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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.

Course Code: ICT-4201

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Experiment N0: 03

Experiment Name : TCP and Router Queues

Objective :

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. Add drop tail queues of size QueueSize5 and QueueSize6 to Node5 and Node6, respectively.
3. Install a TCP socket instance on Node1 that will connect to Node3.
4. Install a TCP socket instance on Node2 that will connect to Node3.
5. Install a TCP socket instance on Node2 that will connect to Node4.
6. Start Node1--Node3 flow at time 1s, then measure it's throughput. How long does it take to fill link's entire capacity?
7. Start Node2--Node3 and Node2--Node4 flows at time 15s, measure their throughput.
8. Measure packet loss and cwnd size, and plot graphs throughput/time, cwnd/time and packet loss/time for each of the flows.
9. Plot graph throughput/cwnd and packet loss/cwnd for the first flow.

Source Code:

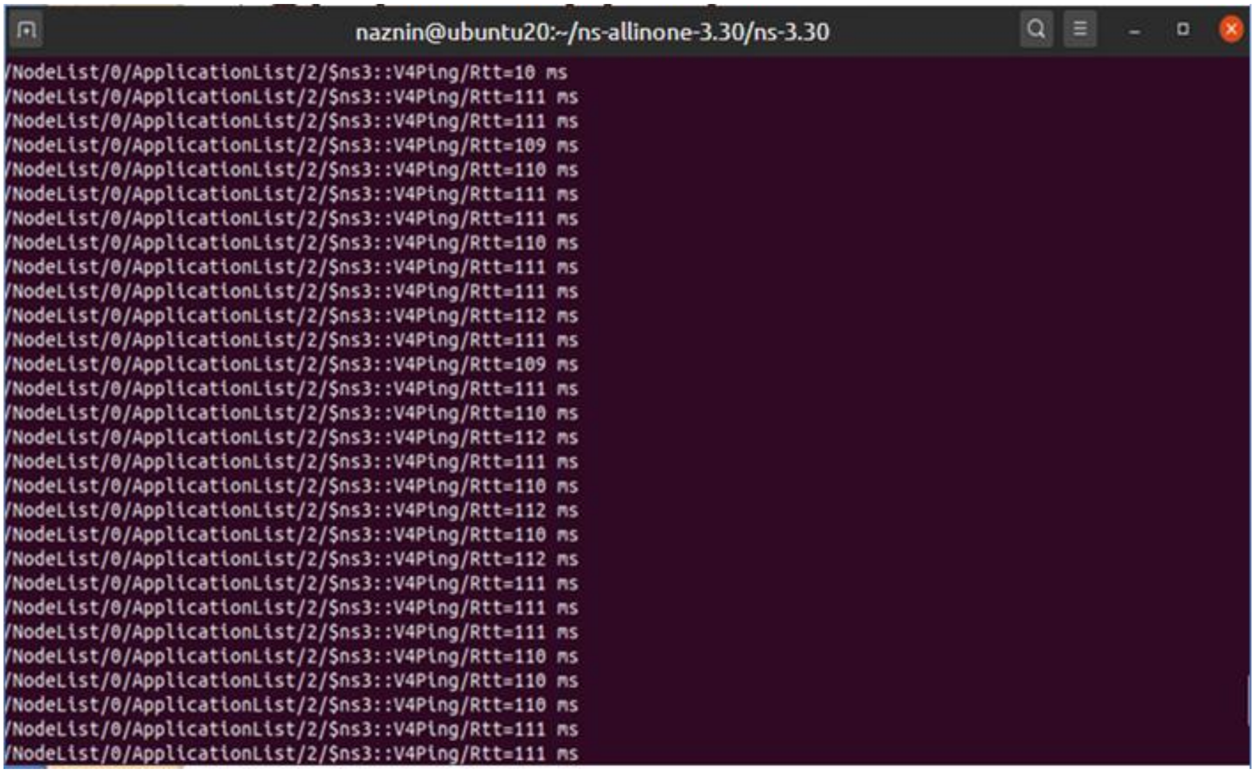
```
// This example serves as a benchmark for all the queue discs (with BQL enabled or not)

//

// 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;
  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:



```
/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=111 ms
```

Conclusion:

Ns-3 tracing mechanism are used to record changes in congestion window size of the TCP instance over time. & used gnuplot/matplotlib to visualise plots of cwnd vs time. TCP and router is related to connecting the network packages simultaneously.From this lab, we learned about Queues, packet drops and their effect on congestion window size.For this , we first create a simple dumbell Topology of six node using point to point links. Then we install the TCP socket among node1-node3,node2-node3 and node2-node4. After that we measure the throughput of node1—node3 flow at time 1s and node2—node3 flows at time 15s. At last we plot the graphical throughput.