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ns-3 Tutorial (Part III)

Hands-On:

Point-to-point and CSMA - Ethernet

WLAN 2013

Time Table

- ▶ 09:00 - 10:15 ns-3 Introduction & Installation
- ▶ 10:15 - 10.30 Break
- ▶ 10:30 - 12:00 Hands-On:
Point-to-point and CSMA (Ethernet)
- ▶ 12:00 - 13:00 Lunch
- ▶ 13:00 - 14:15 Hands-On:
Wireless & Tracing System and Visualizing Results
- ▶ 14:15 - 14:30 Break
- ▶ 14:30 - 15:30 Demonstation:
ns-3 protocol stack modification
- ▶ 15:30 - 16:00 Q&A

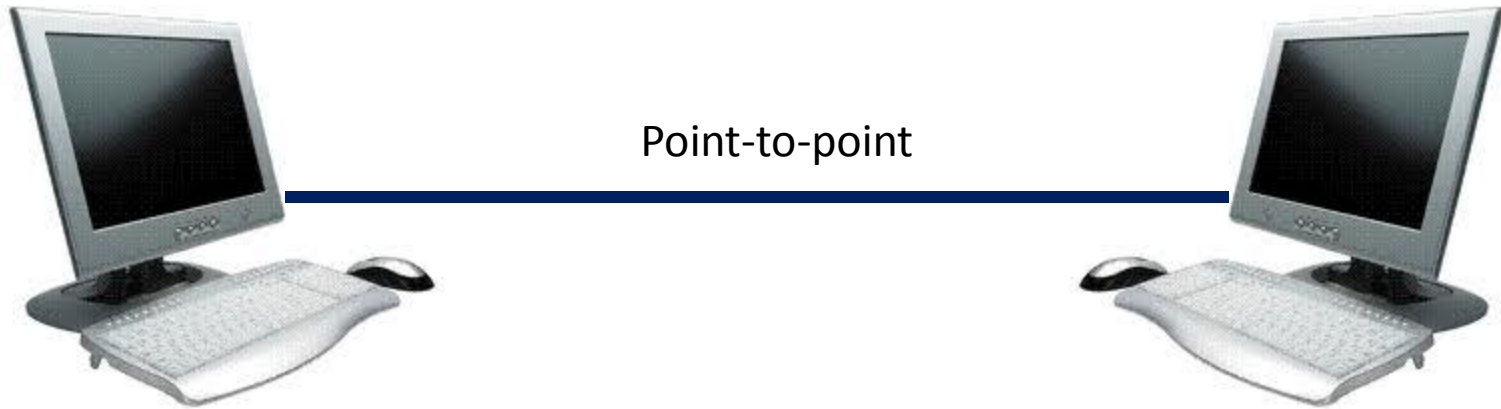
Exploring the directories

```
anan@AP-Moose:~/tarballs/ns-allinone-3.10/ns-3.10$ ls
AUTHORS      examples      ns3           src           VERSION      wutils.py
bindings     LICENSE      README       test.py      waf          wutils.pyc
build        #log.out#    RELEASE_NOTES testpy-output waf.bat
CHANGES.html log.out      samples      testpy.supp  waf-tools
doc          #myfirst.tr# scratch       utils        wscript
```

▶ cd examples/tutorial

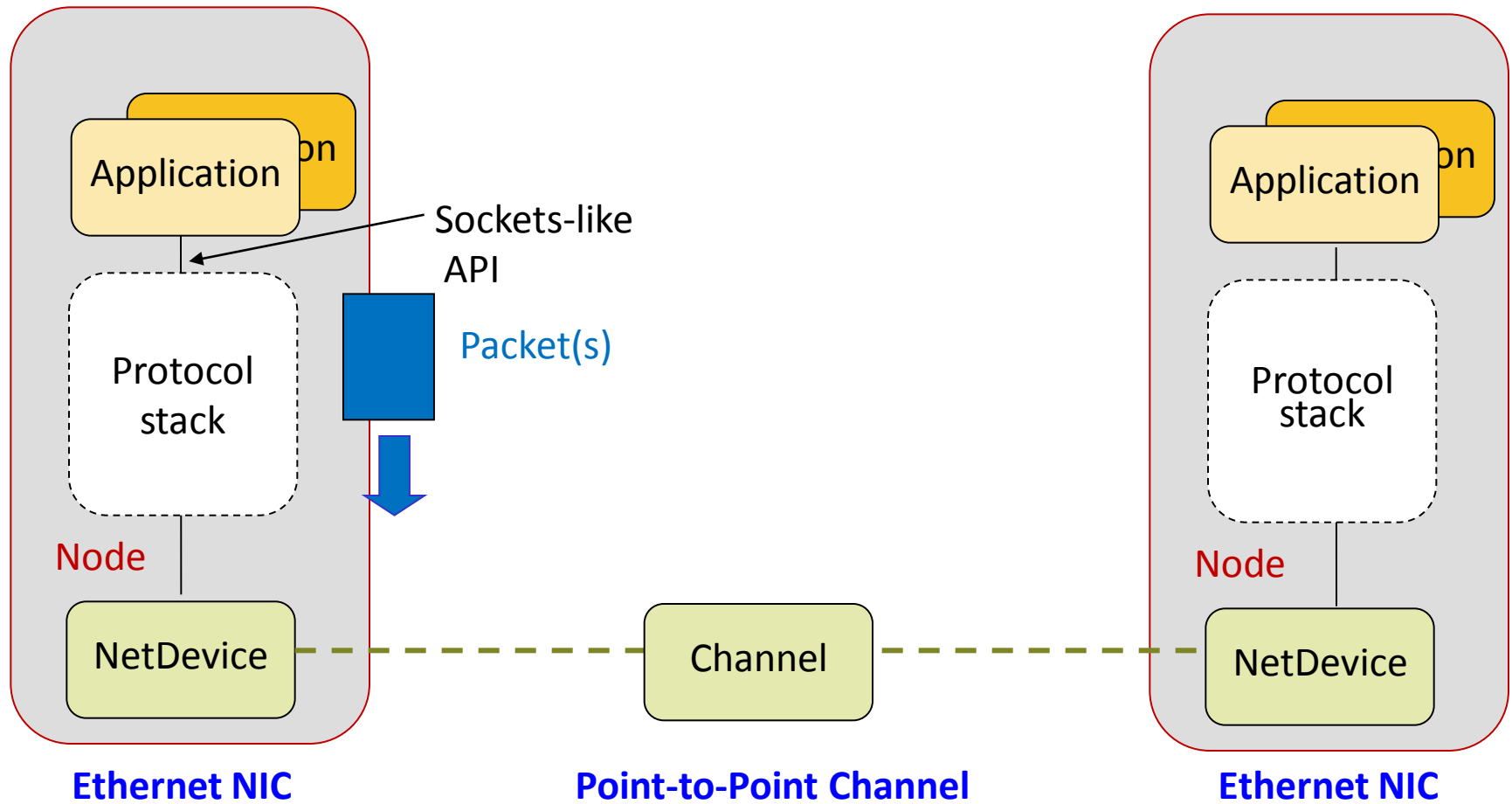
```
anan@AP-Moose:~/tarballs/ns-allinone-3.10/ns-3.10$ cd examples/tutorial/
anan@AP-Moose:~/tarballs/ns-allinone-3.10/ns-3.10/examples/tutorial$ ls
fifth.cc  first.py  hello-simulator.cc  sixth.cc  waf
first.cc  fourth.cc  second.cc           third.cc  wscript
```

Topology



Simple Example: first.cc

Topology in ns-3 (first.cc)



vi examples/tutorial/first.cc

emacs mode line: formatting conventions (coding style)

```
/* -*- Mode:C++; c-file-style:"gnu"; indent-tabs-mode:nil; -*- */
```

GNU General Public License

```
/*  
 * This program is free software; you can redistribute it and/or modify  
 * it under the terms of the GNU General Public License version 2 as  
 * published by the Free Software Foundation;  
 *  
 * This program is distributed in the hope that it will be useful,  
 * but WITHOUT ANY WARRANTY; without even the implied warranty of  
 * MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the  
 * GNU General Public License for more details.  
 *  
 * You should have received a copy of the GNU General Public License  
 * along with this program; if not, write to the Free Software  
 * Foundation, Inc., 59 Temple Place, Suite 330, Boston, MA 02111-1307  
 * USA  
 */
```



first.cc

Module Includes

```
#include "ns3/core-module.h"  
#include "ns3/simulator-module.h"  
#include "ns3/node-module.h"  
#include "ns3/helper-module.h"
```

C++ namespace called ns3

```
using namespace ns3;
```

Logging

```
NS_LOG_COMPONENT_DEFINE("FirstScriptExample");
```

first.cc

define a main function

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

enable two logging components

```
LogComponentEnable  
("UdpEchoClientApplication", LOG_LEVEL_INFO) ;  
  
LogComponentEnable  
("UdpEchoServerApplication", LOG_LEVEL_INFO) ;
```


NodeContainer

- ▶ Provides a convenient way
 - ▶ to create, manage and access any **Node objects**
- ▶ Stores pointer to those objects internally
- ▶ The nodes as they stand in the script do nothing
 - ▶ To construct a topology is to connect our nodes together into a network



Container picture from www.TheContainerMan.com

PointToPointHelper

- ▶ To **construct a point-to-point link**
- ▶ Perform the low-level work required to put the link together
- ▶ Typically these two things **NetDevice** and **Channel** are intimately tied together (cannot expect to interchange)
 - ▶ Ethernet devices and CSMA channels
 - ▶ Wifi devices and wireless channels



first.cc

create the ns-3 Node objects

```
NodeContainer nodes;  
nodes.Create (2);
```

instantiates a PointToPointHelper object on the stack

```
PointToPointHelper pointToPoint;
```

as the "DataRate" when it creates a PointToPointNetDevice object

```
pointToPoint.SetDeviceAttribute ("DataRate",  
    StringValue ("5Mbps"));
```

as the "Delay" when it creates a PointToPointChannel object

```
pointToPoint.SetChannelAttribute ("Delay",  
    StringValue ("2ms"));
```

first.cc

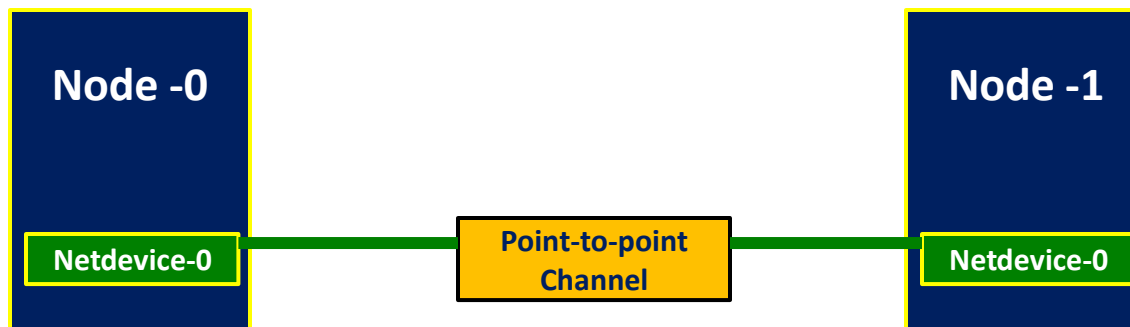
create the NetDevice objects

```
NetDeviceContainer devices;
```



Install NICs to Nodes and link Point-to-point

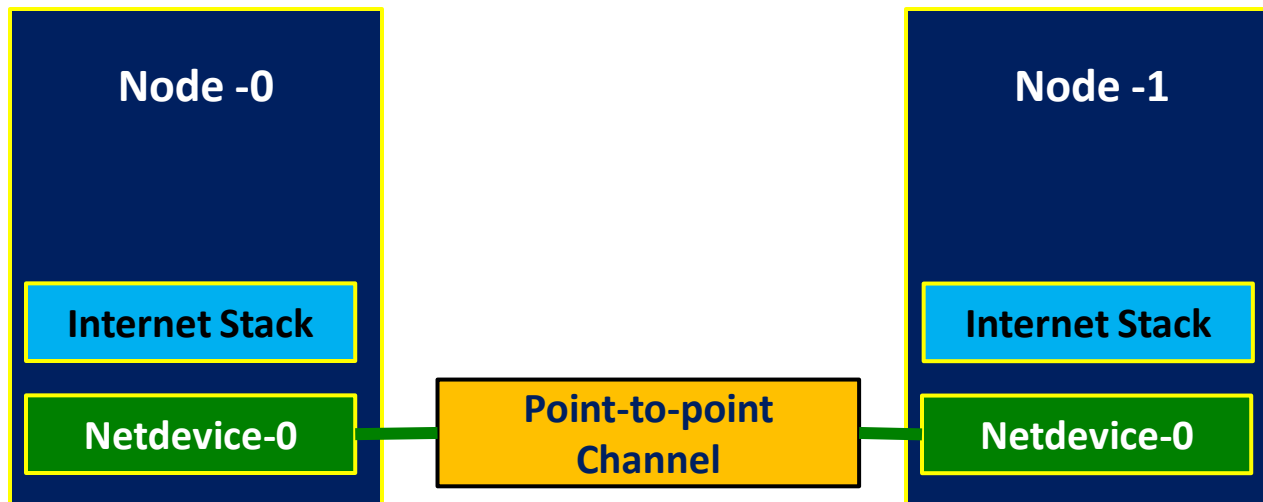
```
devices = pointToPoint::Install (nodes);
```



first.cc

install an Internet Stack
(TCP, UDP, IP, etc.) on each of the nodes in the node container

```
InternetStackHelper stack;  
stack.Install (nodes);
```



first.cc

to associate the devices on our nodes with IP addresses

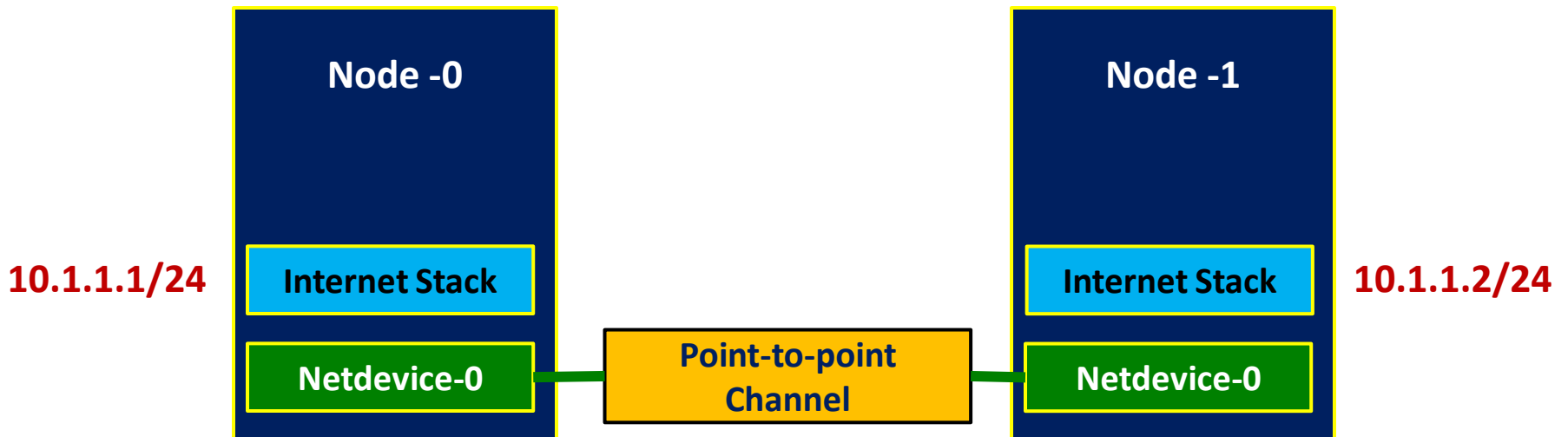
```
Ipv4AddressHelper address;  
address.SetBase ("10.1.1.0", "255.255.255.0");
```

- ▶ begin allocating IP addresses
 - ▶ from network 10.1.1.0 using the mask 255.255.255.0
 - ▶ In our case, 10.1.1.1/24 followed by 10.1.1.2/24

first.cc

performs the actual address assignment

```
Ipv4InterfaceContainer interfaces =  
    address.Assign (devices);
```



first.cc

set up a UDP echo server application

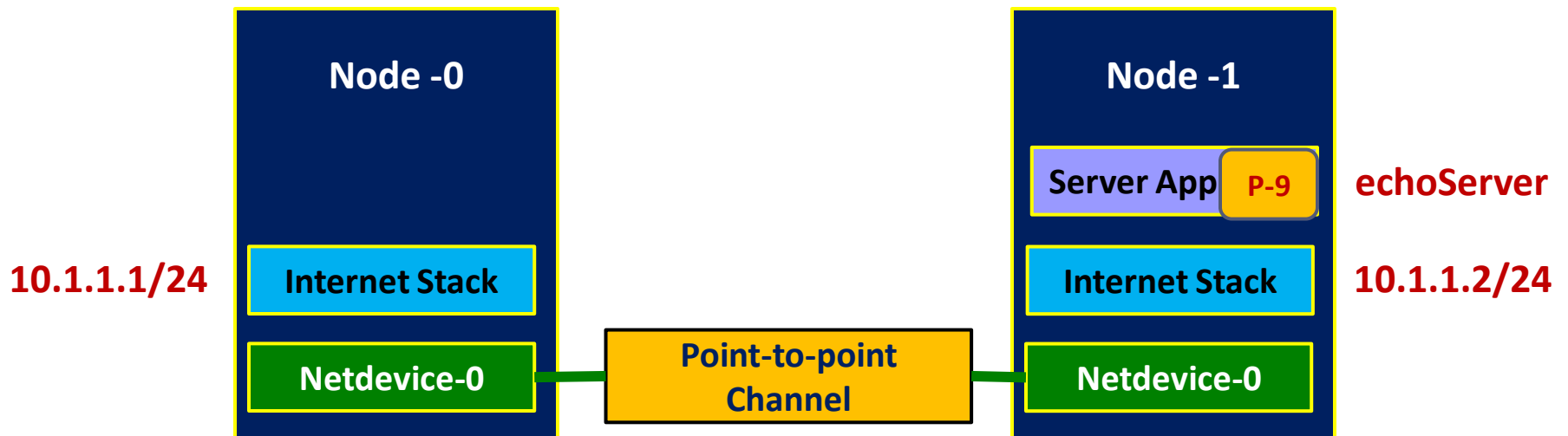
```
UdpEchoServerHelper echoServer (9) ;
```

- ▶ Set up a UDP **echo server application** on one of the nodes
- ▶ Require the **port number** as a parameter to the constructor

first.cc

install server application @node(1)

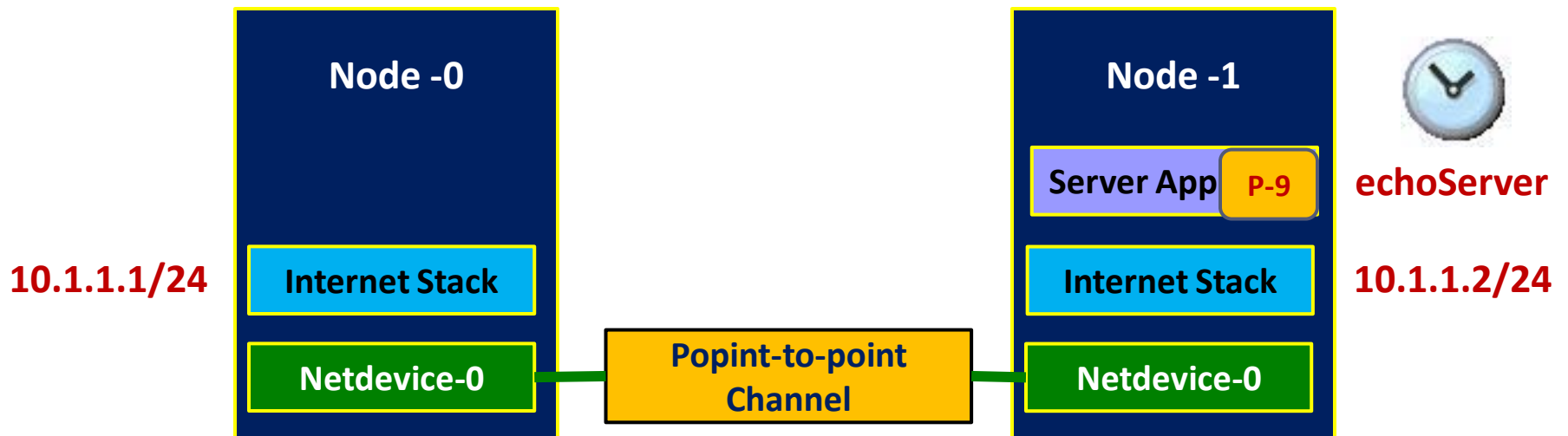
```
ApplicationContainer serverApps =  
    echoServer.Install (nodes.Get (1)) ;
```



first.cc

echo server application starts (enable itself) at 1 sec
and to Stop (disable itself) at 10 sec

```
serverApps.Start (Seconds (1.0));  
serverApps.Stop (Seconds (10.0));
```



first.cc

Set remote add and port

```
UdpEchoClientHelper echoClient (interfaces.GetAddress(1), 9);
```

- ▶ Pass parameters (to helper) to set the **Remote Address** and **Remote Port** for echoClient to connect
- ▶ Remote: 10.1.1.2, Port 9

Set echo Client's attributes

```
echoClient.SetAttribute("MaxPackets", UintegerValue(1));  
echoClient.SetAttribute("Interval", TimeValue (Seconds(1.)));  
echoClient.SetAttribute("PacketSize", UintegerValue(1024));
```

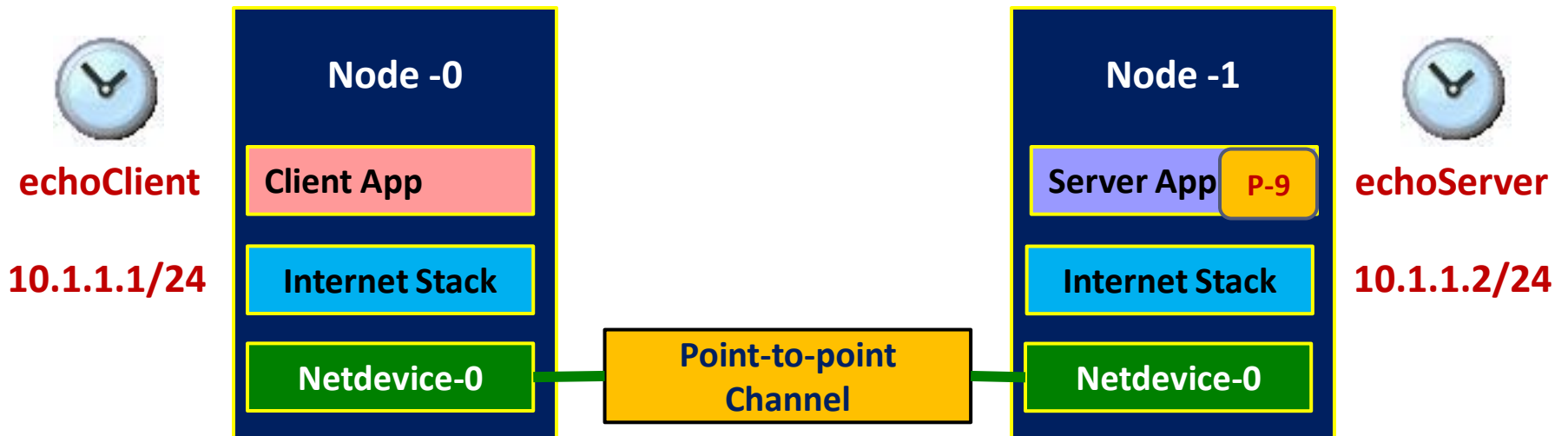
first.cc

install client application @node(0)

```
ApplicationContainer clientApps =  
    echoClient.Install (nodes.Get (0));
```

Set echo Client's attributes

```
clientApps.Start (Seconds (2.0));  
clientApps.Stop (Seconds (10.0));
```



first.cc

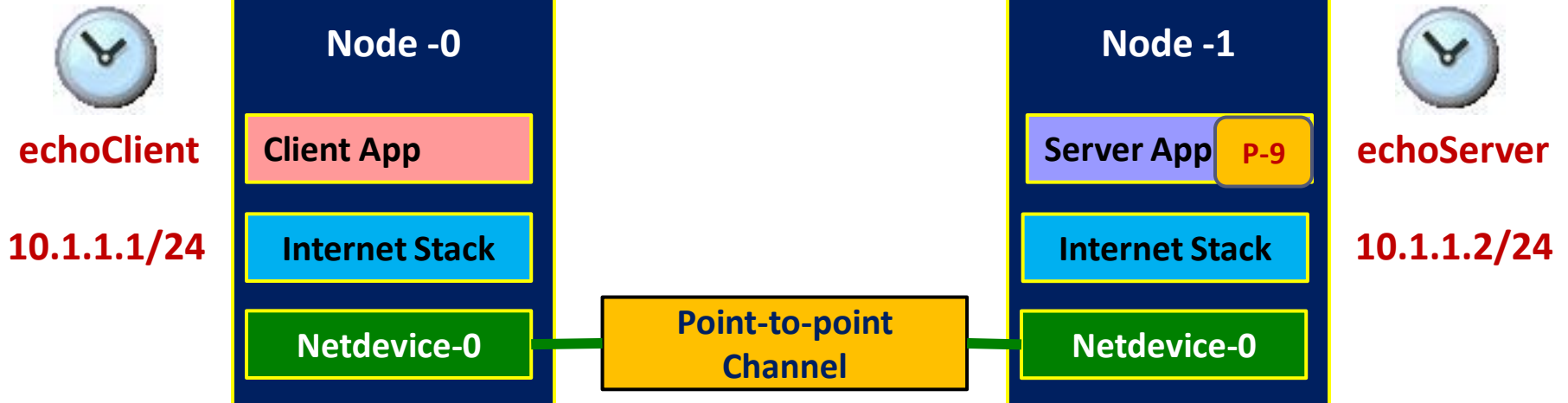
to actually run the simulation

```
Simulator::Run ();
```

to clean up

```
Simulator::Destroy ();  
return 0;
```

```
}
```



Classes

- ▶ Container
 - ▶ NodeContainer
 - ▶ NetDeviceContainer
 - ▶ Ipv4InterfaceContainer
 - ▶ ApplicationContainer
- ▶ Helper
 - ▶ PointToPointHelper
 - ▶ InternetStackHelper
 - ▶ Ipv4AddressHelper
 - ▶ UdpEchoServerHelper
 - ▶ UdpEchoClientHelper

Building and Running Your Script

- ▶ Copy `examples/tutorial/first.cc` into the `scratch` directory
 - ▶ `cp examples/tutorial/first.cc scratch/myfirst.cc`
- ▶ Now build your script using **waf**
 - ▶ `./waf`
- ▶ Run it out of the `scratch` directory
 - ▶ `./waf --run scratch/myfirst`
- ▶ Output

```
Waf: Entering directory `/home/anan/tarballs/ns-allinone-3.10/ns-3.10/build'  
[ 568/1204] cxx: scratch/myfirst.cc -> build/debug/scratch/myfirst_3.o  
[1204/1204] cxx_link: build/debug/scratch/myfirst_3.o -> build/debug/scratch/myfirst  
Waf: Leaving directory `/home/anan/tarballs/ns-allinone-3.10/ns-3.10/build'  
'build' finished successfully (8.591s)
```

Sent 1024 bytes to 10.1.1.2

Received 1024 bytes from 10.1.1.1

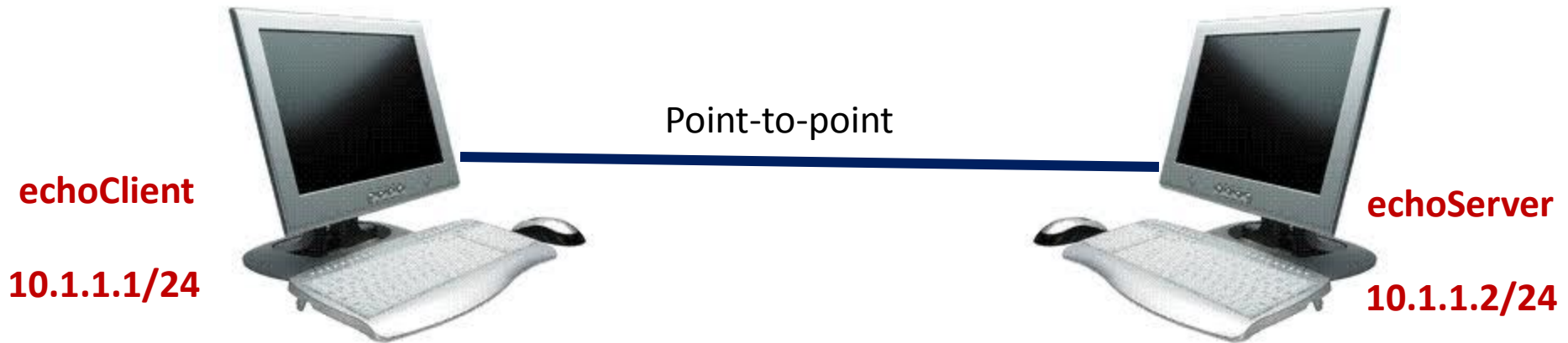
Received 1024 bytes from 10.1.1.2

output

Sent 1024 bytes to 10.1.1.2

Received 1024 bytes from 10.1.1.1

Received 1024 bytes from 10.1.1.2



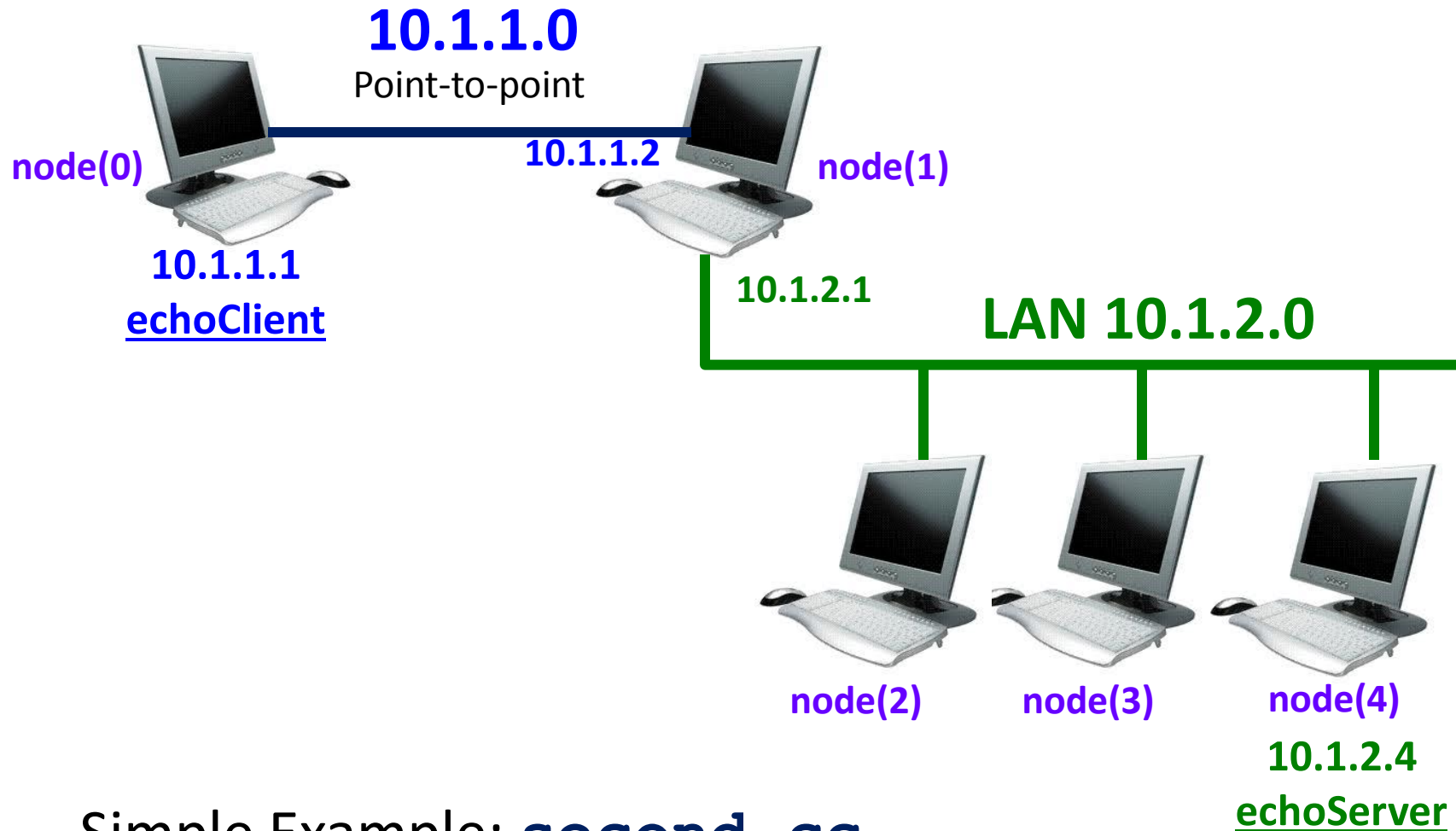
Logging

- ▶ Adding log in the code before creating nodes
 - ▶ `NS_LOG_INFO ("WLAN Class KU 2013");`
- ▶ `./waf`
- ▶ `export NS_LOG=`
- ▶ `./waf --run scratch/myfirst`

- ▶ `export NS_LOG=FirstScriptExample=info`
- ▶ `./waf --run scratch/myfirst`

Move on ...

Building a Bus Network Topology



Simple Example: **second.cc**

second.cc

```
using namespace ns3;

NS_LOG_COMPONENT_DEFINE ("SecondScriptExample");

int
main (int argc, char *argv[])
{
    bool verbose = true;
    uint32_t nCsma = 3;

    CommandLine cmd;
    cmd.AddValue ("nCsma", "Number of \"extra\" CSMA nodes/devices", nCsma);
    cmd.AddValue ("verbose", "Tell echo applications to log if true", verbose);

    cmd.Parse (argc,argv);

    if (verbose)
    {
        LogComponentEnable("UdpEchoClientApplication", LOG_LEVEL_INFO);
        LogComponentEnable("UdpEchoServerApplication", LOG_LEVEL_INFO);
    }
}
```

second.cc

```
nCsma = nCsma == 0 ? 1 : nCsma;
```

```
NodeContainer p2pNodes;  
p2pNodes.Create (2);
```

```
NodeContainer csmaNodes;  
csmaNodes.Add (p2pNodes.Get (1));  
csmaNodes.Create (nCsma);
```

```
PointToPointHelper pointToPoint;  
pointToPoint.SetDeviceAttribute ("DataRate", StringValue ("5Mbps"));  
pointToPoint.SetChannelAttribute ("Delay", StringValue ("2ms"));
```

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

second.cc

```
CsmaHelper csma;  
csma.SetChannelAttribute ("DataRate", StringValue ("100Mbps"));  
csma.SetChannelAttribute ("Delay", TimeValue (NanoSeconds (6560)));
```

```
NetDeviceContainer csmaDevices;  
csmaDevices = csma.Install (csmaNodes);
```

```
InternetStackHelper stack;  
stack.Install (p2pNodes.Get (0));  
stack.Install (csmaNodes);
```

```
Ipv4AddressHelper address;  
address.SetBase ("10.1.1.0", "255.255.255.0");  
Ipv4InterfaceContainer p2pInterfaces;  
p2pInterfaces = address.Assign (p2pDevices);
```

```
address.SetBase ("10.1.2.0", "255.255.255.0");  
Ipv4InterfaceContainer csmaInterfaces;  
csmaInterfaces = address.Assign (csmaDevices);
```

second.cc

```
UdpEchoServerHelper echoServer (9);
```

```
ApplicationContainer serverApps = echoServer.Install (csmaNodes.Get (nCsma));  
serverApps.Start (Seconds (1.0));  
serverApps.Stop (Seconds (10.0));
```

```
UdpEchoClientHelper echoClient (csmaInterfaces.GetAddress (nCsma), 9);  
echoClient.SetAttribute ("MaxPackets", UIntegerValue (1));  
echoClient.SetAttribute ("Interval", TimeValue (Seconds (1.)));  
echoClient.SetAttribute ("PacketSize", UIntegerValue (1024));
```

```
ApplicationContainer clientApps = echoClient.Install (p2pNodes.Get (0));  
clientApps.Start (Seconds (2.0));  
clientApps.Stop (Seconds (10.0));
```

second.cc

```
Ipv4GlobalRoutingHelper::PopulateRoutingTables ();
```

```
pointToPoint.EnablePcapAll ("second");
```

```
csma.EnablePcap ("second", csmaDevices.Get (1), true);
```

```
Simulator::Run ();
```

```
Simulator::Destroy ();
```

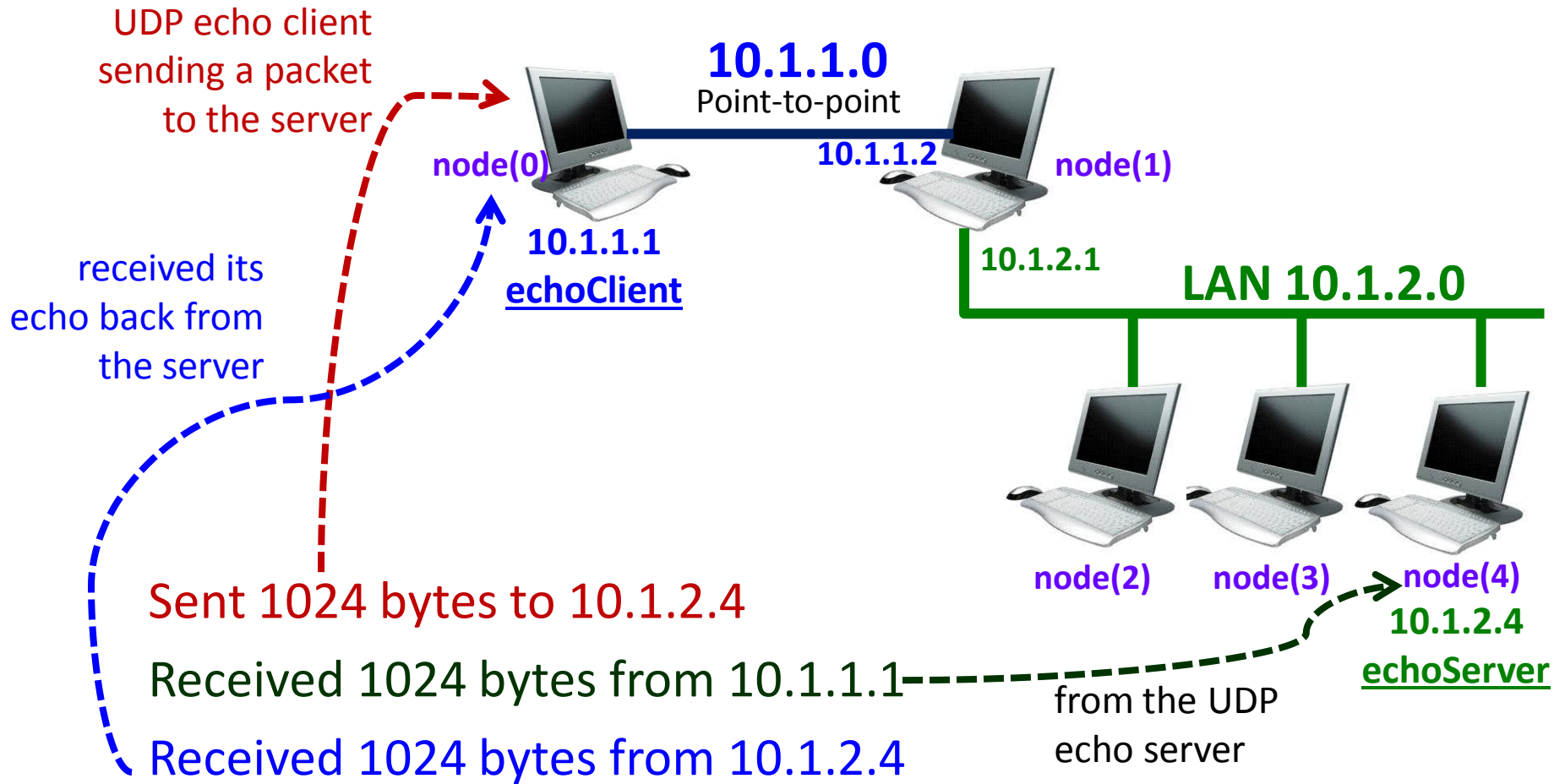
```
return 0;
```

```
}
```

Building and Running Your Script

- ▶ Copy `examples/tutorial/second.cc` into the `scratch` directory
 - ▶ `cp examples/tutorial/second.cc scratch/mysecond.cc`
- ▶ Now build your script using **waf**
 - ▶ `./waf`
- ▶ Run it out of the `scratch` directory
 - ▶ `./waf --run scratch/mysecond`

Output... mysecond

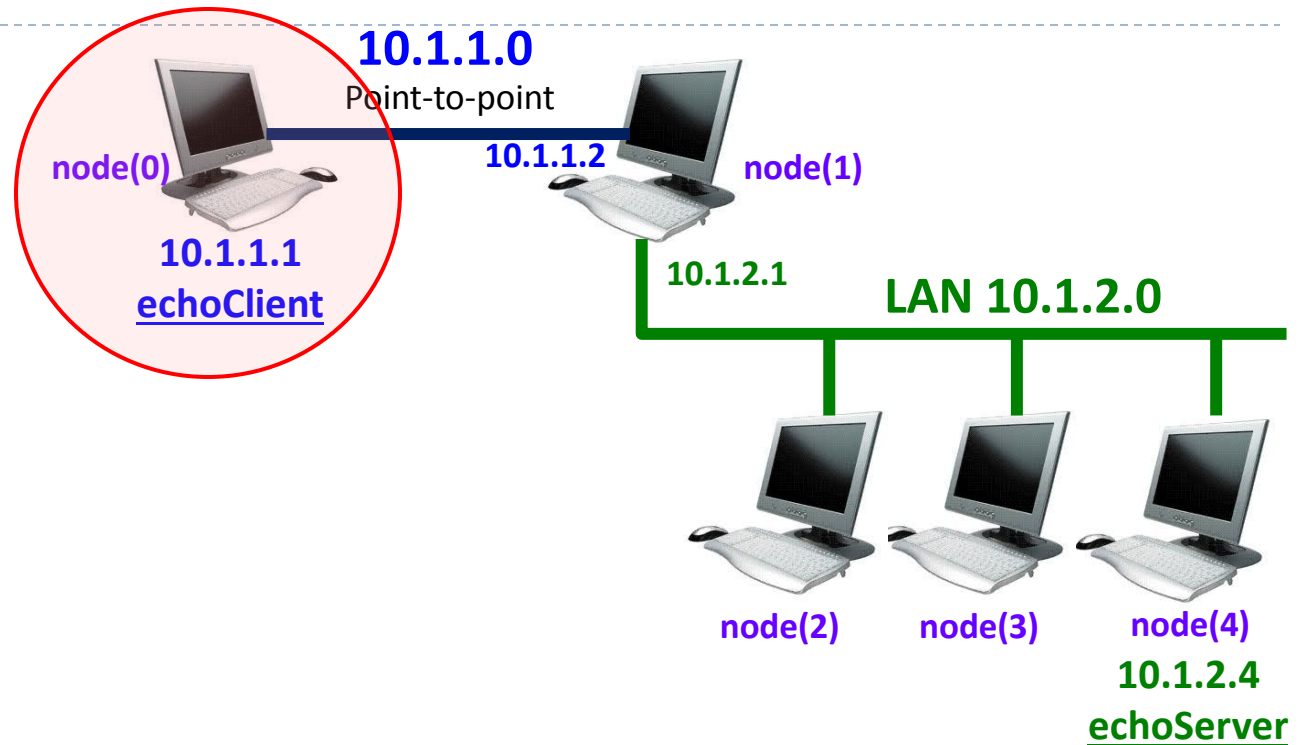


Pcap Output

```
pointToPoint.EnablePcapAll ("second");  
csma.EnablePcap ("second", csmaDevices.Get(1), true);
```

- ▶ top level directory
 - ▶ **second-0-0.pcap**
 - ▶ **second-1-0.pcap**
 - ▶ **second-2-0.pcap**

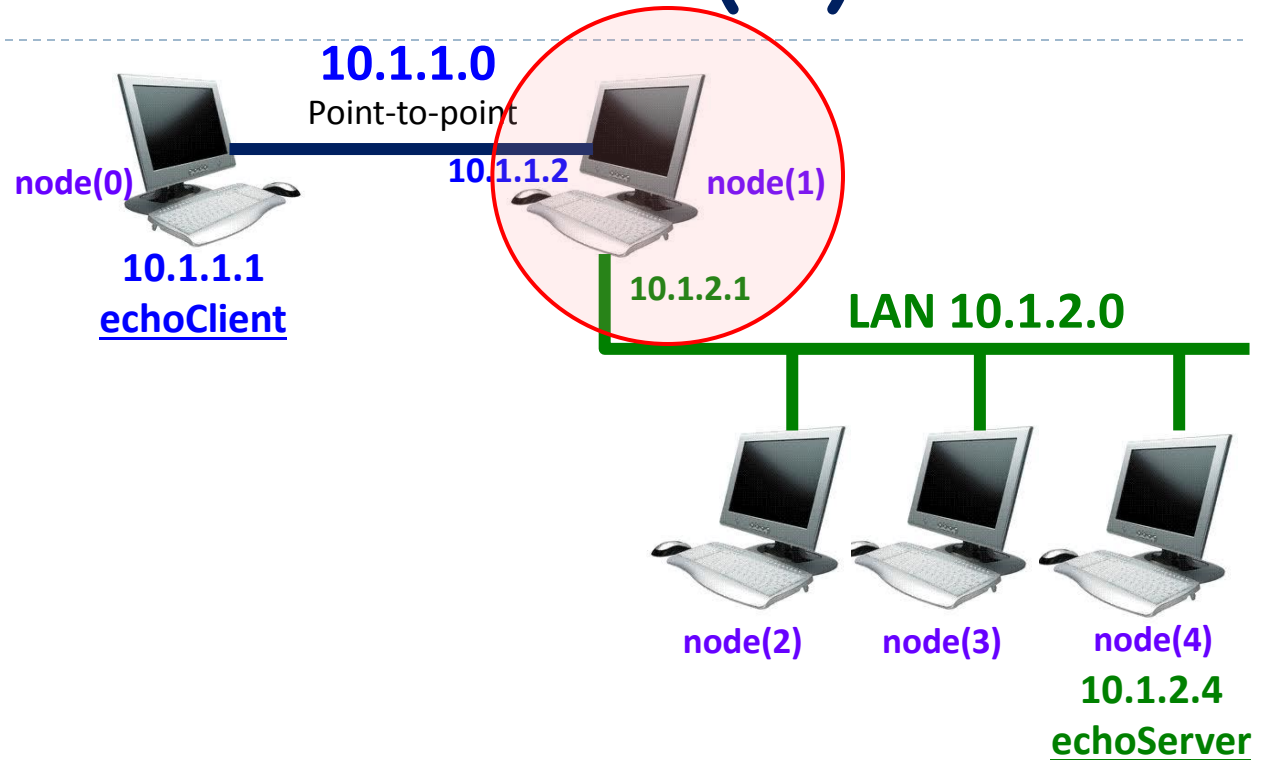
node (0) - netDevice (0)



▶ **tcpdump -nn -tt -r second-0-0.pcap**

```
reading from file second-0-0.pcap, link-type PPP (PPP)
2.000000 IP 10.1.1.1.49153 > 10.1.2.4.9: UDP, length 1024
2.007602 IP 10.1.2.4.9 > 10.1.1.1.49153: UDP, length 1024
```

node (1) - netDevice (0)



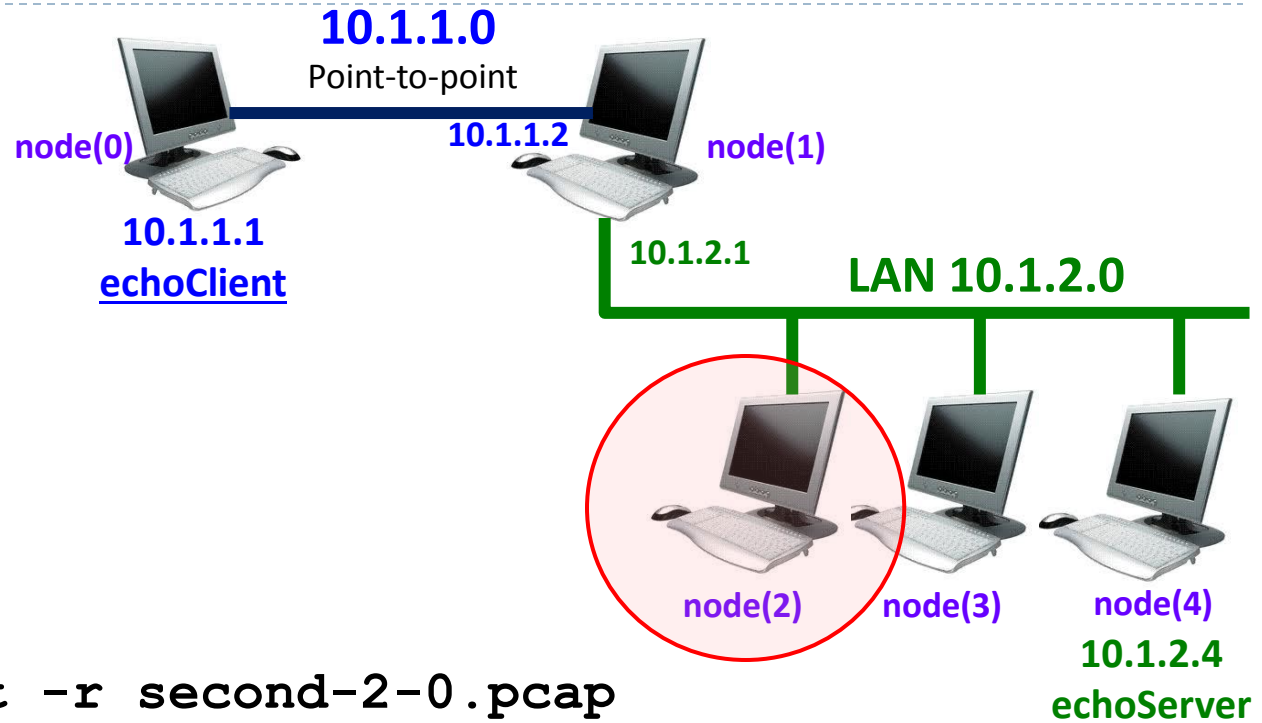
▶ **tcpdump -nn -tt -r second-1-0.pcap**

reading from file second-1-0.pcap, link-type PPP (PPP)

2.003686 IP 10.1.1.1.49153 > 10.1.2.4.9: UDP, length 1024

2.003915 IP 10.1.2.4.9 > 10.1.1.1.49153: UDP, length 1024

node (2) - netDevice (0)



▶ **tcpdump -nn -tt -r second-2-0.pcap**

```
reading from file second-2-0.pcap, link-type EN10MB (Ethernet)
2.003696 arp who-has 10.1.2.4 (ff:ff:ff:ff:ff:ff) tell 10.1.2.1
2.003707 arp reply 10.1.2.4 is-at 00:00:00:00:00:06
2.003801 IP 10.1.1.1.49153 > 10.1.2.4.9: UDP, length 1024
2.003811 arp who-has 10.1.2.1 (ff:ff:ff:ff:ff:ff) tell 10.1.2.4
2.003822 arp reply 10.1.2.1 is-at 00:00:00:00:00:03
2.003915 IP 10.1.2.4.9 > 10.1.1.1.49153: UDP, length 1024
```

More on second.cc

- ▶ `wireshark second-2-0.pcap`
- ▶ `./waf --run "scratch/mysecond -nCsma=50"`