

Network Modeling and Simulation

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Overview

- **Goals of Network M&S**
- **M&S Tools Highlights**
 - **NS-2**
 - **Glomosim**
 - **Qualnet**
 - **OPNET**
- **Increasing Performance**
- **Caveat Emptor**
- **Wrap-up**



Network M&S Goals

- **Model network performance**
 - **Verify distributed functions**
 - **Debug network protocols**
 - **Test reliability of new components**
- **Reduce the scale of the network to make validation tractable**

Available Tools

This is *not* an exhaustive list

NETWORK SIMULATION TOOL	URL
BRITE	http://www.cs.bu.edu/brite
Cnet	http://www.csse.uwa.edu.au/cnet/
GloMoSim	http://pcl.cs.ucla.edu/projects/glomosim
J-Sim	http://www.j-sim.org/
NS-2	http://www.isi.edu/nsnam/ns/
OMNeT++	http://www.omnetpp.org/
OPNET*	http://www.opnet.com/
PacketStorm-Network Emulator*	http://www.packetstorm.com/4xg.php
QualNet*	http://www.scalable-networks.com
SSFNet	http://www.ssfnet.org/homePage.html
x-sim	http://www.cs.arizona.edu/projects/xkernel/
NetSim*	http://www.tetcos.com/software.html
GTNetS	http://www.ece.gatech.edu/research/labs/maniacs/gtnets/index.html

(*) denotes a commercial product



NS-2

- Discrete event simulator
- Derivative of REAL
 - LBL, Xerox PARC, UCB, and ISI developed
 - Components contributed from *many* sources
- Substantial support of TCP, IP, routing, multicast, and applications
- Supports wired and wireless networks



NS-2

- Installation package comes with validation tests and demos
- Open source allows customization
 - C/C++ for low-level functionality
 - Objective TCL (OTcl) for high-level models
- OTcl usage simplifies model validation
- Protocols generally come from their inventors
- www.isi.edu/nsnam/ns/index.html



GloMoSim

- **Discrete event simulator**
 - **Based on Parsec**
- **Currently supports wireless protocols**
 - **Limits usefulness in wired or hybrid networks**
- **Developed in C**
- **Layered approach allows rapid integration of new models**
- **pcl.cs.ucla.edu/projects/glomosim/**

QualNet

- **Commercial spin-off of GloMoSim simulator**
- **C++ based**
- **Key selling point is high degree of scalability**
- **Command line or GUI/**



OPNET

- Family of simulation tools
- Commercial product
 - Customer support available
 - Simulator code available (but not some protocols or the sim engine)
- User development in C/C++ and XML
- Contains detailed models of **specific** network equipment



OPNET

- **Integrated analysis tools**
- **GUI and animation are key features**
- **www.opnet.com/products/modeler/**

Which Tool do I Choose?

- **Which simulation tool is best?**
 - **Depends on your needs**
 - **No single tool does it all**
- **Many comparative studies exist**
 - **Can be used as individual data points in decision-making process**

Comparative Studies (just a few)

- “Analysis of simulation environments for mobile ad hoc networks,” Gianni A. Di Caro, Technical Report No. IDSIA-24-03, December 2003.
- “OPNET Modeler and NS-2: Comparing the Accuracy of Network Simulators for Packet-Level Analysis using a Network Testbed,” Gilberto Flores Lucio, et al.
- “On the Accuracy of MANET Simulators,” David Cavin, et al., Proceedings of the Workshop on Principles of Mobile Computing (POMC'02).
- “Scalability of Network Simulators Revisited,” David M. Nicol.
- “Utility Analysis of Network Simulators,” David M. Nicol.
- “Tools for Peer-to-Peer Network Simulation, Alan Brown and Mario Kolbert, draft-irtf-p2prf-core-simulators-00.txt
- “Using Existing Network Simulators for Power-Aware Self-Organizing Wireless Sensor Network Protocols,” Thomas Watteyne, INRIA No 6020, September 2006.
- “Comparison of Network Simulators Revisited,” David M. Nicol, <http://www.ssfnet.org/Exchange/gallery/dumbbell/dumbbell-performance-May02.pdf>
- “Comparative Study of Wireless Network Simulators,” J. Lessmann, P. Janacik, and D. Orfanus, Seventh International Conference on Networking, April 2008.
- “Performance of Wireless Network Simulators: A Case Study,” D. Orfanus, J. Lessmann, P. Janacik, and L. Lachev, Proceedings of the 3rd ACM Workshop on Performance Monitoring and Measurement of Heterogeneous Wireless and Wired Networks

Protocol Support from Various Tools

Network Layer Protocols in GloMoSim, NS-2, QualNet, and OPNET

QualNet	GloMoSim (v.2.02)	NS-2 (v. 2.1b8)	OPNET
IPv4, IPv6, Dual-IP Stack, Mobile IPv4, HSRP	IPv4	IP, Mobile IPv4, Mobile IPv6, NEMO	IPv4, IPv6, Mobile IPv4, Mobile IPv6, HSRP, RSVP

Wireless Network Layer Routing Protocols

Wired Network Layer Routing Protocols

QualNet	GloMoSim (v.2.02)	NS-2 (v. 2.1b8)	OPNET
Static, RIP, BGPv4, BGPv6, EIGRP, IGRP, OSPFv2, OSPFv3	N/A	Static, RIP, OSPF, BGPv4, IS-IS	Static, RIP, BGP, EIGRP, IGRP, IS, OSPF, OSPFv3

QualNet	GloMoSim (v.2.02)	NS-2 (v. 2.1b8)	OPNET
AODV, BRP, DSR, DYMO, Fisheye, IARP, IERP, OLSR, OLSRv2, STAR, ZRP	AODV, DSR, Fisheye, ODMRP, WRP	AODV, OLSR, DSR, Fisheye, DYMO,	AODV, DSR, GRP, OLSR, TORA

Protocol Support from Various Tools: Some Observations

- Generally speaking, GloMoSim supports a smaller set of network layer protocols as compared with its counterparts
- OPNET and QualNet, both commercial tools, both support a rich set of network layer protocols for both wired and wireless environments.
- QualNet has extensive support for wireless network layer protocols, supporting all major ad-hoc routing protocols under development to date
- Commercially-available tools generally have a far greater set of supported protocols as compared to open source counterparts
- It is sometimes difficult to even determine what is available for open-source tools since they are typically user-created and not always centrally located. Even when an implementation of a particular protocol is available, it sometimes requires effort to obtain.

Performance Boosts

- **Staged simulations (reduce redundant calculations)**
 - Restructure discrete events
 - Pre-compute and cache partial results
- **Distributed & Parallel operation**
- **Model validation and verification**
 - Bugs impact results *and* performance
- **Output collection and analysis**
 - Mapping variable controlled to results

Issues, Pitfalls, Concerns

- **Random number generator impacts quality of simulation results**
- **Simulation results can differ greatly between**
 - Different simulator platforms
 - Simulator and real-world testbed
 - Higher data rates aggravate differences
- **Large-scale simulations impacted by platform capabilities**
- **Simplistic models (not realistic)**
- **Integration of environmental parameters unrealistic**

Using Existing Implementations

- Implementor has gone through the process of deciding the proper level of detail *in their determination* and have implemented simplified algorithms
- Important for two reasons:
 - Two network simulation tools may yield different results for the exact same simulation scenario and protocol
 - A particular network simulation may be designed to capture behaviors different than the behaviors in which you are interested
- It is imperative that you properly understand what has been implemented to ensure that it *models the behaviors you are interested in* and to the *appropriate degree of detail to meet your particular needs*

Mobility Models

- As mentioned earlier, mobility models have significant impact on the performance of a network
 - *Most pronounced at MAC and network layers*
 - *B. Divecha, A. Abraham, C. Grosnan, and S. Sanyal, “Impact of Node Mobility on MANET Routing Protocols Models”*
- Many different types of mobility models commonly employed
 - **Random Waypoint (RW)**: Location and velocity are randomly chosen (typically) according to a uniform distribution
 - **Random Point Group Mobility (RPGM)**: Nodes are grouped in clusters (an area about a center point). Random motion within cluster. Cluster as a whole moves according to RW-type model
 - **Freeway Model (FM)**: Movement constrained to straight lines

Mobility Models (continued)

- **Many sources in open literature that describes mobility models**
 - E.g. G. Lin, G. Noubir, and R. Rajaraman, “Mobility Models for Ad-Hoc Network Simulation,” Proceedings of IEEE INFOCOM 2004, Vol. 1, pp. 7-11, 2004.
 - T. Camp, J. Boleng, and V. Davies, “A Survey of Mobility Models for Ad-hoc Networks,” Special Issue on Mobile Ad-Hoc Networking: Research, Trends, and Applications,” Vol. 2, No. 5, pp. 483-502, 2002.
- **IMPORTANT framework for analyzing mobility in NS-2-based simulations**
 - F. Bai and A. Helmy, “The IMPORTANT Framework for Analyzing and Modeling the Impact of Mobility in Wireless Ad-Hoc Networks,” Wireless Ad-Hoc and Sensor Networks, Kluwer Academic Publishers, 2004.
 - F. Bai, N. Sadagopan, and A. Helmy, “User Manual for IMPORTANT Mobility Tool Generators in NS-2 Simulator,” <http://nile.cise.ufl.edu/important/mobility-user-manual.pdf>, Release Date February 2004.

Traffic Models

- As mentioned earlier, traffic models have significant impact on the performance of a network
 - *Most pronounced at MAC and network layers*
 - *Almost any performance statement must be conditioned on the traffic loading of the network*
- Traffic models generally arbitrary
- Important to perform sensitivity analysis to understand the impact of discrepancies in simulated vs. real traffic on network performance

Traffic Models (continued)

This is *not* an exhaustive list

Traffic Generation Tool	NOTES	URL
NSWEB	WWW Traffic Generator for NS-2	http://www.net.t-labs.tu-berlin.de/~joerg/
<u>PackMime-HTTP</u>	HTTP Traffic Generator for NS-2	http://www.dirt.cs.unc.edu/packmime/
<u>TMix</u>	TCP Workload Generator for NS-2	http://ccr.sigcomm.org/online/?q=node/50
Harpoon	Traffic generator for <u>testbeds</u>	http://pages.cs.wisc.edu/~jsommers/harpoon/
D-ITG	Internet traffic generator for <u>testbeds</u>	http://www.grid.unina.it/software/ITG/
<u>GenSyn</u>	Internet traffic generator for <u>testbeds</u>	http://www.item.ntnu.no/people/personalpages/fac/poulh/gensyn
Ixia*	Traffic generator for <u>testbeds</u>	http://www.ixiacom.com/
<u>iPerf</u>	TCP and UDP traffic generator for <u>testbeds</u>	http://sourceforge.net/projects/iperf/

* Indicates commercial product

Traffic Models (continued)

- The NSWEB Traffic Generator for NS-2.29, <http://www.net.t-labs.tu-berlin.de/~joerg/>
- The PackMime-HTTP Traffic Generator for NS-2, <http://www.dirt.cs.unc.edu/packmime/>
- TMix: A Tool for Generating Realistic TCP Application Workloads in NS-2, <http://ccr.sigcomm.org/online/?q=node/50>
- Harpoon: A Flow-Level Traffic Generator, <http://pages.cs.wisc.edu/~jsommers/harpoon/>



Wrap-up

- **Simulators generally have steep learning curve**
- **Beware the Random Number Generator**
- **Be willing to integrate new models into simulators**
- **Pick a simulator most useful for your problem**
- **Search for prior work**
- **Validate models**
- **Understand mobility and traffic model implications**

Questions?



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