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Code Explanation:

```
int
main (int argc, char *argv[])
{
    bool verbose = true;
    uint32_t nWifi = 3;
    bool tracing = true;
    uint32_t nRx = 1;
    uint32_t SentPackets = 0;
    uint32_t ReceivedPackets = 0;
    uint32_t LostPackets = 0;
    uint32_t datarate = 6000000;
    uint32_t pksize = 512;

    CommandLine cmd (__FILE__);
    cmd.AddValue ("nWifi", "Number of wifi STA devices", nWifi);
    cmd.AddValue ("verbose", "Tell echo applications to log if true", verbose);
    cmd.AddValue ("tracing", "Enable pcap tracing", tracing);
    cmd.AddValue ("datarate", "datarate", datarate);
    cmd.AddValue ("packetsize", "packetsize", pksize);

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

Set up important parameters for later calculation of thruput, per-node thruput, and also node configuration.

```
NodeContainer wifiTxNodes;
wifiTxNodes.Create (nWifi);
NodeContainer wifiRxNodes;
wifiRxNodes.Create(nRx);

YansWifiChannelHelper channel = YansWifiChannelHelper::Default ();
YansWifiPhyHelper phy = YansWifiPhyHelper::Default ();
phy.SetChannel (channel.Create ());

WifiHelper wifi;
wifi.SetStandard (WIFI_STANDARD_80211a);

//Config::SetDefault("ns3::WifiMac::BE_Max_Backoffs", UintegerValue(1023));
//Config::SetDefault("ns3::WifiMac::BE_Min_Backoff_Slots", UintegerValue(1));

WifiMacHelper mac;
mac.SetType("ns3::AdhocWifiMac");
```

Create nodes and set up a channel, physical parameters to 802.11a, and mac parameters(ad hoc Wi-Fi), which is corresponding to 802.11 cs/ma Wi-Fi.

```
NetDeviceContainer TxDevices;  
TxDevices = wifi.Install (phy, mac, wifiTxNodes);  
  
NetDeviceContainer RxDevices;  
RxDevices = wifi.Install (phy, mac, wifiRxNodes);
```

Install those parameters to transmission devices and receive devices.

```
mobility.SetPositionAllocator ("ns3::UniformDiscPositionAllocator",  
                               "rho", DoubleValue(8.0),  
                               "X", DoubleValue(0.0),  
                               "Y", DoubleValue(0.0));  
  
mobility.SetMobilityModel ("ns3::ConstantPositionMobilityModel");  
  
mobility.Install (wifiTxNodes);  
mobility.Install (wifiRxNodes);  
  
NS_LOG_INFO("Setting up IPv4 stack.");  
  
InternetStackHelper stack;  
stack.Install (wifiTxNodes);  
stack.Install (wifiRxNodes);
```

Set up a disk-bound for node allocation with a radius of 8m and the origin is at point (0,0) Then install it to the nodes we previously created. And install Internet stacks for later transmission preparations.

```
NS_LOG_INFO("Assigning IPv4 address.");  
Ipv4AddressHelper address;  
  
address.SetBase ("192.168.0.0", "255.255.255.0");  
  
Ipv4InterfaceContainer wifiInterfaces;  
wifiInterfaces = address.Assign (TxDevices);  
Ipv4InterfaceContainer RxInterfaces;  
RxInterfaces = address.Assign (RxDevices);
```

Assign nodes with a network of 192.168.0.0 and netmask ok 255.255.255.0.

```

NS_LOG_INFO("Setting up UDP receive sink.");
//create a packet sink on the receiver
uint16_t port = 9;
Address sinkLocalAddress(InetSocketAddress(RxInterfaces.GetAddress (0),port));
//cout<< AddressValue(InetSocketAddress(RxInterfaces.GetAddress (0),port))<<endl;
PacketSinkHelper sinkHelper("ns3::UdpSocketFactory", sinkLocalAddress);
ApplicationContainer sinkApp = sinkHelper.Install(wifiRxNodes.Get(0));

sinkApp.Start(Seconds(1.0));
sinkApp.Stop(Seconds(10.0));

```

Set up a udp sink with a socket for the Rx node and start at time 1s which is earlier than the Tx nodes.

```

NS_LOG_INFO("Setting up onoff application.");
for(uint32_t i= 0; i< nWifi;i++){
    OnOffHelper clientHelper("ns3::UdpSocketFactory", wifiInterfaces.GetAddress(i));
    clientHelper.SetAttribute("Remote", AddressValue(InetSocketAddress(RxInterfaces.GetAddress (0),port)));
    clientHelper.SetAttribute("PacketSize", UintegerValue(pktsize));
    clientHelper.SetConstantRate(DataRate(datarate));
    ApplicationContainer clientApps = (clientHelper.Install(wifiTxNodes.Get(i)));
    clientApps.Start(Seconds(2.0));
    clientApps.Stop(Seconds(10.0));
}

```

Setting up transmission udp socket of Tx nodes and use on-off applications to send packets in corresponding CBR.

```

Ipv4GlobalRoutingHelper::PopulateRoutingTables ();
FlowMonitorHelper flowmon;
Ptr<FlowMonitor> monitor = flowmon.InstallAll();

Simulator::Stop (Seconds (10.0));
//Throughput and Delay using Tracemetrics
/*
AsciiTraceHelper ascii;
phy.EnableAsciiAll(ascii.CreateFileStream("phy.tr"));
*/

if (tracing == true)
{
    phy.EnablePcapAll ("third");
    //wifi.EnablePcap ("third", RxDevices.Get(0),true)
}

Simulator::Run ();

```

Set up flow monitor for thruput and per-node thruput calculations:

```
int j=0;
float avg = 0;
float TotalThroughput = 0;
Time Delay;

Ptr<Ipv4FlowClassifier> classifier = DynamicCast<Ipv4FlowClassifier> (flowmon.GetClassifier ());
std::map<FlowId, FlowMonitor::FlowStats> stats = monitor->GetFlowStats ();

for (std::map<FlowId, FlowMonitor::FlowStats>::const_iterator iter = stats.begin (); iter != stats.end (); ++iter)
{
    Ipv4FlowClassifier::FiveTuple t = classifier->FindFlow (iter->first);

    NS_LOG_UNCOND("Node:" <<j);
    NS_LOG_UNCOND("Tx Node Address" <<t.sourceAddress << "    Rx Address "<< t.destinationAddress);
    NS_LOG_UNCOND("Total Throughput =" << TotalThroughput<< "Mbps");
    NS_LOG_UNCOND("Throughput =" <<(iter->second.rxBytes * 8.0/(iter->second.timeLastRxPacket.GetSeconds()-iter->second.timeFirstTxPacket.GetSeconds())/1024)/1000<<"Mbps");
    SentPackets = SentPackets +(iter->second.txPackets);
    ReceivedPackets = ReceivedPackets + (iter->second.rxPackets);
    LostPackets = LostPackets + (iter->second.txPackets-iter->second.rxPackets);
    avg = avg + (iter->second.rxBytes * 8.0/(iter->second.timeLastRxPacket.GetSeconds()-iter->second.timeFirstTxPacket.GetSeconds())/1024)/1000;
    Delay = Delay + (iter->second.delaySum);
    j++;
}
TotalThroughput = avg;
avg = avg/j;

NS_LOG_UNCOND("-----"<<std::endl);
NS_LOG_UNCOND("Total sent packets =" << SentPackets);
NS_LOG_UNCOND("Total Received Packets =" << ReceivedPackets);
NS_LOG_UNCOND("Total Lost Packets =" << LostPackets);
NS_LOG_UNCOND("Packet Loss ratio =" << ((LostPackets*100)/SentPackets)<< "%");
NS_LOG_UNCOND("Packet delivery ratio =" << ((ReceivedPackets*100)/SentPackets)<< "%");
NS_LOG_UNCOND("Average Throughput =" << avg<< "Mbps");
NS_LOG_UNCOND("Total Throughput =" << TotalThroughput<< "Mbps");
Simulator::Destroy ();
return 0;
}
```

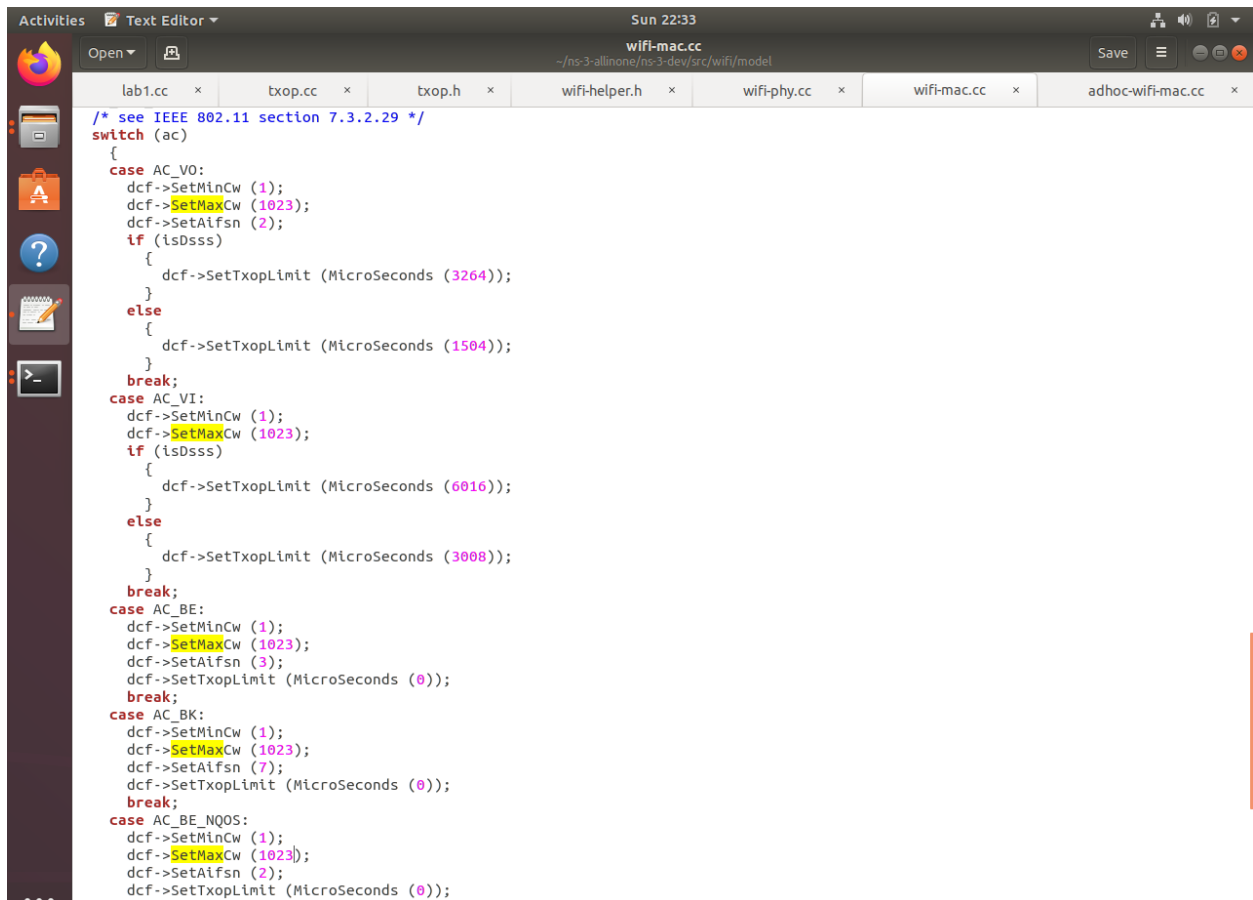
Set the parameters needed by using flow monitor and map to calculate total thruput and per-node thruput.

Evaluation of Case A E1:

First set the window size to fit Case A:

```
bool verbose = true;
uint32_t nWifi = 3;
bool tracing = true;
uint32_t nRx = 1;
uint32_t SentPackets = 0;
uint32_t ReceivedPackets = 0;
uint32_t LostPackets = 0;
uint32_t datarate = 6000000;
uint32_t pksize = 512;
```

Here is default parameters



```
/* see IEEE 802.11 section 7.3.2.29 */
switch (ac)
{
case AC_VO:
    dcf->SetMinCw (1);
    dcf->SetMaxCw (1023);
    dcf->SetAifsn (2);
    if (isDsss)
    {
        dcf->SetTxopLimit (MicroSeconds (3264));
    }
    else
    {
        dcf->SetTxopLimit (MicroSeconds (1504));
    }
    break;
case AC_VI:
    dcf->SetMinCw (1);
    dcf->SetMaxCw (1023);
    if (isDsss)
    {
        dcf->SetTxopLimit (MicroSeconds (6016));
    }
    else
    {
        dcf->SetTxopLimit (MicroSeconds (3008));
    }
    break;
case AC_BE:
    dcf->SetMinCw (1);
    dcf->SetMaxCw (1023);
    dcf->SetAifsn (3);
    dcf->SetTxopLimit (MicroSeconds (0));
    break;
case AC_BK:
    dcf->SetMinCw (1);
    dcf->SetMaxCw (1023);
    dcf->SetAifsn (7);
    dcf->SetTxopLimit (MicroSeconds (0));
    break;
case AC_BE_NQOS:
    dcf->SetMinCw (1);
    dcf->SetMaxCw (1023);
    dcf->SetAifsn (2);
    dcf->SetTxopLimit (MicroSeconds (0));
    break;
}
```

E1:

Run 3 times for each n and 10 n from 3 to 10:

N = 3:

```

ee597@ee597-VirtualBox:~/ns-3-allinone/ns-3-dev$ ./waf --run "lab1"
Waf: Entering directory `/home/ee597/ns-3-allinone/ns-3-dev/build'
Waf: Leaving directory `/home/ee597/ns-3-allinone/ns-3-dev/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (1.138s)
Node:0
Tx Node Address192.168.0.1      Rx Address 192.168.0.4
Total Throughput =0Mbps
Throughput =5.99178Mbps
Node:1
Tx Node Address192.168.0.2      Rx Address 192.168.0.4
Total Throughput =0Mbps
Throughput =0.439468Mbps
Node:2
Tx Node Address192.168.0.3      Rx Address 192.168.0.4
Total Throughput =0Mbps
Throughput =6.1373Mbps
-----
Total sent packets  =35154
Total Received Packets =23655
Total Lost Packets =11499
Packet Loss ratio =32%
Packet delivery ratio =67%
Average Throughput =4.18952Mbps
Total Throughput =12.5685Mbps

```

Thruput = 4.189Mbps

N = 4:

```

ee597@ee597-VirtualBox:~/ns-3-allinone/ns-3-dev$ ./waf --run "lab1 nWIFI=4"
Waf: Entering directory `/home/ee597/ns-3-allinone/ns-3-dev/build'
[2702/2749] Compiling scratch/lab1.cc
[2710/2749] Linking build/scratch/lab1
Waf: Leaving directory `/home/ee597/ns-3-allinone/ns-3-dev/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (4.122s)
Node:0
Tx Node Address192.168.0.1      Rx Address 192.168.0.5
Throughput =-0Mbps
Node:1
Tx Node Address192.168.0.2      Rx Address 192.168.0.5
Throughput =-0Mbps
Node:2
Tx Node Address192.168.0.3      Rx Address 192.168.0.5
Throughput =-0Mbps
Node:3
Tx Node Address192.168.0.4      Rx Address 192.168.0.5
Throughput =6.18023Mbps
-----
Total sent packets  =46872
Total Received Packets =11718
Total Lost Packets =35154
Packet Loss ratio =75%
Packet delivery ratio =25%
Average Throughput =1.54506Mbps
Total Throughput =6.18023Mbps

```

N=5:

```
ee597@ee597-VirtualBox:~/ns-3-allinone/ns-3-dev$ ./waf --run "lab1 nWifi==5"
Waf: Entering directory `/home/ee597/ns-3-allinone/ns-3-dev/build'
[2702/2749] Compiling scratch/lab1.cc
[2710/2749] Linking build/scratch/lab1
Waf: Leaving directory `/home/ee597/ns-3-allinone/ns-3-dev/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (4.160s)
Node:0
Tx Node Address192.168.0.1      Rx Address 192.168.0.6
Throughput =6.18023Mbps
Node:1
Tx Node Address192.168.0.2      Rx Address 192.168.0.6
Throughput =-0Mbps
Node:2
Tx Node Address192.168.0.3      Rx Address 192.168.0.6
Throughput =-0Mbps
Node:3
Tx Node Address192.168.0.4      Rx Address 192.168.0.6
Throughput =-0Mbps
Node:4
Tx Node Address192.168.0.5      Rx Address 192.168.0.6
Throughput =-0Mbps
-----
Total sent packets  =58590
Total Received Packets =11718
Total Lost Packets =46872
Packet Loss ratio =80%
Packet delivery ratio =20%
Average Throughput =1.23605Mbps
Total Throughput =6.18023Mbps
```

Thruput = 6.18023

N=6:

```
ee597@ee597-VirtualBox:~/ns-3-allinone/ns-3-dev$ ./waf --run "lab1 nWifi==6"
Waf: Entering directory `/home/ee597/ns-3-allinone/ns-3-dev/build'
[2702/2749] Compiling scratch/lab1.cc
[2710/2749] Linking build/scratch/lab1
Waf: Leaving directory `/home/ee597/ns-3-allinone/ns-3-dev/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (4.045s)
Node:0
Tx Node Address192.168.0.1      Rx Address 192.168.0.7
Throughput =1.26735Mbps
Node:1
Tx Node Address192.168.0.2      Rx Address 192.168.0.7
Throughput =0.438481Mbps
Node:2
Tx Node Address192.168.0.3      Rx Address 192.168.0.7
Throughput =-0Mbps
Node:3
Tx Node Address192.168.0.4      Rx Address 192.168.0.7
Throughput =6.15978Mbps
Node:4
Tx Node Address192.168.0.5      Rx Address 192.168.0.7
Throughput =4.21752Mbps
Node:5
Tx Node Address192.168.0.6      Rx Address 192.168.0.7
Throughput =-0Mbps
-----
Total sent packets  =70308
Total Received Packets =22716
Total Lost Packets =47592
Packet Loss ratio =67%
Packet delivery ratio =32%
Average Throughput =2.01386Mbps
Total Throughput =12.0831Mbps
```

Thruput = 12.0831Mbps



N=7:

```
ee597@ee597-VirtualBox:~/ns-3-allinone/ns-3-dev$ ./waf --run "lab1 nWifi==7"
Waf: Entering directory `/home/ee597/ns-3-allinone/ns-3-dev/build'
[2702/2749] Compiling scratch/lab1.cc
[2710/2749] Linking build/scratch/lab1
Waf: Leaving directory `/home/ee597/ns-3-allinone/ns-3-dev/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (3.979s)
Node:0
Tx Node Address192.168.0.1      Rx Address 192.168.0.8
Throughput =4.09427Mbps
Node:1
Tx Node Address192.168.0.2      Rx Address 192.168.0.8
Throughput =-0Mbps
Node:2
Tx Node Address192.168.0.3      Rx Address 192.168.0.8
Throughput =-0Mbps
Node:3
Tx Node Address192.168.0.4      Rx Address 192.168.0.8
Throughput =-0Mbps
Node:4
Tx Node Address192.168.0.5      Rx Address 192.168.0.8
Throughput =0.88006Mbps
Node:5
Tx Node Address192.168.0.6      Rx Address 192.168.0.8
Throughput =-0Mbps
Node:6
Tx Node Address192.168.0.7      Rx Address 192.168.0.8
Throughput =5.99551Mbps
-----

Total sent packets  =82026
Total Received Packets =20780
Total Lost Packets =61246
Packet Loss ratio =74%
Packet delivery ratio =25%
Average Throughput =1.56712Mbps
Total Throughput =10.9698Mbps
```

Thruput = 10.9698Mbps

N = 8:

```
ee597@ee597-VirtualBox:~/ns-3-allinone/ns-3-dev$ ./waf --run "lab1 nWifi==8"
Waf: Entering directory `/home/ee597/ns-3-allinone/ns-3-dev/build'
[2701/2749] Compiling scratch/lab1.cc
[2710/2749] Linking build/scratch/lab1
Waf: Leaving directory `/home/ee597/ns-3-allinone/ns-3-dev/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (4.015s)
Node:0
Tx Node Address192.168.0.1      Rx Address 192.168.0.9
Throughput =-0Mbps
Node:1
Tx Node Address192.168.0.2      Rx Address 192.168.0.9
Throughput =0.146008Mbps
Node:2
Tx Node Address192.168.0.3      Rx Address 192.168.0.9
Throughput =-0Mbps
Node:3
Tx Node Address192.168.0.4      Rx Address 192.168.0.9
Throughput =1.40384Mbps
Node:4
Tx Node Address192.168.0.5      Rx Address 192.168.0.9
Throughput =0.53707Mbps
Node:5
Tx Node Address192.168.0.6      Rx Address 192.168.0.9
Throughput =1.61383Mbps
Node:6
Tx Node Address192.168.0.7      Rx Address 192.168.0.9
Throughput =4.36085Mbps
Node:7
Tx Node Address192.168.0.8      Rx Address 192.168.0.9
Throughput =0.545593Mbps
-----
Total sent packets  =93744
Total Received Packets =16154
Total Lost Packets =77590
Packet Loss ratio =82%
Packet delivery ratio =17%
Average Throughput =1.0759Mbps
Total Throughput =8.60719Mbps
```

Thruput = 8.6Mbps

N = 9:

```

ee597@ee597-VirtualBox:~/ns-3-allinone/ns-3-dev$ ./waf --run "lab1 nWifi==9"
Waf: Entering directory `/home/ee597/ns-3-allinone/ns-3-dev/build'
[2702/2749] Compiling scratch/lab1.cc
[2710/2749] Linking build/scratch/lab1
Waf: Leaving directory `/home/ee597/ns-3-allinone/ns-3-dev/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (4.096s)
Node:0
Tx Node Address192.168.0.1      Rx Address 192.168.0.10
Throughput =0.214142Mbps
Node:1
Tx Node Address192.168.0.2      Rx Address 192.168.0.10
Throughput =1.04399Mbps
Node:2
Tx Node Address192.168.0.3      Rx Address 192.168.0.10
Throughput =0.0849318Mbps
Node:3
Tx Node Address192.168.0.4      Rx Address 192.168.0.10
Throughput =-0Mbps
Node:4
Tx Node Address192.168.0.5      Rx Address 192.168.0.10
Throughput =1.1754Mbps
Node:5
Tx Node Address192.168.0.6      Rx Address 192.168.0.10
Throughput =2.30791Mbps
Node:6
Tx Node Address192.168.0.7      Rx Address 192.168.0.10
Throughput =0.175787Mbps
Node:7
Tx Node Address192.168.0.8      Rx Address 192.168.0.10
Throughput =-0Mbps
Node:8
Tx Node Address192.168.0.9      Rx Address 192.168.0.10
Throughput =2.23459Mbps
-----

Total sent packets  =105462
Total Received Packets =13663
Total Lost Packets =91799
Packet Loss ratio =87%
Packet delivery ratio =12%
Average Throughput =0.804082Mbps
Total Throughput =7.23674Mbps

```

N = 10:

```

ee597@ee597-VirtualBox:~/ns-3-allinone/ns-3-dev$ ./waf --run "lab1 nWifi==10"
Waf: Entering directory `/home/ee597/ns-3-allinone/ns-3-dev/build'
[2701/2749] Compiling scratch/lab1.cc
[2710/2749] Linking build/scratch/lab1
Waf: Leaving directory `/home/ee597/ns-3-allinone/ns-3-dev/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (4.030s)
Node:0
Tx Node Address192.168.0.1      Rx Address 192.168.0.11
Throughput =1.85114Mbps
Node:1
Tx Node Address192.168.0.2      Rx Address 192.168.0.11
Throughput =2.88545Mbps
Node:2
Tx Node Address192.168.0.3      Rx Address 192.168.0.11
Throughput =-0Mbps
Node:3
Tx Node Address192.168.0.4      Rx Address 192.168.0.11
Throughput =-0Mbps
Node:4
Tx Node Address192.168.0.5      Rx Address 192.168.0.11
Throughput =5.39976Mbps
Node:5
Tx Node Address192.168.0.6      Rx Address 192.168.0.11
Throughput =-0Mbps
Node:6
Tx Node Address192.168.0.7      Rx Address 192.168.0.11
Throughput =-0Mbps
Node:7
Tx Node Address192.168.0.8      Rx Address 192.168.0.11
Throughput =-0Mbps
Node:8
Tx Node Address192.168.0.9      Rx Address 192.168.0.11
Throughput =0.456841Mbps
Node:9
Tx Node Address192.168.0.10     Rx Address 192.168.0.11
Throughput =0.833904Mbps
-----
Total sent packets  =117180
Total Received Packets =21640
Total Lost Packets  =95540
Packet Loss ratio  =81%
Packet delivery ratio =18%
Average Throughput =1.14271Mbps
Total Throughput =11.4271Mbps

```

Case B E1:

First set backoff window size:

```

/* see IEEE 802.11 section 7.3.2.29 */
switch (ac)
{
case AC_VO:
    dcf->SetMinCw (63);
    dcf->SetMaxCw (127);
    dcf->SetAifsn (2);
    if (isDsss)
    {
        dcf->SetTxopLimit (MicroSeconds (3264));
    }
    else
    {
        dcf->SetTxopLimit (MicroSeconds (1504));
    }
    break;
case AC_VI:
    dcf->SetMinCw (63);
    dcf->SetMaxCw (127);
    if (isDsss)
    {
        dcf->SetTxopLimit (MicroSeconds (6016));
    }
    else
    {
        dcf->SetTxopLimit (MicroSeconds (3008));
    }
    break;
case AC_BE:
    dcf->SetMinCw (63);
    dcf->SetMaxCw (127);
    dcf->SetAifsn (3);
    dcf->SetTxopLimit (MicroSeconds (0));
    break;
case AC_BK:
    dcf->SetMinCw (63);
    dcf->SetMaxCw (127);
    dcf->SetAifsn (7);
    dcf->SetTxopLimit (MicroSeconds (0));
    break;
case AC_BE_NQOS:
    dcf->SetMinCw (63);
    dcf->SetMaxCw (127);
    dcf->SetAifsn (7);

```

N=1:

```

Node:0
Tx Node Address192.168.0.1      Rx Address 192.168.0.4
Throughput =4.6726Mbps
Node:1
Tx Node Address192.168.0.2      Rx Address 192.168.0.4
Throughput =4.68671Mbps
Node:2
Tx Node Address192.168.0.3      Rx Address 192.168.0.4
Throughput =4.62856Mbps
-----

Total sent packets  =35154
Total Received Packets =26521
Total Lost Packets =8633
Packet Loss ratio =24%
Packet delivery ratio =75%
Average Throughput =4.66262Mbps
Total Throughput =13.9879Mbps

```

N=4:

```

Total Throughput =13.9879Mbps
ee597@ee597-VirtualBox:~/ns-3-allinone/ns-3-dev$ ./waf --run "lab1 nWifi==4"
Waf: Entering directory `/home/ee597/ns-3-allinone/ns-3-dev/build'
[2702/2749] Compiling scratch/lab1.cc
[2710/2749] Linking build/scratch/lab1
Waf: Leaving directory `/home/ee597/ns-3-allinone/ns-3-dev/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (3.997s)
Node:0
Tx Node Address192.168.0.1      Rx Address 192.168.0.5
Throughput =3.89534Mbps
Node:1
Tx Node Address192.168.0.2      Rx Address 192.168.0.5
Throughput =3.32322Mbps
Node:2
Tx Node Address192.168.0.3      Rx Address 192.168.0.5
Throughput =3.79335Mbps
Node:3
Tx Node Address192.168.0.4      Rx Address 192.168.0.5
Throughput =3.79987Mbps
-----

Total sent packets  =46872
Total Received Packets =28083
Total Lost Packets =18789
Packet Loss ratio =40%
Packet delivery ratio =59%
Average Throughput =3.70294Mbps
Total Throughput =14.8118Mbps

```

N=5:

```

ee597@ee597-VirtualBox:~/ns-3-allinone/ns-3-dev$ ./waf --run "lab1 nWifi==5"
Waf: Entering directory `/home/ee597/ns-3-allinone/ns-3-dev/build'
[2702/2749] Compiling scratch/lab1.cc
[2710/2749] Linking build/scratch/lab1
Waf: Leaving directory `/home/ee597/ns-3-allinone/ns-3-dev/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (4.147s)
Node:0
Tx Node Address192.168.0.1      Rx Address 192.168.0.6
Throughput =3.89425Mbps
Node:1
Tx Node Address192.168.0.2      Rx Address 192.168.0.6
Throughput =2.37962Mbps
Node:2
Tx Node Address192.168.0.3      Rx Address 192.168.0.6
Throughput =2.27488Mbps
Node:3
Tx Node Address192.168.0.4      Rx Address 192.168.0.6
Throughput =2.3012Mbps
Node:4
Tx Node Address192.168.0.5      Rx Address 192.168.0.6
Throughput =3.81374Mbps
-----
Total sent packets  =58590
Total Received Packets =27801
Total Lost Packets =30789
Packet Loss ratio =52%
Packet delivery ratio =47%
Average Throughput =2.93274Mbps
Total Throughput =14.6637Mbps

```

N=6:

```
Node:0
Tx Node Address192.168.0.1      Rx Address 192.168.0.7
Throughput =2.73455Mbps
Node:1
Tx Node Address192.168.0.2      Rx Address 192.168.0.7
Throughput =2.56207Mbps
Node:2
Tx Node Address192.168.0.3      Rx Address 192.168.0.7
Throughput =2.63671Mbps
Node:3
Tx Node Address192.168.0.4      Rx Address 192.168.0.7
Throughput =2.55596Mbps
Node:4
Tx Node Address192.168.0.5      Rx Address 192.168.0.7
Throughput =2.5762Mbps
Node:5
Tx Node Address192.168.0.6      Rx Address 192.168.0.7
Throughput =2.27947Mbps
-----

Total sent packets  =70308
Total Received Packets =29092
Total Lost Packets  =41216
Packet Loss ratio  =58%
Packet delivery ratio =41%
Average Throughput =2.55749Mbps
Total Throughput =15.345Mbps
```

N=7:



```

Node:0
Tx Node Address192.168.0.1      Rx Address 192.168.0.8
Throughput =2.2879Mbps
Node:1
Tx Node Address192.168.0.2      Rx Address 192.168.0.8
Throughput =1.92077Mbps
Node:2
Tx Node Address192.168.0.3      Rx Address 192.168.0.8
Throughput =2.2192Mbps
Node:3
Tx Node Address192.168.0.4      Rx Address 192.168.0.8
Throughput =1.90769Mbps
Node:4
Tx Node Address192.168.0.5      Rx Address 192.168.0.8
Throughput =2.23865Mbps
Node:5
Tx Node Address192.168.0.6      Rx Address 192.168.0.8
Throughput =2.26326Mbps
Node:6
Tx Node Address192.168.0.7      Rx Address 192.168.0.8
Throughput =2.28712Mbps
-----
Total sent packets  =82026
Total Received Packets =28675
Total Lost Packets =53351
Packet Loss ratio =65%
Packet delivery ratio =34%
Average Throughput =2.16066Mbps
Total Throughput =15.1246Mbps

```

N=8:

```
Node:0
Tx Node Address192.168.0.1      Rx Address 192.168.0.9
Throughput =1.92202Mbps
Node:1
Tx Node Address192.168.0.2      Rx Address 192.168.0.9
Throughput =1.9272Mbps
Node:2
Tx Node Address192.168.0.3      Rx Address 192.168.0.9
Throughput =1.21369Mbps
Node:3
Tx Node Address192.168.0.4      Rx Address 192.168.0.9
Throughput =1.9499Mbps
Node:4
Tx Node Address192.168.0.5      Rx Address 192.168.0.9
Throughput =1.94456Mbps
Node:5
Tx Node Address192.168.0.6      Rx Address 192.168.0.9
Throughput =1.24475Mbps
Node:6
Tx Node Address192.168.0.7      Rx Address 192.168.0.9
Throughput =1.92729Mbps
Node:7
Tx Node Address192.168.0.8      Rx Address 192.168.0.9
Throughput =1.1948Mbps
-----

Total sent packets  =93744
Total Received Packets =25259
Total Lost Packets  =68485
Packet Loss ratio =73%
Packet delivery ratio =26%
Average Throughput =1.66553Mbps
Total Throughput =13.3242Mbps
```

N=9:

```
Node:0
Tx Node Address192.168.0.1      Rx Address 192.168.0.10
Throughput =0.715155Mbps
Node:1
Tx Node Address192.168.0.2      Rx Address 192.168.0.10
Throughput =0.789794Mbps
Node:2
Tx Node Address192.168.0.3      Rx Address 192.168.0.10
Throughput =0.652128Mbps
Node:3
Tx Node Address192.168.0.4      Rx Address 192.168.0.10
Throughput =0.653558Mbps
Node:4
Tx Node Address192.168.0.5      Rx Address 192.168.0.10
Throughput =0.836009Mbps
Node:5
Tx Node Address192.168.0.6      Rx Address 192.168.0.10
Throughput =0.810112Mbps
Node:6
Tx Node Address192.168.0.7      Rx Address 192.168.0.10
Throughput =0.848684Mbps
Node:7
Tx Node Address192.168.0.8      Rx Address 192.168.0.10
Throughput =0.689846Mbps
Node:8
Tx Node Address192.168.0.9      Rx Address 192.168.0.10
Throughput =0.769886Mbps
-----

Total sent packets  =105462
Total Received Packets =12809
Total Lost Packets =92653
Packet Loss ratio =87%
Packet delivery ratio =12%
Average Throughput =0.751686Mbps
Total Throughput =6.76517Mbps
```

N=10:

```

Node:0
Tx Node Address192.168.0.1      Rx Address 192.168.0.11
Throughput =0.825956Mbps
Node:1
Tx Node Address192.168.0.2      Rx Address 192.168.0.11
Throughput =0.928721Mbps
Node:2
Tx Node Address192.168.0.3      Rx Address 192.168.0.11
Throughput =0.668684Mbps
Node:3
Tx Node Address192.168.0.4      Rx Address 192.168.0.11
Throughput =0.771723Mbps
Node:4
Tx Node Address192.168.0.5      Rx Address 192.168.0.11
Throughput =0.944313Mbps
Node:5
Tx Node Address192.168.0.6      Rx Address 192.168.0.11
Throughput =0.732624Mbps
Node:6
Tx Node Address192.168.0.7      Rx Address 192.168.0.11
Throughput =0.736404Mbps
Node:7
Tx Node Address192.168.0.8      Rx Address 192.168.0.11
Throughput =0.684816Mbps
Node:8
Tx Node Address192.168.0.9      Rx Address 192.168.0.11
Throughput =0.771442Mbps
Node:9
Tx Node Address192.168.0.10     Rx Address 192.168.0.11
Throughput =0.696164Mbps
-----

Total sent packets  =117180
Total Received Packets =14708
Total Lost Packets =102472
Packet Loss ratio =87%
Packet delivery ratio =12%
Average Throughput =0.776085Mbps
Total Throughput =7.76085Mbps

```

Case B E2:

R = 3Mbps

```

-----

Total sent packets  =117180
Total Received Packets =11662
Total Lost Packets =105518
Packet Loss ratio =90%
Packet delivery ratio =9%
Average Throughput =0.308264Mbps
Total Throughput =6.16528Mbps

```

R=6Mbps:

```
-----  
Total sent packets  =234360  
Total Received Packets =11663  
Total Lost Packets  =222697  
Packet Loss ratio  =95%  
Packet delivery ratio =4%  
Average Throughput =0.308289Mbps  
Total Throughput  =6.16578Mbps
```

R=9Mbps:

```
-----  
Total sent packets  =351560  
Total Received Packets =11663  
Total Lost Packets  =339897  
Packet Loss ratio  =96%  
Packet delivery ratio =3%  
Average Throughput =0.308289Mbps  
Total Throughput  =6.16578Mbps
```

R = 12Mbps:

```
-----  
Total sent packets  =468740  
Total Received Packets =11663  
Total Lost Packets  =457077  
Packet Loss ratio  =97%  
Packet delivery ratio =2%  
Average Throughput =0.308289Mbps  
Total Throughput  =6.16578Mbps
```

R=15Mbps:

```
-----  
Total sent packets  =585920  
Total Received Packets =11663  
Total Lost Packets  =574257  
Packet Loss ratio  =98%  
Packet delivery ratio =1%  
Average Throughput =0.308289Mbps  
Total Throughput  =6.16578Mbps
```

Case A E2:

R=3Mbps:

```
-----  
Total sent packets  =117180  
Total Received Packets =11514  
Total Lost Packets =105666  
Packet Loss ratio =90%  
Packet delivery ratio =9%  
Average Throughput =0.303771Mbps  
Total Throughput =6.07543Mbps
```

R=6Mbps:

```
-----  
Total sent packets  =234360  
Total Received Packets =18155  
Total Lost Packets =216205  
Packet Loss ratio =92%  
Packet delivery ratio =7%  
Average Throughput =0.47893Mbps  
Total Throughput =9.57859Mbps  
=587900587 Virtual Bytes (as 2.511Mbps/as 2.5Mbps)
```

R=9Mbps:

```
-----  
Total sent packets  =351560  
Total Received Packets =30873  
Total Lost Packets =320687  
Packet Loss ratio =91%  
Packet delivery ratio =8%  
Average Throughput =0.825969Mbps  
Total Throughput =16.5194Mbps
```

R=12Mbps:

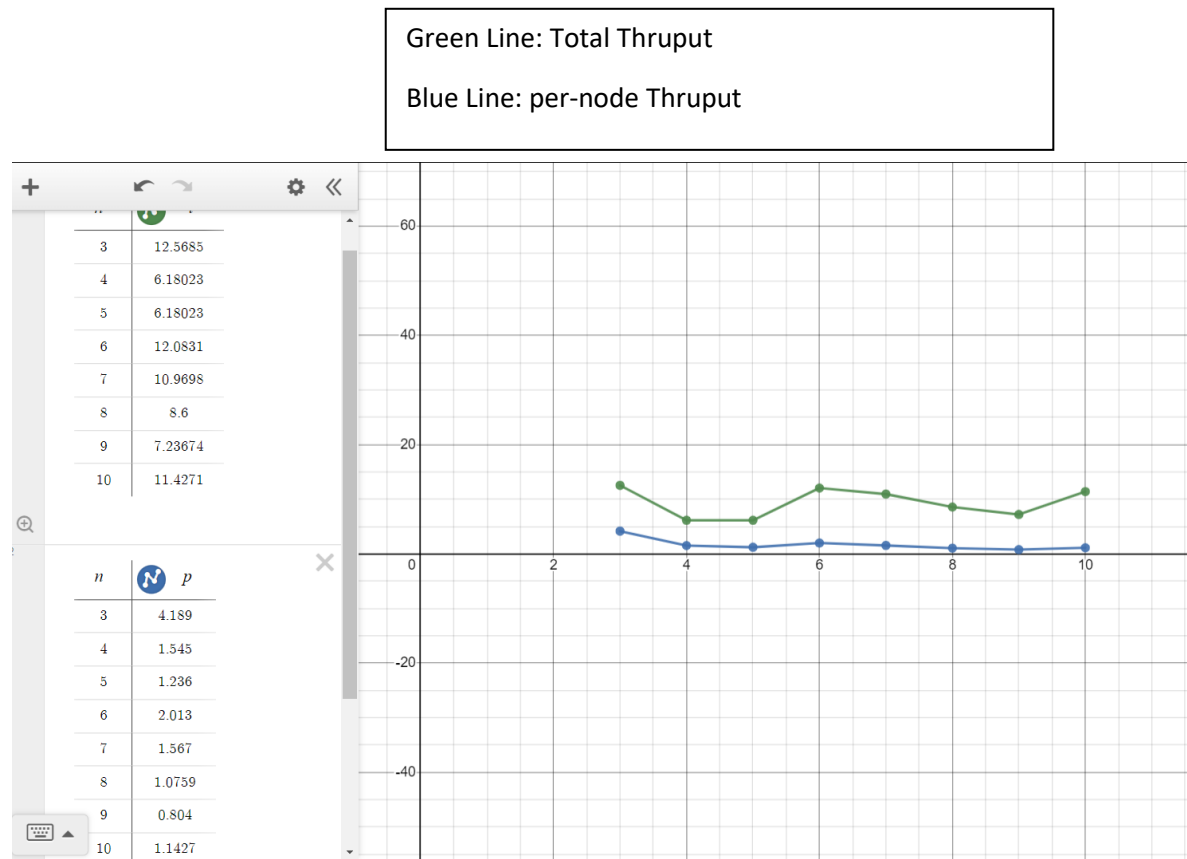
```
-----  
Total sent packets  =468740  
Total Received Packets =27109  
Total Lost Packets =441631  
Packet Loss ratio =94%  
Packet delivery ratio =5%  
Average Throughput =0.781767Mbps  
Total Throughput =15.6353Mbps
```

R=15Mbps:

Discussion:

CAE1 and CBE1:

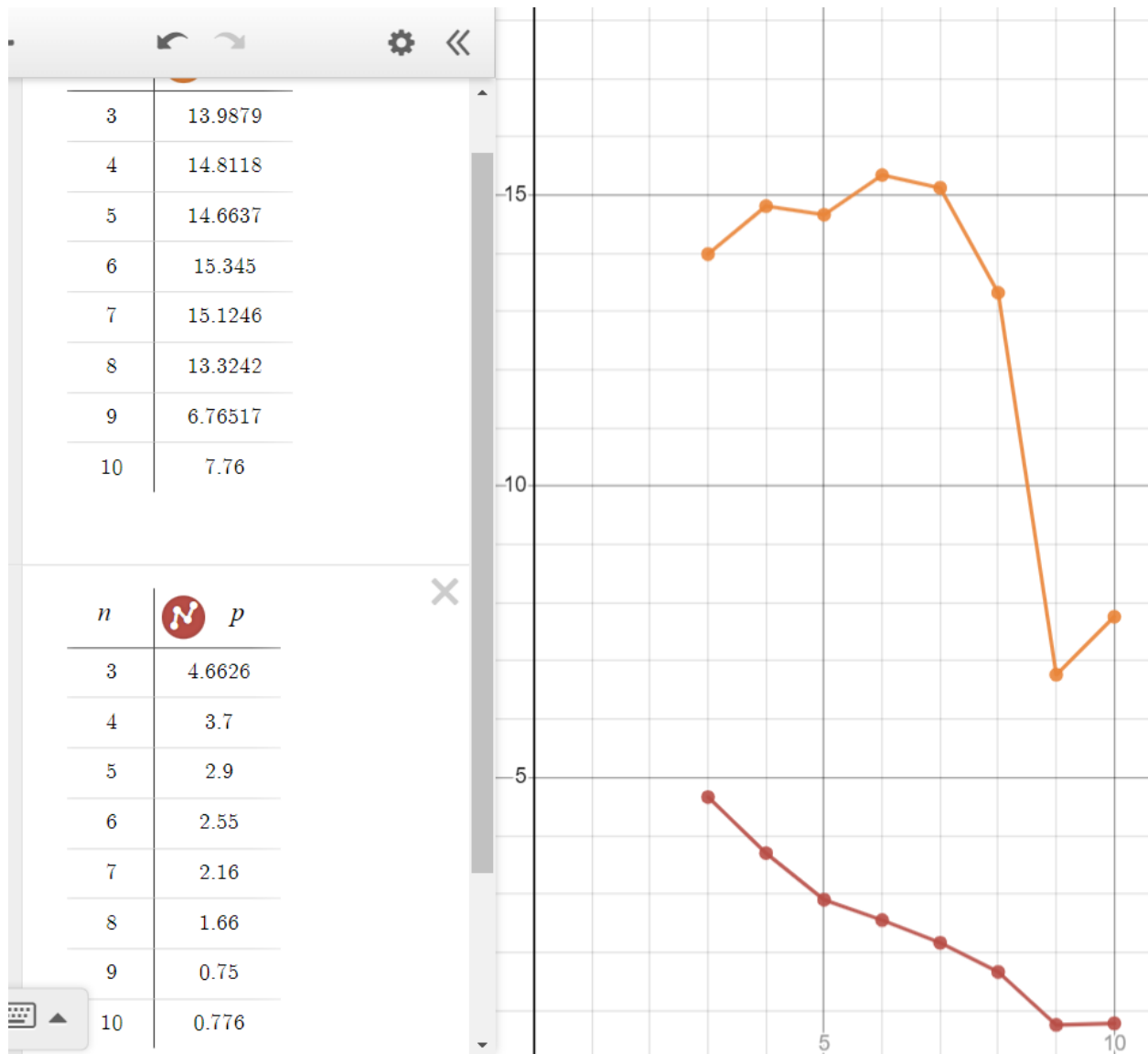
CAE1's graph and CSV file:



In Case A, we choose a low backoff window size of 1 slot and a large max backoff window size of 1023 slots. This means there will be more stages in such a situation and will cause each node to be difficult to reach 0 to transmit if there are some collisions happened. We can see the small window size and large max window result in the best total throughput when the n number is small ( $n=3$ , thruput = 12.56), and has a thruput of no more than 12 Mbps as n increases. However, the per-node thruput seems going to decrease. Although there is a peak when  $n=6$  but the best per-node thruput is also when n is small when  $n=3$ .

CBE1's graph and CSV file:

Orange Line: Total Thruput  
Red Line: per-node Thruput



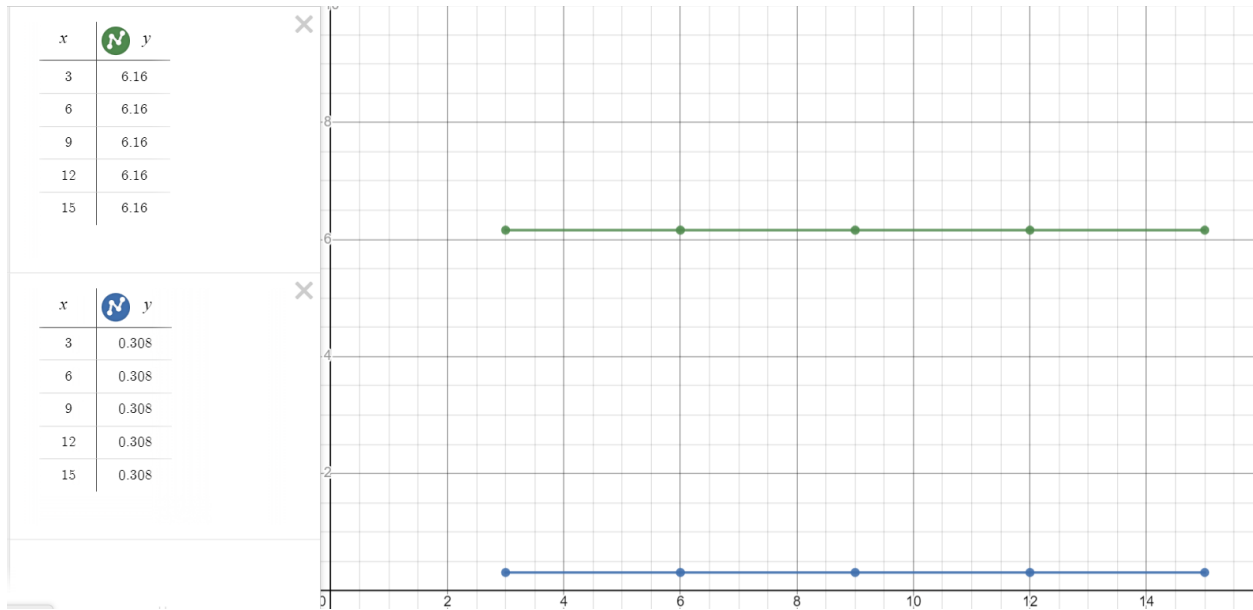
In the case of B, the min backoff window size increase to 63 and the max backoff window size decreases to 127, which means the the difference between min backoff size and the max backoff window size is small. Indicates there are fewer stages in such a situation, which helps each node to have more chance to transmit even when there are collisions. We can see on the graph, the total thruput keeps going up from  $n=3$  to  $n=6$ , and start to drop after  $n=6$ , it seems like when node number = 6 this case can reach its best total thruput. As  $N$  increase, the per-node throughput is keep decreasing, but when  $n$  reaches 9, the per-node throughput stops decreasing and stay around the number of 0.76 Mbps. It seems like as  $n$  keeps increasing, the per-node thruput won't be less than this number.



CBE2's graph and CSV file:

Green Line: Total Thruput

Blue Line: per-node Thruput

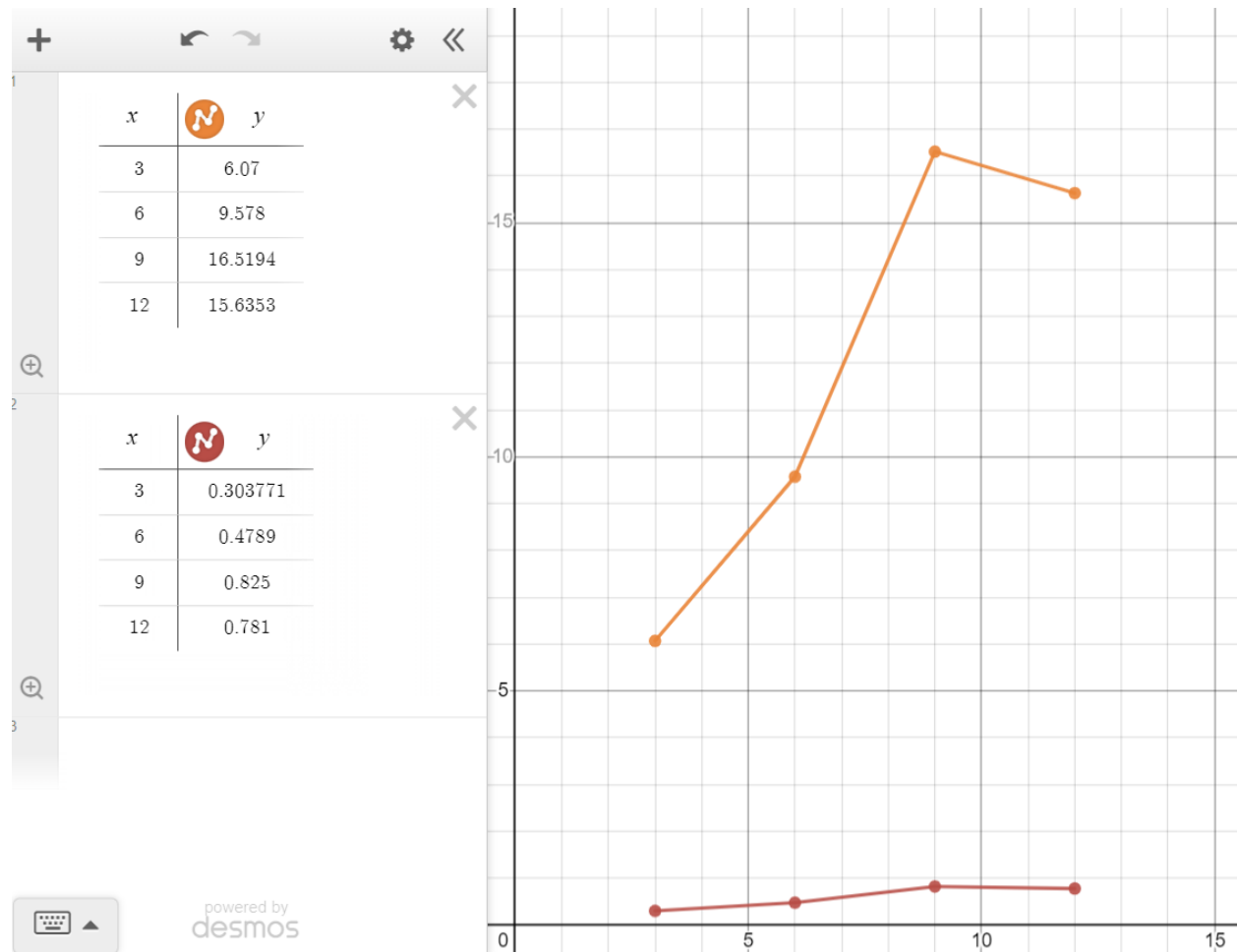


As we can see in CaseBE1, when the min backoff window size = 63 and the max back-off window size reaches 127, it reaches relatively good thruput when n is small. But in Case B, the n is fixed at 20 which seems much larger than what we set for n in case A. Moreover, we have fixed the packet size to 512 bytes. As we increase the data rate, the transmit time will be shorter and shorter which may cause an effect on total thruput and per-node thruput as well. In our case, it seems like both total thruput and per-node thruput under this case reach a point that as n keeps increasing both total thruput and per-node thruput won't be less than.

CBE1:

Orange Line: Total Thruput

Red Line: per-node Thruput



As we can see, when fixing  $n$  in relatively large numbers, increasing the data rate seems to help to reach a good thruput. As we increase datarate, the total thruput reaches an optimal thruput at datarate = 9Mbps. The per-node thruput follows the same pattern as the total thruput. But after datarate = 12Mbps, the total thruput and the per-node thruput didn't go any higher. Thus we can see there is a limit even though we have more data rates for this case.