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Modeling computer networks by the help of OPNet tools^{*}

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Abstract

The presentation deals with a family of modeling tools concerning physical infocommunication network problems. OPNet offers two free licence tools for academic use. The IT Guru can be used with an individual licence while the Modeler with an organizational licence. In this paper the use of IT Guru will be presented in education and in research, as well. This tool can be used for protocols and problems in each OSI ISO layers. Equipments from different manufacturers can be investigated. The range and the topology of the network under consideration have also a lots of options to choose.

In the modeling process numerous individual and global parameters and statistics can be chosen, the results provided by a discrete event simulation can be displayed as a scalar or a vector panel, there is a lot of output options, and the graphs of different scenarios can be compared easily. An example is provided on the effect of different queueing disciplines of routers.

Keywords: network, simulation, performance evaluation

MSC: 81T80, 91B74, 68M20

1. Introduction

The question of modeling and simulating the behavior and the performance characteristics of real world systems, eg. computer networks has a great importance for all information technology experts. During a project of designing a computer network architecture it's very important how the system meets the requirements and works on an optimal performance. Before implementing expensive equipments, some information would be preferable about the operational parameters of the system. However, developing a balanced simulation environment is not a trivial task. A

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deep understanding of modeling and simulation concepts and thorough knowledge of the properties is required.

The OPNET® Technologies Inc. was founded in 1986, became one of the market leader industries and was acquired by Riverbed in 2012 for 1 billion USD. OPNET® has several solutions for modeling, analyzing and simulating computer networks. The most popular products provided by OPNET® are the Modeler and its simplified version, the IT Guru Academic Edition. They are widely used by governments and enterprises for investigate, simulation and performance prediction of various real network architectures, as well as in higher education for teaching and researching basic and advanced topics of the theory of computer networks and infocommunication. In a frame of university program, IT Guru can be licenced freely for students and university staff, as well.



Figure 1: OPNET® IT Guru Academic Edition

OPNET® IT Guru provides an easy-to-use GUI. By the help of the tools of the software you can easily build up numerous network topologies and configurations and investigate the system characteristics and performance. IT Guru includes a lot of model families which enables you the simulation of existing hardware environment and OSI ISO protocols. These model boxes are, for example for more details see [1], [2], [3]):

- 3Com,
- CISCO,
- Ethernet,
- Hewlett Packard

- Juniper,
- NEC,
- xDSL Toolkit.



Figure 2: Different Model Families

2. OSI ISO Layers

Teachers in networking courses in higher education always keep on looking for various new educational tools for involving the students into classroom discussion, and getting students to become more interested in the topics of networking.

For OPNET® IT Guru you can find various pre-made laboratory practices and other models provided by another qualified users from universities around the world. Here are listed some examples for problems of layers of the hybrid network model:

2.1. Physical and Data Link Layer

For this layer there are some comprehensive examples. Ethernet standard is discussed with a well know bus topology. The different values of the inter arrival times are investigated, and some scalar panel will be generated with the correspondence of generated frames and received frames. Additional scenarios investigate the effect of frame size and number of workstations. Token rings with THT and switched LANs are also considered here. Wireles LANs, the effect of node mobility can also be modeled here.

2.2. Network Layer

IP address management, advanced IP protocol features, Network Address Translation, questions of IPv6, Quality of Service and the routing protocols (RIP, OSPF) can be investigated here.

2.3. Transport Layer

Compact models can be developed to study the usage and the work of UDP and TCP protocols. For TCP the questions of congestion window, fast retransmit etc. can also be considered in the models.

2.4. Application Layer

OPNET® enables to include applications in the simulation model. A special Applications node describes the applications (explicit traffic, background traffic and hybrid traffic) working on the network. Beside the standard applications (FTP, E-mail, Telnet, Web browsing, Video conferencing, Voice, Print) custom applications can be defined, as well. For the described applications specific user profiles can be built up.

3. Modeling a Network

In OPNET® the modeling process, ie. building up a model, running the simulation and viewing the result has some typical steps. These are the following see Figure 3):

- Step 1: Create the network topology,
- Step 2: Create scenarios,
- Step 3: Choose statistics,
- Step 4: Execute the simulation,
- Step 5: Analyze the result,
- Step 6: If necessary, go back to Step 2.

Using scenarios in a model helps us to split a large simulation work into small components, that investigate a specific point of view or configuration of the topic under consideration. If you want to repeat the simulation with some small changes only, scenarios also proved very useful. The basic scenario has to be duplicated, you can modify the considered parameters (eg. inter arrival time for packet generation, number of nodes in a topology, data rate for a link). Then perform the simulation again and you are able to compare the effect of the modification with the original results (see Figure 4).

OPNET® provides a large variety of statistics which can be collected during the simulation. However, statistics are not selected automatically for a simulation. A simulation can be run without any selected statistics, so it is the user responsibility to select the appropriate statistics for the study. The available statistics are divided into to classes:



Figure 3: The modeling process



Figure 4: Overlaid results of the scenarios

Object statistics describes the behavior of a specific component of the network. It can be a node, link or demand statistic.

Global statistics describes eg. the behavior of a specified protocol in the whole simulated network. A global statistics is shared by all the objects in the simulation.

The value of the statistics can be vector or scalar data and the software uses three collection modes: all values, sample and bucket.

4. Modeling Queueing Disciplines – an Example

This example focuses on the problem of congestion or queueing management. It is described more detailed in [4]. The incoming packets can be send into different, separated buffer queues based on their differentiated service values. The routers are able to handle these queues by several queueing disciplines. This example uses the First-In-First-Out (FIFO), the Priority Queueing (PQ) and the Weighted Fair Queueing (WFQ) tools.

FIFO – This is the most simple queueing discipline, the incoming packets are put into a single queue, and the order of processing is based on their order of arrival. It is a fast, predictable queueing tool, their characteristics can be computed standard ways. But it has some disadvantages. This discipline could not offer different types of services for packets from different types of sources, or some time sensitive communication data (eg. interactive voice) can suffer significant delay.

PQ – This tool offers a natural solution for the differentiated service. The incoming packets are separated into different queues based on the priority value of the packet. The packet with the highest priority will be served at any time. In case of large flow of high priority data can cause again some delay for packets with lower priority.

WFQ – This method is a flow-based algorithm that schedules delay-sensitive traffic to the top of a buffer to reduce response time, and also shares the remaining bandwidth fairly among high-bandwidth flows.

In OPNET® the following Type of Service bits in IP header are used for the priority values of packets (instead of ToS based, Protocol based and Port based methods also can be used):

- FTP: Best Effort (0)
- Http: Standard (2)
- Video: Streaming Multimedia (4)
- VoIP: Interactive Voice (6)

For the simulation the following statistics were selected (as vector data):

- Traffic Dropped (packets/sec)
- Traffic Received (bytes/sec)
- Packet Delay Variation
- Packet End-to-End Delay (sec)
- Page Response Time (sec)



Figure 5: Number of dropped packets



Figure 6: End-to-End delay in Voice packets (time average)

After a 150 second Discrete Event Simulation (DES) the following results can be analysed, for example.

On Figure 5 the leading constant zero part is the consequence of setting the start time of the simulation to 100 seconds. It can be seen that the WFQ discipline

is the most powerful among the investigated three tools. Figure 6 also ensures this result.

The green line for WFQ result is covered by the red PQ line. The two queueing methods result the same values here.

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