NS3 Basics

CSE 322 - Computer Networking Sessional

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NS3 installation steps

- Version to be used - **3.39**

- https://www.nsnam.org/docs/release/3.39/installation/html/quick-start.html

- Follow the exact steps mentioned in the link. Install the **prerequisites** first.
- After following the steps, run the following command :

```
$ ./ns3 run hello-simulator
```

- If it outputs “Hello Simulator”, then it was installed correctly.

- *Some modules may not build due to missing dependency,* which won’t be a problem. You may solve this error by installing the missing dependencies if you wish.

- Python bindings are not required for this course.

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NS3 - A Network Simulator

- **Resources:**
  - **Official Website :** https://www.nsnam.org/
  - **Tutorial** : https://www.nsnam.org/docs/release/3.39/tutorial/ns-3-tutorial.pdf
    - Useful chapters : 5-9
  - **Models:** https://www.nsnam.org/docs/release/3.39/models/html/index.html
    - Description of models are provided here. Helpful for understanding the concepts.
  - **Doxygen API documentation:**
    - https://www.nsnam.org/docs/release/3.39/doxygen/index.html
  - **IDEs :** VSCode, Jetbrains CLion etc (Install the necessary plugins)
  - **Google group :** https://groups.google.com/g/ns-3-users

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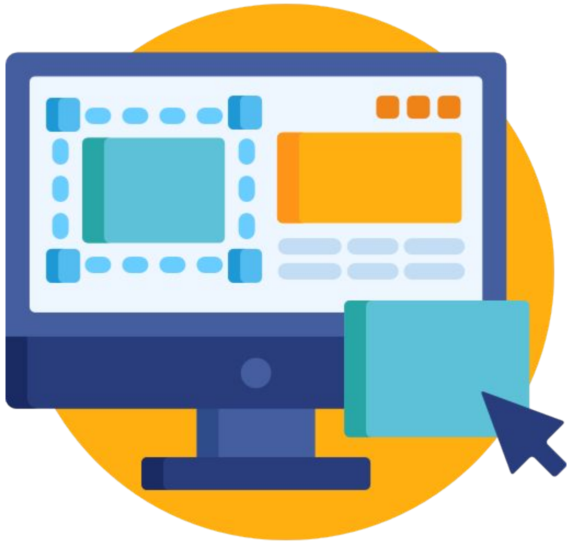
Conceptual Overview - Node

- A basic computing device abstraction, e.g : Computer
- A class defined in C++
- Purpose :
    - Adding functionality such as applications, protocol stacks, peripheral cards etc



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Conceptual Overview - Application

- Representation of user-level software applications
- A class defined in C++
- Purpose :
  - Runs on nodes to to run different types of simulations
- Examples:
  - *UDPEchoServer/ClientApplication, BulkSendApplication, OnOffApplication, PacketSinkApplication etc*
  - *built- in applications directory : src/application/models*

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Conceptual Overview - Channel

- Abstraction of the media through which data flows in the network
- Connect *Node* to a channel
- A class defined in C++
- Types :
  - CsmaChannel (Ethernet)
  - PointToPointChannel
  - WifiChannel

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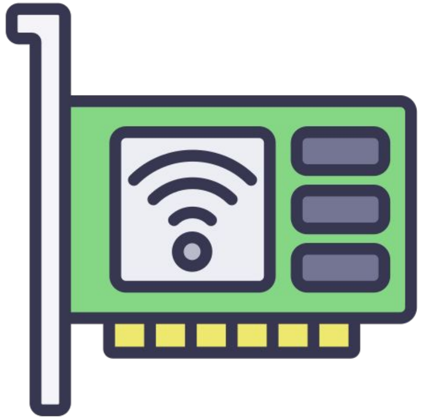
Conceptual Overview - Net Device

- Abstraction of both software driver and Network Interface Card used to connect a Node to a network
- A net device is “installed” in a *Node* to enable the *Node* to communicate with other Nodes via *Channels*.
- A *Node* may be connected to more than one *Channel* via multiple *NetDevices*.
- Types :
    - CsmaNetDevice (Ethernet)
    - PointToPointNetDevice
    - WifiNetDevice



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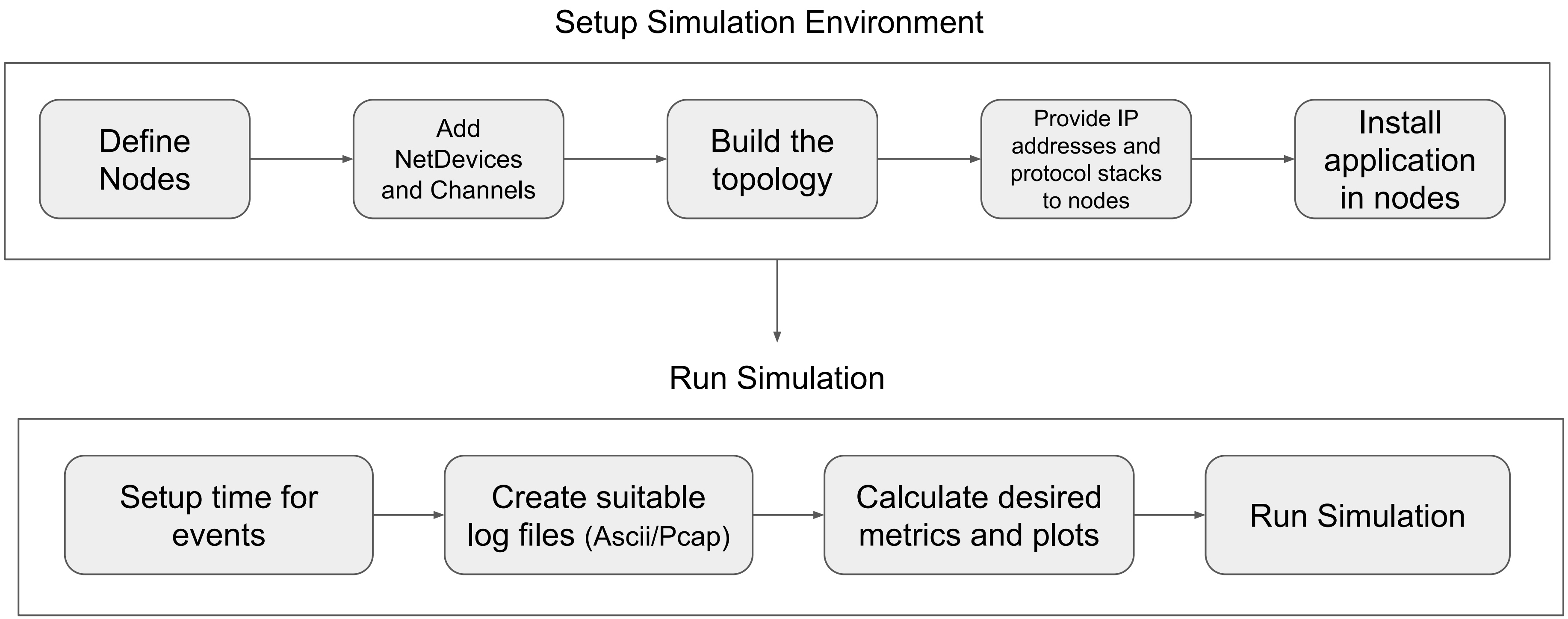
Conceptual Overview - Topology Helpers

In each simulation, simplify common tasks such as:

- Connecting Nodes to NetDevices
- Connecting NetDevices to Channels
- Assigning IP addresses etc.

Examples: PointToPointHelper, InternetStackHelper, UDPEchoServerHelper etc.

Simulation Overview


Setup Simulation Environment
Define Nodes
Add NetDevices and Channels
Build the topology
Provide IP addresses and protocol stacks to nodes
Install application in nodes
Run Simulation
Setup time for events
Create suitable log files (Ascii/Pcap)
Calculate desired metrics and plots
Run Simulation

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Run first.cc

- cp examples/tutorial/first.cc scratch/first.cc
- ./ns3 build
- ./ns3 run scratch/first

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When the simulator will stop?

- No further events are in the event queue.
- A special Stop event is found.
  - Simulator::Stop(stopTime)
  - Necessary when there are recurring events (WiFi)
  - *Important to call Simulator::Stop before calling Simulator::Run*

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Logging Overview

Log Type	Purpose	Macro
LOG_ERROR	error messages	NS_LOG_ERROR
LOG_WARN	warning messages	NS_LOG_WARN
LOG_DEBUG	relatively rare, ad-hoc debugging messages	NS_LOG_DEBUG
LOG_INFO	informational messages about program progress	NS_LOG_INFO
LOG_FUNCTION	a message describing each function called	NS_LOG_FUNCTION - member func. NS_LOG_FUNCTION_NOARGS - static func.
LOG_LOGIC	messages describing logical flow within a function	NS_LOG_LOGIC
LOG_ALL	Log everything mentioned above	no associated macro

Logging Overview

- **LOG_LEVEL_TYPE:** Enables logging of all the levels above it.
    - **Ex : LOG_LEVEL_INFO :** Enable logging for ERROR, WARN, DEBUG, INFO types.
- **NS_LOG_UNCOND** – Log the associated message unconditionally (no associated log level).

Logging Overview

- Using the shell environment variable -> NS_LOG
  - increase the logging level without changing the script
    - export NS_LOG=UdpEchoClientApplication=level_all
  - Distinguish which method generates a log message - ORing
    - export 'NS_LOG=UdpEchoClientApplication=level_all|prefix_func'
  - Enable two logging components together - Colon separated
    - export 'NS_LOG=UdpEchoClientApplication=level_all|prefix_func:UdpEchoServerApplication=level_all|prefix_func'
  - See the simulation time
    - export 'NS_LOG=UdpEchoClientApplication=level_all|prefix_func|prefix_time:UdpEchoServerApplication=level_all|prefix_func|prefix_time'
  - Print all logging information
    - export 'NS_LOG=*=level_all|prefix_func|prefix_time'
    - ./ns3 run scratch/myfirst > log.out 2>&1

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Logging Overview

- Turn off logging previously enabled
  - export NS_LOG=""
- Enable logging in code
  - export NS_LOG=FirstScriptExample=info

Using Command Line Arguments

- Declare command line parser.

- Show general arguments for a program.
  - ./ns3 run "scratch/first --PrintHelp"

- Provide new command line argument
  - ./ns3 run "scratch/first --ns3::PointToPointNetDevice::DataRate=32Kbps"

- Provide multiple command line arguments
  - ./ns3 run "scratch/myfirst --ns3::PointToPointNetDevice::DataRate=32Kbps --ns3::PointToPointChannel::Delay=2ms"

- Add your own values with AddValue function

ASCII Tracing

+	An enqueue operation occurred on the device queue
-	A dequeue operation occurred on the device queue
d	A packet was dropped, typically because the queue was full
r	A packet was received by the netdevice

ASCII Tracing

+	Enqueue
2	Time (Seconds)
/NodeList/0/DeviceList/0/$ns3::PointToPointNetDevice/TxQueue/Enqueue	Trace source origin
ns3::PppHeader (Point-to-Point Protocol: IP (0x0021)) ns3::Ipv4Header (tos 0x0 DSCP Default ECN Not-ECT ttl 64 id 0 protocol 17 offset (bytes) 0 flags [none] length: 1052 10.1.1.1 > 10.1.1.2) ns3::UdpHeader (length: 1032 49153 > 9) Payload (size=1024)	Packet information

Pcap Tracing

- Wireshark
- Tcpdump
  - tcpdump -nn -tt -r filename.pcap

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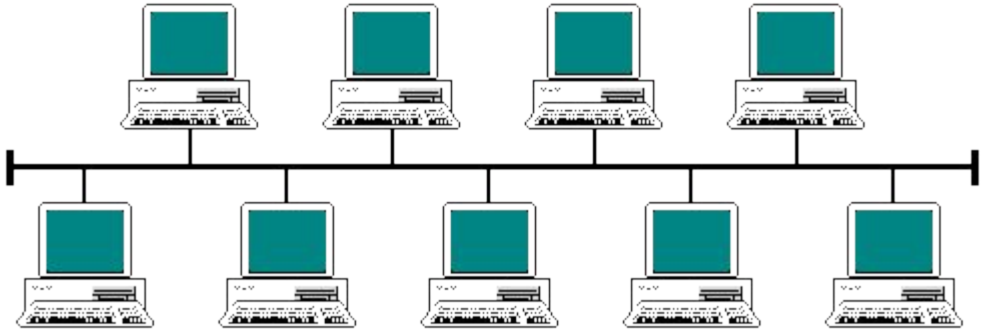
Ethernet (Bus Network)



- CSMA NetDevice and channel
- Promiscuous mode - allows a network device to intercept and read each packet.
- ARP (Address Resolution Protocol) - retrieves the receiver’s MAC address.

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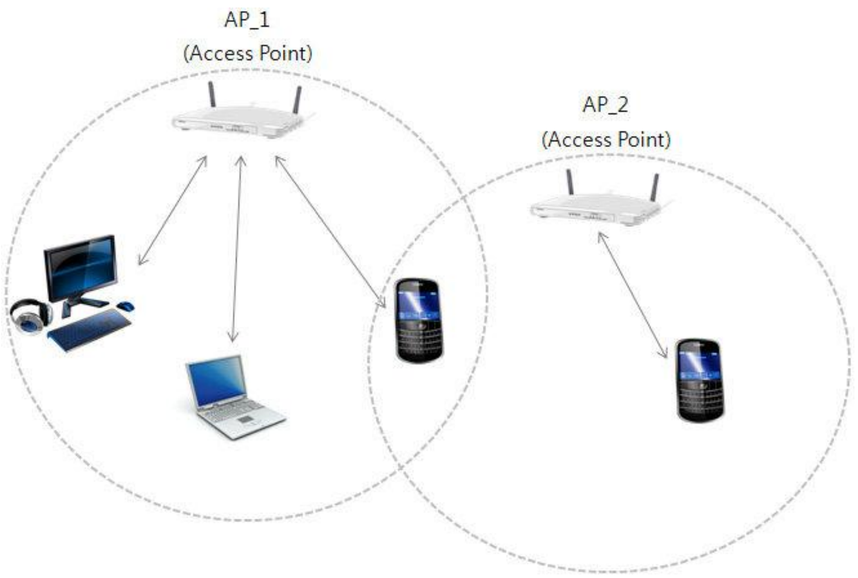
Wireless Network

- AP - Access Point
- AP generates beacons continuously
- Beacon - regular transmissions from access points (APs)
  - purpose to inform user devices (clients) about available Wi-Fi services and near-by access points



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Tracing

Trace Source	Trace Sink
signal events that happen in a simulation & provide access to underlying data	consume trace information
Signals when a state change happens in a model	Can be more than one sink for a trace source
Ex: the congestion window of a TCP model, when a packet is received by a netdevice and give access to the underlying packet contents	Ex: A function that outputs the new and old congestion window or increases the received packet count

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AddTraceSource

Parameters	Description
name	Name of the trace source
Help string	Comment
MakeTraceSourceAccessor	TracedVariable name
Typedef of the callback signature	Provides a string which is a typedef specified for the callback signature

Callbacks

- **Trace sinks** are **callbacks**
- Each **trace source** has a list for callbacks.
- When a trace sink expresses interest in receiving trace events, it **adds** itself as a Callback to the list of Callbacks internally held by the trace source.
- When an interesting event happens, the trace source makes an indirect call to all the **callbacks of its list.** (possible by overriding assignment operator)
- Resource : ns3 Manual -> Callbacks
  - https://www.nsnam.org/docs/manual/html/callbacks.html

Connecting Trace Source to sink

- **TraceConnect**
    - The object makes the call itself
    - Parameters -
        - Name of the trace source
        - Trace sink
    - Ex : fourth.cc
      -myObject->TraceConnectWithoutContext("MyInteger",MakeCallback(&IntTrace));
    - Context - path to the trace source

- **Config::Connect**
    - Parameters -
        - path to the trace source
        - the trace sink
    - Ex: third.cc : Config::Connect(oss.str(), MakeCallback(&CourseChange));

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Config

- **Config::Connect**
  - Path to the trace source : last segment of the path must be a trace source of an object.
  - If an object has the same trace source, we can interchange between config and trace connect.
    - For example : as CourseChange is a trace source of a MobilityModel, so the two codes are same (As a mobility model is added to the node, we can access the trace source from the node too):

      -
        ```
        Ptr<Object> theObject = wifiStaNodes.Get(nWifi - 1);
        theObject->TraceConnectWithoutContext("CourseChange", MakeCallback(&CourseChange));
        ```

      -
        ```
        std::ostringstream oss;
        oss << "/NodeList/"<< wifiStaNodes.Get(nWifi - 1)->GetId()<</$ns3::MobilityModel/CourseChange";
        Config::Connect(oss.str(), MakeCallback(&CourseChange));
        ```
  - **Config::ConnectWithoutContext** and **Config::Connect** actually find a **Ptr<Object>** and call the appropriate **TraceConnect** method at the lowest level.

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Steps of using trace sources

1. **Finding available trace sources**
   - Resource : https://www.nsnam.org/doxygen/de/de5/_trace_source_list.html

2. **Figure out the Config path**
   - API Documentation -> Model -> Detailed Description -> Config Paths
   - find . -name '*.cc' | xargs grep trace_source_name | grep Connect

3. **Callback signatures**
   - Model -> trace sources -> callback signature
   - **Arguments :** parameter list of the TracedCallBack<> declaration
   - Return parameter : Normally void

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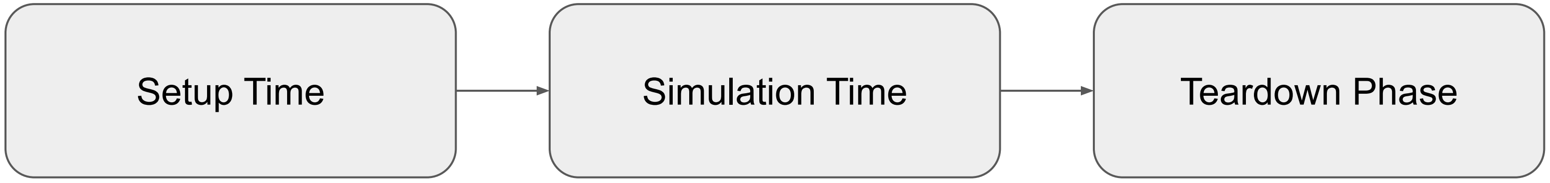
Execution Phases



Before Simulator::Run()

During Simulator::Run()

After Simulator::Run()

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Running fifth.cc

- ./ns3 run fifth > scratch/cwnd.dat 2>&1

- **Gnuplot**
  - gnuplot> set terminal png size 640,480
  - gnuplot> set output "cwnd.png"
  - gnuplot> plot "cwnd.dat" using 1:2 title 'Congestion Window' with linespoints
  - gnuplot> exit

Adding a new module

- https://www.nsnam.org/docs/manual/html/new-models.html
- https://www.nsnam.org/docs/manual/html/new-modules.html
- Add your .h, .cc files in the model directory of the necessary folder
- Add the filenames in the CMakeList.txt
- Run /.test.py to check if everything is okay