SECURING SDN WITH SNORT

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Abstract : Software Defined Networking is a network paradigm shift and is changing the network industry by revolutionizing the control plane and data plane architecture. SDN centralizes all the control plane work brining heaps of benefits as compared with traditional networks. Some challenges are also under review in this paper like SDN Security. Security is a vital part of the network and as controller is centralized in SDN, any vulnerability in the controller can results in exploitation of whole network. Security Issues like DDoS attacks on controller, malware attacks, spoofing etc. can create a havoc in the network. Snort is used as a security package to secure SDN controller from DDoS and malware detection attempts by using the rules or policies created on Snort.

Keywords **– Software Defined Networking, Openflow, Control Plane, Data Plane, DDOS, Malware Detection, Snort.**

Introduction: SDN is the emerging networking technology which has changed almost all the sectors of networking like Enterprise, Data Center and Service Provider Networks with the plethora of advantages that it brings with its deployment. Traditional Networks technologies were in use for a long time and a Stanford University student started a project named "Clean Slate Project", with an objective that how would internet be like if we start it again from the scratch. So he redesigned the traditional network architecture by decoupling the control plane and data plane[21]. SDN got the nod from large number of network giant companies like Cisco, Juniper, Huawei, Google, Microsoft etc. SDN takes the centralization[14] approach by having a centralized controller and all other devices acting as data plane devices follows the controller instructions to get the path related information. Controller and data plane switches communicates with each other using Openflow protocol. Controller is the brain of the network, just like in traditional network technologies, routing protocols builds the control plane, controller is used to build the control plane and is the major part of the SDN architecture. Control Clustering is also used in critical networks as it saves the network if there is any problem occurred in Controller, then the primary controller can also be used. SDN Controllers can be implemented in DC as a Virtual Machine or directly on a hardware server over Linux platform. Below is the figure that shows the comparison of architecture of traditional and Software Defined Networking:

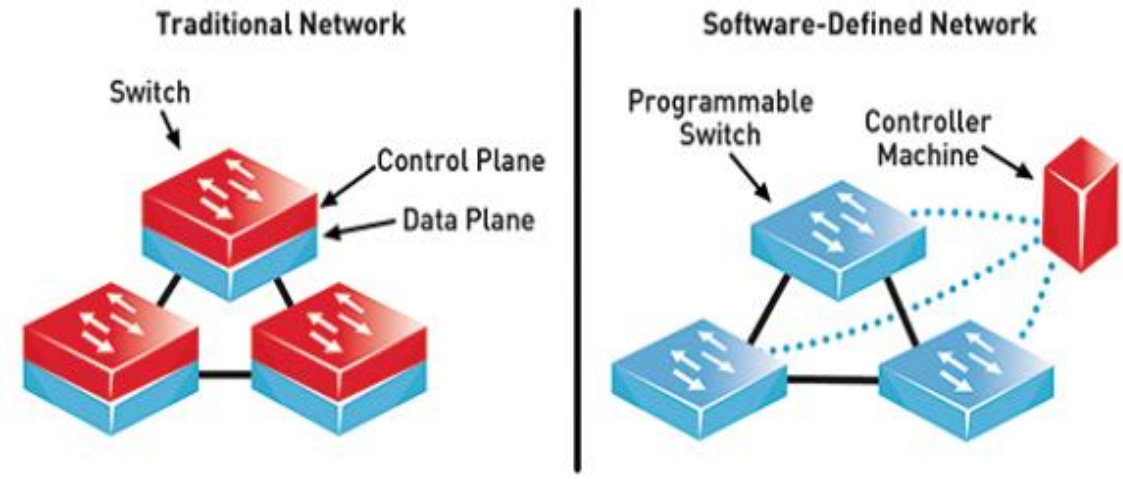

Figure 1.1 – Traditional Network vs SDN[22]

1.1. SDN ARCHITECTURE

SDN Architecture comprises of three different layers[17-19] i.e. Application, Control and Infrastructure Layer as shown in figure 1.2 below:

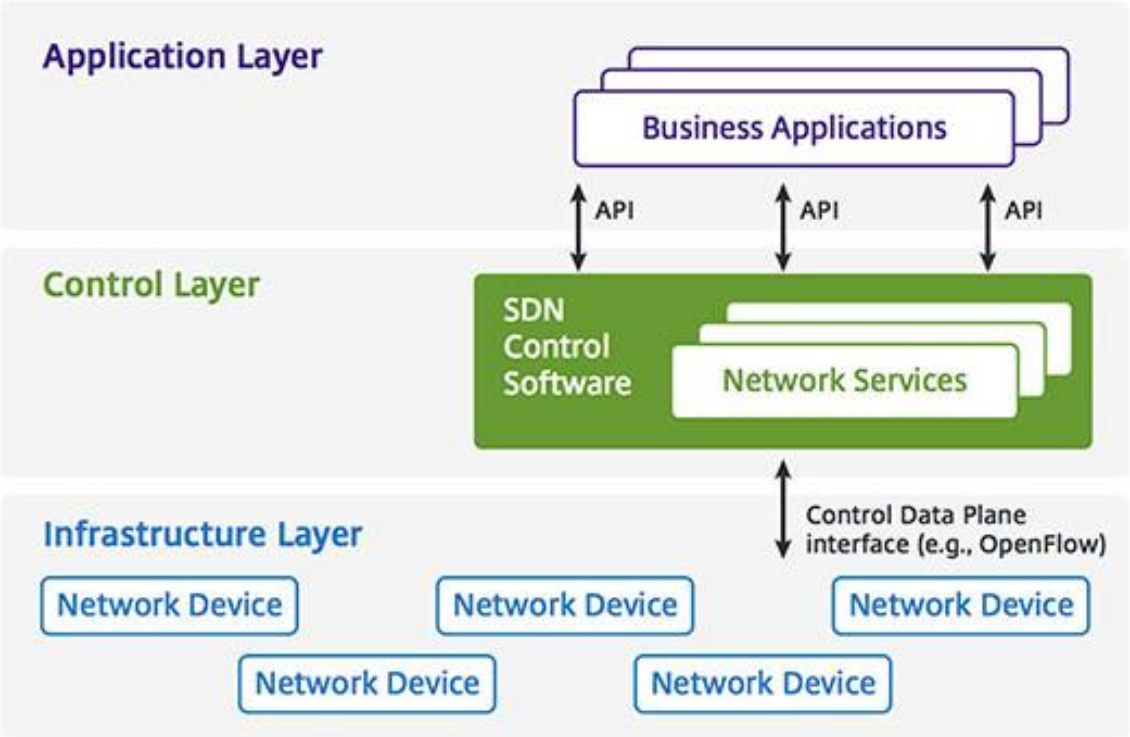

Figure 1.2 – SDN Architecture[23]

Application Layer – This layer holds the programs that communicate with the controller via Application Programming Interfaces(APIs).These applications can be of network management, analytics or they can be business related applications that runs in large scale data centers.
Control Layer – This layer is the intermediate layer of SDN Architecture. They get the instructions from Application Layer and then relays them to network components in the infrastructure layer. Controller also gets the information from the hardware devices and provide this information to the application layer.
Infrastructure Layer – This layer holds the devices that have data lane capabilities and they forwards the data as per the instructions provided to them by controller.

1.2. SDN BENEFITS

Enhancing Configuration–Configuring networks is one of the most complex and critical tasks, as a single mistake and make whole network vulnerable. In traditional networks adding a new network device like router needs configuration on that device in a tested manner, so that any changes would not affect the current network. Manual Configuration has to be performed on the new addition on devices so that they can be in working condition. With SDN, controller is the brain of the network and all the flows are controlled by the controller and it automatically reduces the configuration[6] time.

Programmable and Customizable–SDN brings the power of programming into the network where new applications and features related with network can be deployed easily. Traditional network technologies are mostly proprietary, for example, if we buy one vendor router, then it comes with a base Operating System, and in case we need to have some specific feature, then we have to buy the license for that and we do not have any customization or programmable option available on that device to add some new feature. Also, experimentation can be a big issue in traditional networks. With SDN, new features can be added[7] by using the programmable interfaces and it makes it much more flexible than using traditional networks. This is one of the reason why data center giant companies like Google and Facebook have shifted their networks to SDN from traditional networks.

Lesser Network Infrastructure Costs –Traditional networks are costly and SDN makes a very cost efficient solution for the network infrastructure industry and has reduced the network hardware and software costs by large margin. With no proprietary hardware and software needed, no control plane feature required in every device, costs have significantly reduced. Companies use single or multiple controllers in large environments and all other data plane devices are cheap in cost.

Granular Security –With large number of devices connecting with internet and cloud ,new challenges related with scalability and security have also arised in the network security industry. Controller can provide security[6] in centralized manner making security related policies easier to implement.

Better Visibility into the Network –Centralized controller means better visibility and view of the network. Finding bugs and monitoring become easy as there is no need to monitor all the devices like in traditional network, and we can get full network view from centralized controller.

Better Uptime and more reliable network –SDN and its centralization makes implementation and troubleshooting much faster than before. In traditional networks, in case of any bugs or issues, first the devices or link which creates the issues has to be found

to rectify the problem and in case of a large network, it can be very difficult. But with SDN, it easy to troubleshoot the network as the only device which has to be troubleshoot is the SDN controller.

2. SDN CHALLENGES

Tackling Fast On-Demand Growth –Technologies like IoT, Cloud Computing, Machine Learning etc are making big changes in the industry and with that the need for network, compute resources have also increased. Tackling the growth, where billions of bytes of data is produced in data centers has to be make sure so that no performance related issues should arise.

Addressing automatic real-time changes –Network and Server automation is one of the big things happened with SDN in data center industry. APIs are used by SDN based controllers in application layer which are used to add functionality related with different services. Monitoring should be based on OpenAPIs so that any changes or updation related with SDN controllers or topology should be directly monitored and bring better visibility of the network.

Security –One of the major concerns related with SDN is the security of the controller. Protecting[3-5] controller against unauthorized access and other attacks like malware and DDOS is very important. As SDN Controller applications are mainly open source, third party applications can also be added and customized which can also become threats as there can be chances that the application added to the controller is not tested and verified and may introduce some vulnerabilities in the SDN controller and its working. Various types of attacks are explained below:

- Third party applications can be integrated with the SDN controller using its application layer and these applications are not verified and can also be malware infected which can result in malware attacks on the SDN controller.
- DDoS attacks are implemented by hacking groups in order to disrupt the application, network and service availability. This attack can be used on the controller to disrupt the controller from doing its work. Large amount of ICMP, TCP SYN, UDP, HTTP traffic bursts can be sent using the botnets which disrupts the controller services.
- Man-in-the-Middle attack is used in order to break confidentiality. Controller connects with data plane switches using Openflow protocol for the path selection process. Hackers can use the MiTM attack to steal the data over the communication channel in case strong encryption standard is not in place.
- Controller Spoofing can also be done to make the data plane switches in the network think that rogue controller is the real one.

2.1. SDN CONTROLLERS

Controller is the brain and heart of the SDN Architecture and it plays the intermediary role in connecting first and third layer of SDN model. Controller controls the whole network paths with the help of flow tables and other information shared with the data plane switches over the network. Most used and popular SDN Controllers are listed in below table:

Table 1 – SDN Controllers

Controller	**Company**	**Open Source**
POX Controller	Nicira	Yes
Beacon Controller	Stanford University	Yes
Floodlight Controller	Big Switch Networks	Yes
Floodlight-Plus Controller	Big Switch Networks	Yes
Ryu Controller	NTT Labs	Yes
OpenDaylight Controller	Linux Foundation	Yes
ONOS Controller	Linux Foundation	Yes
Open Contrail Controller	Open Contrail	Yes

3. DDOS

Distributed Denial of Service attack is implemented by the hackers in order to disrupt the availability of their network and application services. These attacks takes websites or servers down by bombarding large number of requests which in actual looks valid but they aren't.Most of the DDoS attacks these days are on Cloud based applications, Network Applications and websites. Hackers also used DDoS attacks in order to make target organizations focus away from some other security breach or to steal data. Companies in financial sector, ecommerce etc are susceptible to these types of attacks. Hackers launch the phishing attacks to the

IT administrators of the bank and if they are successful in getting the login credentials, they launch the DDoS attack straight away so that bank become busy in dealing with the DDoS attack and hackers steal data and money via backdoor attack. Hackers also use Home routes, IoT devices, android devices with malicious apps etc can also be used to launch the attack and they become part of the botnet network. Bots are the infected devices used by cyber criminals or hackers in order to launch the attack while botnet is the network of bots used to attack the target. SDN Controllers are also susceptible to DDoS attacks

3.1. DDOS TYPES

We can perform DDoS attacks in different forms. These types are explained below:

- **Volume Based–**This attack involves gigantic amount of requests to the target. System thinks these requests of either valid or invalid. These attacks are used to choke the network bandwidth capacity. One way hacker uses for these sort of attacks are UDP amplification attack, where hackers requests for data from some third-party server and while doing this, they spoofed your target server address. Then the third party server sends the massive amount of data on the target server.
- **Application Based** – In this type of attack, hackers use vulnerabilities in the web based applications or websites which further leads to crash of web server. Hackers keep on sending application connection requests to make the database pool busy in the manner that it starts to block the legitimate requests.
- **Protocol Based** – This type of attacks are mainly on the servers or the load balancers by exploiting the method systems used for communication. In this type of attacks, packets are designed to make servers wait for response which does not exist for example with three way handshake process with TCP SYN Flood.

3.2. COMMON DDOS ATTACKS

- **SYN Flood –** TCP SYN Flood uses the TCP 3-way handshake process and it exploits the server by sending hundreds of thousands of TCP SYN messages and in response Server sends TCP-SYN-ACK messages to which Attacker do not respond with TCP ACK message making the server stuck in the waiting state resulting in shutting down the service.
- **UDP Flood –** UDP is a connectionless protocol. UDP Flood uses random ports on a machine using UDP packets. Hosts then looks for the application on that port number, but unable to find any.
- **HTTP Flood –** This message sends the HTTP GET and PUT requests on the server with an advantage that it uses lesser bandwidth than other attacks, but it has the ability to make web server to use maximum resources.
- **Ping of Death –** It attacks the servers by sending malicious pings. It is not as effective as other DDoS attacks.

3.3. DDOS TOOLS

- **LOIC –** This tool is one of the most popular and used tool for DOS[24] attacks. Anonymous, one of the largest hacking groups uses this tool for DDOS. This tool is very simple to use with its GUI Interface. LOIC can be used to attack the victim using TCP, UDP, or HTTP requests. With this tool, we just need to know either URL or IP Address of the target machine.
- **PyLoris –** This tools is used for DOS attack testing for servers. It performs DOS attack on a service. PyLoris uses SOCKS proxies along with the SSL connection in order to attack a server. Different protocols which can be targeted using PyLoris[26] are HTTP, FTP, SMTP, IMAP and Telnet.
- **Hping –** This package is a command line based TCP/IP packet analyzer. Hping3[27] is used for security testing. This package supports TCP, UDP, ICMP and IP protocol based attacks. It is a powerful DDOS attack tool with the customization is brings in testing DDOS vulnerabilities.
- **Xerxes –** This DOS tool[25] is one of the most powerful tools available freely on the internet. Xerxes is written in C language. This tool is used for HTTP based attacks.
- **GoldenEye HTTP DOS Tool –** One of the simplest tools used for DOS[24] attacks. This tool was developed in Python for testing DOS vulnerabilities. It attacks using HTTP Flood method.

3.4. MALWARE

Malwares is always a big security threat to the computing system and SDN is like no other. SDN brings customization possible in the network industry and applications can be integrated with the controller at the application layer level. Third party applications which are not verified are also used by large number of companies, which can also be vulnerable to different security threats and can be malware infected. Various types of malware including Virus, Worms. Spywares, Trojan Horses etc. can be used by attacker to attack the controller.

3.5. SPOOFING

The attacker can spoof the controller by using the spoofing attack. If spoofing attack is conducted successfully, then the attacker can easily create new flow entries and updates the flow table. Attacker by having the full privileged access of controller have full control over the network. Once entered, attacker can steal the data, or disrupt the network functioning.

4. RESULTS AND DISCUSSIONS

Snort is an open-source and free and is also one of the most used signature based network intrusion detection and prevention system(NIDS-NIPS). It monitors the data sent or received over a particular network interface. Snort do the protocol analysis, content based searching and matching, performs real-time analysis of data coming from internet and going to internet. It also does the packet logging of real time IP networks. Recent attacks related with malwares can be determined. Snort comes with different features, for example, buffer overflow, port scanning, worms and other vulnerability related issues. Snort can be easily installed in linux and

Windows based Operating systems. We have used Snort on Ubuntu OS, but before installing Snort, we need to fulfil some prerequisites which are shown below:

```
root@onos-sdn:/home/onos# apt-get install openssh-server ethtool build-essential libpcap-dev libpcre3-dev libdumbnet-dev bison flex zlib1g-dev
liblzma-dev openssl libssl-dev
Reading package lists... Done
Building dependency tree
Reading state information... Done
ethtool is already the newest version.
ethtool set to manually installed.
The following extra packages will be installed:
  cpp-4.8 dpkg-dev fakeroot g++ g++-4.8 gcc-4.8 gcc-4.8-base
  libalgorithm-diff-perl libalgorithm-diff-xs-perl libalgorithm-merge-perl
  libasan0 libatomic1 libbison-dev libdpkg-perl libdumbnet1 libfakeroot
  libfl-dev libgcc-4.8-dev libgomp1 libitm1 libpcap0.8-dev libpcrecpp0
  libquadmath0 libsigsegv2 libssl-doc libssl1.0.0 libstdc++-4.8-dev libstdc++6
  libtsan0 m4 openssh-client zlib1g
Suggested packages:
  bison-doc gcc-4.8-locales debian-keyring g++-multilib g++-4.8-multilib
  gcc-4.8-doc libstdc++6-4.8-dbg gcc-4.8-multilib libgcc1-dbg libgomp1-dbg
  libitm1-dbg libatomic1-dbg libasan0-dbg libtsan0-dbg libquadmath0-dbg
  liblzma-doc libstdc++-4.8-doc libpam-ssh keychain monkeysphere rssh
  molly-guard
The following NEW packages will be installed:
  bison build-essential dpkg-dev fakeroot flex g++ g++-4.8
  libalgorithm-diff-perl libalgorithm-diff-xs-perl libalgorithm-merge-perl
  libbison-dev libdumbnet-dev libdumbnet1 libfakeroot libfl-dev liblzma-dev
  libpcap-dev libpcap0.8-dev libpcre3-dev libpcrecpp0 libsigsegv2 libssl-dev
  libssl-doc libstdc++-4.8-dev m4 zlib1g-dev
The following packages will be upgraded:
  cpp-4.8 gcc-4.8 gcc-4.8-base libasan0 libatomic1 libdpkg-perl libgcc-4.8-dev
  libgomp1 libitm1 libquadmath0 libssl1.0.0 libstdc++6 libtsan0 openssh-client
  openssh-server openssl zlib1g
17 upgraded, 26 newly installed, 0 to remove and 446 not upgraded.
Need to get 38.1 MB of archives.
After this operation, 56.3 MB of additional disk space will be used.
Do you want to continue? [Y/n]
```

Figure 4.1 – Prerequisites of snort on linux

Next, we need to install Data Acquisition Package or DAQ in your system by installing latest DAQ package by using the wget package and following command:

```
root@onos-sdn:/home/onos# wget https://www.snort.org/downloads/snort/daq-2.0.6.tar.gz
--2019-09-01 23:28:54--  https://www.snort.org/downloads/snort/daq-2.0.6.tar.gz
Resolving www.snort.org (www.snort.org)... 104.18.139.9, 104.18.138.9
Connecting to www.snort.org (www.snort.org)|104.18.139.9|:443... connected.
HTTP request sent, awaiting response... 302 Found
Location: https://snort-org-site.s3.amazonaws.com/production/release_files/files/000/011/188/original/daq-2.0.6.tar.gz?X-Amz-Algorithm=AWS4-HMA
C-SHA256&X-Amz-Credential=AKIAIXACIED2SPMSC7GA%2F20190901%2Fus-east-1%2Fs3%2Faws4_request&X-Amz-Date=20190901T175858Z&X-Amz-Expires=3600&X-Amz-
SignedHeaders=host&X-Amz-Signature=0a1b1068747fcf65d5ae634e88111371da2ae463e64e6c0d07ffef47658c3113 [following]
--2019-09-01 23:28:58--  https://snort-org-site.s3.amazonaws.com/production/release_files/files/000/011/188/original/daq-2.0.6.tar.gz?X-Amz-Alg
orithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIAIXACIED2SPMSC7GA%2F20190901%2Fus-east-1%2Fs3%2Faws4_request&X-Amz-Date=20190901T175858Z&X-Amz-Expi
res=3600&X-Amz-SignedHeaders=host&X-Amz-Signature=0a1b1068747fcf65d5ae634e88111371da2ae463e64e6c0d07ffef47658c3113
Resolving snort-org-site.s3.amazonaws.com (snort-org-site.s3.amazonaws.com)... 52.216.128.51
Connecting to snort-org-site.s3.amazonaws.com (snort-org-site.s3.amazonaws.com)|52.216.128.51|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 518013 (506K) [binary/octet-stream]
Saving to: 'daq-2.0.6.tar.gz'

100%[=====================================================================================================>] 5,18,013     146KB/s   in 3.5s

2019-09-01 23:29:03 (146 KB/s) - 'daq-2.0.6.tar.gz' saved [518013/518013]

root@onos-sdn:/home/onos#
```

Figure 4.2 – Downloading DAQ using the wget command

As we have downloaded the tar.gz file, first we need to extract it using the tar –xvzf attributes as shown below:

```
root@onos-sdn:/home/onos# tar -xvzf daq-2.0.6.tar.gz
daq-2.0.6/
daq-2.0.6/ChangeLog
daq-2.0.6/missing
daq-2.0.6/daq.dsp
daq-2.0.6/configure
daq-2.0.6/sfbpf/
daq-2.0.6/sfbpf/sf_bpf_printer.c
daq-2.0.6/sfbpf/IP6_misc.h
daq-2.0.6/sfbpf/sf_gencode.c
```

Figure 4.3 – tar command to extract the daq.tar.gz file

To install the DAQ, we need to change the directory to daq-2.0.6 and then use the ./configure, to configure the DAQ process as shown below in figure 3.4

```
root@onos-sdn:/home/onos# cd daq-2.0.6
root@onos-sdn:/home/onos/daq-2.0.6# ls
aclocal.m4  ChangeLog  config.guess  config.sub  configure.ac  daq.dsp  install-sh  m4           Makefile.in  os-daq-modules  sfbpf
api         compile    config.h.in   configure   COPYING       depcomp  ltmain.sh   Makefile.am  missing      README
root@onos-sdn:/home/onos/daq-2.0.6# ./configure
checking for a BSD-compatible install... /usr/bin/install -c
checking whether build environment is sane... yes
checking for a thread-safe mkdir -p... /bin/mkdir -p
checking for gawk... no
checking for mawk... mawk
checking whether make sets $(MAKE)... yes
checking whether make supports nested variables... yes
checking for gcc... gcc
checking whether the C compiler works... yes
checking for C compiler default output file name... a.out
checking for suffix of executables...
checking whether we are cross compiling... no
checking for suffix of object files... o
checking whether we are using the GNU C compiler... yes
checking whether gcc accepts -g... yes
```

Figure 4.4 – Configuring DAQ

Below are the modules which are installed under the DAQ process:

```
Build AFPacket DAQ module.. : yes
Build Dump DAQ module...... : yes
Build IPFW DAQ module...... : yes
Build IPQ DAQ module....... : no
Build NFQ DAQ module....... : no
Build PCAP DAQ module...... : yes
Build netmap DAQ module.... : no

root@onos-sdn:/home/onos/daq-2.0.6#
```

Figure 4.5 – Module installed with DAQ process.

After configuring DAQ, we need to make and make install the DAQ to install the DAQ as shown in below figures 4.6 and 4.7

```
root@onos-sdn:/home/onos/daq-2.0.6# make
make  all-recursive
make[1]: Entering directory `/home/onos/daq-2.0.6'
Making all in api
make[2]: Entering directory `/home/onos/daq-2.0.6/api'
/bin/bash ../libtool  --tag=CC   --mode=compile gcc -DHAVE_CONFIG_H -I. -I..    -I/usr/include  -g -O2 -fvisibility=hidden -Wall -Wwrite-strings
 -Wsign-compare -Wcast-align -Wextra -Wformat -Wformat-security -Wno-unused-parameter -fno-strict-aliasing -fdiagnostics-show-option -pedantic
-std=c99 -D_GNU_SOURCE -MT daq_base.lo -MD -MP -MF .deps/daq_base.Tpo -c -o daq_base.lo daq_base.c
libtool: compile:  gcc -DHAVE_CONFIG_H -I. -I.. -I/usr/include -g -O2 -fvisibility=hidden -Wall -Wwrite-strings -Wsign-compare -Wcast-align -We
xtra -Wformat -Wformat-security -Wno-unused-parameter -fno-strict-aliasing -fdiagnostics-show-option -pedantic -std=c99 -D_GNU_SOURCE -MT daq_b
ase.lo -MD -MP -MF .deps/daq_base.Tpo -c daq_base.c  -fPIC -DPIC -o .libs/daq_base.o
libtool: compile:  gcc -DHAVE_CONFIG_H -I. -I.. -I/usr/include -g -O2 -fvisibility=hidden -Wall -Wwrite-strings -Wsign-compare -Wcast-align -We
xtra -Wformat -Wformat-security -Wno-unused-parameter -fno-strict-aliasing -fdiagnostics-show-option -pedantic -std=c99 -D_GNU_SOURCE -MT daq_b
ase.lo -MD -MP -MF .deps/daq_base.Tpo -c daq_base.c -o daq_base.o >/dev/null 2>&1
mv -f .deps/daq_base.Tpo .deps/daq_base.Plo
/bin/bash ../libtool  --tag=CC   --mode=compile gcc -DHAVE_CONFIG_H -I. -I..    -I/usr/include  -g -O2 -fvisibility=hidden -Wall -Wwrite-strings
 -Wsign-compare -Wcast-align -Wextra -Wformat -Wformat-security -Wno-unused-parameter -fno-strict-aliasing -fdiagnostics-show-option -pedantic
-std=c99 -D_GNU_SOURCE -MT daq_mod_ops.lo -MD -MP -MF .deps/daq_mod_ops.Tpo -c -o daq_mod_ops.lo daq_mod_ops.c
libtool: compile:  gcc -DHAVE_CONFIG_H -I. -I.. -I/usr/include -g -O2 -fvisibility=hidden -Wall -Wwrite-strings -Wsign-compare -Wcast-align -We
xtra -Wformat -Wformat-security -Wno-unused-parameter -fno-strict-aliasing -fdiagnostics-show-option -pedantic -std=c99 -D_GNU_SOURCE -MT daq_m
od_ops.lo -MD -MP -MF .deps/daq_mod_ops.Tpo -c daq_mod_ops.c  -fPIC -DPIC -o .libs/daq_mod_ops.o
libtool: compile:  gcc -DHAVE_CONFIG_H -I. -I.. -I/usr/include -g -O2 -fvisibility=hidden -Wall -Wwrite-strings -Wsign-compare -Wcast-align -We
xtra -Wformat -Wformat-security -Wno-unused-parameter -fno-strict-aliasing -fdiagnostics-show-option -pedantic -std=c99 -D_GNU_SOURCE -MT daq_m
od_ops.lo -MD -MP -MF .deps/daq_mod_ops.Tpo -c daq_mod_ops.c -o daq_mod_ops.o >/dev/null 2>&1
mv -f .deps/daq_mod_ops.Tpo .deps/daq_mod_ops.Plo
/bin/bash ../libtool  --tag=CC   --mode=link gcc  -g -O2 -fvisibility=hidden -Wall -Wwrite-strings -Wsign-compare -Wcast-align -Wextra -Wformat
 -Wformat-security -Wno-unused-parameter -fno-strict-aliasing -fdiagnostics-show-option -pedantic -std=c99 -D_GNU_SOURCE -version-info 2:4:0
-o libdaq.la -rpath /usr/local/lib daq_base.lo daq_mod_ops.lo -ldl
libtool: link: gcc -shared  -fPIC -DPIC  .libs/daq_base.o .libs/daq_mod_ops.o   -ldl  -g -O2   -Wl,-soname -Wl,libdaq.so.2 -o .libs/libdaq.so.2
.0.4
libtool: link: (cd ".libs" && rm -f "libdaq.so.2" && ln -s "libdaq.so.2.0.4" "libdaq.so.2")
libtool: link: (cd ".libs" && rm -f "libdaq.so" && ln -s "libdaq.so.2.0.4" "libdaq.so")
libtool: link: ar cru .libs/libdaq.a  daq_base.o daq_mod_ops.o
libtool: link: ranlib .libs/libdaq.a
libtool: link: ( cd ".libs" && rm -f "libdaq.la" && ln -s "../libdaq.la" "libdaq.la" )
```

Figure 4.6 – make command output of DAQ

After successful completion of DAQ make process, we can use make install command to install the DAQ and its libraries as shown below:

```
root@onos-sdn:/home/onos/daq-2.0.6# make install
Making install in api
make[1]: Entering directory `/home/onos/daq-2.0.6/api'
make[2]: Entering directory `/home/onos/daq-2.0.6/api'
 /bin/mkdir -p '/usr/local/lib'
 /bin/bash ../libtool   --mode=install /usr/bin/install -c   libdaq.la libdaq_static.la '/usr/local/lib'
libtool: install: /usr/bin/install -c .libs/libdaq.so.2.0.4 /usr/local/lib/libdaq.so.2.0.4
libtool: install: (cd /usr/local/lib && { ln -s -f libdaq.so.2.0.4 libdaq.so.2 || { rm -f libdaq.so.2 && ln -s libdaq.so.2.0.4 libdaq.so.2; };
})
libtool: install: (cd /usr/local/lib && { ln -s -f libdaq.so.2.0.4 libdaq.so || { rm -f libdaq.so && ln -s libdaq.so.2.0.4 libdaq.so; }; })
libtool: install: /usr/bin/install -c .libs/libdaq.lai /usr/local/lib/libdaq.la
libtool: install: /usr/bin/install -c .libs/libdaq_static.lai /usr/local/lib/libdaq_static.la
libtool: install: /usr/bin/install -c .libs/libdaq.a /usr/local/lib/libdaq.a
libtool: install: chmod 644 /usr/local/lib/libdaq.a
libtool: install: ranlib /usr/local/lib/libdaq.a
libtool: install: /usr/bin/install -c .libs/libdaq_static.a /usr/local/lib/libdaq_static.a
libtool: install: chmod 644 /usr/local/lib/libdaq_static.a
libtool: install: ranlib /usr/local/lib/libdaq_static.a
libtool: finish: PATH="/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin:/bin:/usr/games:/usr/local/games:/sbin" ldconfig -n /usr/local/l
ib
----------------------------------------------------------------------
Libraries have been installed in:
   /usr/local/lib
```

Figure 4.7 – DAQ make install output

After successful installation of DAQ, we need to get the Snort latest package using the wget and then install it using the same process we have used to install the DAQ process as shown below in figure 3.8 and 3.9:

```
root@onos-sdn:/home/onos/daq-2.0.6# wget https://www.snort.org/downloads/snort/snort-2.9.14.1.tar.gz
--2019-09-01 23:39:43--  https://www.snort.org/downloads/snort/snort-2.9.14.1.tar.gz
Resolving www.snort.org (www.snort.org)... 104.18.139.9
Connecting to www.snort.org (www.snort.org)|104.18.139.9|:443... connected.
HTTP request sent, awaiting response... 302 Found
Location: https://snort-org-site.s3.amazonaws.com/production/release_files/files/000/011/182/original/snort-2.9.14.1.tar.gz?X-Amz-Algorithm=AWS
4-HMAC-SHA256&X-Amz-Credential=AKIAIXACIED2SPMSC7GA%2F20190901%2Fus-east-1%2Fs3%2Faws4_request&X-Amz-Date=20190901T180943Z&X-Amz-Expires=3600&X
-Amz-SignedHeaders=host&X-Amz-Signature=e0a96d99238cddc3d8b0fdbb12e4cd1f3f66e776c378531b1ea2ce80c7048207 [following]
--2019-09-01 23:39:44--  https://snort-org-site.s3.amazonaws.com/production/release_files/files/000/011/182/original/snort-2.9.14.1.tar.gz?X-Am
z-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIAIXACIED2SPMSC7GA%2F20190901%2Fus-east-1%2Fs3%2Faws4_request&X-Amz-Date=20190901T180943Z&X-Amz
-Expires=3600&X-Amz-SignedHeaders=host&X-Amz-Signature=e0a96d99238cddc3d8b0fdbb12e4cd1f3f66e776c378531b1ea2ce80c7048207
Resolving snort-org-site.s3.amazonaws.com (snort-org-site.s3.amazonaws.com)... 52.217.32.220
Connecting to snort-org-site.s3.amazonaws.com (snort-org-site.s3.amazonaws.com)|52.217.32.220|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 6531749 (6.2M) [binary/octet-stream]
Saving to: ‘snort-2.9.14.1.tar.gz’

100%[=======================================================================================================>] 65,31,749    140KB/s   in 47s

2019-09-01 23:40:32 (137 KB/s) - ‘snort-2.9.14.1.tar.gz’ saved [6531749/6531749]

root@onos-sdn:/home/onos/daq-2.0.6#
```

Figure 4.8 – Downloading Snort

```
root@onos-sdn:/home/onos/daq-2.0.6/snort-2.9.14.1# ./configure --enable-sourcefire --disable-open-appid
checking for a BSD-compatible install... /usr/bin/install -c
checking whether build environment is sane... yes
checking for a thread-safe mkdir -p... /bin/mkdir -p
checking for gawk... no
checking for mawk... mawk
checking whether make sets $(MAKE)... yes
checking whether make supports nested variables... yes
checking for style of include used by make... GNU
checking for gcc... gcc
checking whether the C compiler works... yes
checking for C compiler default output file name... a.out
checking for suffix of executables...
checking whether we are cross compiling... no
checking for suffix of object files... o
checking whether we are using the GNU C compiler... yes
checking whether gcc accepts -g... yes
checking for gcc option to accept ISO C89... none needed
checking dependency style of gcc... gcc3
checking for gcc option to accept ISO C99... -std=gnu99
checking for gcc -std=gnu99 option to accept ISO Standard C... (cached) -std=gnu99
checking for gcc... (cached) gcc
checking whether we are using the GNU C compiler... (cached) yes
checking whether gcc accepts -g... (cached) yes
checking for gcc option to accept ISO C89... (cached) none needed
checking dependency style of gcc... (cached) gcc3
checking build system type... x86_64-unknown-linux-gnu
checking host system type... x86_64-unknown-linux-gnu
checking how to print strings... printf
checking for a sed that does not truncate output... /bin/sed
```

Figure 4.9 – Configuring Snort

After finishing all the processes, we can verify the snort package using command snort –V sh shown below:

```
root@onos-sdn:/home/onos/daq-2.0.6/snort-2.9.14.1# snort -V

   ,,_     -*> Snort! <*-
  o"  )~   Version 2.9.14.1 GRE (Build 15003)
   ''''    By Martin Roesch & The Snort Team: http://www.snort.org/contact#team
           Copyright (C) 2014-2019 Cisco and/or its affiliates. All rights reserved.
           Copyright (C) 1998-2013 Sourcefire, Inc., et al.
           Using libpcap version 1.5.3
           Using PCRE version: 8.31 2012-07-06
           Using ZLIB version: 1.2.8

root@onos-sdn:/home/onos/daq-2.0.6/snort-2.9.14.1#
```

Figure 4.10 – Snort installed verification

Next we need to configure snort using one of the three modes as given below:

- **Sniffer Mode:** Using this mode, all the output is shown on the terminal. You can check the packets using the continuous flow.
- **Packet Logger Mode:** Here output is stored in disk and one can monitor it later.
- **Network IDS Mode –** In IDS mode, we can configure the parameters which integrated the snort while performing network scans.

Snort IDS Mode is configured in the next step, a directory based structure is created for snort. We have created a directory structure using the following commands to create directory and files as shown below:

```
root@onos-sdn:/home/onos/daq-2.0.6/snort-2.9.14.1# mkdir /etc/snort /etc/snort/preproc_rules /etc/snort/rules /var/log/snort /usr/local/lib/sno
rt_dynamicrules
root@onos-sdn:/home/onos/daq-2.0.6/snort-2.9.14.1# touch /etc/snort/rules/white_list.rules /etc/snort/rules/black_list.rules /etc/snort/rules/l
ocal.rules
root@onos-sdn:/home/onos/daq-2.0.6/snort-2.9.14.1#
```

Figure 4.11 – Snort directory and files

We have set the permissions to different directories related with Snort as shown below:

```
root@onos-sdn:/home/onos/daq-2.0.6/snort-2.9.14.1# chmod -R 5775 /etc/snort/ /var/log/snort/ /usr/local/lib/snort /usr/local/lib/snort_dynamicr
ules/
```

Figure 4.12 – Setting permissions to all the snort related directories

After setting the permissions, we need to copy all the configuration from Snort source as shown below:

```
cd /root/snort-2.9.11.1/etc
cp -avr .conf .map .dtd .config /etc/snort/
cp -avr /root/snort-2.9.11.1/src/dynamic-
preprocessors/build/usr/local/lib/snort_dynamicpreprocessor/*/usr/local/lib/snort_dynamicpreprocessor/
```

After copy the sources, we need to comment out all rule sets using the following command:

```
sed -i "s/include &dollar;RULE\_PATH/#include \$RULE_PATH/" /etc/snort/snort.conf
```

We have to configure the snort configuration file as shown below in /etc/snort.conf

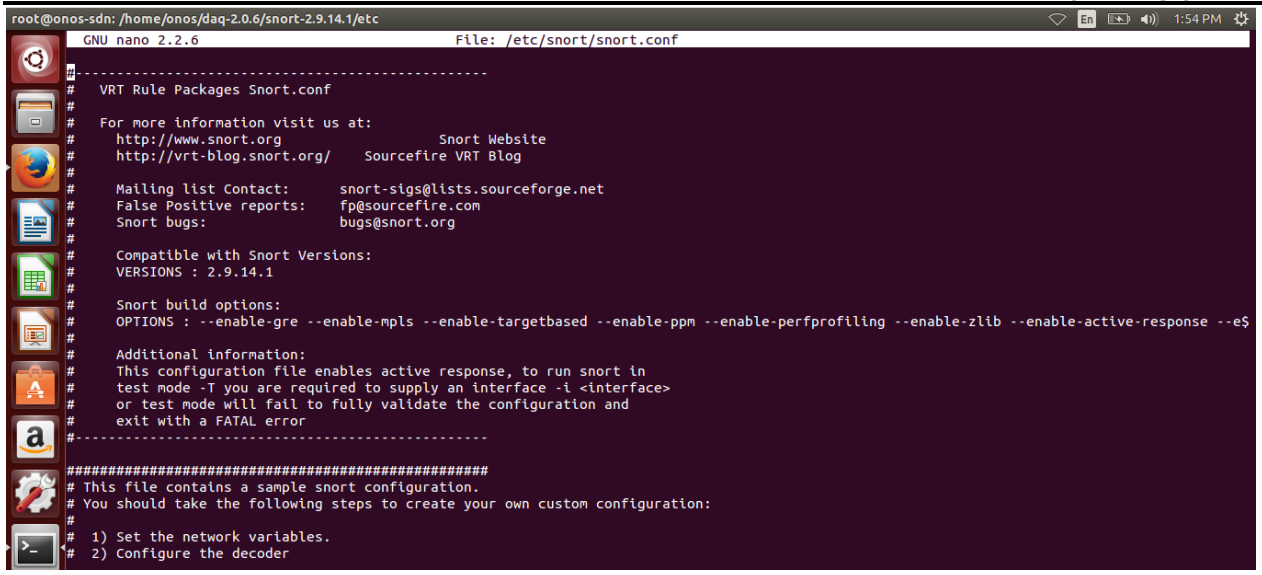

Figure 4.13 – Snort Conf File

After editing snort.conf file, we need to validate the configuration file as shown below:

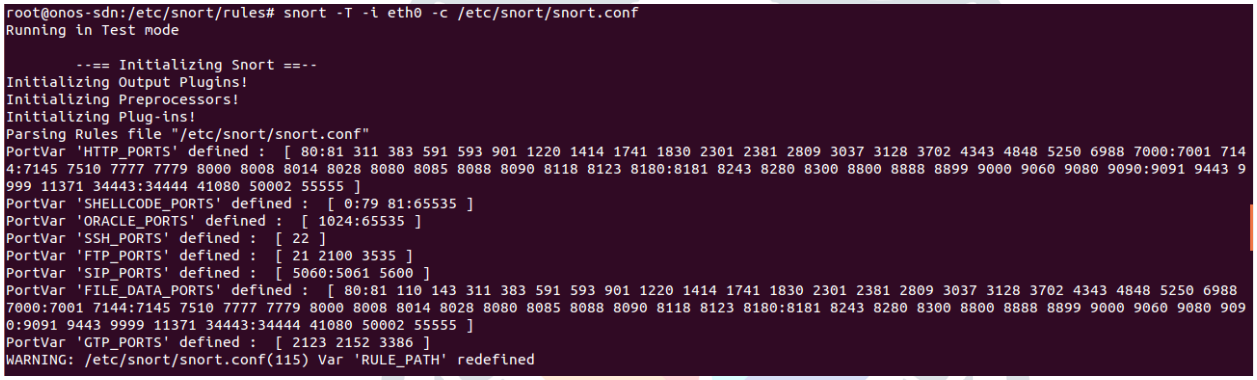

Figure 4.14 – Initialization of Snort

After initialization of snort and validation of snort configuration is completed as shown below in Figure 3.15:

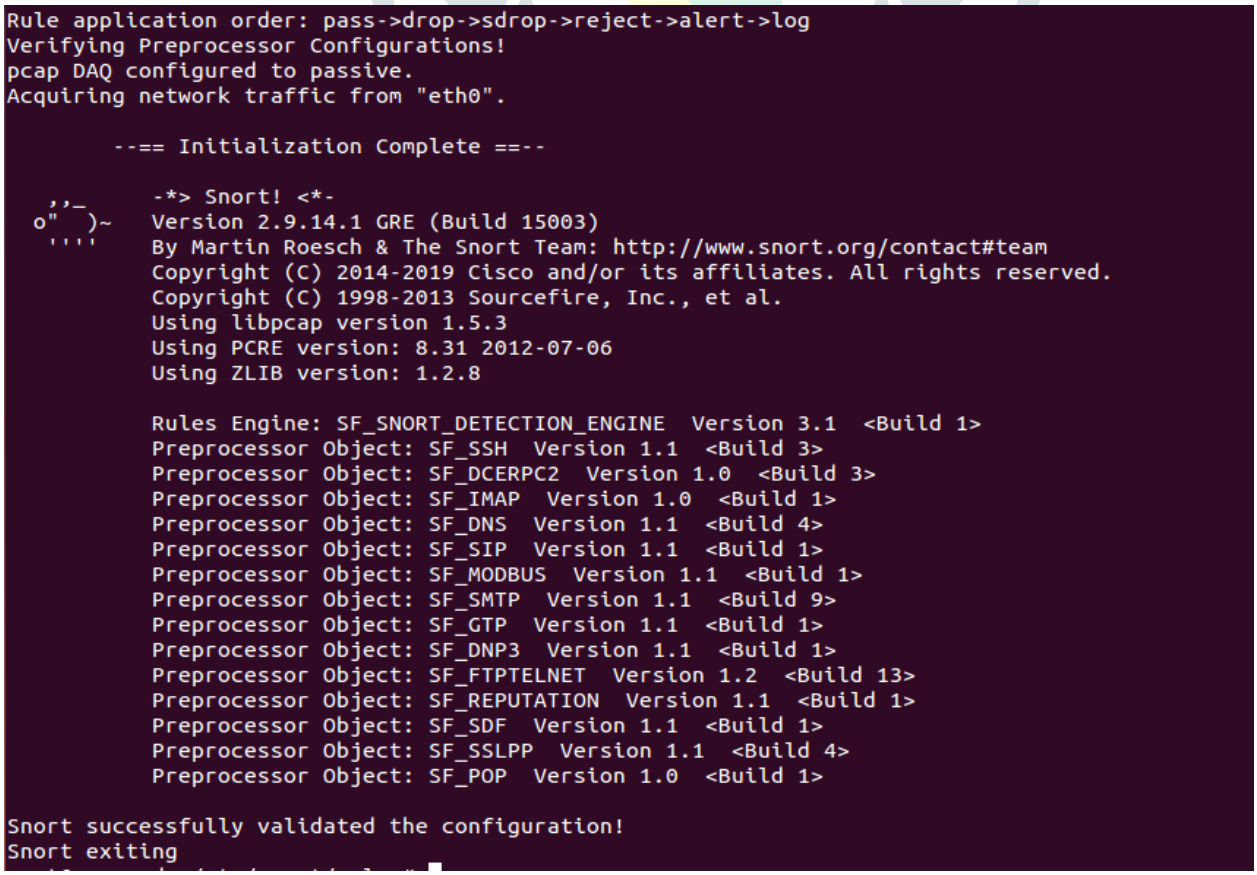

Figure 4.15 – Validating Snort

As seen in the above figure, snort has successfully validated the configuration process. Snort is not needed to be configured with rules to be configured for SDN security, so we have created the local.rules file as shown below with following rules:

```
  GNU nano 2.2.6                          File: /etc/snort/rules/local.rules

alert tcp any any -> $HOME_NET 8181 (msg:"SDN connection attempt"; sid:1000001; rev:1;)
alert icmp any any -> $HOME_NET any (msg:"ICMP connection attempt"; sid:1000002; rev:1;)
alert tcp any any -> $HOME_NET 80 (msg:"Web connection attempt"; sid:1000003; rev:1;)
alert tcp any any -> $HOME_NET 22 (msg:"SSH connection attempt"; sid:1000004; rev:1;)
```

Figure 4.16 – Adding Local Rules in snort

Above rules are alerts the user if any traffic attempts to create connection with SDN controller, any ICMP requests or SSH connection requests on SDN controller server.
After successfully adding the rules, below output shows alerts when SDN connection was attempted remotely and it shows the source IP address i.e.192.168.1.6 tries to attempt 192.168.1.36 i.e. IP address of the SDN controller based server machine:

```
root@onos-sdn:/etc/snort/rules# snort -A console -q -c /etc/snort/snort.conf -i eth0
09/02-14:57:29.088661  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52651 -> 192.168.1.36:8181
09/02-14:57:29.089019  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52651 -> 192.168.1.36:8181
09/02-14:57:29.091655  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52651 -> 192.168.1.36:8181
09/02-14:57:29.092518  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52651 -> 192.168.1.36:8181
09/02-14:57:29.123790  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52651 -> 192.168.1.36:8181
09/02-14:57:29.124971  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52651 -> 192.168.1.36:8181
09/02-14:57:29.167203  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52651 -> 192.168.1.36:8181
09/02-14:57:29.174551  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52651 -> 192.168.1.36:8181
09/02-14:57:29.589121  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52651 -> 192.168.1.36:8181
09/02-14:57:29.596786  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52651 -> 192.168.1.36:8181
09/02-14:57:29.596802  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52651 -> 192.168.1.36:8181
09/02-14:57:29.596806  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52651 -> 192.168.1.36:8181
09/02-14:57:29.596811  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52651 -> 192.168.1.36:8181
09/02-14:57:29.596815  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52651 -> 192.168.1.36:8181
09/02-14:57:29.596818  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52652 -> 192.168.1.36:8181
09/02-14:57:29.600206  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52652 -> 192.168.1.36:8181
09/02-14:57:29.600243  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52652 -> 192.168.1.36:8181
09/02-14:57:29.601977  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52651 -> 192.168.1.36:8181
09/02-14:57:29.601990  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52651 -> 192.168.1.36:8181
09/02-14:57:29.601995  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52651 -> 192.168.1.36:8181
09/02-14:57:29.601999  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52651 -> 192.168.1.36:8181
09/02-14:57:29.609073  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52652 -> 192.168.1.36:8181
09/02-14:57:29.626827  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52652 -> 192.168.1.36:8181
09/02-14:57:29.626847  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52652 -> 192.168.1.36:8181
09/02-14:57:29.626856  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52652 -> 192.168.1.36:8181
09/02-14:57:29.626860  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52652 -> 192.168.1.36:8181
09/02-14:57:29.626864  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52652 -> 192.168.1.36:8181
09/02-14:57:29.650938  [**] [1:1000001:1] SDN connection attempt [**] [Priority: 0] {TCP} 192.168.1.6:52651 -> 192.168.1.36:8181
```

Figure 4.17 – Alerting Snort Console of SDN connection attempt

CONCLUSION

SDN is changing the networks around the world and security is one of the biggest concern of the SDN, security challenges like DDoS, malware attacks, reliability issues are faced by SDN. Snort is the open-source security package, which can be used with Microsoft Windows or Linux to secure the servers and applications by creating rules or policies. We have used Snort package along with DAQ, which alerts any connection attempt as mentioned in the local rules file of the snort rules. Snort Console shows the live connection attempts which can be ICMP or HTTP based DDoS or any connection request to SDN controller along with the source IP address of those machines that attempts to create connection.

FUTURE SCOPE

SDN is a hot research topic in recent years and is rising at a rapid pace in network industry because of the advantages that it provides. Snort can be integrated with machine learning and that can bring much more accuracy in filtering of suspicious packets in future. Machine Learning algorithms like SVM or ASVM can be used with Snort in order to differentiate between legitimate and illegitimate traffic.

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