

Fall 2005

Opnet, Arne, and the Classroom

Philip Doane
Regis University

Follow this and additional works at: <https://epublications.regis.edu/theses>



Part of the [Computer Sciences Commons](#)

Recommended Citation

Doane, Philip, "Opnet, Arne, and the Classroom" (2005). *All Regis University Theses*. 420.
<https://epublications.regis.edu/theses/420>

This Thesis - Open Access is brought to you for free and open access by ePublications at Regis University. It has been accepted for inclusion in All Regis University Theses by an authorized administrator of ePublications at Regis University. For more information, please contact epublications@regis.edu.

Regis University
School for Professional Studies Graduate Programs
Final Project/Thesis

Disclaimer

Use of the materials available in the Regis University Thesis Collection ("Collection") is limited and restricted to those users who agree to comply with the following terms of use. Regis University reserves the right to deny access to the Collection to any person who violates these terms of use or who seeks to or does alter, avoid or supersede the functional conditions, restrictions and limitations of the Collection.

The site may be used only for lawful purposes. The user is solely responsible for knowing and adhering to any and all applicable laws, rules, and regulations relating or pertaining to use of the Collection.

All content in this Collection is owned by and subject to the exclusive control of Regis University and the authors of the materials. It is available only for research purposes and may not be used in violation of copyright laws or for unlawful purposes. The materials may not be downloaded in whole or in part without permission of the copyright holder or as otherwise authorized in the "fair use" standards of the U.S. copyright laws and regulations.

OPNET, ARNe, and the Classroom

By

Philip Doane

Professional Project

MSC696

Dan Likarish

24 August 2005

Regis University

Acknowledgments

Thanks to itSMF UK for the use of material from their website in this paper.
Thanks to Dan Likarish for answering my question, and reviewing this paper.

Abstract

This paper examines OPNET Technology, Inc's management programs, and Regis University's Academic Research Network (ARNe) needs to find out which OPNET programs can meet the needs of ARNe.

The method used was to examine ARNe's needs, and research Microsoft's SMF/MOF management framework, research OPNET's program and module offerings, research OPNET's University Program, and research how OPNET's programs are used at some other universities.

The research was used to create a match up between Microsoft's Service Management Functions and OPNET's programs and modules. And it was used to create a list of textbooks, labs, and lab manuals that would work with OPNET's IT Guru and Modeler in a classroom to help teach networking theory.

The examination was combined with the research to create an evaluation criteria matrix from which project recommendations could be drawn.

The conclusion was that the following OPNET Technology programs and modules could be of benefit to Regis University's ARNe – ACE, Automation module, Commander, DAC module, Flow Analysis module, IT Sentinel, IT Guru, NetDoctor, Report Server, and VNE Server.

Table of Contents

Certification of Authorship.....	2
Advisor Approval Form.....	3
Project Paper Revisions/Change Tracking History.....	4
Acknowledgments.....	5
Abstract.....	6
Table of Contents.....	7
List of Exhibits and Addenda.....	10
Paper Conventions.....	11
Chapter One – Introduction.....	12
Problem Statement.....	12
Project Relevance.....	13
Issues to be Addressed.....	14
Statement of Scope.....	15
Summary.....	16
Chapter Two – Literature Review/Research.....	17
Overview of Literature	17
ITIL.....	17
MOF/MSF.....	19
Microsoft Operational Framework	19
Microsoft Solutions Framework.....	20
Adam Brennen's Paper and SMF's	21
Literature Relevant to This Project	22
About OPNET Technologies, Inc.	22
OPNET Programs.....	22
ONET Modules.....	26
OPNET's University Program.....	31
OPNET Programs at Selected Universities.....	33

OPNET, Citrix MetaFrame, and ICA Client.....	36
OPNET Technology Workshop.....	37
Summary.....	37
Chapter Three – Methodology	38
Development Methods.....	38
Life-cycle of Project.....	38
Procedures Used.....	40
Format for Deliverables.....	40
Deliverables.....	40
Resource Requirements.....	40
Outcomes.....	40
Summary.....	41
Chapter Four – Project History.....	41
How the Project Began	41
How the Project Was Managed	42
Significant Milestones.....	42
Changes to the Project Plan.....	43
Evaluation of Project.....	43
Results of Analysis.....	45
Summary.....	45
Chapter Five – Lessons Learned.....	45
What I Learned.....	45
What I Would Do Again.....	46
What I Would Do Differently.....	46
Potential Next Steps.....	46
Outcome Versus Project Expectations.....	46
Conclusion.....	47
Summary.....	48

Chapter Six – Back Matter.....	48
Bibliography.....	48
References.....	49
Glossary.....	58
Exhibit 1 – University Program programs and modules.....	59
Exhibit 2 – Textbooks, lab manuals, and labs for OPNET.....	60
Exhibit 3 – How OPNET's programs fit into SMFs.....	61
Exhibit 4 – OPNET software recommendations.....	64
Addendum A – Microsoft MOF SMFs.....	68
Addendum B – OPNET Software Evaluation Criteria.....	76

List of Exhibits / Addenda

Exhibit 1 – University Program programs and modules

Exhibit 2 – Textbooks, Lab Manuals, and Labs for OPNET

Exhibit 3 – How OPNET's Programs Fit Into SMFs

Exhibit 4 – OPNET Software Recommendations

Addendum A – Microsoft MOF SMFs

Addendum B – OPNET Software Evaluation Criteria

Conventions

Citations after a period indicate that the entire foregoing paragraph is taken from source. Citations within a sentence indicate that only that sentence or phrase is taken from source.

Chapter One – Introduction

Problem Statement

Network management of Regis University's Academic Research Network (ARNe) is more difficult than it would be at some organizations for several reasons. The first reason is because students in the Practicum play a part in managing and maintaining it. This is a problem because these students rotate in and out of the program every 6 months so continuity of student management and maintenance is broken semiannually. The second reason is that ARNe is not fully documented in terms of diagrams. There are pieces of the network in logical and physical diagrams, but not the network as a whole. There is no master document for it. The third problem is that changes to ARNe are made on an ad hoc basis. (Likarish). There is, as of yet, no formal change process for modifying the network, though the foundation for it has been laid by Adam Brennen (Brennen).

Another problem to address is that computer networking classes have a lot of theory behind them but do not provide hands on experience with seeing how networking protocols behave or seeing how a prospective network design is actually going to work when put to the test.

A way of dealing with the first problem of rotating student management and maintenance personnel in the Practicum is to organize the processes and procedures involved in managing the Academic Research Network using network management frameworks so that students in one rotation can build on the documented activities of students in the previous rotation. Adam Brennen in his paper – Operational Guidelines for Academic Research Network-Network Lab Practicum has outlined a method for doing this.

Another way of dealing with the rotating student management and maintenance personnel in the Practicum is to use application programs that automate processes and procedures as much as possible. The programs and modules provided by OPNET Technologies, Inc can automate some of the network functions executed by ARNe. These programs can be used to monitor, measure, track, model, and simulate the behavior of a network. This paper proposes to describe the capabilities of OPNET's programs and modules and make recommendations as to which ones would be the most useful to Regis University.

A good way to deal with the second problem of doing network diagramming to document the network is to use a program like IT Guru to create diagrams for ARNe. IT Guru can be used to model the ARNE as a whole while also modeling the parts by doing it hierarchical fashion.

A way to deal with the third problem of ad hoc network design is to use a System Design Life Cycle to design a network. The first step would be to create a lifecycle process model, or adapt one of the existing ones. The second step would be to gather information and analyze it. OPNET programs could be used to model the network and provide information about the network. The third step could be to create a logical network design. OPNET programs help one to do this. The fourth step could be to create a physical design of the network. OPNET programs could help with this step. The fifth step could be to test the network design and finalize it. OPNET programs could be used to run simulations of the already created models to see how the design works. Any needed changes could be made to the design and tested. Then the design could be finalized. The sixth step could be to implement the final design. And the seventh step could be to monitor how the network is doing over time to see if any changes need to be made. OPNET programs can help here too.

A good way to deal with the problem of providing some hands on experience for networking classes is to use a networking modeling and simulation program that can show how networking protocols can behave on a network, and also how a prospective network is going to behave when users are accessing network services.

Project Relevance

First, ARNe's various application programs affect it in a variety of ways. Firewalls protect the network affecting what traffic has access potentially creating bottlenecks. Citrix servers offer a number of application programs to client use over the Internet affecting bandwidth usage on the network. Oracle databases are used in database classes creating traffic between clients and Oracle servers. DNS services create traffic on the network. VNC creates traffic on the network, as do Rational tools, Telnet, Terminal Services, and other services.

Discovery, modeling and simulation program can demonstrate how well the network is handling the traffic from these different sources. OPNET Technology, Inc offers a number of such programs. Regis

University's networks can be modeled pretty accurately and in an automated fashion by using the right programs and modules. Regis University has begun the process by having already licensed IT Guru, Simulation Runtime Single, and Wireless capabilities from OPNET, Inc. for educational use only. (“OPNET Technologies”)

Second, the Practicum was created to serve the needs of students in the MSCIT Masters Degree programs. These students needed a place to put developed skills to use and a place from which they can develop theses for their degrees. The Practicum fills those needs. Students complete their course work, write their theses, fulfill their degree requirements, graduate and move on. Then new students come in to take their place. The side effect of this is that rotating student personnel is a fact of life for ARNe. I think automated processes can help make their adjustments to ARNe easier. I believe OPNET programs can help with this.

Third, students at Regis at the graduate level have other time commitments and so only have limited time to devote to maintaining ARNe. Application programs that make efficient use of the time that students can devote to the Practicum and ARNe can only be helpful to them and ARNe.

And fourth, networking modeling and network performance simulation labs that go along with textbooks can help students gain a better understanding of networking theory and how networks actually behave.

Issues to be Addressed

First, OPNET, Inc offers 11 different programs and 22 different modules, with which one can discover, model, simulate the performance of a network, troubleshoot a network, and report on its performance. Some of those offerings are redundant and some may not be helpful. Finding out which ones are not redundant is part of the process is to be undertaken.

Second, ARN and the student Practicum have specific needs which can be filled by the use of the right software. OPNET Technologies, Inc's programs may be able to fill several of those needs. Finding out what the problems are and documenting them, then specifying which OPNET programs call fill what need is part of the process that can be undertaken.

Third, Adam Brennen has specified in his paper how selected Microsoft MOF SMFs can be applied to ARNe. It is up to this author to figure out where the relevant OPNET programs fit into that framework or outside of it.

Fourth, network modeling and network performance simulations can serve more than one use. Modeling and network performance simulations can illustrate traffic flows, reveal network bottlenecks, show the consequences of device failure, test network redesigns, help troubleshoot problems, do what-if simulations, show how protocols discussed in textbooks actually behave in a given network design, and many other things.

And fifth, quite a few schools and universities around the world have used OPNET programs to model their networks and model networks in networking classes. This paper will summarize some of their experiences in using OPNET programs in network modeling for their own networks and for networking classes.

OPNET's programs can be used to build a functional model of ARNe, to visualize exactly how ARNe is behaving at any given time period in any given portion or the entirety of ARNe, to test prospective changes to ARNe, to uncover problems on ARNe, to troubleshoot problems with ARNe, to create VLABs for networking and security classes, to illustrate how protocols behave in various scenarios, to document any of the above, and to create reports on any of the above.

Statement of Scope

Objectives

- Describe how OPNET, Inc's programs and modules are used at some other schools and Universities
- List OPNET Technologies, Inc's programs and modules with descriptions
- Determine which one are available through OPNET's University Program
- Map programs and modules to Microsoft's MOF/MSF
- Develop evaluation criteria for determining which programs can be of use on ARNe based on ARNe needs
- Determine which ones could be of use on the Academic Research Network
- Recommend programs and modules to Regis University's Practicum management with explanations

- List which textbooks are available that have already created labs that demonstrate some aspect of networking technology.

Constraints

- Limited amount of time to devote to this project
- Unknown budget for support on the part of the Practicum
- The Practicum may not be able to meet all of OPNET's licensing requirements
- OPNET Technologies, Inc. licenses have to be renewed every six months (“OPNET Technology”)

Assumptions

- ARNe management, excepting upper management and IT personnel rotate out of the program every 6 months.
- Automation of processes makes network management easier with regularly rotating personnel.
- Automated software processes can substitute for personnel.
- OPNET programs can provide some of that automation.

Desired Outcomes

- This paper completed
- A written description of OPNET Technologies, Inc. management programs and modules
- A written list of OPNET management programs and modules that is available through the OPNET University program that can be used in the classroom and in faculty or student research projects.
- A written list of textbooks and labs that could be used with OPNET's programs in the classroom.
- A written recommendation to ARNe management as to which OPNET programs could be helpful in the management of ARNe.

Summary

The Practicum students have a limited amount of time to devote to the Practicum and the maintenance of ARNe. OPNET Technology, Inc. licenses network management software that can maximize the effectiveness of the time student's spent in the Practicum and in the maintenance of ARNe.

OPNET software can also be used in classrooms to illustrate how networks behave and in research projects to examine and document how something in particular on a network behaves. This software is available for free or low cost.

This project is intended to provide guidance in how OPNET's programs can be useful to the Practicum, to the management of ARNe, and to illustrate network behavior in VLABs for specific classes.

Chapter Two – Literature Review

Overview of Literature

The management of organizational networks is a complex interactive process involving roles, procedures, processes, tools, and devices. It is made manageable by taking an organized approach to that management. That organized approach is provided by developmental/operational management frameworks such as those provided by the Information Technology Infrastructure Library (ITIL), and the Microsoft Operational Framework/Microsoft Solutions Framework (MOF/MSF).

ITIL

ITIL is a registered trademark of the Office of Government Commerce in the United Kingdom. (Rudd 1). ITIL provides a framework for “IT Service Management.” It consists of best practices as codified in ITIL and published by OGC in their books Software Asset Management, Service Delivery, Service Support, ICT Infrastructure Management, Planning to Implement Service Management, Application Management, The Business Perspective, and Security Management. Software Asset Management is concerned with managing organizational software (“ITIL Publications”). Service Delivery is concerned with planning for and delivering quality IT services, Service Support is concerned with daily support and maintenance processes that are part of IT provisioning. ICT Infrastructure Management is concerned with the identification of business requirements and the subsequent design, “testing, installation, deployment,” operational support, and service optimization of IT services and ICT components. Planning to Implement Service Management is concerned with Service Management strategy, planning, implementation, and

optimization. Application Management is concerned with managing applications throughout their lifecycle from acquisition through disposal. The Business Perspective is concerned with the business objectives and the roles and services that stem from them. And Security Management is concerned with the security management lifecycle of assessing risk, risk planning and management, implementing countermeasures, reacting to security incidents, evaluating security processes, and costing security processes. (Rudd 11)

IT Service Management breaks down into two service areas – Service Delivery and Service Support. Service Delivery breaks down into Availability Management, Capacity Management, IT Service Continuity and Availability Management, Financial Management for IT Services, and Service Level Management (Rudd 13). And Service Support breaks down into Change Management, Configuration Management, Incident Management, Problem Management, Release Management, and Service Desk. (Rudd 16)

The ITIL service management process (including the IT Service Management process) includes every aspect of ITIL service provisioning. It is described in the eight ITIL books listed above. It is oriented towards providing quality customer service by satisfying the expectations and requirements of a business and its customers. It culminates in Service Level Agreements between IT and a business and IT and a business's customers. (Rudd 6)

MOF/MSF

Microsoft Corporation has adapted the ITIL framework, their own experience, and ISO 15504 to create their own approach to IT management. Their approach encompasses two complementary frameworks: the Microsoft Operations Framework (MOF) and the Microsoft Solutions Framework (MSF). The Microsoft Operations Framework is oriented towards planning, deploying, and maintaining IT operational processes (“Process”). It is designed for service management (“MSF_v3_Overview 7”). And the Microsoft Solutions Framework is oriented towards the planning, development, and deployment of software (“Process”). It takes business needs and creates solutions to fill them. It is designed for the delivery of software solutions (“MSF_v3_Overview 7”). The two frameworks combine to create a complete IT project management lifecycle. (“Process”)

Microsoft Operational Framework

The Microsoft Operational Framework breaks down into two sections: the Process Model, and the Team Model. The Process Model divides operations into four Quadrants: the Changing Quadrant, the Operating Quadrant, the Supporting Quadrant, and the Optimizing Quadrant. The Changing Quadrant processes consist of activities that introduce new processes, services, technologies, and applications into the corporate network (“MOF”). The Operating Quadrant processes consist of daily activities that keep organizational systems and services running efficiently. The Supporting Quadrant processes consist of activities that respond to IT service user's requests, that handles and resolves incidents, and that fields and resolves user, network, and systems problems. And the Optimizing Quadrant processes consist of activities that optimize costs, optimize performance levels, optimize network and service availability, and drive capacity planning (“MOF”). The four quadrants combine to form a circle that iterates into a spiral lifecycle. (“Process”)

Between each of the adjacent above-mentioned quadrants are management reviews that evaluate the activities of the previous quadrant and prepare for the activities of the next quadrant. The Release Readiness Review, which is between the Changing and Operating Quadrants, provides approval for the deployment of new releases of processes, services, technologies, and applications onto the corporate network. The Operations Review, which is between the Operating and Supporting Quadrants, periodically reviews and evaluates the IT staff's ability to maintain services and meet service levels, and documents the IT staff's experiences in a knowledge base. The Service Level Agreement Review, which is between the Supporting and Optimizing Quadrants, periodically “evaluates the IT staff's ability to meet service level requirements” defined in service level agreements. And the Change Initiation Review, which is between the Optimizing and Changing Quadrants, strives to keep proposed changes to the corporate network in alignment with the corporation's “business objectives and operability requirements”. (“MOF”)

Each quadrant mentioned in the Process Model contains service management functions (SMFs) that incorporate specific service activities and processes. The Changing Quadrant SMFs are Change Management, Configuration Management, and Release Management. The Operating SMFs are Service Monitoring and Control, System Administration, Network Administration, Directory Services Administration, Security Administration, Storage Management, and Job Scheduling. The Supporting Quadrant SMFs are Incident Management, Problem Management, and Service Desk. And the Optimizing

Quadrant SMFs are Service Level Management, Capacity Management, Availability Management, Security Management, Financial Management, Workforce Management, IT Service Continuity Management, and Infrastructure Engineering. (“Process”)

[see Addendum A for definitions of the SMFs]

The Team Model provides guidelines for dividing organizational teams into role clusters of specific competencies and activities (“Process”) associated with service functions. The role clusters are Release, Service, Infrastructure, Support, Operations, Partner, and Security. The Release cluster roles can be change management, release engineering, configuration and asset management, software distribution and licensing, and quality assurance. The Service cluster roles can be service level agreement drafting, service level agreement review, service improvement initiation, service catalog management, customer relationship management, and service level management. The Infrastructure cluster roles can be enterprise architecture, infrastructure/systems engineering, capacity management, budget management, resource and long-range planning. The Support cluster roles can be service/help desk, production and production support, problem management, service level management. The Operations cluster roles can be messaging operations, database operations, network administration, monitoring and metrics, and availability management. The Partner cluster roles can be managed service outsourcers, software and hardware suppliers, maintenance vendors, environment support, and training partners. And the Security cluster roles can be intellectual property protection, network and system security, intrusion detection, virus protection, audit and compliance administration, and contingency planning. (“MOF”)

Microsoft Solutions Framework

The Microsoft Solutions Framework (MSF) also breaks down into two models: the Process Model and the Team Model. The Process Model breaks solutions development down into 5 phases: the Envisioning Phase, the Planning Phase, the Developing Phase, the Stabilizing Phase, and the Deploying Phase (“MSF Process” 23). The Envisioning Phase sets the goals of a project, its scope, and its core team membership. This phase produces a vision/scope, document, a project structure document, and a risk document (“MSF Process” 24). The Planning Phase derives functional specifications from requirements, creates a design solution, and creates a plan for execution of the design with cost estimates (“MSF Process” 26). This phase

results in a project plan, functional specifications, and a risk management plan (“MSF Process” 28). The Developing Phase creates the early iterations of the design solution. This phase produces software code, installation and configuration scripts, and test routines (“MSF Process” 32). The Stabilizing Phase conducts tests of software looking for bugs, finding them, and modifying software code to fix them (“MSF Process 34”). This phase results in stable software, test results, and supporting documentation. And the Deploying Phase deploys the solution, obtains customer acceptance of the solution, and then hands it off to operations. This phase produces “operation and support information systems,” processes and procedures, a knowledge base with reports and logbooks, a documentation repository, final versions of documents, “customer/user satisfaction data,” a “project closeout report,” and a description of the next steps (“MSF Process” 41).

The MSF Team Model divides up teams into 6 role clusters: the Product Management role, the Program Management role, the Development role, the Test role, the Release Management role, and the User Experience role. The Product Management role is to identify the end customer, find out what the customer wants and needs (“MSF Team” 20), define a product, determine if there is a business value to the product, market the product, and communicate with the customers (“MSF Team” 21). The Program Management role is to make sure that a project meets customer expectations, delivers the right feature set, and is kept on schedule and on budget” (“MSF Team” 23). The Development role is to create a solution that meets functional specifications and meets the customer's expectations (“MSF Team” 27). The Test role is to make sure that software bugs are identified and fixed, or documented with a work-around solutions (“MSF Team” 30). The User Experience role is to make sure that solutions are usable, accessible to all users, national and international, include support documentation and training solutions, and incorporate a good user interface (“MSF Team” 32). And the Release Management role is to develop release criteria, manage tool selections, plan and manage releases, manage training for operations groups, and be an advocate between project and operations groups (MSF Team” 36).

Adam Brennen's paper and SMFs

Adam Brennan, in his paper “Operational Guidelines for Academic Research Network-Network Lab Practicum,” examined the operations frameworks ITIL and MOF. He wrote that the NLP has selected the Microsoft Operational Framework as its network operations model for its operations management

functions. And he wrote that the service management functions (SMFs) he recommended for use for NLP management would be – system administration, network administration, directory services administration, security administration, service monitoring configuration, configuration management, change management, storage management, and continuity management. (Brennen 111)

Those nine SMFs fit into the MOF quadrant model as follows - change management and configuration management would apply to the Changing quadrant, systems administration, network administration, directory services administration, security administration, service monitoring configuration, and storage management would apply to the Operations quadrant, with no SMFs that would apply to the Supporting quadrant, and service continuity management would apply to the Optimizing quadrant.

Literature Relevant to This Project

About OPNET Technologies, Inc.

OPNET Technologies, Inc. corporate headquarters is located in Bethesda, MD. It licenses software to manage applications and networks to corporations. Its numerous clients include various departments in the U.S. Government, ITT, National Semiconductor, Sony, Radio Shack, Oracle, DaimlerChrysler, IBM Global Services, and many others. (“Corporate Fact”)

OPNET Programs

The following programs are available from OPNET, Inc. – IT Guru, IT Sentinel, SP Guru, SP Sentinel, WDM Guru, Modeler, Commander, Panorama, VNE Server, Report Server, and OPNET Development Kit.

IT Guru is a modeling and simulation program. It is used to model hierarchical networks, network protocols, servers, routers, switches, and application programs and to run simulations on those network models. (“OPNET IT Guru”) “IT Guru provides a Virtual Network Environment” in which network models are created and in which network simulations are run. IT Guru models and simulations can be used to help diagnose configuration and network problems, audit security policy compliance, test changes to the configuration of a network before it is implemented, set accurate SLAs for application response time, and plan for growth in traffic on a network, or plan new facilities. (“IT Guru's Virtual”)

IT Guru comes in two versions: the full commercial IT Guru version and the limited IT Guru Academic Edition. The full commercial version can be used with a paid license by anyone or with a free or low cost six-month license by any academic institution. And the limited Academic version can be downloaded and installed by students using its free, renewable, six month license. (“OPNET IT Guru”)

There are a number of differences between the two versions of IT Guru. The educational version is designed for classroom use and has ACE and Wireless capabilities built-in. It has limited import, modeling, analysis, and export capabilities. It includes no support. And the full version, which is available for research, does not have ACE and Wireless capabilities built-in. It has the full commercial feature set. It also has low-cost support available. (“OPNET Technology”)

IT Sentinel is a configuration audit program that audits network device configurations. It uses data collected from network devices and other programs to create a network model (“OPNET IT Sentinel” 4). It audits that network model against a set of rules to “diagnose device misconfiguration, policy violations, inefficiencies, and security gaps” (“OPNET IT Sentinel” 2). It automates the configuration audit workflow process. It tells the IT staff when it is finished. And it publishes its results in report form to a web server (“OPNET IT Sentinel” 5). The finished report can be used to demonstrate compliance with federal regulations such as HIPAA and Sarbanes-Oxley (“OPNET IT Sentinel” 2).

SP Guru is a modeling, simulation, and network management program oriented towards service providers. (“SP Guru: Intelligent”). It collects network data using the included VNE Server (“SP Guru's Virtual”). It takes the data collected from VNE Server or another program, or from device configuration files, and creates a network model (“The Intelligence to Understand”). It uses NetDoctor to test that model against a set of rules to identify network problems and to test and validate changes to the network (“The Intelligence to Troubleshoot”). And it does network simulations to show what the consequences would be of making a potential change to the modeled production network.

SP Sentinel is a configuration audit program that audits a network. It is oriented towards service providers (“OPNET SP Sentinel: SP”). It automates the configuration audit workflow process. It uses data collected from network devices and other programs to create a network model. It audits its network model against a set of rules or some templates (“OPNET SP Sentinel: 24x7” 4). It looks for “device misconfigurations, policy violations, inefficiencies, and security gaps (“OPNET SP Sentinel: SP”). It

notifies the IT staff when it is finished with its audits. And it publishes its results in report form using its report server (“OPNET SP Sentinel: 24x7” 5). The finished reports produced by it can be used to demonstrate compliance with federal regulations such as HIPAA and Sarbanes-Oxley (“OPNET SP Sentinel: 24x7” 2).

WDM Guru is a modeling and simulation program used for network planning. It is oriented towards network equipment manufacturers and service providers. It is used to model optical and SONET networks (“WDMGuru”). It provides a Virtual Network Environment in which an IT staff can analyze network growth patterns, build resilience into a network, optimize a current network, and evaluate network services delivery (“WDM Guru's”).

Modeler is modeling and simulation program. It is used to model wired, wireless, cellular, and satellite networks. And it can be used to model terrain with the optional Terrain Modeling Module. It has a large library of models that include protocol models, application models, and network device models. (“OPNET Modeler: the World”) Modeler has a Project Editor to model networks, a Node Editor to model network systems and devices, and a Process Editor to model protocols, applications, algorithms, resources, and queuing policies (“OPNET Modeler: Accelerating” 3).

Commander is an application service level monitoring program. It is used to monitor application availability and service levels, and to troubleshoot reduced application service levels (“Active Application”). It tests against service response times as specified in Service Level Agreements (“How It Works”). It verifies the operation of HTTP, DNS, FTP, SMTP, IMAP, POP3, SNMP servers with tests, executes custom scripts, verifies the existence of selected files, checks those files “for needed content” (“Commander Test Types”), and does several other types of tests. And Commander notifies IT staff if service levels drop below the specified thresholds (“Features and Benefits”).

Panorama is a server performance testing and monitoring program. It works with operating systems, with selected web servers, application servers, database servers, and with SNMP. (“Application Coverage/Data”). It is used to perform load testing on applications during pre-production testing before an application is deployed on a network, to monitor applications performance, and to locate and analyze complex application performance problems after applications have been deployed on a network (“Realtime Systems Analytics”). Panorama works by using deployed agents to gather time-synchronized data from

server applications and network devices. These agents forward the data to the Panorama Console which analyzes the data and correlates events against metrics to generate useful event thresholds. If a threshold is exceeded an alarm is generated and sent to the user interface (“OPNET Panorama”).

Panorama generates a number of user screens from its data store. It generates a Performance screen that shows how major applications are performing. It generates a TopN screen that shows the metrics with the highest values. It generates a Deviation screen that shows which metrics are outside of their normal values. It generates a Correlation Screen that shows real time or historical values for sets of related metrics. It generates a Histogram Chart that shows correlated data over a 12 hour time period. And it generates a Reports Screen that shows metrics and events for a given time period. (“Panorama Console”)

VNE Server is a data management program (“OPNET VNE”). It is used to display network data such as software and hardware configurations, network topology, device utilization statistics, and performance data imported from a variety of network devices and third-party software (“VNE Server Supported”). It integrates that data into a single, online, view of an entire network. System administrators can use that view for problem detection, resolution, and prevention, and for network planning, engineering, and operations (“OPNET VNE Server”). And system administrators can import the configuration, integrated topology, and traffic information “into IT Guru or SP Guru via a 'single click,' fully automating the process of building network models in the Virtual Network Environment” (“VNE Server Return”).

VNE server can display over 50 different reports to its user interface. Those reports can be current operations reports, operations alerts, interface summaries, node summaries, and link summaries, and many others (“VNE Server Advanced Features.”).

Report Server is a web-based report repository program. It displays reports generated by other OPNET programs. It automatically organizes and archives them. Users can “automatically publish network reports” for retrieval through a web browser. Users can study those reports or publish them. (“OPNET Report Server”)

Report Server can display reports from OPNET programs like IT and SP Guru, IT and SP Sentinel, ACE, NetDoctor, Modeler, and VNE Server. It can also display “Network Difference Reports”, “Security Demand Analysis Reports”, and “User-Defined Reports”. (“OPNET Report Server”)

OPNET Development Kit is a development program. It is used “to develop custom network management applications”, to “customize OPNET IT and SP Guru, and OPNET Modeler”, to improve workflows, to create new device and protocol models, and to customize “visualization and reporting.” It uses C and C++ APIs to create “network application support packages,” to import and export network data, to create network topologies, to do rules-based analysis, and to create reports, among other things. (“OPNET Development”)

OPNET modules

The following modules are available from OPNET, Inc to go with many of their programs: the Application Characterization Environment (ACE), the ACE Decode module, the Automation module, the Distributed Agent Controller (DAC), the Flow Analysis module, the High-Level Analysis module, the IPv6 module, the Multi-Vendor Import module, the Mainframe Model module, the MPLS Module, the NetDoctor module, the Planning and Design Module, the Server Specialized Models module, the System Performance Module for BMC Performance Assurance (SPBMC), the System Performance Module for HP OpenView, the Terrain Modeling module, the TIREM Module, the 3D Network Visualizer Module, the UMTS Module, the Wireless module, and three other modules.

The OPNET Application Characterization Environment (ACE) module works with IT Guru and SP Guru. ACE provides Capture Agents that can be distributed around a network. The Capture Agents gather network packet traces off of the network. The “Capture Agents” are managed by the “ACE Capture Manager”. Besides using information from Capture Agents, ACE can also import packet traces from other programs like tcpdump. ACE displays multiple traces in the “Application Message Chart” which is a graph of application requests and replies, and the “Network Packet Chart” which is a graph of network packet activity. (“Capture Application Traces”). ACE can display application traces in several additional ways to show message performance statistics and dependencies, and facts about the messages (“Visualize Transactions”).

ACE automatically diagnoses application performance problems. It uses an expert engine to analyze captured traces. When the analysis is done by the ACE AppDoctor component (which includes a display

screen), it can show sources of delay in the network, and it can make recommendations as to what can be done about the delay. Then the results of the trace analysis can be published in report form showing such things as potential bottlenecks, sources of packet delay, and a variety of statistics about each application analyzed. Note that ACE works best with the separate ACE Decode Modules which can decode over 400 applications and protocols. (“Diagnose Performance Problems”)

When combined with IT Guru and SP Guru, ACE can be used to create models using ACE Wizard, then do predictive modeling to test what the results would be if one follows the recommendations made by AppDoctor. It can also be used for doing what-if analysis of possible modifications to a network (“Validate Solutions”).

The OPNET ACE Decode Module works only with Windows 2000, XP, and NT. It provides decodes for more than 400 protocols such as http, ftp, POP3, Microsoft SMB, Novell IPX, and SUN NFS, and for applications such as Oracle, MS-SQL Server, NetWare 5 and Citrix, using a decode engine from Sniffer Technologies. (“ACE Decode”) The decodes enable ACE to breakdown and analyze protocol and application traces it otherwise could not work with.

The OPNET Automation Module works with IT Guru and SP Guru programs and the Flow Analysis and NetDoctor modules. It automates the “unattended execution of many workflows in OPNET IT Guru and SP Guru.” It automates end-to-end workflow management “including importing data to create a network model, performing NetDoctor audits, executing Flow and Failure Analysis, and producing reports.” It audits configurations, performs network vulnerability assessments, and does resiliency analysis. And it provides end user notification of NetDoctor results by pager or e-mail. (“OPNET Automation Module”)

The OPNET Distributed Agent Controller Module works with IT Guru and ACE. It also works with third party programs like IBM Rational Robot, and HP OpenView Internet Services. It “integrates with synthetic transaction generators that monitor response times in a production network” (“DAC”), like the one in OPNET Commander (“Capture”). And it provides automatic capturing and archiving of multi-tier application traces that can be used by IT Guru and ACE to analyze intermittent performance problem. (“DAC”)

The OPNET Flow Analysis Module works with IT Guru and Modeler and is part of SP Guru. It provides traffic flow analysis. It graphically depicts traffic flows including paths taken (individually and as

a whole), and volume and type of flow. It depicts the consequences of network congestion, device configuration changes, and device failures. It calculates queuing, transmission, and propagation delays. And it produces ATM and IP network reports for protocol configurations, IP forwarding and routing tables, and performance and utilization statistics for network nodes. (“Flow Analysis”)

The OPNET High Level Architecture Module (HLA) works with HLA federation models. It provides the ability to federate many simulators as they model all or part of “the communications aspects of the HLA federation models.” It also provides the mechanisms for the simulators to share time synchronizations, exchange messages, and to “share common object representation.” It works with RTI objects and interactions. It updates OPNET object attributes from RTI attributes. And it lets users map the relationship between OPNET and RTI objects. (“High-Level Architecture”)

The OPNET IPv6 module provides the ability to model “IPv6 features including: expanded addressing, dual stack implementation, routing with RIPng and IPv6 static routing, IPv6 tunnels, ICMPv6, and neighbor discovery.” This makes it possible to study different ways to transition from IPv4 usage to IPv6 usage. This module works with SP Guru, Modeler, and ODK. (“IPV6”)

The OPNET Mainframe Model module provides models for the IBM and OEM OS/390 and Z-Series mainframe systems. These models when combined with other OPNET models enable the modeling of end-to-end networks that include “applications, servers, networks, network protocols and mainframes.” (“Mainframe”)

The MPLS Module contains an MPLS model that can be used by Modeler, SP Guru, or ODK, to offer performance predictions for MPLS enabled networks. The MPLS model offers the features “Fast Reroute,” “VPLS and Layer 2 VPNs,” “Compatibility with Layer 3 VPNs,” and “Configuration of Dynamic / Static LSPs.” (“MPLS”)

The OPNET Multi-Vendor Import (MVI) module works with IT Guru, Modeler, VNE Server, and is a part of SP Guru. It provides expert knowledge of how servers, network devices, protocols and applications work to IT Guru and Modeler so they can create highly accurate models in their Virtual Network Environments. It provides an alternate path for both programs to import utilization and traffic data, device configuration, and network topology information from a variety of sources. Note that both programs can get similar, but not the same, information on their own or through VNE Server. Further, the three different

modeling processes MVI can use cannot be combined other than by MVI obtaining up-to-date information through VNE Server and doing its own modeling with it. In any case, MVI automates the creation of model attributes “that control routing and switching behavior” for the devices, protocols, access lists, and other things it knows about. (“Multi-Vendor Import”)

The OPNET NetDoctor Module provides automated configuration audits of production networks. NetDoctor checks configuration files. It uses simulations to check network security. It provides policy enforcement checks from user provided policy rules. It runs over 400 standard checks including almost 100 different security checks. It provides several different views of its audit results. It publishes the results of its audits in html, xml, and Microsoft Word format. It automatically publishes its results to Report Server if desired. And it automatically produces reports that show how well a network complies with federal regulations including HIPPA and Sarbanes-Oxley. (“NetDoctor”)

The OPNET Planning and Design Module works with IT Guru and Modeler, and is a part of SP Guru. It is dependent on the Flow Analysis Module. It can be used with the OPNET Development Kit to create customized design actions. It “provides a library of automated design actions.” It automates network design using those design actions. It is capable of multiple design actions. It uses user provided design parameters. And it can be used to optimize bandwidth in production networks or planned network designs. (“OPNET Planning and Design Modules”)

OPNET's Server Specialized Models module provides vendor specific models for Dell, HP, IBM, Sun, and other server manufacturers' servers. The models integrate with the Virtual Network Environment provided by various OPNET programs to enable the creation of highly accurate network models. (“Server”)

OPNET's System Performance Module for BMC Performance Assurance (SBPMC) module works with the application program BMC Patrol. It “can import server workload measurements directly from the BMC Visualizer database, simplifying the process of characterizing workloads for modeling.” This information can be used to build a model of a network's infrastructure. (“System”)

The OPNET System Performance Module for HP OpenView (SPHP) works with the program HP OpenView. It imports data from HP OpenView's Performance Agent via OpenView's Performance Manager which is used by OPNET's Server Characterization Editor. It is used to model servers, do capacity planning, and do “consolidation analysis.” It provides integrated workflow for all three of those processes.

And when used with OPNET's model library and ACE it produces accurate network models. ("OPNET System")

The Terrain Modeling Module (TMM) works with the Wireless Module. It provides the capability for modeling the effects of environment on wireless networks. It will model "any known atmospheric or topological conditions and their combined impact on signal propagation." It can create "signal-power comparisons of mobile network models," line -of-site profiles, and elevation maps. And it will read "DTED and USGS DEM terrain data." ("Terrain Modeling")

The TIREM Module works with the Terrain Modeling Module and the 3D Network Visualizer Module. It provides an algorithm for computing "propagation loss due to terrain effects, such as diffraction and absorption" that can be used by the Terrain Modeling Module. It supports terrain data formats such as "DTED Level 0 and Level 1, and USGS DEM 15 minute, 2 arc second, and 1 degree." And it can import data from "OpenFlight synthetic environment databases" via "OPNET's 3D Network Visualizer (3DNV) module." ("OPNET TIREM")

The OPNET 3D Network Visualizer ("3DNV") module works with the Wireless module and the HLA module. It generates a realistic three dimensional view of terrain for wireless simulations that incorporates "topology, node relationships, and performance statistics" such as delay, throughput, transmission quality, and line of site information ("3D NV" 2). It gets information from "OPNET's platform products" using an HLA standard interface. It uses terrain data from an OpenFlight database. It has simulation and planning modes, as well as, a 3D Logger that enables the replay of network simulations. And it has an API that permits the creation of custom visualizations. ("3D NV" 3)

The OPNET UTMS Module provides a model of the UMTS wireless protocol. This protocol is a third-generation (3G) wireless protocol. It enables the modeling of UMTS wireless communications networks when used with Modeler, the Wireless module, and the optional IPv6 module. ("UMTS ")

The OPNET Wireless module works with IT Guru, SP Guru, Modeler, and the OPNET Development Kit, the Terrain Modeling Module, the HLA Module, and OPNET's Model Library. It provides the ability to model wireless networks in IT Guru, SP Guru, and Modeler which can then run performance simulations on the models. It can simulate wireless links using a framework "called the Transceiver Pipeline." And with TMM the Wireless module will calculate the effects of environment on wireless performance, and

with HLA it will model communications effects on wireless network performance. The Wireless module will calculate the effects RF propagation, interference, receiver/transmitter characteristics, node movement, and interconnection with wired networks on wireless network performance. (“Wireless Module”)

And the three remaining modules are Circuit Switching, DOCSIS, and PNNI modules. The Circuit Switching module enables circuit switching using discrete event simulation. The DOCSIS module enables DOCSIS protocol discrete event simulation. And the PNNI module enables PNNI routing discrete event simulation. All three modules are intended for use in research and development and in planning activities. (“OPNET Products”)

To support the use of their programs and modules OPNET Technologies, Inc provides the Discrete Event Simulation Model Library. This model library has models for protocols and technology, both wired and wireless, and for some vendor devices. The Standard Model Library models are included with OPNET's products. There are other models that have been contributed by OPNET's users and can be used for free (“Discrete”), and there are models available for purchase. The latter are product modules, NETWARS models, and some specialized models.

OPNET'S University Program

OPNET Technologies, Inc has a University Program in which it makes its programs available for free, or low cost, to academic institutions and students for teaching and research purposes. OPNET describes this program on its web site at (<http://www.opnet.com/services/university/home.html>). This site lists 2 options available to the academic community in the University Program. The options are classroom use or research use. Classroom use, using OPNET programs, is described on the web page “Teaching with OPNET.” Research use, using OPNET programs, is described on the web page “Research with OPNET”. (“OPNET University”)

The classroom option offers the limited feature IT Guru Academic Edition to students and teachers as a free download with no support, or the full versions of IT Guru, WDM Guru, or Modeler for a reduced fee with support (with an accepted application) that includes access to the “Contributed Model Depot” and the “Support Center.” (“Teaching”)

The research option offers full versions of IT Guru, WDM Guru, or Modeler to researchers for free with no support, or for a reduce fee with support that includes access to the “Support Center”, user community, and online resources. Either option requires an accepted application (“Accelerating R&D with OPNET”)

The OPNET University web site offers a list of textbooks that can be used in the classroom for which there are network simulation models available. The models work with IT Guru and Modeler. Three of the textbooks are Computer Networks, Third Edition, by Andrew Tannenbaum (“Computer Networks, Third”), Computer Networks – A Systems Approach, Third Edition, by Larry Peterson and Bruce Davie (“Computer Networks, A”), Data and Computer Communications by William Stallings (“Data Communications”), and Computer Networking with Internet Protocols by William Stallings (“BookStore”). Two other textbooks also listed for classroom use are Business Data Networks & Telecommunications, Fourth Edition by Raymond R. Panko, and Business Data Communications by William Stallings (“OPNET University”).

To go along with four of the above mentioned textbooks there are some lab manuals that include OPNET labs. They are Lab Manual, 7E by Kevin Brown (“Lab Manual, 7E”) to go with Data and Computer Communications, 7E, (“OPNET Lab”) or with Computer Networking with Internet Protocols by William Stallings (“BookStore”), Lab Manual, 5E by Leann Christianson (“Lab Manual, 5E”) to go with Business Data Communications, Fifth Edition (“OPNET Lab”), and Lab Manual by Emad Aboeela to go with Computer Networks – A Systems Approach, Third Edition, by Larry Peterson and Bruce Davie (“BookStore”).

To go along with the textbook Business Data Networks & Telecommunications, Fourth Edition there are seven lab manuals that can be downloaded from OPNET's web site (“Teaching”) And to go along with the textbook Computer Networks, A Systems Approach for there are 11 labs available for download (“OPNET University”).

Besides OPNET's web site - Amazon.com lists the lab manual Data and Computer Communications and Computer Networking with Internet Protocols and Technology: Opnet Lab Manual to Accompany the seventh edition and fourth edition by William Stallings, Kevin Brown, and Leann Christianson. It is designed to accompany the textbook Data and Computer Communications, Seventh Edition by William Stallings. (“Data and”)

The OPNET University Program, through their web site, provides scores of contributed papers that can be downloaded and read, and scores of contributed models that can be downloaded and used by the academic community, provided one has proper licensing and authorization for a modeling program. And the University Program offers the Academic Resource Center, lesson plans, syllabi, and textbooks recommendation to teachers. (“OPNET University”)

Additionally, the University Program web site lists some of the universities that are using OPNET programs and how they are using them. These Universities are spread around the world. (“See”)

OPNET Programs at Selected Universities

SUNY Fredonia is a university in Fredonia, New York, which is southwest of Buffalo, New York. It uses the OPNET program Modeler. Mike Zuber, and Junaid Ahmed Zubairi of SUNY wrote a paper – “SUNY Fredonia Campus Network Simulation and Performance Analysis Using OPNET” – about how OPNET Modeler was used to model the school network, and test how time sensitive traffic behaves under various load conditions on the school network. (Zubairi 1)

According to that paper SUNY Fredonia faculty and students have been making increasing use of the campus computers and network in its offices, classrooms, and labs. To handle the demand the school has built a switched Ethernet/Fast Ethernet network with a Gigabit Ethernet backbone. (Zubairi 1)

The problems that SUNY faces can be modeled on a network model and simulation program. The problems are the increasing amount of time-sensitive multimedia traffic on the network, the desire to add voice traffic to the network (Zubairi 1), and the need to test the effects of IPv6 traffic (currently in use) on the network. OPNET Modeler was used to create models of the Cisco devices being used on the school network and create a model of the whole network (Zubairi 2) including clients and servers. Using Modeler, simulations were done to test the performance of the overall network, to test potential changes to the network to handle congestion points, and to test the effects of voice traffic between two clients (Zubairi 3) on the network.

Katholieke Universiteit Leuven (K.U.Leuven) *is a university in Leuven, Belgium.* J. Potemans, J. Theunis, B. Rodiers, B. Van den Broeck, P. Leys, E. Van Lil, and A. Van de Capelle of K.U. Leuven wrote

a paper on how OPNET Modeler has been used to model the network backbone of the campus network. The paper summarized a study done that looked into “the possibilities, problems and limitations of today’s simulation tools” (Potemans 1).

The paper said that the network backbone is arranged into a full-duplex ring using 5 Gigabit Ethernet switches that do network routing. It is designed to be redundant, so it is governed by the Spanning Tree Protocol. It has some peripheral switches connected to it that provide connectivity to local campus sites (Potemans 1). The campus part of the network is divided up into VLANs to control group accesses (Potemans 2).

OPNET Modeler was used to build the network model (Potemans 1). Information gathered from SNMP Management Information Bases was used to run the simulations (Potemans 2). Results of the simulations were recorded.

The study found that Opnet Modeler could not model all of the capabilities present in the backbone network, but that if it could Modeler would be “a very useful tool for the design and management” of the backbone network (Poteman 7).

Another study was done at K.U. Leuven in Leuven, Belgium. It was summarized in a paper by B. Van den Broeck, P. Leys, J. Potemans, J. Theunis, E. Van Lil, and A. Van de Capelle entitled “Validation of Router Models in OPNET.” The objective of the study was to do research to determine how closely OPNET router models matched the performance of the the real routers using OPNET Modeler 8.1A (Van den Broeck 1).

The researchers determined that the model interfaces and protocols closely matched the real thing but that performance parameters had not been tuned (Van den Broeck 1). So the researchers setup a measurement method to “calculate the parameters needed to model the performance characteristics of a router in OPNET” (Van den Broeck 5). For the simulations they modeled a Cisco 2621router (Van den Broeck 1) and 2 Pentium III PCs (Van den Broeck 2). They compared the simulation results to the measured performance of the router and PCs and found them to be a close match. (Van den Broeck 5)

And another study done at K.U. Leuven uses OPNET Modeler for student projects for students enrolled in the Electrical Engineering program who are focusing on Telecommunications. The goal of the projects is to provide the students with practical skills that they will be able to use in the future. J. Theunis, B. Van den

Broeck, J. Potemans, E. Van Lil, and A. Van de Capelle wrote a paper titled “OPNET in Advanced Networking Education” about the OPNET tutorial created by the school for the students and about the network design projects the students do. (Theunis 1)

Modeler includes some tutorials for users, but they did not meet the project's needs, so a tutorial was created that does. The tutorial teaches students how “to create a project, create and configure a network topology, import traffic on the network in several ways, choose statistics, and view results.” (Theunis 2)

The student do network design projects in the areas of Wireless LANs, Voice over IP, or Video Streaming. They are divided up between the three areas and work as teams. Each team has to analyze its respective assigned design problem, measure the performance of an existing network, propose a design solution, model it analytically and then with Modeler, run simulations of the proposed design, and then draw some conclusions from the results of the simulations. (Theunis 2)

North Carolina State University is a university in Raleigh, North Carolina. David J. Thuente of NCSU has written a paper titled “Using OPNET Modules in an Undergraduate Network Projects Class.” The paper describes how OPNET Modeler with ACE, MVI, and NetDoctor, HP OpenView, and router configuration files have been used in an undergraduate networking class (“Network Projects”) to “construct and analyze” complex networks. (Thuente 1)

In the class project teams of four students plan, design, implement, test, and manage networks, network communication and application software, and a network project. The goal is for the project teams to apply concepts learned in previous classes to a network project in a project environment (Thuente 2)

In the class this students follow this routine– OPNET Modeler is installed on several NT servers. Students do some tutorials on how to use Modeler. Then students, with the help of NCSU ComTech staff, have OPNET Modeler import network topology information from the school's HP OpenView server. Next, students have Modeler use the Multi Vendor Import (MVI) module to import router configuration files from school routers which are constructed into a network topology. In both cases some manual adjustment of the imported information is done to improve the models that were constructed. Then the two network models are compared using network topology diagrams generated by OPNET Modeler and these are compared to topology diagrams created by NCSU staff. Next generic traffic simulations are run on the HP sourced model. Then video conferencing traffic is simulated on the other model. In both simulations traffic

is added until the networks begin to fail. Next, NetDoctor is used analyze the IP addressing and static routing for weaknesses. Then the way each model handles additional traffic is analyzed. Next, ACE is used to analyze some obtained H.323 (voice over IP) traffic. Then H.323 and video conferencing models are analyzed for similarity. (Thuente 3)

Wichita State University is a university located in Wichita, Kansas. A. Sambari, R. Bhagavathula, N. Thanthry and Dr. R. Pendse of WSU have written a paper entitled “Teaching with OPNET: WSU's Experience.” It is about how OPNET Modeler has been used in a classroom environment to demonstrate key network concepts and how it has been used to do research. (Sambari 1)

First students are taught how to use Modeler and some its modules. They run some network simulation scenarios to see some of its capabilities and the modules capabilities. (Sambari 2) Then they run simulations using a campus design scenario to see how FDDI and Token Ring networks work, and a voice over IP scenario so they can experiment with various codecs and see the effects of queuing delays (Sambari 3).

OPNET, Citrix Metaframe and ICA Client

A paper titled “Benchmarking OPNET Performance Using Multiple Clients and a Single Server” describes some tests using one server and multiple clients. The server was a 700 Mhz Pentium III running 2 GB of RAM. The operating systems for the server was Microsoft NT 4.0 Terminal Server. The test accessed OPNET Modeler and DecisionGuru via Citrix Metaframe 1.8 from clients running Citrix ICA Client 4.0. (Epstein 1) The clients accessed the server from (1) the local Fast Ethernet LAN, (2) from a remote office through a T1 connection, and (3) from a local office via a 28.8 Kbps dialup line from an ISP. The tests measured response times between clients and the server running four OPNET simulations. The test results showed “virtually no performance degradation, even with four simulations running at the same time” on the server. (Epstein 3) They showed that up to nine simulations could be run on the server with little network performance degradation “for general user operations” (Epstein 4). They showed that Citrix Metaframe effectively allocated processor power between clients. And they showed that connection speed made a large difference in performance responsiveness for general users. The paper concluded that the 700 MHz server with 2 GBs of memory could handle as many as 20 simultaneous connections from general

operations users when several of those connections were to active OPNET simulations running on the server. (Epstein 4)

OPNET Technology Workshop

At an OPNET Technology Workshop held on 19 April 2005 the Vice-President of OPNET said that any of the programs offered by OPNET can be used by the educational community with an approved application, a class syllabus for teachers, a detailed description of the research to be done by researchers, maintenance of a web page describing one's progress with current projects, the contribution of models or papers referencing use of OPNET, and user licenses. The user licenses are available to teachers in blocks of 30 are and available to researchers as a single user license. The licenses are good for six months. (“OPNET Technology”)

Summary

Management frameworks give administrators some methodology with which to manage their networks in an organized fashion. ITIL provides one of those frameworks and Microsoft's MOF/MSF provides another.

But a management framework is not enough to effectively manage a network, some tools are also needed. OPNET Technologies, Inc provides some of those tools in the form of programs that help administrators understand what is happening on their network, programs that help them document their networks, programs that help them troubleshoot problems on their networks, and programs that let them plan changes to their networks and test those changes before they are implemented. OPNET also provides a University Program that makes its programs and modules available to universities for a low fee or not cost at all. The University Program provides the programs and modules so that students can see how networks work in a classroom situation and so that faculty and students can do research projects covering some area of networking. The University Program also provides contributed OPNET-ready models, contributed papers describing how OPNET programs are used at various universities around the world, a list of

textbooks and lab manuals that can be used with OPNET programs, and some downloadable labs that can be used with several of the textbooks.

Chapter Three – Methodology

Development Method

The development method I am using for this project is a modified version of the systems development life cycle that includes lots of overlap. The systems development life cycle of choice consists of five phases: an initiation phase, a planning phase, an analysis phase, a design phase, and implementation phase, but no maintenance phase. The initiation phase is the activities that begin a project. The planning phase is the activities that outline what steps the project will take to create the project. The analysis phase is the activities that gather information, determine what is useful, and make recommendations as to what that project will look like. The design phase is the activities that create a blueprint of the project and an execution plan for its creation. The implementation phase is the activities that follow the execution plan that result in a completed project.

Life-cycle of Project

The initiation phase consisted of three parts. The first part consisted of selecting as a project the exploring of the programs offered by OPNET Technologies, Inc., what they do, and how they could be helpful to Regis University in their classrooms and on the Practicum network. The second part consisted of making a project proposal that included the outline for this paper. And the third part consisted of sending the proposal to my class instructor and getting the go ahead from him to pursue it.

The planning phase consisted of determining that the scope of the project would be researching the operational frameworks ITIL and MSF/MOF, of researching which OPNET Technologies, Inc. programs are offered to universities for free use if certain conditions are met, of researching what textbooks and labs could help in the classroom, of researching how other universities are using OPNET programs on their networks and in their classrooms, determining which OPNET programs could help with the management of

the Practicum network and could help in the classroom, and researching, briefly, how OPNET programs get along with Citrix MetaFrame.

The analysis phase consisted of four parts. The first part was researching the operational frameworks ITIL and MSF/MOF, of researching the MOF SMFs, of researching the capabilities of OPNET's programs and modules, of researching which textbooks match up with which OPNET ready labs, and of researching OPNET and Citrix MetaFrame. The second part consisted of estimating which OPNET programs match up with each of Microsoft's SMFs. The third part consisted of asking Dan Likarish questions about the Practicum and what software selection criteria he would like to see for developing evaluation criteria for selecting the OPNET programs that could fill Practicum network management needs and Regis University classroom needs. And the fourth part consisted of finding out from OPNET Technologies, Inc. which programs and modules are part of their University Program and are therefore available to universities either for free, or for a low fee.

The design phase consisted of creating the evaluation criteria table for the selection of useful OPNET software, and of creating the list that matches up OPNET software and Microsoft's MOFs.

And the implementation phase consisted of creating this paper, of listing and describing the software available through OPNET's University program, of listing which OPNET software can be used in universities in the classroom and in research projects, of listing the textbooks and labs that work with OPNET's programs, of filling out the evaluation criteria table, and of creating the OPNET software recommendations that Regis University's Practicum can use.

Procedures Used

One procedure used was to ask representatives of several different companies' questions about whether or not I could use information from their web sites in my paper, ask OPNET's representative questions about OPNET programs, and ask Dan Likarish questions about ARNe and ARNe management.

Another procedure used was to do web searches for information, and library searches for information about OPNET programs, about ITIL, and about MOF.

Format for Deliverables

All the document deliverables for this project are to be done in the MLA (Modern Language Association) style.

Deliverables

The deliverable for this project is this paper with four required content areas. The first content area is a list of the programs offered OPNET Technologies, Inc., with short descriptions that are available to universities for no fee or a low fee through the OPNET University Program. The second content area is a list of which OPNET programs can be used in classrooms or in faculty or student research projects. The third content area is a list of textbooks and labs that are available for use in the classroom. And the fourth content area is a set of recommendations to ARNe management as to which OPNET programs would be helpful in the management of ARNe, in the classroom, and in research projects.

Resource Requirements

The resource requirements for this paper are my computer, an Internet connection, the Internet, time, whatever documents I can lay hands through libraries or other sources that provide needed information, and thought.

Outcomes

- This paper completed.
- A written description of OPNET Technology, Inc management programs and modules
- Written list of OPNET programs that are available through the OPNET University program that can be used in the classroom and in faculty or student research projects.
- Written list of textbooks and labs that could be used in the classroom.

- Written recommendations to ARNe management as to which OPNET programs would be helpful in the management of ARNe, in the classroom, and in research projects.

Summary

The methodology of this paper consisted of selecting a project lifecycle type, determining what that lifecycle would be, determining what procedures I would use, determining what the format for the deliverables would be, determining what the deliverables would be, determining what the resource requirements would be, and determining what project outcomes would be.

Chapter Four – Project history

How the Project Began

This project has its roots in several different places. But it started with my being assigned to the OPNET group after being accepted into the Networking Lab Practicum. Dan Likarish suggested to me that for a meeting presentation I look into the modules that would work with IT Guru and make some recommendations as to which ones it would be worthwhile additions for IT Guru. I found out that OPNET's modules added quite a bit of capability to the original program and that several of them could be quite useful.

Contributing factors that led to the selection of this particular project was that besides being able to model and diagram the ARNe network, programs like IT Guru with supplementary modules could be used to observe what the network is doing, map the network, analyze packet traces to locate bottlenecks and performance problems, and do future network planning. So I was curious as to what other OPNET programs could do to automate or otherwise help with network management.

Another contributing factor came from some experiences when I took a networking class over the Internet using a dialup connection where I was given access to Visio Pro, via Citrix, to design a network for a class exercise. I found that between the hours of 5 PM and 10 PM Citrix I could get a Citrix connection, but no Visio response. I think that network modeling and performance simulations could tell how to improve a situation like this.

Also contributing to this project selection was that I had downloaded IT Guru Academic version early on and had done the available network labs so I had an idea of what IT Guru could do and could see how it could help in the classroom and in network management. So I thought this could be valuable to explore too.

So I began this project as a survey of OPNET program capabilities with the outcome being to provide to others information about how these programs could help with ARNe management, and help with network classroom learning. Then once this was done other people could see to the implementation of any OPNET programs of interest.

How the Project Was Managed

The procedures I used gained me almost all of the information I needed to complete the project. The shortfalls that I see in this project cannot be laid at the doorstep of the procedures.

Significant Milestones

- Completed Project Paper Outline 5 April 2005.
- Completed Chapters One and Two 14 May 2005.
- Removed outline, revised Ch. 1& 2 28 June 2005
- Added Table of Contents 28 June 2005
- Added Addendum A 12 July 2005
- Added Exhibit 1 12 July 2005.
- Added Exhibit 2 20 July 2005
- Added Exhibit 3 25 July 2005
- Completed Chapter 5 26 July 2005
- Completed Chapter 4 26 July 2005
- Added Exhibit 4 26 July 2005
- Added Addendum B 26 July 2005
- Added Abstract 28 July 2005
- Finished First Draft of Paper 28 July 2005

Changes to the Project Plan

I figured out that two of my outcomes were actually two parts of the same one, so I combined them. I added an outcome to Chapter 1 one that I had overlooked, but had included in my deliverables in Chapter 3. I made some minor changes to my paper outline several times as I went along, when I pulled the outline out of my paper, and when created a Table of Contents. I changed the title of my paper between the original proposal and this finished paper. And I added researching how OPNET programs get along with Citrix MetaFrame into my background research.

Evaluation of Project

This project went fairly well in terms of finding background information on the Internet about Microsoft's operational and developmental frameworks, and OPNET programs and modules. However finding free information about ITIL was difficult. I did not find much. Fortunately I found quite a bit of information on Microsoft's web site about their operational framework MOF, their solutions framework MSF, and their service management functions (SMFs). However I found little outside of their web site. And fortunately I found quite a bit of descriptive information on OPNET Technology, Inc's programs and modules on their web site, though three of the modules have scant descriptions. However, I turned up very little of use outside of their web site.

Turning up information about how OPNET programs are used at universities around the world proved to be fruitless until I located some on OPNET's web site. Then I was surprised at how much was there, though much of it was of a highly technical nature, very narrow in scope and not what I was specifically looking for. Still, I found more than enough for my purposes.

I found enough information on OPNET's University Program on OPNET's web site and through an online OPNET Technology Workshop to determine that all of OPNET's programs are available to a teacher or student if they go through the application process and follow OPNET's rules. So that part turned out okay, though when I tried to confirm my understanding of this by e-mail OPNET's representative had not answered one way or the other as of 5 August 2005. So, I could be wrong about some program and module availability.

When I worked on developing evaluation criteria I discovered I had almost enough information to do a good job, but when I tried to get the last bits of information I needed to fill out the criteria matrix by requesting the needed information from OPNET, I got no response (as of 5 August 2005).

Mapping OPNET programs to Microsoft's operational framework was an exercise in uncertainty. All I know about OPNET's programs is what I have read about them, except for the educational version of IT Guru which I have on my computer and have used a little bit, and all I know about SMF's is what I have read (I have not used them in a work environment), so there is lots of room for error in the match ups I created between OPNET's programs and SMFs. I see possibilities for OPNET's programs in most SMFs, but I have no way to confirm the accuracy of my assignments one way or the other.

- Develop evaluation criteria for determining which programs can be of use on ARNe based on ARNe needs.

The evaluation criteria itself is complete as I can make it. Unfortunately, it is only partially reliable since some details in the evaluation matrix are missing, or are missing confirmation. This was unexpected and dissatisfying.

- Determine which OPNET programs could be of use on the Academic Research Network

This worked out as expected. I was able to gather enough information to make a determination.

- Recommend programs and modules to Regis University with explanations

This has worked out well enough that others should be able to look at my recommendations for ARNe and select OPNET programs for research projects and for classroom use without having to canvas OPNET's extensive web site for needed information. This worked out better than expected

- Determine which textbooks, labs, and lab manuals could be useful in a classroom

Finding out which textbooks had labs to go with them was easy since OPNET provides a list of them and the labs that go with them on their web site. This turned out as expected.

Results of Analysis

I found enough information about Microsoft's MSF/MOFs and SMFs, and OPNET's programs to list them with descriptions. I found enough information on how OPNET's programs are used at other universities to provide information about this in my paper.

I was able to create a list textbooks, labs, and lab manuals that work with OPNET's programs. I was able to create the evaluation criteria table, and the match ups between OPNET's programs and Microsoft's MOFs. And I was able to make recommendations as to which OPNET programs could be useful to the Practicum and in the classroom so I think this turned out well enough to be provide a jumping off point for anyone who wants to take this process to the next step. However, the incomplete evaluation criteria, and tentative match-ups of SMF's and OPNET's programs should be taken for what they are an no more.

Summary

This chapter consists of descriptions of how this project began how this project was managed, what changes were made to the project, my analysis of the project, and a list of project milestones. On the whole I think this project turned out better than I expected.

Chapter Five – Lessons Learned

What I Learned

I have learned that there is a formal process for creating papers called theses that follows sequential steps, with each step deriving from the preceding step. The first step consists of deciding upon a topic and what one wants to learn about the topic. The second step consists of starting the thesis by defining its scope, objectives, goals, and outcomes. The third step consists of writing the outline. The fourth step consisting gathering information pertinent to the thesis. And the fifth step consists of analyzing the gathered information, deriving conclusions about what was found, and writing the thesis.

What I Would Do Again

I would write a research paper again. There is a lot of information available about a lot of subjects if one persists in digging it up and there are conclusions that can be derived from that research. And I would use this process again now that it makes some sense to me if the occasion ever comes up.

What I Would Do Differently

I would start writing sooner in the process. It did not occur to me to take notes when I was researching sources of information, so I did not look at them very closely. The result was that I had a lot of unsifted sources of little value. So I omitted them from the bibliography.

It did not occur to me to take notes because I typically write research papers piecemeal, with a very rough outline in my head. As I find useful sources I fill in the holes in my paper. Then I tie everything together in my paper and finish it. And if I need a table of contents I pull it out of the body of my paper and put it in the front of it. Writing an outline first, then researching sources, then writing a paper like I have done in this project is unfamiliar to me.

I would also not let my word processor underline http links that I typed as I was adding reference to my paper. At the time I was doing this I did not know that MLA documentation rules do not permit that. So I had to delete and replace the http web addresses in my citations with versions that were not underlined. It was time-consuming to do so.

Potential Next Steps

The next step would be for someone to do the logical and physical design of how to incorporate any of the recommended programs into the ARNe network, either as research projects or classroom programs. This, of course, presupposes that anyone will have any interest in doing so which is not a given.

As for the classroom, teachers could use some of the available textbooks and OPNET labs for classes for networking classes or research projects.

Outcome Versus Project Expectations

- This paper completed

I expected to get this paper completed and it is.

- Written list of OPNET programs that can be used in the classroom and in faculty or student research projects

I was able to get a definitive answer of the availability of several of the programs – IT Guru, WDM Guru, and Modeler – through OPNET's University Program web site. I was unable to get a written statement as to the availability of OPNET's other programs. All I was able to find out was that the Vice-President of OPNET said at an online technology workshop that all of OPNET's programs were available through the University Program. This was disappointing; I had anticipated more cooperation from OPNET.

- Written list of textbooks and labs that could be used in the classroom.

This outcome was achieved as I anticipated. OPNET's web site had the textbooks listed on several different web pages. All I had to do was pull the information together. And, Amazon.com had three books listed about OPNET programs. One lab manual listed was current, one book that was outdated, so I did not list or reference it, and one that lab manual did not have any details besides title and authors since it has not been published yet. I did not list or reference it either of the latter. Turning up books about OPNET on Amazon.com's web site was a surprise.

- Written recommendations to ARNe management as to which OPNET programs would be helpful in the management of ARNe.

OPNET Technology, Inc proved to be considerably less helpful to me than I had anticipated, so the evaluation matrix is not complete, and therefore the written recommendations are less solid than I had hoped.

Conclusion

I did what I set out to do. I did some research. I compiled some information and put in this paper, though I omitted a bunch of useless citations from the bibliography. I analyzed the information gathered. I derived some conclusions from this analysis which turned out somewhat better than I had hoped. For instance, the matching up of OPNET programs and MOFs is as good as I can make it without actually using the programs. And I made some recommendations as to what programs would be useful on ARNe. So, this

project is not as complete as I had hoped, but it is as good as I can make it without cooperation from OPNET.

Summary

I made a list of programs and modules available from OPNET Technology, Inc. I made a list of the programs that are available through its University Program, though accuracy is unconfirmed. I made a list of textbooks and lab manuals that work with several of OPNET's programs. And I made a list of OPNET's programs that I recommend for use on ARNe based on an incomplete and unfinishable evaluation matrix. I filled in all the sections in my paper. I completed the project. It is as good as I can make it.

Chapter 6 – Back Matter

Bibliography

“3.1 and 3.2 System Requirements”. OPNET Technologies, Inc. 2005. 18 May 2005.

<http://www.opnet.com/products/system_req/commander/system_requirements.html>

Alred, Gerald J., Charles T. Brusaw, and Walter E. Oliu. Handbook of Technical Writing, Seventh Edition.

Boston: Bedford, 2003.

Burns, Christine. “LAN MANAGEMENT: LAN monitoring; desktop, server, mobile-device management; remote-control tools”. Network World, Inc. 23 February 2004. InfoTrac OneFile Plus. Regis University Library. 19 March 2005.

<http://web1.infotrac.galegroup.com.dml.regis.edu/itw/infomark/726/612/65660476w1/purl=rc1_I TOF_0_A115409171&dyn=18!xrn_7_0_A115409171?sw_aep=regis_main>

Hacker, Diane. The Bedford Handbook, Fifth Edition. Boston: Bedford, 1998.

Jennings, Tim. “OPNET Optimises IT Governance”. Butler Direct Ltd. June 2004. 25 March 2005.

<<http://www.butlergroup.com/research/DocView.asp?ID={97D9B224-3BC8-4CF2-8C62-9922366FF0B6}>>

Kaloudis, Todd. “Minimising downtime: OPNET Technologies' vice president of marketing, Todd

Kaloudis, reveals best practice techniques for preventing mission-critical downtime. (Opinion)”.

Communicate. June 2002. DMG World Media Ltd. 2002. InfoTrac OneFile Plus. Regis University

- Library. 22 March 2005.
<[http://web1.infotrac.galegroup.com.dml.regis.edu/itw/infomark/726/612/65660476w1/purl=rc1_I
TOF_0_A88995813&dyn=6!xrn_1_0_A88995813?sw_aep=regis_main](http://web1.infotrac.galegroup.com.dml.regis.edu/itw/infomark/726/612/65660476w1/purl=rc1_I
TOF_0_A88995813&dyn=6!xrn_1_0_A88995813?sw_aep=regis_main)>
- “NETWARS Communications Model Library”. OPNET Technologies, Inc. 18 April 2005.
<http://www.opnet.com/products/library/netwars_models.html>
- “OPNET 11.0 Versions of IT Guru, SP Guru, Modeler, and ODK Products Available to Customers
Worldwide.” Business Wire, Inc. 13 December 2004. Lexis-Nexis. Regis University Library. 18
March 2005. <[http://web.lexis-
nexus.com.dml.regis.edu/universe/document?_m=543a5984dfce05244af46b103ea7f918&_docnu
m=1&wchp=dGLbVlb-zSkVA&_md5=c7fc7af89d347da15a642f47d3b0e6a0](http://web.lexis-
nexus.com.dml.regis.edu/universe/document?_m=543a5984dfce05244af46b103ea7f918&_docnu
m=1&wchp=dGLbVlb-zSkVA&_md5=c7fc7af89d347da15a642f47d3b0e6a0)>
- “Service Management Functions”. Microsoft Corporation. 2005. 28 June 2005.
<<http://www.microsoft.com/technet/itsolutions/cits/mo/smf/default.msp>>

References

- “Active Application Monitoring”. OPNET Technologies, Inc. 2005. 22 April 2005.
<<http://www.opnet.com/products/commander/home.html>>
- “ACE Decode Module”. OPNET Technologies, Inc. 22 April 2005.
<<http://www.opnet.com/products/modules/adm.html>>
- “Accelerating R&D With OPNET”. OPNET Technologies, Inc. 3 May 2005.
<<http://www.opnet.com/services/university/research.html>>
- “Application Coverage/Data Adapters”. OPNET Technologies, Inc. 2005. 22 April 2005.
<http://www.opnet.com/products/panorama/app_cov_data_adp.html>
- “BookStore”. OPNET Technologies, Inc. 19 July 2005. <<http://www.opnet.com/store/books.html>>
- Brennen, Adam. Operational Guidelines for Academic Research Network – Network Lab Practicum. 13
April 2004.
- “Capture Application Traces”. OPNET Technologies, Inc. 22 April 2005.
<http://www.opnet.com/products/modules/ace/capture_app_traces.html>

“Commander Test Types”. OPNET Technologies, Inc. 2005. 22 April 2005.

<<http://www.opnet.com/products/commander/testcoverage.html>>

“Computer Networks: A Systems Approach, Third Edition”. OPNET Technologies, Inc. 4 May 2005.

<http://www.opnet.com/services/university/Computer_Networks.html>

“Computer Networks, Third Edition”. OPNET Technologies, Inc. 4 May 2005.

<<http://www.opnet.com/services/university/tanenbaum.html>>

“Corporate Fact Sheet”. OPNET Technologies, Inc. 2004. 13 May 2005.

<<http://www.opnet.com/opnet/about.html>>

“DAC: Distributed Agent Controller”. OPNET Technologies, Inc. 23 April 2005.

<<http://www.opnet.com/products/modules/dac.html>>

“Data Communications”. OPNET Technologies, Inc. 4 May 2005.

<<http://www.opnet.com/services/university/stallings.html>>

“Data and Computer Communications and Computer Networking with internet Protocols and Technology:

Opnet Lab Manual to Accompany the seventh edition and fourth edition.” Amazon.com, Inc. 2005.

18 July 2005. <http://www.amazon.com/exec/obidos/tg/detail/-/0131482521/ref=pd_sxp_f/103-7031109-4671044?v=glance&s=books>

“Diagnose Performance Problems”. OPNET Technologies, Inc. 23 April 2005.

<http://www.opnet.com/products/modules/ace/diagnose_prfrmnc_prblms.html>

“Digital elevation model.” Wikipedia: the Free Encyclopedia. 15 May 2005. 28 June 2005.

<http://en.wikipedia.org/wiki/Digital_elevation_model>

“Digital Terrain Elevation and Data [DTED]”. FAS. 24 January 2000. 28 June 2005

<<http://www.fas.org/irp/program/core/dted.htm>>

“Discrete Event Simulation Model Library”. OPNET Technologies, Inc. January 2005. 18 April 2005.

<http://www.opnet.com/products/library/des_model_library.html>

Epstein, Alex. “Benchmarking OPNET Performance Using Multiple Clients and a Single Server”. OPNET

Technologies, Inc. 9 June 2000. 29 March 2005.

<[ftp://enterprise8.opnet.com/cmp_root/papers/76/Benchmark.zip](http://enterprise8.opnet.com/cmp_root/papers/76/Benchmark.zip)>

“Features and Benefits”. OPNET Technologies, Inc. 2005. 22 April 2005.

<<http://www.opnet.com/products/commander/featureandbenefits.html>>

“Flow Analysis”. OPNET Technologies, Inc. 23 April 2005.

<http://www.opnet.com/products/modules/flow_analysis.html>

“High-Level Architecture”. OPNET Technologies, Inc. 23 April 2005.

<<http://www.opnet.com/products/modules/hla.html>>

“How It Works”. OPNET Technologies, Inc. 2005. 22 April 2005.

<<http://www.opnet.com/products/commander/howitworks.html>>

“The Intelligence to Understand”. OPNET Technologies, Inc. 2003. 20 April 2005.

<<http://www.opnet.com/products/spguru/models.html>>

“The Intelligence to Troubleshoot Problems and Validate Network Changes”. OPNET Technologies, Inc.

2003. 20 April 2005. <<http://www.opnet.com/products/spguru/diagnose.html>>

“Introduction to VNE Server”. OPNET Technologies, Inc. 21 June 2005.

<http://www.opnet.com/services/training/vne_server.html>

“IPv6 Module: Discrete Event Simulation, Specialized Module.” OPNET Technologies, Inc. 21 June 2005.

<<http://www.opnet.com/products/library/IPv6.html>>

“IT Guru's Virtual Network Environment” OPNET Technologies, Inc. 2004. 13 May 2005.

<<http://www.opnet.com/products/itguru/vne.html>>

“ITIL Publications”. OGC: Office of Government Publications. 27 January 2004. 28 April 2005.

<<http://www.ogc.gov.uk/index.asp?id=1000364>>

“Lab Manual, 5E”. Pearson Education. 2005. 3 May 2005.

<<http://vig.prenhall.com/catalog/academic/product/0,1144,013148253X,00.html>>

“Lab Manual, 7E”. Pearson Education. 2005. 3 May 2005.

<<http://vig.prenhall.com/catalog/academic/product/0,1144,0131482521,00.htm>>

Likarish, Dan. “RE: OPNET programs usage”. E-mail. 12 April 2005.

“Mainframe Model.” OPNET Technologies, Inc. 21 June 2005.

<http://www.opnet.com/products/modules/mainframe_model.html>

“MOF Executive Overview v3.0”. Microsoft Corporation. 9 August 2004. 28 April 2005.

<<http://www.microsoft.com/technet/itsolutions/cits/mo/mof/mofeo.msp>>

“MPLS Module: Discrete Event Simulation, Specialized Model.” OPNET Technologies, Inc. 24 May 2005.

<<http://www.opnet.com/products/library/mpls.html>>

“MSF_v3_Overview Whitepaper.pdf”. “Microsoft Solutions Framework Version 3 White Papers”.

Microsoft Corporation. 2002. 28 April 2005.

<<http://www.microsoft.com/downloads/details.aspx?familyid=A71AC896-1D28-45A4-880C-8B0CC8265C63&displaylang=en>>

“MSF Process Model v. 3.1.pdf”. “Microsoft Solutions Framework Version 3 White Papers”. Microsoft Corporation. 2002. 30 April 2005.

<<http://www.microsoft.com/downloads/details.aspx?familyid=A71AC896-1D28-45A4-880C-8B0CC8265C63&displaylang=en>>

“Multi-Vender Import”. OPNET Technologies, Inc. 23 April 2005.

<<http://www.opnet.com/products/modules/mvi.html>>

“NetDoctor”. OPNET Technologies, Inc. 23 April 2005.

<<http://www.opnet.com/products/modules/netdoctor.html>>

“OPNET Automation Module”. OPNET Technologies, Inc. 22 April 2005.

<http://www.opnet.com/products/modules/automation_module.html>

“OPNET Development Kit: Customizing OPNET Solutions”. 2005. 22 April 2005.

<<http://www.opnet.com/products/odk/home.html>>

“OPNET IT Guru”. OPNET Technologies, Inc. 2004. 19 April 2005.

<<http://www.opnet.com/products/itguru/home.html>>

“OPNET IT Sentinel: 24x7 Network Integrity”. OPNET Technologies, Inc. 2004. 20 April 2005.

<http://www.opnet.com/products/modules/automation_module.html>

“OPNET Lab Manuals”. OPNET Technologies, Inc. 3 May 2005.

<http://www.opnet.com/services/university/lab_manuals.html>

“OPNET Modeler: the World’s Leading Network Modeling and Simulation Environment”. OPNET

Technologies, Inc. 2004. 19 April 2005. <<http://www.opnet.com/products/modeler/home.html>>

- “OPNET Modeler: Accelerating Network R&D”. OPNET Technologies, Inc. 2004. 19 April 2005.
<http://www.opnet.com/products/modeler/opnet_modeler.pdf>
- “OPNET Panorama”. OPNET Technologies, Inc. 2005. 22 April 2005.
<<http://www.opnet.com/products/panorama/howitworks.html>>
- “OPNET Panorama: Panorama Console Views”. OPNET Technologies, Inc. 2005. 22 April 2005.
<http://www.opnet.com/products/panorama/user_inteface_views.html>
- “OPNET Products.” OPNET Technologies, Inc. 21 June 2005. <<http://www.opnet.com/products/opnet-products.html>>
- “OPNET Planning and Design Module”. OPNET Technologies. 23 April 2005.
<http://www.opnet.com/products/modules/p_d_module.html>
- “OPNET Report Server”. OPNET Technologies, Inc. 2004. 22 April 2005.
<http://www.opnet.com/products/report_server/home.html>
- “OPNET SP Sentinel: 24x7 Network Security”. 2004. 20 April 2004.
<http://www.opnet.com/products/spsentinel/SP_Sentinel.pdf>
- “OPNET SP Sentinel: SP Sentinel: 24x7 Network Security”. OPNET Technologies, Inc. 2004. 20 April 2005. <<http://www.opnet.com/products/spsentinel/>>
- “OPNET System Performance Module for HP OpenView (SPHP)”. 11 January 2005. 23 April 2005.
<http://www.opnet.com/products/modules/sphp_module.html>
- “OPNET Technologies, Inc. License Agreement Review.” OPNET Technologies, Inc. 28 June 2005.
<https://ds1.opnet.com/4dcgi/LA_WS_Main>
- “OPNET Technology Workshop”. OPNET Technologies, Inc. 19 April 2005. 19 April 2005.
<<http://opnet.webex.com/>>
- “OPNET University Program”. OPNET Technologies, Inc. 2005. 3 May 2005.
<<http://www.opnet.com/services/university/home.html>>
- “OPNET VNE Server: Unified Network Management”. OPNET Technologies, Inc. 2005. 22 April 2005.
<<http://www.opnet.com/products/vne/home.html>>
- “OPNET TIREM Module”. OPNET Technologies, Inc. 23 April 2005.
<http://www.opnet.com/products/modules/tirm_module.html>

Potemans, Jan and J. Theunis, B. Rodiers, B. Van den Broeck, P. Leys, E. Van Lil, A. Van de Capell.

“Simulation of a Campus Backbone Network, a case-study”. OPNET Technologies, Inc. 2002. 29 March 2005. <ftp://enterprise8.opnet.com/cmp_root/papers/369/401.doc>

“Process Model for Operations”. Microsoft Corporation. 17 February 2004. 29 April 2005.

<<http://www.microsoft.com/technet/itsolutions/cits/mo/mof/mofpm.msp>>

“Product Updates: OPNET IT Guru 11.0 for Windows”. OPNET Technologies, Inc. 2005. 18 May 2005.

<https://secure.opnet.com/Lic_Priv/support/updates/110/itguru-win.html>

“Product Updates: OPNET IT Sentinel 11.0”. OPNET Technologies, Inc. 2005. 18 May 2005.

<https://secure.opnet.com/Lic_Priv/support/updates/110/itsentinel.html>

“Realtime System Analytics”. OPNET Technologies, Inc. 2005. 22 April 2005.

<<http://www.opnet.com/products/panorama/>>

Rudd, Colin. “An Introductory Overview of ITIL Overview”. “ItSMF Overview Pocket Guide.pdf”. itSMF Ltd. July 2004. 14 March 2005.

<<https://asp5.catalog.com/khamilto2/books/itSMF%20Overview%20Pocket%20Guide.pdf>>

“Runtime infrastructure”. Wikipedia: the Free Encyclopedia. 23 May 2005. 28 June 2005.

<http://en.wikipedia.org/wiki/Runtime_infrastructure>

Sambari, A. and R. Bhagavathula, N. Thanthy and Dr. R. Pendse. “Teaching with OPNET: WSU’s Experience”. OPNET Technologies, Inc. 2002. 29 March

“See How Some Universities Are Applying OPNET Software”. OPNET Technologies, Inc. 4 May 2005.

<http://www.opnet.com/services/university/univ_use_opnet_list.html>

“Server Specialized Models.” OPNET Technologies, Inc. 21 June 2005.

<http://www.opnet.com/products/modules/server_model.html>

“Service Management Functions: Availability Management”. Microsoft Corporation. 2005. 17 May 2005.

<<http://www.microsoft.com/technet/itsolutions/cits/mo/smf/smfavamg.msp>>

“Service Management Functions: Capacity Management”. Microsoft Corporation. 2005. 17 May 2005.

<<http://www.microsoft.com/technet/itsolutions/cits/mo/smf/smfcapmg.msp>>

“Service Management Functions: Change Management”. Microsoft Corporation. 26 March 2004. 20 May 2005. <<http://www.microsoft.com/technet/itsolutions/cits/mo/smf/smfchgmg.msp>>

- “Service Management Functions: Configuration Management”. Microsoft Corporation. 26 March 2004. 20 May 2005. <<http://www.microsoft.com/technet/itsolutions/cits/mo/smf/smfcfgmg.mspix>>
- “Service Management Functions: Directory Services Administration”. Microsoft Corporation. 2005. 20 May 2005. <<http://www.microsoft.com/technet/itsolutions/cits/mo/smf/smfdirsa.mspix>>
- “Service Management Functions: Financial Management”. Microsoft Corporation. 2005. 20 May 2005. <<http://www.microsoft.com/technet/itsolutions/cits/mo/smf/smfainmg.mspix>>
- “Service Management Functions: Incident Management”. Microsoft Corporation. 2005. 20 May 2005. <<http://www.microsoft.com/technet/itsolutions/cits/mo/smf/smfincmg.mspix>>
- “Service Management Functions: Infrastructure Engineering”. Microsoft Corporation. 2005. 21 May 2005. <<http://www.microsoft.com/technet/itsolutions/cits/mo/smf/smfinfeng.mspix>>
- “Service Management Functions: Job Scheduling.” Microsoft Corporation. 2005. 23 May 2005. <<http://www.microsoft.com/technet/itsolutions/cits/mo/smf/smfjobsc.mspix>>
- “Service Management Functions: Network Administration”. Microsoft Corporation. 31 May 2005. 5 July 2005. <<http://www.microsoft.com/technet/itsolutions/cits/mo/smf/smfnetadm.mspix>>
- “Service Management Functions: Problem Management”. Microsoft Corporation. 2005. 23 May 2005. <<http://www.microsoft.com/technet/itsolutions/cits/mo/smf/smfprbmg.mspix>>
- “Service Management Functions: Release Management”. Microsoft Corporation. 27 March 2004. 23 May 2005. <<http://www.microsoft.com/technet/itsolutions/cits/mo/smf/smfrelmg.mspix>>
- “Service Management Functions: Security Administration”. Microsoft Corporation. 18 April 2005. 23 May 2005. <<http://www.microsoft.com/technet/itsolutions/cits/mo/smf/smfsecad.mspix>>
- “Service Management Functions: Security Management”. Microsoft Corporation. 18 April 2005. 23 May 2005. <<http://www.microsoft.com/technet/itsolutions/cits/mo/smf/mofsmsmf.mspix>>
- “Service Management Functions: Service Continuity Management”. Microsoft Corporation. 2005. 24 May 2005. <<http://www.microsoft.com/technet/itsolutions/cits/mo/smf/smfsrcmg.mspix>>

- “Service Management Functions: Service Desk”. Microsoft Corporation. 2005. 24 May 2005.
<<http://www.microsoft.com/technet/itsolutions/cits/mo/smf/smfsrcmg.msp>>
- “Service Management Functions: Service Monitoring and Control”. Microsoft Corporation. 27 March 2004. 24 May 2005. <<http://www.microsoft.com/technet/itsolutions/cits/mo/smf/smfsmc.msp>>
- “Service Management Functions: Storage Management”. Microsoft Corporation. 2005. 24 May 2005.
<<http://www.microsoft.com/technet/itsolutions/cits/mo/smf/smfstomg.msp>>
- “Service Management Functions: System Administration”. Microsoft Corporation. 2005. 25 May 2005.
<<http://www.microsoft.com/technet/itsolutions/cits/mo/smf/smfsysad.msp>>
- “Service Management Function: Workforce Management”. Microsoft Corporation. 2005. 25 May 2005.
<<http://www.microsoft.com/technet/itsolutions/cits/mo/smf/smfwrkmg.msp>>
- “SP Guru: Intelligent Network Management for Service Providers”. (SP Guru) OPNET Technologies, Inc. 2003. 20 April 2005. <<http://www.opnet.com/products/spguru/home.html>>
- “SP Guru's Virtual Network Environment”. OPNET Technologies, Inc. 2003. 20 April 2005.
<<http://www.opnet.com/products/spguru/vne.html>>
- “Teaching with IT Guru”. OPNET Technologies, Inc. 3 May 2005.
<http://www.opnet.com/services/university/itg_panko.html>
- “Teaching with OPNET - Overview”. OPNET Technologies, Inc. 3 May 2005. <<http://www.opnet.com/services/university/teaching.html>>
- “Terrain Modeling”. OPNET Technologies, Inc. 23 April 2005.
<<http://www.opnet.com/products/modules/tm.html>>
- “3D NV: 3D Network Visualizer”. OPNET Technologies, Inc. 2004. 20 April 2005.
<http://www.opnet.com/products/modules/3DNV_brochure.pdf>
- “System Performance Module for BMC Performance Assurance”. OPNET Technologies, Inc. 21 June 2005. <http://www.opnet.com/products/modules/spbmc_module.html>

- Theunis, J. and B. Van den Broeck, J. Potemans, E. Van Lil, and A. Van de Capelle. "OPNET in Advanced Networking Education". OPNET Technologies, Inc. 2002. 30 March 2005.
<ftp://enterprise8.opnet.com/cmp_root/papers/818/opnetwork02_johan.pdf>
- Thuente, David J. "Using OPNET Modules in an Undergraduate Network Projects Class". OPNET Technologies, Inc. 2002. 29 March 2005.
<ftp://enterprise8.opnet.com/cmp_root/papers/388/448.doc>
- "United States Geological Survey". Wikipedia: the Free Encyclopedia. 23 June 2005. 28 June 2005.
<<http://en.wikipedia.org/wiki/USGS>>
- "Validate Solutions", OPNET Technologies, Inc. 23 April 2005.
<http://www.opnet.com/products/modules/ace/validate_solutions.html>
- Van den Broeck, B. and P. Leys, J. Potemans, J. Theunis, E. Van Lil, A. Van de Capelle. "Validation of Router Models in OPNET." OPNET Technologies, Inc. 2002. 29 March 2005.
<ftp://enterprise8.opnet.com/cmp_root/papers/370/402.doc>
- "Visualize Transactions". OPNET Technologies, Inc. 23 April 2005.
<http://www.opnet.com/products/modules/ace/visualize_transactions.html>
- "UMTS Module: Discrete Event Simulation, Specialized Model". OPNET Technologies, Inc. 21 June 2005. <<http://www.opnet.com/products/library/umts.html>>
- "VNE Server Advanced Features." OPNET Technologies, Inc. 2003. 22 April 2005.
<http://www.opnet.com/products/vne/advanced_features.html>
- "VNE Server Supported Data Sources". OPNET Technologies, Inc. 2003. 22 April 2005.
<<http://www.opnet.com/products/vne/home.html>>
- "WDM Guru's Virtual Network Environment". OPNET Technologies, Inc. 20 April 2005.
<<http://www.opnet.com/products/wdmguru/vne.html>>
- "WDMGuru: Intelligent Planning for Optical Network". OPNET Technologies, Inc. 20 April 2005.
<<http://www.opnet.com/products/wdmguru/>>
- Whitman, Michael E. and Herbert J. Mattord. Principles of Information Security, Second Edition. Boston: Thomson, 2005.

“Wireless Module”. OPNET Technologies, Inc. 20 April 2005.

<http://www.opnet.com/products/modules/wireless_module.html>

Zubairi, Junaid Ahmed & Mike Zuber. “SUNY Fredonia Campus Network Simulation and Performance Analysis Using OPNET”. 28 August 2000. 26 March 2005.

<ftp://enterprise8.opnet.com/cmp_root/papers/113/179_.doc>

Note: Only people with OPNET Technologies, Inc's usernames and passwords can access any of the above documents starting with <ftp://enterprise8.opnet.com>. They are contributed paper accessed from OPNET University Program web pages.

Glossary

ARNe – Regis University's Academic Research Network

DecisionGuru – A program no longer produced by OPNET Technologies, Inc.

DEM (Digital Elevation Model) – A “representation of the topography of the Earth, or another surface in digital format,” consisting of “coordinates and numerical descriptions of altitude” stored in a raster format suitable for display on a computer monitor. (“Digital elevation”)

DTED (Digital Terrain Elevation Data) – Standard digital datasets for terrain elevation values developed by the National Imagery and Mapping Agency intended for modeling and assessment purposes. (“Digital Terrain”)

HIPAA (Health Insurance Portability and Accountability Act) – Law that “protects the confidentiality and security of health care data” (Whitman 540).

ISP (Internet Service Provider) – A company that provides access to the Internet to another company or to an individual for a fee.

ITIL (Information Technology Infrastructure Library) – a set of documents produced by the Office of Government Commerce, a government agency in the United Kingdom. These documents describe an operational framework for managing an organization.

MOF (Microsoft Operations Framework) – A management framework intended to provide guidance in how to effectively manage network operations developed by Microsoft Corporation that it uses and recommends for use to others.

MSF (Microsoft Solutions Framework) – A management framework intended to provide guidance in how to effectively manage software development developed by Microsoft Corporation that it uses and recommends for use to others.

NLP (Networking Lab Practicum) – A Regis University program intended to provide students with an opportunity to obtain some practical experience with information technology and a place to develop a professional project.

OGC (Office of Government Commerce) – A government agency in the United Kingdom
Practicum – New name for NLP.

RTI (Runtime Infrastructure) – Middleware required to implement High Level Architecture (“Runtime”)

Sarbanes-Oxley Act of 2002 – Law that “affects publicly traded corporation and public accounting firms.” It governs financial reporting, corporate governance (Whitman 84).

SLA (Service Level Agreement) – An agreement made by an IT department to deliver to deliver a certain service and service quality to an end user.

SMF (Service Management Function) – A set of services provisioned and managed in a given functional management area such as availability management or change management (“Service”)

T1 – A type of wide area network connection that has an operational speed of 1.544 Mbps.

USGS (United States Geological Survey) – An agency of the United States government that, among other things, produces topographical maps of the US from data it has acquired through research. (“United”)

Exhibit 1 – University Program programs and modules

The following programs are available from OPNET Technologies, Inc. through its University Program – IT Guru, IT Sentinel, SP Guru, SP Sentinel, WDM Guru, Modeler, Commander, Panorama, VNE Server, Report Server, and OPNET Development Kit.

The following modules are available from OPNET Technologies, Inc that work with the some of the above programs: the Application Characterization Environment (ACE), the ACE Decode module, the

Automation module, the Distributed Agent Controller (DAC), the Flow Analysis module, the High-Level Analysis module, the IPv6 module, the Multi-Vendor Import module, the Mainframe Model module, the MPLS Module, the NetDoctor module, the Planning and Design Module, the Server Specialized Models module, the System Performance Module for BMC Performance Assurance (SPBMC), the System Performance Module for HP OpenView, the Terrain Modeling module, the TIREM Module, the 3D Network Visualizer Module, the UMTS Module, the Wireless module, and three other modules.

Exhibit 2 – Textbooks, Lab Manuals, and Labs for OPNET

Textbooks and Labs that work with IT Guru and Modeler in the classroom.

Computer Networks, Third Edition, by Andrew Tannenbaum

See web page “Academic Resource Center” at http://www.opnet.com/services/university/arc_home.html for IT Guru Plan and Modeler Plan

Textbook:

Business Data Communications, Fifth Edition, by William Stallings

Lab Manual:

Lab Manual, 5E by Leann Christianson

Textbook:

Business Data Networks & Telecommunications, Fourth Edition by Raymond R. Panko

Labs:

There are seven labs available for IT Guru that can be downloaded from OPNET's web site

Textbook:

Computer Networks, A Systems Approach, Edition 3, by Larry Peterson and Bruce Davie

Labs:

There are 11 labs available for download from OPNET's web site

Textbook:

Computer Networks by Larry Peterson and Bruce Davie

Lab Manual:

Lab Manual by Emad Aboeela

Textbook:

Computer Networking with Internet Protocols by William Stallings

Lab Manual:

Lab Manual, 7E by Kevin Brown

Textbook:

Data and Computer Communications, 7E, by William Stallings

Lab Manual:

Lab Manual, 7E by Kevin Brown

Textbook:

Data and Computer Communications, Seventh Edition by William Stallings

Lab Manual:

Data and Computer Communications and Computer Networking with Internet Protocols and Technology:

Opnet Lab Manual to Accompany the seventh edition and fourth edition by William Stallings, Kevin Brown, and Leann Christianson.

Exhibit 3 – How OPNET's Programs Fit Into SMFs

MOF SMFs

Changing Quadrant

- Change Management* – no OPNET programs (initiates, categorizes, assesses, plans, approves, and manages changes to networks, systems, processes, and procedures)

- Configuration Management* – Flow Analysis Module, IT Guru, IT Sentinel, NetDoctor, Report Server, SP Guru, SP Sentinel, VNE Server, WDM Guru (discovers, monitors, tracks and audits network configurations and systems configurations)
- Release Management – IT Guru, IT Sentinel, Panorama, Report Server, SP Guru, SP Sentinel, VNE Server, WDM Guru (plans, builds, acceptance tests, prepares, deploys, and evaluates releases)

Operations Quadrant

- Directory Services Administration* – Commander, IT Guru, IT Sentinel, NetDoctor, Report Server, SP Guru, SP Sentinel, VNE Server, WDM Guru (configures, monitors, maintains, supports, and troubleshoots directory services and directory databases)
- Job Scheduling – no OPNET programs (schedules batch processing jobs to have minimal impact on systems users, plans, executes, and monitors batch processing jobs, maintains quality standards for batch processing)
- Network Administration* – ACE, ACE Decode, Automation Module, Commander DAC, Flow Analysis Module, IT Guru, Modeler, IT Sentinel, MVI Module, NetDoctor, Planning and Design Module, Panorama, Report Server, Report Server, SP Guru, SP Sentinel, VNE Server, WDM Guru (deploys, configures, operates, monitors, maintains, and troubleshoots networks and core networking components, performs routine maintenance, documents network configurations)
- Security Administration* – ACE, ACE Decode, Automation Module, Commander, DAC, Flow Analysis Module, IT Guru, IT Sentinel, Modeler, MVI Module, NetDoctor, Planning and Design Module, Panorama, Report Server, SP Guru, SP Sentinel, VNE Server, WDM Guru (maintains secure computing environment, does risk assessments, does risk planning, develops, deploys, and maintains risk handling measures, and monitors security policies and measures)
- Service Monitoring and Control – ACE, ACE Decode, Automation Module, DAC, Flow Analysis module, IT Guru, NetDoctor, Commander, Panorama, Report Server SP Guru, VNE Server, WDM Guru, (measures and monitors service levels; generates service exception alerts, and automates service exception corrections)

- Storage Management* – Flow Analysis Module, IT Guru, Modeler, Planning and Design Module, Report Server, SP Guru, VNE Server, WDM Guru (manages company data backups and restores, manages company storage resources, and forecasts future storage needs)
- Systems Administration* – ACE module, ACE Decode module, Automation Module, Commander, DAC, Flow Analysis Module, IT Guru, IT Sentinel, MVI Module, NetDoctor, Report Server, SP Guru, SP Sentinel, VNE Server, WDM Guru (defines processes and procedures used to administer systems, administers the services that support the elements that make up a production environment, and may assist in security policy enforcement)

Supporting Quadrant

- Incident Management – ACE, ACE Decode, Automation Module, Commander, DAC, Flow Analysis Module, IT Guru, IT Sentinel, MVI Module, NetDoctor, Panorama, Report Server SP Guru, SP Sentinel, VNE Server, WDM Guru, (detects, responds to, classifies, analyzes, and resolves incidents, responds to service requests, and restores services)
- Problem Management – ACE, ACE Decode, Automation Module, Commander, DAC, Flow Analysis Module, IT Guru, IT Sentinel, Modeler, MVI Module, NetDoctor, Panorama, Report Server, SP Guru, SP Sentinel, VNE server, WDM Guru (analyzes the underlying causes of incidents, initiates changes to procedures and processes that remove or work around the causes found)
- Service desk – no OPNET programs (answers questions, fields complaints about services, takes service requests, authorizes work orders, assigns technicians to work orders, tracks work orders and their resolution, and reports on service desk activities)

Optimizing Quadrant

- Availability Management – ACE, ACE Decode, Automation Module, Commander, IT Guru, Flow Analysis Module, IT Sentinel, Modeler, MVI Module, NetDoctor, Planning and Design Module, Panorama, Report Server, SP Guru, SP Sentinel, VNE Server (measures, monitors, and audits system availability, negotiates service level and operating level agreements, assesses risks to availability and ways to mitigate those risks)
- Capacity Management – ACE, ACE Decode, Automation Module, Commander, DAC, Flow Analysis Module, IT Guru, IT Sentinel, Modeler, MVI Module, NetDoctor, Panorama, Planning and Design

Module, Report Server, SP Guru, SP Sentinel, VNE Server, WDM Guru (monitors service delivery levels, ensures service and operational level agreements are fulfilled, forecasts future service level needs)

- Financial Management – Report Server (identifies costs of assets and activities, assesses how to disperse funds for technology and resources, creates budgets, and does cost/benefit analysis of present and future technology and resources)
- Infrastructure Engineering – no OPNET programs (manages and promotes the discovery, development, and use of standards and policies that apply to infrastructure)
- Security Management – Report Server (advises management on security needs, security policies, and methods of implementing security, develops security management processes)
- Service Continuity Management * – no OPNET programs (defines key business processes, determines the risks to the processes, determines the mitigations to the risks, defines ways to restore key business processes that have failed because of unexpected events, puts the results in a business continuity plan)
- Service Level Management – Commander, Panorama, Report Server, VNE Server (defines the services needed by a business, creates a service level catalog, determines the service levels needed to meet the business's needs, monitors service levels, reports on service levels)
- Workforce Management – no OPNET programs (determines what skills are needed by a business to meet its goals, creates a favorable work environment for employees, develops skills of employees)

* SMFs selected by Adam Brennen

Note: I have omitted consideration of OPNET Development Kit as it is used for building custom network management application, something Regis University is doing. I have also omitted consideration of wireless network modules – Terrain Modeling Module, TIREM Module, 3D Network Visualizer Module – as Regis University only has a small wireless network. And I have omitted consideration of some other modules which I do not believe have any utility for ARNe.

[See Addendum A for descriptions of the MOF SMFs.]

Exhibit 4 – OPNET Software Recommendations

Software Recommendations:

These programs meet the following criteria:

Runs on Microsoft 2003 Server, unless otherwise noted

Available for low or no cost

Compatible with VMware, unless otherwise noted

Automates, or helps with, a network management function

Application Characterization Environment (ACE)

Dependencies: IT Guru, SP Guru

Services provided: Captures and analyzes packet traces; diagnoses problems; validates network changes

Automates function: Automatically diagnoses performance problems

SMFs: Availability Management, Capacity Management, Incident Management, Network Administration, Problem Management, Security Administration, Service Monitoring and Control, System Administration

Automation module

Dependencies: IT Guru, SP Guru, Flow Analysis modules, and NetDoctor

Services provided: Provides end-to-end work flow management

Automates function: Automates end-to-end workflow management

SMFs: Availability Management, Capacity Management, Incident Management, Network Administration, Problem Management, Security Administration, Service Monitoring and Control, Systems Administration

Commander

Limitation: Runs on MS Windows 2003 Server, but not on VMware emulation of same)

Dependencies: Requires database, either Oracle 9i Enterprise Edition or Microsoft SQL Server 2000 Standard Edition

Services provided: Monitors application availability and application service levels

SMFs: Availability Management, Capacity Management, Directory Services Administration, Incident Management, Network Administration, Problem Management, Security Administration, Service Level Management, Service Monitoring and Control, Systems Administration

Distributed Agent Controller (DAC) module

Dependencies: IT Guru, Synthetic transaction generators

Services provided: Captures and archives application traces for later analysis

Automates functions: Automatically captures and archives application traces

SMFs: Capacity management, Incident Management, Network Administration, Problem Management, Security Administration, Service Monitoring and Control, Systems Administration

Flow Analysis module

Dependencies: IT Guru, Modeler

Services provided: Does traffic flow analysis of links and circuits network

Automates functions: Automates the selective failure of network objects in a network model

SMFs: Availability Management, Capacity Management, Configuration Management, Incident Management, Network Administration, Problem Management, Security Administration, Service Monitoring and Control, Storage Management, Systems Administration,

IT Guru

Components: IT Guru software, models, IT Guru documentation (“Product”)

Services provided: Demonstrate network behavior in the classroom; does network mapping, modeling, performance simulations

SMFs: Availability Management, Capacity Management, Configuration Management, Release Management, Directory Services Administration, Incident Management, Network Administration, Problem Management, Security Administration, Service Monitoring and Control, Storage Management, System Administration,

IT Sentinel

Components: CD set includes IT Sentinel, Model Library, VNE Server, Report Server, IT Sentinel documentation (“Product Updates: OPNET IT Sentinel 11.0”)

Services provided: Configuration audits for network devices; Creates network models

Automates function: Automates configuration workflow process

SMFs: Availability Management, Capacity Management, Configuration Management, Directory Services Administration, Incident Management, Network Administration, Problem Management, Release Management, Security Administration, System Administration

NetDoctor

Services provided: Does configuration audits, security audits, policy enforcement checks, and report generation

Automates functions: Automates network configuration, policy, and security audits, and report generation

SMFs: Availability Management, Capacity Management, Configuration Management, Directory Services Administration, Incident Management, Problem Management, Network Administration, Security Administration, Service Monitoring and Control, Systems Administration

Report Server

Dependencies: Other OPNET programs to provide reports to store and display

Services provided: Archives reports generated by other OPNET programs; publishes reports to network

Automates function: Automates the organizing and archiving of reports

SMFs: Availability Management, Capacity Management, Configuration Management, Directory Services Administration, Incident Management, Network Administration, Problem Management, Release Management, Security Administration, Service Monitoring and Control, Security Management, Service Level Management, Storage Management, Systems Administration

VNE Server

Dependencies: Oracle 8i or 9i databases

Services provided: Can import data; merges disparate data from multiple sources; provides multiple views of near real-time network state (“VNE Server Return”)

Automates Function: Automates the display of network data; Merges data; automatically determines network topology (“VNE Server Advanced”)

SMFs: Availability Management, Capacity Management, Configuration Management, Directory Services Administration, Incident Management, Network Administration, Problem Management, Release Management, Security Administration, Service Level Management, Service Monitoring and Control, Storage Management, Systems Administration

Limitation to the use of the programs under the University Program.

IT Guru Academic Edition can be installed on student's home computers, all of the rest of OPNET's programs can only be installed on university computers.

Three Possible Combinations:

IT Guru + ACE + ACE Decode (Windows 2000 only) + Flow Analysis + DAC + Automation module + VNE Server + Report Server

Information imported into IT Guru from VNE Server automates network model building; Total combination does high quality performance analysis, and what-if analysis; produces an integrated view of network that is near real-time; creates reports and displays them to all interested parties

VNE Server + NetDoctor + Flow Analysis + Report Server

Provides near real-time views of network; audits network and security configurations; analyzes network traffic flow; publishes reports

IT Sentinel + VNE Server + Report Server

Automates workflow for configuration audits; shows near-real time network state; publish reports on configuration audit and network performance; publishes reports

Addendum A – Microsoft MOF SMFs

Availability management manages the availability of IT services throughout their lifecycle. New technologies and services are assessed by the customer and availability management to define what their level of availability should be. Current technology and services are measured for their current levels of availability. If they falls short of what is desired ways are sought to improve their levels of availability.

Availability management assesses the risks to availability of everyday services, then mitigates them with counter-measures. And it ensures that prompt action is taken to handle and recover from incidents if they do happen. This encompasses activities like availability planning, modeling, collection, and interpretation of availability metrics, establishment of attainable service level agreements, incident detection and recovery, and forecasting future availability needs. Availability management considers policy, procedures, process effectiveness, skills, training, and tools when assessing service availability levels. (“Service Management Functions: Availability”)

Capacity Management right-sizes computer system infrastructure and staffing to deliver optimized services at performance levels specified in service level agreements and operating level agreements. It spans business capacity needs, service capacity needs, and resource capacity needs. Its processes include “planning, analyzing, sizing, and optimizing capacity to satisfy demand in a timely manner at a reasonable cost” in a way that can meet a business's requirements. This is done by establishing quality of service metrics, monitoring computer systems, analyzing system performance, modeling computer systems, optimizing computer systems, analyzing trends, and initiating appropriate changes. Capacity management encompasses all hardware, software, peripherals, networking equipment, and human resources (human resources to the extent that sufficient staff is on the job to get tasks done without affecting service availability). (“Service Management Functions: Capacity”)

Change Management provides an orderly process for introducing changes into an IT environment. This encompasses activities like initiating change with a request of change (RFC), classifying the change according to its urgency and impact on infrastructure and users, moving RFCs to the “change manager and change advisory board (CAB) for approval or rejection,” doing deployment planning for the change, working with the Release Management SMF to manage the deployment of the change, and reviewing the change for effectiveness and evaluating “whether to keep the change or back it out.” (“Service Management Functions: Change”)

Configuration Management identifies, controls, and tracks all versions of authorized procedures, processes, software, hardware, and documentation. It creates, provides access to, and uses a configuration database to do the tracking. It involves activities like deciding what needs to be managed, setting up the configurations for network items, verifying the configurations, managing the configurations, managing changes to the configurations, and controlling access to the configuration management database. (“Service Management Functions: Configuration”)

Directory Services Administration provides accurate, personalized directory services for the easy location of network resources by application programs or authorized network user. The resources accessed can be applications, services, tools, servers, and users. Directory services administration involves activities like monitoring, maintaining, and supporting the directory, and troubleshooting problems with the directory. (“Service Management Functions: Directory “)

Financial Management is concerned with how funds are dispersed to support needed technology and services that support a business's goals. It identifies the costs of assets and activities. It compares the cost of providing technology and services to the financial benefits of providing that technology and those services. It assesses the potential costs and the potential benefits of prospective technology and services. It allocates direct and indirect costs to the various departments in a company. It decides how to divide up capital costs over a period of years. It determines the return on investment for expenditures. It involves activities such as “budgeting, cost accounting, cost recovery, cost allocations,” charge-back accounting, revenue accounting, billing, and determining the cost of ownership of assets. (“Service Management Functions: Financial”)

Incident Management detects and responds to incidents as quickly as possible, responds to service desk requests, analyzes incidents, targets support resources needed to resolve incidents, then restores interrupted services as quickly as possible. It involves activities such as detecting and recording incidents, classifying and prioritizing incidents, investigating and diagnosing incidents, resolving and recovering from

incidents, closing incidents, providing incident response procedures, reporting incidents to management, and providing access to information on recorded incidents to authorized personnel. (“Service Management Functions: Incident”)

Infrastructure Engineering discovers existing standards and policies, promotes their use company wide, manages the development of new ones where they are needed, and coordinates their use across the company. It involves activities such as discovering and documenting the policies, standards, and processes used in the infrastructure environment, dividing the infrastructure policies and standards into logical groupings, deciding to what extent those policies and standards can be applied to logically grouped infrastructure and be guided by them, aligning policies and standards with business processes, documenting the infrastructure environment guided by policies and standards, and reviewing the degree to which policies and standards are applied to see if changes are needed. (“Service Management Functions: Infrastructure”)

Job Scheduling schedules and runs batch processing jobs in such a way that users are minimally affected. Job scheduling involves such activities as creating batch processing schedules, maintaining quality standards, using change management to manage changes in batch processing schedules, controlling batch runs, monitoring batch runs, analysis and tuning of batch runs, and working in requests as they are made with minimal impact on current schedules. Batch processing can run jobs such as marketing reports, financial management reports, inventory reports, automated data backup reports, and system processing reports.” (“Service Management Functions: Job”)

Network Administration configures, operates, monitors, maintains, and troubleshoots core networking components such routers, switches, hubs, firewalls, network interface cards, wireless access points, cabling, and in some cases servers which provide network services such as DHCP, DNS, WINS, and RAS. It involves activities such as deploying network devices and services, configuring network devices and

services according to their manufacturer's recommendation and company needs, reconfiguring network devices and services as network needs change, documenting configurations, monitoring network health, performing routine hardware and software maintenance, troubleshooting performance fall-offs, network problems, and device or service failures, and performing data backups on applicable servers. (“Service Management Functions: Network “)

Problem Management investigates and analyzes “the root causes of incidents” and initiates changes to processes and procedures that work around the problems underlying the incidents or resolve them. It involves activities such as recording incident data, classifying incidents and underlying problems, problem investigation, problem analysis, problem diagnosis, problem resolution, and problem closure. (“Service Management Functions: Problem”)

Release Management introduces change into the network environment with the least amount of disruption. It involves activities such as planning a release based upon approved changes, packaging a set of changes into a release, determining if a release is ready for production, designing a release strategy, testing release mechanisms to see if disruptions to production environment are minimal, reviewing release preparation, and deploying a release upon approval by change management. (“Service Management Functions: Release”)

Security Administration maintains a secure computing environment that protects data integrity, confidentiality, and availability. It also maintains a secure facilities environment for an organization's personnel. It involves such activities as defining security policies and procedures, defining data lifecycle policies, identifying and authenticating users, setting up and maintaining system, folder, and file access controls, maintaining the security of applications, hardware, middleware, and operating systems, maintaining network, systems, facilities, and personnel security, conducting security audits, maintaining audit logs, configuring and maintaining firewalls, packet filtering routers, intrusion detection systems, and other security systems, setting up, maintaining and monitoring encryption methods and systems, doing vulnerability testing, and doing security assessments. (“Service Management Functions: Security”)

Security Management advises organizational management about the high-level security needs of an organization, defines the security roles in an organization, describes security program best practices, develops a security management program, and develops key performance metrics. It involves such activities as developing security leadership, developing methods of assessing risks to security, developing a schema for classifying assets, identifying components of security plans and policies, identifying security measure options, establishing processes for managing risk, establishing processes for responding to incidents, and establishing processes for security monitoring and security auditing. (“Service Management Functions: Security”)

Service Continuity Management manages the risks to IT services and infrastructure with the goal of maintaining services in the face of unanticipated and unlikely event. It produces a written contingency plan called a business continuity plan outlining what should be done when the unlikely happens. It involves such activities as analyzing business processes and their importance to a business, determining which processes are the key business processes, determining what vulnerabilities these processes have, and defining ways of reducing or mitigating vulnerabilities to those processes. It also involves defining required operating levels and service levels for business processes, defining ways to maintain or restore certain minimum operating and service levels in critical processes in the face of the unexpected, and creating agreements within the company that reflect its operating and service level needs. (“Service Management Functions: Service Continuity”)

Service Desk Management provides a single point of contact between an organization's staff and its customers in the form of a call center, a service desk, a help desk, or a customer hot line. It involves activities such as managing service desk resources, communicating with customers, doing service desk processes, marketing and promoting use of the service desk, managing costs, monitoring services desk personnel performance, and preparing reports on service desk operations. (“Service Management Functions: Service Desk”)

Service Level Management provides and improves upon IT service levels to company service users. It ensures that delivered IT services meet the business needs of the company providing those services. It involves activities such as creating and maintaining a service catalog, creating service level baselines, creating metrics for service levels, using the metrics to monitor service levels to make sure that agreed upon service levels are maintained, creating service level agreements based on the metrics, reporting results of measurements of service levels delivered against agreed upon service levels, and doing service level agreement reviews to see if established service levels meet the organizations needs. (“Service Management Functions: Service Level “)

Service Monitoring and Control monitors the “health conditions” (identifiable characteristics indicating success or failure) of a computing environment, provides alerts, provides automatic correction of “service exceptions,” and initiates service repairs when service lags or fails. It also provides monitoring data to other service management functions. It involves activities such as determining instrumentation needed to monitor the health state of the network and its components, setting up management instrumentation against service level and operations level agreements, monitoring management instrumentation, documenting management instrumentation, documenting “service health states and transitions,” creating a health model of the network, and identifying network and component conditions that require the involvement of an administrator. (“Service Management Functions: Service Monitoring”)

Storage Management manages data storage, both on site and off site, for archival and data restoration purposes. It defines data, classifies data, tracks data, maintains data, backs up data, restores data, recovers data, and maintains storage resources. It also manages the physical security of archives and backups. It involves activities such as developing storage plans, developing storage policies and procedures, developing monitoring procedures for storage resources, monitoring storages resources, and forecasting future storage needs. It also involves activities such as acquiring storage media, formatting storage media, organizing storage media, and retiring storage media. (“Service Management Functions: Storage “)

System Administration defines the processes and procedures used to administer computing infrastructure and provides day-to-day administrative services that support computing infrastructure. This means “managing and providing operational support for various elements” within a production environment. It may also mean administering things it does not implement or manage, like user account management, data backups and restores, printing resource management, “first level performance and capacity monitoring,” and it may assist with enforcing security policy.

System administration does “Security Administration, Service Monitoring and Control, Job Scheduling, Network Administration, Directory Services Administration, Print and Output Administration, and Storage Management.” (“Service Management Functions: System”)

Workforce Management is concerned with recruiting, developing, and retaining IT operations personnel, and with creating an ergonomic work environment that is conducive to safety and efficiency. It determines what skill sets a business needs, what staffing levels it needs, and then fills the positions by either hiring people who have those skills, or by training employees so that they have those skills. It provides clear career paths for company employees. It provides mentoring, training, and certifications to company employees so that employees can maintain and develop their skills. And it maintains an inventory of employee skill sets so that it always knows what it has compared to what it needs. It involves activities such as developing job descriptions, developing needed skill sets in employees, creating new hire induction programs, planning ways to retain employees, measuring employee retention rates, managing employee absences, setting job performance goals with metrics, monitoring and measuring employee job performance, evaluating job performance, developing and using reward systems for strong job performance, and promoting workplace safety. (“Service Management Function: Workforce”)

Addendum B – Evaluation Criteria

OPNET programs	OSs	VMWare emulation	Also needed	Free/Low Cost	University Program?	Automates a function	Services Provided
Commander	M1, M2, S1, S2	No Windows emulation	Oracle 9i Enterprise Edition or Microsoft SQL Server 2000 databases	Yes	Provisional		Monitors application service levels and application availability Creates network models; Runs network simulations
IT Guru	M1, M2, M3, M4, M5, S1, S2		VNE Server for Sentinel, Oracle, Report Server for Sentinel, Sentinel Analysis and Automation	Yes	Explicit		Does configuration audits; Creates network models Does advanced network modeling and simulations
IT Sentinel	M1, M2, M3			Yes	Provisional	Automates configuration workflow process	
Modeler	M1, M2, M3, M4, M5, S1, S2			Yes	Explicit		
ODK	M1, M2, M3, M4, M5, S1, S2		ANSI C or C++, or Visual C/C++, or .NET compiler	Yes	Provisional		Software development toolkit for customizing IT Guru or SP Guru
Panorama Console System	M1, M2, S1, S2	No Windows emulation		Yes	Provisional		Analyzes collected performance data; Displays results
Panorama Collector System	M1, M2, M3, M4, M5, RH1, RH2, S1, S2, HP1, IBM1	No Windows emulation		Yes	Provisional		Collects performance data about devices or applications

Report Server	M1, M2, M3, ?		Yes	Provisional	Automatically organizes and archives reports	Archives reports and displays them in a web browser
SP Guru	M1, M2, M3, M4, M5, S1, S2		Yes	Provisional		Network modeling and simulations
SP Sentinel	M1, M2, M3, M4, M5, S1, S2		Yes	Provisional	Automates configuration workflow process	Configuration audit program; Creates network model
VNE Server	M1, M2, M3, M4	Oracle 8i, 9i	Yes	Provisional	Automates display of network data; merges data and automatically determines network topology	Imports data; Provides multiple views of current network state
WDM Guru	M1, M2, M3, M4, M5, S1, S2		Yes	Explicit		Network modeling and simulations
OPNET modules						
ACE module	M1, M2, M3, M4, M5, S1, S2	IT Guru, SP Guru	Yes	Provisional	Automatically diagnoses application performance problems	Captures and analyzes packet traces, diagnose problems, validate network changes
ACE Capture Agents	M1, M2, M3, M4, M5, S1, S2, HP1, IBM1, other	IT Guru, SP Guru	Yes	Provisional		

ACE Decode module	M3, M4, M5	ACE IT Guru or SP Guru,	Yes	Provisional		Provides 400+ application and protocol decodes
Automation module	M1, M2, M3, M4, M5, S1, S2	Flow Analysis, and NetDoctor	Yes	Provisional	Automates end-to-end workflow	Provides end to end workflow management
DAC module	M1, M2, M3, M4, M5, S1, S2	IT Guru, Synthetic Transaction Generator	Yes	Provisional	Automatically captures and archives application traces	Captures and archives application traces for analysis by ACE
Flow Analysis module	M1, M2, M3, M4, M5, S1, S2	IT Guru, Modeler	Yes	Provisional	Automates selective failure of objects in network model revealing weaknesses	Provides traffic flow analysis of links and circuits
HLA module	M1, M2, M3, M4, M5, S1, S2	IT Guru, SP Guru, Modeler, ODK	Yes	Provisional		Federates simulators using the HLA federation models
Mainframe Model module	M1, M2, M3, M4, M5, S1, S2	IT Guru	?	?		Provides models for zSeries and S/90 mainframes
MPLS Module	M1, M2, M3, M4, M5, S1, S2	SP Guru, Modeler, ODK	?	?		Provides MPLS model
MVI module	M1, M2, M3, M4, M5, S1, S2	IT Guru, Modeler, VNE Server (part of SP Guru)	? No	No		Imports data from proprietary programs

NetDoctor module	M1, M2, M3, M4, M5, S1, S2	IT Guru or Modeler; part of SP Guru IT Guru, Modeler, Flow Analysis module (part of SP Guru)	Yes	Provisional	Automates network configuration, policy, and security audits	Does network configuration audits, policy, and security audits, and report generation
Planning and Design module	M1, M2, M3, M4, M5, S1, S2	IT Guru or Modeler; part of SP Guru IT Guru, Modeler, Flow Analysis module (part of SP Guru)	Yes	Provisional	Automatically designs network topologies	“provides library of automated design actions”
Server Specialized Models module	M1, M2, M3, M4, M5, S1, S2	IT Guru	?	?		Provides models for a variety of vendors servers
SPBMC	M1, M2, M3, M4, M5, S1, S2	BMC Patrol, IT Guru	?	?		SPBMC imports data from BMC Visualizer database
SPHP module	M4, M5	HP OpenView, IT Guru	Yes	Provisional		SPHP imports data from HP OpenView Performance agents
Terrain Modeling module	M1, M2, M3, M4, M5, S1, S2	IT Guru, SP Guru, Modeler, ODK	Yes	Provisional		Enables the modeling of environmental effects on wireless networks
TIREM module	M1, M2, M3, M4, M5, S1, S2	IT Guru, SP Guru, Modeler, ODK	Yes	Provisional		Computes propagation loss due to terrain contours
3D Network Visualizer module	M3, M4	IT Guru, SP Guru, Modeler	?	?		Generates 3D view of terrain of wireless network modeling

UMTS Module	M1, M2, M3, M4, M5, S1, S2	Modeler, Wireless module, IPv6 module	?	?	Provides model for UMTS wireless protocol
Wireless module	M1, M2, M3, M4, M5, S1, S2	IT Guru, SP Guru, Modeler, ODK	Yes	Provisional	Enable modeling of wireless networks

Legend
 HP_UX 11i HP1
 IBM AIX 4.3, 5L IBM1

Microsoft Windows 2000 Server M1
 Microsoft Windows 2003 Server M2
 Microsoft Windows 2000 Pro M3
 Microsoft Windows XP Pro M4
 Microsoft Windows NT 4.0 M5

 Red Hat 7.2, 7.3, 8.0 RH1
 Red Hat Enterprise 2.1, 3.0 RH2

 Sun Solaris 8 S1
 Sun Solaris 9 S2