Mobile Wireless Networking
The University of Kansas EECS 882
Introduction to Network Simulation with ns-3

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http://www.ittc.ku.edu/~jpngs/courses/mwnets
Network Simulation with ns-3

Outline

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NS.2 ns-3 installation and use
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Network Simulation with ns-3
Motivation and Overview

NS.1 Motivation and overview
NS.2 ns-3 installation and use
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Motivation and Overview

Network Analysis Techniques

- Analytical analysis
  - mathematical analysis/modeling of systems (e.g. RTT calc.)
- Simulation
  - model the system at abstract level via software
  - various network simulators exist (e.g. ns-3, OPNET, OMNet)
- Emulation
  - HW component that behave like real system (e.g. ONL)
- Measurement
  - active (e.g. ping, traceroute) or passive (e.g. Wireshark)
- Experimentation
  - experiment on a testbed (e.g. GpENI)
Motivation and Overview

Network Simulation

- **Goal**
  - build software *simulation model* of system
  - to analyze/study/improve/develop network protocols
- **Reason**
  - real systems are expensive, complex, unavailable
- **Advantages**
  - relatively easy and less time consuming
- **Disadvantages**
  - simplified view of complex interactions
  - could be immensely misleading
    - dependence on assumptions and model
Motivation and Overview
Simplified Network Simulation Flowchart

- Define topology, protocols, models
- Specify initial values
- Process output/trace files
- Plot throughput, goodput, delay etc.
- Are results expected?
- Confidence level attained?
Motivation and Overview
ns-3 Highlights and History

- ns-3 is a discrete-event network simulator for:
  - Internet systems
    - emphasis on layer 1.5 – 4
  - targeted for research and education
  - aims to replace venerable ns-2 simulator

- Community-oriented open source development
  - integration of open source tools/software
    - e.g. Wireshark, tcpdump

- First release in June 2008
  - latest release (ns-3.24) on 15 September 2015
  - planned for new releases every 3 – 4 months
Motivation and Overview
Architecture, Protocols, Models of ns-3

• ns-3 software architecture is built on C++
  – Python for front-end (e.g. scripting, visualization)

• Some protocols/models include:
  – socket like API, on/off application
  – TCP, TCP stack emulation (Linux, BSD), UDP
  – IPv4, IPv6 support, Static routing (Dijkstra)
  – MANET routing: OLSR, AODV, DSDV¹, DSR²
    • ¹ Hemanth Narra & ² Yufei Cheng supervised by Dr. Sterbenz
  – IEEE 802.11 and variants, WiMAX, LTE, PPP
  – IEEE 802 physical layers, Rayleigh fading channel
  – mobility models: Random direction, RW, RWP, 3D GMM*
    • * developed by Dan Broyles under supervision of Dr. Sterbenz
Network Simulation with ns-3
ns-3 Installation and Use

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ns-3 Installation and Use

Installation Overview

- ns-3 can be installed on common platforms
  - desktop & servers – 32 bit & 64 bit architectures
  - any major OS: Linux, Mac OS, Windows
    - Windows requires Cygwin
    - we do not support ns-3 in Cygwin, use virtual machine instead
  - detailed instructions

- Installation includes following steps:
  - download
  - build
  - validation
ns-3 Installation and Use

Installation Steps Using waf

• Download ns-3 package, unzip and untar it
  – http://www.nsnam.org/releases/
  – tar -jxf ns-3.x.tar.bz2

• Check the system for prerequisites and build
  – change directory to ns-3.x
  – ./waf -d debug configure
  – ./waf

• Validate build by running tests
  – ./test.py -c core
ns-3 Installation and Use

Installation Notes

- At the end of installation run following and verify:
  - ./waf --run hello-simulator
  - Hello Simulator

- Source code can be downloaded from a repository
  - Mercurial

- There are other methods of building the ns-3
  - using Python script to install downloaded source code

- If you need to uninstall ns-3 package
  - rm -rf ns-3.x
  - where ns-3.x is the directory
ns-3 Installation and Use

Usage Overview

• Decide what you want to simulate
  – define the topology
  – create nodes, channel, network interfaces
  – configure Internet stack and applications
  – set attributes

• Build the simulation script using a text editor
  – e.g. emacs, vi, textpad

• Execute the .cc program via waf

• Analyze output

• Good documentation always helps!
ns-3 Installation and Use
Abstractions

- Simulations performed on an abstract model
- Abstracts represented in C++ by classes
- Classes provide methods to manage representations
- Key objects in ns-3
  - node
  - application
  - channel
  - net device
  - topology helpers
ns-3 Installation and Use

Script Structure

• C++ scripts include the following structure
  – boilerplate: important for documentation
  – module includes: include header files
  – ns-3 namespace: global declaration
  – logging: optional
  – main function: declare main function
  – topology helpers: objects to combine distinct operations
  – applications: on/off application, UdpEchoClient/Server
  – tracing: .tr and/or .pcap files
  – simulator: start/end simulator, cleanup
ns-3 Installation and Use

waf

- waf is a general purpose build system to:
  - configure
  - compile
  - install
- Instead of ./configure;make type ./waf
- waf is Python based
- More information can be found on
  - http://code.google.com/p/waf/
ns-3 Installation and Use

Post-Processing

• Once the simulations are over process trace files
• Trace files can be filtered via a script
  – e.g. Python, Perl
• Filtered results can be processed via a plotting tool
  – gnuplot
  – gpwrapper (developed by Abdul Jabbar at KU)
• Output files in .pcap format is possible
  – Wireshark or tcpdump can be used to view .pcap files
• Logs can be enabled to analyze output
• ns-3 package built-in tools for post-processing
  – statistical framework, flow monitor
ns-3 Installation and Use
Troubleshooting

- Internal workings can be viewed by log output
  - export 'NS_LOG=*=level_all|prefix_func|prefix_time'
  - ./waf --run scratch/first >& log.out

- For C++ you can use gdb tool for debugging
  - ./waf -shell
  - gdb ./build/debug/scratch/my-app

- Memory debugging via valgrind tool
  - ./waf --valgrind --regression
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Network Simulation Example

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Network Simulation Example

Network Simulation Setup

- Two nodes, one network interface device per node
- Point-to-point link
  - transmission delay: 2 ms, data rate: 5 Mbps
- Application
  - UdpEchoClient on node 0, UdpEchoServer on node 1
  - payload size of 1024-byte packet
  - time interval between packets is 1 s

Point-to-point link
IP block: 10.1.1.0/24
Network Simulation Example

First.cc Script

- **Main function**
  - int main (int argc, char *argv[]) {
- **NodeContainer class, create method**
  - NodeContainer nodes;
  - nodes.Create (2);
- **PointToPoint helper, set link attributes**
  - PointToPointHelper pointToPoint;
  - pointToPoint.SetDeviceAttribute ("DataRate", StringValue ("5Mbps"));
  - pointToPoint.SetChannelAttribute ("Delay", StringValue ("2ms"));
Network Simulation Example

First.cc Script²

- **NetDevice container**
  - NetDeviceContainer devices;
  - devices = pointToPoint.Install (nodes);

- **InternetStackHelper**
  - InternetStackHelper stack;
  - stack.Install (nodes);

- **Ipv4AddressHelper**
  - Ipv4AddressHelper address;
  - address.SetBase ("10.1.1.0", "255.255.255.0");
  - Ipv4InterfaceContainer interfaces = address.Assign (devices);
Network Simulation Example
First.cc Script

• Application
  – UdpEchoServerHelper echoServer (9);
  – ApplicationContainer serverApps = echoServer.Install (nodes.Get (1));
  – serverApps.Start (Seconds (1.0));
  – serverApps.Stop (Seconds (10.0));
  – UdpEchoClientHelper echoClient (interfaces.GetAddress (1), 9);
  – ApplicationContainer clientApps = echoClient.Install (nodes.Get (0));
  – clientApps.Start (Seconds (2.0)); clientApps.Stop (Seconds (10.0));
Network Simulation Example
First.cc Script

- Simulator run of scheduled events
  - Simulator::Run ();

- Destruction of objects and cleanup
  - Simulator::Destroy ();
  - return 0; }


Network Simulation Example
Post-processing with Wireshark

- pcap traces can be viewed by Wireshark
- For flow diagram: statistics → flow graph
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Laboratory Assignment

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Assignment Configuration

- 2 nodes, with 1 interface each
- Point-to-point link
  - data rate: 8 Mbps, transmission delay: 4 ms
- IP address assignment
  - 192.168.40.0/24
- Application
  - UdpEchoServerServer on port 93
  - packet size: 256 byte
- Enable ASCII and pcap tracing
- Rest of the attribute values: use from the example
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Extra Credit

- Use matrix-topology example in the folder:
  - `../examples/matrix-topology`
- Generate a topology with at least three nodes
  - do not use the default matrix
- Place nodes of your choice
- Generate NetAnim screenshot
- *Extra more credits* for identifying bugs in that code
Network Simulation with ns-3
Assignment Submission Guidelines

• Write 1–2 page summary
• Report should include the following sections:
  – experiment setup and procedure (topology, issues, etc.)
  – results
    • include flow diagram in Wireshark as screenshot in report
  – conclusions (what you learned, etc.)
• You can discuss with other students but ...
  ... everyone must submit individual report
• Attach .cc file along with your submission
• Send report in PDF format to GTA, cc: Dr. Sterbenz
Network Simulation with ns-3
EECS 882 Assignment Submission Guidelines

• Use *only* standard release for homework: ns-3.25
• Send only source files (.cc, .pl, .pdf, etc.)
  – this means *no* .zip, zipped, .tar files
  – do *not* send trace files
• *Brownie points for identifying and fixing ns-3 bugs*
• ns-3 scripts will be graded based on
  – functionality
    • major grade will be deducted for errors!!!
    • warnings will reduce your grade as well
  – documentation
    • use sensible file names: e.g. lab1_ikus.cc
Network Simulation with ns-3
EECS 882 Commenting Guidelines

• Use comments as necessary:
  – Boilerplate... (optional)
  – //GNU release blah ... 
  – /* File name: lab1_ikus.cc 
  – Purpose: This is a sample script etc.
  – Author: Ima KU Student
  – Date: 04 April 2016
  – Version: 1 */
  – #include <iostream.h>

• Use comments for block of codes:
  – // This is an example comment for a block of code
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Further Reading

- ns-3 main page (for documents, news, announcements)
  http://www.nsnam.org/
- ns-3 wiki (howtos, roadmap)
  http://www.nsnam.org/wiki/index.php/Main_Page
- ns-3 documentation: *tutorial (chapter 1-6.2)*, manual, doxygen
  https://www.nsnam.org/ns-3-24/documentation/
- ns-3 users mailing list (usage, implementations, discussions)
  http://groups.google.com/group/ns-3-users
- ns-3 bug list (closed, open bugs)
  http://www.nsnam.org/bugzilla/
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Acknowledgements

Some material in these foils comes from the ns-3 tutorial presentations from conferences, workshops:

- Tom Henderson, 
  *ns-3 tutorial*
  *SIMUTools 2009*
  [http://www.nsnam.org/documentation/presentations/](http://www.nsnam.org/documentation/presentations/)

- Gustavo Carneiro,
  *NS-3 Tutorial*
  *RTCM 2009*
  [http://telecom.inescporto.pt/~gjc/NS-3-RTCM.pdf](http://telecom.inescporto.pt/~gjc/NS-3-RTCM.pdf)
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Other References

- C++ tutorials online
  - and many more links and books on the subject

- GDB
  - http://www.gnu.org/software/gdb/

- valgrind
  - http://valgrind.org/

- gnuplot
  - http://www.gnuplot.info/

- Python
  - http://www.python.org/