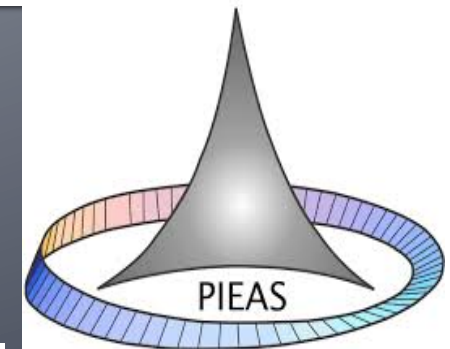


# Open Network Operating System (ONOS) Learning Tutorial

Muhammad Imran (Ph.D Scholar)  
Department of Computer and Information Sciences,  
Pakistan Institute of Engineering and Applied Sciences, Islamabad.



# Contents

- Introduction
  - SDN
    - What, Why and Where?
  - ONOS
- Building ONOS for Development
  - Prerequisites and Setup
  - Install Required Software
- ONOS Major Components
  - Mininet
    - Walkthrough
    - Basic Commands
  - Basic ONOS
    - CLI Commands
    - Graphical User Interface
  - Development Environment
    - Importing and Building Application
    - Generate Your ONOS Application

# Introduction

- Computing has advanced rapidly over the past three decades.
- But the networking has remained virtually unchanged.
- The networks themselves have become a critical component of all infrastructures in society.
- Networks are also important part of the emerging public and private clouds.

# Traditional Network Systems

- The traditional network devices are:
  - Closed
  - Complex
  - Inflexible
  - Proprietary
  - Operationally Expensive
  - Not supported for innovation and progress

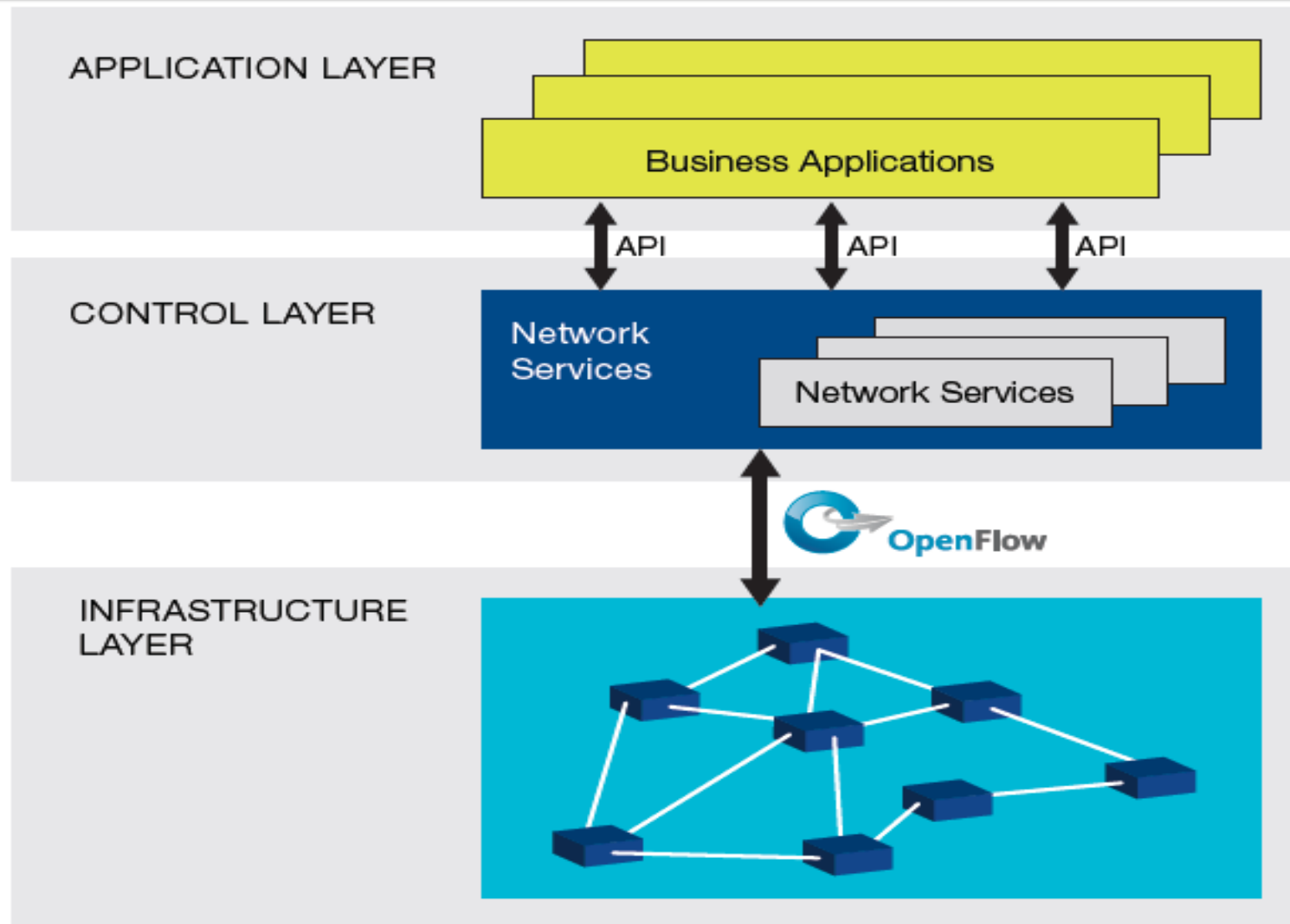
# Problems with Traditional Systems

- In this environment, it is too difficult, if not impossible, for network operators, third parties, and even vendors to innovate.
- Operators cannot customize and optimize networks for their use cases that are relevant to their business and cannot offer customized solutions to their customers.
- Traditional networks lack a common set of APIs, which make it very difficult to program applications directly to network resources.

# Software Defined Network (SDN)

- Software Defined Networking (SDN) separates the control plane from the data plane.
- Freeing software innovation cycles to become independent of hardware innovation cycles.
- SDN accelerates Internet and Cloud innovation while significantly reducing the costs of building and operating networks.

# SDN Architecture



# Why to use SDN?

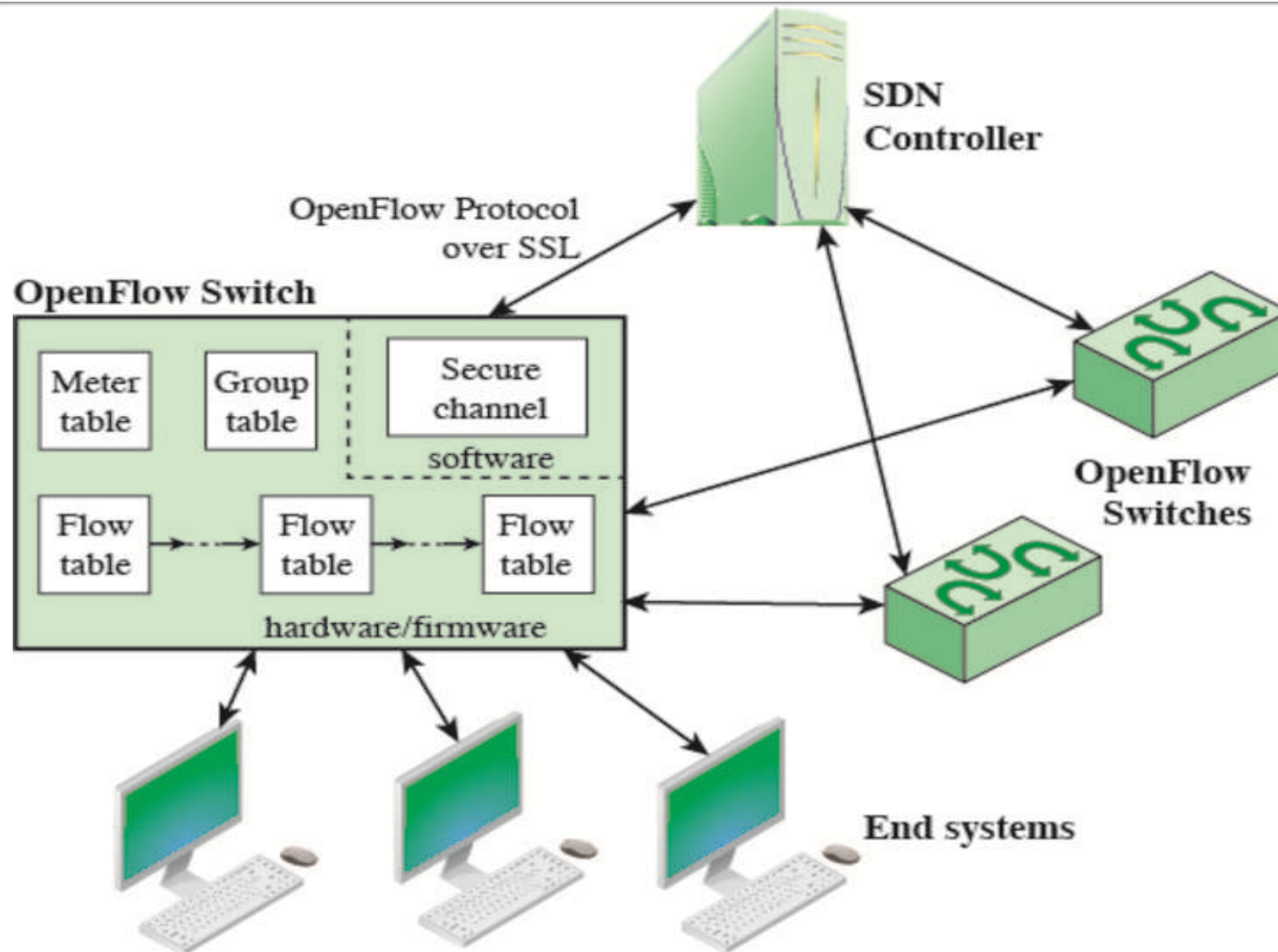
- The software defined networks are:
  - Open
  - Simple
  - Flexible
  - Reduced operational costs
  - Improved network visibility
  - To support the innovation and progress



# Why and Where to Deploy?

- SDN support for network "slices" in campus environments, which enable IT managers to segment the network for specific departments (such as research and development) while allowing other network user groups to run independently.
- Enterprises
- Data centers

# OpenFlow (OF)



# SDN Operating Systems (Controllers)

- Following are some Open and community driven controllers:
  - Open Daylight
  - ONOS (Open Networking Operating System)
  - Project Floodlight
  - Beacon
  - NOX/POX
  - Open vSwitch
  - Ryu Controller (supported by NTT Labs)
  - Faucet (Python based on Ryu for production networks)

# Open Networking Operating System (ONOS)

- ONOS is a SDN operating system for service providers to make it easy to create apps and services.
- Top-Level Features:
  - High availability through clustering and distributed state management.
  - Scalability through clustering and sharing of network device control.
  - Northbound abstractions for a global network view, network graph and application intents.
  - Pluggable southbound for support of OpenFlow and new or legacy protocols.
  - Graphical user interface to view multi-layer topologies and inspect elements of the topology.
  - REST API for access to Northbound abstractions as well as CLI commands.
  - CLI for debugging.
  - Support for both proactive and reactive flow setup.

# Official Releases

Name	Version	JAVA API	Date	File types	Release Notes	Documentation
Ibis	1.8.0	<a href="#">API-1.8.0</a>	Dec. 9, 2016	<a href="#">zip</a> , <a href="#">tar.gz</a>	<a href="#">Coming soon</a>	<a href="#">Coming soon</a>
Hummingbird	1.7.1	<a href="#">API-1.7.1</a>	Oct. 25, 2016	<a href="#">zip</a> , <a href="#">tar.gz</a>	<a href="#">Release Notes for 1.7.1</a>	<a href="#">Coming soon</a>
	1.7.0	<a href="#">API-1.7.0</a>	Sept. 23, 2016	<a href="#">zip</a> , <a href="#">tar.gz</a>	<a href="#">Release Notes for 1.7.0</a>	
Goldeneye	1.6.0	<a href="#">API-1.6.0</a>	Jun. 24, 2016	<a href="#">zip</a> , <a href="#">tar.gz</a>	<a href="#">Release Notes for 1.6.0</a>	<a href="#">Coming soon</a>
Falcon	1.5.1	<a href="#">API-1.5.1</a>	Apr. 20, 2016	<a href="#">zip</a> , <a href="#">tar.gz</a>	<a href="#">Release Notes for 1.5.1</a>	<a href="#">Documentation for 1.5.x</a>
	1.5.0	<a href="#">API-1.5.0</a>	Mar. 10, 2016	<a href="#">zip</a> , <a href="#">tar.gz</a>	<a href="#">Release Notes for 1.5.0</a>	
Emu	1.4.0	<a href="#">API-1.4.0</a>	Dec. 16, 2015	<a href="#">zip</a> , <a href="#">tar.gz</a>	<a href="#">Release Notes for 1.4.0</a>	<a href="#">Documentation for 1.4.x</a>
Drake	1.3.0	<a href="#">API-1.3.0</a>	Sept. 18, 2015	<a href="#">zip</a> , <a href="#">tar.gz</a> , <a href="#">deb</a> , <a href="#">rpm</a>	<a href="#">Release Notes for 1.3.0</a>	<a href="#">Documentation for 1.3.x</a>
Cardinal	1.2.2	<a href="#">API-1.2.2</a>	Sept. 1, 2015	<a href="#">zip</a> , <a href="#">tar.gz</a>	<a href="#">Release Notes for 1.2.2</a>	<a href="#">Documentation for 1.2.x</a>
	1.2.1	<a href="#">API-1.2.1</a>	June 25, 2015	<a href="#">zip</a> , <a href="#">tar.gz</a>	<a href="#">Release Notes for 1.2.1</a>	
	1.2.0	<a href="#">API-1.2.0</a>	June 5, 2015	<a href="#">zip</a> , <a href="#">tar.gz</a>	<a href="#">Release Notes for 1.2.0</a>	
Blackbird	1.1.0	<a href="#">API-1.1.0</a>	Mar. 17, 2015	<a href="#">zip</a> , <a href="#">tar.gz</a>	<a href="#">Release Notes for 1.1.0</a>	<a href="#">Documentation for 1.1.x</a>
Avocet	1.0.1	<a href="#">API-1.0.1</a>	Jan. 22, 2015	<a href="#">zip</a> , <a href="#">tar.gz</a>	<a href="#">Release Notes for 1.0.1</a>	<a href="#">Documentation for 1.0.x</a>
	1.0.0	<a href="#">API-1.0.0</a>	Dec. 5, 2014	<a href="#">zip</a> , <a href="#">tar.gz</a>	<a href="#">Release Notes for 1.0.0</a>	

# ONOS Partners



# ONOS Deployment Models

- In broad scenario, there are four ONOS deployment models
  - Full build and full remote deployment
  - Full build and full local deployment
  - Application build and remote redeployment
  - Application build and local redeployment

# Building ONOS

- In this tutorial, we will build the complete ONOS development environment from scratch in a Virtual Machine.
- Hardware Requirements (**minimum**) :
  - Core i7 Processor (**Core i3**)
  - 8 GB RAM (**4GB**)
  - 40 GB Disk Space (**15 GB**)



# Required Softwares

- Following softwares are required:
  - Oracle Virtual Box (or VM Ware)
  - Ubuntu 14.04
  - Java 8 JDK (Oracle Java recommended)
  - Apache Maven 3.3.9
  - Apache Karaf 3.0.5
  - ONOS 1.8.1
  - IDE IntelliJ (or Eclipse)

# Conventions

- The commands at the build machine shell will start with `sdn@ONOS:~$`
  - `sdn@ONOS:~$ sudo su`
  - `root@ONOS:~#`
- Commands at the shell of the remote onos shell will begin with `sdn@onos1:~$`
  - `sdn@onos1:~$ sudo su`
  - `sdn@onos1:~#`

# Virtual Environment Setup

- Install Oracle's Virtual Box
- Create a new VM with following specifications:
  - Ubuntu Server 14.04 LTS 64-bit
  - 2GB or more RAM
  - 2 or more processors
  - 15GB or more hard disk
  - 2 network adapters

# VM Settings

The screenshot displays the Oracle VM VirtualBox Manager interface. On the left, a list of virtual machines is shown, with 'ONOS' selected and highlighted in blue. The main area is divided into two panes: 'General' and 'Preview'. The 'General' pane shows the VM's name as 'ONOS' and its operating system as 'Ubuntu (64-bit)'. Below this, the 'System' section lists the base memory as 4096 MB, 2 processors, and the boot order as 'Optical, Hard Disk'. The 'Display' section shows 24 MB of video memory and disabled remote desktop and video capture. The 'Storage' section shows an IDE controller with a secondary master drive containing the 'ubuntu-14.04.1-desktop-amd64.iso' (981.00 MB) and a SATA controller with a primary drive 'ONOS.vdi' (32.00 GB). The 'Audio' section shows the host driver as 'Windows DirectSound' and the controller as 'ICH AC97'. The 'Network' section shows two adapters: 'Intel PRO/1000 MT Desktop (Bridged Adapter, Intel(R) Ethernet Connection (2) I219-LM)' and 'Intel PRO/1000 MT Desktop (Host-only Adapter, 'VirtualBox Host-Only Ethernet Adapter)'. The 'USB' section shows the controller as 'OHCI, EHCI' and no active device filters.

Oracle VM VirtualBox Manager

File Machine Help

New Settings Discard Start

Details Snapshots

**SDN** Powered Off

**Mininet** Powered Off

**SecurityOnion** Powered Off

**Ubuntu GNS3** Powered Off

**ONOS-Tutorial\_1** Powered Off

**ONOS-Build** Powered Off

**ONOS** Powered Off

**General**

Name: ONOS  
Operating System: Ubuntu (64-bit)

**System**

Base Memory: 4096 MB  
Processors: 2  
Boot Order: Optical, Hard Disk  
Acceleration: VT-x/AMD-V, Nested Paging, KVM Paravirtualization

**Preview**

ONOS

**Display**

Video Memory: 24 MB  
Remote Desktop Server: Disabled  
Video Capture: Disabled

**Storage**

Controller: IDE  
IDE Secondary Master: [Optical Drive] ubuntu-14.04.1-desktop-amd64.iso (981.00 MB)  
Controller: SATA  
SATA Port 0: ONOS.vdi (Normal, 32.00 GB)

**Audio**

Host Driver: Windows DirectSound  
Controller: ICH AC97

**Network**

Adapter 1: Intel PRO/1000 MT Desktop (Bridged Adapter, Intel(R) Ethernet Connection (2) I219-LM)  
Adapter 2: Intel PRO/1000 MT Desktop (Host-only Adapter, 'VirtualBox Host-Only Ethernet Adapter')

**USB**

USB Controller: OHCI, EHCI  
Device Filters: 0 (0 active)

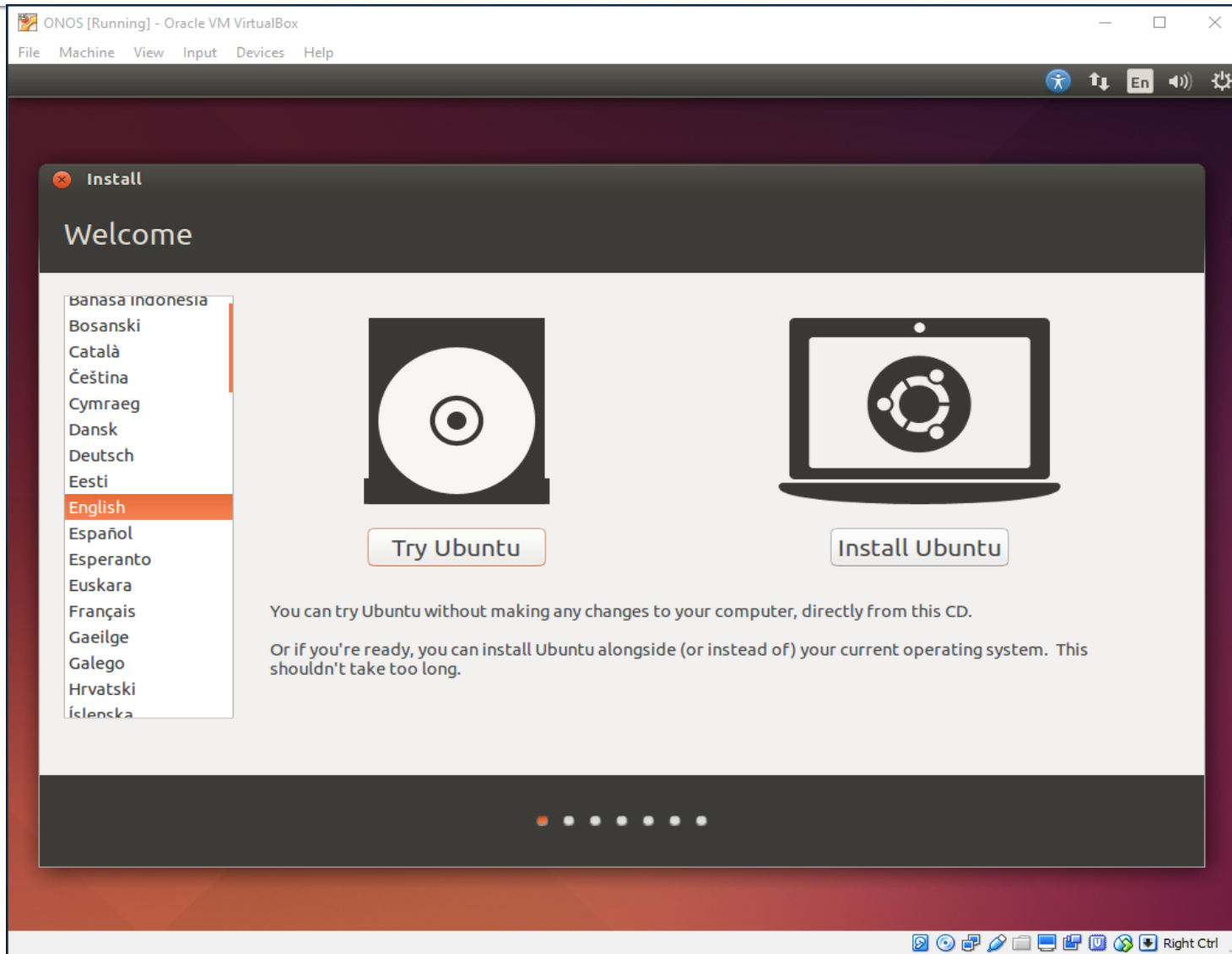
# VM Settings

The screenshot displays the Oracle VM VirtualBox Manager interface. On the left, a list of virtual machines is shown, with 'ONOS' selected and highlighted in blue. The main area shows the settings for the 'ONOS' VM, organized into several tabs: General, System, Display, Storage, Audio, Network, and USB. The 'ONOS' VM is currently powered off. The settings are as follows:

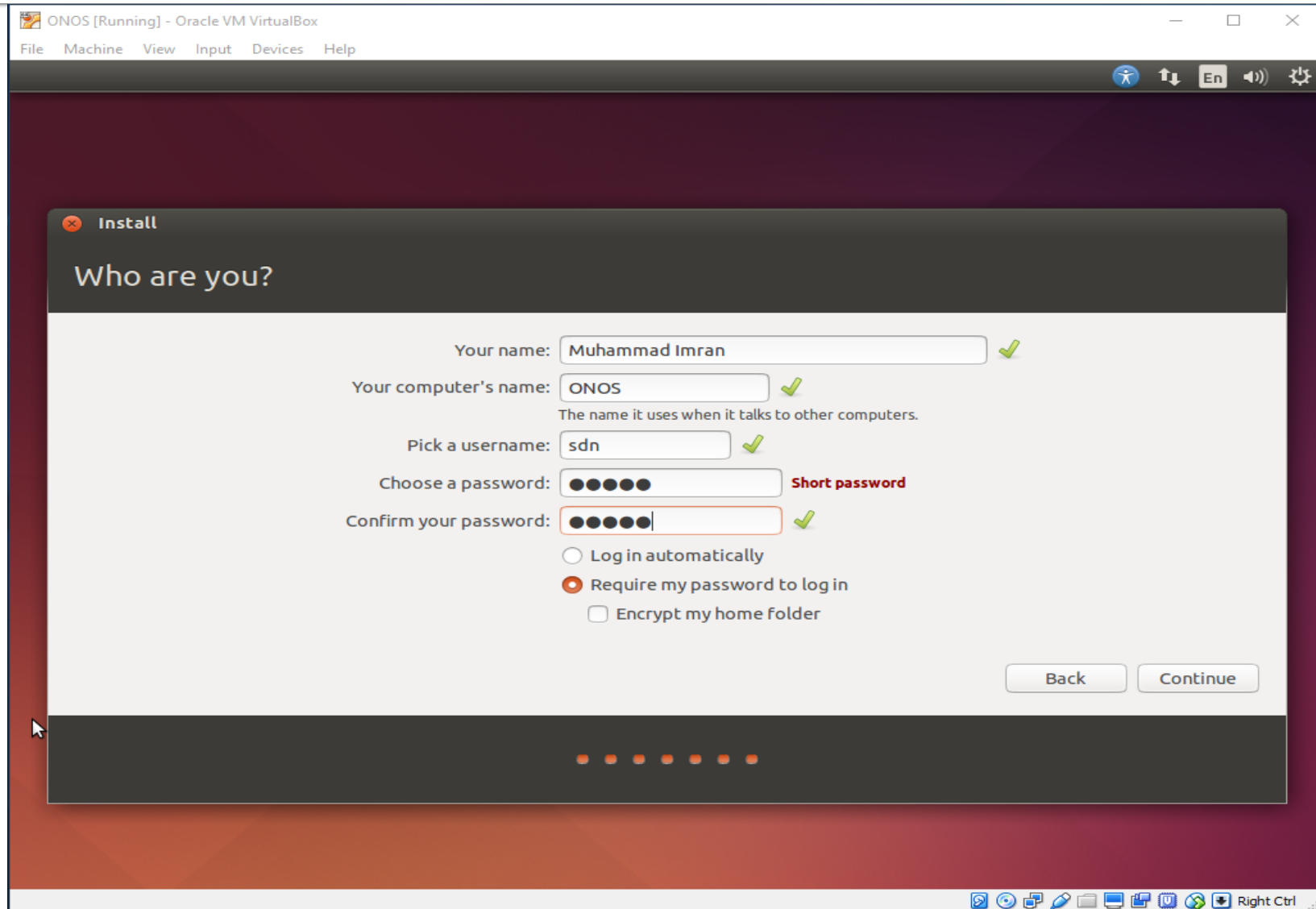
- General:** Name: ONOS, Operating System: Ubuntu (64-bit)
- System:** Base Memory: 4096 MB, Processors: 2, Boot Order: Optical, Hard Disk, Acceleration: VT-x/AMD-V, Nested Paging, KVM Paravirtualization
- Display:** Video Memory: 24 MB, Remote Desktop Server: Disabled, Video Capture: Disabled
- Storage:** Controller: IDE, IDE Secondary Master: [Optical Drive] ubuntu-14.04.1-desktop-amd64.iso (981.00 MB), Controller: SATA, SATA Port 0: ONOS.vdi (Normal, 32.00 GB)
- Audio:** Host Driver: Windows DirectSound, Controller: ICH AC97
- Network:** Adapter 1: Intel PRO/1000 MT Desktop (Bridged Adapter, Intel(R) Ethernet Connection (2) I219-LM), Adapter 2: Intel PRO/1000 MT Desktop (Host-only Adapter, 'VirtualBox Host-Only Ethernet Adapter')
- USB:** USB Controller: OHCI, EHCI, Device Filters: 0 (0 active)

The 'Preview' window on the right shows a black screen with the text 'ONOS' in white.

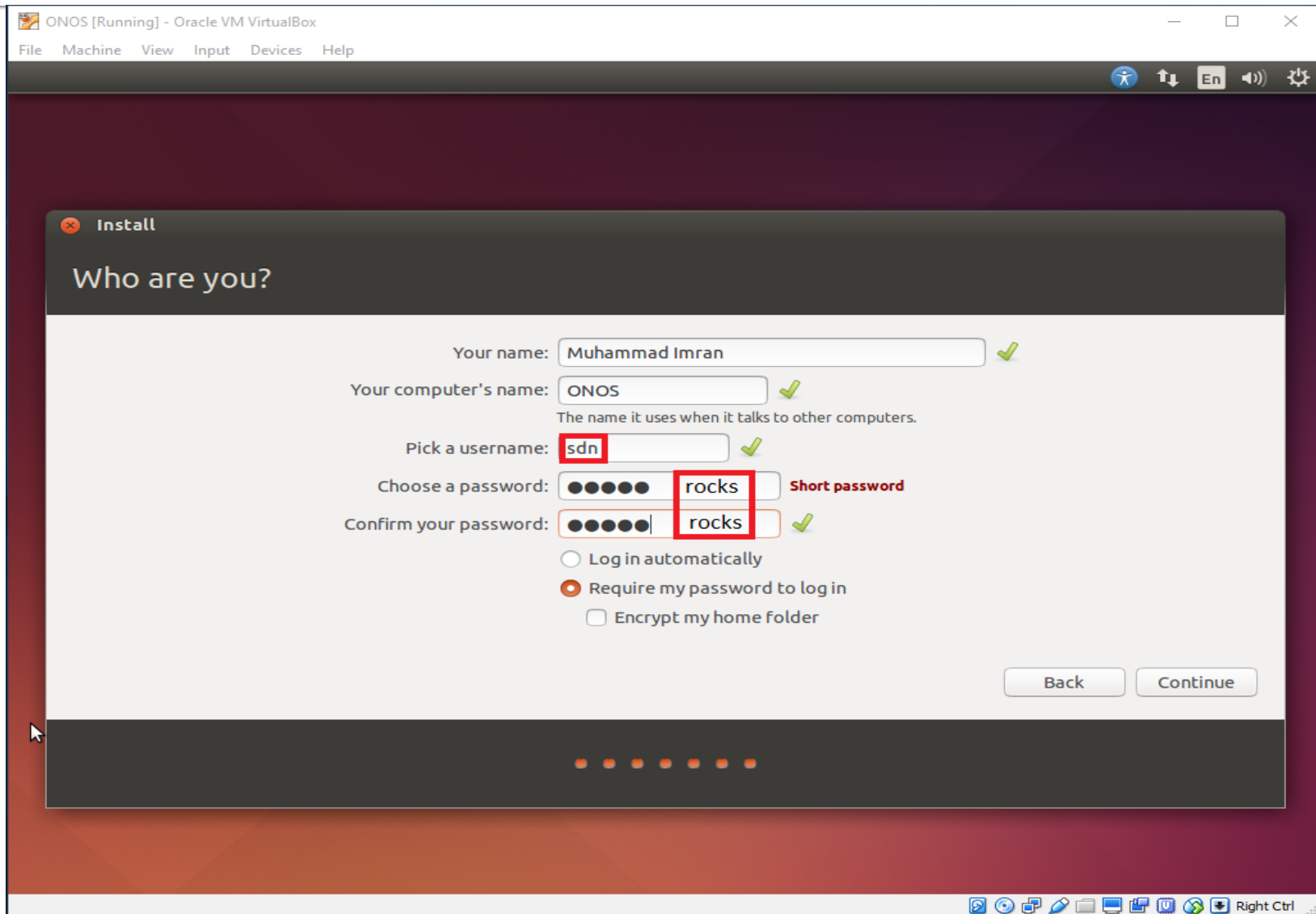
# Ubuntu Installation



# Operating System Settings

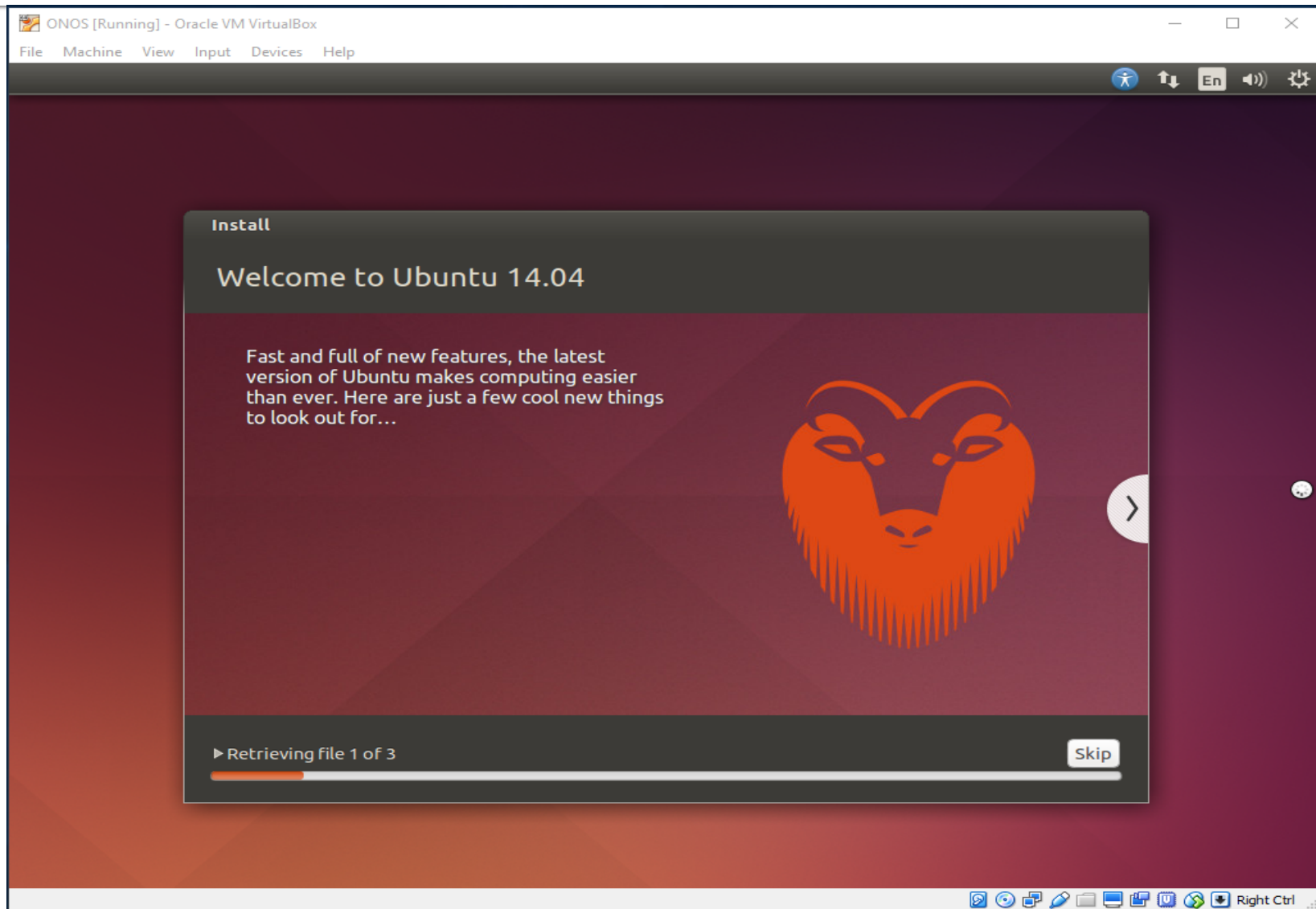


# Operating System Settings

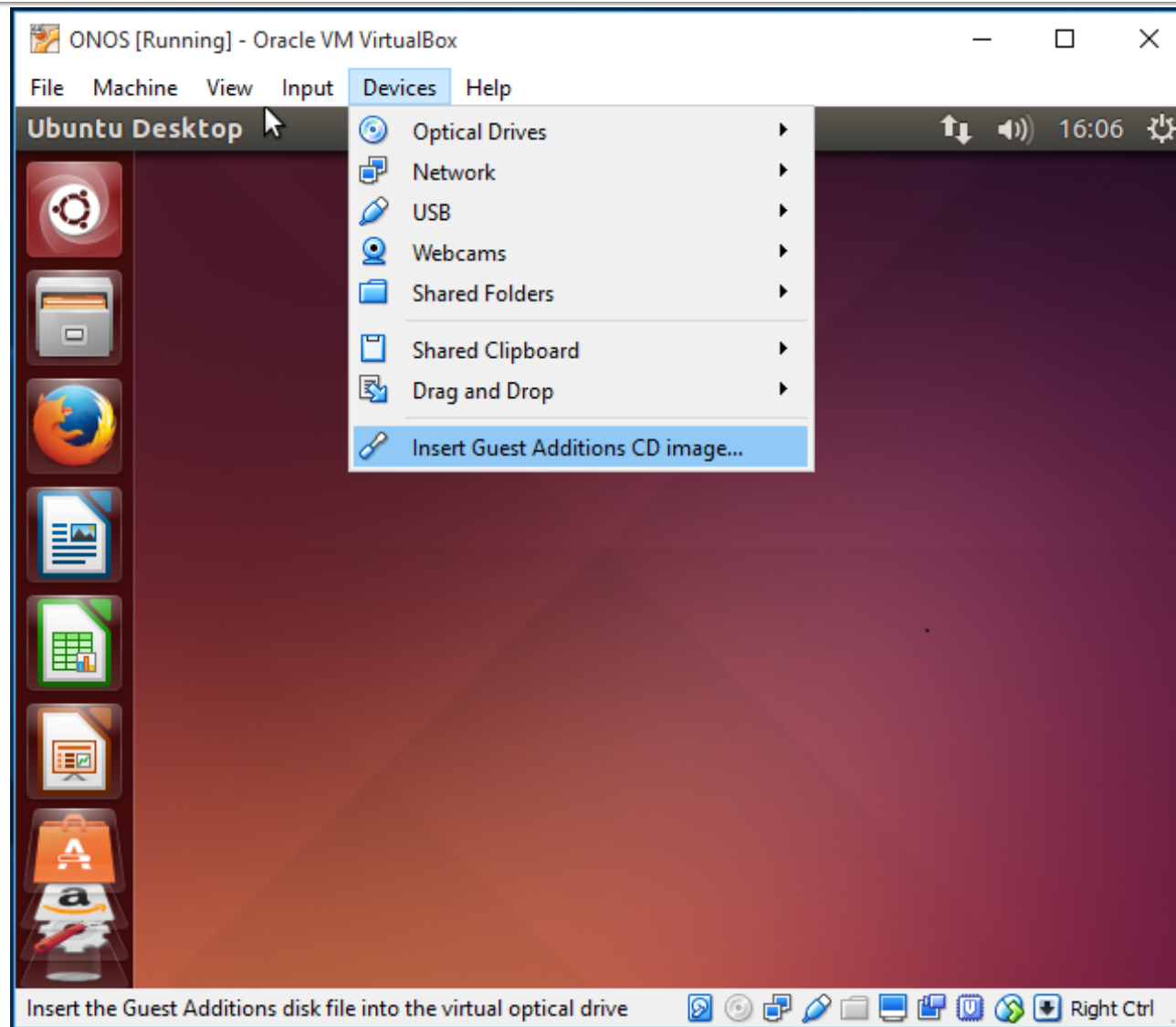




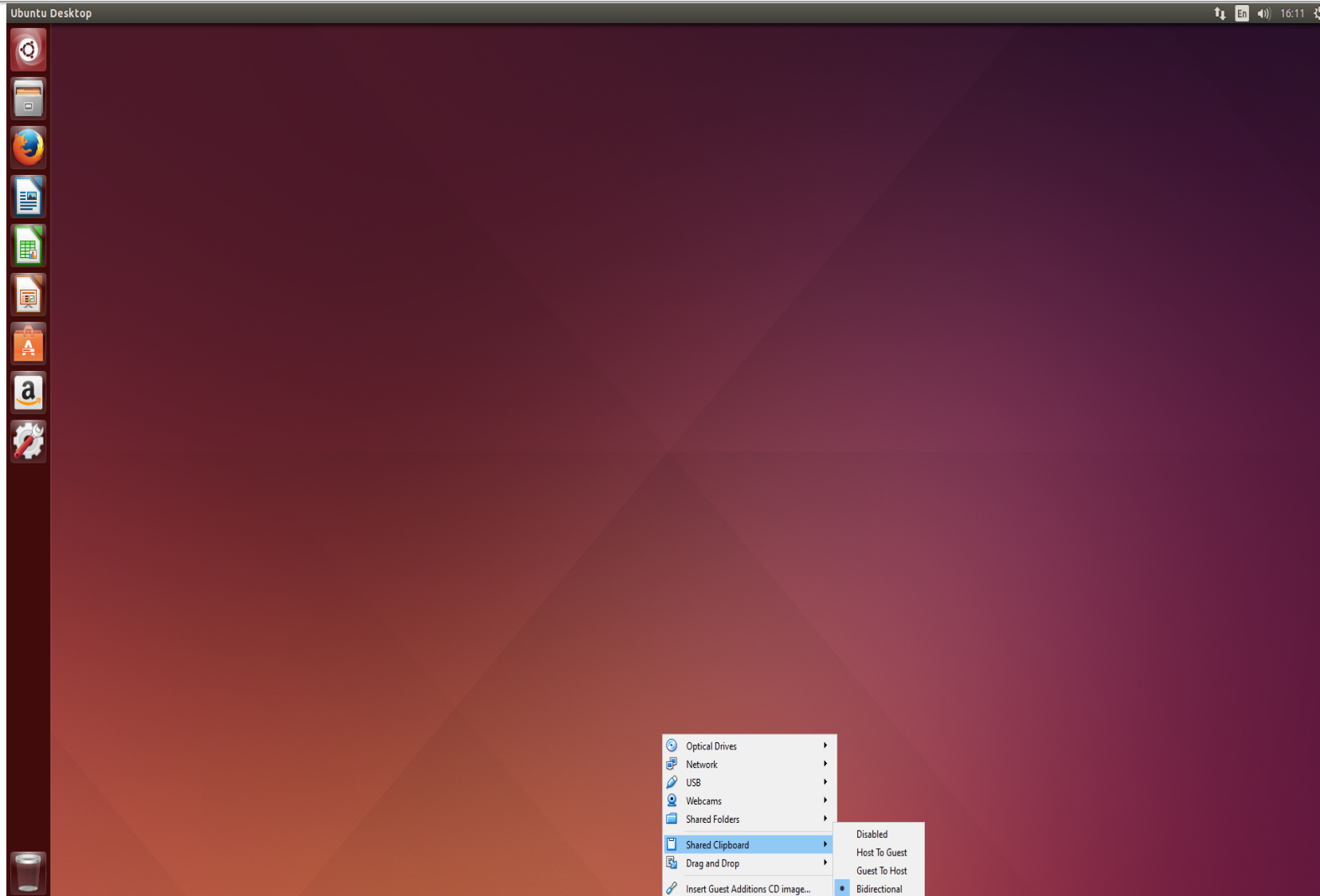
# Start Installation



# Virtual Box guest Additions Installer



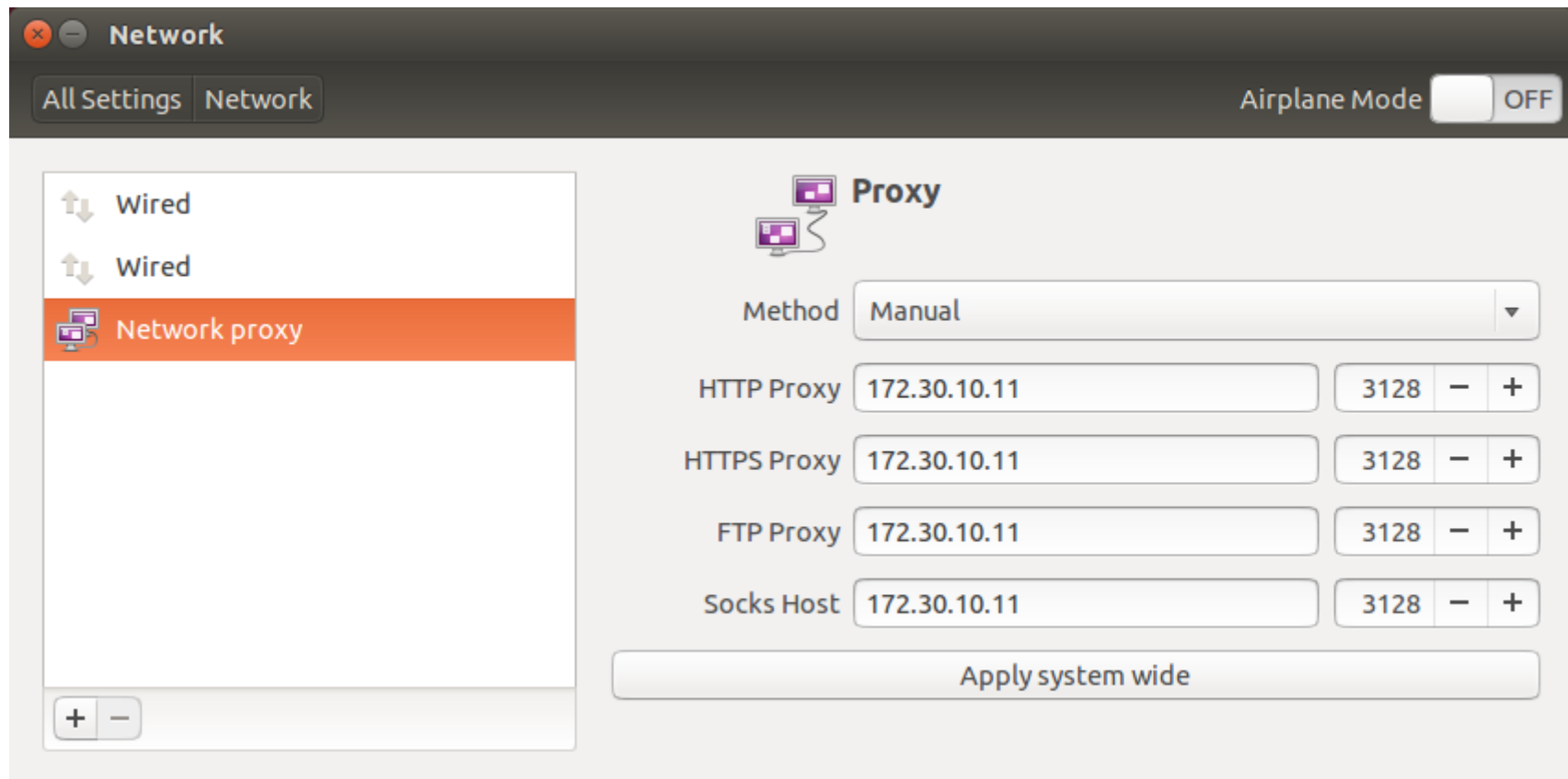
# Share Clipboard Settings



# Complete Deployment Steps

1. Apply proxy setting and password less **sudo** access (optional)
2. Install pre-requisite software
3. Install Mininet
4. Install Karaf and Maven
5. Install Oracle Java 8
6. Clone ONOS 1.8
7. Apply settings for ONOS 1.8.1
8. Apply cell settings for ONOS
9. Build ONOS
10. Package ONOS
11. Setting up controller on remote system
12. Run ONOS
13. Install IntelliJ

# 1. Proxy Settings (optional)



# 1. Password less sudo access

- In terminal type **sudo visudo** and add highlighted lines

```
sdn@ONOS: ~  
GNU nano 2.2.6 File: /etc/sudoers.tmp Modified  
  
# User alias specification  
  
# Cmnd alias specification  
  
# User privilege specification  
root    ALL=(ALL:ALL) ALL  
  
# Members of the admin group may gain root privileges  
%admin  ALL=(ALL) ALL  
  
# Allow members of group sudo to execute any command  
%sudo   ALL=(ALL:ALL) ALL  
  
# See sudoers(5) for more information on "#include" directives:  
  
#includedir /etc/sudoers.d  
  
# Making sudo passwordless  
sdn ALL=(ALL) NOPASSWD:ALL  
  
# If your are behind a proxy  
Defaults env_keep += "http_proxy https_proxy ftp_proxy"  
█  
  
^G Get Help   ^O WriteOut  ^R Read File  ^Y Prev Page  ^K Cut Text   ^C Cur Pos  
^X Exit       ^J Justify   ^W Where Is   ^V Next Page  ^U UnCut Text ^T To Spell
```

## 2. Install pre-requisite software

- Execute following commands in Linux terminal to install pre-requisite softwares
  - `sdn@ONOS:~$ sudo apt-get update`
  - `sdn@ONOS:~$ sudo apt-get install git`
  - `sdn@ONOS:~$ git config --global url."https://".insteadOf git://`
  - `sdn@ONOS:~$ sudo apt-get install openssh-server`
  - `sdn@ONOS:~$ sudo apt-get install curl`
  - `sdn@ONOS:~$ ssh-keygen -t rsa`

## 3. Install Mininet

- To download and install Mininet execute following commands:
  - `sdn@ONOS:~$ git clone http://github.com/mininet/mininet`
  - `sdn@ONOS:~$ mininet/util/install.sh -nvfw`
  - `sdn@ONOS:~$ sudo mn`
  - `sdn@ONOS:~$ exit`
- This will also install wireshark which is a famous packet analysis tool.



# 3. Install Mininet

```
sdn@ONOS: ~  
WARN missing oftype_to_wireshark_type for of_header_t  
WARN missing oftype_to_base for of_header_t  
WARN missing oftype_to_wireshark_type for of_time_t  
WARN missing oftype_to_base for of_time_t  
WARN missing oftype_to_wireshark_type for of_time_t  
WARN missing oftype_to_base for of_time_t  
WARN missing oftype_to_wireshark_type for of_time_t  
WARN missing oftype_to_base for of_time_t  
WARN missing oftype_to_wireshark_type for of_time_t  
WARN missing oftype_to_base for of_time_t  
WARN missing oftype_to_wireshark_type for of_controller_status_entry_t  
WARN missing oftype_to_base for of_controller_status_entry_t  
WARN missing oftype_to_wireshark_type for of_bitmap_512_t  
WARN missing oftype_to_base for of_bitmap_512_t  
WARN missing oftype_to_wireshark_type for of_bitmap_512_t  
WARN missing oftype_to_base for of_bitmap_512_t  
WARN missing oftype_to_wireshark_type for of_bitmap_512_t  
WARN missing oftype_to_base for of_bitmap_512_t  
WARN missing oftype_to_wireshark_type for of_header_t  
WARN missing oftype_to_base for of_header_t  
WARN missing oftype_to_base for of_table_desc_t  
WARN missing oftype_to_base for of_controller_uri_t  
Writing wireshark/openflow.lua  
touch .loxi_ts.wireshark  
Copied openflow plugin loxi_output/wireshark/openflow.lua to /usr/lib/x86_64-linux-gnu/wireshark/libwireshark3/plugins/  
sdn@ONOS:~$
```

## 4. Install Karaf and Maven

- To download and install Apache Karaf and Maven execute following commands in terminal:
  - `sdn@ONOS:~$ mkdir Applications`
  - `sdn@ONOS:~$ cd Downloads/`
  - `sdn@ONOS:~$ wget http://archive.apache.org/dist/karaf/3.0.5/apache-karaf-3.0.5.tar.gz`
  - `sdn@ONOS:~$ wget http://archive.apache.org/dist/maven/maven-3/3.3.9/binaries/apache-maven-3.3.9-bin.tar.gz`
  - `sdn@ONOS:~$ tar -zxvf apache-karaf-3.0.5.tar.gz -C ../Applications/`
  - `sdn@ONOS:~$ tar -zxvf apache-maven-3.3.9-bin.tar.gz -C ../Applications/`
  - `sdn@ONOS:~$ mvn -v`
  - `sdn@ONOS:~$ cd`

## 4. Install Karaf and Maven

```
sdn@ONOS: ~/Downloads
sdn@ONOS:~$ mkdir Applications
sdn@ONOS:~$ cd Downloads/
sdn@ONOS:~/Downloads$ wget http://archive.apache.org/dist/karaf/3.0.5/apache-karaf-3.0.5.tar.gz
--2017-01-07 16:26:53-- http://archive.apache.org/dist/karaf/3.0.5/apache-karaf-3.0.5.tar.gz
Connecting to 172.30.10.11:3128... connected.
Proxy request sent, awaiting response... 200 OK
Length: 18737694 (18M) [application/x-gzip]
Saving to: 'apache-karaf-3.0.5.tar.gz'

100%[=====>] 18,737,694 870KB/s in 18s

2017-01-07 16:27:12 (1003 KB/s) - 'apache-karaf-3.0.5.tar.gz' saved [18737694/18737694]

sdn@ONOS:~/Downloads$ wget http://archive.apache.org/dist/maven/maven-3/3.3.9/binaries/apache-maven-3.3.9-bin.tar.gz
--2017-01-07 16:27:52-- http://archive.apache.org/dist/maven/maven-3/3.3.9/binaries/apache-maven-3.3.9-bin.tar.gz
Connecting to 172.30.10.11:3128... connected.
Proxy request sent, awaiting response... 200 OK
Length: 8491533 (8.1M) [application/x-gzip]
Saving to: 'apache-maven-3.3.9-bin.tar.gz'

100%[=====>] 8,491,533 668KB/s in 18s

2017-01-07 16:28:10 (474 KB/s) - 'apache-maven-3.3.9-bin.tar.gz' saved [8491533/8491533]

sdn@ONOS:~/Downloads$ █
```

## 5. Install Oracle Java 8

- To install Oracle's Java 8 execute following commands in terminal :
  - sdn@ONOS:~\$ sudo apt-get install software-properties-common -y
  - sdn@ONOS:~\$ sudo add-apt-repository ppa:webupd8team/java -y
  - sdn@ONOS:~\$ sudo apt-get update
  - sdn@ONOS:~\$ sudo apt-get install oracle-java8-installer oracle-java8-set-default -y

# 5. Install Oracle Java 8

```
sdn@ONOS: ~  
Package configuration
```

Configuring oracle-java8-installer

Oracle Binary Code License Agreement for the Java SE Platform Products and JavaFX

You MUST agree to the license available in <http://java.com/license> if you want to use Oracle JDK.

<Ok>

# 5. Install Oracle Java 8

```
sdn@ONOS: ~  
Package configuration  
  
Configuring oracle-java8-installer  
  
In order to install this package, you must accept the license terms, the "Oracle Binary  
Code License Agreement for the Java SE Platform Products and JavaFX ". Not accepting will  
cancel the installation.  
  
Do you accept the Oracle Binary Code license terms?  
  
  <Yes>                                <No>
```

# 5. Install Oracle Java 8

```
sdn@ONOS: ~  
116736K ..... 67% 65.8K 14m6s  
119808K ..... 69% 60.2K 13m23s  
122880K ..... 71% 61.1K 12m40s  
125952K ..... 72% 62.4K 11m55s  
129024K ..... 74% 54.5K 11m13s  
132096K ..... 76% 53.6K 10m31s  
135168K ..... 78% 48.6K 9m50s  
138240K ..... 79% 52.1K 9m6s  
141312K ..... 81% 52.0K 8m22s  
144384K ..... 83% 63.6K 7m36s  
147456K ..... 84% 57.5K 6m50s  
150528K ..... 86% 57.4K 6m3s  
153600K ..... 88% 58.3K 5m17s  
156672K ..... 90% 73.0K 4m29s  
159744K ..... 91% 62.2K 3m42s  
162816K ..... 93% 63.3K 2m54s  
165888K ..... 95% 54.6K 2m7s  
168960K ..... 97% 60.7K 80s  
172032K ..... 98% 60.8K 32s  
175104K ..... 100% 74.0K=45m45s  
  
2017-01-05 19:17:10 (64.5 KB/s) - 'jdk-8u111-linux-x64.tar.gz' saved [181442359/181442359]  
  
Download done.  
Removing outdated cached downloads...  
update-alternatives: error: no alternatives for java  
update-alternatives: using /usr/lib/jvm/java-8-oracle/jre/bin/ControlPanel to provide /usr/bin/ControlPanel (ControlPanel) in auto mode  
update-alternatives: using /usr/lib/jvm/java-8-oracle/jre/bin/java to provide /us
```

# 5. Install Oracle Java 8

```
sdn@ONOS: ~
update-alternatives: using /usr/lib/jvm/java-8-oracle/bin/jstat to provide /usr/bin/jstat (jstat)
in auto mode
update-alternatives: using /usr/lib/jvm/java-8-oracle/bin/jstatd to provide /usr/bin/jstatd (jstatd)
in auto mode
update-alternatives: using /usr/lib/jvm/java-8-oracle/bin/jvisualvm to provide /usr/bin/jvisualvm
(jvisualvm) in auto mode
update-alternatives: using /usr/lib/jvm/java-8-oracle/bin/native2ascii to provide /usr/bin/native2
ascii (native2ascii) in auto mode
update-alternatives: using /usr/lib/jvm/java-8-oracle/bin/rmic to provide /usr/bin/rmic (rmic) in
auto mode
update-alternatives: using /usr/lib/jvm/java-8-oracle/bin/schemagen to provide /usr/bin/schemagen
(schemagen) in auto mode
update-alternatives: using /usr/lib/jvm/java-8-oracle/bin/serialver to provide /usr/bin/serialver
(serialver) in auto mode
update-alternatives: using /usr/lib/jvm/java-8-oracle/bin/wsgen to provide /usr/bin/wsgen (wsgen)
in auto mode
update-alternatives: using /usr/lib/jvm/java-8-oracle/bin/wsimport to provide /usr/bin/wsimport (w
simport) in auto mode
update-alternatives: using /usr/lib/jvm/java-8-oracle/bin/xjc to provide /usr/bin/xjc (xjc) in aut
o mode
update-alternatives: using /usr/lib/jvm/java-8-oracle/jre/lib/amd64/libnpjp2.so to provide /usr/li
b/mozilla/plugins/libjavaplugin.so (mozilla-javaplugin.so) in auto mode
Oracle JRE 8 browser plugin installed
Oracle JDK 8 installed

#####Important#####
To set Oracle JDK8 as default, install the "oracle-java8-set-default" package.
E.g.: sudo apt install oracle-java8-set-default.
Setting up gsfonts-x11 (0.22) ...
Setting up oracle-java8-set-default (8u111+8u111arm-1~webupd8~0) ...
sdn@ONOS:~$
```



## 6. Clone ONOS

- To download the ONOS 1.8 source code
  - sdn@ONOS:~\$ git checkout onos
  - sdn@ONOS:~\$ cd Downloads/
  - sdn@ONOS:~\$ wget https://github.com/opennetworkinglab/onos/archive/onos-1.8.zip
  - sdn@ONOS:~\$ unzip onos-1.8.zip -d ~/
  - sdn@ONOS:~\$ cd
  - sdn@ONOS:~\$ mv onos-onos-1.8/ onos/
  - sdn@ONOS:~\$ cd onos

## 7. Apply settings for ONOS

- To apply settings for ONOS, execute following command in Linux terminal and add highlighted lines in files:
  - `sdn@ONOS:~$ gedit .bashrc`
  - `sdn@ONOS:~$ gedit Applications/apache-karaf-3.0.5/etc/org.apache.karaf.features.cfg`
  - `sdn@ONOS:~$ gedit onos/.buckconfig`
  - `sdn@ONOS:~$ gedit .m2/settings.xml`
  - `sdn@ONOS:~$ . ~/.bashrc`
  - `sdn@ONOS:~$ env`

# 7. Apply settings for ONOS

```
.bashrc (~) - gedit
Open Save Undo
.bashrc x
alias alert='notify-send --urgency=low -t "${BASH_SOURCE[0]}" && echo terminal ||
echo error)' "${history|tail -n1|sed -e '\''s/^\s*[0-9]\+\s*//;s/[\;&]'\s*alert
$//'\''}"

# Alias definitions.
# You may want to put all your additions into a separate file like
# ~/.bash_aliases, instead of adding them here directly.
# See /usr/share/doc/bash-doc/examples in the bash-doc package.

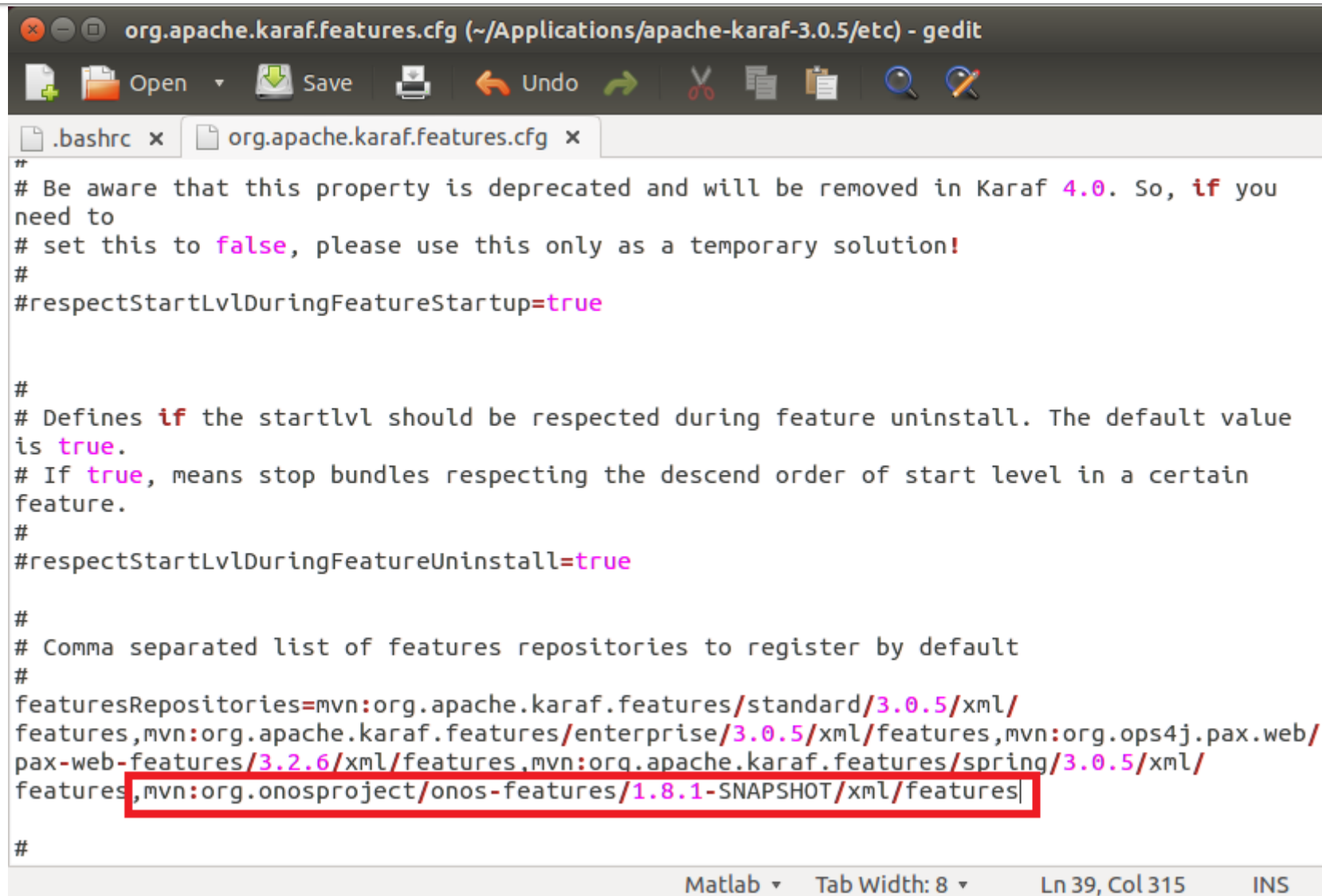
if [ -f ~/.bash_aliases ]; then
    . ~/.bash_aliases
fi

# enable programmable completion features (you don't need to enable
# this, if it's already enabled in /etc/bash.bashrc and /etc/profile
# sources /etc/bash.bashrc).
if ! shopt -oq posix; then
    if [ -f /usr/share/bash-completion/bash_completion ]; then
        . /usr/share/bash-completion/bash_completion
    elif [ -f /etc/bash_completion ]; then
        . /etc/bash_completion
    fi
fi

. ~/onos/tools/dev/bash_profile
```

Plain Text ▾ Tab Width: 8 ▾ Ln 116, Col 32 INS

# 7. Apply settings for ONOS



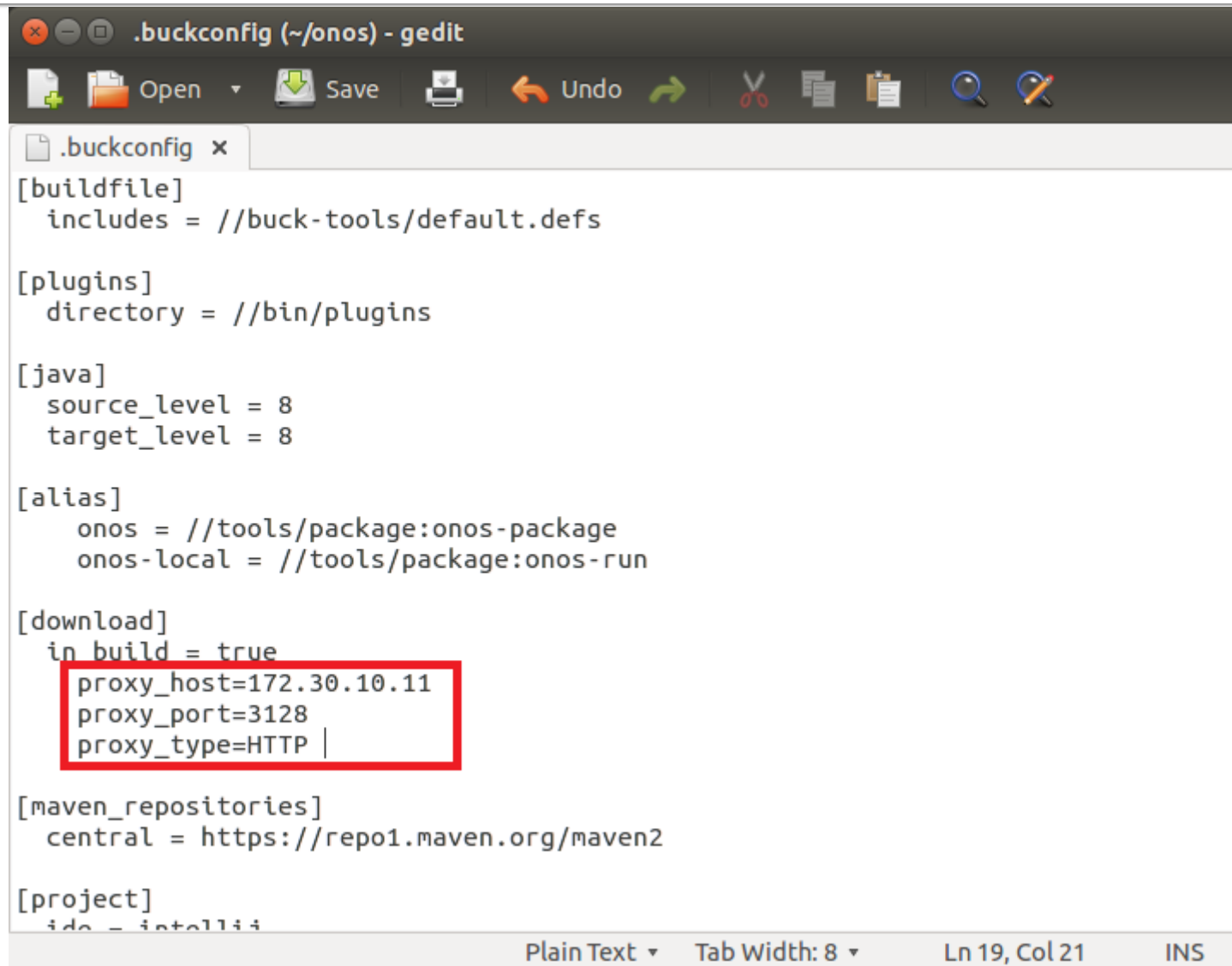
```
org.apache.karaf.features.cfg (~/.Applications/apache-karaf-3.0.5/etc) - gedit
Open Save Undo
.org.apache.karaf.features.cfg x
**
# Be aware that this property is deprecated and will be removed in Karaf 4.0. So, if you
need to
# set this to false, please use this only as a temporary solution!
#
#respectStartLvlDuringFeatureStartup=true

#
# Defines if the startlvl should be respected during feature uninstall. The default value
is true.
# If true, means stop bundles respecting the descend order of start level in a certain
feature.
#
#respectStartLvlDuringFeatureUninstall=true

#
# Comma separated list of features repositories to register by default
#
featuresRepositories=mvn:org.apache.karaf.features/standard/3.0.5/xml/
features,mvn:org.apache.karaf.features/enterprise/3.0.5/xml/features,mvn:org.ops4j.pax.web/
pax-web-features/3.2.6/xml/features,mvn:org.apache.karaf.features/spring/3.0.5/xml/
features,mvn:org.onosproject/onos-features/1.8.1-SNAPSHOT/xml/features|

#
Matlab Tab Width: 8 Ln 39, Col 315 INS
```

# 7. Apply settings for ONOS (optional)



```
.buckconfig (~/onos) - gedit
Open Save Undo
[buckconfig x]
[buildfile]
  includes = //buck-tools/default.defs

[plugins]
  directory = //bin/plugins

[java]
  source_level = 8
  target_level = 8

[alias]
  onos = //tools/package:onos-package
  onos-local = //tools/package:onos-run

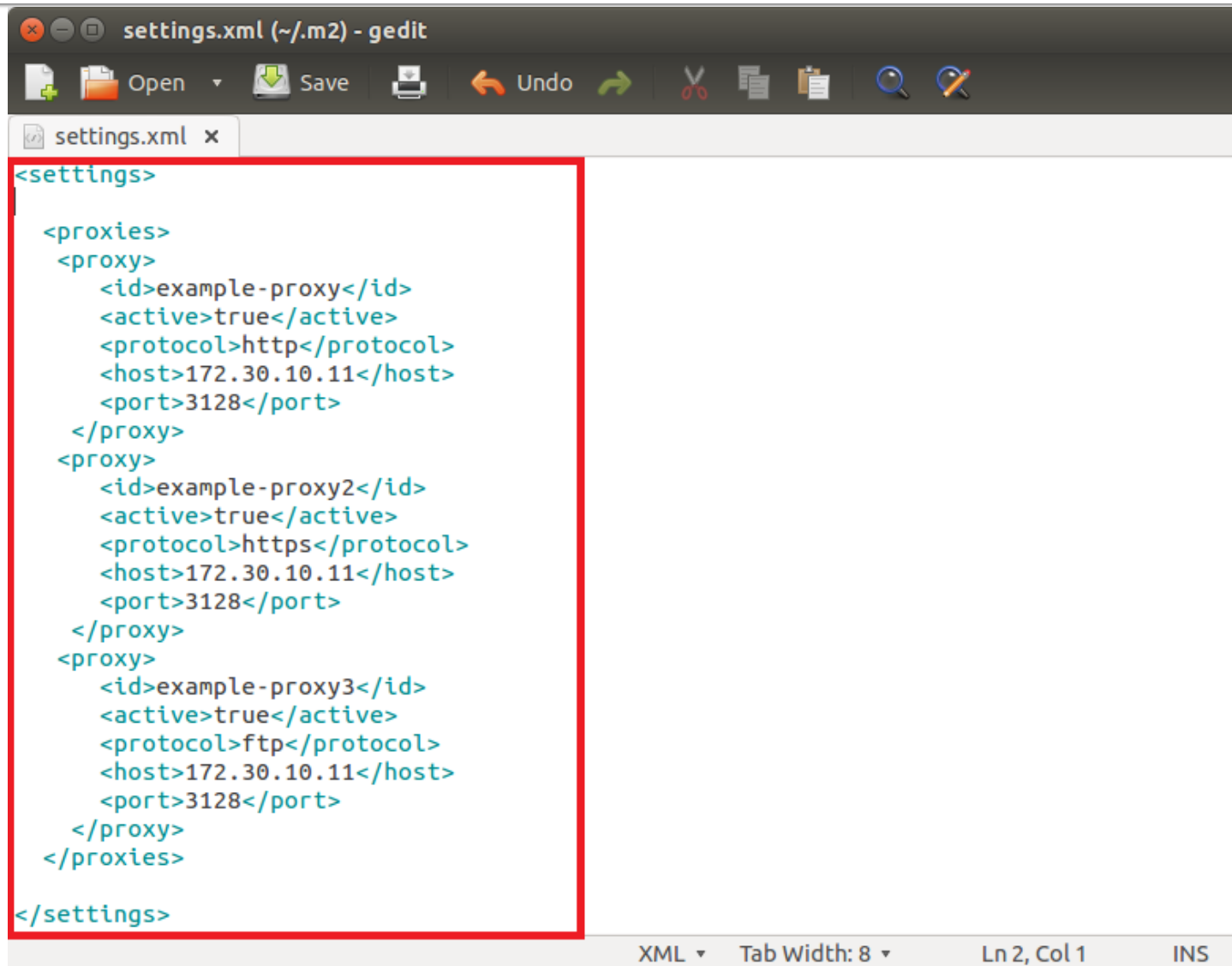
[download]
  in_build = true
  proxy_host=172.30.10.11
  proxy_port=3128
  proxy_type=HTTP

[maven_repositories]
  central = https://repo1.maven.org/maven2

[project]
  id = install
```

Plain Text ▾ Tab Width: 8 ▾ Ln 19, Col 21 INS

# 7. Apply settings for ONOS (optional)



```
<settings>
  <proxies>
    <proxy>
      <id>example-proxy</id>
      <active>true</active>
      <protocol>http</protocol>
      <host>172.30.10.11</host>
      <port>3128</port>
    </proxy>
    <proxy>
      <id>example-proxy2</id>
      <active>true</active>
      <protocol>https</protocol>
      <host>172.30.10.11</host>
      <port>3128</port>
    </proxy>
    <proxy>
      <id>example-proxy3</id>
      <active>true</active>
      <protocol>ftp</protocol>
      <host>172.30.10.11</host>
      <port>3128</port>
    </proxy>
  </proxies>
</settings>
```

XML ▾ Tab Width: 8 ▾ Ln 2, Col 1 INS

## 8. Apply Cell Settings

- To apply ONOS environment settings execute following commands:
  - sdn@ONOS:~\$ export ONOS\_NIC="10.0.3.\* "
  - sdn@ONOS:~\$ export OC1="192.168.56.101"
  - sdn@ONOS:~\$ export OCI=\$OC1
  - sdn@ONOS:~\$ export OCN="192.168.56.103"
  - sdn@ONOS:~\$ export ONOS\_APPS="drivers,openflow"
  - sdn@ONOS:~\$ export ONOS\_USER=sdn
  - sdn@ONOS:~\$ export ONOS\_GROUP=sdn

# 8. ONOS Cell Settings

```
ubuntu@onos1: ~  
sdn@ONOS:~$ cell lxc  
ONOS_CELL=lxc  
OCI=10.0.3.148  
OC1=10.0.3.148  
OCN=192.168.56.9  
ONOS_APPS=drivers,openflow,proxyarp,optical,bgprouter  
ONOS_GROUP=ubuntu  
ONOS_NIC=10.0.3.*  
ONOS_SCENARIOS=/home/sdn/onos/tools/test/scenarios  
ONOS_TOPO=default  
ONOS_USER=ubuntu  
ONOS_USE_SSH=true  
ONOS_WEB_PASS=rocks  
ONOS_WEB_USER=onos  
sdn@ONOS:~$ onos-push-keys $OCI  
The authenticity of host '10.0.3.148 (10.0.3.148)' can't be established.  
ECDSA key fingerprint is ec:85:75:d2:bc:cd:15:50:02:40:d5:8a:33:fd:ad:26.  
Are you sure you want to continue connecting (yes/no)? yes  
Warning: Permanently added '10.0.3.148' (ECDSA) to the list of known hosts.  
ubuntu@10.0.3.148's password:  
sdn@ONOS:~$  
sdn@ONOS:~$ ssh ubuntu@$OCI  
Welcome to Ubuntu 14.04.5 LTS (GNU/Linux 3.13.0-32-generic x86_64)  
  
* Documentation: https://help.ubuntu.com/  
ubuntu@onos1:~$ sudo visudo  
[sudo] password for ubuntu:  
ubuntu@onos1:~$
```



## 9. Building ONOS

- Run the following command to build ONOS:

- sdn@ONOS:~\$ cd ~/onos
- sdn@ONOS:~\$ mvn clean install # or use the alias 'mci'
- sdn@ONOS:~\$ onos-package
- sdn@ONOS:~\$ stc setup
- sdn@ONOS:~\$ onos

# 9. Building ONOS

```
sdn@ONOS: ~/onos
[INFO] onos-app-tetunnel ..... SUCCESS [ 0.646 s]
[INFO] onos-actn-mdsc ..... SUCCESS [ 0.185 s]
[INFO] onos-actn-mdsc-tetunnel-pce ..... SUCCESS [ 0.401 s]
[INFO] onos-actn-mdsc-tetunnel-ctl ..... SUCCESS [ 0.499 s]
[INFO] onos-actn-mdscapp ..... SUCCESS [ 0.265 s]
[INFO] onos-incubator-core ..... SUCCESS [ 0.613 s]
[INFO] onos-incubator-rpc ..... SUCCESS [ 2.099 s]
[INFO] onos-incubator-grpc ..... SUCCESS [ 32.737 s]
[INFO] onos-incubator-rpc-grpc ..... SUCCESS [01:06 min]
[INFO] onos-incubator-protobuf-nb ..... SUCCESS [ 0.826 s]
[INFO] onos-incubator-rpc-nb ..... SUCCESS [ 0.532 s]
[INFO] onos-features ..... SUCCESS [ 0.302 s]
[INFO] onos-archetypes ..... SUCCESS [ 0.020 s]
[INFO] onos-api-archetype ..... SUCCESS [02:40 min]
[INFO] onos-bundle-archetype ..... SUCCESS [ 0.032 s]
[INFO] onos-cli-archetype ..... SUCCESS [ 0.016 s]
[INFO] onos-rest-archetype ..... SUCCESS [ 0.019 s]
[INFO] onos-ui-archetype ..... SUCCESS [ 0.033 s]
[INFO] onos-uitab-archetype ..... SUCCESS [ 0.068 s]
[INFO] onos-uitopo-archetype ..... SUCCESS [ 0.026 s]
[INFO] onos-branding ..... SUCCESS [ 0.415 s]
[INFO] -----
[INFO] BUILD SUCCESS
[INFO] -----
[INFO] Total time: 01:04 h
[INFO] Finished at: 2017-01-05T23:09:06+05:00
[INFO] Final Memory: 252M/737M
[INFO] -----
sdn@ONOS:~/onos$
```

# 10. Packaging ONOS

```
sdn@ONOS: ~  
libcurl3  
1 upgraded, 1 newly installed, 0 to remove and 647 not upgraded.  
Need to get 296 kB of archives.  
After this operation, 317 kB of additional disk space will be used.  
Do you want to continue? [Y/n] y  
Get:1 http://pk.archive.ubuntu.com/ubuntu/ trusty-updates/main libcurl3 amd64 7.35.0-1ubuntu2.10 [173 kB]  
Get:2 http://pk.archive.ubuntu.com/ubuntu/ trusty-updates/main curl amd64 7.35.0-1ubuntu2.10 [123 kB]  
Fetched 296 kB in 0s (3,170 kB/s)  
(Reading database ... 168442 files and directories currently installed.)  
Preparing to unpack .../libcurl3_7.35.0-1ubuntu2.10_amd64.deb ...  
Unpacking libcurl3:amd64 (7.35.0-1ubuntu2.10) over (7.35.0-1ubuntu2) ...  
Selecting previously unselected package curl.  
Preparing to unpack .../curl_7.35.0-1ubuntu2.10_amd64.deb ...  
Unpacking curl (7.35.0-1ubuntu2.10) ...  
Processing triggers for man-db (2.6.7.1-1) ...  
Setting up libcurl3:amd64 (7.35.0-1ubuntu2.10) ...  
Setting up curl (7.35.0-1ubuntu2.10) ...  
Processing triggers for libc-bin (2.19-0ubuntu6) ...  
sdn@ONOS:~$ op  
Updating Buck...  
  % Total    % Received % Xferd  Average Speed   Time    Time     Time  Current  
                                 Dload  Upload   Total   Spent    Left   Speed  
100 43.8M  100 43.8M    0     0  22744      0  0:33:43  0:33:43  --:--:-- 18509  
Archive:  cache/buck-v2016.12.02.01.zip  
  inflating: buck  
  extracting: .buck_version  
   creating: plugins/  
  inflating: plugins/onos.jar  
  inflating: plugins/yang.jar  
Successfully updated Buck in /home/sdn/onos/bin/buck to buck-v2016.12.02.01.zip
```

# 10. Packaging ONOS

```
sdn@ONOS: ~  
[-] PROCESSING BUCK FILES...FINISHED 2.9s [100%] [01F433] New buck daemon  
[-] DOWNLOADING... (0.00 B/S AVG, TOTAL: 0.00 B, 0 Artifacts)  
[-] BUILDING...FINISHED 12.9s [100%] (82/739 JOBS, 0 UPDATED, 0 [0.0%] CACHE MISS)  
sdn@ONOS:~/onos$ git checkout onos  
fatal: Not a git repository (or any of the parent directories): .git  
sdn@ONOS:~/onos$ git checkout onos-1.2  
fatal: Not a git repository (or any of the parent directories): .git  
sdn@ONOS:~/onos$ git checkout onos-1.3  
fatal: Not a git repository (or any of the parent directories): .git  
sdn@ONOS:~/onos$ git checkout onos-1.5  
fatal: Not a git repository (or any of the parent directories): .git  
sdn@ONOS:~/onos$ git checkout onos-1.7  
fatal: Not a git repository (or any of the parent directories): .git  
sdn@ONOS:~/onos$ git checkout onos-1.7.0  
fatal: Not a git repository (or any of the parent directories): .git  
sdn@ONOS:~/onos$ git checkout onos-1.9  
fatal: Not a git repository (or any of the parent directories): .git  
sdn@ONOS:~/onos$ cd  
sdn@ONOS:~$ op  
Not using buckd because NO_BUCKD is set.  
[-] PROCESSING BUCK FILES...FINISHED 1.8s [100%] [01F433] New buck daemon  
[+] DOWNLOADING... (0.00 B/S, TOTAL: 0.00 B, 0 Artifacts)  
[+] BUILDING...25m35.4s [100%] (739/739 JOBS, 733 UPDATED, 733 [99.2%] CACHE MISS)  
  |=> IDLE  
  |=> IDLE  
The outputs are:  
//tools/package:onos-package buck-out/gen/tools/package/onos-package/onos.tar.gz  
lrwxrwxrwx 1 sdn sdn 66 6 15:33 /tmp/onos-1.8.1.sdn.tar.gz -> /home/sdn/onos/buck-out/gen/tools/  
package/onos-package/onos.tar.gz  
1264042504 138764946 /tmp/onos-1.8.1.sdn.tar.gz  
sdn@ONOS:~$
```

# 10. Packaging ONOS


```
sdn@ONOS: ~  
ntWebResourceTest  
PASS 2.1s 7 Passed 0 Skipped 0 Failed org.onosproject.rest.resources.Topo  
logyResourceTest  
PASS 1.6s 28 Passed 0 Skipped 0 Failed org.onosproject.rest.resources.Virt  
ualNetworkWebResourceTest  
PASS 187ms 1 Passed 0 Skipped 0 Failed //web/api:onos-rest-tests-checkstyl  
e  
PASS 226ms 1 Passed 0 Skipped 0 Failed //web/gui:onos-gui-checkstyle-files  
-checkstyle  
NOTESTS <100ms 0 Passed 0 Skipped 0 Failed org.onosproject.ui.impl.AbstractUiI  
mplTest  
NOTESTS <100ms 0 Passed 0 Skipped 0 Failed org.onosproject.ui.impl.birds.BirdE  
ncoderTest  
PASS <100ms 4 Passed 0 Skipped 0 Failed org.onosproject.ui.impl.topo.Topo2J  
sonifierTest  
PASS <100ms 1 Passed 0 Skipped 0 Failed org.onosproject.ui.impl.topo.UiTopo  
LayoutManagerTest  
NOTESTS <100ms 0 Passed 0 Skipped 0 Failed org.onosproject.ui.impl.topo.model.  
AbstractTopoModelTest  
PASS <100ms 10 Passed 0 Skipped 0 Failed org.onosproject.ui.impl.topo.model.  
ModelCacheTest  
NOTESTS <100ms 0 Passed 0 Skipped 0 Failed org.onosproject.ui.impl.topo.model.  
RegionServiceAdapter  
PASS <100ms 1 Passed 0 Skipped 0 Failed //web/gui:onos-gui-tests-checkstyle  
TESTS PASSED  
sdn@ONOS:~$
```

# 11. Setting up ONOS on remote controller

```
sdn@ONOS: ~
lrwxrwxrwx 1 sdn sdn 66 10:10 /tmp/onos-1.8.1.sdn.tar.gz -> /home/sdn/onos/bu
ck-out/gen/tools/package/onos-package/onos.tar.gz
1473535380 138757875 /tmp/onos-1.8.1.sdn.tar.gz
Downloading STC binary...Done.
2017-01-08 10:12:40 Setup started
2017-01-08 10:12:40 Push-Bits-2 started -- onos-push-bits 10.0.3.157
2017-01-08 10:12:40 Push-Bits-1 started -- onos-push-bits 10.0.3.117
2017-01-08 10:12:40 Uninstall-2 started -- onos-uninstall 10.0.3.157
2017-01-08 10:12:40 Uninstall-1 started -- onos-uninstall 10.0.3.117
2017-01-08 10:12:50 Uninstall-2 completed
2017-01-08 10:12:50 Uninstall-1 completed
2017-01-08 10:12:50 Kill-2 started -- onos-kill 10.0.3.157
2017-01-08 10:12:50 Kill-1 started -- onos-kill 10.0.3.117
2017-01-08 10:13:01 Kill-2 completed
2017-01-08 10:13:01 Kill-1 completed
2017-01-08 10:13:02 Push-Bits-1 completed
2017-01-08 10:13:02 Push-Bits-2 completed
2017-01-08 10:13:02 Install-1 started -- onos-install 10.0.3.117
2017-01-08 10:13:02 Install-2 started -- onos-install 10.0.3.157
2017-01-08 10:14:10 Install-1 completed
2017-01-08 10:14:10 Secure-SSH-1 started -- onos-secure-ssh -u onos -p rocks 10.0.3.1
17
2017-01-08 10:14:10 Install-2 completed
2017-01-08 10:14:10 Secure-SSH-2 started -- onos-secure-ssh -u onos -p rocks 10.0.3.1
57
2017-01-08 10:14:45 Secure-SSH-1 completed
2017-01-08 10:14:45 Wait-for-Start-1 started -- onos-wait-for-start 10.0.3.117
2017-01-08 10:14:49 Secure-SSH-2 completed
2017-01-08 10:14:49 Wait-for-Start-2 started -- onos-wait-for-start 10.0.3.157
2017-01-08 10:17:55 Wait-for-Start-1 completed
2017-01-08 10:17:55 Check-Components-1 started -- onos-check-components 10.0.3.117
2017-01-08 10:17:55 Check-Nodes-1 started -- onos-check-nodes 10.0.3.117
2017-01-08 10:17:59 Check-Nodes-1 completed
2017-01-08 10:18:00 Wait-for-Start-2 completed
2017-01-08 10:18:00 Check-Nodes-2 started -- onos-check-nodes 10.0.3.157
2017-01-08 10:18:00 Check-Components-2 started -- onos-check-components 10.0.3.157
2017-01-08 10:18:01 Check-Components-1 completed
2017-01-08 10:18:01 Check-Logs-1 started -- onos-check-logs 10.0.3.117
2017-01-08 10:18:01 Check-Apps-1 started -- onos-check-apps 10.0.3.117 includes
2017-01-08 10:18:03 Check-Nodes-2 completed
2017-01-08 10:18:05 Check-Components-2 completed
2017-01-08 10:18:05 Check-Logs-2 started -- onos-check-logs 10.0.3.157
2017-01-08 10:18:05 Check-Apps-2 started -- onos-check-apps 10.0.3.157 includes
2017-01-08 10:18:11 Check-Logs-1 completed
2017-01-08 10:18:15 Check-Logs-2 completed
```

# 12. Run ONOS

```
sdn@ONOS: ~
sdn@ONOS:~$ onos
Welcome to Open Network Operating System (ONOS)!



Documentation: wiki.onosproject.org
Tutorials:     tutorials.onosproject.org
Mailing lists: lists.onosproject.org

Come help out! Find out how at: contribute.onosproject.org

Hit '<tab>' for a list of available commands
and '[cmd] --help' for help on a specific command.
Hit '<ctrl-d>' or type 'system:shutdown' or 'logout' to shutdown ONOS.

onos> app -s -a
Error executing command onos:app: undefined option -s
Try <command> --help' for more information.
onos> apps -s -a
* 24 org.onosproject.optical-model      1.8.1.SNAPSHOT Optical information model
* 37 org.onosproject.hostprovider      1.8.1.SNAPSHOT Host Location Provider
* 38 org.onosproject.lldpprovider      1.8.1.SNAPSHOT LLDP Link Provider
* 39 org.onosproject.openflow-base    1.8.1.SNAPSHOT OpenFlow Provider
* 40 org.onosproject.openflow          1.8.1.SNAPSHOT OpenFlow Meta App
* 56 org.onosproject.drivers            1.8.1.SNAPSHOT Default device drivers
onos> 
```

# Mininet using remote controller

```
sdn@ONOS: ~
sdn@ONOS:~$ sudo mn --controller=remote,$OCI
*** Creating network
*** Adding controller
Connecting to remote controller at 10.0.3.117:6653
*** Adding hosts:
h1 h2
*** Adding switches:
s1
*** Adding links:
(h1, s1) (h2, s1)
*** Configuring hosts
h1 h2
*** Starting controller
c0
*** Starting 1 switches
s1 ...
*** Starting CLI:
mininet> pingall
*** Ping: testing ping reachability
h1 -> X
h2 -> X
*** Results: 100% dropped (0/2 received)
mininet> pingall
*** Ping: testing ping reachability
h1 -> h2
h2 -> h1
*** Results: 0% dropped (2/2 received)
mininet> █
```



# Mininet

- A complete SDN simulation tool with different controllers, switches and other networking tools like Wireshark and Scapy.
- Controllers
  - NOX
  - Ryu
  - OVS Controller
  - POX
- Switches
  - OVSSwitch
  - IVSSwitch
  - LinuxBridge
  - OVSBridge

# Basic Commands

- To make basic topology
  - `$ sudo mn`
- To display mininet CLI commands
  - `mininet> help`
- To display nodes
  - `mininet> nodes`
- To display links
  - `mininet> net`
- To dump information about all nodes
  - `mininet> dump`

# Commands for nodes

- To execute a command on a specific node
  - mininet> h1 ifconfig -a
  - mininet> s1 ifconfig -a
  - mininet> h1 ps -a
  - mininet> s1 ps -a

# Test connectivity between hosts

- To ping from host 1 to host 2
  - mininet> h1 ping -c 1 h2
- To check all connections
  - mininet> pingall
- To run a simple web server and client
  - mininet> h1 python -m SimpleHTTPServer 80 &
  - mininet> h2 wget -O - h1
  - ...
  - mininet> h1 kill %python

# Advanced Startup Options

- Run a Regression Test
  - `$ sudo mn --test pingpair`
- Run a bandwidth test
  - `$ sudo mn --test iperf`
- Link variations
  - `$ sudo mn --link tc,bw=10,delay=10ms`
  - `mininet> iperf`
  - `mininet> h1 ping -c10 h2`
- Adjustable verbosity
  - `$ sudo mn -v debug`

# Topologies

- To make single topology
  - `$ sudo mn --topo single,3`
- To make bus topology
  - `$ sudo mn --topo linear,4`
- To make tree topology
  - `$ sudo mn --topo tree,2,2`
- Custom topologies can also be made

# XTerm Display

- To start an xterm for every host and switch, pass the -x option
  - `$ sudo mn -x`
- To start xterm while in mininet
  - `mininet> xterm h1 h2`

# Link Up/Down

- For fault tolerance testing, it can be helpful to bring links up and down
- To disable both halves of a virtual ethernet pair
  - `mininet> link s1 h1 down`
- To bring the link back up
  - `mininet> link s1 h1 up`



# Basic ONOS

- This component of ONOS is very useful to learn the basic knowledge of SDN.
- We can make any topology in mininet and connect to it with ONOS controller and then visualize it in GUI.
- There are also some built-in topologies and scripts in it.

# ONOS Basic Commands

- To see help
  - onos> help onos
- To check devices
  - onos> devices
- To check links
  - onos> links
- To check hosts
  - onos> hosts

# ONOS Basic Commands

- To check flows
  - `onos> flows`
- To check paths
  - `onos> paths <TAB>`
- To check intents
  - `onos> intents`

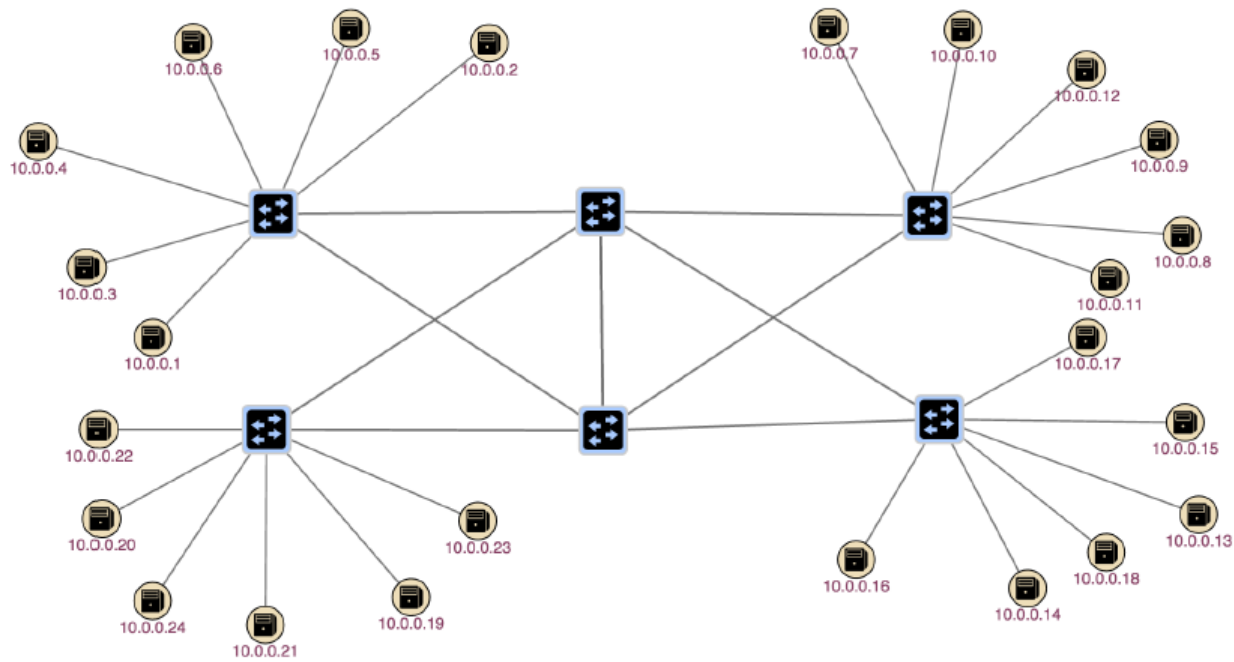
# ONOS App Commands

- To check all applications
  - `onos> apps`
- To check running applications
  - `onos> apps -s -a`
- To activate an application
  - `onos> app activate org.onosproject.fwd`
- To deactivate an application
  - `onos> app deactivate org.onosproject.fwd`

# ONOS Graphical Interface

- ONOS has ability to show the topology in graphical form in the browser.
- Graph shows the switches and hosts attached to each other.
- IP addresses are shown on hosts.

# ONOS Graphical Interface



# Development Environment

- This component of ONOS is used for development purpose.
- It is very easy to create, install, activate, modify or reinstall an application in ONOS.
- It provides different tools for this purpose.
- A sample application onos-byon is provided for experiment.

# Importing Project in IntelliJ IDEA

- Run IntelliJ IDEA
- Select "Import Project" and import the onos-byon project.
- Import the project from external model, and select "Maven".
- Check "Sources" and "Documentation" in the Automatically download section
- Click 'Next' and click next as well on the following window.
- Pick Java 8 in the next window by first clicking on the green '+' sign and selecting 'java8openjdkamd64` and click 'ok'
- Finally click on 'Finish`



# Build Application

- To build new application
  - onos-create-app
- Enter appropriate parameters
  - Define value for property 'groupId': : org.foo
  - Define value for property 'artifactId': : foo-app
  - Define value for property 'version': 1.0-SNAPSHOT: :
  - Define value for property 'package': org.foo: : org.foo.app
  - Confirm properties configuration:
    - groupId: org.foo
    - artifactId: foo-app
    - version: 1.0-SNAPSHOT
    - package: org.foo.app
    - Y: :

# Build Success

- [INFO] Parameter: package, Value: org.foo.app
- [INFO] Parameter: version, Value: 1.0-SNAPSHOT
- [INFO] Parameter: groupId, Value: org.foo
- [INFO] Parameter: artifactId, Value: foo-app
- [INFO] project created from Archetype in dir: /private/tmp/onos-app/foo-app
- [INFO] -----
- [INFO] BUILD SUCCESS
- [INFO] -----
- [INFO] Total time: 01:54 min
- [INFO] Finished at: 2014-12-03T18:00:55-08:00
- [INFO] Final Memory: 14M/245M
- [INFO] -----

# Installation of Application

- Edit the Pom.xml file
  - `$ cd foo-app`
  - `$ vi pom.xml`
- Uncomment the `onos.app.name` and `onos.app.origin` properties as shown in the `pom.xml`
  - ...
  - `<properties>`
  - `<onos.version>1.2.0-SNAPSHOT</onos.version>`
  - `<onos.app.name>org.foo.app</onos.app.name>`
  - `<onos.app.origin>Foo, Inc.</onos.app.origin>`
  - `</properties>`
  - ...

# Installation of Application

- `$ mvn clean install`
- `$ onos-app localhost install target/foo-app-1.0-SNAPSHOT.oar`
- `onos> apps -s`
- ...
- `29 org.foo.app`                      `1.0.SNAPSHOT ONOS OSGi`  
bundle archetype

# Application Activation

- onos> app activate org.foo.app
- onos> apps -s
- ...
- \* 29 org.foo.app                    1.0.SNAPSHOT ONOS OSGi  
bundle archetype

# Re-building and Re-installing of Application

- mvn clean install
- onos-app localhost reinstall org.foo.app target/foo-app-1.0-SNAPSHOT.oar
- onos> app activate org.foo.app

# Testing of Application

- onos> sample
- Hello World

# References

- <http://onosproject.org/>
- <https://wiki.onosproject.org/display/ONOS/Wiki+Home>
- <https://github.com/>
- <https://www.opennetworking.org/>
- <http://opennetsummit.org/>
- <http://searchsdn.techtarget.com/>
- <https://en.wikipedia.org/wiki/>