Network Simulators: OPNET Overview and Examples

Roman Dunaytsev

Department of Communications Engineering
Tampere University of Technology
roman.dunaytsev@tut.fi

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Outline

1. About OPNET
2. IT Guru Academic Edition
3. OPNET Modeler
4. Simulation workflow
5. Example
6. OPNET Modeler editors
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About OPNET

- Alain Cohen, a 20-year-old MIT student, developed OPNET in 1986
- Alain Cohen and his classmate Steven Baraniuk developed a prototype data network modeling and simulation system they called "Optimized Network Engineering Tools", or OPNET for short
About OPNET (cont’d)

- Alain Cohen, along with his brother Marc and Steven Baraniuk, founded **MIL 3, Inc.** in 1986 (OPNET 1.1)
- In 2000, MIL 3, Inc. changed name to **OPNET Technologies, Inc.** (OPNET 7.0)

Today, OPNET Technologies, Inc. is a provider of software products and related services for:

- Application performance management
- Network planning and engineering
- Network research and development

**www.opnet.com**

- Chairman & Chief Executive Officer: Marc Cohen
- President & Chief Technology Officer: Alain Cohen
About OPNET (cont’d)

- Selected consolidated financial data:
  - Huge investments in R&D

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<thead>
<tr>
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<tbody>
<tr>
<td><strong>Revenue:</strong></td>
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<tr>
<td>Product</td>
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<td>Professional services</td>
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<td>Total revenue</td>
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<td><strong>Cost of revenue:</strong></td>
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<td>Product</td>
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<td>Amortization of acquired technology</td>
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<td>Total cost of revenue</td>
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<td><strong>Gross profit:</strong></td>
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<td><strong>58,284</strong></td>
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<td><strong>Operating expenses:</strong></td>
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<td>Research and development</td>
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<td>Sales and marketing</td>
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<td><strong>85,181</strong></td>
<td><strong>78,575</strong></td>
<td><strong>66,815</strong></td>
<td><strong>58,318</strong></td>
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The company’s first product was **OPNET Modeler**, a software tool for network simulation and modeling.

Since then, it has been diversified to provide a range of solutions for:

- **Application performance management**
  - ACE Analyst Standard, ACE Analyst Plus, ACE Enterprise Management Server, OPNET Panorama, ACE Live Appliance, ACE Live Rover, ACE Live on RSP, ACE Live VMon, IT Guru Systems Planner

- **Network planning and engineering**
  - IT Guru, SP Guru Network Planner, SP Guru Transport Planner, IT Guru Network Planner, NetOne, VNE Server, Report Server, IT NetMapper, IT Sentinel, SP Sentinel, OPNET nCompass for Enterprises, OPNET nCompass for Service Providers

- **Network R&D**
About OPNET (cont’d)

- Sample list of clients:
  - **Service providers**
    - British Telecom, Deutsche Telekom, France Telecom, Inmarsat, . . .
  - **Enterprises**
    - Deutsche Post AG, FBI, Oracle, 20th Century Fox, Xerox, . . .
  - **Network equipment manufacturers**
    - 3Com Corporation, Cisco Systems, Ericsson, Fujitsu, HP, Nokia, . . .
  - **Defense and homeland security**

- **University Program**
  - Over 25,000 university professors and students use OPNET products in Electrical Engineering, Computer Science, and related disciplines
The following products are available through the University Program:

1. **IT Guru**
   - Modeling of a broad range of network protocols and technologies
   - 800+ protocol and vendor device models

2. **OPNET Modeler**
   - IT Guru with source code for protocol and technology models

3. **OPNET Modeler Wireless Suite**
   - OPNET Modeler with a broad range of wireless models

4. **SP Guru Transport Planner**
   - Optical network planning and engineering

5. **IT Guru Academic Edition**
   - Based on IT Guru commercial version 9.1 (Build 1999)
   - Created for introductory level networking courses
   - Greatly simplified licensing (6-month renewable license)
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5. Example
6. OPNET Modeler editors
IT Guru Academic Edition

- **IT Guru Academic Edition limitations:**
  - Limited import and export capabilities
  - Limited wireless functionality
  - Other product modules are not supported
  - The maximum number of simulation events is limited by 50 million
  - The maximum number of intermediate nodes is limited by 20

- **Supported platforms:**
  - **Microsoft:** Windows 2000, Windows XP, Windows Vista, Windows 7

- **ITG_Academic_Edition_v1999.exe:** \( \sim 190 \text{ MB} \)
IT Guru Academic Edition (cont’d)

1. Registration
   - www.opnet.com/university_program/itguru_academic_edition/

2. Download and installation
   - www.opnet.com/itguru-academic/download.html

3. Activation
   - www.opnet.com/itguru-academic/instructions.html
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System Requirements

- **Supported platforms:**
  - **Linux:** Red Hat Enterprise, Fedora

- **OPNET software does not work with number representation different from English**
  - The reason is the different decimal separator: point in English, comma practically in all others
  - Start ⇒ Control Panel ⇒ Regional and Language Options ⇒ Standards and formats ⇒ English (United States)
Installing OPNET Modeler

- **Supporting software for OPNET Modeler:**
  - **Linux:** gcc 3.4 or higher

- **Install OPNET components in the following order:**
  1. Software
  2. Additional modules (if any)
  3. Model library
  4. Documentation
OPNET network R&D solutions enable:

- Test technology designs in realistic scenarios
- Evaluate enhancements to standards-based protocols
- Develop new protocols and technologies
Key Features

- **Hierarchical GUI-based editors**
- **High-fidelity modeling**
  - 800+ wired/wireless protocol and vendor device models with source code
  - Different aspects of wireless communication, including RF propagation, antenna modeling, signal modulation, node mobility, and interference
- **Scalable simulation**
  - 32-bit and 64-bit fully parallel simulation kernel
  - Grid computing support for distributed simulation
- **Sophisticated analysis**
  - Integrated GUI-based debugging and analysis
- **Integrating live network and application behavior**
  - Optional **System-in-the-Loop** module to interface simulations with live systems
  - Open interface for integrating external files, libraries, and other simulators
OPNET supports 4 simulation technologies:
- Discrete Event Simulation (DES)
- Flow Analysis
- ACE QuickPredict
- Hybrid Simulation (within the DES environment)
Simulation Technologies (cont’d)

- **Discrete Event Simulation** provides highly detailed models that explicitly simulate packets and protocol messages.

- The models in DES execute the protocol in much the same way as a production environment.

- Although DES provides very high-fidelity results, simulation runtimes are longer than with the other methods.
Hybrid simulation combines 2 distinct modeling techniques (analytical and discrete) to provide accurate, detailed results for targeted flows.

Hybrid simulation relies on background and explicit traffic:
- **Background traffic** is used to represent most of a network’s ambient load at an abstract level.
- Selected network application flows are represented in detail, using the **explicit traffic** models.

Execution runtimes can be significantly faster as compared with DES.
Flow Analysis uses analytical techniques and algorithms to model steady-state network behavior.

Flow Analysis does not model individual protocol messages or packets, therefore it does not generate results for transient network conditions.

It can be used to study routing and reachability across the network in steady state, and in scenarios with one or more failed devices.

Execution runtimes can be significantly faster as compared with DES.
ACE QuickPredict uses an analytical technique for studying the impact on application response time of changing network parameters (e.g., bandwidth, latency, utilization, packet loss).

This technique is supported within the OPNET Application Characterization Environment (ACE).
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OPNET Modeler uses a project-and-scenario approach to model networks.

- **Project** – a collection of network-related scenarios, each of which explores a particular aspect of the network design. All projects contain at least 1 scenario.

- **Scenario** – a single instance of a network. Typically, a scenario presents a unique configuration for the network. The term "configuration" can refer to different aspects such as topology, protocols, applications, traffic, and simulation settings.
Projects and Scenarios (cont’d)

- **OPNET simulation workflow**:
  1. Create a project
  2. Create a baseline scenario
     - Import or create a network topology
     - Import or create traffic
     - Choose statistics to be collected
     - Run the simulation
     - View the results
  3. Duplicate the scenario
     - Make changes
     - Re-run the simulation
     - Compare the obtained results
  4. Repeat Step 3 if needed
Projects and Scenarios (cont’d)

- New project
- **Project Editor** is used to construct and edit the topology of a network model
Projects and Scenarios (cont’d)

- Project Editor window

![Project Editor window with labeled sections: Menu Bar, Tool Bar, Workspace.]

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workspace
Network Topologies

- Initial topology
Network Topologies (cont’d)

- There are several methods for creating a network topology:
  - Manually, by dragging and dropping objects from an **Object Palette** to the Project Editor workspace
  - Manually, using the Topology ⇒ **Rapid Configuration**... command from the Menu Bar to specify and build a complete network topology quickly
  - Automatically, by **importing** the network model from an external data source – either a system that monitors your network or one or more data files that describe the network
  - Importing a topology ensures that the network model you build corresponds to the existing network exactly
Network Topologies (cont’d)

- Network scale
Network Topologies (cont’d)

- Background maps
Network Topologies (cont’d)

- Zooming
Network Topologies (cont’d)

- Dragging and dropping objects from an **Object Palette** into the Project Editor workspace
Using the Topology ⇒ **Rapid Configuration...** command from the Menu Bar to quickly deploy common network topologies.
Network Topologies (cont’d)

- Available configurations: Bus, Mesh (Full or Randomized), Ring, Star, Tree, and Unconnected Net
Network Topologies (cont’d)

- Using the Topology ⇒ **Deploy Wireless Network...** command from the Menu Bar to specify and build a wireless network
Model Library

- OPNET Modeler provides an extensive library of models that you can use to build networks

- These models are called **standard models** because users can also develop their own models
  - Those models can then be shared with other OPNET users if desired

- Certain models support the needs of users with particular interests in emerging or vendor-specific technologies (aka **specialized models**)
  - An additional license is needed to use these models in a simulation
The standard model library consists of the following types of objects:

- Subnetworks
- Nodes (aka devices)
- Links
- LANs and clouds
- Utility objects
Objects

- **Model Family**: internet_toolbox
Subnetworks are essentially containers that abstract the network components specified within them into one object. A subnetwork can also contain other subnetworks. A special subnetwork called the top level or global subnetwork is the highest level subnetwork in the network hierarchy.
- **Nodes**

  - A node represents a network device with a wide range of possible capabilities (router, switch, hub, workstation, server, firewall, etc.)
  - The actual function and behavior of a node is determined by its **node model**
Objects (cont’d)

- **Links**
  - Links represent the physical media and properties (line rate in bits per second, delay, likelihood of data corruption, etc.)
  - Links are represented as line segments or a series of line segments with arrowheads
Objects (cont’d)

- **LANs**
  - A LAN object abstracts the LAN infrastructure into one object
  - LAN objects dramatically reduce the amount of configuration required to do to represent an internetwork of LANs, and the amount of memory needed to run the simulation

![Image of Object Palette Tree project1-scenario1](image-url)
Clouds

- A cloud object abstracts the WAN infrastructure into one object
- Cloud objects provide high-level characteristics (packet latency and discard ratio) used to simulate the behavior of ATM, Frame Relay, and IP WANs
Utility objects

- Utility objects do not correspond to the actual physical infrastructure
- Instead, they perform logical functions in the network (configuration of network resources, scheduling special events, etc.)
Applications and Traffic

- The first step is to drag and drop Application Config and Profile Config objects from the Object Palette to the Project Editor workspace.

  **Application Config** specifies *standard* and *custom* applications used in the simulation, including traffic and QoS parameters.
  - Standard applications (Light/Heavy): Database, Email, FTP, HTTP, Print, Remote Login, Video Conferencing, Voice

  **Profile Config** specifies the activity patterns of a user or groups of users in terms of the applications used over a period of time.
  - You can have several different profiles running on a given workstation or a LAN.
  - These profiles can represent different user groups and behavior patterns.
Profiles describes activity patterns, such as:

- When does a user start using applications?
- What is the duration of his/her activity?
- What applications does he/she use?
- How often does he/she use each application?

Configure applications ⇒ Define profiles ⇒ (Menu Bar ⇒ Protocols ⇒ Applications ⇒ **Deploy Defined Applications**)
Choosing Statistics

- Choose statistics to collect
  - Menu Bar ⇒ DES ⇒ Choose Individual Statistics...
  - Or Right-click in the Project Editor ⇒ Choose Individual DES Statistics
  - List of statistics appears

- Types of statistics
  - **Global**: collected on the total network (e.g., application response time)
  - **Node**: collected on individual nodes (e.g., delay, delay variation)
  - **Link**: collected on individual links (e.g., utilization, throughput, queuing delay)
Choosing Statistics (cont’d)

- Choose Results dialog box
Running Simulation

- Menu Bar ⇒ DES ⇒ Configure/Run Discrete Event Simulation...
- Set simulation options and click Run
Viewing Results

- Menu Bar ⇒ DES ⇒ Results ⇒ **View Results**...
- Or Right-click in the Project Editor ⇒ **View Results**
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Case study: Small Internetworks

In this example, you plan for the expansion of a small company’s intranet.

Currently, the company has a star topology network on the first floor of its office building and plans to add an additional star topology network on another floor.

You will build and test this ”what-if” scenario to ensure that the load added by the second network will not cause the network to fail.
Creating the network

Initial Topology: Create empty scenario

Choose Network Scale: Office & Use metric units

Specify Size: 100 m x 100 m

Select Technologies: Sm_Int_Model_List
Small Internetworks (cont’d)

- **Rapid Configuration**: Star
- **Center Node Model**: 3C_SSII_1100_3300_4s_ae52_e48_ge3
- **Periphery Node Model**: Sm_Int_wkstn
- **Number (of periphery nodes)**: 30
- **Link Model**: 10BaseT
- **Center X x Y**: 25 x 25
- **Radius**: 20
- **Sm_Int_server, 10BaseT, Sm_Application_Config, Sm_Profile_Config**
Right-click on a node ⇒ View Node Description

3C_SSII_1100_3300_4s_ae52_e48_ge3 represents a stack of 4 3Com switches (4s):
- 2 SuperStack II 1100 switches
- 2 SuperStack II 3300 switches

- 52 auto-sensing Ethernet ports (ae52)
- 48 Ethernet ports (e48)
- 3 Gigabit Ethernet ports (ge3)
Small Internetworks (cont’d)

- Compare with an abstract node in ns-2
  - set node_30 [$ns node]
Small Internetworks (cont’d)

- The original network

![Diagram of network with nodes and connections]
Will the server be able to handle the additional load of the second network?
- Right-click on the **server** node ⇒ Individual DES Statistics ⇒ Node Statistics ⇒ Ethernet ⇒ **Load (bits/sec)**

Will the total delay across the network be acceptable once the second network is installed?
- Right-click in the **workspace** (but not on an object) ⇒ Individual DES Statistics ⇒ Global Statistics ⇒ Ethernet ⇒ **Delay (sec)**

Run the simulation for **30 minutes**
Expanding the network

Rapid Configuration: Star

Center Node Model: 3C_SI11_1100_3300_4s_ae52_e48_ge3

Periphery Node Model: Sm_Int_wkstn

Number (of periphery nodes): 15

Link Model: 10BaseT

Center X x Y: 75 x 62.5

Radius: 20

CS_2514_1s_e2_sl2 (Cisco 2514 router), 10BaseT
Small Internetworks (cont’d)

- The extended network
Comparing results

Menu Bar ⇒ DES ⇒ Results ⇒ **Compare Results...**
Small Internetworks (cont’d)

- The average load for the expansion scenario is higher (as expected)
- But there is no significant change in Ethernet delay on the network
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The **Project Editor** is used to construct and edit the topology of a network model.
The **Node Editor** provides operations to support creation and editing of node models.
The **Process Editor** is used to specify the behavior of process models. Process models use a **finite state machine (FSM)** paradigm to express behavior that depends on the current state and a new stimuli.
The operations performed by a process model are described in statements based on the **C or C++ languages**.

These statements can be associated with states, transitions, or special blocks within the process model.