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Lab Report

Department of Information and Communication Technology

Report No: 03
Report Name: TCP and router queues.

Course Title: Wireless and Mobile Communication Lab.
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Objective:

NS-3 provides a couple of classic queue models and the ability to trace certain queue operations such as enqueuing, dequeuing, and dropping. These may be added to certain NetDevice objects that take a Ptr<Queue> pointer.We have to Install a TCP socket instance on Node2 that will connect to Node3 and also Install a TCP socket instance on Node2 that will connect to Node4. Measure packet loss and cwnd size, and plot graphs throughput/time, cwnd/time and packet loss/time for each of the flows.

Source Code:

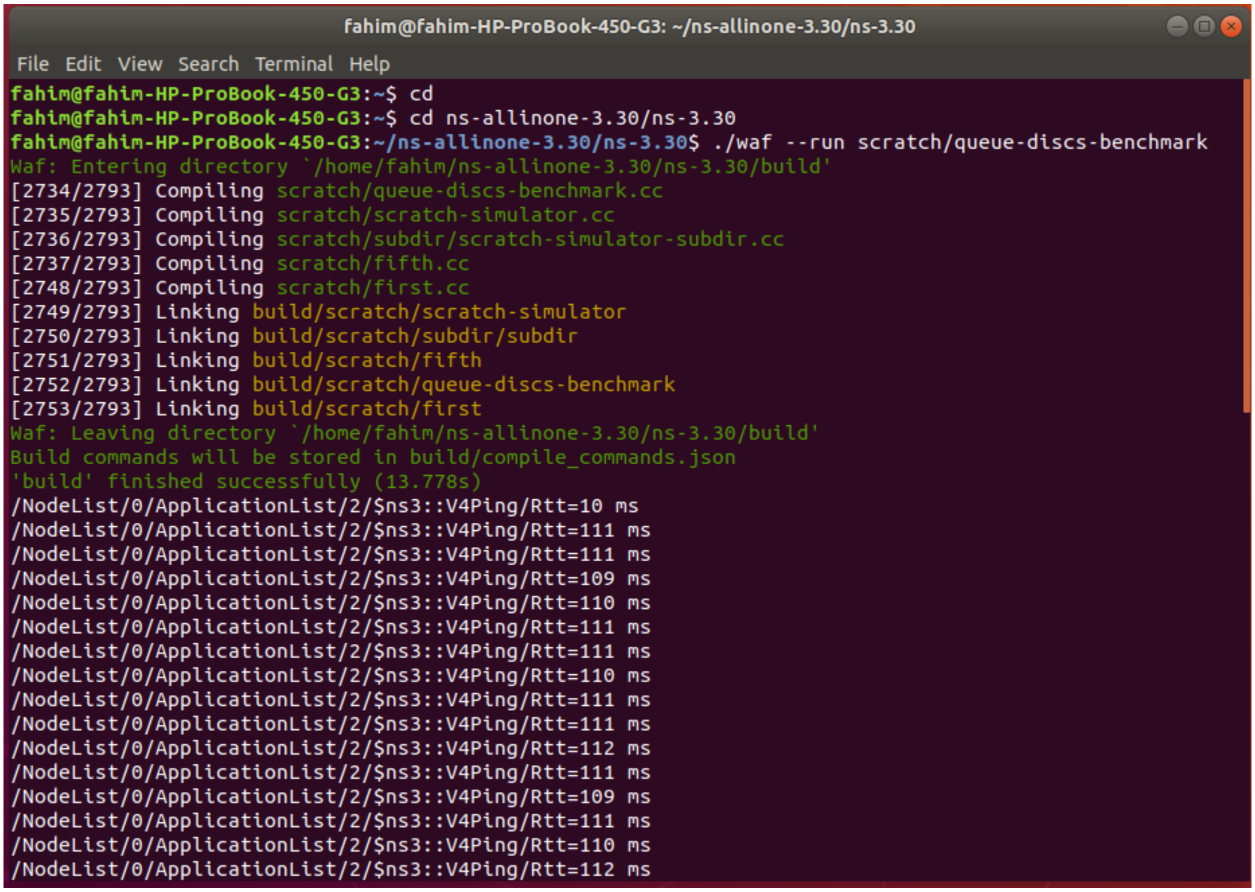
```
//            192.168.1.0                         192.168.2.0

// 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;
  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"));

  PointToPointHelper bottleneckLink;
  bottleneckLink.SetDeviceAttribute ("DataRate", StringValue (bandwidth));
  bottleneckLink.SetChannelAttribute ("Delay", StringValue (delay));

  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");
    }

  Config::SetDefault ("ns3::QueueBase::MaxSize", StringValue ("100p"));

  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);

  Config::SetDefault ("ns3::QueueBase::MaxSize", StringValue (std::to_string (netdevicesQueueSize) + "p"));

  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:


fahim@fahim-HP-ProBook-450-G3: ~/ns-allinone-3.30/ns-3.30
File Edit View Search Terminal Help

```
fahim@fahim-HP-ProBook-450-G3:~$ cd
fahim@fahim-HP-ProBook-450-G3:~$ cd ns-allinone-3.30/ns-3.30
fahim@fahim-HP-ProBook-450-G3:~/ns-allinone-3.30/ns-3.30$ ./waf --run scratch/queue-discs-benchmark
Waf: Entering directory `/home/fahim/ns-allinone-3.30/ns-3.30/build'
[2734/2793] Compiling scratch/queue-discs-benchmark.cc
[2735/2793] Compiling scratch/scratch-simulator.cc
[2736/2793] Compiling scratch/subdir/scratch-simulator-subdir.cc
[2737/2793] Compiling scratch/fifth.cc
[2748/2793] Compiling scratch/first.cc
[2749/2793] Linking build/scratch/scratch-simulator
[2750/2793] Linking build/scratch/subdir/subdir
[2751/2793] Linking build/scratch/fifth
[2752/2793] Linking build/scratch/queue-discs-benchmark
[2753/2793] Linking build/scratch/first
Waf: Leaving directory `/home/fahim/ns-allinone-3.30/ns-3.30/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (13.778s)
/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=10 ms
/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=111 ms
/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=111 ms
/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=109 ms
/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=110 ms
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/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=111 ms
/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=110 ms
/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=112 ms
```

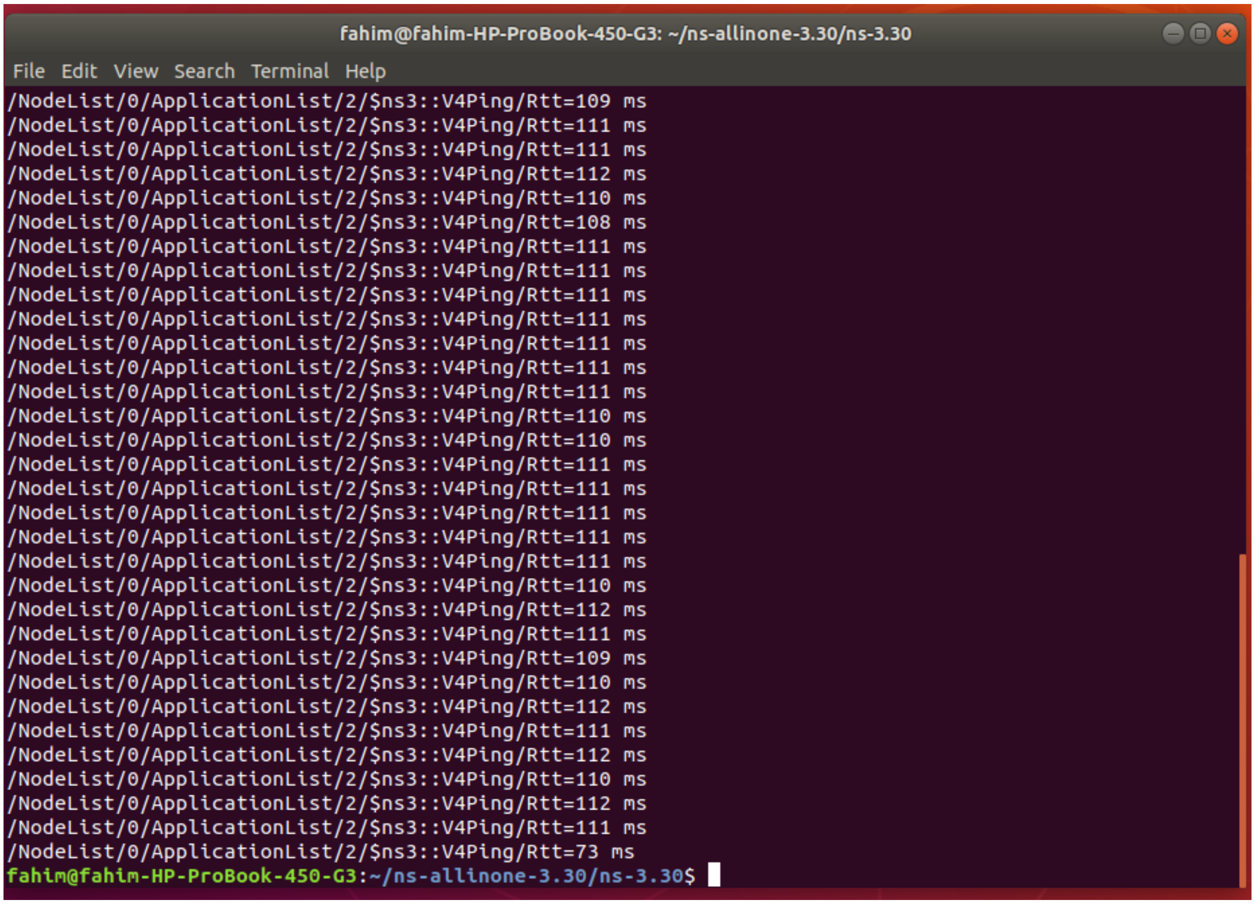
fahim@fahim-HP-ProBook-450-G3: ~/ns-allinone-3.30/ns-3.30
File Edit View Search Terminal Help

```
/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=109 ms
/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=111 ms
/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=111 ms
/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=112 ms
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/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=110 ms
/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=112 ms
/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=111 ms
/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=73 ms
fahim@fahim-HP-ProBook-450-G3:~/ns-allinone-3.30/ns-3.30$
```

Conclusion:

TCP has mechanisms for limiting the amount of data that is sent over the network, and each connection has a queue on which the data is held while waiting to be transmitted. The data is not removed from the queue until the receiver has acknowledged the reception of the data. If no acknowledgment is received within a specific time, the data is retransmitted.This has the added benefit of preventing issues with TCP and router queues loops.