

## Networking with Linux Lab

### Module 2 & 3: Client Server Network topology using NS-3 and Animating the Network

#### Assignment 8: Program to simulate DHCP server and n clients

**Aim:** To simulate a DHCP (Dynamic Host Configuration Protocol) server and multiple clients to understand the process of dynamic IP address allocation in a network

#### Theory: DHCP Protocol

In a DHCP (Dynamic Host Configuration Protocol) simulation, the DHCP server dynamically assigns IP addresses and other network configuration parameters to multiple clients within a network. The server responds to clients' requests by leasing IP addresses for a limited period, ensuring efficient utilization of available addresses while preventing conflicts. The simulation involves the server listening for client requests, negotiating lease terms, and managing the address pool, mimicking real-world network dynamics.

#### Code:

> **dhcp-example.cc**

```
#include "ns3/core-module.h"
#include "ns3/internet-apps-module.h"
#include "ns3/csma-module.h"
#include "ns3/internet-module.h"
#include "ns3/point-to-point-module.h"
#include "ns3/applications-module.h"
#include "ns3/netanim-module.h"
#include "ns3/mobility-helper.h"

using namespace ns3;

NS_LOG_COMPONENT_DEFINE ("DhcpExample");

int
main (int argc, char *argv[])
{
    CommandLine cmd (__FILE__);

    bool verbose = false;
    bool tracing = false;
    cmd.AddValue ("verbose", "turn on the logs", verbose);
```

```
cmd.AddValue ("tracing", "turn on the tracing", tracing);

cmd.Parse (argc, argv);

// GlobalValue::Bind ("ChecksumEnabled", BooleanValue (true));

if (verbose)
{
    LogComponentEnable ("DhcpServer", LOG_LEVEL_ALL);
    LogComponentEnable ("DhcpClient", LOG_LEVEL_ALL);
    LogComponentEnable ("UdpEchoServerApplication", LOG_LEVEL_INFO);
    LogComponentEnable ("UdpEchoClientApplication", LOG_LEVEL_INFO);
}

Time stopTime = Seconds (20);

NS_LOG_INFO ("Create nodes.");
NodeContainer nodes;
NodeContainer router;
nodes.Create (3);
router.Create (2);

NodeContainer net (nodes, router);

NS_LOG_INFO ("Create channels.");
CsmaHelper csma;
csma.SetChannelAttribute ("DataRate", StringValue ("5Mbps"));
csma.SetChannelAttribute ("Delay", StringValue ("2ms"));
csma.SetDeviceAttribute ("Mtu", UIntegerValue (1500));
NetDeviceContainer devNet = csma.Install (net);

NodeContainer p2pNodes;
p2pNodes.Add (net.Get (4));
p2pNodes.Create (1);

PointToPointHelper pointToPoint;
pointToPoint.SetDeviceAttribute ("DataRate", StringValue ("5Mbps"));
pointToPoint.SetChannelAttribute ("Delay", StringValue ("2ms"));

NetDeviceContainer p2pDevices;
p2pDevices = pointToPoint.Install (p2pNodes);

InternetStackHelper tcpip;
tcpip.Install (nodes);
tcpip.Install (router);
tcpip.Install (p2pNodes.Get (1));
```

```
Ipv4AddressHelper address;
address.SetBase ("172.30.1.0", "255.255.255.0");
Ipv4InterfaceContainer p2pInterfaces;
p2pInterfaces = address.Assign (p2pDevices);

// manually add a routing entry because we don't want to add a dynamic routing
Ipv4StaticRoutingHelper ipv4RoutingHelper;
Ptr<Ipv4> ipv4Ptr = p2pNodes.Get (1)->GetObject<Ipv4> ();
Ptr<Ipv4StaticRouting> staticRoutingA = ipv4RoutingHelper.GetStaticRouting (ipv4Ptr);
staticRoutingA->AddNetworkRouteTo (Ipv4Address ("172.30.0.0"), Ipv4Mask ("/24"),
                                   Ipv4Address ("172.30.1.1"), 1);

NS_LOG_INFO ("Setup the IP addresses and create DHCP applications.");
DhcpHelper dhcpHelper;

// The router must have a fixed IP.
Ipv4InterfaceContainer fixedNodes = dhcpHelper.InstallFixedAddress (devNet.Get (4),
Ipv4Address ("172.30.0.17"), Ipv4Mask ("/24"));
// Not really necessary, IP forwarding is enabled by default in IPv4.
fixedNodes.Get (0).first->SetAttribute ("IpForward", BooleanValue (true));

// DHCP server
ApplicationContainer dhcpServerApp = dhcpHelper.InstallDhcpServer (devNet.Get (3),
Ipv4Address ("172.30.0.12"),
                                   Ipv4Address ("172.30.0.0"), Ipv4Mask ("/24"),
                                   Ipv4Address ("172.30.0.10"), Ipv4Address
("172.30.0.15"),
                                   Ipv4Address ("172.30.0.17"));

// This is just to show how it can be done.
DynamicCast<DhcpServer> (dhcpServerApp.Get (0))->AddStaticDhcpEntry (devNet.Get
(2)->GetAddress (), Ipv4Address ("172.30.0.14"));

dhcpServerApp.Start (Seconds (0.0));
dhcpServerApp.Stop (stopTime);

// DHCP clients
NetDeviceContainer dhcpClientNetDevs;
dhcpClientNetDevs.Add (devNet.Get (0));
dhcpClientNetDevs.Add (devNet.Get (1));
dhcpClientNetDevs.Add (devNet.Get (2));

ApplicationContainer dhcpClients = dhcpHelper.InstallDhcpClient (dhcpClientNetDevs);
dhcpClients.Start (Seconds (1.0));
dhcpClients.Stop (stopTime);
```

```
UdpEchoServerHelper echoServer (9);

ApplicationContainer serverApps = echoServer.Install (p2pNodes.Get (1));
serverApps.Start (Seconds (0.0));
serverApps.Stop (stopTime);

UdpEchoClientHelper echoClient (p2pInterfaces.GetAddress (1), 9);
echoClient.SetAttribute ("MaxPackets", UIntegerValue (100));
echoClient.SetAttribute ("Interval", TimeValue (Seconds (1.0)));
echoClient.SetAttribute ("PacketSize", UIntegerValue (1024));

ApplicationContainer clientApps = echoClient.Install (nodes.Get (1));
clientApps.Start (Seconds (10.0));
clientApps.Stop (stopTime);

Simulator::Stop (stopTime + Seconds (10.0));

if (tracing)
{
    csma.EnablePcapAll ("dhcp-csma");
    pointToPoint.EnablePcapAll ("dhcp-p2p");
}

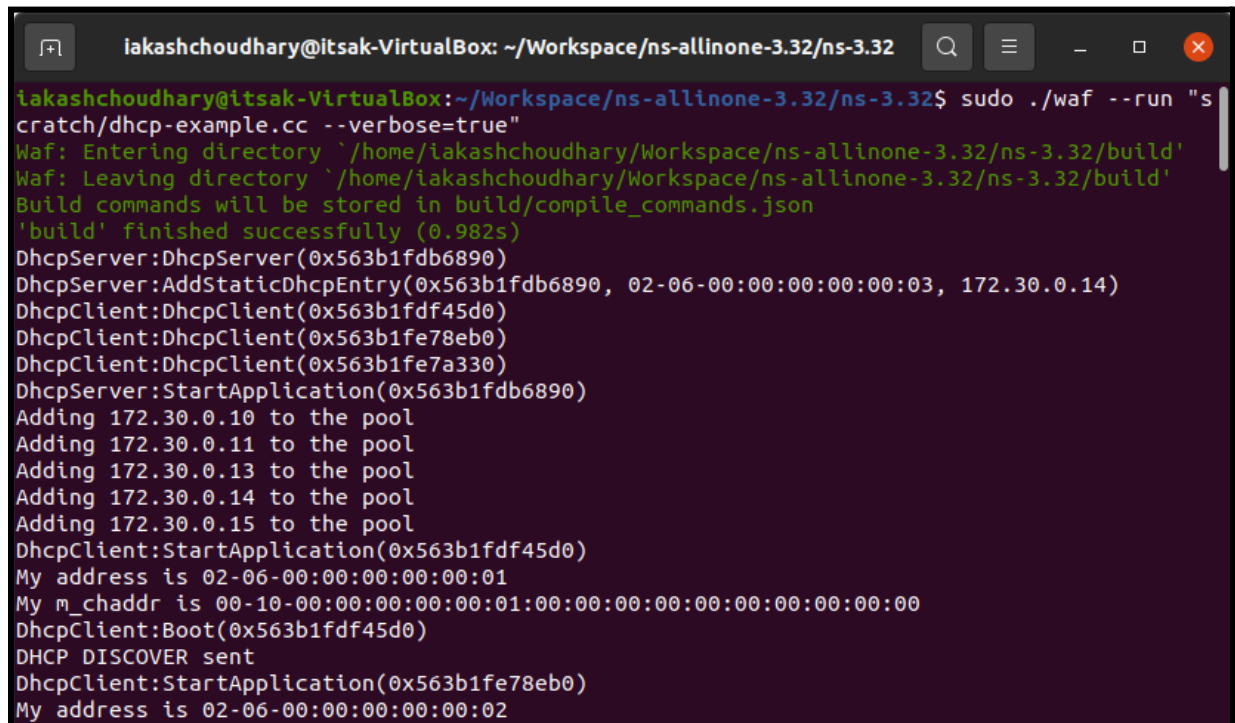
// NetAnimation ---before simulator run
MobilityHelper mobility;
mobility.SetMobilityModel("ns3::ConstantPositionMobilityModel");
mobility.Install(p2pNodes);
mobility.Install(net);

AnimationInterface anim("dhcp.xml");
AnimationInterface::SetConstantPosition(p2pNodes.Get(1), 0, 0);
AnimationInterface::SetConstantPosition(net.Get(0), 0, 5);
AnimationInterface::SetConstantPosition(net.Get(1), -5, 10);
AnimationInterface::SetConstantPosition(net.Get(2), -2.5, 15);
AnimationInterface::SetConstantPosition(net.Get(3), 2.5, 15);
AnimationInterface::SetConstantPosition(net.Get(4), 5, 10);
anim.EnablePacketMetadata(true);

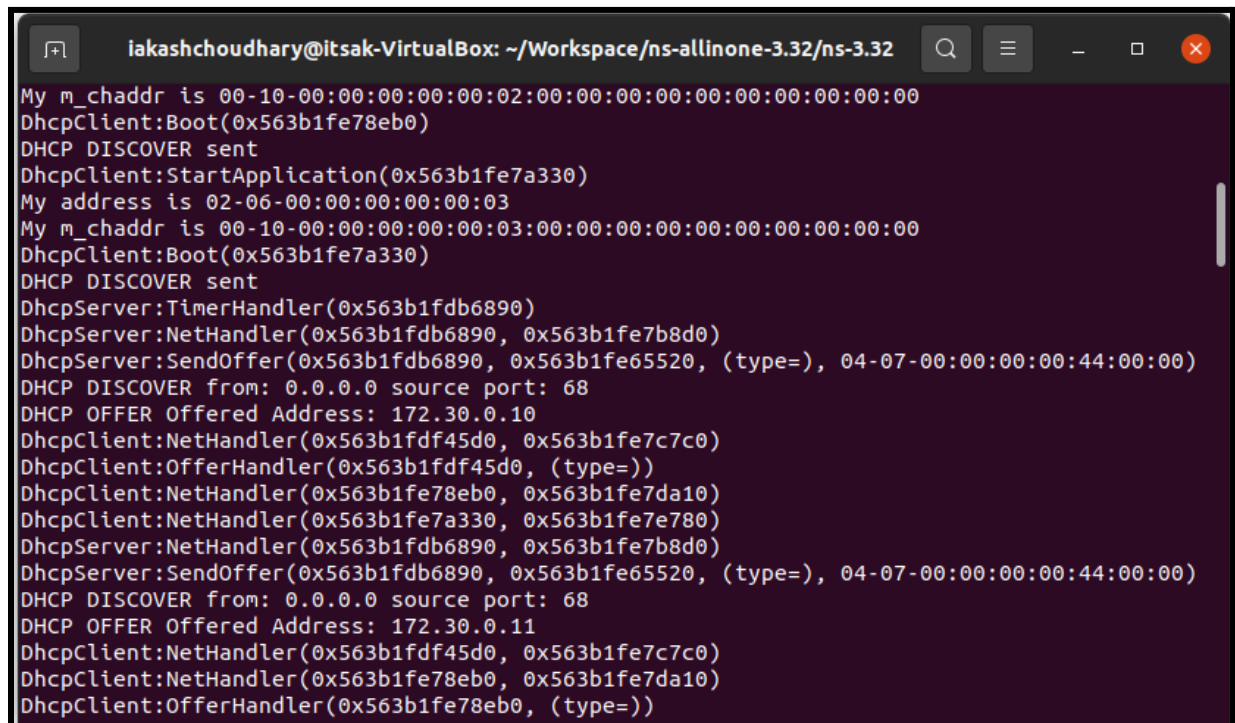
NS_LOG_INFO ("Run Simulation.");
Simulator::Run ();
Simulator::Destroy ();
NS_LOG_INFO ("Done.");
}
```

## Command & Screenshot:

> \$ sudo ./waf --run "scratch/dhcp-example.cc --verbose=true"



```
iakashchoudhary@itsak-VirtualBox: ~/Workspace/ns-allinone-3.32/ns-3.32
iakashchoudhary@itsak-VirtualBox:~/Workspace/ns-allinone-3.32/ns-3.32$ sudo ./waf --run "s
scratch/dhcp-example.cc --verbose=true"
Waf: Entering directory `/home/iakashchoudhary/Workspace/ns-allinone-3.32/ns-3.32/build'
Waf: Leaving directory `/home/iakashchoudhary/Workspace/ns-allinone-3.32/ns-3.32/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (0.982s)
DhcpServer:DhcpServer(0x563b1fdb6890)
DhcpServer:AddStaticDhcpEntry(0x563b1fdb6890, 02-06-00:00:00:00:00:03, 172.30.0.14)
DhcpClient:DhcpClient(0x563b1fdf45d0)
DhcpClient:DhcpClient(0x563b1fe78eb0)
DhcpClient:DhcpClient(0x563b1fe7a330)
DhcpServer:StartApplication(0x563b1fdb6890)
Adding 172.30.0.10 to the pool
Adding 172.30.0.11 to the pool
Adding 172.30.0.13 to the pool
Adding 172.30.0.14 to the pool
Adding 172.30.0.15 to the pool
DhcpClient:StartApplication(0x563b1fdf45d0)
My address is 02-06-00:00:00:00:00:01
My m_chaddr is 00-10-00:00:00:00:00:01:00:00:00:00:00:00:00:00:00:00:00:00:00
DhcpClient:Boot(0x563b1fdf45d0)
DHCP DISCOVER sent
DhcpClient:StartApplication(0x563b1fe78eb0)
My address is 02-06-00:00:00:00:00:02
```



```
My m_chaddr is 00-10-00:00:00:00:00:02:00:00:00:00:00:00:00:00:00:00:00:00:00
DhcpClient:Boot(0x563b1fe78eb0)
DHCP DISCOVER sent
DhcpClient:StartApplication(0x563b1fe7a330)
My address is 02-06-00:00:00:00:00:03
My m_chaddr is 00-10-00:00:00:00:00:03:00:00:00:00:00:00:00:00:00:00:00:00:00
DhcpClient:Boot(0x563b1fe7a330)
DHCP DISCOVER sent
DhcpServer:TimerHandler(0x563b1fdb6890)
DhcpServer:NetHandler(0x563b1fdb6890, 0x563b1fe7b8d0)
DhcpServer:SendOffer(0x563b1fdb6890, 0x563b1fe65520, (type=), 04-07-00:00:00:00:44:00:00)
DHCP DISCOVER from: 0.0.0.0 source port: 68
DHCP OFFER Offered Address: 172.30.0.10
DhcpClient:NetHandler(0x563b1fdf45d0, 0x563b1fe7c7c0)
DhcpClient:OfferHandler(0x563b1fdf45d0, (type=))
DhcpClient:NetHandler(0x563b1fe78eb0, 0x563b1fe7da10)
DhcpClient:NetHandler(0x563b1fe7a330, 0x563b1fe7e780)
DhcpServer:NetHandler(0x563b1fdb6890, 0x563b1fe7b8d0)
DhcpServer:SendOffer(0x563b1fdb6890, 0x563b1fe65520, (type=), 04-07-00:00:00:00:44:00:00)
DHCP DISCOVER from: 0.0.0.0 source port: 68
DHCP OFFER Offered Address: 172.30.0.11
DhcpClient:NetHandler(0x563b1fdf45d0, 0x563b1fe7c7c0)
DhcpClient:NetHandler(0x563b1fe78eb0, 0x563b1fe7da10)
DhcpClient:OfferHandler(0x563b1fe78eb0, (type=))
```

```

iakashchoudhary@itsak-VirtualBox: ~/Workspace/ns-allinone-3.32/ns-3.32
DhcpClient:NetHandler(0x563b1fe7a330, 0x563b1fe7e780)
DhcpServer:NetHandler(0x563b1fdb6890, 0x563b1fe7b8d0)
DhcpServer:SendOffer(0x563b1fdb6890, 0x563b1fe65520, (type=), 04-07-00:00:00:00:44:00:00)
DHCP DISCOVER from: 0.0.0.0 source port: 68
DHCP OFFER Offered Address: 172.30.0.14
DhcpClient:NetHandler(0x563b1fdf45d0, 0x563b1fe7c7c0)
DhcpClient:NetHandler(0x563b1fe78eb0, 0x563b1fe7da10)
DhcpClient:NetHandler(0x563b1fe7a330, 0x563b1fe7e780)
DhcpClient:OfferHandler(0x563b1fe7a330, (type=))
DhcpServer:TimerHandler(0x563b1fdb6890)
DhcpServer:TimerHandler(0x563b1fdb6890)
DhcpServer:TimerHandler(0x563b1fdb6890)
DhcpServer:TimerHandler(0x563b1fdb6890)
DhcpServer:TimerHandler(0x563b1fdb6890)
DhcpClient:Select(0x563b1fdf45d0)
DhcpClient:Request(0x563b1fdf45d0)
DhcpServer:NetHandler(0x563b1fdb6890, 0x563b1fe7b8d0)
DhcpServer:SendAck(0x563b1fdb6890, 0x563b1fe65520, (type=), 04-07-00:00:00:00:44:00:00)
DHCP REQUEST from: 0.0.0.0 source port: 68 - refreshed addr: 172.30.0.10
DhcpClient:NetHandler(0x563b1fdf45d0, 0x563b1fe7c7c0)
DhcpClient:AcceptAck(0x563b1fdf45d0, (type=), 04-07-ac:1e:00:0c:43:00:00)
DHCP ACK received
Got a new address (172.30.0.10), removing old one: 0.0.0.0
Current DHCP Server is 172.30.0.12

```

```

iakashchoudhary@itsak-VirtualBox: ~/Workspace/ns-allinone-3.32/ns-3.32
DhcpClient:NetHandler(0x563b1fe78eb0, 0x563b1fe7da10)
DhcpClient:NetHandler(0x563b1fe7a330, 0x563b1fe7e780)
DhcpClient:Select(0x563b1fe78eb0)
DhcpClient:Request(0x563b1fe78eb0)
DhcpServer:NetHandler(0x563b1fdb6890, 0x563b1fe7b8d0)
DhcpServer:SendAck(0x563b1fdb6890, 0x563b1fe65520, (type=), 04-07-00:00:00:00:44:00:00)
DHCP REQUEST from: 0.0.0.0 source port: 68 - refreshed addr: 172.30.0.11
DhcpClient:NetHandler(0x563b1fdf45d0, 0x563b1fe7c7c0)
DhcpClient:NetHandler(0x563b1fe78eb0, 0x563b1fe7da10)
DhcpClient:AcceptAck(0x563b1fe78eb0, (type=), 04-07-ac:1e:00:0c:43:00:00)
DHCP ACK received
Got a new address (172.30.0.11), removing old one: 0.0.0.0
Current DHCP Server is 172.30.0.12
DhcpClient:NetHandler(0x563b1fe7a330, 0x563b1fe7e780)
DhcpClient:Select(0x563b1fe7a330)
DhcpClient:Request(0x563b1fe7a330)
DhcpServer:NetHandler(0x563b1fdb6890, 0x563b1fe7b8d0)
DhcpServer:SendAck(0x563b1fdb6890, 0x563b1fe65520, (type=), 04-07-00:00:00:00:44:00:00)
DHCP REQUEST from: 0.0.0.0 source port: 68 - refreshed addr: 172.30.0.14
DhcpClient:NetHandler(0x563b1fdf45d0, 0x563b1fe7c7c0)
DhcpClient:NetHandler(0x563b1fe78eb0, 0x563b1fe7da10)
DhcpClient:NetHandler(0x563b1fe7a330, 0x563b1fe7e780)
DhcpClient:AcceptAck(0x563b1fe7a330, (type=), 04-07-ac:1e:00:0c:43:00:00)
DHCP ACK received

```

```
iakashchoudhary@itsak-VirtualBox: ~/Workspace/ns-allinone-3.32/ns-3.32
Got a new address (172.30.0.14), removing old one: 0.0.0.0
Current DHCP Server is 172.30.0.12
DhcpServer:TimerHandler(0x563b1fdb6890)
DhcpServer:TimerHandler(0x563b1fdb6890)
DhcpServer:TimerHandler(0x563b1fdb6890)
DhcpServer:TimerHandler(0x563b1fdb6890)
At time +10s client sent 1024 bytes to 172.30.1.2 port 9
At time +10.0196s server received 1024 bytes from 172.30.0.11 port 49153
At time +10.0196s server sent 1024 bytes to 172.30.0.11 port 49153
At time +10.0362s client received 1024 bytes from 172.30.1.2 port 9
DhcpServer:TimerHandler(0x563b1fdb6890)
At time +11s client sent 1024 bytes to 172.30.1.2 port 9
At time +11.0074s server received 1024 bytes from 172.30.0.11 port 49153
At time +11.0074s server sent 1024 bytes to 172.30.0.11 port 49153
At time +11.0148s client received 1024 bytes from 172.30.1.2 port 9
DhcpServer:TimerHandler(0x563b1fdb6890)
At time +12s client sent 1024 bytes to 172.30.1.2 port 9
At time +12.0074s server received 1024 bytes from 172.30.0.11 port 49153
At time +12.0074s server sent 1024 bytes to 172.30.0.11 port 49153
At time +12.0148s client received 1024 bytes from 172.30.1.2 port 9
DhcpServer:TimerHandler(0x563b1fdb6890)
At time +13s client sent 1024 bytes to 172.30.1.2 port 9
At time +13.0074s server received 1024 bytes from 172.30.0.11 port 49153
At time +13.0074s server sent 1024 bytes to 172.30.0.11 port 49153
```

```
iakashchoudhary@itsak-VirtualBox: ~/Workspace/ns-allinone-3.32/ns-3.32
At time +13.0148s client received 1024 bytes from 172.30.1.2 port 9
DhcpServer:TimerHandler(0x563b1fdb6890)
At time +14s client sent 1024 bytes to 172.30.1.2 port 9
At time +14.0074s server received 1024 bytes from 172.30.0.11 port 49153
At time +14.0074s server sent 1024 bytes to 172.30.0.11 port 49153
At time +14.0148s client received 1024 bytes from 172.30.1.2 port 9
DhcpServer:TimerHandler(0x563b1fdb6890)
At time +15s client sent 1024 bytes to 172.30.1.2 port 9
At time +15.0074s server received 1024 bytes from 172.30.0.11 port 49153
At time +15.0074s server sent 1024 bytes to 172.30.0.11 port 49153
At time +15.0148s client received 1024 bytes from 172.30.1.2 port 9
DhcpServer:TimerHandler(0x563b1fdb6890)
At time +16s client sent 1024 bytes to 172.30.1.2 port 9
At time +16.0074s server received 1024 bytes from 172.30.0.11 port 49153
At time +16.0074s server sent 1024 bytes to 172.30.0.11 port 49153
At time +16.0148s client received 1024 bytes from 172.30.1.2 port 9
DhcpServer:TimerHandler(0x563b1fdb6890)
At time +17s client sent 1024 bytes to 172.30.1.2 port 9
At time +17.0074s server received 1024 bytes from 172.30.0.11 port 49153
At time +17.0074s server sent 1024 bytes to 172.30.0.11 port 49153
At time +17.0148s client received 1024 bytes from 172.30.1.2 port 9
DhcpServer:TimerHandler(0x563b1fdb6890)
At time +18s client sent 1024 bytes to 172.30.1.2 port 9
At time +18.0074s server received 1024 bytes from 172.30.0.11 port 49153
```

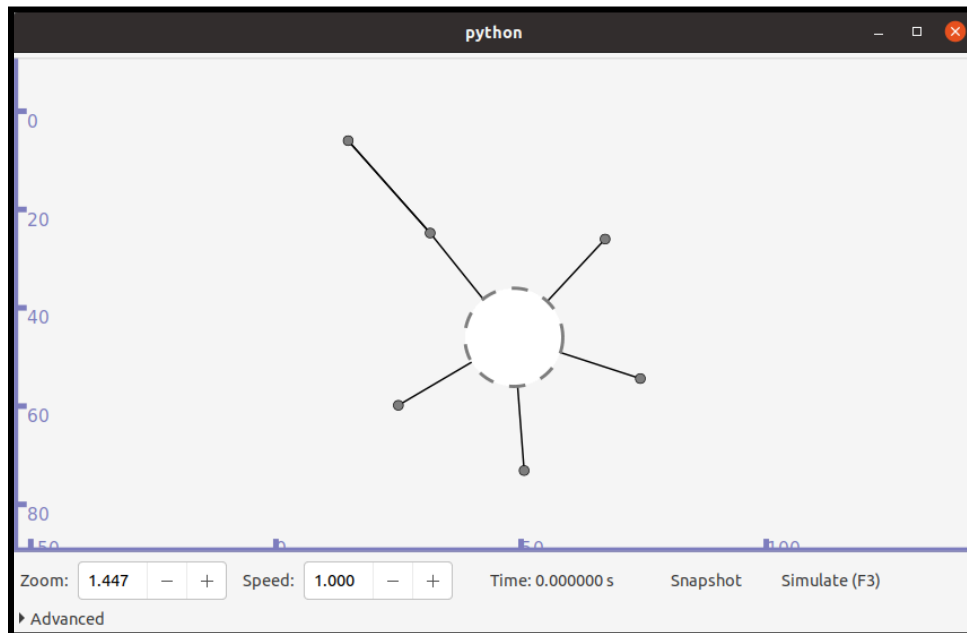


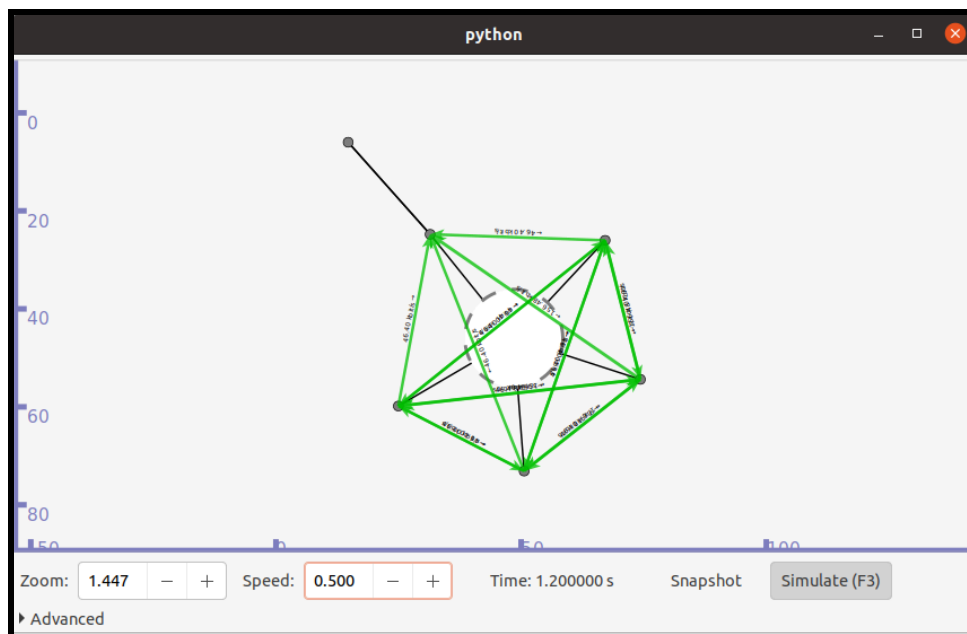
```
lakashchoudhary@itsak-VirtualBox: ~/Workspace/ns-allinone-3.32/ns-3.32
At time +17.0148s client received 1024 bytes from 172.30.1.2 port 9
DhcpServer:TimerHandler(0x563b1fdb6890)
At time +18s client sent 1024 bytes to 172.30.1.2 port 9
At time +18.0074s server received 1024 bytes from 172.30.0.11 port 49153
At time +18.0074s server sent 1024 bytes to 172.30.0.11 port 49153
At time +18.0148s client received 1024 bytes from 172.30.1.2 port 9
DhcpServer:TimerHandler(0x563b1fdb6890)
At time +19s client sent 1024 bytes to 172.30.1.2 port 9
At time +19.0074s server received 1024 bytes from 172.30.0.11 port 49153
At time +19.0074s server sent 1024 bytes to 172.30.0.11 port 49153
At time +19.0148s client received 1024 bytes from 172.30.1.2 port 9
DhcpClient:StopApplication(0x563b1fdf45d0)
DhcpClient:StopApplication(0x563b1fe78eb0)
DhcpClient:StopApplication(0x563b1fe7a330)
DhcpServer:StopApplication(0x563b1fdb6890)
DhcpClient:DoDispose(0x563b1fdf45d0)
DhcpClient:DoDispose(0x563b1fe78eb0)
DhcpClient:DoDispose(0x563b1fe7a330)
DhcpServer:DoDispose(0x563b1fdb6890)
DhcpClient::~DhcpClient(0x563b1fdf45d0)
DhcpClient::~DhcpClient(0x563b1fe78eb0)
DhcpClient::~DhcpClient(0x563b1fe7a330)
DhcpServer::~DhcpServer(0x563b1fdb6890)
lakashchoudhary@itsak-VirtualBox:~/Workspace/ns-allinone-3.32/ns-3.32$
```



> Perform animation using pygraphviz: **\$ sudo ./waf --run "scratch/dhcp-example.cc" --vis**

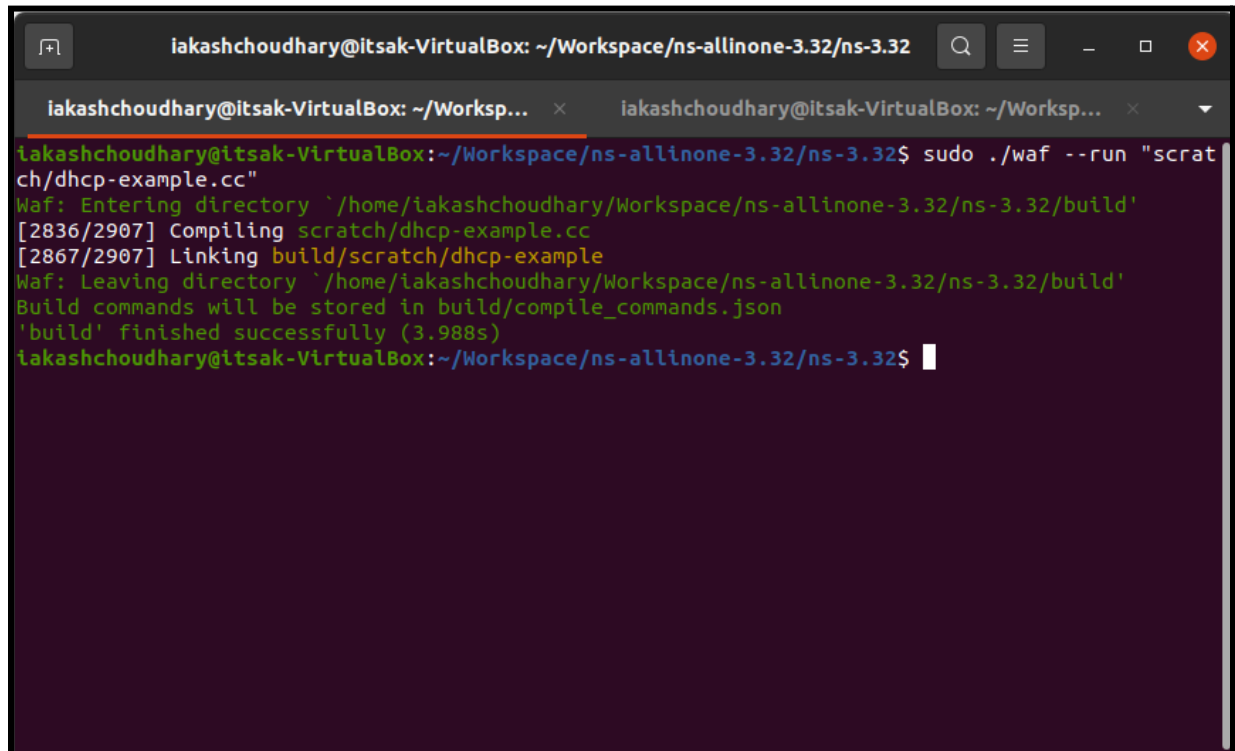
```
iakashchoudhary@itsak-VirtualBox: ~/Workspace/ns-allinone-3.32/ns-3.32
iakashchoudhary@itsak-VirtualBox:~/Workspace/ns-allinone-3.32/ns-3.32$ sudo ./waf --run "s
cratch/dhcp-example.cc" --vis
Waf: Entering directory `/home/iakashchoudhary/Workspace/ns-allinone-3.32/ns-3.32/build'
Waf: Leaving directory `/home/iakashchoudhary/Workspace/ns-allinone-3.32/ns-3.32/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (0.854s)
Could not load plugin 'show_last_packets.py': No module named 'kiwi'
Could not load icon applets-screenshooter due to missing gnomedesktop Python module
scanning topology: 6 nodes...
scanning topology: calling graphviz layout
scanning topology: all done.
```





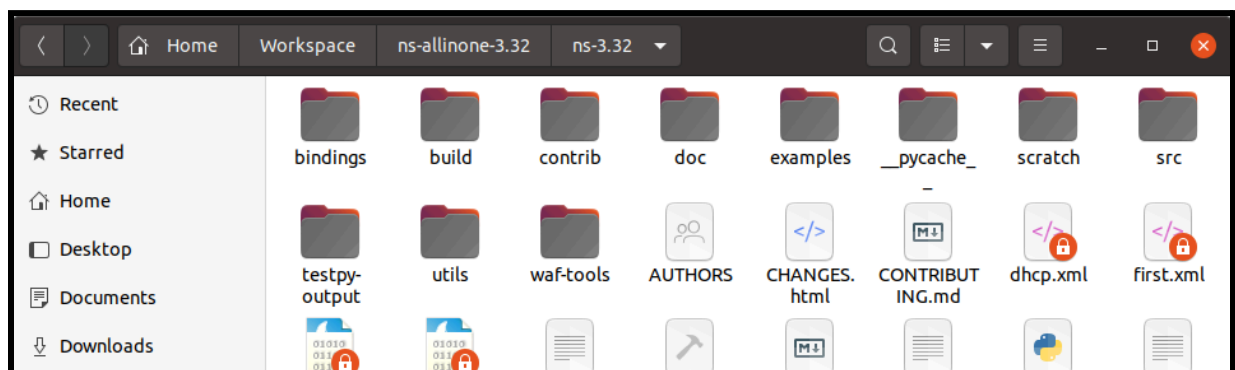
> Perform animation using NetAnim:

**Step 1:** Use the command `$ sudo ./waf --run "scratch/dhcp-example.cc"` to create a `dhcp.xml` file.



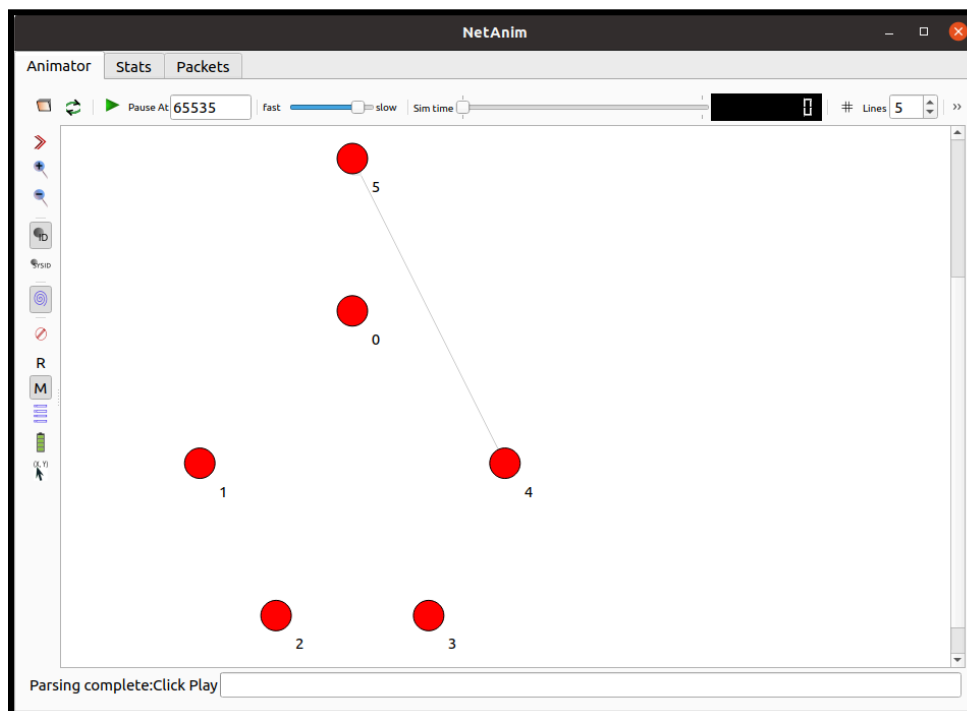
```
iakashchoudhary@itsak-VirtualBox: ~/Workspace/ns-allinone-3.32/ns-3.32
iakashchoudhary@itsak-VirtualBox: ~/Worksp... x iakashchoudhary@itsak-VirtualBox: ~/Worksp... x
iakashchoudhary@itsak-VirtualBox:~/Workspace/ns-allinone-3.32/ns-3.32$ sudo ./waf --run "scratch/dhcp-example.cc"
Waf: Entering directory `/home/iakashchoudhary/Workspace/ns-allinone-3.32/ns-3.32/build'
[2836/2907] Compiling scratch/dhcp-example.cc
[2867/2907] Linking build/scratch/dhcp-example
Waf: Leaving directory `/home/iakashchoudhary/Workspace/ns-allinone-3.32/ns-3.32/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (3.988s)
iakashchoudhary@itsak-VirtualBox:~/Workspace/ns-allinone-3.32/ns-3.32$
```

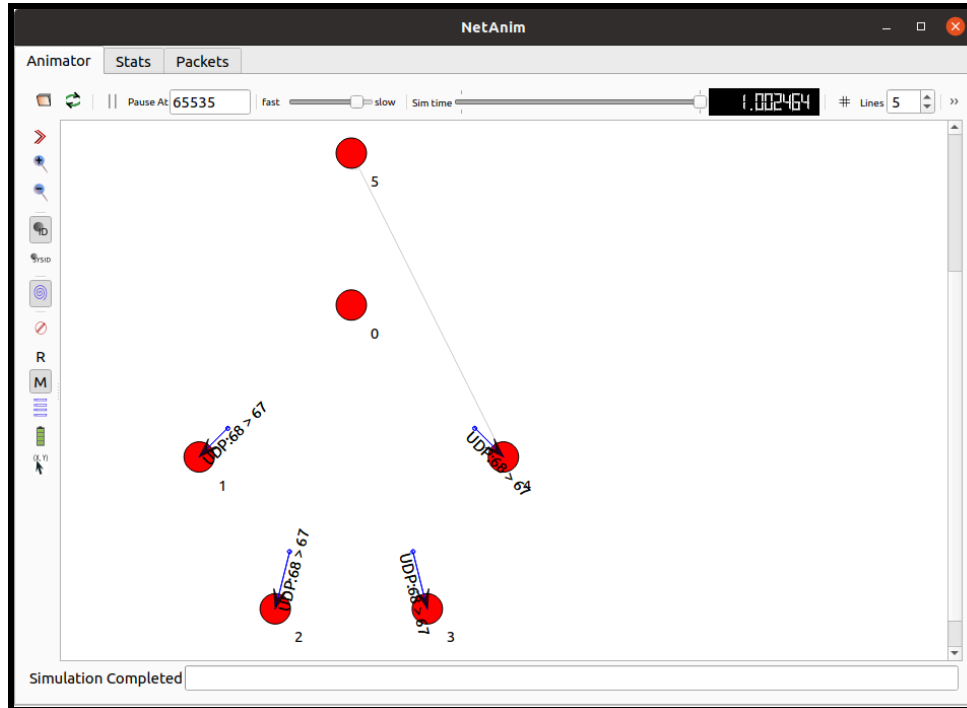
As you can see, the **dhcp.xml** file is created in the **ns-3.32** directory.



**Step 2:** Open the Terminal from `ns-3.32`; go back to the previous directory by entering `$ cd ..`; then change the directory to `netanim-3.108` by typing `$ cd netanim-3.108/`; lastly, open NetAnim by using the command `$ ./NetAnim` | Open **dhcp.xml**.

```
iakashchoudhary@itsak-VirtualBox: ~/Workspace/ns-allinone-3.32/netanim-3.108
iakashchoudhary@itsak-VirtualBox: ~/Worksp... x iakashchoudhary@itsak-VirtualBox: ~/Worksp... x
iakashchoudhary@itsak-VirtualBox:~/Workspace/ns-allinone-3.32/ns-3.32$ cd ..
iakashchoudhary@itsak-VirtualBox:~/Workspace/ns-allinone-3.32$ cd netanim-3.108/
iakashchoudhary@itsak-VirtualBox:~/Workspace/ns-allinone-3.32/netanim-3.108$ ./NetAnim
```





**Conclusion:** DHCP server efficiently assigns dynamic IP addresses to multiple clients in a network.