO nova.scheduler.host_manager [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: consume_from_instance host_manager.py
%2016-11-23 04:30:01.042 14886 INFO nova.scheduler.host_manager [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: get_filtered_hosts: [(compute04, compute04) ram:7220 disk:880640 io_ops:0 instances:0, (compute05, compute05) ram:31101
```

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     disk:207872 io_ops:1 instances:1, (compute02, compute02) ram
    :31030 disk:854016 io_ops:1 instances:1, (compute01, compute01)
    ram:14501 disk:216064 io_ops:1 instances:1, (compute03, compute03)
     ram:14940 disk:439296 io_ops:1 instances:1]
%2016-11-23 04:30:01.043 14886 INFO nova.scheduler.filters.ram_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 11598.0
%2016-11-23 04:30:01.044 14886 INFO nova.scheduler.filters.ram_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 48187.5
%2016-11-23 04:30:01.044 14886 INFO nova.scheduler.filters.ram_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 48081.0
%2016-11-23 04:30:01.044 14886 INFO nova.scheduler.filters.ram_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 23287.5
%2016-11-23 04:30:01.045 14886 INFO nova.scheduler.filters.ram_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 23946.0
%2016-11-23 04:30:01.045 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 911.0
%2016-11-23 04:30:01.046 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 219.0
%2016-11-23 04:30:01.046 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 884.0
%2016-11-23 04:30:01.047 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 229.0
%2016-11-23 04:30:01.047 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 458.0
%2016-11-23 04:30:01.048 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute04
```

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%2016-11-23 04:30:01.048 14886 INFO nova.scheduler.weights.metrics [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: _weigh_object: value: 0.0, for host: compute05
%2016-11-23 04:30:01.049 14886 INFO nova.scheduler.weights.metrics [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: _weigh_object: value: 0.0, for host: compute02
%2016-11-23 04:30:01.049 14886 INFO nova.scheduler.weights.metrics [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: _weigh_object: value: 0.0, for host: compute01
%2016-11-23 04:30:01.050 14886 INFO nova.scheduler.weights.metrics [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: _weigh_object: value: 0.0, for host: compute03
%2016-11-23 04:30:01.050 14886 INFO nova.scheduler.host_manager [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: consume_from_instance host_manager.py
%2016-11-23 04:30:01.052 14886 INFO nova.scheduler.host_manager [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: get_filtered_hosts: [(compute04, compute04) ram:6708 disk:879616 io_ops:1 instances:1, (compute05, compute05) ram:31101 disk:207872 io_ops:1 instances:1, (compute02, compute02) ram:31030 disk:854016 io_ops:1 instances:1, (compute01, compute01) ram:14501 disk:216064 io_ops:1 instances:1, (compute03, compute03) ram:14940 disk:439296 io_ops:1 instances:1]
%2016-11-23 04:30:01.053 14886 INFO nova.scheduler.filters.ram_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes: BaseRamFilter: 11598.0
%2016-11-23 04:30:01.054 14886 INFO nova.scheduler.filters.ram_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes: BaseRamFilter: 48187.5
%2016-11-23 04:30:01.055 14886 INFO nova.scheduler.filters.ram_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes: BaseRamFilter: 48081.0
%2016-11-23 04:30:01.056 14886 INFO nova.scheduler.filters.ram_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes: BaseRamFilter: 23287.5
%2016-11-23 04:30:01.057 14886 INFO nova.scheduler.filters.ram_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes: BaseRamFilter: 23946.0
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%2016-11-23 04:30:01.057 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 911.0
%2016-11-23 04:30:01.058 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 219.0
%2016-11-23 04:30:01.058 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 884.0
%2016-11-23 04:30:01.058 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 229.0
%2016-11-23 04:30:01.059 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 458.0
%2016-11-23 04:30:01.059 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute04
%2016-11-23 04:30:01.060 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute05
%2016-11-23 04:30:01.060 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute02
%2016-11-23 04:30:01.060 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute01
%2016-11-23 04:30:01.061 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute03
%2016-11-23 04:30:01.061 14886 INFO nova.scheduler.host_manager [req-
    a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: consume_from_instance host_manager.py
%2016-11-23 04:30:01.063 14886 INFO nova.scheduler.host_manager [req-
    a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: get_filtered_hosts: [(compute04, compute04) ram:6708
    disk:879616 io_ops:1 instances:1, (compute05, compute05) ram:30589
```

```
     disk:206848 io_ops:2 instances:2, (compute02, compute02) ram
    :31030 disk:854016 io_ops:1 instances:1, (compute01, compute01)
    ram:14501 disk:216064 io_ops:1 instances:1, (compute03, compute03)
     ram:14940 disk:439296 io_ops:1 instances:1]
%2016-11-23 04:30:01.064 14886 INFO nova.scheduler.filters.ram_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 11598.0
%2016-11-23 04:30:01.065 14886 INFO nova.scheduler.filters.ram_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 48187.5
%2016-11-23 04:30:01.065 14886 INFO nova.scheduler.filters.ram_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 48081.0
%2016-11-23 04:30:01.066 14886 INFO nova.scheduler.filters.ram_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 23287.5
%2016-11-23 04:30:01.066 14886 INFO nova.scheduler.filters.ram_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 23946.0
%2016-11-23 04:30:01.067 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 911.0
%2016-11-23 04:30:01.067 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 219.0
%2016-11-23 04:30:01.068 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 884.0
%2016-11-23 04:30:01.068 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 229.0
%2016-11-23 04:30:01.069 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 458.0
%2016-11-23 04:30:01.069 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute04
```

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%2016-11-23 04:30:01.070 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute05
%2016-11-23 04:30:01.070 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute02
%2016-11-23 04:30:01.071 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute01
%2016-11-23 04:30:01.071 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute03
%2016-11-23 04:30:01.072 14886 INFO nova.scheduler.host_manager [req-
    a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: consume_from_instance host_manager.py
%2016-11-23 04:30:01.074 14886 INFO nova.scheduler.host_manager [req-
    a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: get_filtered_hosts: [(compute04, compute04) ram:6708
    disk:879616 io_ops:1 instances:1, (compute05, compute05) ram:30589
     disk:206848 io_ops:2 instances:2, (compute02, compute02) ram
    :30518 disk:852992 io_ops:2 instances:2, (compute01, compute01)
    ram:14501 disk:216064 io_ops:1 instances:1, (compute03, compute03)
     ram:14940 disk:439296 io_ops:1 instances:1]
%2016-11-23 04:30:01.075 14886 INFO nova.scheduler.filters.ram_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 11598.0
%2016-11-23 04:30:01.076 14886 INFO nova.scheduler.filters.ram_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 48187.5
%2016-11-23 04:30:01.076 14886 INFO nova.scheduler.filters.ram_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 48081.0
%2016-11-23 04:30:01.077 14886 INFO nova.scheduler.filters.ram_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 23287.5
%2016-11-23 04:30:01.077 14886 INFO nova.scheduler.filters.ram_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 23946.0
```

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%2016-11-23 04:30:01.078 14886 INFO nova.scheduler.filters.disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes disk_filter: 911.0
%2016-11-23 04:30:01.078 14886 INFO nova.scheduler.filters.disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes disk_filter: 219.0
%2016-11-23 04:30:01.079 14886 INFO nova.scheduler.filters.disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes disk_filter: 884.0
%2016-11-23 04:30:01.080 14886 INFO nova.scheduler.filters.disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes disk_filter: 229.0
%2016-11-23 04:30:01.080 14886 INFO nova.scheduler.filters.disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes disk_filter: 458.0
%2016-11-23 04:30:01.081 14886 INFO nova.scheduler.weights.metrics [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: _weigh_object: value: 0.0, for host: compute04
%2016-11-23 04:30:01.081 14886 INFO nova.scheduler.weights.metrics [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: _weigh_object: value: 0.0, for host: compute05
%2016-11-23 04:30:01.082 14886 INFO nova.scheduler.weights.metrics [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: _weigh_object: value: 0.0, for host: compute02
%2016-11-23 04:30:01.082 14886 INFO nova.scheduler.weights.metrics [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: _weigh_object: value: 0.0, for host: compute01
%2016-11-23 04:30:01.083 14886 INFO nova.scheduler.weights.metrics [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: _weigh_object: value: 0.0, for host: compute03
%2016-11-23 04:30:01.084 14886 INFO nova.scheduler.host_manager [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: consume_from_instance host_manager.py
%2016-11-23 04:30:01.086 14886 INFO nova.scheduler.host_manager [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: get_filtered_hosts: [(compute04, compute04) ram:6708 disk:879616 io_ops:1 instances:1, (compute05, compute05) ram:30589
```

```
     disk:206848 io_ops:2 instances:2, (compute02, compute02) ram
    :30518 disk:852992 io_ops:2 instances:2, (compute01, compute01)
    ram:14501 disk:216064 io_ops:1 instances:1, (compute03, compute03)
     ram:14428 disk:438272 io_ops:2 instances:2]
%2016-11-23 04:30:01.087 14886 INFO nova.scheduler.filters.ram_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 11598.0
%2016-11-23 04:30:01.088 14886 INFO nova.scheduler.filters.ram_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 48187.5
%2016-11-23 04:30:01.088 14886 INFO nova.scheduler.filters.ram_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 48081.0
%2016-11-23 04:30:01.089 14886 INFO nova.scheduler.filters.ram_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 23287.5
%2016-11-23 04:30:01.089 14886 INFO nova.scheduler.filters.ram_filter
     [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 23946.0
%2016-11-23 04:30:01.090 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 911.0
%2016-11-23 04:30:01.090 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 219.0
%2016-11-23 04:30:01.091 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 884.0
%2016-11-23 04:30:01.091 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 229.0
%2016-11-23 04:30:01.093 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 458.0
%2016-11-23 04:30:01.093 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute04
```

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%2016-11-23 04:30:01.094 14886 INFO nova.scheduler.weights.metrics [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: _weigh_object: value: 0.0, for host: compute05
%2016-11-23 04:30:01.094 14886 INFO nova.scheduler.weights.metrics [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: _weigh_object: value: 0.0, for host: compute02
%2016-11-23 04:30:01.095 14886 INFO nova.scheduler.weights.metrics [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: _weigh_object: value: 0.0, for host: compute01
%2016-11-23 04:30:01.095 14886 INFO nova.scheduler.weights.metrics [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: _weigh_object: value: 0.0, for host: compute03
%2016-11-23 04:30:01.096 14886 INFO nova.scheduler.host_manager [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: consume_from_instance host_manager.py
%2016-11-23 04:30:01.098 14886 INFO nova.scheduler.host_manager [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: get_filtered_hosts: [(compute04, compute04) ram:6708 disk:879616 io_ops:1 instances:1, (compute05, compute05) ram:30077 disk:205824 io_ops:3 instances:3, (compute02, compute02) ram:30518 disk:852992 io_ops:2 instances:2, (compute01, compute01) ram:14501 disk:216064 io_ops:1 instances:1, (compute03, compute03) ram:14428 disk:438272 io_ops:2 instances:2]
%2016-11-23 04:30:01.099 14886 INFO nova.scheduler.filters.ram_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes: BaseRamFilter: 11598.0
%2016-11-23 04:30:01.100 14886 INFO nova.scheduler.filters.ram_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes: BaseRamFilter: 48187.5
%2016-11-23 04:30:01.100 14886 INFO nova.scheduler.filters.ram_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes: BaseRamFilter: 48081.0
%2016-11-23 04:30:01.101 14886 INFO nova.scheduler.filters.ram_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes: BaseRamFilter: 23287.5
%2016-11-23 04:30:01.102 14886 INFO nova.scheduler.filters.ram_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12 b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: host_passes: BaseRamFilter: 23946.0
```

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%2016-11-23 04:30:01.102 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 911.0
%2016-11-23 04:30:01.103 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 219.0
%2016-11-23 04:30:01.103 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 884.0
%2016-11-23 04:30:01.104 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 229.0
%2016-11-23 04:30:01.104 14886 INFO nova.scheduler.filters.
    disk_filter [req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 458.0
%2016-11-23 04:30:01.106 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute04
%2016-11-23 04:30:01.107 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute05
%2016-11-23 04:30:01.107 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute02
%2016-11-23 04:30:01.108 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute01
%2016-11-23 04:30:01.108 14886 INFO nova.scheduler.weights.metrics [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute03
%2016-11-23 04:30:01.109 14886 INFO nova.scheduler.host_manager [req-
    a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: consume_from_instance host_manager.py
%2016-11-23 04:30:01.113 14886 INFO nova.scheduler.filter_scheduler [
    req-a2449432-6b13-444f-941c-0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] 10 number of instances scheduled with filter scheduler in
    0.116468191147 seconds
```

```
%2016−11−23 04:30:01.115 14886 INFO nova.scheduler.manager [req−
    a2449432−6b13−444f−941c−0ffd742e6737 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 −
    − −] Hanif: select_destinations SchedulerManager [{'host': u'
    compute05', 'nodename': u'compute05', 'limits': {'memory_mb':
    48187.5, 'disk_gb': 219.0}}, {'host': u'compute02', 'nodename': u'
    compute02', 'limits': {'memory_mb': 48081.0, 'disk_gb': 884.0}},
    {'host': u'compute03', 'nodename': u'compute03', 'limits': {'
    memory_mb': 23946.0, 'disk_gb': 458.0}}, {'host': u'compute01', '
    nodename': u'compute01', 'limits': {'memory_mb': 23287.5, 'disk_gb
    ': 229.0}}, {'host': u'compute04', 'nodename': u'compute04', '
    limits': {'memory_mb': 11598.0, 'disk_gb': 911.0}}, {'host': u'
    compute05', 'nodename': u'compute05', 'limits': {'memory_mb':
    48187.5, 'disk_gb': 219.0}}, {'host': u'compute02', 'nodename': u'
    compute02', 'limits': {'memory_mb': 48081.0, 'disk_gb': 884.0}},
    {'host': u'compute03', 'nodename': u'compute03', 'limits': {'
    memory_mb': 23946.0, 'disk_gb': 458.0}}, {'host': u'compute05', '
    nodename': u'compute05', 'limits': {'memory_mb': 48187.5, 'disk_gb
    ': 219.0}}, {'host': u'compute02', 'nodename': u'compute02', '
    limits': {'memory_mb': 48081.0, 'disk_gb': 884.0}}]
```

Listing B.2: The filter scheduler log trace for 10 virtual instances

B.3 cPlex based Scheduler log trace for creation of 10 virtual instances

```
2016−11−23 05:30:56.706 15170 INFO nova.scheduler.host_manager [req
    −8849ed8c−fd84−43bc−85de−9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 −
    − −] Hanif: get_all_host_states
2016−11−23 05:30:56.729 15170 INFO nova.scheduler.host_manager [req
    −8849ed8c−fd84−43bc−85de−9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 −
    − −] Hanif: _add_instance_info, host_manager = compute01
2016−11−23 05:30:56.754 15170 INFO nova.scheduler.host_manager [req
    −8849ed8c−fd84−43bc−85de−9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 −
    − −] Hanif: _add_instance_info, host_manager = compute03
2016−11−23 05:30:56.776 15170 INFO nova.scheduler.host_manager [req
    −8849ed8c−fd84−43bc−85de−9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 −
    − −] Hanif: _add_instance_info, host_manager = compute02
2016−11−23 05:30:56.800 15170 INFO nova.scheduler.host_manager [req
    −8849ed8c−fd84−43bc−85de−9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _add_instance_info, host_manager = compute04
2016-11-23 05:30:56.823 15170 INFO nova.scheduler.host_manager [req
    -8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _add_instance_info, host_manager = compute05
2016-11-23 05:30:56.853 15170 INFO nova.scheduler.host_manager [req
    -8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: get_filtered_hosts: <dictionary-valueiterator object
    at 0x7f548d5c57e0>
2016-11-23 05:30:56.854 15170 INFO nova.scheduler.filters.ram_filter
    [req-8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 11598.0
2016-11-23 05:30:56.854 15170 INFO nova.scheduler.filters.ram_filter
    [req-8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 48187.5
2016-11-23 05:30:56.855 15170 INFO nova.scheduler.filters.ram_filter
    [req-8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 48081.0
2016-11-23 05:30:56.855 15170 INFO nova.scheduler.filters.ram_filter
    [req-8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 23287.5
2016-11-23 05:30:56.855 15170 INFO nova.scheduler.filters.ram_filter
    [req-8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: BaseRamFilter: 23946.0
2016-11-23 05:30:56.856 15170 INFO nova.scheduler.filters.disk_filter
     [req-8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 911.0
2016-11-23 05:30:56.856 15170 INFO nova.scheduler.filters.disk_filter
     [req-8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 219.0
2016-11-23 05:30:56.857 15170 INFO nova.scheduler.filters.disk_filter
     [req-8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 884.0
2016-11-23 05:30:56.857 15170 INFO nova.scheduler.filters.disk_filter
     [req-8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 229.0
2016-11-23 05:30:56.858 15170 INFO nova.scheduler.filters.disk_filter
     [req-8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes disk_filter: 458.0
2016-11-23 05:30:56.858 15170 INFO nova.scheduler.filters.
    compute_filter [req-8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: ComputeFilter
2016-11-23 05:30:56.859 15170 INFO nova.scheduler.filters.
    compute_filter [req-8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: ComputeFilter
2016-11-23 05:30:56.859 15170 INFO nova.scheduler.filters.
    compute_filter [req-8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: ComputeFilter
2016-11-23 05:30:56.859 15170 INFO nova.scheduler.filters.
    compute_filter [req-8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: ComputeFilter
2016-11-23 05:30:56.860 15170 INFO nova.scheduler.filters.
    compute_filter [req-8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: host_passes: ComputeFilter
2016-11-23 05:30:56.860 15170 INFO nova.scheduler.weights.metrics [
    req-8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute04
2016-11-23 05:30:56.861 15170 INFO nova.scheduler.weights.metrics [
    req-8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute05
2016-11-23 05:30:56.861 15170 INFO nova.scheduler.weights.metrics [
    req-8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute02
2016-11-23 05:30:56.862 15170 INFO nova.scheduler.weights.metrics [
    req-8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute01
2016-11-23 05:30:56.863 15170 INFO nova.scheduler.weights.metrics [
    req-8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: _weigh_object: value: 0.0, for host: compute03
2016-11-23 05:30:56.985 15170 INFO nova.scheduler.host_manager [req
    -8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: consume_from_instance host_manager.py
2016-11-23 05:30:56.987 15170 INFO nova.scheduler.host_manager [req
    -8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: consume_from_instance host_manager.py
2016-11-23 05:30:56.989 15170 INFO nova.scheduler.host_manager [req
    -8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: consume_from_instance host_manager.py
2016-11-23 05:30:56.992 15170 INFO nova.scheduler.host_manager [req
    -8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: consume_from_instance host_manager.py
2016-11-23 05:30:56.994 15170 INFO nova.scheduler.host_manager [req
    -8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: consume_from_instance host_manager.py
2016-11-23 05:30:56.996 15170 INFO nova.scheduler.host_manager [req
    -8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: consume_from_instance host_manager.py
2016-11-23 05:30:56.999 15170 INFO nova.scheduler.host_manager [req
    -8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: consume_from_instance host_manager.py
2016-11-23 05:30:57.001 15170 INFO nova.scheduler.host_manager [req
    -8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: consume_from_instance host_manager.py
2016-11-23 05:30:57.003 15170 INFO nova.scheduler.host_manager [req
    -8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: consume_from_instance host_manager.py
2016-11-23 05:30:57.005 15170 INFO nova.scheduler.host_manager [req
    -8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] Hanif: consume_from_instance host_manager.py
2016-11-23 05:30:57.007 15170 INFO nova.scheduler.tuc_ccn_scheduler [
    req-8849ed8c-fd84-43bc-85de-9a65e9dcabbd 12
    b8f78400724c8fa549aec66ad1a43a 9ea57ff8c67544b78c8096ea4dc1d081 -
    - -] 10 number of instances scheduled with tuc scheduler in
    0.142965078354 seconds
2016-11-23 05:30:57.009 15170 INFO nova.scheduler.manager [req-8849
    ed8c-fd84-43bc-85de-9a65e9dcabbd 12b8f78400724c8fa549aec66ad1a43a
    9ea57ff8c67544b78c8096ea4dc1d081 - - -] Hanif: select_destinations
     SchedulerManager [{'host': u'compute03', 'nodename': u'compute03
    ', 'limits': {'memory_mb': 23946.0, 'disk_gb': 458.0}}, {'host': u
    'compute03', 'nodename': u'compute03', 'limits': {'memory_mb':
    23946.0, 'disk_gb': 458.0}}, {'host': u'compute03', 'nodename': u'
    compute03', 'limits': {'memory_mb': 23946.0, 'disk_gb': 458.0}},
    {'host': u'compute03', 'nodename': u'compute03', 'limits': {'
    memory_mb': 23946.0, 'disk_gb': 458.0}}, {'host': u'compute03', '
    nodename': u'compute03', 'limits': {'memory_mb': 23946.0, 'disk_gb
    ': 458.0}}, {'host': u'compute03', 'nodename': u'compute03', '
    limits': {'memory_mb': 23946.0, 'disk_gb': 458.0}}, {'host': u'
    compute03', 'nodename': u'compute03', 'limits': {'memory_mb':
    23946.0, 'disk_gb': 458.0}}, {'host': u'compute03', 'nodename': u'
    compute03', 'limits': {'memory_mb': 23946.0, 'disk_gb': 458.0}},
    {'host': u'compute03', 'nodename': u'compute03', 'limits': {'
    memory_mb': 23946.0, 'disk_gb': 458.0}}, {'host': u'compute03', '
    nodename': u'compute03', 'limits': {'memory_mb': 23946.0, 'disk_gb
    ': 458.0}}]
```

Listing B.3: The cPlex based scheduler log trace for 10 virtual instances

Appendix C

Performance Data

In this Appendix Performance Data, the time required for placement decision of the virtual instances is captured in the logs of the `scheduler.log` file and have been used for comparision and performance evaluation.

C.1 FilterScheduler's Scheduling Time Logs Data

The time taken for the FilterScheduler for placement decision of virtual instances on the hosts for different number of data set has been recorded.

```
2016-11-23 06:17:59.466 17314 INFO nova.scheduler.filter_scheduler:
    Hanif: _schedule FilterScheduler:
2016-11-23 06:17:59.471 17314 INFO nova.scheduler.filter_scheduler: 1
     number of instances scheduled with filter scheduler in
    0.00402498245239 seconds

2016-11-23 06:23:39.579 17314 INFO nova.scheduler.filter_scheduler:
    Hanif: _schedule FilterScheduler:
2016-11-23 06:23:39.590 17314 INFO nova.scheduler.filter_scheduler: 5
     number of instances scheduled with filter scheduler in
    0.0108880996704 seconds

2016-11-23 06:25:55.949 17314 INFO nova.scheduler.filter_scheduler:
    Hanif: _schedule FilterScheduler:
2016-11-23 06:25:55.975 17314 INFO nova.scheduler.filter_scheduler:
    10 number of instances scheduled with filter scheduler in
    0.0240979194641 seconds

2016-11-23 06:37:36.863 17314 INFO nova.scheduler.filter_scheduler:
    Hanif: _schedule FilterScheduler:
2016-11-23 06:37:36.914 17314 INFO nova.scheduler.filter_scheduler:
    20 number of instances scheduled with filter scheduler in
    0.0496470928192 seconds
```

```

2016-11-23 06:41:16.201 17314 INFO nova.scheduler.filter_scheduler:
    Hanif: _schedule FilterScheduler:
2016-11-23 06:41:16.282 17314 INFO nova.scheduler.filter_scheduler:
    30 number of instances scheduled with filter scheduler in
    0.0802478790283 seconds

2016-11-23 06:50:20.638 17314 INFO nova.scheduler.filter_scheduler:
    Hanif: _schedule FilterScheduler:
2016-11-23 06:50:20.746 17314 INFO nova.scheduler.filter_scheduler 40
     number of instances scheduled with filter scheduler in
    0.10618185997 seconds
```

Listing C.1: The filter scheduler based scheduler time logs for scheduling different numbers of virtual instances

Requested Number of Instances	Time taken by Filter-Scheduler in secs	Percentage change in time with reference to time taken for scheduling 1 instance
1	4.03ms	0.00%
10	24.10ms	498.70%
20	49.65ms	1133.47%
30	80.25ms	1893.74%
40	106.18ms	2538.07%

Table C.1: FilterScheduler Time Data

C.2 TUC CCN Scheduler's Scheduling Time Logs Data

The time taken for the TUC_CCN_Scheduler for placement decision of virtual instances on the hosts for different numbers of data set has been recorded.

```
2016-11-23 07:01:33.293 27964 INFO nova.scheduler.tuc_ccn_scheduler:
    Hanif: _schedule tuc_ccn_scheduler
2016-11-23 07:01:33.310 27964 INFO nova.scheduler.tuc_ccn_scheduler:
    1 number of instances scheduled with tuc scheduler in
    0.0136959552765 seconds

```

```
2016-11-23 07:25:37.228 27964 INFO nova.scheduler.tuc_ccn_scheduler:
    Hanif: _schedule tuc_ccn_scheduler
2016-11-23 07:25:37.283 27964 INFO nova.scheduler.tuc_ccn_scheduler:
    5 number of instances scheduled with tuc scheduler in
    0.049889087677 seconds

2016-11-23 07:12:07.047 27964 INFO nova.scheduler.tuc_ccn_scheduler:
    Hanif: _schedule tuc_ccn_scheduler
2016-11-23 07:12:07.097 27964 INFO nova.scheduler.tuc_ccn_scheduler:
    10 number of instances scheduled with tuc scheduler in
    0.0462019443512 seconds

2016-11-23 07:28:47.675 27964 INFO nova.scheduler.tuc_ccn_scheduler:
    Hanif: _schedule tuc_ccn_scheduler
2016-11-23 07:28:47.741 27964 INFO nova.scheduler.tuc_ccn_scheduler:
    20 number of instances scheduled with tuc scheduler in
    0.0637698173523 seconds

2016-11-23 07:37:45.585 27964 INFO nova.scheduler.tuc_ccn_scheduler:
    Hanif: _schedule tuc_ccn_scheduler
2016-11-23 07:37:45.672 27964 INFO nova.scheduler.tuc_ccn_scheduler:
    30 number of instances scheduled with tuc scheduler in
    0.0839061737061 seconds

2016-11-23 08:11:37.874 27964 INFO nova.scheduler.tuc_ccn_scheduler:
    Hanif: _schedule tuc_ccn_scheduler
2016-11-23 08:11:37.979 27964 INFO nova.scheduler.tuc_ccn_scheduler:
    40 number of instances scheduled with tuc scheduler in
    0.103586912155 seconds
```

Listing C.2: The tuc_ccn_scheduler scheduler based time logs for scheduling different amounts of virtual instances

Requested Number of Instances	Time taken by Filter-Scheduler in secs	Percentage change in time
1	13.69ms	0%
10	46.20ms	237%
20	63.77ms	365%
30	83.91ms	512%
40	103.59ms	656%

Table C.2: cPlex based Scheduler Time Data

Versicherung

Hiermit versichere ich, dass ich die vorliegende Arbeit ohne unzulässige Hilfe Dritter und ohne Benutzung anderer als der angegebenen Hilfsmittel angefertigt habe; die aus fremden Quellen direkt oder indirekt übernommenen Gedanken sind als solche kenntlich gemacht.
Bei der Auswahl und Auswertung des Materials sowie bei der Herstellung des Manuskripts habe ich Unterstützungsleistungen von folgenden Personen erhalten:

keine

Weitere Personen waren an der Abfassung der vorliegenden Arbeit nicht beteiligt. Die Hilfe eines Promotionsberaters habe ich nicht in Anspruch genommen. Weitere Personen haben von mir keine geldwerten Leistungen für Arbeiten erhalten, die im Zusammenhang mit dem Inhalt der vorgelegten Dissertation stehen.

Die Arbeit wurde bisher weder im Inland noch im Ausland in gleicher oder ähnlicher Form einer anderen Prüfungsbehörde vorgelegt.

Chemnitz, March 18, 2017

Nishant Ravi