

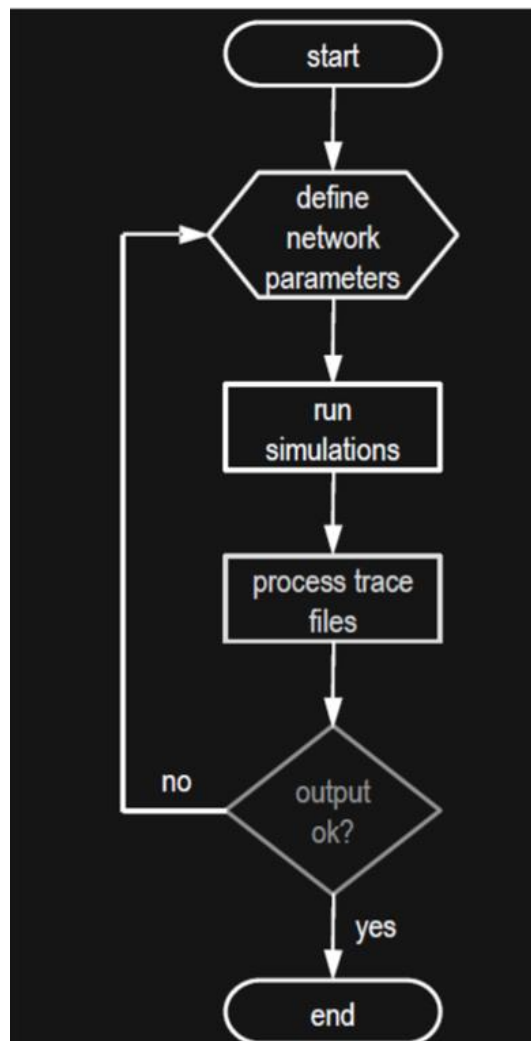
PART-B

NS-3

Network Simulator (NS-3)

This section gives in depth view of how computer networks works in real time, simulation of various topologies are performed using ns3 tool.

ns-3 has been developed to provide an open, extensible network simulation platform, for networking research and education. In brief, ns-3 provides models of how packet data networks work and perform, and provides a simulation engine for users to conduct simulation experiments. Some of the reasons to use ns-3 include to perform studies that are more difficult or not possible to perform with real systems, to study system behaviour in a highly controlled, reproducible environment, and to learn about how networks work. Users will note that the available model set in ns-3 focuses on modelling how Internet protocols and networks work, but ns-3 is not limited to Internet systems; several users are using ns-3 to model non-Internet-based systems. Flow chart for sample ns-3 program execution.

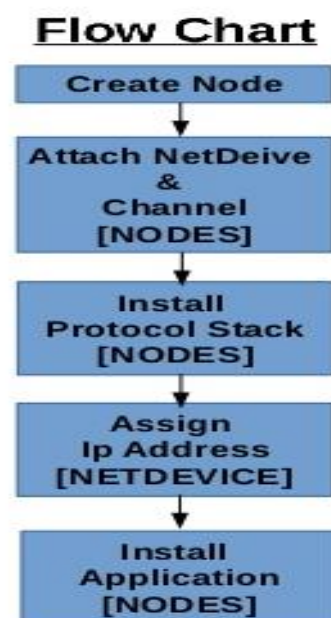


Many simulation tools exist for network simulation studies. Below are a few distinguishing features of ns-3 in contrast to other tools.

1. ns-3 is designed as a set of libraries that can be combined together and also with other external software libraries. While some simulation platforms provide users with a single, integrated graphical user interface environment in which all tasks are carried out, ns-3 is more modular in this regard. Several external animators and data analysis and visualization tools can be used with ns-3.
2. However, users should expect to work at the command line and with C++ and/or Python software development tools.
3. ns-3 is primarily used on Linux systems, although support exists for FreeBSD, Cygwin (for Windows), and native Windows Visual Studio support is in the process of being developed.

Some Important Points about NS3:

1. NS3 is not backward compatible with NS2; it's built from the scratch to replace NS2.
2. NS3 is written in C++, Python Programming Language can be optionally used as an interface.
3. NS3 is trying to solve problems present in NS2.
4. There is very limited number of contributed codes made with NS3 compared to NS2.
5. In NS2, bi-language system make debugging complex (C++/Tcl), but for NS3 only knowledge of C++ is enough (single-language architecture is more robust in the long term).
6. NS3 has an emulation mode, which allows for the integration with real networks.



NS -3 Program Structure flow chart

Steps to Install NS3:

Once ubuntu is installed run following command opening your terminal(ctrl+alt+T).

To install prerequisites-

1. `sudo apt-get update`

2. `sudo apt-get install gcc g++ python && sudo apt-get install gcc g++ python && sudo apt-get install mercurial python-setuptools git && sudo apt-get install qt5-default && sudo apt-get install python-pygraphviz python-kiwi python-pygoocanvas libgoocanvas-dev ipython && sudo apt-get install openmpi-bin openmpi-common openmpi-doc libopenmpi-dev && sudo apt-get install autoconf cvs bzip2 unrar && sudo apt-get install gdb valgrind && sudo apt-get install uncrustify && sudo apt-get install doxygen graphviz imagemagick && sudo apt-get install texlive texlive-extra-utils texlive-latex-extra texlive-font-utils texlive-lang-portuguese dvipng && sudo apt-get install python-sphinx dia && sudo apt-get install gsl-bin libgsl2 libgsl-dev && sudo apt-get install flex bison libfl-dev && sudo apt-get install tcpdump && sudo apt-get install sqlite sqlite3 libsqlite3-dev && sudo apt-get install libxml2 libxml2-dev && sudo apt-get install cmake libc6-dev libc6-dev-i386 libclang-dev && sudo pip install cxxfilt && sudo apt-get install libgtk2.0-0 libgtk2.0-dev && sudo apt-get install vtun lxc && sudo apt-get install libboost-signals-dev libboost-filesystem-dev`

Downloading NS-3(ns-3 version 3.27)

3. `mkdir ns3`

4. `cd ns3`

5. `wget https://www.nsnam.org/release/ns-allinone-3.27.tar.bz2`

6. `tar xjf ns-allinone-3.27.tar.bz2`

7. `cd ns-allinone-3.27/`

8. `ls`

Then you can find build.py along with other files.

Then to build the examples in ns-3 to run

9. `./build.py --enable-examples --enable-tests`

If the build is successful then it will give output

"Build finished successfully".

Now run the following command to configure with waf(build tool)

10. `cd ns3/ns-allinone-3.27/ns-3.27`

11. `./waf -d debug --enable-examples --enable-tests configure`

To build with waf(optional)

```
./waf
```

```
To test everything allright
```

```
12. ./test.py
```

```
If the tests are ok the ns3 installation is done. :)
```

Steps to install NetAnim.

Run following command opening your terminal(ctrl+alt+T).

```
1. sudo apt-get install qt4-qmake && sudo apt-get install libqt4-dev && sudo apt-get install libxml2-dev
```

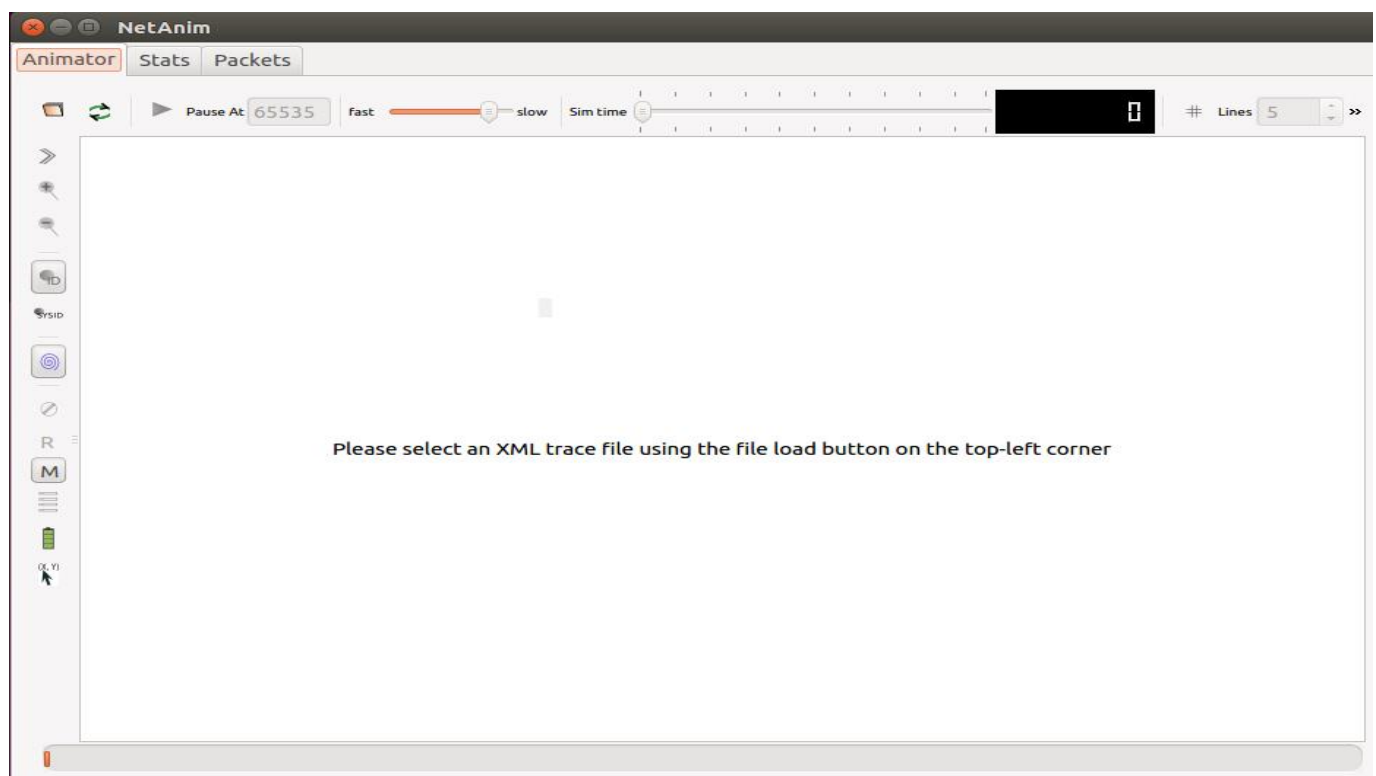
```
2. cd ns3/ns-allinone-3.27/netanim-3.108
```

```
3. make clean
```

```
4. qmake NetAnim.pro
```

```
5. make
```

```
6. ./NetAnim
```

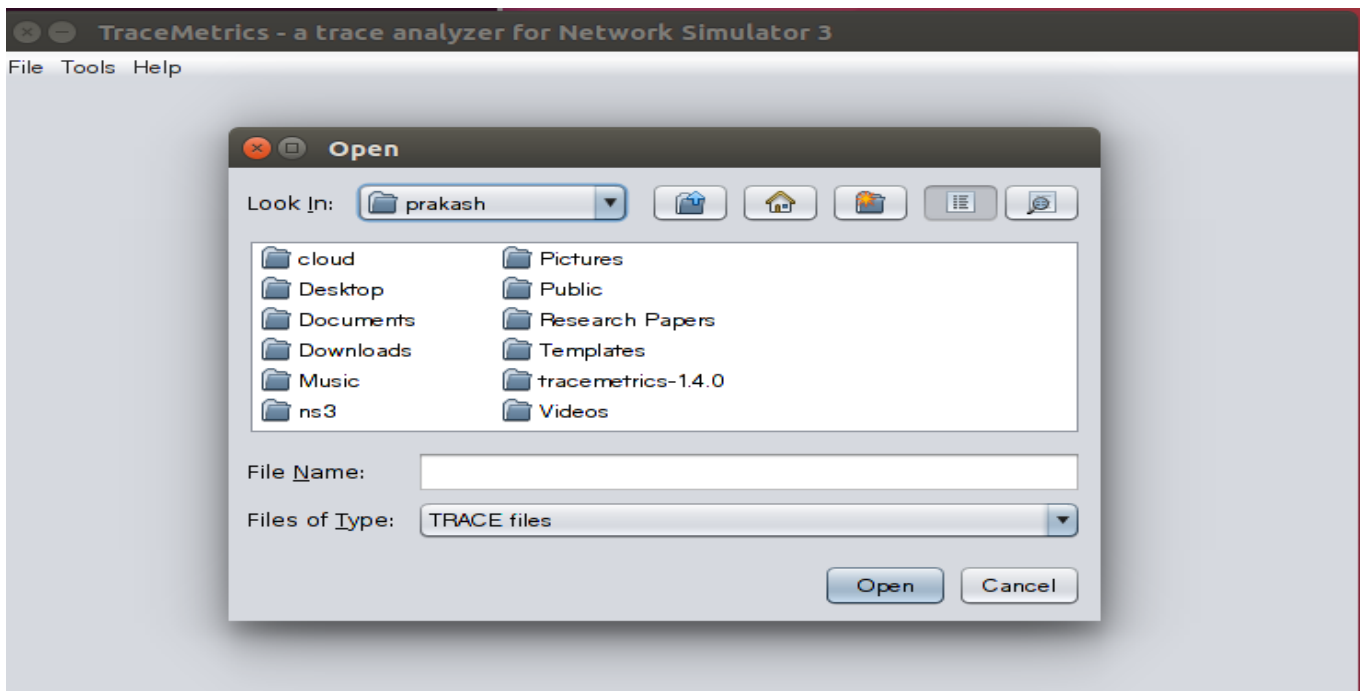


Steps to install tracemetrics:

Run following command opening your terminal(ctrl+alt+T).

Go to TraceMetrics site to download

1. <http://sourceforge.net/projects/tracemetrics/>
2. open the .zip file with Archive Manager to extract the files.
3. `cd tracemetrics-1.4.0/`
4. `java -jar "tracemetrics.jar"`



1. Write a C++ program to connect two nodes on NS-3 (for practice only)

```
// header files
#include "ns3/core-module.h"
#include "ns3/network-module.h"
#include "ns3/internet-module.h"
#include "ns3/point-to-point-module.h"
#include "ns3/applications-module.h"
#include "ns3/netanim-module.h"

using namespace ns3;

NS_LOG_COMPONENT_DEFINE ("FirstScriptExample");

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

    //Log files
    Time::SetResolution (Time::NS); //Total time your application consumes
    LogComponentEnable ("UdpEchoClientApplication", LOG_LEVEL_INFO);
    LogComponentEnable ("UdpEchoServerApplication", LOG_LEVEL_INFO);

    NodeContainer nodes;
    nodes.Create (2); //Take number of nodes

    PointToPointHelper pointToPoint; //Technology to communicate like csma, wifi ethernet pointtopoint
    pointToPoint.SetDeviceAttribute ("DataRate", StringValue ("1Mbps"));
    pointToPoint.SetChannelAttribute ("Delay", StringValue ("1ms"));

    NetDeviceContainer devices; //Install technology on devices
    devices = pointToPoint.Install (nodes);

    InternetStackHelper stack; //ask to follow the rules
    stack.Install (nodes);

    Ipv4AddressHelper address; //IP address to communicate
    address.SetBase ("10.1.1.0", "255.255.255.0"); //ip address and subnet address

    Ipv4InterfaceContainer interfaces = address.Assign (devices);

    UdpEchoServerHelper echoServer (9); //type of server you want to create with port number

    ApplicationContainer serverApps = echoServer.Install (nodes.Get (1));
    serverApps.Start (Seconds (1.0));
    serverApps.Stop (Seconds (10.0));

    UdpEchoClientHelper echoClient (interfaces.GetAddress (1), 9);
    echoClient.SetAttribute ("MaxPackets", UIntegerValue (1));
```

```
echoClient.SetAttribute ("Interval", TimeValue (Seconds (1.0)));
echoClient.SetAttribute ("PacketSize", UIntegerValue (2048));

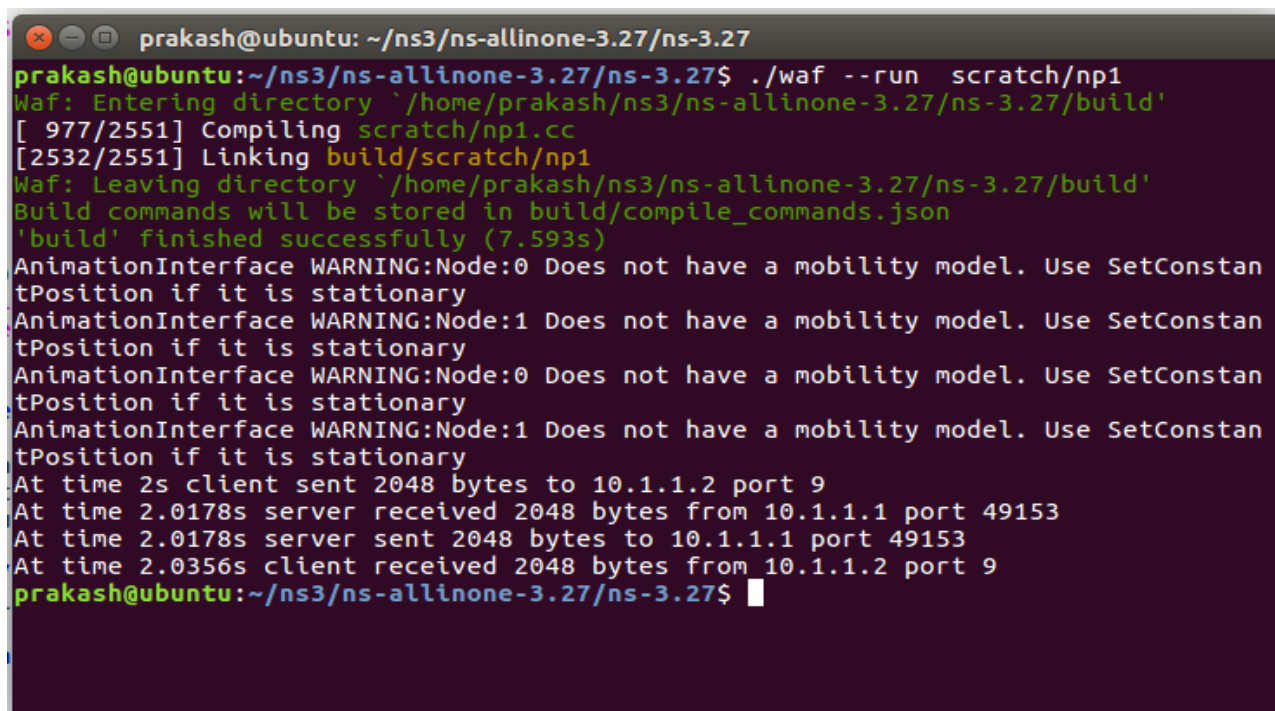
ApplicationContainer clientApps = echoClient.Install (nodes.Get (0));
clientApps.Start (Seconds (2.0));
clientApps.Stop (Seconds (10.0));

AnimationInterface anim("np1.xml");

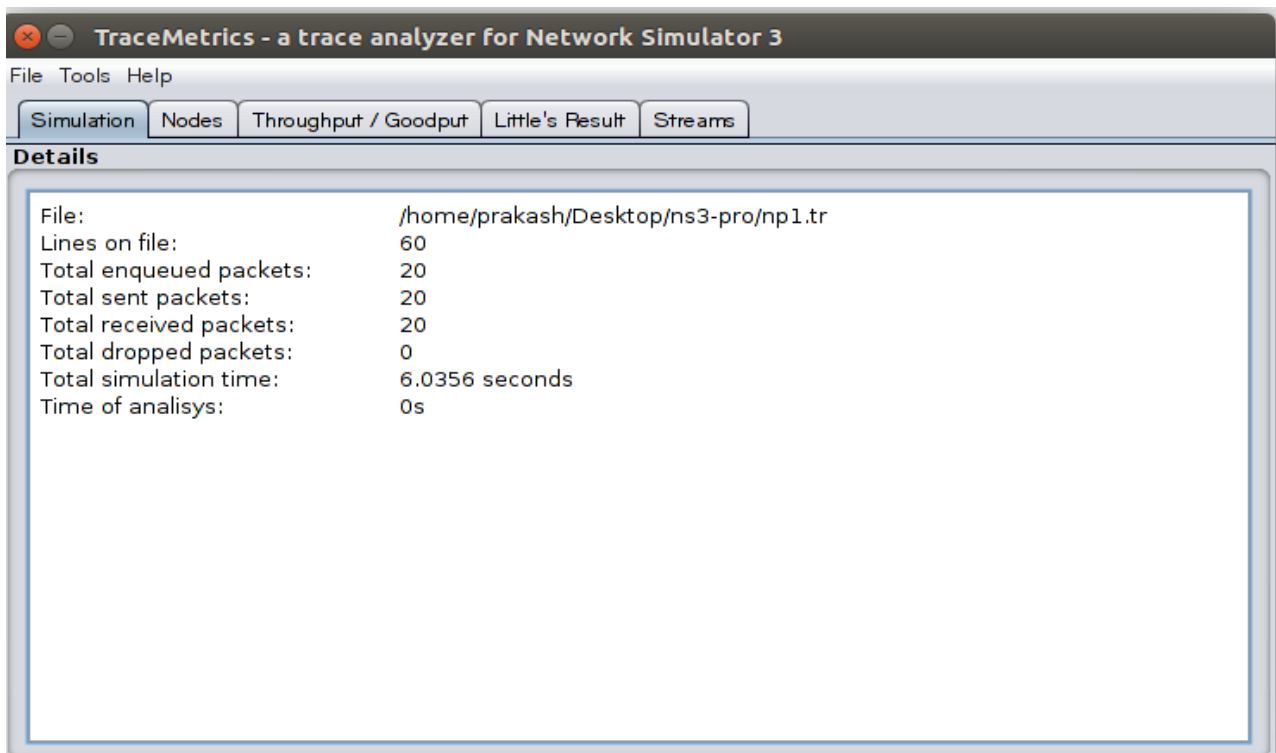
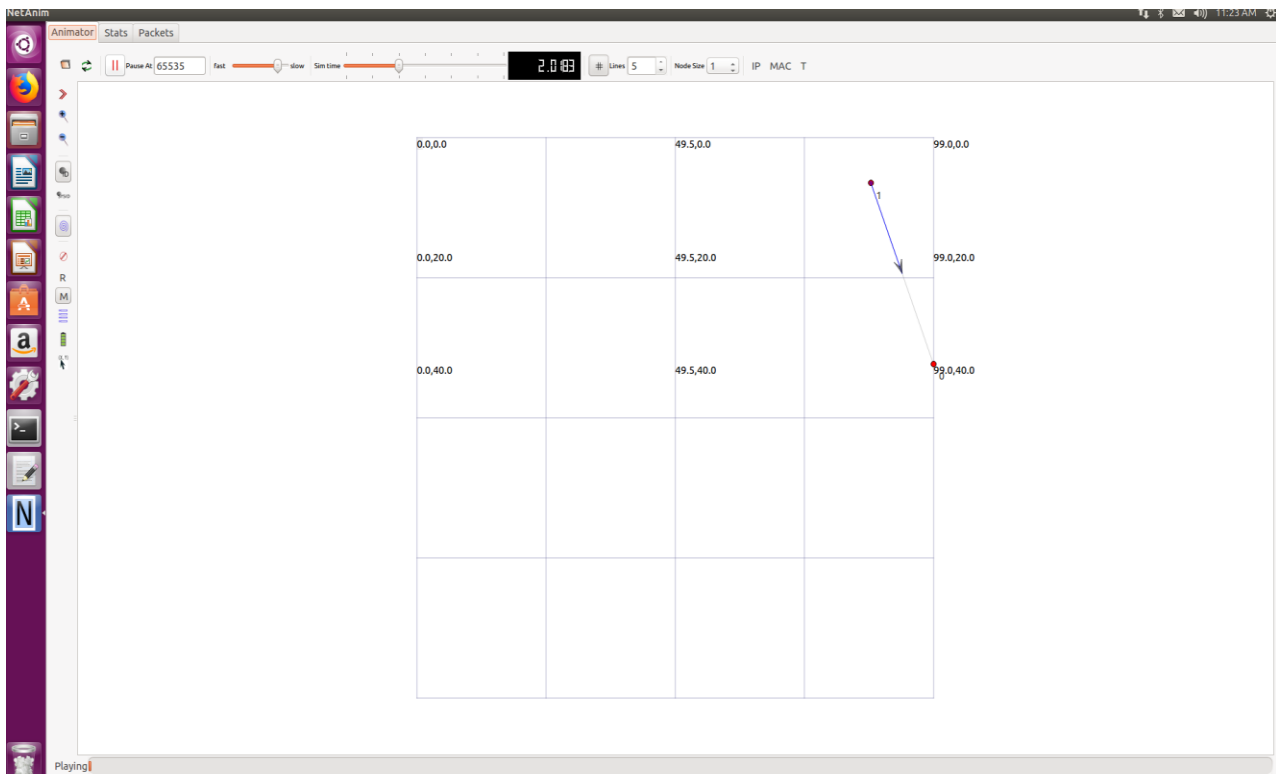
AsciiTraceHelper eventTraces;
pointToPoint.EnableAsciiAll(eventTraces.CreateFileStream("np1.tr"));
pointToPoint.EnablePcapAll ("np1");

Simulator::Run ();
Simulator::Destroy ();
return 0;
}
```

OUTPUT



```
prakash@ubuntu: ~/ns3/ns-allinone-3.27/ns-3.27
prakash@ubuntu:~/ns3/ns-allinone-3.27/ns-3.27$ ./waf --run scratch/np1
Waf: Entering directory `/home/prakash/ns3/ns-allinone-3.27/ns-3.27/build'
[ 977/2551] Compiling scratch/np1.cc
[2532/2551] Linking build/scratch/np1
Waf: Leaving directory `/home/prakash/ns3/ns-allinone-3.27/ns-3.27/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (7.593s)
AnimationInterface WARNING:Node:0 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:1 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:0 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:1 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
At time 2s client sent 2048 bytes to 10.1.1.2 port 9
At time 2.0178s server received 2048 bytes from 10.1.1.1 port 49153
At time 2.0178s server sent 2048 bytes to 10.1.1.1 port 49153
At time 2.0356s client received 2048 bytes from 10.1.1.2 port 9
prakash@ubuntu:~/ns3/ns-allinone-3.27/ns-3.27$
```

2. Write a C++ program to connect three nodes considering one as a central node on NS-3 (for practice only)

```
#include "ns3/core-module.h"
#include "ns3/network-module.h"
#include "ns3/internet-module.h"
#include "ns3/point-to-point-module.h"
#include "ns3/applications-module.h"
#include "ns3/netanim-module.h"

using namespace ns3;

NS_LOG_COMPONENT_DEFINE ("SecondScriptExample");

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

    Time::SetResolution (Time::NS);
    LogComponentEnable ("UdpEchoClientApplication", LOG_LEVEL_INFO);
    LogComponentEnable ("UdpEchoServerApplication", LOG_LEVEL_INFO);

    NodeContainer nodes;
    nodes.Create (3);

    PointToPointHelper p2p1;
    p2p1.SetDeviceAttribute ("DataRate", StringValue ("5Mbps"));
    p2p1.SetChannelAttribute ("Delay", StringValue ("1ms"));

    PointToPointHelper p2p2;
    p2p2.SetDeviceAttribute ("DataRate", StringValue ("10Mbps"));
    p2p2.SetChannelAttribute ("Delay", StringValue ("5ms"));

    InternetStackHelper stack;
    stack.Install (nodes);

    Ipv4AddressHelper address;
    address.SetBase ("10.1.1.0", "255.255.255.0");
    NetDeviceContainer devices;
    devices=p2p1.Install (nodes.Get (0), nodes.Get (1));
    Ipv4InterfaceContainer interfaces = address.Assign (devices);

    devices=p2p2.Install (nodes.Get (1), nodes.Get (2));
    address.SetBase ("10.1.2.0", "255.255.255.0");
    interfaces = address.Assign (devices);

    Ipv4GlobalRoutingHelper::PopulateRoutingTables();
```

```
UdpEchoServerHelper echoServer (9);//90
```

```
ApplicationContainer serverApps = echoServer.Install (nodes.Get (2));
serverApps.Start (Seconds (1.0));
serverApps.Stop (Seconds (10.0));
```

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

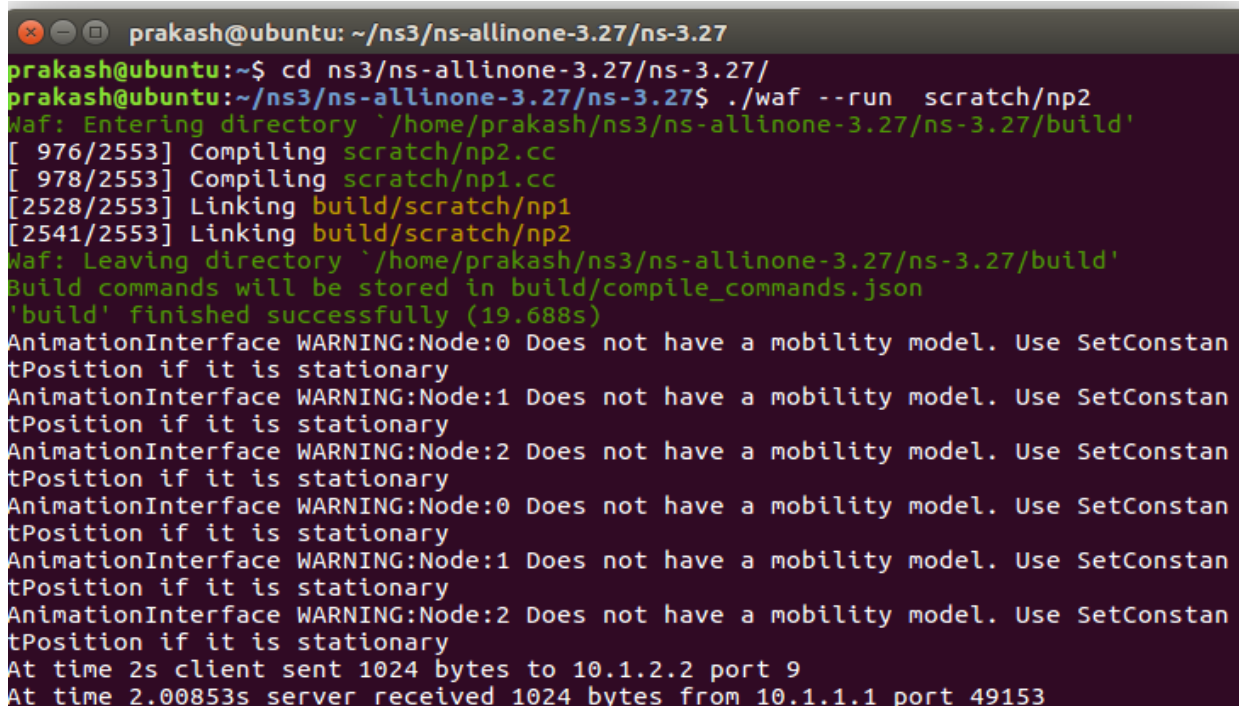
```
ApplicationContainer clientApps = echoClient.Install (nodes.Get (0));
clientApps.Start (Seconds (2.0));
clientApps.Stop (Seconds (10.0));
```

```
AnimationInterface anim("np2.xml");
```

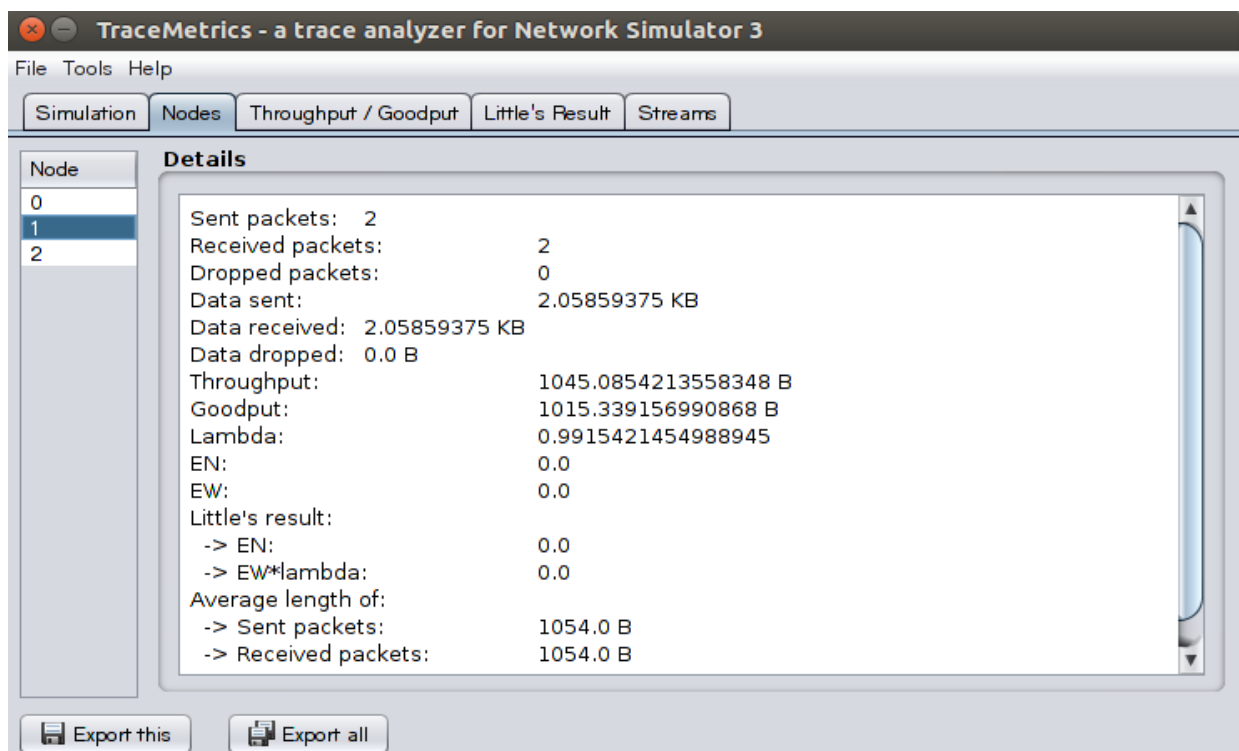
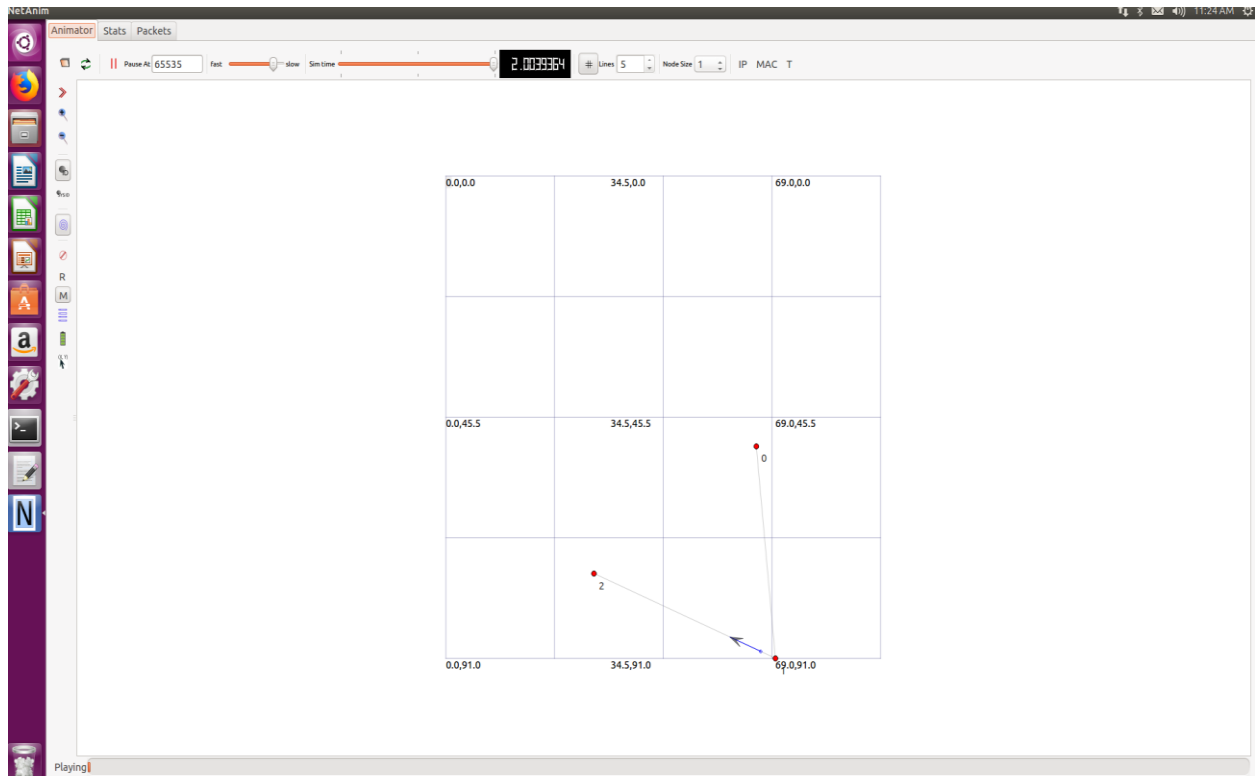
```
AsciiTraceHelper eventTraces;
p2p1.EnableAsciiAll(eventTraces.CreateFileStream("np2.tr"));
p2p1.EnablePcapAll ("np2");
```

```
Simulator::Run ();
Simulator::Destroy ();
return 0;
}
```

OUTPUT



```
prakash@ubuntu: ~/ns3/ns-allinone-3.27/ns-3.27
prakash@ubuntu:~/ns3/ns-allinone-3.27/ns-3.27$ cd ns3/ns-allinone-3.27/ns-3.27/
prakash@ubuntu:~/ns3/ns-allinone-3.27/ns-3.27$ ./waf --run scratch/np2
Waf: Entering directory `/home/prakash/ns3/ns-allinone-3.27/ns-3.27/build'
[ 976/2553] Compiling scratch/np2.cc
[ 978/2553] Compiling scratch/np1.cc
[2528/2553] Linking build/scratch/np1
[2541/2553] Linking build/scratch/np2
Waf: Leaving directory `/home/prakash/ns3/ns-allinone-3.27/ns-3.27/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (19.688s)
AnimationInterface WARNING:Node:0 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:1 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:2 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:0 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:1 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:2 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
At time 2s client sent 1024 bytes to 10.1.2.2 port 9
At time 2.00853s server received 1024 bytes from 10.1.1.1 port 49153
```



3. Write a C++ program to implement a star topology on NS-3

```
#include "ns3/core-module.h"
#include "ns3/network-module.h"
#include "ns3/netanim-module.h"
#include "ns3/internet-module.h"
#include "ns3/point-to-point-module.h"
#include "ns3/applications-module.h"
#include "ns3/point-to-point-layout-module.h"
#include "ns3/netanim-module.h"

using namespace ns3;

NS_LOG_COMPONENT_DEFINE ("Star");

int
main (int argc, char *argv[])
{

    Config::SetDefault ("ns3::OnOffApplication::PacketSize", UIntegerValue (137));

    Config::SetDefault ("ns3::OnOffApplication::DataRate", StringValue ("14kb/s"));

    uint32_t nSpokes = 8;

    CommandLine cmd;
    cmd.AddValue ("nSpokes", "Number of nodes to place in the star", nSpokes);
    cmd.Parse (argc, argv);

    NS_LOG_INFO ("Build star topology.");
    PointToPointHelper pointToPoint;
    pointToPoint.SetDeviceAttribute ("DataRate", StringValue ("5Mbps"));
    pointToPoint.SetChannelAttribute ("Delay", StringValue ("2ms"));
    PointToPointStarHelper star (nSpokes, pointToPoint);

    NS_LOG_INFO ("Install internet stack on all nodes.");
    InternetStackHelper internet;
    star.InstallStack (internet);

    NS_LOG_INFO ("Assign IP Addresses.");
    star.AssignIpv4Addresses (Ipv4AddressHelper ("10.1.1.0", "255.255.255.0"));

    NS_LOG_INFO ("Create applications.");

    uint16_t port = 50000;
    Address hubLocalAddress (InetSocketAddress (Ipv4Address::GetAny (), port));
    PacketSinkHelper packetSinkHelper ("ns3::TcpSocketFactory", hubLocalAddress);
    ApplicationContainer hubApp = packetSinkHelper.Install (star.GetHub ());
    hubApp.Start (Seconds (1.0));
```

```
hubApp.Stop (Seconds (10.0));

OnOffHelper onOffHelper ("ns3::TcpSocketFactory", Address ());
onOffHelper.SetAttribute ("OnTime", StringValue ("ns3::ConstantRandomVariable[Constant=1]"));
onOffHelper.SetAttribute ("OffTime", StringValue ("ns3::ConstantRandomVariable[Constant=0]"));

ApplicationContainer spokeApps;

for (uint32_t i = 0; i < star.SpokeCount (); ++i)
{
    AddressValue remoteAddress (InetSocketAddress (star.GetHubIpv4Address (i), port));
    onOffHelper.SetAttribute ("Remote", remoteAddress);
    spokeApps.Add (onOffHelper.Install (star.GetSpokeNode (i)));
}
spokeApps.Start (Seconds (1.0));
spokeApps.Stop (Seconds (10.0));

NS_LOG_INFO ("Enable static global routing.");

Ipv4GlobalRoutingHelper::PopulateRoutingTables ();

NS_LOG_INFO ("Enable pcap tracing.");

AnimationInterface anim("np3.xml");

AsciiTraceHelper eventTraces;
pointToPoint.EnableAsciiAll(eventTraces.CreateFileStream("np3.tr"));
pointToPoint.EnablePcapAll ("np3");

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

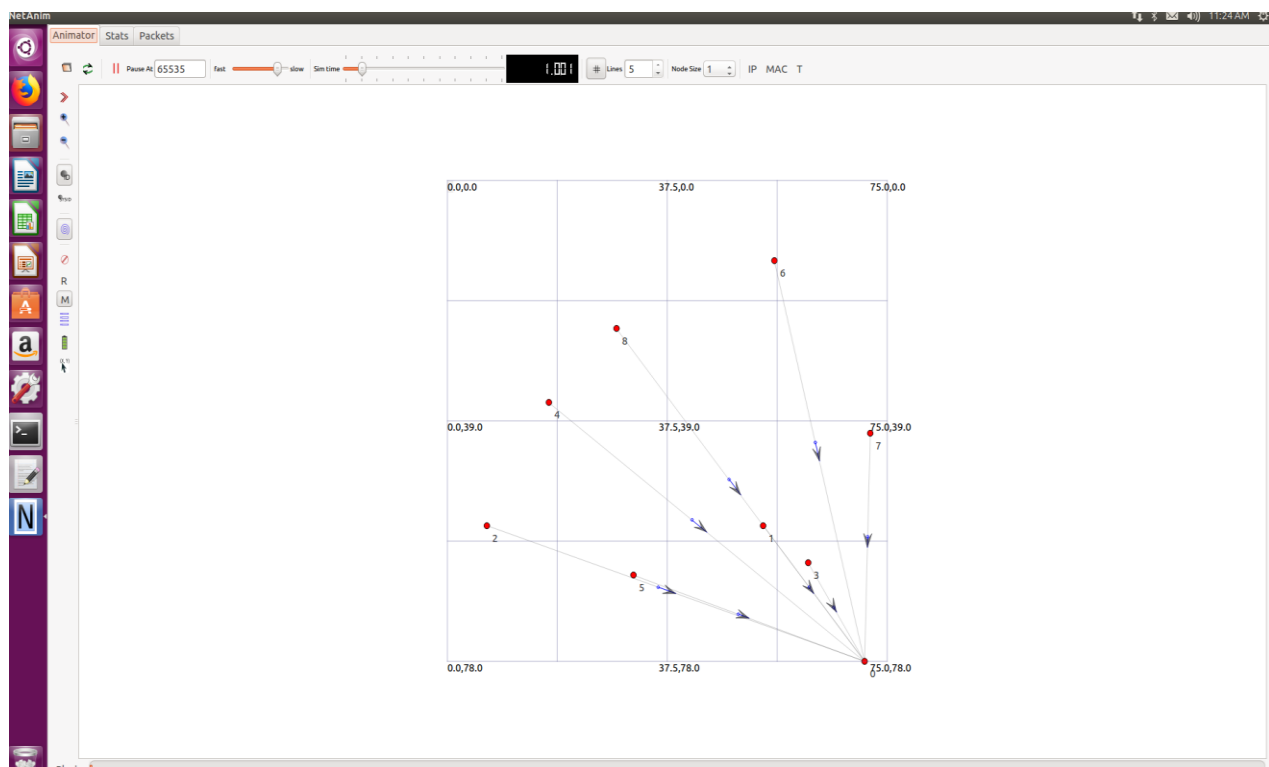
return 0;
}
```

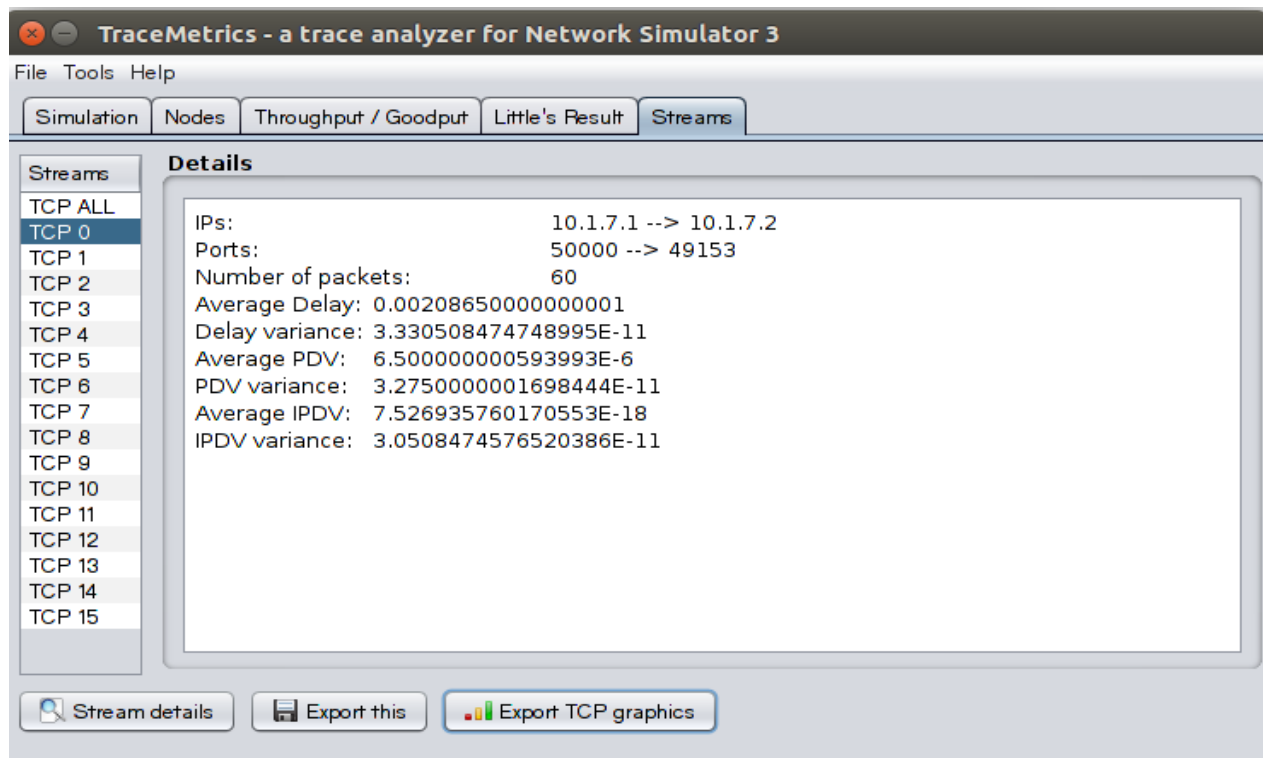
OUTPUT

```

prakash@ubuntu: ~/ns3/ns-allinone-3.27/ns-3.27
At time 2s client sent 1024 bytes to 10.1.2.2 port 9
At time 2.00853s server received 1024 bytes from 10.1.1.1 port 49153
At time 2.00853s server sent 1024 bytes to 10.1.1.1 port 49153
At time 2.01706s client received 1024 bytes from 10.1.2.2 port 9
prakash@ubuntu:~/ns3/ns-allinone-3.27/ns-3.27$ ./waf --run scratch/np3
waf: Entering directory `/home/prakash/ns3/ns-allinone-3.27/ns-3.27/build'
[ 979/2555] Compiling scratch/np3.cc
[2539/2555] Linking build/scratch/np3
waf: Leaving directory `/home/prakash/ns3/ns-allinone-3.27/ns-3.27/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (10.163s)
AnimationInterface WARNING:Node:0 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:1 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:2 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:3 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:4 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:5 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:6 Does not have a mobility model. Use SetConstan

```





4. Write a C++ program to implement a bus topology on NS-3

```
#include "ns3/core-module.h"
#include "ns3/network-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/ipv4-global-routing-helper.h"
#include "ns3/netanim-module.h"

using namespace ns3;

NS_LOG_COMPONENT_DEFINE ("SecondScriptExample");

int
main (int argc, char *argv[])
{
    bool verbose = true;
    uint32_t nCsma = 3;

    CommandLine cmd;
    cmd.AddValue ("nCsma", "Number of \"extra\" CSMA nodes/devices", nCsma);
    cmd.AddValue ("verbose", "Tell echo applications to log if true", verbose);

    cmd.Parse (argc,argv);

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

    nCsma = nCsma == 0 ? 1 : nCsma;

    NodeContainer p2pNodes;
    p2pNodes.Create (2);

    NodeContainer csmaNodes;
    csmaNodes.Add (p2pNodes.Get (1));
    csmaNodes.Create (nCsma);

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

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

    CsmaHelper csma;
    csma.SetChannelAttribute ("DataRate", StringValue ("100Mbps"));
```

```
csma.SetChannelAttribute ("Delay", TimeValue (NanoSeconds (6560)));

NetDeviceContainer csmaDevices;
csmaDevices = csma.Install (csmaNodes);

InternetStackHelper stack;
stack.Install (p2pNodes.Get (0));
stack.Install (csmaNodes);

Ipv4AddressHelper address;
address.SetBase ("10.1.1.0", "255.255.255.0");
Ipv4InterfaceContainer p2pInterfaces;
p2pInterfaces = address.Assign (p2pDevices);

address.SetBase ("10.1.2.0", "255.255.255.0");
Ipv4InterfaceContainer csmaInterfaces;
csmaInterfaces = address.Assign (csmaDevices);

UdpEchoServerHelper echoServer (9);

ApplicationContainer serverApps = echoServer.Install (csmaNodes.Get (nCsma));
serverApps.Start (Seconds (1.0));
serverApps.Stop (Seconds (10.0));

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

ApplicationContainer clientApps = echoClient.Install (p2pNodes.Get (0));
clientApps.Start (Seconds (2.0));
clientApps.Stop (Seconds (10.0));

Ipv4GlobalRoutingHelper::PopulateRoutingTables ();

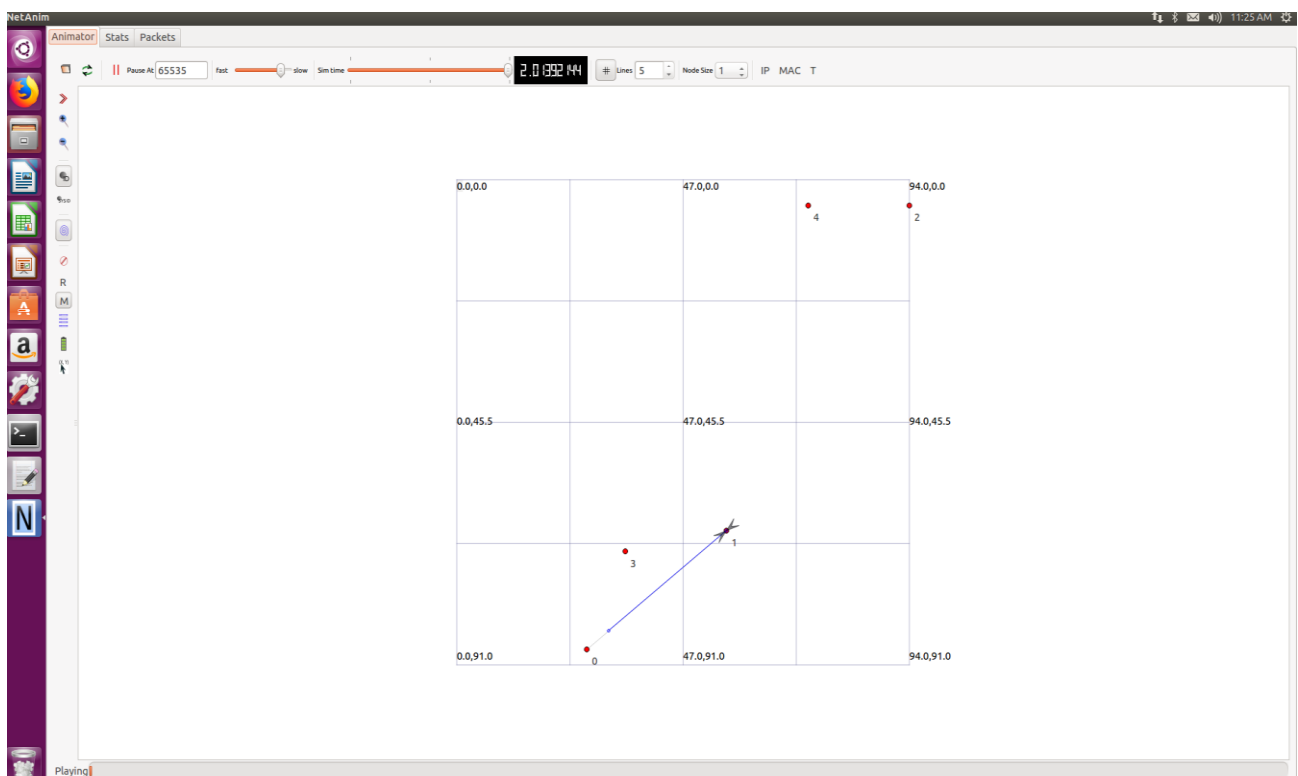
AnimationInterface anim("np4.xml");

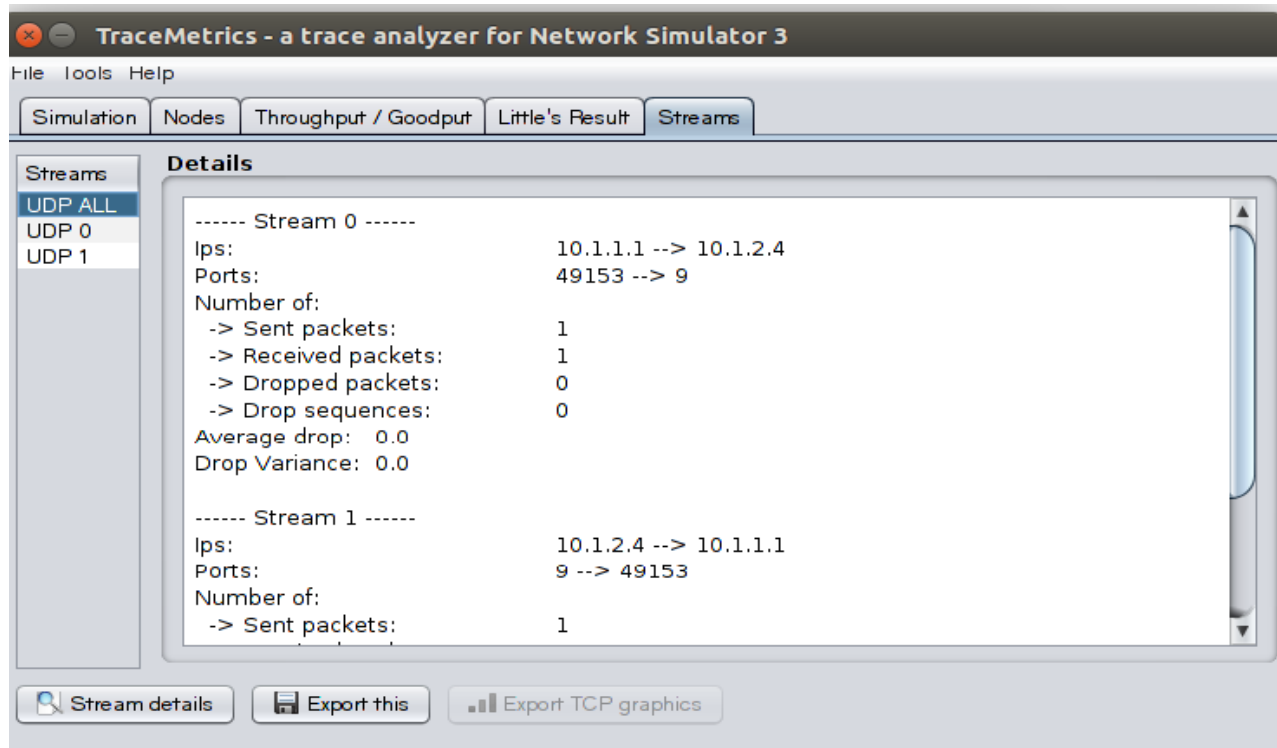
AsciiTraceHelper eventTraces;
pointToPoint.EnableAsciiAll(eventTraces.CreateFileStream("np4.tr"));
pointToPoint.EnablePcapAll ("np4");

Simulator::Run ();
Simulator::Destroy ();
return 0;
}
```

OUTPUT

```
prakash@ubuntu: ~/ns3/ns-allinone-3.27/ns-3.27
prakash@ubuntu:~/ns3/ns-allinone-3.27/ns-3.27$ ./waf --run scratch/np4
Waf: Entering directory `/home/prakash/ns3/ns-allinone-3.27/ns-3.27/build'
[ 978/2557] Compiling scratch/np4.cc
[ 979/2557] Compiling scratch/np1.cc
[ 980/2557] Compiling scratch/np3.cc
[2528/2557] Linking build/scratch/np3
[2545/2557] Linking build/scratch/np1
[2545/2557] Linking build/scratch/np4
Waf: Leaving directory `/home/prakash/ns3/ns-allinone-3.27/ns-3.27/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (23.970s)
AnimationInterface WARNING:Node:0 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:1 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:2 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:3 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:4 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:0 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:1 Does not have a mobility model. Use SetConstan
```





5. Write a C++ program showing the connection of two nodes and four routers such that the extreme nodes act as client and server on NS-3

```
#include "ns3/core-module.h"
#include "ns3/network-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/ipv4-global-routing-helper.h"
#include "ns3/netanim-module.h"

using namespace ns3;
NS_LOG_COMPONENT_DEFINE ("SecondScriptExample");
int main (int argc, char *argv[])
{
    bool verbose = true;
    if (verbose)
    {
        LogComponentEnable ("UdpEchoClientApplication", LOG_LEVEL_INFO);
        LogComponentEnable ("UdpEchoServerApplication", LOG_LEVEL_INFO);
    }
    NodeContainer host, router, host1;
    host.Create (2);
    router.Create (4);
    NodeContainer subnet1;
    subnet1.Add (host.Get (0));
    subnet1.Add (router.Get (0));

    PointToPointHelper pointToPoint;
    pointToPoint.SetDeviceAttribute ("DataRate", StringValue ("5Mbps"));
    pointToPoint.SetChannelAttribute ("Delay", StringValue ("2ms"));
    NetDeviceContainer subnet1Devices;
    subnet1Devices = pointToPoint.Install (subnet1);
    InternetStackHelper stack;
    stack.Install (router);
    stack.Install (host);

    Ipv4AddressHelper address1, address2, address3, address4, address5, address6 ;
    address1.SetBase ("10.1.1.0", "255.255.255.0");
    Ipv4InterfaceContainer subnet1Interfaces;
    subnet1Interfaces = address1.Assign (subnet1Devices);
    NodeContainer subnet2;
    subnet2.Add (router.Get (0));
    subnet2.Add (router.Get (1));

    NetDeviceContainer subnet2Devices;
    subnet2Devices = pointToPoint.Install (subnet2);
    address2.SetBase ("10.1.2.0", "255.255.255.0");
    Ipv4InterfaceContainer subnet2Interfaces;
```

```
subnet2Interfaces = address2.Assign (subnet2Devices);
NodeContainer subnet3; subnet3.Add (router.Get (1));
subnet3.Add (router.Get (2));

NetDeviceContainer subnet3Devices;
subnet3Devices = pointToPoint.Install (subnet3);
address3.SetBase ("10.1.3.0", "255.255.255.0");
Ipv4InterfaceContainer subnet3Interfaces;
subnet3Interfaces = address3.Assign (subnet3Devices);
NodeContainer subnet4; subnet4.Add (router.Get (1));
subnet4.Add (router.Get (3));

NetDeviceContainer subnet4Devices;
subnet4Devices = pointToPoint.Install (subnet4);
address4.SetBase ("10.1.4.0", "255.255.255.0");
Ipv4InterfaceContainer subnet4Interfaces;
subnet4Interfaces = address4.Assign (subnet4Devices);
NodeContainer subnet5; subnet5.Add (router.Get (2));
subnet5.Add (host.Get (1));

NetDeviceContainer subnet5Devices;
subnet5Devices = pointToPoint.Install (subnet5);
address5.SetBase ("10.1.5.0", "255.255.255.0");
Ipv4InterfaceContainer subnet5Interfaces;
subnet5Interfaces = address5.Assign (subnet5Devices);
UdpEchoServerHelper echoServer (9);
ApplicationContainer serverApps = echoServer.Install (subnet5.Get (1));
serverApps.Start (Seconds (1.0));
serverApps.Stop (Seconds (10.0));

UdpEchoClientHelper echoClient (subnet5Interfaces.GetAddress (1), 9);
echoClient.SetAttribute ("MaxPackets", UIntegerValue (3));
echoClient.SetAttribute ("Interval", TimeValue (Seconds (1.0)));
echoClient.SetAttribute ("PacketSize", UIntegerValue (1024));
ApplicationContainer clientApps = echoClient.Install (subnet1.Get (0));
clientApps.Start (Seconds (1.0)); clientApps.Stop (Seconds (10.0));
Ipv4GlobalRoutingHelper::PopulateRoutingTables ();

AnimationInterface anim("np5.xml");
AsciiTraceHelper eventTraces;
pointToPoint.EnableAsciiAll(eventTraces.CreateFileStream("np5.tr"));
pointToPoint.EnablePcapAll ("np5");

Simulator::Run ();
Simulator::Destroy ();
return 0;
}
```

OUTPUT

```
prakash@ubuntu: ~/ns3/ns-allinone-3.27/ns-3.27
['/home/prakash/ns3/ns-allinone-3.27/ns-3.27/build/scratch/np5.cc.3.o']
prakash@ubuntu:~/ns3/ns-allinone-3.27/ns-3.27$ ./waf --run scratch/np5
Waf: Entering directory `/home/prakash/ns3/ns-allinone-3.27/ns-3.27/build'
[ 978/2559] Compiling scratch/np5.cc
[2530/2559] Linking build/scratch/np5
[2531/2559] Linking build/scratch/np1
[2539/2559] Linking build/scratch/np3
[2548/2559] Linking build/scratch/np4
Waf: Leaving directory `/home/prakash/ns3/ns-allinone-3.27/ns-3.27/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (17.826s)
AnimationInterface WARNING:Node:0 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:1 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:2 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:3 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:4 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:5 Does not have a mobility model. Use SetConstan
tPosition if it is stationary
AnimationInterface WARNING:Node:0 Does not have a mobility model. Use SetConstan
```

