PART-A

INTRODUCTION TO NS3

NS3 Simulator Basics

- NS-3 is a network simulator
- Developed for network research and education
- Developed after ns-2
- ns-3 is written in C++
- Bindings in Python
- ns-3 uses the waf build system

Waf is a build automation tool designed to assist in the automatic compilation and installation of computer software. It is written in Python.

Waf features:

- Portable to Unix and non-Unix systems
- Lightweight
- Offers a Turing-complete programming language (similar to SCons)
- Support for standard targets: configure, build, clean, distclean, install, and uninstall
- Parallel builds
- Colored output and progress bar display
- Scripts are Python modules
- XML script front-end and a dedicated, easy-to-parse "IDE output" mode to ease the interaction with integrated development environments
- Modular configuration scheme with customizable command-line parsing
- Daemon mode for background recompilation
- Find source files intelligently (glob()-like) to ease script maintenance
- Support for global object cache to avoid unnecessary recompilations
- Support for unit tests run on programs at the end of builds

  Waf supports:

- A C/C++ preprocessor for computing dependencies simulation programs are C++ executables or python scripts

Features

- It it a discrete event simulator
- Modular design / Open source
- Actively developed (Contrast NS-2)
- Developed in C++. Python binding available.
- Live visualizer
- Logging facility for debugging

- Tracing facility for getting output
- Can be connected to a real network
- Direct Code Execution (DCE)

How to install ns3?
Download tarball from www.nsnam.org the recent release in your directory. Go to that directory and untar the tarball.

```
tar xvfj ns3.tar
```

It creates the directory for ns3 change to it.

```
cd ns3
```

For compiling and installing

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

How to run ns3 script?
To test the installation copy one example available in the distribution to scratch directory and build and run the same using the commands below:

```
cd ns3.26
cp examples/tutorial/first.cc scratch/first.cc
./waf --run scratch/first
```

Steps in writing scripts

- Include necessary files
- Use appropriate name space
- Set simulation time resolution(Optional)
- Enable logging for different modules(Optional)
- Create nodes
- Create net devices with MAC and PHY
- Attach Net devices to nodes and set interconnections
- Install protocol stack in nodes
- Set network address for interfaces
- Setup routing
- Install applications in nodes
- Setup tracing(Optional)
- Set application start and stop time
- Set simulation start time(Optional)
- Run simulation
- Release resources at end of simulation

Tutorial : First.cc
Simple point to point (Wired network) link between server and client is established here. This program is in your NS3 repository. (example/tutorial/first.cc)
Note : To know about NS3, you must have the base knowledge in c++ and OOPS concept.

1. Module Includes

#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"

Each of the ns-3 include files is placed in a directory called ns3 (under the build directory) during the build process to help avoid include file name collisions. The ns3/core-module.h file corresponds to the ns-3 module you will find in the directory src/core in your downloaded release distribution. If you list this directory you will find a large number of header files. When you do a build, Waf will place public header files in an ns3 directory under the appropriate build/debug or build/optimized directory depending on your configuration. Waf will also automatically generate a module include file to load all of the public header files.

2. NS3 Namespace

using namespace ns3;
The ns-3 project is implemented in a C++ namespace called ns3. This groups all ns-3-related declarations in a scope outside the global namespace, which we hope will help with integration with other code. The C++ using statement introduces the ns-3 namespace into the current (global) declarative region. This is a fancy way of saying that after this declaration, you will not have to type ns3:: scope resolution operator before all of the ns-3 code in order to use it. If you are unfamiliar with namespaces, please consult almost any C++ tutorial and compare the ns3 namespace and usage here with instances of the std namespace and the using namespace std; statements you will often find in discussions of cout and streams.

3. Set simulation time resolution

*int main (int argc, char *argv[])*
This is just the declaration of the main function of your program (script). Just as in any C++ program, you need to define a main function that will be the first function run. There is nothing at all special here. Your ns3 script is just a C++ program.
The next line sets the time resolution to one nanosecond, which happens to be the default value:
Time::SetResolution (Time::NS);
The resolution is the smallest time value that can be represented (as well as the smallest represent able difference between two time values). You can change the resolution exactly once. The mechanism enabling this flexibility is somewhat memory hungry, so once the resolution has been set explicitly we release the memory, preventing further updates. (If you don't set the resolution explicitly, it will default to one nanosecond, and the memory will be released when the simulation starts.)

4. Enable logging for different modules

NS_LOG_COMPONENT_DEFINE ("FirstScriptExample");
this line declares a logging component called FirstScriptExample that allows you to enable and disable console message logging by reference to the name.

5. Create nodes

NodeContainer nodes;
nodes.Create (2);
The NodeContainer topology helper provides a convenient way to create, manage and access any Node objects that we create in order to run a simulation. The first line above just declares a NodeContainer which

we call nodes. The second line calls the Create method on the nodes object and asks the container to create two nodes.

6. Create net devices with MAC and PHY

PointToPointHelper pointToPoint;
It instantiates a PointToPointHelper object on the stack. From a high-level perspective the next line,
pointToPoint.SetDeviceAttribute ("DataRate", StringValue ("5Mbps"));
Above line tells the PointToPointHelper object to use the value “5Mbps” (five megabits per second) as the “DataRate” when it creates a PointToPointNetDevice object. From a more detailed perspective, the string “DataRate” corresponds to what we call an Attribute of the PointToPointNetDevice.
pointToPoint.SetChannelAttribute ("Delay", StringValue ("2ms"));
It tells the PointToPointHelper to use the value “2ms” (two milliseconds) as the value of the transmission delay of every point to point channel it subsequently creates.

7. Attach Net devices to nodes and set interconnections

NetDeviceContainer devices;
devices = pointToPoint.Install (nodes);
The first line declares the device container mentioned above and the second does the heavy lifting. The Install method of the PointToPointHelper takes a NodeContainer as a parameter. Internally, a NetDeviceContainer is created. For each node in the NodeContainer (there must be exactly two for a point-to-point link) a PointToPointNetDevice is created and saved in the device container.
A PointToPointChannel is created and the two PointToPointNetDevices are attached. When objects are created by the PointToPointHelper, the Attributes previously set in the helper are used to initialize the corresponding Attributes in the created objects. After executing the pointToPoint.Install (nodes) call we will have two nodes, each with an installed point-to-point net device and a single point-to-point channel between them. Both devices will be configured to transmit data at five megabits per second over the channel which has a two millisecond transmission delay.

8. Install protocol stack in nodes

The only user-visible API is to set the base IP address and network mask to use when performing the actual address allocation (which is done at a lower level inside the helper).
Ipv4AddressHelper address;
address.SetBase ("10.1.1.0", "255.255.255.0");
It declares an address helper object and tell it that it should begin allocating IP addresses from the network 10.1.1.0 using the mask 255.255.255.0 to define the allocatable bits. By default the addresses allocated will start at one and increase monotonically, so the first address allocated from this base will be 10.1.1.1, followed by 10.1.1.2, etc. The low level ns3 system actually remembers all of the IP addresses allocated and will generate a fatal error if you accidentally cause the same address to be generated twice (which is a very hard to debug error, by the way).

9. Set network address for interfaces

Ipv4InterfaceContainer interfaces = address.Assign (devices);
It performs the actual address assignment. In ns-3 we make the association between an IP address and a device using an Ipv4Interface object. Just as we sometimes need a list of net devices created by a helper for future reference we sometimes need a list of Ipv4Interface objects. The Ipv4InterfaceContainer provides this functionality. Now we have a point-to-point network built, with stacks installed and IP addresses assigned. What we need at this point are applications to generate traffic.

10. Setup routing

UdpEchoServerHelper echoServer (9);
ApplicationContainer serverApps = echoServer.Install (nodes.Get (1));
The first line of code in the above snippet declares the UdpEchoServerHelper. As usual, this isn't the application itself, it is an object used to help us create the actual applications. One of our conventions is to place required Attributes in the helper constructor. In this case, the helper can't do anything useful unless it is provided with a port number that the client also knows about. Rather than just picking one and hoping it all works out, we require the port number as a parameter to the constructor. The constructor, in turn, simply does a SetAttribute with the passed value. If you want, you can set the "Port" Attribute to another value later using SetAttribute.

Similar to many other helper objects, the UdpEchoServerHelper object has an Install method. It is the execution of this method that actually causes the underlying echo server application to be instantiated and attached to a node. Interestingly, the Install method takes a NodeContainter as a parameter just as the other Install methods we have seen. This is actually what is passed to the method even though it doesn't look so in this case. There is a C++ implicit conversion at work here that takes the result of nodes.Get (1) (which returns a smart pointer to a node object — Ptr<Node>) and uses that in a constructor for an unnamed NodeContainer that is then passed to Install. If you are ever at a loss to find a particular method signature in C++ code that compiles and runs just fine, look for these kinds of implicit conversions.
serverApps.Start (Seconds (1.0));
serverApps.Stop (Seconds (10.0));
Above lines cause the echo server application to Start (enable itself) at one second into the simulation and to Stop (disable itself) at ten seconds into the simulation. By virtue of the fact that we have declared a simulation event (the application stop event) to be executed at ten seconds, the simulation will last at least ten seconds.

11. Install applications in nodes

UdpEchoClientHelper echoClient (interfaces.GetAddress (1), 9);
echoClient.SetAttribute ("MaxPackets", UintegerValue (1));
echoClient.SetAttribute ("Interval", TimeValue (Seconds (1.0)));
echoClient.SetAttribute ("PacketSize", UintegerValue (1024));
For the echo client, however, we need to set five different Attributes. The first two Attributes are set during construction of the UdpEchoClientHelper. We pass parameters that are used (internally to the helper) to set the "RemoteAddress" and "RemotePort" Attributes in accordance with our convention to make required Attributes parameters in the helper constructors.

The zeroth interface in the interfaces container is going to correspond to the IP address of the zeroth node in the nodes container. The first interface in the interfaces container corresponds to the IP address of the first node in the nodes container. So, in the first line of code (from above), we are creating the helper and telling it so set the remote address of the client to be the IP address assigned to the node on which the server resides. We also tell it to arrange to send packets to port nine.

The "MaxPackets" Attribute tells the client the maximum number of packets we allow it to send during the simulation.

The "Interval" Attribute tells the client how long to wait between packets, and the "PacketSize" Attribute tells the client how large its packet payloads should be. With this particular combination of Attributes, we are telling the client to send one 1024-byte packet.

12. Set application start and stop time

serverApps.Start (Seconds (1.0));
serverApps.Stop (Seconds (10.0));
First it will run the event at 1.0 seconds, which will enable the echo server application (this event may, in turn, schedule many other events). Then it will run the event scheduled for t=2.0 seconds which will start the

echo client application. Again, this event may schedule many more events. The start event implementation in the echo client application will begin the data transfer phase of the simulation by sending a packet to the server.

13. Run simulation

Simulator::Run ();
When Simulator::Run is called, the system will begin looking through the list of scheduled events and executing them. Eventually, since we only send one packet (recall the MaxPackets Attribute was set to one), the chain of events triggered by that single client echo request will taper off and the simulation will go idle. Once this happens, the remaining events will be the Stop events for the server and the client. When these events are executed, there are no further events to process and Simulator::Run returns. The simulation is then complete.

14. Release resources at end of simulation

All that remains is to clean up. This is done by calling the global function Simulator::Destroy. As the helper functions (or low level ns-3 code) executed, they arranged it so that hooks were inserted in the simulator to destroy all of the objects that were created. You did not have to keep track of any of these objects yourself — all you had to do was to call Simulator::Destroy and exit. The ns-3 system took care of the hard part for you. The remaining lines of our first ns-3 script, first.cc, do just that:
Simulator::Destroy ();

1. Implement three nodes point – to – point network with duplex links between them. Set the queue size, vary the bandwidth and find the number of packets dropped.

```
Network topology

      10.1.1.0       10.1.2.0
n0 -------------- n1..........n2
point-to-point
```

In this program we have created 3 point to point nodes n0, n1, n2. Node n0 has IP address 10.1.1.1 and n3 has 10.1.2.2. Node n1 has 2 interfaces(10.1.1.2 and 10.1.2.1). OnOffHelper application is used to generate the traffic at source node n0. Packets move from n0 to n2 via n1. Acknowledgment is sent from n2 to n0 via n1. Details of the flow(Number of packets sent, received and dropped) can be verified by using tracemetrics(lab1.tr file).

Program

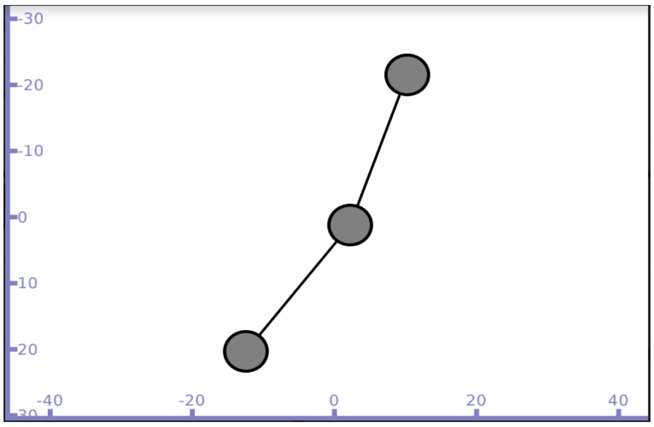
```
#include "ns3/core-module.h"
#include "ns3/network-module.h"
#include "ns3/internet-module.h"
#include "ns3/point-to-point-module.h"
#include "ns3/applications-module.h"
#include "ns3/traffic-control-module.h"

using namespace ns3;

NS_LOG_COMPONENT_DEFINE ("Lab-Program-1");

int main (int argc, char *argv[])
{
std::string socketType= "ns3::TcpSocketFactory";;

CommandLine cmd;
cmd.Parse (argc, argv);

NodeContainer nodes;
nodes.Create (3);          //3 point-to-point nodes are created

InternetStackHelper stack;
stack.Install (nodes);    //TCP-IP layer functionality configured on all nodes
```

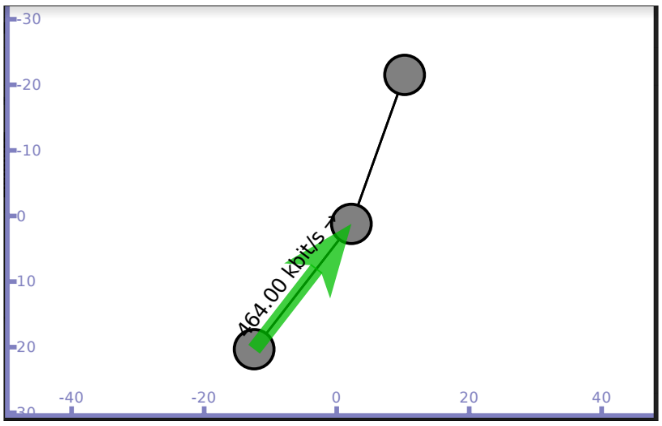
```
//Bandwidth and delay set for the point-to-point channel. Vary these
parameters to  //see the variation in number of packets sent/received/dropped.
PointToPointHelper p2p1;
p2p1.SetDeviceAttribute ("DataRate", StringValue ("5Mbps"));
p2p1.SetChannelAttribute ("Delay", StringValue ("1ms"));

//Set the base address for the first network(nodes n0 and n1)
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);

//Set the base address for the second network(nodes n1 and n2)
devices = p2p1.Install (nodes.Get (1), nodes.Get (2));
address.SetBase ("10.1.2.0", "255.255.255.0");
interfaces = address.Assign (devices);

//RateErrorModel allows us to introduce errors into a Channel at a given rate.
//Vary the error rate value to see the variation in number of packets dropped
Ptr<RateErrorModel>em = CreateObject<RateErrorModel> ();
em->SetAttribute ("ErrorRate", DoubleValue (0.00002));
devices.Get (1)->SetAttribute ("ReceiveErrorModel", PointerValue (em));

//create routing table at all nodes
Ipv4GlobalRoutingHelper::PopulateRoutingTables ();

uint32_t payloadSize = 1448;
OnOffHelper onoff (socketType, Ipv4Address::GetAny ());

//Generate traffic by using OnOff application
onoff.SetAttribute ("OnTime",  StringValue
("ns3::ConstantRandomVariable[Constant=1]"));
onoff.SetAttribute ("OffTime", StringValue
("ns3::ConstantRandomVariable[Constant=0]"));
onoff.SetAttribute ("PacketSize", UintegerValue (payloadSize));
onoff.SetAttribute ("DataRate", StringValue ("50Mbps")); //bit/s

uint16_t port = 7;
//Install receiver (for packetsink) on node 2
Address localAddress1 (InetSocketAddress (Ipv4Address::GetAny (), port));
PacketSinkHelper packetSinkHelper1 (socketType, localAddress1);
ApplicationContainer sinkApp1 = packetSinkHelper1.Install (nodes.Get (2));
sinkApp1.Start (Seconds (0.0));
sinkApp1.Stop (Seconds (10));

//Install sender app on node 0
ApplicationContainer apps;
AddressValue remoteAddress (InetSocketAddress (interfaces.GetAddress (1),
port));
onoff.SetAttribute ("Remote", remoteAddress);
apps.Add (onoff.Install (nodes.Get (0)));
apps.Start (Seconds (1.0));
apps.Stop (Seconds (10));

Simulator::Stop (Seconds (10));
```

```
AsciiTraceHelper ascii;
p2p1.EnableAsciiAll (ascii.CreateFileStream ("lab1.tr"));

//Run the simulator
Simulator::Run ();
Simulator::Destroy ();
return 0;
}
```

./waf - - run scratch/Program1 - -vis

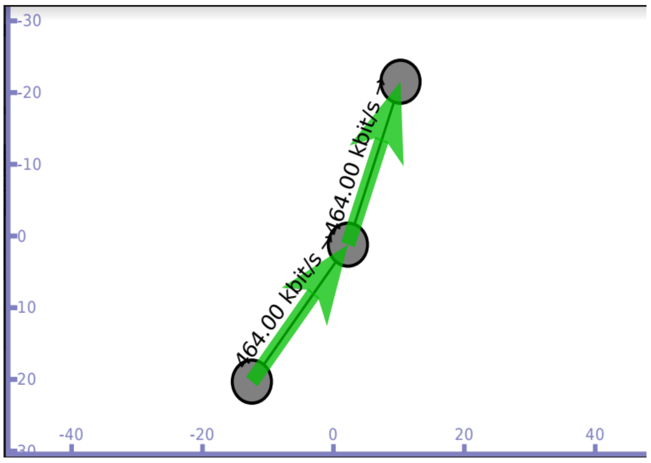
Output

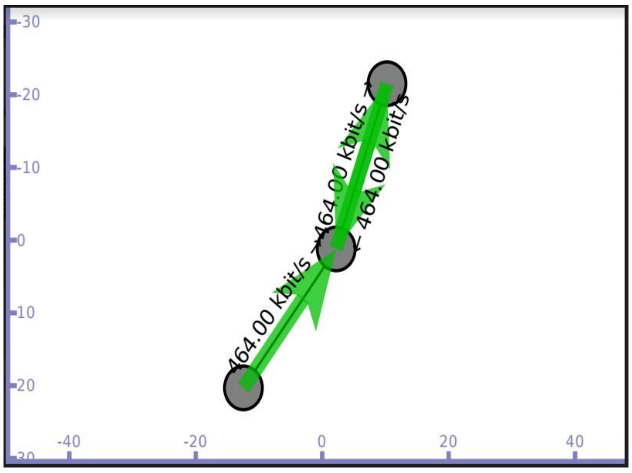




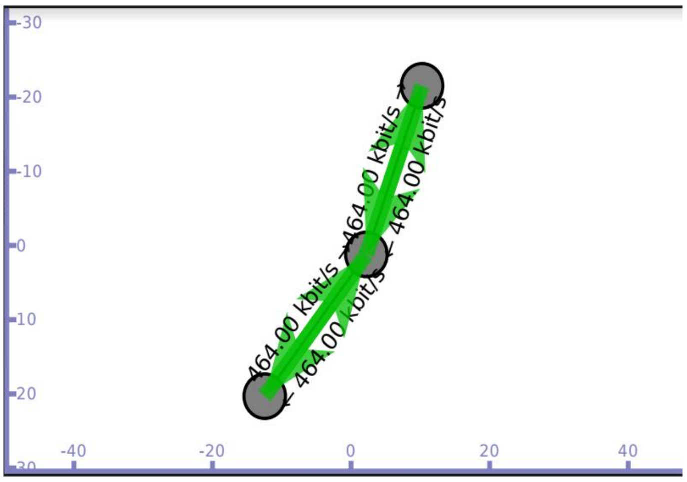
Packet sent from n0 to n1 and then to n2

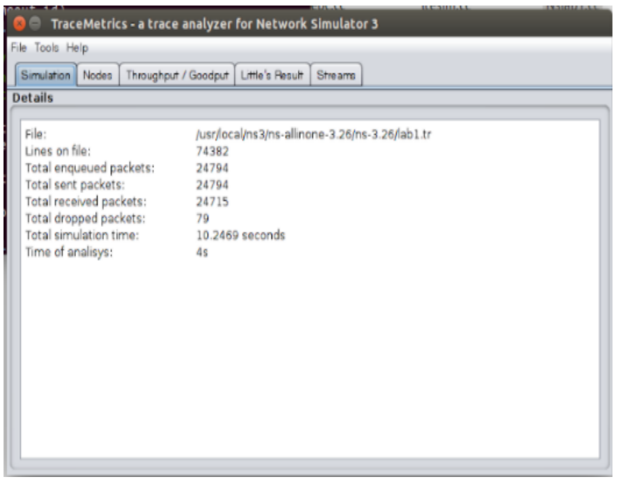
Acknowledgment sent from n2





Flow details on trace file lab1.tr





```
File:                      /usr/local/ns3/ns-allinone-3.26/ns-3.26/lab1.tr
Lines on file:             74382
Total enqueued packets:    24794
Total sent packets:        24794
Total received packets:    24715
Total dropped packets:     79
Total simulation time:     10.2469 seconds
Time of analisys:          4s
```

2. Implement transmission of ping messages/trace route over a network topology consisting of 6 nodes and find the number of packets dropped due to congestion.

```
Network topology

n0    n1   n2   n3  n4   n5
|     |    |    |   |    |
===========================
CSMA channel with base IP 10.1.1.0

In this program we have created 6 CSMA nodes n0, n1, n2, n3, n4 and n5
with IP addresses 10.1.1.1, 10.1.1.2, 10.1.1.3, 10.1.1.4, 10.1.1.5 and
10.1.1.6 respectively.
Nodes n0 and n1 ping node n2, we can visualize the ping messages
transferred between the nodes. Data transfer is also simulated between
the nodes n0 and n2 using UdpSocketFactory to generate traffic.
```

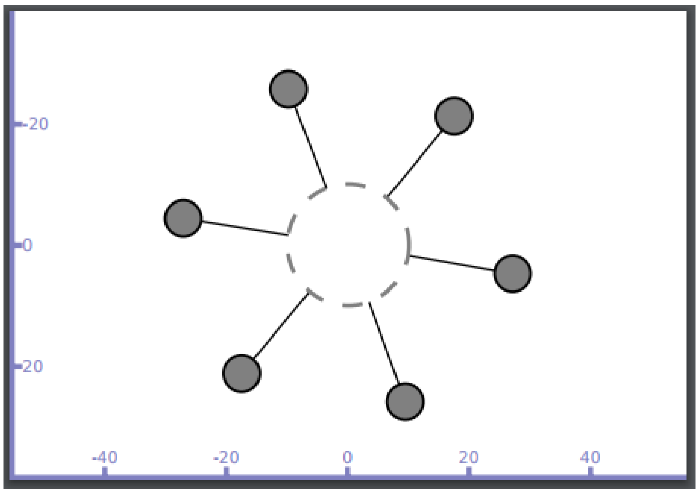
Program

```
#include <iostream>
#include "ns3/core-module.h"
#include "ns3/network-module.h"
#include "ns3/csma-module.h"
#include "ns3/applications-module.h"
#include "ns3/internet-apps-module.h"
#include "ns3/internet-module.h"

using namespace ns3;

NS_LOG_COMPONENT_DEFINE ("Lab-Program-2");

static void PingRtt (std::string context, Time rtt)
{
std::cout << context <<""<< rtt << std::endl;
}

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

// Here, we will explicitly create six nodes.
NS_LOG_INFO ("Create nodes.");
NodeContainer c;
```

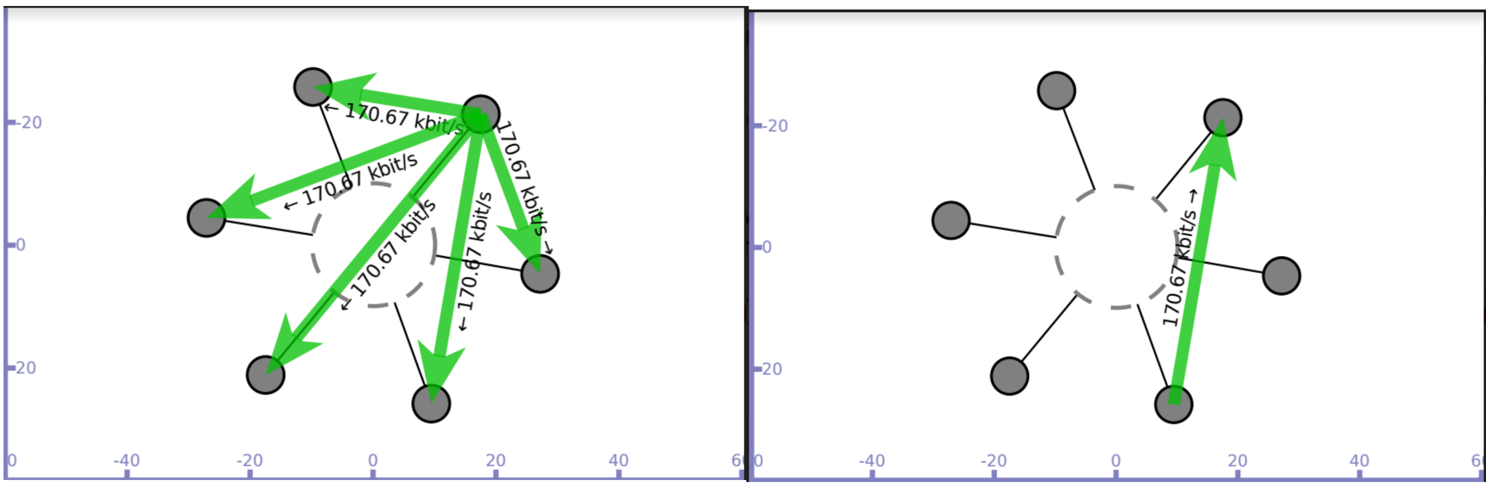
```
c.Create (6);

// connect all our nodes to a shared channel.
NS_LOG_INFO ("Build Topology.");
CsmaHelper csma;
csma.SetChannelAttribute ("DataRate", DataRateValue (DataRate (10000)));
csma.SetChannelAttribute ("Delay", TimeValue (MilliSeconds (0.2)));
NetDeviceContainer devs = csma.Install (c);

// add an ip stack to all nodes.
NS_LOG_INFO ("Add ip stack.");
InternetStackHelper ipStack;
ipStack.Install (c);

// assign ip addresses
NS_LOG_INFO ("Assign ip addresses.");
Ipv4AddressHelper ip;
ip.SetBase ("10.1.1.0", "255.255.255.0");
Ipv4InterfaceContainer addresses = ip.Assign (devs);

NS_LOG_INFO ("Create Sink.");

// Create an OnOff application to send UDP datagrams from node zero to node 1.
NS_LOG_INFO ("Create Applications.");
uint16_t port = 9;   // Discard port (RFC 863)

OnOffHelper onoff ("ns3::UdpSocketFactory",
Address (InetSocketAddress (addresses.GetAddress (2), port)));
onoff.SetConstantRate (DataRate ("500Mb/s"));

ApplicationContainer app = onoff.Install (c.Get (0));
// Start the application
app.Start (Seconds (6.0));
app.Stop (Seconds (10.0));

// Create an optional packet sink to receive these packets
PacketSinkHelper sink ("ns3::UdpSocketFactory",
Address (InetSocketAddress (Ipv4Address::GetAny (), port)));
app = sink.Install (c.Get (2));
app.Start (Seconds (0.0));

NS_LOG_INFO ("Create pinger");
V4PingHelper ping = V4PingHelper (addresses.GetAddress (2));
NodeContainer pingers;
pingers.Add (c.Get (0));
pingers.Add (c.Get (1));

ApplicationContainer apps;
apps = ping.Install (pingers);
apps.Start (Seconds (1.0));
apps.Stop (Seconds (5.0));

// finally, print the ping rtts.
Config::Connect ("/NodeList/*/ApplicationList/*/$ns3::V4Ping/Rtt",
MakeCallback (&PingRtt));

NS_LOG_INFO ("Run Simulation.");

AsciiTraceHelper ascii;
csma.EnableAsciiAll (ascii.CreateFileStream ("ping1.tr"));
```

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

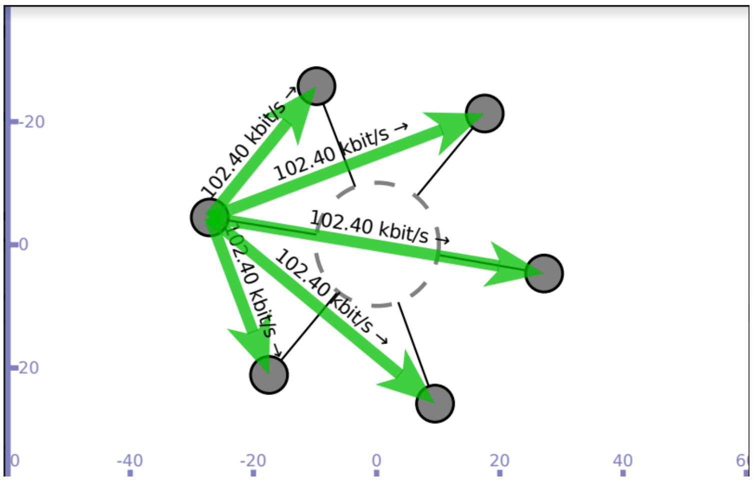
./waf - - run scratch/Program2 - -vis

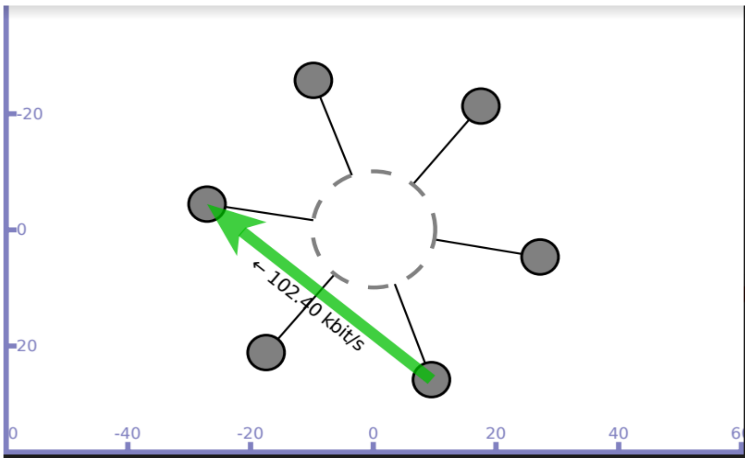


Node n1 sends ping message to n2(Broadcast message is generated) and only n2 responds to n1

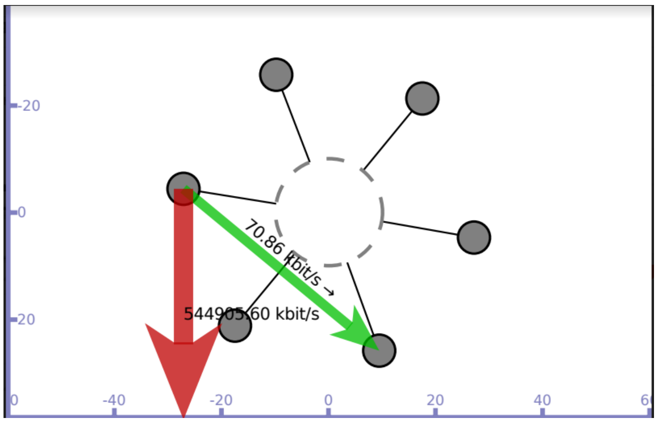


Node n0 sends ping message to n2(Broadcast message is generated) and only n2 responds to n0

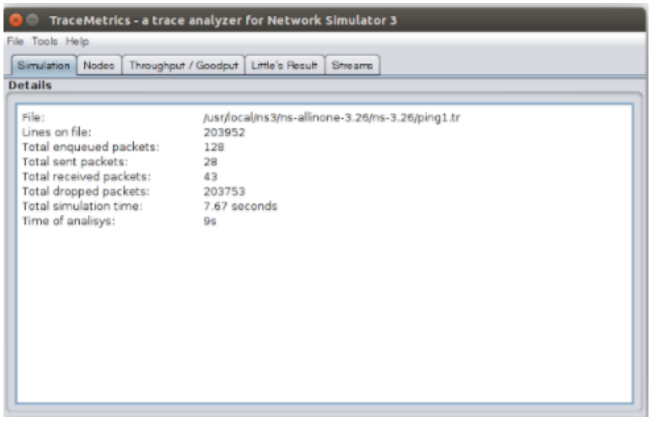




Data transfer simulated between nodes n0 and n2



Trace file(ping1.tr) generated


TraceMetrics - a trace analyzer for Network Simulator 3
File Tools Help
Simulation Nodes Throughput / Goodput Little's Result Streams
Details

```
File:                       /usr/local/ns3/ns-allinone-3.26/ns-3.26/ping1.tr
Lines on file:              203952
Total enqueued packets:     128
Total sent packets:         28
Total received packets:     43
Total dropped packets:      203753
Total simulation time:      7.67 seconds
Time of analisys:           9s
```

3. Implement an Ethernet LAN using n nodes and set multiple traffic nodes and plot congestion window for different source / destination.

```
Network topology

n0    n1   n2   n3
|     |    |    |
===================== CSMA channel with base IP 10.1.1.0
                           Source node – n0    sink node - n1
```

In this program we have created 4 CSMA nodes n0, n1, n2 and n3 with IP addresses 10.1.1.1, 10.1.1.2, 10.1.1.3 and 10.1.1.4 respectively. Data transmission is simulated between nodes n0 and n1. Once the cwnd values are generated, they are exported to .dat file and congestion graph is plot using gnuplot.

Program

```
#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 <iostream>
#include "ns3/csma-module.h"

using namespace ns3;

NS_LOG_COMPONENT_DEFINE ("3rd Lab Program");

//MyApp class inherits the ns-3 Application class defined in
//src/network/model/application.h.
//The MyApp class is obligated to override the StartApplication and //StopApplication
methods. These methods are automatically called when MyApp is //required to start and
stop sending data during the simulation.
class MyApp : public Application
{
public:

MyApp ();
virtual ~MyApp();

void Setup (Ptr<Socket> socket, Address address, uint32_t packetSize, uint32_t
nPackets, DataRate dataRate);

private:
virtual void StartApplication (void);
virtual void StopApplication (void);

void ScheduleTx (void);
void SendPacket (void);

Ptr<Socket>     m_socket;
Address         m_peer;
uint32_t        m_packetSize;
uint32_t        m_nPackets;
DataRate        m_dataRate;
EventId         m_sendEvent;
```

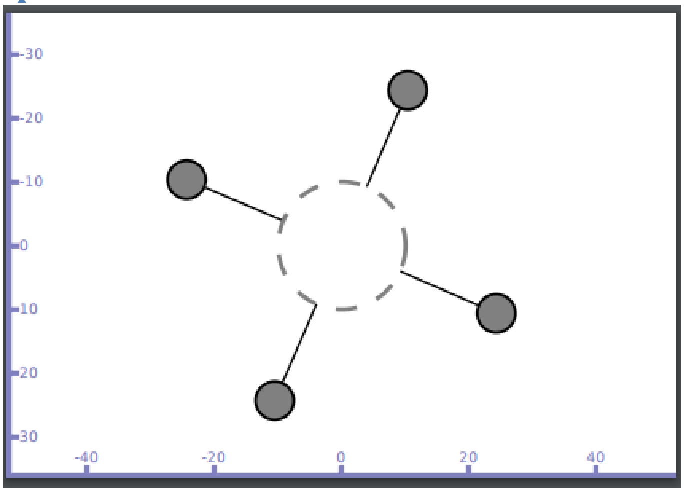
```
bool            m_running;
uint32_t        m_packetsSent;
};
MyApp::MyApp ()      // constructor
: m_socket (0),
m_peer (),
m_packetSize (0),
m_nPackets (0),
m_dataRate (0),
m_sendEvent (),
m_running (false),
m_packetsSent (0)
{
}
MyApp::~MyApp()      // destructor
{
m_socket = 0;
}

// initialize member variables.
void MyApp::Setup (Ptr<Socket> socket, Address address, uint32_t packetSize, uint32_t
nPackets, DataRate dataRate)
{
m_socket = socket;
m_peer = address;
m_packetSize = packetSize;
m_nPackets = nPackets;
m_dataRate = dataRate;
}

// Below code is the overridden implementation of Application::StartApplication. It
//does a socket bind operation and establishes TCP connection with the address
//specified in m_peer.

void MyApp::StartApplication (void)
{
m_running = true;
m_packetsSent = 0;
m_socket->Bind ();
m_socket->Connect (m_peer);
SendPacket ();
}

//The next bit of code explains to the Application how to stop creating simulation
//events.

void MyApp::StopApplication (void)
{
m_running = false;
if (m_sendEvent.IsRunning ())
{
Simulator::Cancel (m_sendEvent);
}
if (m_socket)
{
m_socket->Close ();
}
}
//StartApplication calls SendPacket to start the chain of events that describes the
//Application behavior.
void MyApp::SendPacket (void)
{
Ptr<Packet> packet = Create<Packet> (m_packetSize);
```

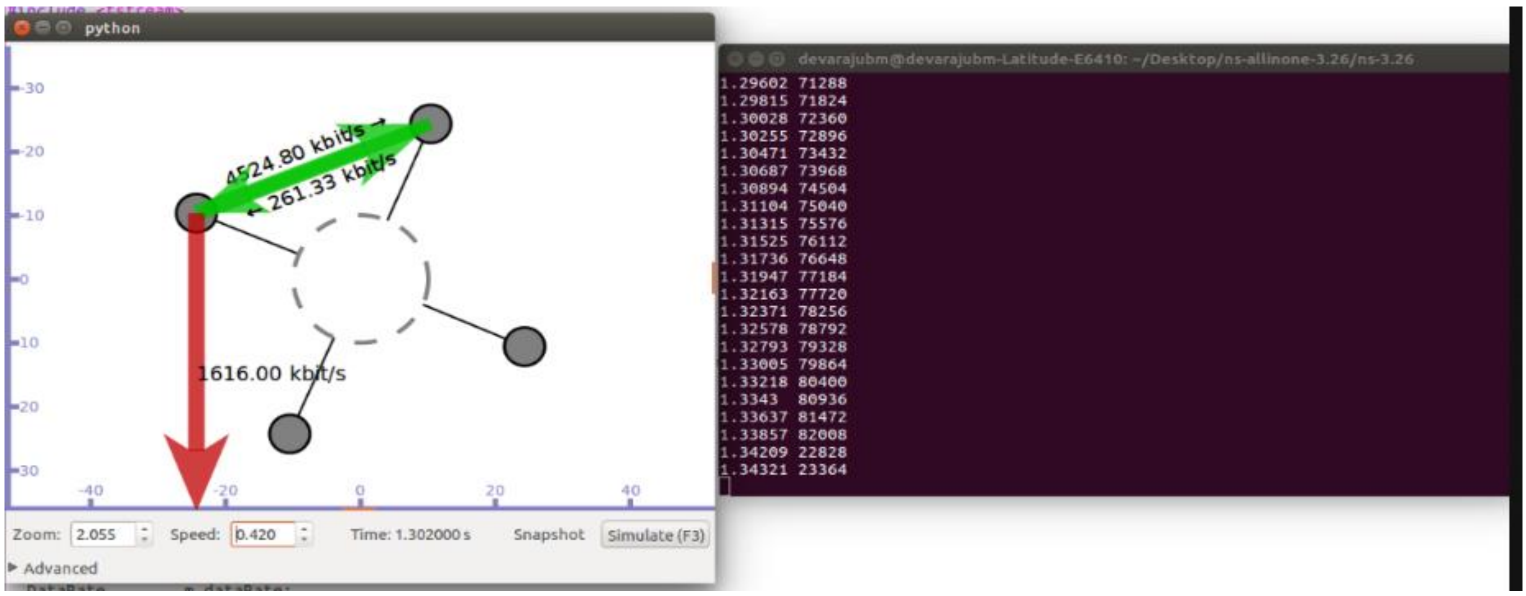
```
m_socket->Send (packet);

if (++m_packetsSent < m_nPackets)
{
ScheduleTx ();
}
}
//It is the responsibility of the Application to keep scheduling the chain of
//events, so the next lines call ScheduleTx to schedule another transmit event
//(a SendPacket) until the Application decides it has sent enough.

void MyApp::ScheduleTx (void)
{
if (m_running)
{
Time tNext (Seconds (m_packetSize * 8 / static_cast<double> (m_dataRate.GetBitRate
())));
m_sendEvent = Simulator::Schedule (tNext, &MyApp::SendPacket, this);
}
}
//Below function logs the current simulation time and the new value of the congestion
window every time it is changed.

static void CwndChange (uint32_t oldCwnd, uint32_t newCwnd)
{
NS_LOG_UNCOND (Simulator::Now ().GetSeconds () <<"\t"<< newCwnd);
}
//trace sink to show where packets are dropped

static void RxDrop (Ptr<const Packet> p)
{
NS_LOG_UNCOND ("RxDrop at "<< Simulator::Now ().GetSeconds ());
}
//main function

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

NS_LOG_INFO ("Create nodes.");
NodeContainer nodes;
nodes.Create (4); //4 csma nodes are created

CsmaHelper csma;
csma.SetChannelAttribute ("DataRate", StringValue ("5Mbps"));
csma.SetChannelAttribute ("Delay", TimeValue (MilliSeconds (0.0001)));

NetDeviceContainer devices;
devices = csma.Install (nodes);

//RateErrorModel allows us to introduce errors into a Channel at a given rate.

Ptr<RateErrorModel>em = CreateObject<RateErrorModel> ();
em->SetAttribute ("ErrorRate", DoubleValue (0.00001));
devices.Get (1)->SetAttribute ("ReceiveErrorModel", PointerValue (em));

InternetStackHelper stack;
stack.Install (nodes);

Ipv4AddressHelper address;
address.SetBase ("10.1.1.0", "255.255.255.0");
Ipv4InterfaceContainer interfaces = address.Assign (devices);
```

```
uint16_t sinkPort = 8080;

//PacketSink Application is used on the destination node to receive TCP connections
//and data.

Address sinkAddress (InetSocketAddress (interfaces.GetAddress (1), sinkPort));
PacketSinkHelper packetSinkHelper ("ns3::TcpSocketFactory", InetSocketAddress
(Ipv4Address::GetAny (), sinkPort));

ApplicationContainer sinkApps = packetSinkHelper.Install (nodes.Get (1));
sinkApps.Start (Seconds (0.));
sinkApps.Stop (Seconds (20.));

//next two lines of code will create the socket and connect the trace source.

Ptr<Socket> ns3TcpSocket = Socket::CreateSocket (nodes.Get (0),
TcpSocketFactory::GetTypeId ());
ns3TcpSocket->TraceConnectWithoutContext ("CongestionWindow", MakeCallback
(&CwndChange));

//creates an Object of type MyApp

Ptr<MyApp> app = CreateObject<MyApp> ();

//tell the Application what Socket to use, what address to connect to, how much //data
to send at each send event, how many send events to generate and the rate at //which
to produce data from those events.

app->Setup (ns3TcpSocket, sinkAddress, 1040, 1000, DataRate ("50Mbps"));
nodes.Get (0)->AddApplication (app);
app->SetStartTime (Seconds (1.));
app->SetStopTime (Seconds (20.));

devices.Get (1)->TraceConnectWithoutContext ("PhyRxDrop", MakeCallback (&RxDrop));

Simulator::Stop (Seconds (20));
Simulator::Run ();
Simulator::Destroy ();

return 0;
}
```

./waf - - run scratch/Program3 - -vis

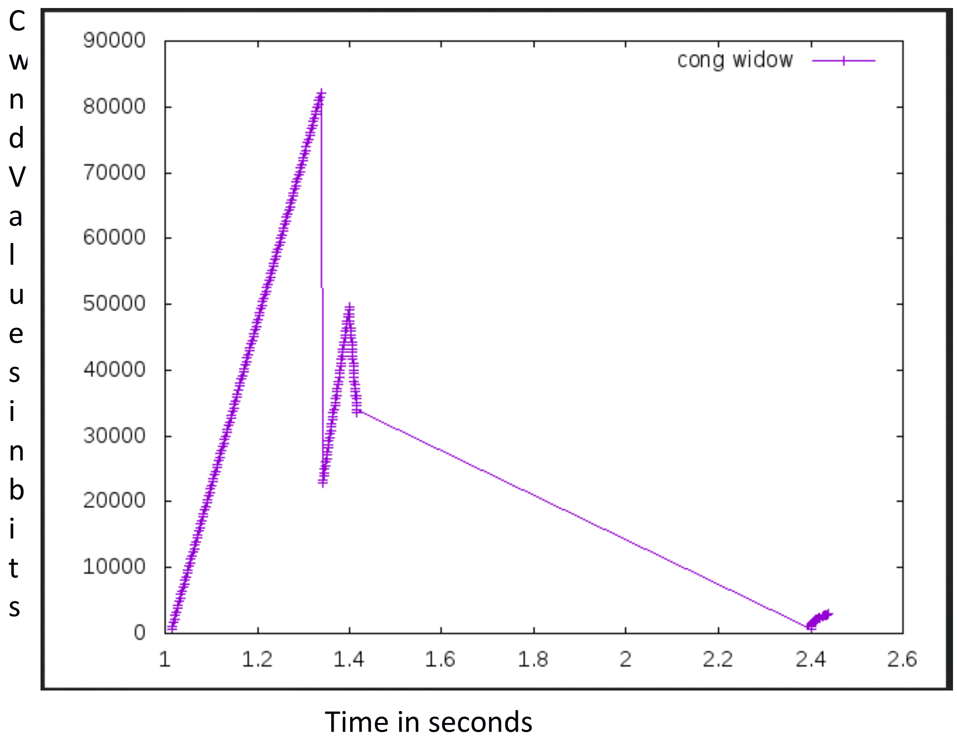
Output





```
1.29602 71288
1.29815 71824
1.30028 72360
1.30255 72896
1.30471 73432
1.30687 73968
1.30894 74504
1.31104 75040
1.31315 75576
1.31525 76112
1.31736 76648
1.31947 77184
1.32163 77720
1.32371 78256
1.32578 78792
1.32793 79328
1.33005 79864
1.33218 80400
1.3343  80936
1.33637 81472
1.33857 82008
1.34209 22828
1.34321 23364
```

```
Redirect the output to a file called cwnd.dat
./waf --run scratch/Program3 > cwnd.dat 2>&1
Now run gnuplot
gnuplot> set terminal png size 640,480
gnuplot> set output "cwnd.png"
gnuplot> plot "cwnd.dat" using 1:2 title 'Congestion Window' with linespoints
gnuplot> exit
```



4. Implement simple ESS and with transmitting nodes in wire-less LAN by simulation and determine the performance with respect to transmission of packets.

```
Default Network Topology
|
Rank 0   |   Rank 1
------------------------ |----------------------------
Wifi 10.1.3.0
AP
*    *    *    *
|    |    |    |    10.1.1.0
n2   n3   n4   n0  n1
point-to-point  |

In this program we have created 3 wifi (STA/mobile)nodes(n2,n3,n4), 2
point to point nodes(n0,n1) where n0 acts as access point n1 is a base
station. This program establishes connection between n2(10.1.3.3) and
n1(10.1.1.2) through access point(10.1.1.1). The Performance is
measured in terms of throughput of the nodes. It can be verified using
tracemetrics(Files generated :  Tracefilewifides and Tracefilewifisrc).
```

Program

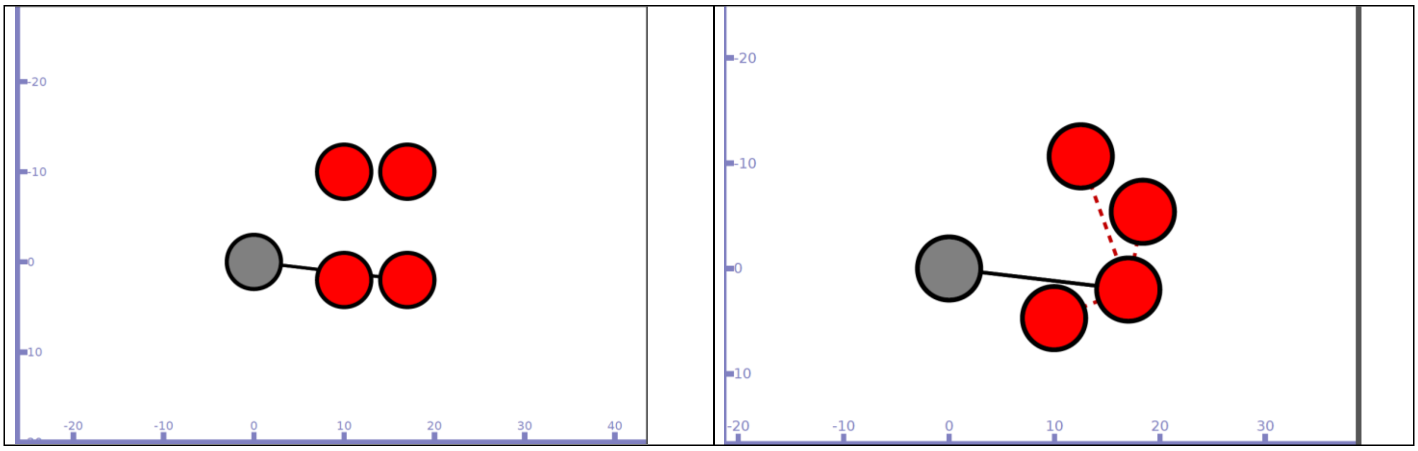
```
#include "ns3/core-module.h"
#include "ns3/point-to-point-module.h"
#include "ns3/network-module.h"
#include "ns3/applications-module.h"
#include "ns3/wifi-module.h"
#include "ns3/mobility-module.h"
#include "ns3/internet-module.h"

using namespace ns3;

NS_LOG_COMPONENT_DEFINE ("ThirdScriptExample");

int main (int argc, char *argv[])
{
bool verbose = true;
uint32_t nWifi = 3; // 3 wi-fi nodes are created

CommandLine cmd;
cmd.AddValue ("nWifi", "Number of wifi STA devices", nWifi);
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);
}

NodeContainer p2pNodes;
p2pNodes.Create (2); // 2 nodes are n0,n1 are created

PointToPointHelper pointToPoint;
```

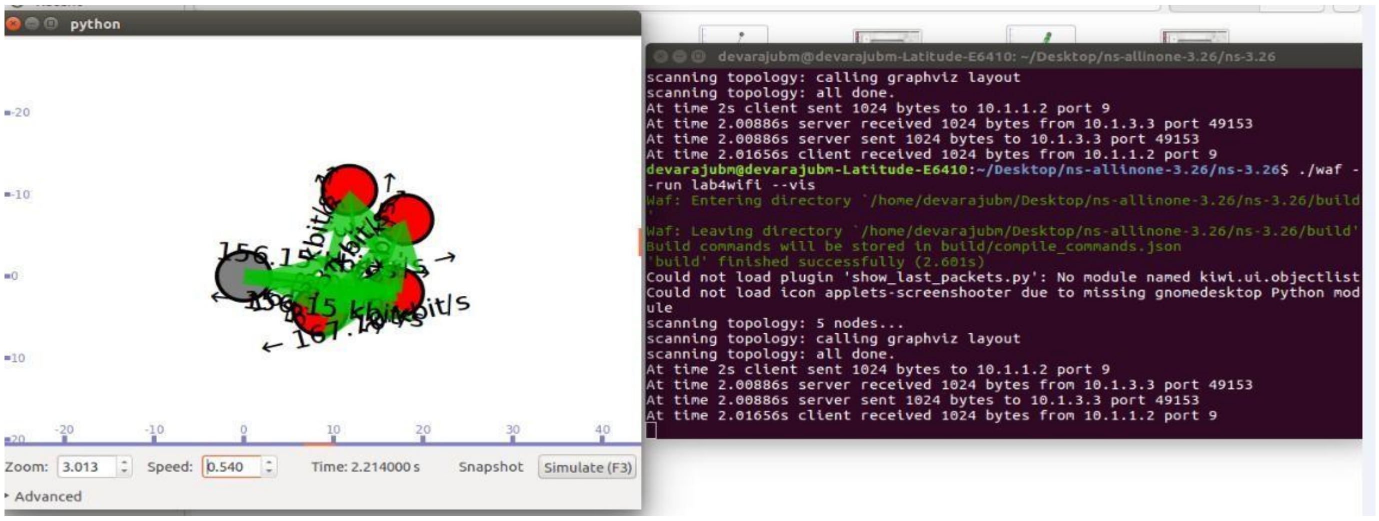
```
pointToPoint.SetDeviceAttribute ("DataRate", StringValue ("5Mbps"));
pointToPoint.SetChannelAttribute ("Delay", StringValue ("2ms"));

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

NodeContainer wifiStaNodes;
wifiStaNodes.Create (nWifi);
NodeContainer wifiApNode = p2pNodes.Get (0);// 1st node of p2p is also access point

// default PHY layer configuration is used for wifi
YansWifiChannelHelper channel = YansWifiChannelHelper::Default ();
YansWifiPhyHelper phy = YansWifiPhyHelper::Default ();
phy.SetChannel (channel.Create ());

WifiHelper wifi;
wifi.SetRemoteStationManager ("ns3::AarfWifiManager");//AARF= rate control
algorithm

WifiMacHelper mac;
Ssid ssid = Ssid ("ns-3-ssid");// ssid=service set identifier in 802.11
mac.SetType ("ns3::StaWifiMac",
"Ssid", SsidValue (ssid),
"ActiveProbing", BooleanValue (false));

NetDeviceContainer staDevices;
staDevices = wifi.Install (phy, mac, wifiStaNodes);

mac.SetType ("ns3::ApWifiMac","Ssid", SsidValue (ssid));

NetDeviceContainer apDevices;
apDevices = wifi.Install (phy, mac, wifiApNode);

MobilityHelper mobility;

// 2 dimensional grid to initially place sta(stationary nodes)
mobility.SetPositionAllocator ("ns3::GridPositionAllocator",
"MinX", DoubleValue (10.0),
"MinY", DoubleValue (-10.0),
"DeltaX", DoubleValue (7.0),
"DeltaY", DoubleValue (12.0),
"GridWidth", UintegerValue (3),
"LayoutType", StringValue ("RowFirst"));

mobility.SetMobilityModel ("ns3::RandomWalk2dMobilityModel",
"Bounds",RectangleValue (Rectangle (-50, 50, -50, 50)));
mobility.Install (wifiStaNodes);

mobility.SetMobilityModel ("ns3::ConstantPositionMobilityModel");
mobility.Install (wifiApNode);

InternetStackHelper stack;
stack.Install (p2pNodes.Get(1));// stack installed on n1 of p2p
stack.Install (wifiApNode); //stack installed on access point
stack.Install (wifiStaNodes); //stack installed on mobile nodes

Ipv4AddressHelper address;
```

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

address.SetBase ("10.1.3.0", "255.255.255.0");
address.Assign (staDevices);
address.Assign (apDevices);

//install echo server application on n1
UdpEchoServerHelper echoServer (9);
ApplicationContainer serverApps = echoServer.Install (p2pNodes.Get (1));
serverApps.Start (Seconds (1.0));
serverApps.Stop (Seconds (10.0));

//install echo client application on n3
UdpEchoClientHelper echoClient (p2pInterfaces.GetAddress (1), 9);
echoClient.SetAttribute ("MaxPackets", UintegerValue (1));
echoClient.SetAttribute ("Interval", TimeValue (Seconds (1.0)));
echoClient.SetAttribute ("PacketSize", UintegerValue (1024));

ApplicationContainer clientApps =
echoClient.Install (wifiStaNodes.Get (nWifi - 1));
clientApps.Start (Seconds (2.0));
clientApps.Stop (Seconds (10.0));

Ipv4GlobalRoutingHelper::PopulateRoutingTables ();

Simulator::Stop (Seconds (10.0));
AsciiTraceHelper ascii;
pointToPoint.EnableAsciiAll (ascii.CreateFileStream ("Tracefilewifides.tr"));
phy.EnableAsciiAll (ascii.CreateFileStream ("Tracefilewifisrc.tr"));

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

./waf - - run scratch/Program4 - -vis

Output

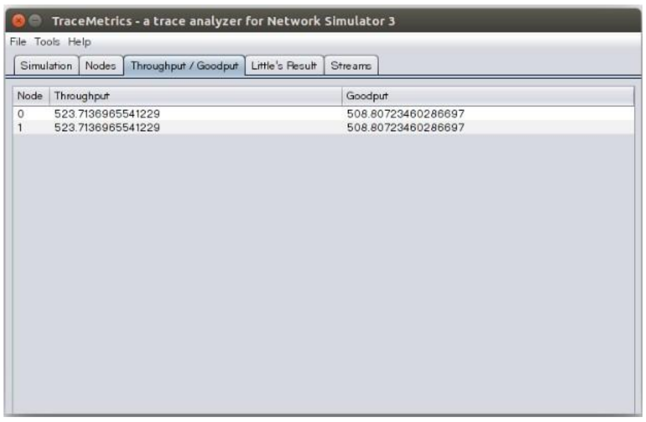




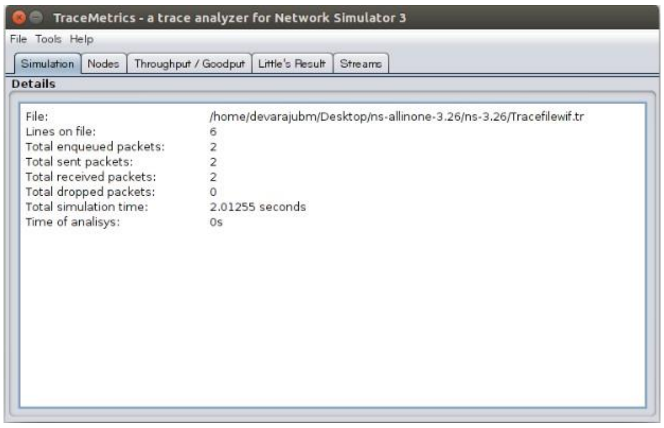
Zoom: 3.013   Speed: 0.540   Time: 2.214000 s

```
devarajubm@devarajubm-Latitude-E6410: ~/Desktop/ns-allinone-3.26/ns-3.26
scanning topology: calling graphviz layout
scanning topology: all done.
At time 2s client sent 1024 bytes to 10.1.1.2 port 9
At time 2.00886s server received 1024 bytes from 10.1.3.3 port 49153
At time 2.00886s server sent 1024 bytes to 10.1.3.3 port 49153
At time 2.01656s client received 1024 bytes from 10.1.1.2 port 9
devarajubm@devarajubm-Latitude-E6410:~/Desktop/ns-allinone-3.26/ns-3.26$ ./waf -
-run lab4wifi --vis
Waf: Entering directory `/home/devarajubm/Desktop/ns-allinone-3.26/ns-3.26/build
'
Waf: Leaving directory `/home/devarajubm/Desktop/ns-allinone-3.26/ns-3.26/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (2.601s)
Could not load plugin 'show_last_packets.py': No module named kiwi.ui.objectlist
Could not load icon applets-screenshooter due to missing gnomedesktop Python mod
ule
scanning topology: 5 nodes...
scanning topology: calling graphviz layout
scanning topology: all done.
At time 2s client sent 1024 bytes to 10.1.1.2 port 9
At time 2.00886s server received 1024 bytes from 10.1.3.3 port 49153
At time 2.00886s server sent 1024 bytes to 10.1.3.3 port 49153
At time 2.01656s client received 1024 bytes from 10.1.1.2 port 9
```

Trace file is used to see the throughput by using TraceMetrics



Node	Throughput	Goodput
0	523.7136965541229	508.80723460286697
1	523.7136965541229	508.80723460286697



Details

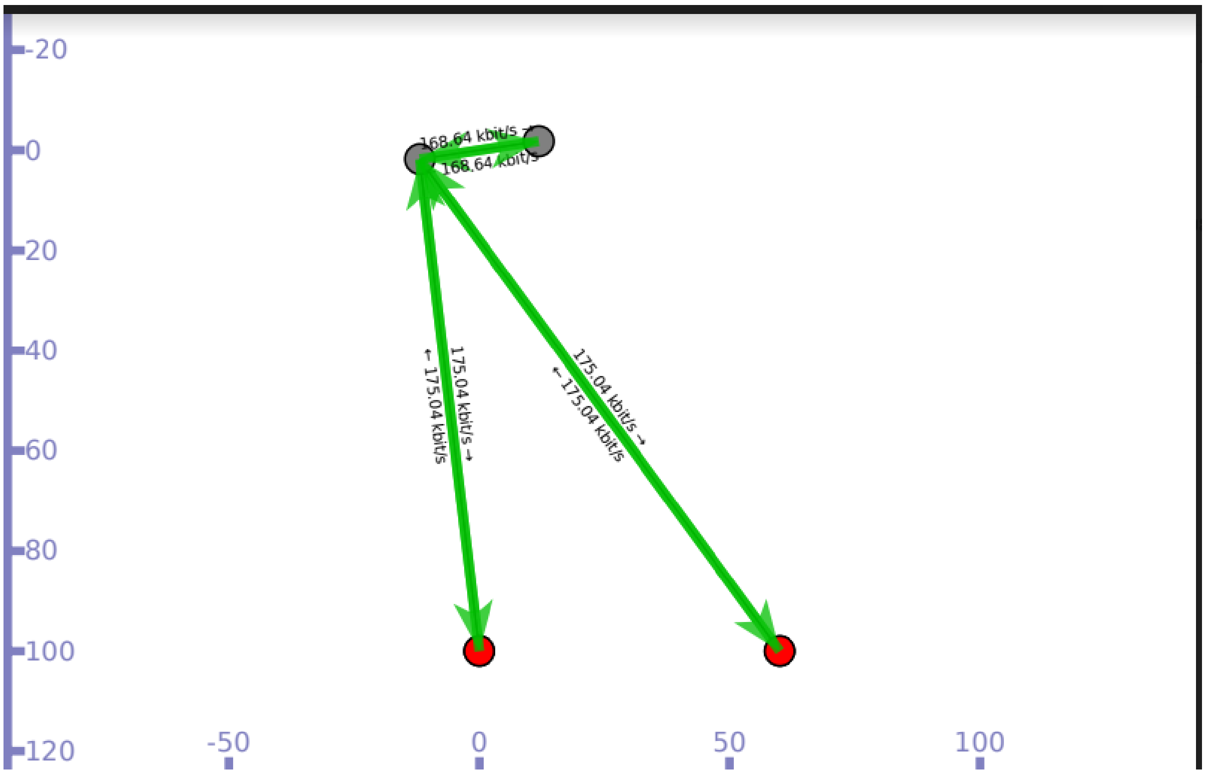
File:	/home/devarajubm/Desktop/ns-allinone-3.26/ns-3.26/Tracefilewif.tr
Lines on file:	6
Total enqueued packets:	2
Total sent packets:	2
Total received packets:	2
Total dropped packets:	0
Total simulation time:	2.01255 seconds
Time of analisys:	0s

5. Implement and study the performance of GSM on NS2/NS3 (Using MAC layer) or equivalent environment.

```
#include "ns3/lte-helper.h"
#include "ns3/epc-helper.h"
#include "ns3/core-module.h"
#include "ns3/network-module.h"
#include "ns3/ipv4-global-routing-helper.h"
#include "ns3/internet-module.h"
#include "ns3/mobility-module.h"
#include "ns3/lte-module.h"
#include "ns3/applications-module.h"
#include "ns3/point-to-point-helper.h"
#include "ns3/config-store.h"
using namespace ns3;

NS_LOG_COMPONENT_DEFINE ("EpcFirstExample");

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

  uint16_t numberOfNodes = 2;
  double simTime = 1.1;
  double distance = 60.0;
  double interPacketInterval = 100;

   CommandLine cmd;
   cmd.Parse(argc, argv);

  Ptr<LteHelper> lteHelper = CreateObject<LteHelper> ();
  Ptr<PointToPointEpcHelper>  epcHelper = CreateObject<PointToPointEpcHelper> ();
  lteHelper->SetEpcHelper (epcHelper);
  ConfigStore inputConfig;
  inputConfig.ConfigureDefaults();
  cmd.Parse(argc, argv);

  Ptr<Node> pgw = epcHelper->GetPgwNode ();
  // Create a single RemoteHost
  NodeContainer remoteHostContainer;
  remoteHostContainer.Create (1);
  Ptr<Node> remoteHost = remoteHostContainer.Get (0);
  InternetStackHelper internet;
  internet.Install (remoteHostContainer);

  // Create the Internet
  PointToPointHelper p2ph;
  p2ph.SetDeviceAttribute ("DataRate", DataRateValue (DataRate ("100Gb/s")));
  p2ph.SetDeviceAttribute ("Mtu", UintegerValue (1500));
  p2ph.SetChannelAttribute ("Delay", TimeValue (Seconds (0.010)));
  NetDeviceContainer internetDevices = p2ph.Install (pgw, remoteHost);
  Ipv4AddressHelper ipv4h;
  ipv4h.SetBase ("1.0.0.0", "255.0.0.0");
  Ipv4InterfaceContainer internetIpIfaces = ipv4h.Assign (internetDevices);
  // interface 0 is localhost, 1 is the p2p device
  Ipv4Address remoteHostAddr = internetIpIfaces.GetAddress (1);
  Ipv4StaticRoutingHelper ipv4RoutingHelper;
  Ptr<Ipv4StaticRouting> remoteHostStaticRouting =
ipv4RoutingHelper.GetStaticRouting (remoteHost->GetObject<Ipv4> ());
  remoteHostStaticRouting->AddNetworkRouteTo (Ipv4Address ("7.0.0.0"), Ipv4Mask
("255.0.0.0"), 1);

  NodeContainer ueNodes;
  NodeContainer enbNodes;
  enbNodes.Create(numberOfNodes);
  ueNodes.Create(numberOfNodes);

  // Install Mobility Model
  Ptr<ListPositionAllocator> positionAlloc = CreateObject<ListPositionAllocator> ();
  for (uint16_t i = 0; i < numberOfNodes; i++)
    {
      positionAlloc->Add (Vector(distance * i, 100, 100));
    }
  MobilityHelper mobility;
  mobility.SetMobilityModel("ns3::ConstantPositionMobilityModel");
  mobility.SetPositionAllocator(positionAlloc);
  mobility.Install(enbNodes);
  mobility.Install(ueNodes);

  // Install LTE Devices to the nodes
  NetDeviceContainer enbLteDevs = lteHelper->InstallEnbDevice (enbNodes);
  NetDeviceContainer ueLteDevs = lteHelper->InstallUeDevice (ueNodes);

  // Install the IP stack on the UEs
  internet.Install (ueNodes);
  Ipv4InterfaceContainer ueIpIface;
  ueIpIface = epcHelper->AssignUeIpv4Address (NetDeviceContainer (ueLteDevs));
  // Assign IP address to UEs, and install applications
  for (uint32_t u = 0; u < ueNodes.GetN (); ++u)
    {
      Ptr<Node> ueNode = ueNodes.Get (u);
      // Set the default gateway for the UE
      Ptr<Ipv4StaticRouting> ueStaticRouting = ipv4RoutingHelper.GetStaticRouting
(ueNode->GetObject<Ipv4> ());
      ueStaticRouting->SetDefaultRoute (epcHelper->GetUeDefaultGatewayAddress (), 1)
    }

  // Attach one UE per eNodeB
  for (uint16_t i = 0; i < numberOfNodes; i++)
      {
        lteHelper->Attach (ueLteDevs.Get(i), enbLteDevs.Get(i));
        // side effect: the default EPS bearer will be activated
      }


  // Install and start applications on UEs and remote host
  uint16_t dlPort = 1234;
  uint16_t ulPort = 2000;
  uint16_t otherPort = 3000;
  ApplicationContainer clientApps;
  ApplicationContainer serverApps;
  for (uint32_t u = 0; u < ueNodes.GetN (); ++u)
    {
      ++ulPort;
      ++otherPort;
      PacketSinkHelper dlPacketSinkHelper ("ns3::UdpSocketFactory",
InetSocketAddress (Ipv4Address::GetAny (), dlPort));
      PacketSinkHelper ulPacketSinkHelper ("ns3::UdpSocketFactory",
InetSocketAddress (Ipv4Address::GetAny (), ulPort));
      PacketSinkHelper packetSinkHelper ("ns3::UdpSocketFactory",
InetSocketAddress (Ipv4Address::GetAny (), otherPort));
      serverApps.Add (dlPacketSinkHelper.Install (ueNodes.Get(u)));
      serverApps.Add (ulPacketSinkHelper.Install (remoteHost));
      serverApps.Add (packetSinkHelper.Install (ueNodes.Get(u)));

      UdpClientHelper dlClient (ueIpIface.GetAddress (u), dlPort);
      dlClient.SetAttribute ("Interval", TimeValue (MilliSeconds
(interPacketInterval)));
      dlClient.SetAttribute ("MaxPackets", UintegerValue(1000000));

      UdpClientHelper ulClient (remoteHostAddr, ulPort);
      ulClient.SetAttribute ("Interval", TimeValue (MilliSeconds
(interPacketInterval)));
      ulClient.SetAttribute ("MaxPackets", UintegerValue(1000000));

      UdpClientHelper client (ueIpIface.GetAddress (u), otherPort);
      client.SetAttribute ("Interval", TimeValue (MilliSeconds
(interPacketInterval)));
      client.SetAttribute ("MaxPackets", UintegerValue(1000000));

      clientApps.Add (dlClient.Install (remoteHost));
      clientApps.Add (ulClient.Install (ueNodes.Get(u)));
      if (u+1 < ueNodes.GetN ())
        {
          clientApps.Add (client.Install (ueNodes.Get(u+1)));
        }
      else
        {
          clientApps.Add (client.Install (ueNodes.Get(0)));
        }
    }
  serverApps.Start (Seconds (0.01));
  clientApps.Start (Seconds (0.01));
  lteHelper->EnableTraces ();
  // Uncomment to enable PCAP tracing
  p2ph.EnablePcapAll("lena-epc-first");

  AsciiTraceHelper ascii;
  p2ph.EnableAsciiAll(ascii.CreateFileStream("cdma.tr"));

  Simulator::Stop(Seconds(simTime));
  Simulator::Run();

  /*GtkConfigStore config;
  config.ConfigureAttributes();*/

  Simulator::Destroy();
  return 0;

}
```

./waf - - run scratch/Program5 - -vis

Output



PART-B

7. Write a program for error detecting code using CRC-CCITT (16- bits).

```
import java.io.*;
class crc
{
    public static void main(String args[]) throws IOException
    {
        BufferedReader br=new BufferedReader(new InputStreamReader(System.in));
        int[] data;
        int[] div;
        int[] divisor;
        int[] rem;
        int[] crc;
        int data_bits, divisor_bits, tot_length;

        System.out.println("Enter number of data bits : ");
        data_bits=Integer.parseInt(br.readLine());
        data=new int[data_bits];

        System.out.println("Enter data bits : ");
        for(int i=0; i<data_bits; i++)
            data[i]=Integer.parseInt(br.readLine());

        System.out.println("Enter number of bits in divisor : ");
        divisor_bits=Integer.parseInt(br.readLine());
        divisor=new int[divisor_bits];

        System.out.println("Enter Divisor bits : ");
        for(int i=0; i<divisor_bits; i++)
            divisor[i]=Integer.parseInt(br.readLine());


        tot_length=data_bits+divisor_bits-1;

        div=new int[tot_length];
        rem=new int[tot_length];
        crc=new int[tot_length];
    /*------------------- CRC GENERATION-----------------------*/
        for(int i=0;i<data.length;i++)
            div[i]=data[i];

        System.out.print("Dividend (after appending 0's) are : ");
        for(int i=0; i< div.length; i++)
            System.out.print(div[i]);
        System.out.println();

        for(int j=0; j<div.length; j++){
              rem[j] = div[j];
        }
        rem=divide(div, divisor, rem);
        for(int i=0;i<div.length;i++)           //append dividend and ramainder
        {
            crc[i]=(div[i]^rem[i]);
        }
        System.out.println();
        System.out.println("CRC code : ");
        for(int i=0;i<crc.length;i++)
            System.out.print(crc[i]);

    /*-------------------ERROR DETECTION---------------------*/
        System.out.println();
        System.out.println("Enter CRC code of "+tot_length+" bits : ");
        for(int i=0; i<crc.length; i++)
```

```
            crc[i]=Integer.parseInt(br.readLine());

        for(int j=0; j<crc.length; j++){
              rem[j] = crc[j];
        }
        rem=divide(crc, divisor, rem);

        for(int i=0; i< rem.length; i++)
        {
            if(rem[i]!=0)
            {
                System.out.println("Error");
                break;
            }
            if(i==rem.length-1)
                System.out.println("No Error");
        }

        System.out.println("THANK YOU.... :)");
    }

    static int[] divide(int div[],int divisor[], int rem[])
    {
        int cur=0;
        while(true)
        {
            for(int i=0;i<divisor.length;i++)
                rem[cur+i]=(rem[cur+i]^divisor[i]);

            while(rem[cur]==0 && cur!=rem.length-1)
                cur++;

            if((rem.length-cur)<divisor.length)
                break;
        }
        return rem;
    }
}
```

```
OUTPUT :
Enter number of data bits :
7
Enter data bits :
1
0
1
1
0
0
1
Enter number of bits in divisor :
3
Enter Divisor bits :
1
0
1
Data bits are : 1011001
divisor bits are : 101
Dividend (after appending 0's) are : 101100100

CRC code :
101100111
```

```
Enter CRC code of 9 bits :
1
0
1
1
0
0
1
0
1
crc bits are : 101100101
Error
THANK YOU.... :)
Press any key to continue...
```

2)
```
Enter number of data bits :
7
Enter data bits :
1
0
1
1
0
0
1
Enter number of bits in divisor :
3
Enter Divisor bits :
1
0
1
Dividend (after appending 0's) are : 101100100

CRC code :
101100111
Enter CRC code of 9 bits :
1
1
1
1
0
0
1
0
1
No Error
THANK YOU.... :)
```

8. Write a program to find the shortest path between vertices using bellman-ford algorithm.

```
package bellmanford;
import java.util.*;
public class Bellmanford {
static int n, dest;
static double[] prevDistanceVector, distanceVector;
static double[][] adjacencyMatrix;
public static void main(String[] args) {
 // TODO code application logic here
Scanner scanner = new Scanner(System.in);
System.out.println("Enter number of nodes");
n = scanner.nextInt();
adjacencyMatrix = new double[n][n];
System.out.println("Enter Adjacency Matrix (Use 'Infinity' for No Link)");
for (int i = 0; i< n; i++)
   for (int j = 0; j < n; j++)
      adjacencyMatrix[i][j] = scanner.nextDouble();
      System.out.println("Enter destination vertex");
      dest = scanner.nextInt();
      distanceVector = new double[n];
      for (int i = 0; i< n; i++)
            distanceVector[i] = Double.POSITIVE_INFINITY;
            distanceVector[dest - 1] = 0;

            bellmanFordAlgorithm();

      System.out.println("Distance Vector");
        for (int i = 0; i< n; i++) {
            if (i == dest - 1) {
                continue;
            }
System.out.println("Distance from " + (i + 1) + " is " + distanceVector[i]);
        }
System.out.println();
    }

    static void bellmanFordAlgorithm() {
        for (int i = 0; i< n - 1; i++) {
prevDistanceVector = distanceVector.clone();
            for (int j = 0; j < n; j++) {
                double min = Double.POSITIVE_INFINITY;
                for (int k = 0; k < n; k++) {
                    if (min >adjacencyMatrix[j][k] + prevDistanceVector[k]) {
                        min = adjacencyMatrix[j][k] + prevDistanceVector[k];
                    }
                }
distanceVector[j] = min;
            }
        }
    }
}
```

OUTPUT

```
run:
Enter number of nodes
6
Enter Adjacency Matrix (Use 'Infinity' for No Link)
0 3 2 5 99 99
3 0 99 1 4 99
2 99 0 2 99 1
5 1 2 0 3 99
99 4 99 3 0 2
99 99 1 99 2 0
```

```
Enter destination vertex
6
Distance Vector
Distance from 1 is 3.0
Distance from 2 is 4.0
Distance from 3 is 1.0
Distance from 4 is 3.0
Distance from 5 is 2.0
```

9. Using TCP/IP sockets, write a client – server program to make the client send the file name and to make the server send back the contents of the requested file if present.

Server
```
package org.tcp;
import java.net.*;
import java.io.*;

public class tcpServer {
	public static void main(String[] args)
	{
		try
		{
			ServerSocket se = new ServerSocket(1537);
			System.out.println("Server waiting");

			Socket server = se.accept();
			System.out.println("Connection established");

			BufferedReader k = new BufferedReader (new
InputStreamReader(server.getInputStream()));
			String filename = k.readLine();
			FileReader f = null;
			BufferedReader ff = null;
			DataOutputStream sendToClient = new
DataOutputStream(server.getOutputStream());
			File file = new File(filename);
			if(file.exists())
			{
				sendToClient.writeBytes("Yes\n");
				f = new FileReader(filename);
				ff = new BufferedReader(f);
				String string;
				while((string = ff.readLine())!=null)
					sendToClient.writeBytes(string+"\n");
			}
			else
			{
				sendToClient.writeBytes("No\n");
			}
			server.close();
			k.close();
			sendToClient.close();
			f.close();
			ff.close();
			se.close();
		}
		catch(Exception ex) {}
	}
}
```

Client
```
package org.tcp;
import java.net.*;
import java.io.*;

public class tcpClient {

	public static void main(String[] args)
	{
		try
		{
			Socket client = new Socket("localhost", 1537);
```

```
                  BufferedReader k = new BufferedReader(new 
InputStreamReader(System.in));
                  System.out.println("Enter file location:");
                  String filename = k.readLine();
                  DataOutputStream sendToServer = new 
DataOutputStream(client.getOutputStream());
                  sendToServer.writeBytes(filename+"\n");

                  BufferedReader i = new BufferedReader(new 
InputStreamReader(client.getInputStream()));
                  String string = i.readLine();
                  if(string.equals("Yes"))
                  {
                        while((string=i.readLine())!=null)
                              System.out.println(string);
                  }
                  else
                        System.out.println("File not found");

                  k.close();
                  client.close();
                  sendToServer.close();
                  i.close();
            }
            catch(Exception ex) {}
      }
}
```

OUTPUT

```
Server Console
Server waiting
Connection established

Client Console
Enter file location:
F:\test.txt
Testing TCP socket
```

10. Write a program on datagram socket for client/server to display the messages on client side, typed at the server side.

```
package labcn;
import java.net.*;
import java.util.*;

public class udpser {

	public static void main(String[] args)
	{
		try
		{
			DatagramSocket server = new DatagramSocket(1537);

			System.out.println("Enter server message:");
			Scanner scan = new Scanner(System.in);

			while(true)
			{
				byte[] buffer = new byte[1000];
				DatagramPacket request = new DatagramPacket(buffer, 
buffer.length);
				server.receive(request);

				String message = scan.nextLine();
				byte[] sendMessage = message.getBytes();
				DatagramPacket reply = new DatagramPacket(sendMessage, 
sendMessage.length, request.getAddress(), request.getPort());
				server.send(reply);

				server.close();
				scan.close();
			}
		}
		catch(Exception ex) {}
	}

}

package labcn;
import java.net.*;
public class udpcli {

	public static void main(String[] args)
	{
		try
		{
			DatagramSocket client = new DatagramSocket();
			int serverSocket = 1537;
			InetAddress host = InetAddress.getByName("127.0.0.1");

			String message = "Text Message";
			byte[] sendMessage = message.getBytes();
			DatagramPacket request = new DatagramPacket(sendMessage, 
sendMessage.length, host, serverSocket);
			client.send(request);

			byte[] buffer = new byte[1000];
			DatagramPacket reply = new DatagramPacket(buffer, buffer.length);
			client.receive(reply);
```

```
                  System.out.println("Client received:\n "+new
String(reply.getData()));

                  client.close();
            }
            catch(Exception ex) {}
      }

}
```

```
OUTPUT
Sever console
Enter server message:
Hello udp client

Client console
Client received:
Hello udp client
```

11. Write a program for simple RSA algorithm to encrypt and decrypt the data.

```
package rsa4;
import java.math.BigInteger;
import java.security.SecureRandom;
import java.util.Scanner;

public class Rsa4 {
     static BigInteger p, q, n, phi_n, e, d;
    static SecureRandomsecureRandom;
    static int bitLength = 64;

    static String encrypt(String msg) {
        return new BigInteger(msg).modPow(e, n).toString();
    }

    static String decrypt(String cipher) {
        return new BigInteger(cipher).modPow(d, n).toString();
    }

        // TODO code application logic here

    public static void main(String[] args) {

        Scanner scanner = new Scanner(System.in);

        secureRandom = new SecureRandom();

        p = BigInteger.probablePrime(bitLength, secureRandom);
        q = BigInteger.probablePrime(bitLength, secureRandom);
        n = p.multiply(q);
        phi_n = p.subtract(BigInteger.ONE).multiply(q.subtract(BigInteger.ONE));

        e = BigInteger.probablePrime(bitLength / 2, secureRandom);
        while (e.gcd(phi_n).compareTo(BigInteger.ONE) != 0 &&e.compareTo(phi_n) < 0) {
            e = e.add(BigInteger.ONE);
        }

        d = e.modInverse(phi_n);

        System.out.println("P assigned as: " + p);
        System.out.println("Q assigned as: " + q);
        System.out.println("N assigned as: " + n);
        System.out.println("PHI_N assigned as: " + phi_n);
        System.out.println("\nEnter Message");
        String msg = scanner.next();
        String encryptedMessage = encrypt(msg);
        System.out.println("Encrypted Message: " + encryptedMessage);
        String decryptedMessage = decrypt(encryptedMessage);
        System.out.println("Decrypted Message: " + decryptedMessage);

    }
}
```

OUTPUT

```
P assigned as: 13330063847181728989
Q assigned as: 10448652783677772539
N assigned as: 139281208723457810526403094838284433071
PHI_N assigned as: 139281208723457810502624378207424931544

Enter Message
5432101
Encrypted Message: 60742093698753105772915807270189084958
Decrypted Message: 5432101
```

12. Write a program for congestion control using leaky bucket algorithm.

```
package lb;
import java.util.*;
public class Lb{
       public static void main(String[] args) {
            System.out.println("enter the number of time intervals");
            Scanner sc=new Scanner(System.in);
            int n=sc.nextInt();
            int t[]=new int[n];
            System.out.println("enter the time intervals");
            for(int i=0;i<n;i++)
                  t[i]=sc.nextInt();
            System.out.println("enter i and l");
            int i=sc.nextInt();
            int l=sc.nextInt();
            int lct=t[0];
            int x=0,y=0;
            for(int j=0;j<n;j++)
            {
                  y=x-(t[j]-lct);
                  if(y>l)
                  {
                        System.out.println("nonconforming packet"+t[j]);
                  }
                        else
                                        x=y+i;
                              lct=t[j];
                              System.out.println("conforming packet"+t[j]);
                        }
                  }
      }
```

```
OUTPUT
enter the number of time intervals
11
enter the time intervals
1 2 3 5 6 8 11 12 13 15 19
enter i and l
4
4
conforming packet1
conforming packet2
nonconforming packet3
conforming packet3
nonconforming packet5
conforming packet5
nonconforming packet6
conforming packet6
nonconforming packet8
conforming packet8
conforming packet11
nonconforming packet12
conforming packet12
nonconforming packet13
conforming packet13
nonconforming packet15
conforming packet15
conforming packet19
```