

## **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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\*/

```
// 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", TypedValue (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", TypedValue (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);

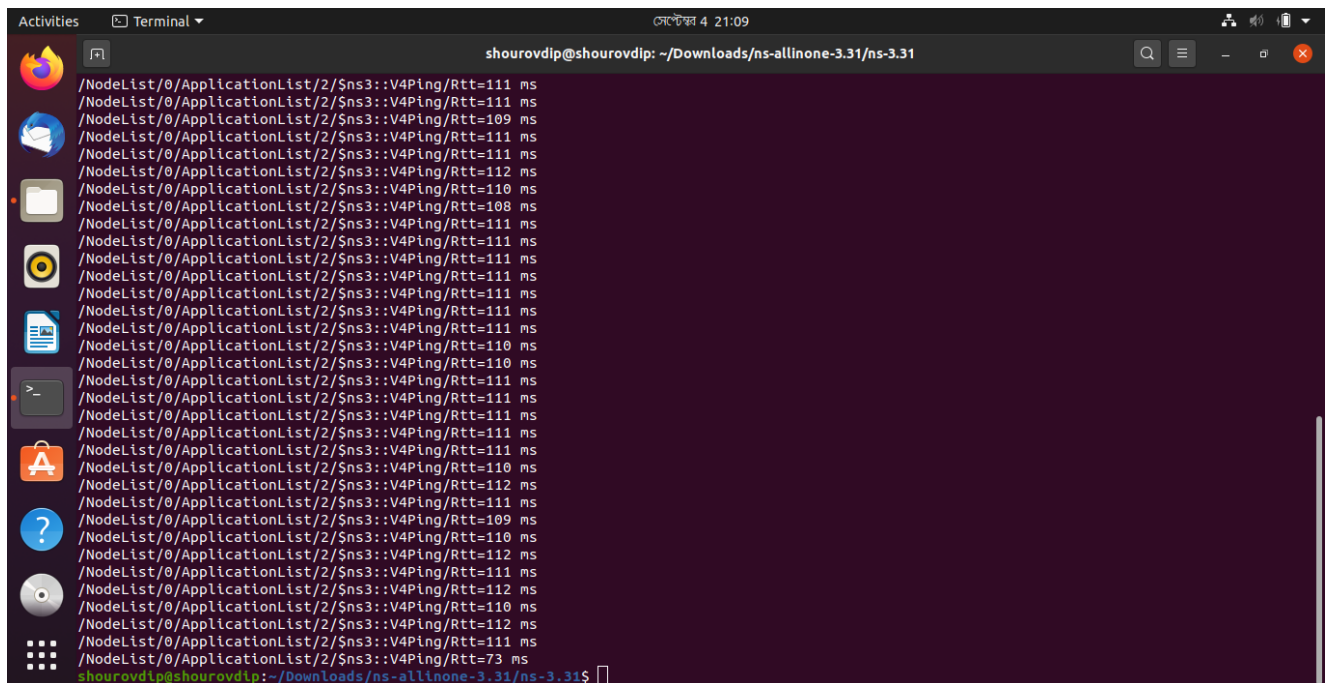
Simulator::Destroy ();
return 0;
}

```

## Output:

```
shourovdip@shourovdip: ~/Downloads/ns-allinone-3.31/ns-3.31
shourovdip@shourovdip:~/Downloads$ cd Downloads/
shourovdip@shourovdip:~/Downloads$ cd ns-allinone-3.31/
shourovdip@shourovdip:~/Downloads/ns-allinone-3.31$ cd ns-3.31/
shourovdip@shourovdip:~/Downloads/ns-allinone-3.31/ns-3.31$ ./waf --run lab
Waf: Entering directory '/home/shourovdip/Downloads/ns-allinone-3.31/ns-3.31/build'
[2685/2739] Compiling scratch/lab.cc
[2686/2739] Compiling scratch/scratch-simulator.cc
[2687/2739] Compiling scratch/fourth.cc
[2688/2739] Compiling scratch/third.cc
[2697/2739] Linking build/scratch/lab
[2698/2739] Linking build/scratch/scratch-simulator
[2699/2739] Linking build/scratch/fourth
[2700/2739] Linking build/scratch/third
Waf: Leaving directory '/home/shourovdip/Downloads/ns-allinone-3.31/ns-3.31/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (1m25.608s)
/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
```

```
shourovdip@shourovdip: ~/Downloads/ns-allinone-3.31/ns-3.31
/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=112 ms
/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=110 ms
/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=112 ms
/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=111 ms
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/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=112 ms
/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=111 ms
/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=111 ms
/NodeList/0/ApplicationList/2/$ns3::V4Ping/Rtt=109 ms
```

A screenshot of a Linux terminal window. The title bar shows 'Activities', 'Terminal', and the date 'শেহতাই ৪ ২১:০৯'. The terminal window has a dark purple background. The prompt is 'shourovdip@shourovdip: ~/Downloads/ns-allinone-3.31/ns-3.31'. The output consists of 25 lines of text, each representing a ping result: '/NodeList/0/ApplicationList/2/\$ns3::V4Ping/Rtt=111 ms'. The first line is followed by 24 identical lines. The last line is followed by a prompt 'shourovdip@shourovdip:~/Downloads/ns-allinone-3.31/ns-3.31\$'. On the left side of the terminal window, there is a vertical sidebar with various application icons: a red and yellow flame (Firefox), a blue and white envelope (Thunderbird), a yellow and black camera (GIMP), a blue and white document (LibreOffice Writer), a green and white terminal icon, an orange and white application icon, a blue and white question mark, and a grey and white CD-ROM icon. The top of the terminal window has a search bar and a menu icon.

## **Conclusion:**

In this experiment, we learnt about the Queues and packet drops. We could also learn about the effect of the packet drops on congestion window size. We took the help of ns-3 simulator in order to implement the experiment successfully.