Experiment N0: 03

Name of Experiments: *TCP and Router Queues.*

Objectives:

1. Create a simple dumbbell topology, two client Node1 and Node2 on the left side of the dumbbell and server nodes Node3 and Node4 on the right side of the dumbbell. Let Node5 and Node6 form the bridge of the dumbbell. Use point to point links.
2. Install a TCP socket instance on Node1 that will connect to Node3.
3. Install a UDP socket instance on Node2 that will connect to Node4.
4. Start the TCP application at time 1s.
5. Start the UDP application at time 20s at rate Rate1 such that it clogs half the dumbbell bridge's link capacity.
6. Increase the UDP application's rate at time 30s to rate Rate2 such that it clogs the whole of the dumbbell bridge's capacity.
7. Use the ns-3 tracing mechanism to record changes in congestion window size of the TCP instance over time. Use gnuplot/matplotlib to visualize plots of cwnd vs time.
8. Mark points of fast recovery and slow start in the graphs.
9. Perform the above experiment for TCP variants Tahoe, Reno and New Reno, all of which are available with ns-3.

Source Code:

```
/* -*- Mode:C++; c-file-style:"gnu"; indent-tabs-mode:nil; -*- */
 /*
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USA
  *
  * Authors: Pasquale Imputato <p.imputato@gmail.com>
  *          Stefano Avallone <stefano.avallone@unina.it>
  */
```

```
 // This example serves as a benchmark for all the queue discs (with BQL
enabled or not)
 //
 // Network topology
 //
 //                192.168.1.0                              192.168.2.0
 // n1 ---------------------------------- n2
---------------------------------- n3
 //   point-to-point (access link)               point-to-point (bottleneck
link)
 //   100 Mbps, 0.1 ms                           bandwidth [10 Mbps], delay
[5 ms]
 //   qdiscs PfifoFast with capacity             qdiscs queueDiscType in
{PfifoFast, ARED, CoDel, FqCoDel, PIE} [PfifoFast]
 //   of 1000 packets                            with capacity of
queueDiscSize packets [1000]
 //   netdevices queues with size of 100 packets  netdevices queues with
size of netdevicesQueueSize packets [100]
 //   without BQL                                bql BQL [false]
 //   *** fixed configuration ***
 //
 // Two TCP flows are generated: one from n1 to n3 and the other from n3 to
n1.
 // Additionally, n1 pings n3, so that the RTT can be measured.
 //
 // The output will consist of a number of ping Rtt such as:
 //
 //    /NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=111 ms
 //    /NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=111 ms
 //    /NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=110 ms
 //    /NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=111 ms
 //    /NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=111 ms
 //    /NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=112 ms
 //    /NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=111 ms
 //
 // The files output will consist of a trace file with bytes in queue and of
a trace file for limits
 // (when BQL is enabled) both for bottleneck NetDevice on n2, two files
with upload and download
 // goodput for flows configuration and a file with flow monitor stats.
 //
 // If you use an AQM as queue disc on the bottleneck netdevices, you can
observe that the ping Rtt
 // decrease. A further decrease can be observed when you enable BQL.

 #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/internet-apps-module.h"
 #include "ns3/traffic-control-module.h"
```

```
 #include "ns3/flow-monitor-module.h"

 using namespace ns3;

 NS_LOG_COMPONENT_DEFINE ("BenchmarkQueueDiscs");

 void
 LimitsTrace (Ptr<OutputStreamWrapper> stream, uint32_t oldVal, uint32_t
newVal)
 {
   *stream->GetStream () << Simulator::Now ().GetSeconds () << " " << newVal
<< std::endl;
 }

 void
 BytesInQueueTrace (Ptr<OutputStreamWrapper> stream, uint32_t oldVal,
uint32_t newVal)
 {
   *stream->GetStream () << Simulator::Now ().GetSeconds () << " " << newVal
<< std::endl;
 }

 static void
 GoodputSampling (std::string fileName, ApplicationContainer app,
Ptr<OutputStreamWrapper> stream, float period)
 {
   Simulator::Schedule (Seconds (period), &GoodputSampling, fileName, app,
stream, period);
   double goodput;
   uint64_t totalPackets = DynamicCast<PacketSink> (app.Get (0))->GetTotalRx
();
   goodput = totalPackets * 8 / (Simulator::Now ().GetSeconds () * 1024); //
Kbit/s
   *stream->GetStream () << Simulator::Now ().GetSeconds () << " " <<
goodput << std::endl;
 }

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

 int main (int argc, char *argv[])
 {
   std::string bandwidth = "10Mbps";
   std::string delay = "5ms";
   std::string queueDiscType = "PfifoFast";
   uint32_t queueDiscSize = 1000;
   uint32_t netdevicesQueueSize = 50;
   bool bql = false;
```

```
   std::string flowsDatarate = "20Mbps";
   uint32_t flowsPacketsSize = 1000;

   float startTime = 0.1f; // in s
   float simDuration = 60;
   float samplingPeriod = 1;

   CommandLine cmd (__FILE__);
   cmd.AddValue ("bandwidth", "Bottleneck bandwidth", bandwidth);
   cmd.AddValue ("delay", "Bottleneck delay", delay);
   cmd.AddValue ("queueDiscType", "Bottleneck queue disc type in {PfifoFast,
ARED, CoDel, FqCoDel, PIE, prio}", queueDiscType);
   cmd.AddValue ("queueDiscSize", "Bottleneck queue disc size in packets",
queueDiscSize);
   cmd.AddValue ("netdevicesQueueSize", "Bottleneck netdevices queue size in
packets", netdevicesQueueSize);
   cmd.AddValue ("bql", "Enable byte queue limits on bottleneck netdevices",
bql);
   cmd.AddValue ("flowsDatarate", "Upload and download flows datarate",
flowsDatarate);
   cmd.AddValue ("flowsPacketsSize", "Upload and download flows packets
sizes", flowsPacketsSize);
   cmd.AddValue ("startTime", "Simulation start time", startTime);
   cmd.AddValue ("simDuration", "Simulation duration in seconds",
simDuration);
   cmd.AddValue ("samplingPeriod", "Goodput sampling period in seconds",
samplingPeriod);
   cmd.Parse (argc, argv);

   float stopTime = startTime + simDuration;

   // Create nodes
   NodeContainer n1, n2, n3;
   n1.Create (1);
   n2.Create (1);
   n3.Create (1);

   // Create and configure access link and bottleneck link
   PointToPointHelper accessLink;
   accessLink.SetDeviceAttribute ("DataRate", StringValue ("100Mbps"));
   accessLink.SetChannelAttribute ("Delay", StringValue ("0.1ms"));
   accessLink.SetQueue ("ns3::DropTailQueue", "MaxSize", StringValue
("100p"));

   PointToPointHelper bottleneckLink;
   bottleneckLink.SetDeviceAttribute ("DataRate", StringValue (bandwidth));
   bottleneckLink.SetChannelAttribute ("Delay", StringValue (delay));
   bottleneckLink.SetQueue ("ns3::DropTailQueue", "MaxSize", StringValue
(std::to_string (netdevicesQueueSize) + "p"));
```

```
   InternetStackHelper stack;
   stack.InstallAll ();

   // Access link traffic control configuration
   TrafficControlHelper tchPfifoFastAccess;
   tchPfifoFastAccess.SetRootQueueDisc ("ns3::PfifoFastQueueDisc",
"MaxSize", StringValue ("1000p"));

   // Bottleneck link traffic control configuration
   TrafficControlHelper tchBottleneck;

   if (queueDiscType.compare ("PfifoFast") == 0)
     {
       tchBottleneck.SetRootQueueDisc ("ns3::PfifoFastQueueDisc", "MaxSize",
                                       QueueSizeValue (QueueSize
(QueueSizeUnit::PACKETS, queueDiscSize)));
     }
   else if (queueDiscType.compare ("ARED") == 0)
     {
       tchBottleneck.SetRootQueueDisc ("ns3::RedQueueDisc");
       Config::SetDefault ("ns3::RedQueueDisc::ARED", BooleanValue (true));
       Config::SetDefault ("ns3::RedQueueDisc::MaxSize",
                           QueueSizeValue (QueueSize
(QueueSizeUnit::PACKETS, queueDiscSize)));
     }
   else if (queueDiscType.compare ("CoDel") == 0)
     {
       tchBottleneck.SetRootQueueDisc ("ns3::CoDelQueueDisc");
       Config::SetDefault ("ns3::CoDelQueueDisc::MaxSize",
                           QueueSizeValue (QueueSize
(QueueSizeUnit::PACKETS, queueDiscSize)));
     }
   else if (queueDiscType.compare ("FqCoDel") == 0)
     {
       tchBottleneck.SetRootQueueDisc ("ns3::FqCoDelQueueDisc");
       Config::SetDefault ("ns3::FqCoDelQueueDisc::MaxSize",
                           QueueSizeValue (QueueSize
(QueueSizeUnit::PACKETS, queueDiscSize)));
     }
   else if (queueDiscType.compare ("PIE") == 0)
     {
       tchBottleneck.SetRootQueueDisc ("ns3::PieQueueDisc");
       Config::SetDefault ("ns3::PieQueueDisc::MaxSize",
                           QueueSizeValue (QueueSize
(QueueSizeUnit::PACKETS, queueDiscSize)));
     }
   else if (queueDiscType.compare ("prio") == 0)
     {
       uint16_t handle = tchBottleneck.SetRootQueueDisc
("ns3::PrioQueueDisc", "Priomap",
                                                       StringValue ("0 1 0
1 0 1 0 1 0 1 0 1 0 1 0 1"));
```

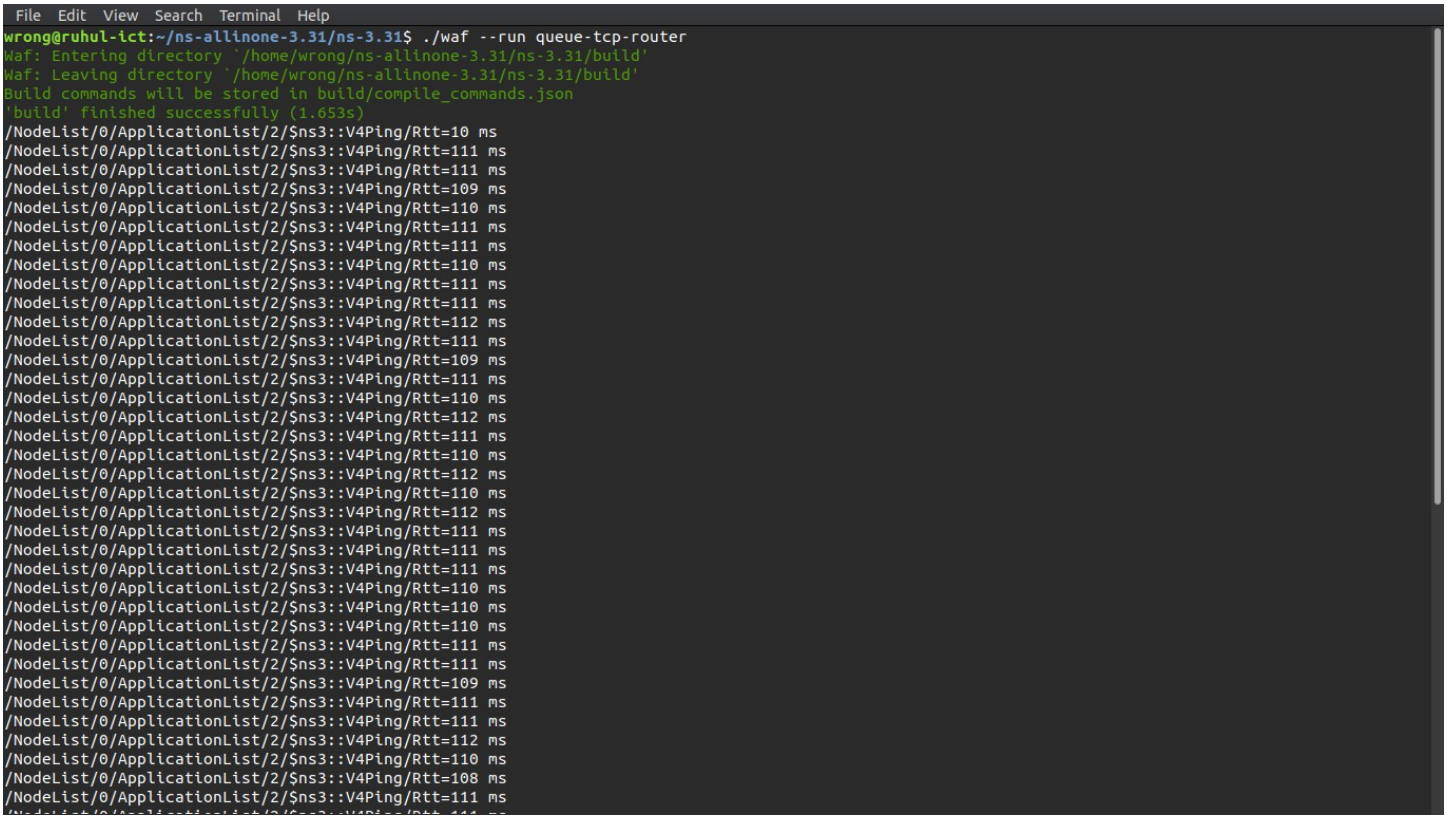
```
      TrafficControlHelper::ClassIdList cid =
tchBottleneck.AddQueueDiscClasses (handle, 2, "ns3::QueueDiscClass");
      tchBottleneck.AddChildQueueDisc (handle, cid[0],
"ns3::FifoQueueDisc");
      tchBottleneck.AddChildQueueDisc (handle, cid[1],
"ns3::RedQueueDisc");
    }
  else
    {
      NS_ABORT_MSG ("--queueDiscType not valid");
    }

  if (bql)
    {
      tchBottleneck.SetQueueLimits ("ns3::DynamicQueueLimits");
    }

  NetDeviceContainer devicesAccessLink = accessLink.Install (n1.Get (0),
n2.Get (0));
  tchPfifoFastAccess.Install (devicesAccessLink);
  Ipv4AddressHelper address;
  address.SetBase ("192.168.0.0", "255.255.255.0");
  address.NewNetwork ();
  Ipv4InterfaceContainer interfacesAccess = address.Assign
(devicesAccessLink);

  NetDeviceContainer devicesBottleneckLink = bottleneckLink.Install (n2.Get
(0), n3.Get (0));
  QueueDiscContainer qdiscs;
  qdiscs = tchBottleneck.Install (devicesBottleneckLink);

  address.NewNetwork ();
  Ipv4InterfaceContainer interfacesBottleneck = address.Assign
(devicesBottleneckLink);

  Ptr<NetDeviceQueueInterface> interface = devicesBottleneckLink.Get (0)-
>GetObject<NetDeviceQueueInterface> ();
  Ptr<NetDeviceQueue> queueInterface = interface->GetTxQueue (0);
  Ptr<DynamicQueueLimits> queueLimits = StaticCast<DynamicQueueLimits>
(queueInterface->GetQueueLimits ());

  AsciiTraceHelper ascii;
  if (bql)
    {
      queueDiscType = queueDiscType + "-bql";
      Ptr<OutputStreamWrapper> streamLimits = ascii.CreateFileStream
(queueDiscType + "-limits.txt");
      queueLimits->TraceConnectWithoutContext ("Limit",MakeBoundCallback
(&LimitsTrace, streamLimits));
    }
```

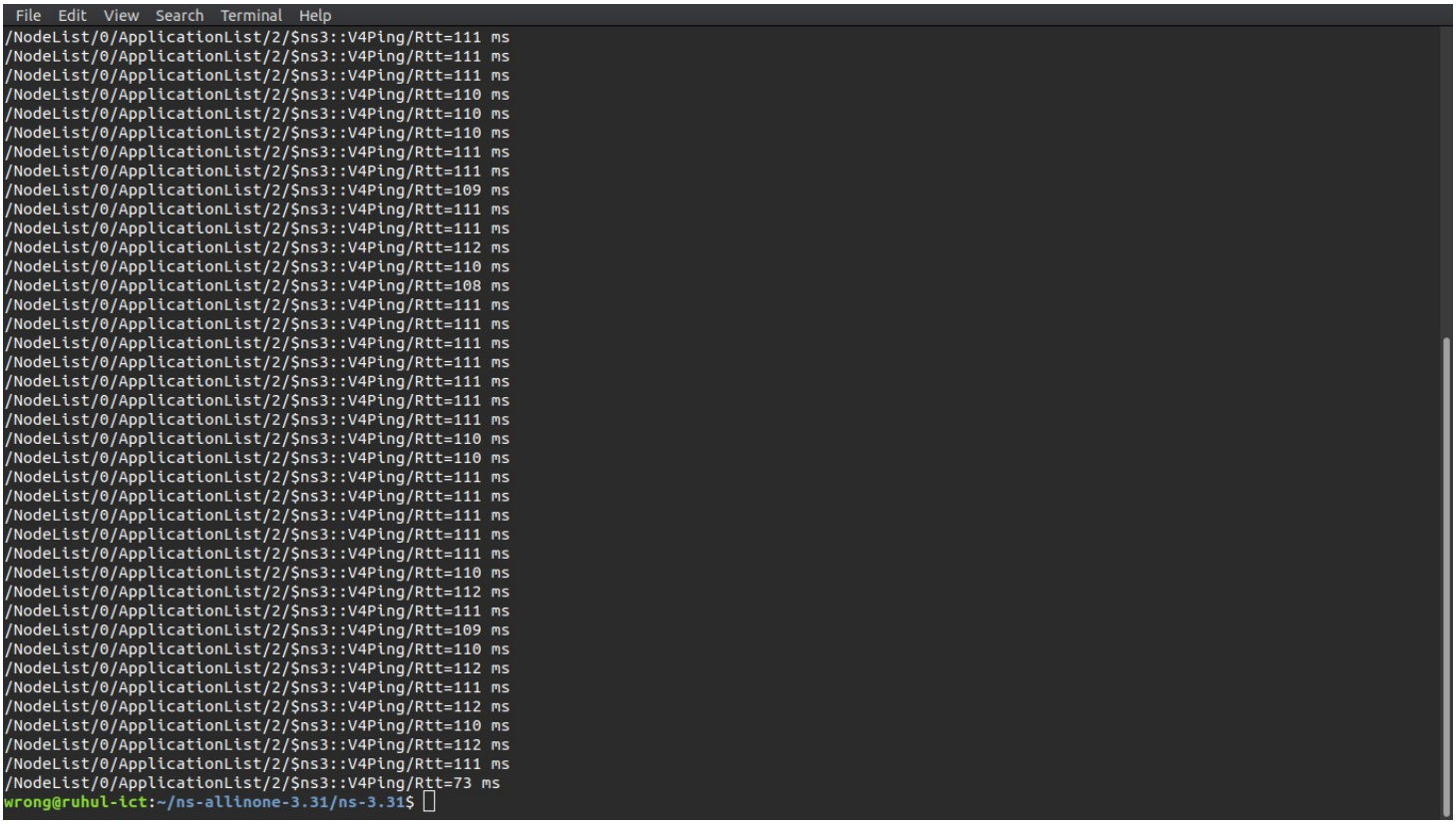
```
   Ptr<Queue<Packet> > queue = StaticCast<PointToPointNetDevice>
(devicesBottleneckLink.Get (0))->GetQueue ();
   Ptr<OutputStreamWrapper> streamBytesInQueue = ascii.CreateFileStream
(queueDiscType + "-bytesInQueue.txt");
   queue->TraceConnectWithoutContext ("BytesInQueue",MakeBoundCallback
(&BytesInQueueTrace, streamBytesInQueue));

   Ipv4InterfaceContainer n1Interface;
   n1Interface.Add (interfacesAccess.Get (0));

   Ipv4InterfaceContainer n3Interface;
   n3Interface.Add (interfacesBottleneck.Get (1));

   Ipv4GlobalRoutingHelper::PopulateRoutingTables ();

   Config::SetDefault ("ns3::TcpSocket::SegmentSize", UintegerValue
(flowsPacketsSize));

   // Flows configuration
   // Bidirectional TCP streams with ping like flent tcp_bidirectional test.
   uint16_t port = 7;
   ApplicationContainer uploadApp, downloadApp, sourceApps;
   // Configure and install upload flow
   Address addUp (InetSocketAddress (Ipv4Address::GetAny (), port));
   PacketSinkHelper sinkHelperUp ("ns3::TcpSocketFactory", addUp);
   sinkHelperUp.SetAttribute ("Protocol", TypeIdValue
(TcpSocketFactory::GetTypeId ()));
   uploadApp.Add (sinkHelperUp.Install (n3));

   InetSocketAddress socketAddressUp = InetSocketAddress
(n3Interface.GetAddress (0), port);
   OnOffHelper onOffHelperUp ("ns3::TcpSocketFactory", Address ());
   onOffHelperUp.SetAttribute ("Remote", AddressValue (socketAddressUp));
   onOffHelperUp.SetAttribute ("OnTime", StringValue
("ns3::ConstantRandomVariable[Constant=1]"));
   onOffHelperUp.SetAttribute ("OffTime", StringValue
("ns3::ConstantRandomVariable[Constant=0]"));
   onOffHelperUp.SetAttribute ("PacketSize", UintegerValue
(flowsPacketsSize));
   onOffHelperUp.SetAttribute ("DataRate", StringValue (flowsDatarate));
   sourceApps.Add (onOffHelperUp.Install (n1));

   port = 8;
   // Configure and install download flow
   Address addDown (InetSocketAddress (Ipv4Address::GetAny (), port));
   PacketSinkHelper sinkHelperDown ("ns3::TcpSocketFactory", addDown);
   sinkHelperDown.SetAttribute ("Protocol", TypeIdValue
(TcpSocketFactory::GetTypeId ()));
   downloadApp.Add (sinkHelperDown.Install (n1));
```

```
   InetSocketAddress socketAddressDown = InetSocketAddress
(n1Interface.GetAddress (0), port);
   OnOffHelper onOffHelperDown ("ns3::TcpSocketFactory", Address ());
   onOffHelperDown.SetAttribute ("Remote", AddressValue
(socketAddressDown));
   onOffHelperDown.SetAttribute ("OnTime", StringValue
("ns3::ConstantRandomVariable[Constant=1]"));
   onOffHelperDown.SetAttribute ("OffTime", StringValue
("ns3::ConstantRandomVariable[Constant=0]"));
   onOffHelperDown.SetAttribute ("PacketSize", UintegerValue
(flowsPacketsSize));
   onOffHelperDown.SetAttribute ("DataRate", StringValue (flowsDatarate));
   sourceApps.Add (onOffHelperDown.Install (n3));

   // Configure and install ping
   V4PingHelper ping = V4PingHelper (n3Interface.GetAddress (0));
   ping.Install (n1);

   Config::Connect ("/NodeList/*/ApplicationList/*/$ns3::V4Ping/Rtt",
MakeCallback (&PingRtt));

   uploadApp.Start (Seconds (0));
   uploadApp.Stop (Seconds (stopTime));
   downloadApp.Start (Seconds (0));
   downloadApp.Stop (Seconds (stopTime));

   sourceApps.Start (Seconds (0 + 0.1));
   sourceApps.Stop (Seconds (stopTime - 0.1));

   Ptr<OutputStreamWrapper> uploadGoodputStream = ascii.CreateFileStream
(queueDiscType + "-upGoodput.txt");
   Simulator::Schedule (Seconds (samplingPeriod), &GoodputSampling,
queueDiscType + "-upGoodput.txt", uploadApp,
                        uploadGoodputStream, samplingPeriod);

   Ptr<OutputStreamWrapper> downloadGoodputStream = ascii.CreateFileStream
(queueDiscType + "-downGoodput.txt");
   Simulator::Schedule (Seconds (samplingPeriod), &GoodputSampling,
queueDiscType + "-downGoodput.txt", downloadApp,
                        downloadGoodputStream, samplingPeriod);

   // Flow monitor
   Ptr<FlowMonitor> flowMonitor;
   FlowMonitorHelper flowHelper;
   flowMonitor = flowHelper.InstallAll();

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

   flowMonitor->SerializeToXmlFile(queueDiscType + "-flowMonitor.xml", true,
true);
```

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

Output:





Conclusion:

TCP and router is related to connecting the network packages simultaneously. The specific characteristics of TCP and Router queues include the manner in which they avoid routing loops, the manner in which they select preferred routes, using information. This has the added benefit of preventing issues with TCP and router queues loops.