Experiment 5 - Building Topologies in NS3

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1 Introduction

Having implemented the point to point, CSMA and Wi-Fi topologies, it is then natural to extend our investigation to the star topology network. For the star topology a predefined number of nodes are connected to a central Hub (packet sink), in a manner similar to the spokes on a wheel.

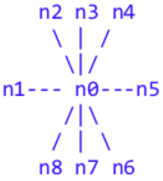
The intent being that once these nodes are properly configured and equipped with the right application,s they will send packets to the sink in a sequential manner, and then await acknowledgment.

2 Objective

Implement and analyze the star topolgy in NS3.

3 Procedure

For the lab task we were instructed to first study the `examples/tcp/star.cc` script and which was intended to implement a standard star topology with $n = 8$ spoke nodes and a central Hub, consequently the topology was constituted by $n + 1 = 9$ nodes in total, as presented in the figure below.



```
    n2 n3 n4
     \ | /
      \|/
n1--- n0---n5
      /|\
     / | \
    n8 n7 n6
```

Figure 1: starTopology.png

Having studied the code required to model the standard star topolgy, we were then required to write code to model a slightly different topology, the details are discussed in the section below.

3.1 The Topology

In contrast to the topology presented in `examples/tcp/star.cc`, the lab task instructed us to install the packet sink application on node nine, in addition we were to refrain from installing any applications on nodes zero and five. An illustration of the required topology is discussed below.

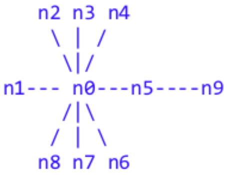


Figure 2: labQuestionTopology.png

3.2 Stratedgy Employed

To implement the topology in question, we first created the standard star topology and then a point to point link between nodes five and nine, installing the net devices and protocol stacks required by all the nodes for both the start and p2p link.

After assigning IPs, to ensure the packet sink application was installed on node nine we used the corresponding IP address stored in the interfaces for the p2p nodes. The remaining key ideas can be inferred from the code and console output presented below.

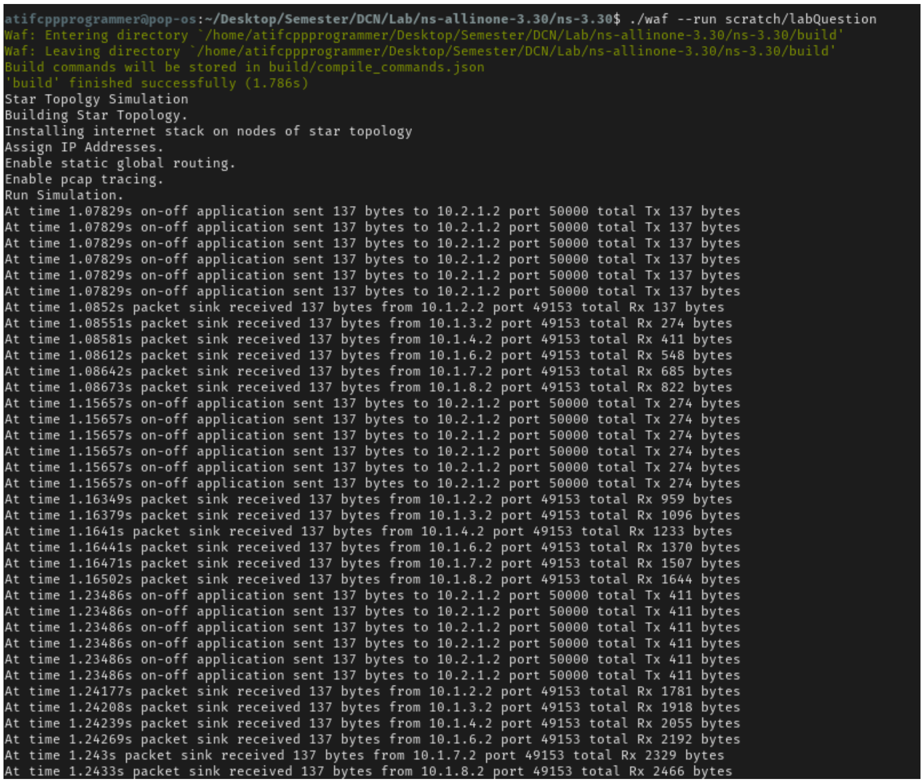
3.3 Code and Console Output

```
#include "ns3/core-module.h"
#include "ns3/network-module.h"
#include "ns3/netanim-module.h"
#include "ns3/internet-module.h"
#include "ns3/point-to-point-module.h"
#include "ns3/applications-module.h"
#include "ns3/point-to-point-layout-module.h"

using namespace ns3;

NS_LOG_COMPONENT_DEFINE ("Star");
```

```
int
main (int argc, char *argv[])
{

  // Adding Log Levels for Console Output.
  LogComponentEnable("Star",LOG_LEVEL_INFO);
  LogComponentEnable("PacketSink",LOG_LEVEL_INFO);
  LogComponentEnable("OnOffApplication",LOG_LEVEL_INFO);
  NS_LOG_INFO("Star Topolgy Simulation");

  //
  // Set up some default values for the simulation.
  //
  Config::SetDefault ("ns3::OnOffApplication::PacketSize", UintegerValue (137));

  // ??? try and stick 15kb/s into the data rate
  Config::SetDefault ("ns3::OnOffApplication::DataRate", StringValue ("14kb/s"));

  //
  // Default number of nodes in the star.  Overridable by command line argument.
  //
  uint32_t nSpokes = 8;

  CommandLine cmd;
  cmd.AddValue ("nSpokes", "Number of nodes to place in the star", nSpokes);
  cmd.Parse (argc, argv);

  // Specifying attributes for point tp point links of star topology.
  NS_LOG_INFO("Building Star Topology.");
  PointToPointHelper pointToPoint;
  pointToPoint.SetDeviceAttribute ("DataRate", StringValue ("5Mbps"));
  pointToPoint.SetChannelAttribute ("Delay", StringValue ("2ms"));
  PointToPointStarHelper star (nSpokes, pointToPoint);

  // Installing internet stack on all nodes of start topology.
  NS_LOG_INFO("Installing internet stack on nodes of star topology");
  InternetStackHelper internet;
  star.InstallStack (internet);

  // Assigning IP Address to nodes of star topology.
  NS_LOG_INFO ("Assign IP Addresses.");
  star.AssignIpv4Addresses (Ipv4AddressHelper ("10.1.1.0", "255.255.255.0"));

  // Creating point to point link for connection between node 5 and node 9.
  NodeContainer p2pNodes;
  p2pNodes.Add(star.GetSpokeNode(4));
```

```
p2pNodes.Create(1);

// Installing netdevices, internet stack and assigning ip's for this link.
NetDeviceContainer p2pDevices;
p2pDevices = pointToPoint.Install(p2pNodes);

internet.Install(p2pNodes.Get(1));

Ipv4AddressHelper address;
address.SetBase ("10.2.1.0", "255.255.255.0");

Ipv4InterfaceContainer interfaces = address.Assign (p2pDevices);

// Installing Hub App on Node 9, (making it the packet sink).
uint16_t port = 50000;
Address hubLocalAddress (InetSocketAddress (Ipv4Address::GetAny (), port));
PacketSinkHelper packetSinkHelper ("ns3::TcpSocketFactory", hubLocalAddress);
ApplicationContainer hubApp = packetSinkHelper.Install (p2pNodes.Get(1));
hubApp.Start (Seconds (1.0));
hubApp.Stop (Seconds (10.0));

// Installing on off applications.
OnOffHelper onOffHelper ("ns3::TcpSocketFactory", Address ());
onOffHelper.SetAttribute ("OnTime",
  StringValue ("ns3::ConstantRandomVariable[Constant=1]"));
onOffHelper.SetAttribute ("OffTime",
  StringValue ("ns3::ConstantRandomVariable[Constant=0]"));

ApplicationContainer spokeApps;

for (uint32_t i = 0; i < star.SpokeCount (); ++i)
  {
    if(i == 0 || i == 4) continue;
    AddressValue remoteAddress (InetSocketAddress
      (interfaces.GetAddress(1), port));
    onOffHelper.SetAttribute ("Remote", remoteAddress);
    spokeApps.Add (onOffHelper.Install (star.GetSpokeNode (i)));
  }
spokeApps.Start (Seconds (1.0));
spokeApps.Stop (Seconds (10.0));

NS_LOG_INFO ("Enable static global routing.");
//
// Turn on global static routing so we can actually be routed across the star.
//
Ipv4GlobalRoutingHelper::PopulateRoutingTables ();
```

```
  NS_LOG_INFO ("Enable pcap tracing.");
  //
  // Do pcap tracing on all point-to-point devices on all nodes.
  //
  pointToPoint.EnablePcapAll ("atif_star");

  NS_LOG_INFO ("Run Simulation.");
  Simulator::Run ();
  Simulator::Destroy ();
  NS_LOG_INFO ("Done.");

  return 0;
}
```



```
atifcppprogrammer@pop-os:~/Desktop/Semester/DCN/Lab/ns-allinone-3.30/ns-3.30$ ./waf --run scratch/labQuestion
Waf: Entering directory `/home/atifcppprogrammer/Desktop/Semester/DCN/Lab/ns-allinone-3.30/ns-3.30/build'
Waf: Leaving directory `/home/atifcppprogrammer/Desktop/Semester/DCN/Lab/ns-allinone-3.30/ns-3.30/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (1.786s)
Star Topolgy Simulation
Building Star Topology.
Installing internet stack on nodes of star topology
Assign IP Addresses.
Enable static global routing.
Enable pcap tracing.
Run Simulation.
At time 1.07829s on-off application sent 137 bytes to 10.2.1.2 port 50000 total Tx 137 bytes
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At time 1.0852s packet sink received 137 bytes from 10.1.2.2 port 49153 total Rx 137 bytes
At time 1.08551s packet sink received 137 bytes from 10.1.3.2 port 49153 total Rx 274 bytes
At time 1.08581s packet sink received 137 bytes from 10.1.4.2 port 49153 total Rx 411 bytes
At time 1.08612s packet sink received 137 bytes from 10.1.6.2 port 49153 total Rx 548 bytes
At time 1.08642s packet sink received 137 bytes from 10.1.7.2 port 49153 total Rx 685 bytes
At time 1.08673s packet sink received 137 bytes from 10.1.8.2 port 49153 total Rx 822 bytes
At time 1.15657s on-off application sent 137 bytes to 10.2.1.2 port 50000 total Tx 274 bytes
At time 1.15657s on-off application sent 137 bytes to 10.2.1.2 port 50000 total Tx 274 bytes
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At time 1.15657s on-off application sent 137 bytes to 10.2.1.2 port 50000 total Tx 274 bytes
At time 1.16349s packet sink received 137 bytes from 10.1.2.2 port 49153 total Rx 959 bytes
At time 1.16379s packet sink received 137 bytes from 10.1.3.2 port 49153 total Rx 1096 bytes
At time 1.1641s packet sink received 137 bytes from 10.1.4.2 port 49153 total Rx 1233 bytes
At time 1.16441s packet sink received 137 bytes from 10.1.6.2 port 49153 total Rx 1370 bytes
At time 1.16471s packet sink received 137 bytes from 10.1.7.2 port 49153 total Rx 1507 bytes
At time 1.16502s packet sink received 137 bytes from 10.1.8.2 port 49153 total Rx 1644 bytes
At time 1.23486s on-off application sent 137 bytes to 10.2.1.2 port 50000 total Tx 411 bytes
At time 1.23486s on-off application sent 137 bytes to 10.2.1.2 port 50000 total Tx 411 bytes
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At time 1.23486s on-off application sent 137 bytes to 10.2.1.2 port 50000 total Tx 411 bytes
At time 1.24177s packet sink received 137 bytes from 10.1.2.2 port 49153 total Rx 1781 bytes
At time 1.24208s packet sink received 137 bytes from 10.1.3.2 port 49153 total Rx 1918 bytes
At time 1.24239s packet sink received 137 bytes from 10.1.4.2 port 49153 total Rx 2055 bytes
At time 1.24269s packet sink received 137 bytes from 10.1.6.2 port 49153 total Rx 2192 bytes
At time 1.243s packet sink received 137 bytes from 10.1.7.2 port 49153 total Rx 2329 bytes
At time 1.2433s packet sink received 137 bytes from 10.1.8.2 port 49153 total Rx 2466 bytes
```

Figure 3: labQuestion.cc

4 Conclusions

NS3 can be used to model an analyze star topologies.

5 Post-Lab Question

For the post lab we were required to implement the following topology, the code and console output are presented below.

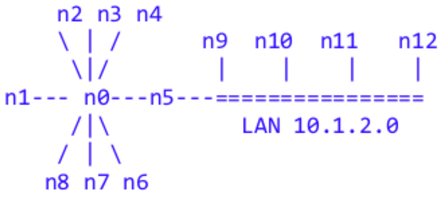
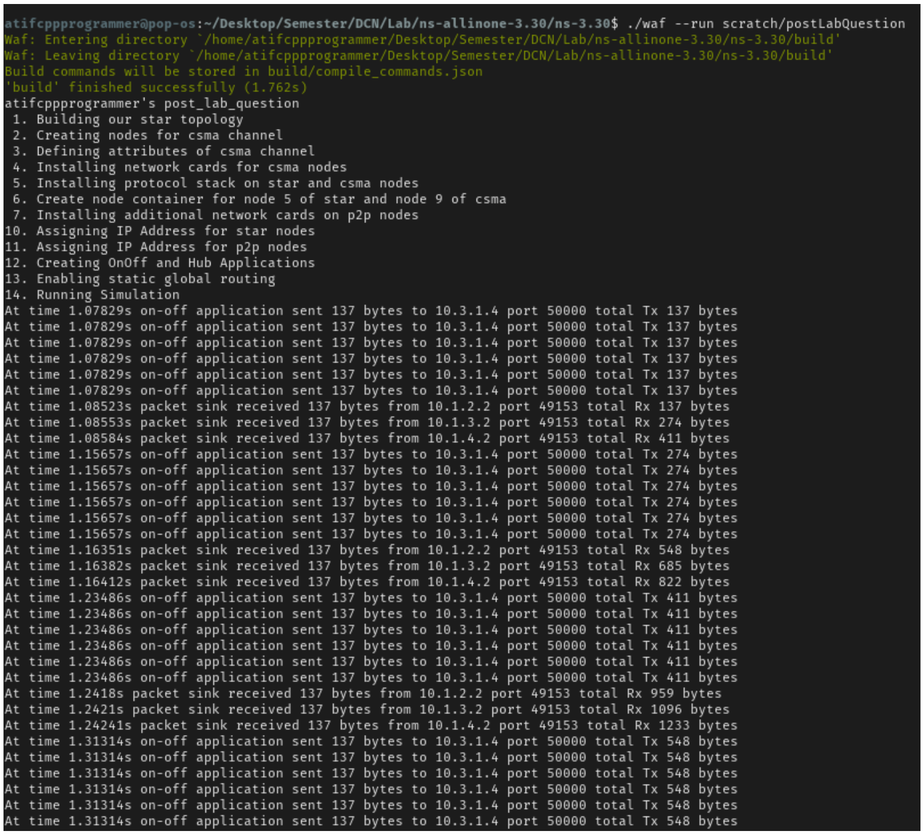


Figure 4: postLabQuestionTopology.png

```
#include "ns3/core-module.h"
#include "ns3/csma-module.h"
#include "ns3/network-module.h"
#include "ns3/netanim-module.h"
#include "ns3/internet-module.h"
#include "ns3/point-to-point-module.h"
#include "ns3/applications-module.h"
#include "ns3/ipv4-global-routing-helper.h"
#include "ns3/point-to-point-layout-module.h"

using namespace ns3;

NS_LOG_COMPONENT_DEFINE ("Star");

int
main (int argc, char *argv[])
{
  // Enabling log components for console output.
  LogComponentEnable("Star",LOG_LEVEL_INFO);
  LogComponentEnable("PacketSink",LOG_LEVEL_INFO);
  LogComponentEnable("OnOffApplication",LOG_LEVEL_INFO);

  // Check to see if loging is enabled.
  NS_LOG_INFO("atifcppprogrammer’s post_lab_question");

  // Setting up default values for the simulation.
```

```
Config::SetDefault ("ns3::OnOffApplication::PacketSize", UintegerValue (137));
Config::SetDefault ("ns3::OnOffApplication::DataRate", StringValue ("14kb/s"));

// Defining spoke count for star and node count for csma.
uint32_t nSpokes = 8,nCsma = 4;

// Case user wishes to ammend above spoke and csma counts at the outset.
CommandLine cmd;
cmd.AddValue ("nSpokes", "Number of nodes to place in star", nSpokes);
cmd.AddValue ("nCsma", "Number of nodes to place in csma", nCsma);
cmd.Parse (argc, argv);

// Building our star topology.
NS_LOG_INFO(" 1. Building our star topology");
PointToPointHelper pointToPoint;
pointToPoint.SetDeviceAttribute("DataRate",StringValue("5Mbps"));
pointToPoint.SetChannelAttribute("Delay",StringValue("2ms"));
PointToPointStarHelper star (nSpokes,pointToPoint);

// Creating nodes for csma channel.
NS_LOG_INFO(" 2. Creating nodes for csma channel");
NodeContainer csmaNodes;
csmaNodes.Create(nCsma);

// Defining attributes of csma channel.
NS_LOG_INFO(" 3. Defining attributes of csma channel");
CsmaHelper csma;
csma.SetChannelAttribute ("DataRate", StringValue ("100Mbps"));
csma.SetChannelAttribute ("Delay", TimeValue (NanoSeconds (6560)));

// Installing network cards on csma channel.
NS_LOG_INFO(" 4. Installing network cards for csma nodes");
NetDeviceContainer csmaDevices;
csmaDevices = csma.Install(csmaNodes);

// Installing internet stack on star and csma nodes.
NS_LOG_INFO(" 5. Installing protocol stack on star and csma nodes");
InternetStackHelper stack;
stack.Install(csmaNodes); star.InstallStack(stack);

// Creating node container for nodes 5 and 9.
NS_LOG_INFO(" 6. Create node container for node 5 of star and node 9 of csma");
NodeContainer p2pNodes = NodeContainer(star.GetSpokeNode(4),csmaNodes.Get(0));

// Installing Network Cards for p2p nodes.
NS_LOG_INFO(" 7. Installing additional network cards on p2p nodes");
```

```
NetDeviceContainer p2pDevices;
p2pDevices = pointToPoint.Install(p2pNodes);

// Assigning IP Addresses for star topology.
NS_LOG_INFO("10. Assigning IP Address for star nodes");
star.AssignIpv4Addresses (Ipv4AddressHelper ("10.1.1.0", "255.255.255.0"));

// Assigning IP Addresses  for p2p nodes.
NS_LOG_INFO("11. Assigning IP Address for p2p nodes");
Ipv4AddressHelper address;
address.SetBase ("10.2.1.0", "255.255.255.0");
Ipv4InterfaceContainer p2pInterfaces;
p2pInterfaces = address.Assign (p2pDevices);

// Assigning IP Addresses  for csma nodes.
address.SetBase ("10.3.1.0", "255.255.255.0");
Ipv4InterfaceContainer csmaInterfaces;
csmaInterfaces = address.Assign (csmaDevices);

// Creating Applications.
NS_LOG_INFO("12. Creating OnOff and Hub Applications");

// Creating a packet sink on node 12 of csma channel.
uint16_t port = 50000;
Address hubLocalAddress (InetSocketAddress (Ipv4Address::GetAny (), port));
PacketSinkHelper packetSinkHelper ("ns3::TcpSocketFactory", hubLocalAddress);
ApplicationContainer hubApp = packetSinkHelper.Install (csmaNodes.Get(nCsma-1));
hubApp.Start (Seconds (1.0));
hubApp.Stop (Seconds (10.0));

// Creating OnOff apps to send tcp packets to hub, on on each spoke node.
OnOffHelper onOffHelper ("ns3::TcpSocketFactory", Address ());
onOffHelper.SetAttribute ("OnTime",
  StringValue ("ns3::ConstantRandomVariable[Constant=1]"));
onOffHelper.SetAttribute ("OffTime",
  StringValue ("ns3::ConstantRandomVariable[Constant=0]"));

ApplicationContainer spokeApps;

for (uint32_t i = 0; i < star.SpokeCount (); ++i){
  // Skipping installation of apps on node 0 and node 4.
  if (!(i == 0 || i == 4)){
    AddressValue remoteAddress (InetSocketAddress
      (csmaInterfaces.GetAddress(nCsma-1), port));
    onOffHelper.SetAttribute ("Remote", remoteAddress);
    spokeApps.Add (onOffHelper.Install (star.GetSpokeNode (i)));
    }
  }
  spokeApps.Start (Seconds (1.0));
  spokeApps.Stop (Seconds (10.0));

  // Enabling global routing.
  NS_LOG_INFO ("13. Enabling static global routing");
  Ipv4GlobalRoutingHelper::PopulateRoutingTables();

  // Running program.
  NS_LOG_INFO ("14. Running Simulation");
  Simulator::Run ();
  Simulator::Destroy ();

  // Ok ! we are done now.
  NS_LOG_INFO ("Done !!!");

  return 0;
}
```



```
atifcppprogrammer@pop-os:~/Desktop/Semester/DCN/Lab/ns-allinone-3.30/ns-3.30$ ./waf --run scratch/postLabQuestion
Waf: Entering directory `/home/atifcppprogrammer/Desktop/Semester/DCN/Lab/ns-allinone-3.30/ns-3.30/build'
Waf: Leaving directory `/home/atifcppprogrammer/Desktop/Semester/DCN/Lab/ns-allinone-3.30/ns-3.30/build'
Build commands will be stored in build/compile_commands.json
'build' finished successfully (1.762s)
atifcppprogrammer's post_lab_question
 1. Building our star topology
 2. Creating nodes for csma channel
 3. Defining attributes of csma channel
 4. Installing network cards for csma nodes
 5. Installing protocol stack on star and csma nodes
 6. Create node container for node 5 of star and node 9 of csma
 7. Installing additional network cards on p2p nodes
10. Assigning IP Address for star nodes
11. Assigning IP Address for p2p nodes
12. Creating OnOff and Hub Applications
13. Enabling static global routing
14. Running Simulation
At time 1.07829s on-off application sent 137 bytes to 10.3.1.4 port 50000 total Tx 137 bytes
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At time 1.07829s on-off application sent 137 bytes to 10.3.1.4 port 50000 total Tx 137 bytes
At time 1.08523s packet sink received 137 bytes from 10.1.2.2 port 49153 total Rx 137 bytes
At time 1.08553s packet sink received 137 bytes from 10.1.3.2 port 49153 total Rx 274 bytes
At time 1.08584s packet sink received 137 bytes from 10.1.4.2 port 49153 total Rx 411 bytes
At time 1.15657s on-off application sent 137 bytes to 10.3.1.4 port 50000 total Tx 274 bytes
At time 1.15657s on-off application sent 137 bytes to 10.3.1.4 port 50000 total Tx 274 bytes
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At time 1.15657s on-off application sent 137 bytes to 10.3.1.4 port 50000 total Tx 274 bytes
At time 1.16351s packet sink received 137 bytes from 10.1.2.2 port 49153 total Rx 548 bytes
At time 1.16382s packet sink received 137 bytes from 10.1.3.2 port 49153 total Rx 685 bytes
At time 1.16412s packet sink received 137 bytes from 10.1.4.2 port 49153 total Rx 822 bytes
At time 1.23486s on-off application sent 137 bytes to 10.3.1.4 port 50000 total Tx 411 bytes
At time 1.23486s on-off application sent 137 bytes to 10.3.1.4 port 50000 total Tx 411 bytes
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At time 1.23486s on-off application sent 137 bytes to 10.3.1.4 port 50000 total Tx 411 bytes
At time 1.2418s packet sink received 137 bytes from 10.1.2.2 port 49153 total Rx 959 bytes
At time 1.2421s packet sink received 137 bytes from 10.1.3.2 port 49153 total Rx 1096 bytes
At time 1.24241s packet sink received 137 bytes from 10.1.4.2 port 49153 total Rx 1233 bytes
At time 1.31314s on-off application sent 137 bytes to 10.3.1.4 port 50000 total Tx 548 bytes
At time 1.31314s on-off application sent 137 bytes to 10.3.1.4 port 50000 total Tx 548 bytes
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At time 1.31314s on-off application sent 137 bytes to 10.3.1.4 port 50000 total Tx 548 bytes
```

Figure 5: postLabQuestion.cc