Evaluating of DNP3 protocol over serial eastern operating unit substations and improving SCADA performance

by

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DECLARATION

I Dion Njova declare that **Evaluating of DNP3 protocol over serial eastern operating unit substations and improving SCADA performance** is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

I declare that I have submitted it to originality checking software.

I further declare that I have not previously submitted this work or part of it for examination at UNISA for another qualification or at any other higher education institution.

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DEDICATION

This study is dedicated to my late Father Mr Mfanilo Njova my mother Mrs Mayalo Princess Msiya, My wife Mrs Nocawe Njova, my son Stephen Njova and my daughter Zinathi Njova.

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3. To my family, friends and colleagues, thank you for your support and motivations.

ABSTRACT

Supervisory Control and Data Acquisition (SCADA) is a critical part of monitoring and controlling of the electrical substation. The aim of this dissertation is to investigate the performance of the Distributed Network Protocol Version 3.3 (DNP3) protocol and to compare its performance to that of International Electro-technical Commission (IEC) 61850 protocol in an electrical substation communication network environment. Building an electrical substation control room and installing the network equipment was going to be expensive and take a lot of time. The better option was to build a model of the electrical substation communication network and run simulations.

Riverbend modeller academic edition known as Optimized Network Engineering Tool (OPNET) was chosen as a software package to model substation communication network, DNP3 protocol and IEC 61850 Protocol stack. Modelling the IEC 61850 protocol stack on OPNET involved building the used Open System Interconnection (OSI) layers of the IEC 61850 protocol stack onto the application definitions of OPNET. The Transmission Control Protocol/Internet Protocol (TCP/IP) configuration settings of DNP3 protocol were also modelled on the OPNET application definitions. The aim is to compare the two protocols and determine which protocol is the best performing one in terms of throughput, data delay and latency.

The substation communication model consists of 10 ethernet nodes which simulate protection Intelligent Electronic Devices (IEDs), 13 ethernet switches, a server which simulates the substation Remote Terminal Unit (RTU) and the DNP3 Protocol over TCP/IP simulated on the model. DNP3 is a protocol that can be used in a power utility computer network to provide communication service for the grid components. DNP3 protocol is currently used at Eskom as the communication protocol because it is widely used by equipment vendors in the energy sector. DNP3 protocol will be modelled before being compared to the new recent robust protocol IEC 61850 in the same model and determine which protocol is the best for Eskom on the network of the power grid. The network load and packet delay parameters were sampled when 10%, 50%, 90% and 100% of devices are online.

The IEC 61850 protocol model has three scenarios and they are normal operation of a Substation, maintenance in a Substation and Buszone operation at a Substation. In these scenarios packet end to end delay of Generic Object Oriented Substation Event (GOOSE),

Generic Substation Status Event (GSSE), Sampled Values (SV) and Manufacturing Messaging Specification (MMS) messages are monitored. The throughput from the IED under maintenance and the throughput at the Substation RTU end is monitored in the model. Analysis of the results of the DNP3 protocol simulation showed that with an increase in number of nodes there was an increase in packet delay as well as the network load. The load on the network should be taken into consideration when designing a substation communication network that requires a quick response such as a smart gird. GOOSE, GSSE, SV results on the IEC 61850 model met all the requirements of the IEC 61850 standard and the MMS did not meet all the requirements of the IEC standard. The design of the substation communication network using IEC 61850 will assist when trying to predict the behavior of the network with regards to this specific protocol during maintenance and when there are faults in the communication network or IED's. After the simulation of the DNP3 protocol and the IEC 61850 the throughput of DNP3 protocol was determined to be in the range (20 – 450) kbps and the throughput of IEC61850 protocol was determined to be in the range (1.6 – 16) Mbps.

KEY TERMS

Supervisory Control and Data Acquisition (SCADA), Optimized Network Engineering Tool (OPNET), Distributive Network Protocol (DNP3), Intelligent Electronic Device (IED), International Electrotechnical Commission (IEC 61850), Substation.

LIST OF PUBLICATIONS

1. D. Njova, K. Ogudo and P. Umenne, "Packet Analysis of DNP3 protocol over TCP/IP at an Electrical Substation Grid modelled in OPNET," 2020 IEEE PES/IAS PowerAfrica, Nairobi, Kenya, 2020, pp. 683-687, https://ieeexplore.ieee.org/document/9219968

2. D. Njova, K. Ogudo and P. Umenne, “Analysis of the IEC 61850 protocol when used for communication during maintenance operation in an electrical substation grid” ICONIC '20: Proceedings of the 2nd International Conference on Intelligent and Innovative Computing Applications September 2020 Article No.: 45, Pages 335 -341, ISBN 978-1-4503-7558-0, https://doi.org/10.1145/3415088.3415133

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LIST OF ABBREVIATIONS

ATM	Asynchronous Transfer Mode
ADS	Active Distribution System
ACSI	Abstract Communication Service Interface
ASCII	American Standard for Information Interchange
CTS	Clear To Send
DNP3	Distributed Network Protocol
ECOU	Eastern Cape Operating Unit
FTP	File Transfer Protocol
GND	Ground
GOOSE	Generic Object Oriented Substation Event
GSSE	Generic Substation Status Event
HTTP	Hyper Text Transfer Protocol
IEEE	Institute of Electronic and Electronic Engineers
IEC	International Electro-technical Commission
IED	Intelligent Electronic Device
IP	Internet Protocol
IETF	Internet Engineering Task Force
ISO	International Standard Organisation
LAN	Local Area Network
MMS	Manufacturing Messaging Specification
MODBUS	Modicon Communication Bus
MTA	Message Transfer Agent
MTU	Master Terminal Unit
OPNET	Optimized Network Engineering Tool
OSI	Open System Interconnection
PLC	Programmable Logic Controller
QoS	Quality of Service
RTU	Remote Terminal Unit
RTS	Request To Send
RX	Receive

SDH	Synchronous Digital Hierarchy
SCADA	Supervisory Control and Data Acquisition
SCL	Substation Configuration Language
SNTP	Simple Network Time Protocol
SMTP	Simple Mail Transfer Protocol
SONET	Synchronous Optical Network
SV	Sampled Values
TCP	Transmission Control Protocol
TX	Transmit
UDP	User Datagram Protocol
UCA	Utility Communication Architecture
VMD	Virtual Manufacturing Device
WAN	Wide Area Network
XML	eXtensible Markup Language

CHAPTER 1

1 Introduction

1.1 Background

The Eastern Cape Operating Unit is using DNP3 protocol on their Substations for Supervisory Control and Data Acquisition (SCADA) system. The protection relays are using parallel hardwire to communicate with the RTU for monitoring and controlling the plant equipment. There is Electrical Substation refurbishment that is currently happening around the country and the building of new Electrical Substation by the Municipalities and Independent Power Producers.

In 2013/2014 Eskom demarcated the Distribution regions into provincial operation unit and the Eastern Cape operating unit inherited some Substations from Kwazulu Natal Operating Unit. The Substations from Kwazulu Natal Operating Unit are using serial communication to communicate between the RTU and the protection relays for monitoring and controlling the plant equipment. There is a problem of input and output points that are failing between the protection relays and the RTU. The protocol that is used by the protection relays and the RTU over serial communication is the DNP3 protocol and it is the protocol that is performing poorly.

The study will be about the evaluation of the DNP3 protocol that is used by the distribution Substation in the Eastern Cape Operating Unit and comparing it to IEC 61850 protocol to dertermine which protocol performs better in terms of throughput, lantency and delay. The IEC 61850 has been chosen because it has more benefits from the Ethernet technology it can handle more data and it is faster. IEC 61850 has more flexibility because of the Ethernet Technology, and it is more reliable compared to hardware-based communication protocols.

IEC 61850 can be simulated in a virtual eviroment before it is implemented in the real environment. The application to do a masters research project on evaluating the DNP3 protocol over serial communication was approved the university of South Africa (UNISA). The expectation is to come up with a practical engineering solution. The solution will include the integration of the latest technology and protocols into the existing substation SCADA system.

IEC61850 protocol and a combination of serial communication medium and optical fibre communication medium are used to improve the performance of the Substation SCADA

system. OPNET modelling software will be used to simulate the Substation communication networks. The performance analyses of DNP3 protocol and IEC61850 will be done using OPNET.

1.2 Problem statement

The SCADA network is one of the crucial elements in the Eskom power network, with the substation control system being one of the most important components considering it is the gateway to the source of data at the station level for remote monitoring and control purposes [1]. The main problem is the poor performance of the SCADA system caused by the communication time delay between the substation RTU and the protection IED. When the substation transformer breaker has tripped and opened, the control center will see the tripped alarm and the breaker open status after a few minutes because of the time delay. The communication protocol used by the substation RTU and the protection IED currently is DNP3 protocol. To gain insight to the Problem there is a need to model the substation communication devices and the communication protocol used.

1.2.1 Problem statement 1

The first challenge will be modelling of the substation communication network devices into OPNET. This will require the designing of the communication network topology to be used, the selection of the communication medium to be used by the network, the selection of IED device that will best represent the Protection IEDs, the selection device that represent the Substation RTU.

1.2.2 Problem statement 2

The second challenge will be the modelling of the DNP3 over IP on OPNET. This will include the encapsulation DNP3 protocol layers into the internet protocol suite, these layers are DNP application layer, DNP transport layer and DNP data link layer. OPNET has to custom application which will be used to model the DNP3 over IP protocol stack

1.2.3 Problem statement 3

The third challenge will be modelling the IEC 61850 protocol on OPNET. This will require the building of the IEC 61850 Protocol stack layers which are Manufacturing Message Services (MMS), Sampled Values (SV), Generic Object-Oriented Substation Events (GOOSE), Generic

Substation Status Events (GSSE) OPNET has built in applications that can be used to model the IEC 61850 protocol.

1.2.4 Problem statement 4

The fourth challenge will be the comparing of DNP3 protocol and the IEC 61850 protool in terms of throughput, delay and lantency and then making recommendations to Eskom to implement the better performing protocol.

1.3 Study Framework

1.3.1 Research objectives and aims

The main objective of this dissertation is to improve the SCADA performance at the substation level using simulation.

- Investigate the performance of DNP3 protocol and IEC61850 protocol through literature.
- Investigate the performance of DNP3 protocol and IEC61850 protocol through simulations.
- To model a SCADA substation network on OPNET Riverbed.
- To develop a high performance SCADA communication model and compare the two protocols performance on OPNET Riverbed.

1.3.2 Research/Core Questions

The main research question is: how can we improve the substation SCADA performance using the DNP3 Protocol and IEC61850 protocol. The following research questions will be answered during the research project.

- What is the performance of the DNP3 protocol as compared to IEC61850 protocol?
- What can improve the SCADA performance?
- How are SCADA communications networks modelled and simulated?
- **The hypothesis** is that the IEC61850 will perform better than DNP3 protocol in terms of throughput and is more robust and versatile in terms of the type of messages that can be used.

1.3.3 Benefit of the study

- The study will benefit the engineers, Technologist and Technicians that will be doing commissioning on these devices.
- The study will benefit developing countries that are using low cost technology and reliable technology to monitor their plant equipment.
- The study will benefit Eskom in the Eastern Cape Operating unit as to which protocol and network topology is best to use.
- The study will benefit scholars that are doing research on simulation models using OPNET modeller

1.3.4 Delimitation of the study

- The modelling and simulation will be done using OPNET Riverbed modeller academic edition.
- The study will be on the DNP3 protocol and IEC 61850 protocol only.
- The Study will focus on Substation SCADA system.
- The study will focus on the Eastern Cape Substation SCADA system

1.4 Literature Review

1.4.1 SCADA

SCADA is a system with a number of Remote Terminal Units (RTU) collecting data from the physical devices and is connected to a master station via a communications system and the data collected from the physical devices is converted to readable information and displayed to a computer monitor for control and monitoring. The control officer at the control centre monitors and controls the remote physical devices in real time [2].

A SCADA makes it possible to monitor and control widely distributed process, such as an electrical substation, gas field, pipeline system, oil field, irrigation system. The control officer uses the SCADA system to open and close electrical substation breakers, monitor alarms, gather measurement information and open or close gas field valves or switches. SCADA system reduces the costs of travelling to site to check for alarms on the plant equipment and also reduces the labour costs by having a function to remotely controlling plant equipment [3].

SCADA system consist of three critical parts which are communication medium of the system, remote terminal and master station. A communication protocol is required for the communication of the devices on the SCADA system [4]. Supervisory control of RTU's is done by the master terminal unit which is the superior component in a communication structure. A smart grid SCADA system has a RTU and a central master terminal unit (MTU) and Sub-MTU. Critical data and control messages are transmitted by the Sub-MTU and MTU [5].

In addition to the master station, communication network and RTU there are also sensors. Communication network connects the master station to RTUs in deferent locations. The master station processes and monitors the entire SCADA System. RTUs collects data from the field and also execute control commands and report back to the master station. Sensors are input and output devices that are on the equipment that is being monitored or controlled [5].

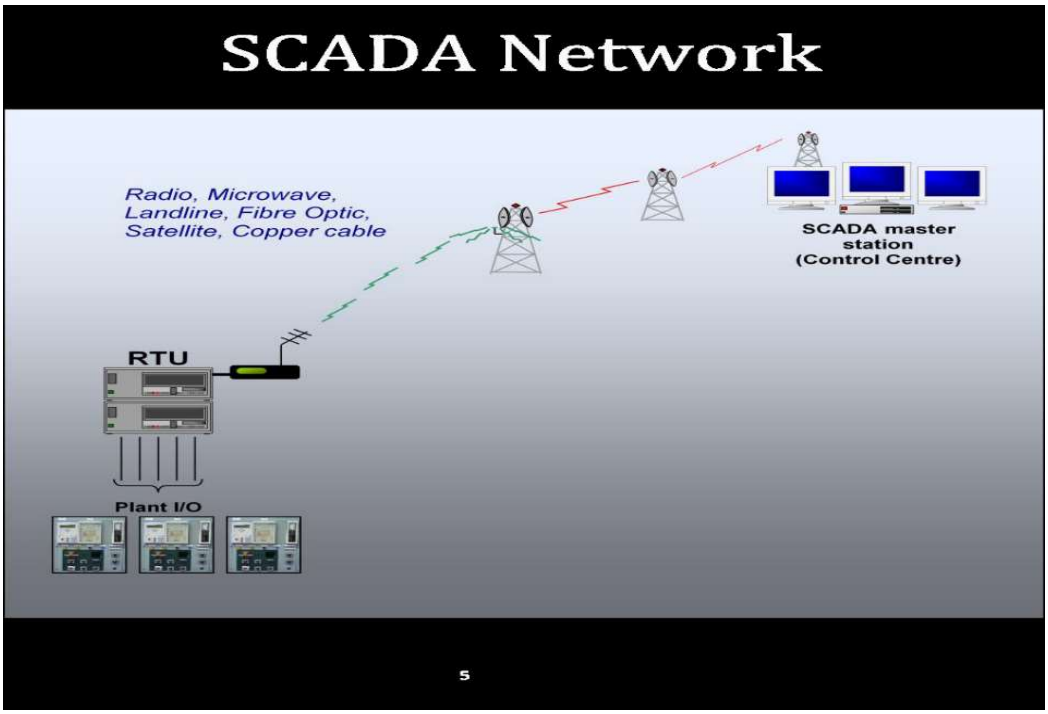

Figure 1.1 SCADA System diagram[6]

1.4.2 Remote Terminal Unit

An RTU is a stand-alone remote telemetry unit that collects data and execute control commands to equipment at remote sites. Most RTUs are microprocessor based and their main task is to collect data from the remote plant equipment and send it to the control center. RTUs have two

key designs the first one is a dedicated port for the configuration of the unit, this port can be accessed remotely to download configuration changes and logs to the central station. The second design feature is the ability to communicate with other RTUs peer to peer and act as a store and forward station or relay station to other RTUs that do not have communication medium to the central station [7].

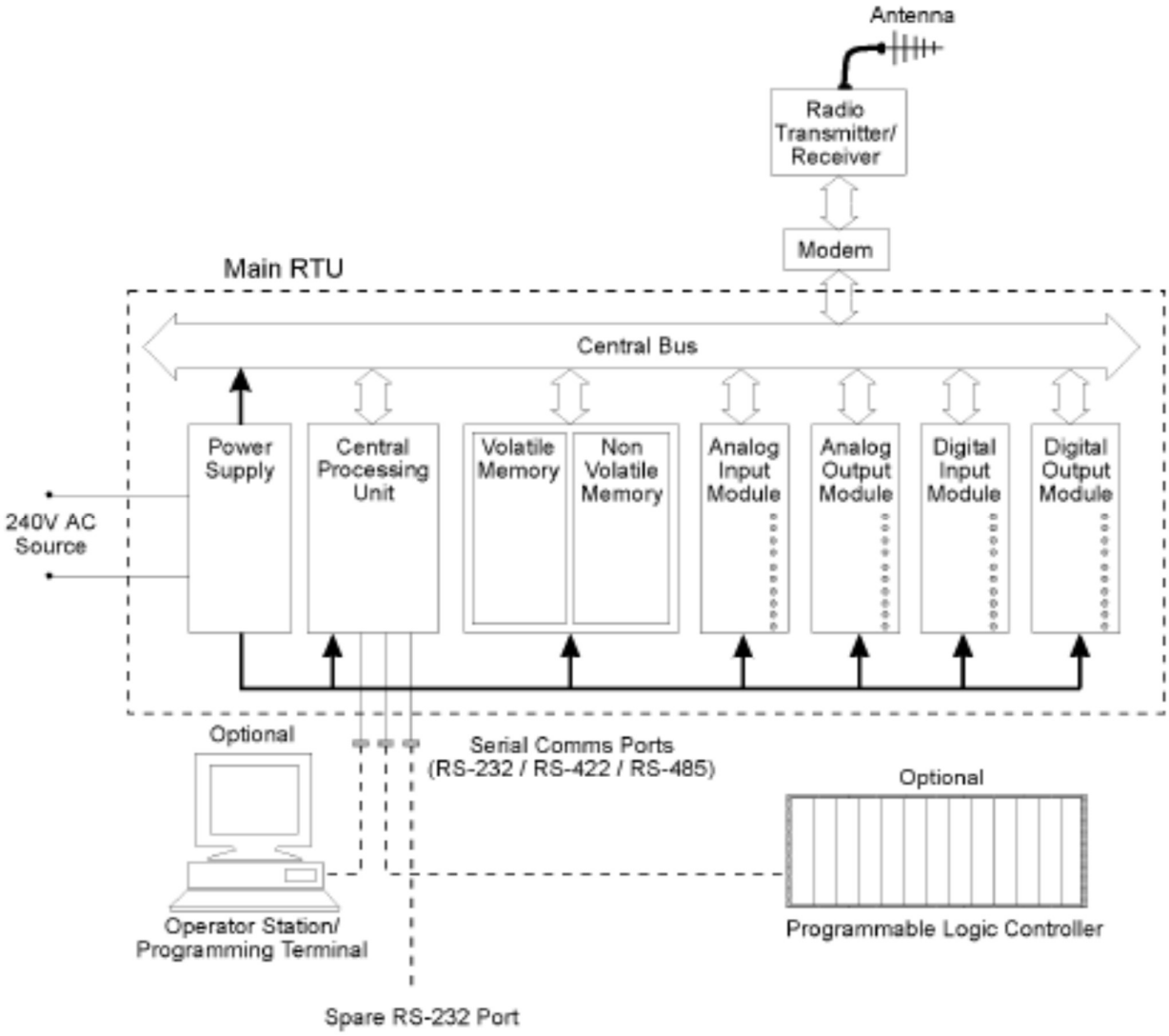

Figure 1.2 Typically RTU hardware structure [2]

1.4.3 Communication Medium

The transmission of data carrying signal from one device to another using communication system indirectly includes Electronic communication. The main purpose of the communication system is transporting data bearing signal from the source to the destination via the communication channel. There is a succession of processes involved in transportation of this data [8].

Data transmission across the communication network happens in the physical layer by means of communication channel. There are two groups of communication channels that we can distinguish from for a mode of transmission, they are guided propagation and free propagation channels. Guided propagation group includes Optic fibre, coaxial cable and telephone channel. Free propagation group includes satellite channels, wireless broadcast channels and mobile radio channels [9].

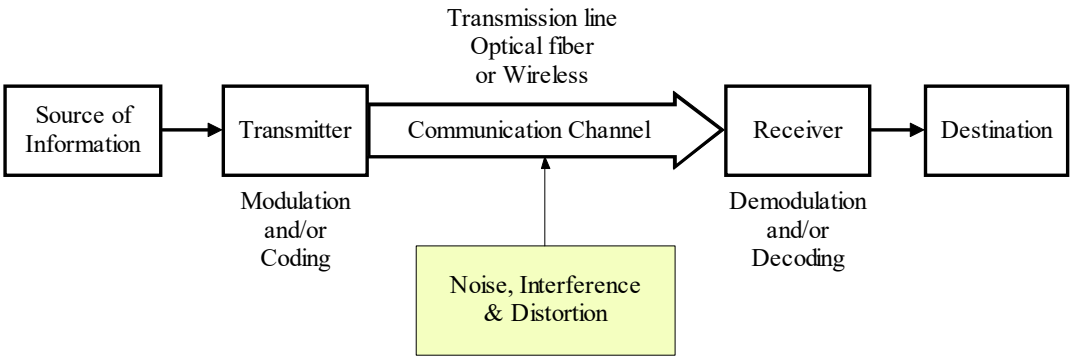

Figure 1.3 Communication System [8]

1.4.4 TCP/IP Protocol Suite

The OSI model layers do not precisely match with the layers of the TCP/IP protocol suite this is because the OSI model was developed after the TCP/IP protocol suite. Four software layers that are built on the hardware define the original TCP/IP protocol suite [10] as seen in figure 1.4. Internet Protocol Suite has the following group of programs File Transfer Protocol (FTP), Transmission Control Protocol (TCP), Simple Mail Transfer Protocol (SMTP) and Internet Protocol. The group of programs on the Internet Protocol Suite performs the Services of the Internet [7].

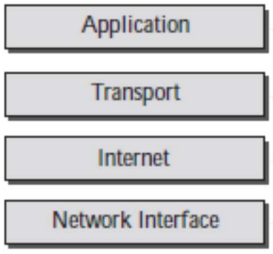

Figure 1.4 Layers in the TCP/IP Protocol Suite [10]

1.4.4.1 Transmission Control Protocol

Transmission control protocol uses connection-oriented methods to transmit data between users and it is a reliable for the transmission of data. The TCP layer on the destination has an error-free transmission on the underlying layers provided by IP when transmitting diagrams [7]. The intermediary between the network operations and application programs is the TCP that lies between the network layer and application layer. To check the sound and safe arrival of data TCP use an acknowledgement mechanism and the TCP is a reliable transport protocol [10].

1.4.4.2 Internet Protocol

Internet protocol is used by the TCP/IP at the network layer as the transport mechanism. Internet protocol is a connectionless datagram protocol and unreliable, it must be pared with a reliable protocol such as TCP to improve its reliability. Internet protocol packets can be lost,

corrupted, delayed, or out of order and may create network congestion [10]. The internet protocol offers what is called a datagram service. It offers a means of sending single packets of data, called datagrams from the source to a specific destination. The datagram header carries 32-bit fields as the destination and the source addresses [7].

1.4.4.3 User Datagram Protocol

User datagram protocol serves as the intermediary between the network operations and the application programs it is found between the IP layer and the application layer. User datagram protocol is unreliable and connectionless protocol. The process-to-process communication services of IP are provided by the User datagram protocol [10]. User datagram protocol is meant for accessing the datagram service of IF directly from the transport layer. UDP datagrams is one IP datagram sent with additional data of the source and destination ports with checksum [7].

1.4.4.4 File Transfer Protocol

File transfer protocol is a mechanism used by TCP/IP for copying files from one device to another device. File transfer protocol uses port 20 for data connection and port 21 for control connection. File transfer protocol creates two connections between the hosts. The first connection is used for control information which are commands and responses and the second connection is used for data transfer [10].

1.4.4.5 Simple Mail Transfer Protocol

Simple Mail Transfer Protocol is an application layer protocol and it is a mechanism used to transport electronic mail between different hosts within the TCP/IP suite [11]. Message Transfer Agents (MTA) are used to transfer the actual mail. For a system to be able to send mail it must have a client message transfer agent and for a system to be able to receive mail it must have a server mail transfer agent. Simple mail transfer protocol is the formal protocol that describes the server in the internet and message transfer agent. SMTP uses responses and commands to transfer messages between a Message Transfer Agent (MTA) server and MTA client [10].

1.4.5 OSI Reference Model

In 1974, the International Standards Organization (ISO) created the Open Systems Interconnection reference model. Vendors were encourage to make network equipment that designed with standardized network architecture and avoid proprietary design. The Reference Model has seven layers [12] as seen on figure 1.5

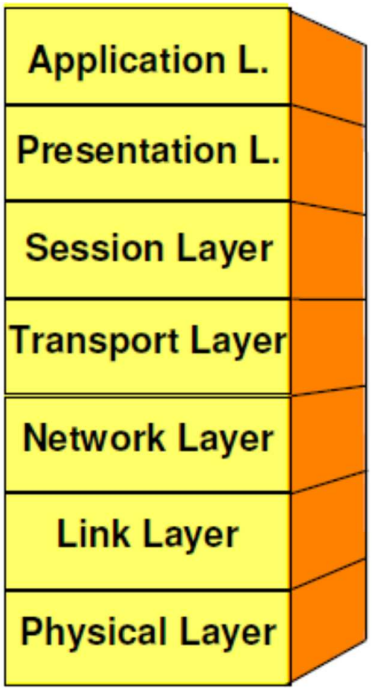

Figure 1.5 Seven layer OSI Model [13]

1.4.5.1 The Physical Layer

The transmission of raw bits over the communication channel is the physical layers concern [14]. The Physical layer of the OSI is found at the lower TCP/IP Network Layer. The Physical layer is responsible for hardware characteristics needed for signal voltage levels of data transmission. The Physical layer also defines the locations and number of interface pins such as RS232 interface connector and IEEE 802.3 standard local area network wiring [12].

1.4.5.2 The Data Link Layer

The Data Link Layer is found in the upper TCP/IP Network Layer. The responsibilities of the data link layer involves reliable handling of data delivery across the physical network [12]. The raw transmission facility is transformed by the data link layer into a line that is free of transmission errors to the network layer [14].

1.4.5.3 The Network Layer

The Network Layer in the OSI model controls the operation of the subnet with the key design issue of determining the routing of packets from source to destination [14]. The functions of the network layer include connection management of the network, the delivery and addressing of the data TCP header added to the message. Also, the separation of the details of the underlying layer to the upper layer protocols is than at network layer [12].

1.4.5.4 The Transport Layer

The OSI Transport Layer is responsible for Host-to-Host Layer functions such as providing error-free communication across the subnetwork and between two host systems performing end-to-end flow control and ensures that the transmitting host sends messages that the receiving host can handle [12]. The transport layer guarantees that the fragments of data arrives correctly to the destination. The function of the transport layer is to pass the accepted data from above to the network layer after it has divided it into smaller units [14].

1.4.5.5 The Session Layer

The Session Layer delivers standard data management routines, which are controlled within the TCP/IP applications. Functions performed in the Session Layer include deals with network connection that operates at the highest layer [12]. The OSI session layer permits users on different devices to establish sessions amongst them. Sessions offer different services such as keeping track of whose turn it is to transmit, token management and synchronization [14].

1.4.5.6 The Presentation Layer

The OSI model Presentation Layer is the lowest layer of the TCP/IP Process Layer. Presentation Layer is responsible for providing network user with common user services [12]. The presentation layer is focusing on the semantics and syntax of the data being transmitted [14].

1.4.5.7 The Application Layer

Application Layer of the OSI model is the upper layer of the TCP/IP Process Layer. The Application is responsible for providing the transparent interface amongst the user and the network to allow the user to elect the task and the application that does the preferred job [12]

The OSI application layer includes a variety of protocols that are normally desired by users. Hyper Text Transfer Protocol (HTTP) is one of the widely used application protocol which is the foundation for the World Wide Web [14]. Figure 1.6 shows the ISO communication stack, the communication hierarchy between the sender and the receiver is depicted on figure 1.6 the communication process on the sender starts from OSI layer 7 up to layer 1 and the communication process on the receiver side starts from OSI layer 1 to layer 7.

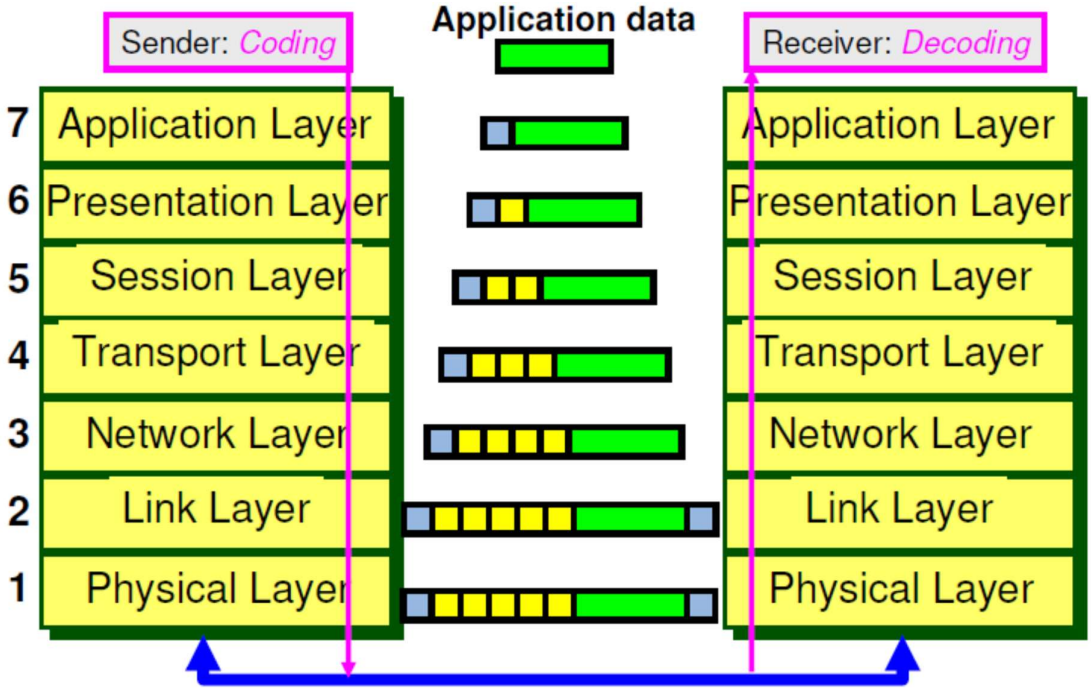

Figure 1.6 ISO Communication Stack [13]

1.4.6 DNP3

DNP3 is a data acquisition protocol used in the electric utility industry. It uses the master/slave polling system to transmit and receive data, but also uses sub-masters within the same system [15]. It is an open, interoperable protocol used specifically in the Supervisory Control and Data Acquisition (SCADA) systems [2]. The Distributed Network Protocol (DNP) was originally created by Westronic, Inc. in 1993 for the power industry. It uses three layers of the OSI model: the application layer, data link layer and physical layer. The physical layer can be used with a serial communication channel such as RS-232, as well as fiber [15]. From its foundation the Distributive Network Protocol version 3 has been used as an open protocol, letting end users to use a common protocol across many hardware devices [15].

The distributed network protocol User layer can take binary and analogue inputs and output it also takes binary signals and analogue signals [16]. The distributed network protocol is can operate over unreliable networks. The distributed network protocol allows evolution and expansion without compromising with strengths such as reliability and interoperability of protocol as it follows object-oriented method to the data [17].

The distributed network protocol is only a software communication protocol. As per the standard of IEC 870-5 the distributive network protocol uses three layers of the OSI model which are the application layer, physical layer and data link layer with an improved agreement structure. The convenient for modularization of software configuration and reliability of data transmission are improved by the layered structure of the distributed network protocol [18].

1.4.6.1 DNP3 Operation

DNP3 offers a way to recognize the remote device's parameters and then use message buffers matching to event data classes 1 through 3 in order to recognize incoming messages and equate them to known point data. In this method, the master device is only required to retrieve new data resulting from a point variation or change event.

Initial communications are normally a class 0 request from the Master to a distant station, used to read all point values into the Master database. Successive communications will normally either be direct poll requests for a precise data class from the Master; unsolicited responses for a precise data class from a distant station; configuration or control requests from the Master to an RTU and following periodic class 0 polls. When a variation occurs on a distant station, a flag is set to the applicable data class. The Master station is then able to poll only the distant

station wherever there is new data to be reported. This is an enormous departure from constant information polling that can result in better responsiveness and much more effective data exchange. The departure from a real-time polling mechanism does need time synchronization, because the time between a change event and a successful poll/request order is variable. Hence, all replies are time-stamped, so that the events between polls can be restored in the accurate order. Communication is started by the Master to the Slave, or in the case of unsolicited responses (alarms) from the slave to the master [19] as can be seen in figure 1.7.

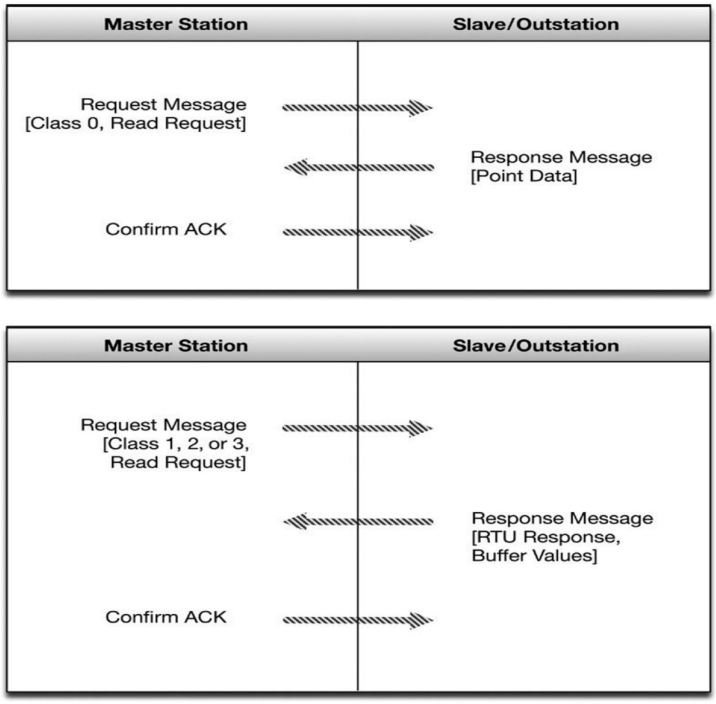

Figure 1.7 DNP3 Protocol Operation [19].

1.4.6.2 DNP3 over IP

The process of having DNP3 over a network environment includes encapsulation of DNP3 data frames from the data link layer inside the transport layer frames of the Internet protocol suite and allowing that the protocol stack to deliver the DNP3 data link layer frames to the destination location in place of the original DNP3 physical layer [7].

The following methodology was recommended by the technical committee

- DNP3 messages of WAN/LAN must be transported using Internet protocol suite.

- Ethernet was recommended as the physical link to be used.
- All devices must support UDP and TCP.
- TCP shall be used for WAN.
- UDP can be used for highly dependable single segment LANs.
- If broadcast messages are required UDP is necessary.
- DNP3 protocol stack must be kept in full
- Confirmation for link layer must be disabled.

The resulting protocol stack is shown in the following diagram.

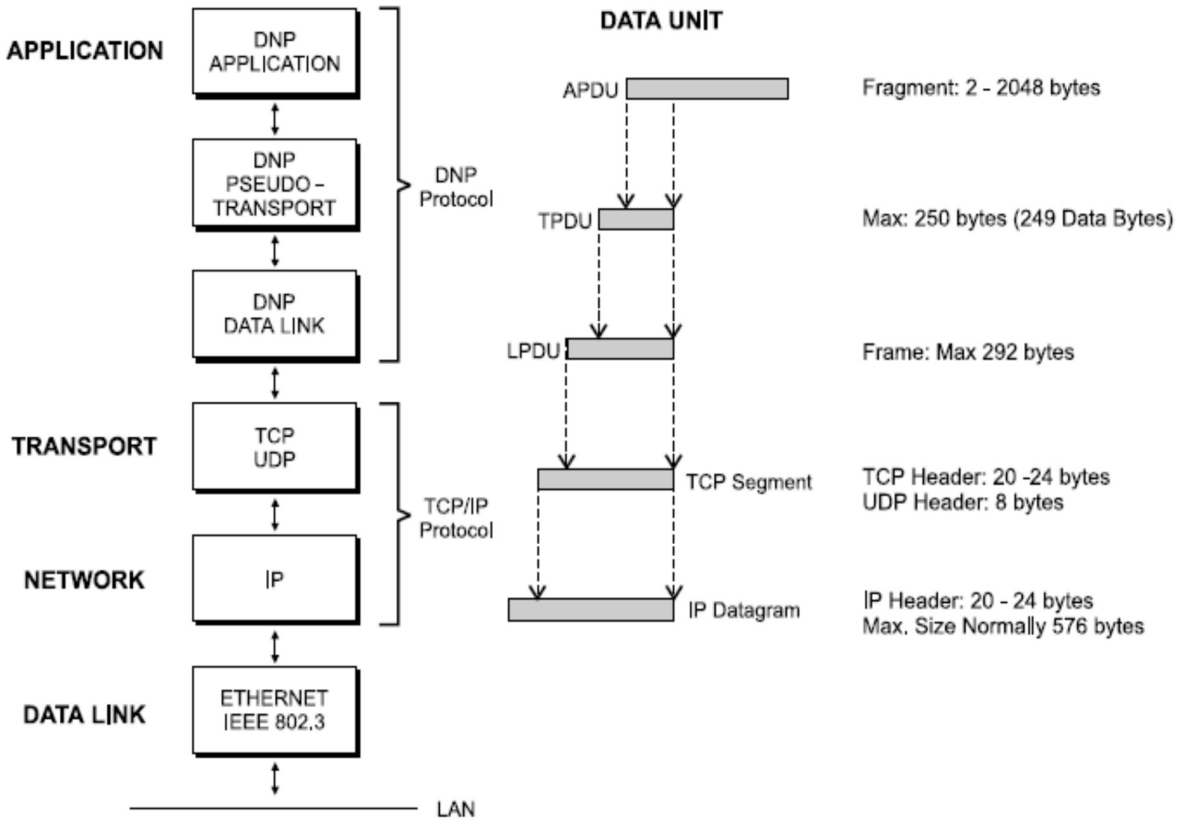

Figure 1.8 DNP3 Over TCP/IP Protocol stack [7]

1.4.7 MODBUS

Modbus operates at layer 7 of the OSI model and that makes it an application layer messaging protocol, meaning that it. It allows for effective communications between connected assets based on a request/reply system. Modbus can be used by very simple devices such as motors or sensors to communicate with a more complex computer, which can read voltage levels,

current levels or any other measurements, execute control commands and perform analysis [19].

Modbus protocol has two modes of communication which are ASCII mode and RTU mode. ASCII mode is a byte split into two ASCII characters to be transmitted and RTU mode is a byte transmitted in hexadecimal form, a byte is one frame. RTU mode data transmission is more efficient than ASCII mode. RTU mode is mostly used by industrial controllers. The same transmission rate and communication patterns must be used by devices on the same network irrespective of the master or slave. The commonly used transmission rate for Modbus protocol is 1200 bit/s ~19200 bit/s [20].

Modbus over serial or Modbus RTU and this type of communication system or interface can be RS-232, RS-485, RS-423, and RS-422. Usually, in this interface, the Modbus devices would need the ground wire (GND), the transmit wire (TX) and the receive wire (RX) to exchange data between the Modbus devices. The Modbus interface can be either full duplex or half duplex. Normally, all intelligent devices can be programmed for both full duplex and half duplex [21].

Modbus TCP/IP – In this type of communication system, the Modbus data is enveloped around TCP/IP internet protocols and then the data is sent over standard internet. Data transfer for various devices can be transferred through a standard RJ45 Ethernet port that the devices are connected to. The open standard implementation of Modbus on internet protocols is the definition of Modbus [21].

1.4.8 IEC 61850

The protocol IEC 61850 was created to standardize communication for Substation devices so that all devices from different manufacturers could communicate using the same protocol in power utilities [22]. The IEC 61850 standard is a foundation of engineering networks for Substation Automation by having a set of standard formats [23]. The IEC 61850 is used to achieve interoperability of intelligent electronic devices in the communication method of power-based networks [24]. The communication architecture of the IEC 61850 has more benefits from Ethernet communication technology, and it gives it more flexibility [22]. Substations use IEC 61850 for Substation automation, protection function and data acquisition, it is an Ethernet based protocol. Ethernet based communications can handle more data, are faster and more reliable as compared to hardware-based communication protocols. Engineers

came up with the solution of IEC 61850 protocol in order to solve the problem of interoperability of relays from different manufactures. The IEC 61850 protocol covers all the relay functions such as control, monitoring and protection. This protocol introduces a new way of communication at an Electrical Substation network. IEC 61850 standard has brought innovation to the engineering technique of Substation protection, integration of devices, control, monitoring and testing [25]. Models for Substation automation, protection and control systems are provided by the IEC 61850. The models provided by IEC 61850 are stored in an XML language format that enables the exchange of information with other devices and systems. The Substation Configuration Language (SCL) schema that permits any manufacturer configuration tool to interpret the IEC 61850 files made by a different manufacturer is defined in the standard [26].

1.4.8.1 IEC 61850 Protocol Stack

Theoretically IEC 61850 can be mapped to any protocol as in [27]. The communication stack of the IEC 61850 is structured according to the Open Systems Interconnection (OSI) layers, consisting of Manufacturing Messaging Specification (MMS) which lies on the application level, TCP/IP lies on the transport level and Ethernet lies on the physical level. The object, oriented services lie on the application layer. Time-critical services lie on the physical layer. The time critical services are used by Generic Object-Oriented Substation Event (GOOSE) and Sampled Values (SV) messages [22]. The substation automation system communication service uses the MMS messages defined in the IEC 61850 standard. MMS is a transmission protocol that can be implemented in Local Area Networks (LAN) and it is most commonly used in utility networks with large data needs, hardware devices and application layer software [24]. To eliminate the processing of the middle layers the GOOSE and SV communicate directly with the Ethernet layer. The connection-oriented layer of the MMS can operate over ISO or TCP/IP as can be seen in figure 1.9, the GSSE operates over connectionless ISO service. The data is connected onto an Ethernet data frame using the data type “Ethertype” for the case of GOOSE, TIMESYNC, and SV messages. The data is connected using the data type “802.3” for GSSE and ISO messages [27] as can be seen in figure 1.9. The content carried by GOOSE messages has a maximum delay of 3 ms for data carried between IED’s [28]. Figure 1.9 shows IEC 61850 protocol stack

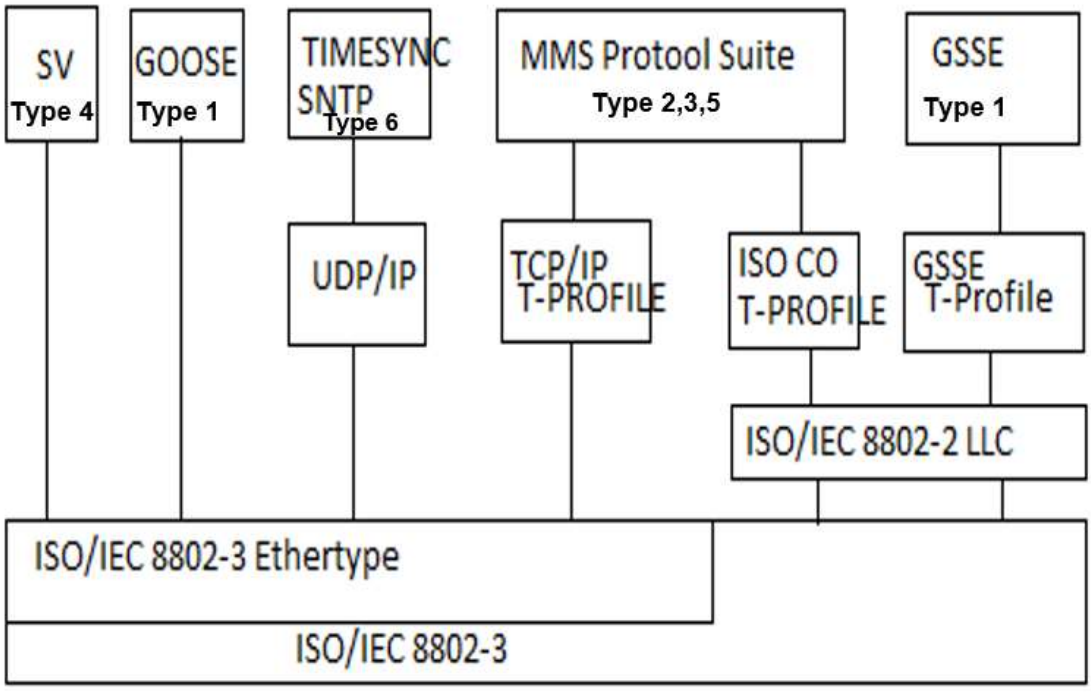

Figure 1.9 IEC 61850 Protocol stack [27, 29]

1.4.8.2 IEC 61850 Device Model

Figure 1.10 shows IEC61850 device model, an IEC 61850 device consists of a physical device, which connects to a network and is defined by its network address, within each physical device there are logical devices. There are logical nodes within a logical device. Logical nodes have elements of data. The IEC 61850 standard has determined a unique name within the element of data. These data names are operationally related to the power system function such as measure, description, status and control. The data elements inside the logical node relate to the specifications of the common data class as per the IEC 61850-7-3[27] standard.

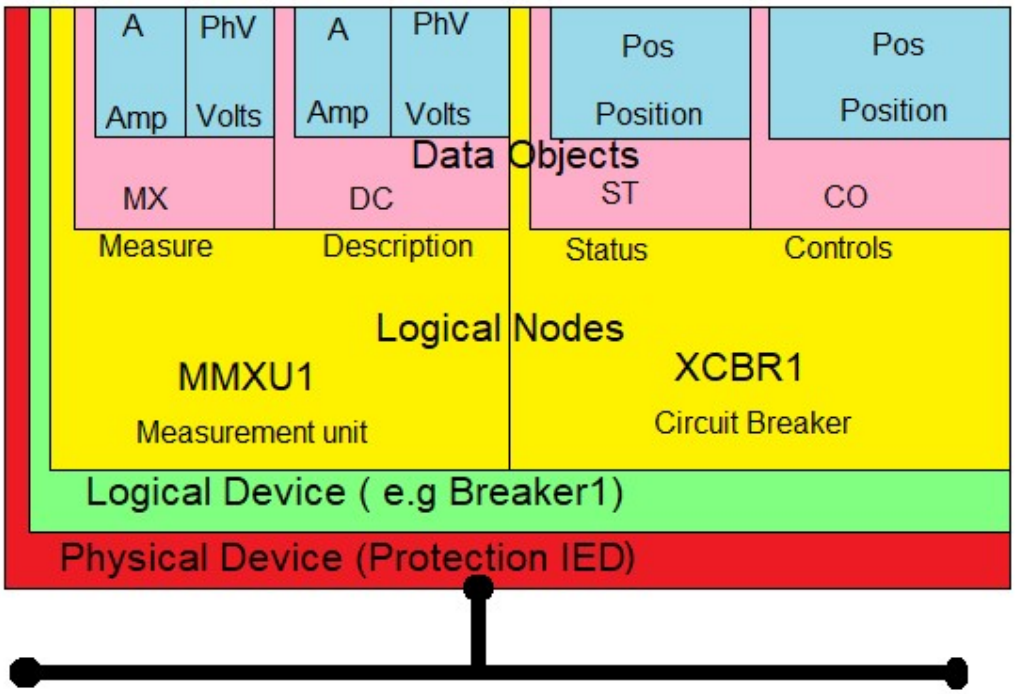

Figure 1.10 IEC 61850 device model[30]

1.4.8.3 IEC 61850 Standard Overview

The 61850 consists of the following parts under the general title Communication networks and systems in substations [31].

- Part 1: Introduction and overview
- Part 2: Glossary
- Part 3: General requirements
- Part 4: System and project management
- Part 5: Communication requirements for functions and device models
- Part 6: Configuration description language for communication in electrical substations related to IEDs.
- Part 7-1: Basic communication structure for substation and feeder equipment- principles and models.
- Part 7-2: Basic communication structure for substation and feeder equipment- Abstract communication service interface (ACSI).

- Part 7-3: Basic communication structure for substation and feeder equipment- common data classes.
- Part 7-4: Basic communication structure for substation and feeder equipment- Compatible logical node classes and data classes.
- Part 8-1: Specific communication service mapping (SCSM)-Mappings to MMS (ISO/IEC 9506-1 and ISO/IEC 9506-2) and to ISO/IEC 8802-3.
- Part 9-1: Specific communication service mapping (SCSM) - Sampled values over ISO/IEC 8802-3.
- Part 9-2: Specific communication service mapping (SCSM) - Sampled values over ISO/IEC 8802-3.
- Conformance testing.

1.4.9 OPNET

Optimize network engineering tool (OPNET) is network simulator that is a leading software that is used for simulation, modeling and analysis of communication networks and also test the performance of applications. OPNET software allows experts to quickly analyze and plan complicated network systems and services to improve performance at lower lifespan costs. OPNET has large number of libraries embedded in it and they enable the user to access the models of standard equipment, such as routers, switches, links, servers as well as the patented models. The OPNET built in topologies save development time when simulating different design topologies or network topologies. The entire network that includes routers, servers, protocols, switches and individual applications can be modeled on OPNET software that provides virtual network environment that models the network behaviour. OPNET software can be used to help in finding any network or system glitches, simulate networks for network and system planning, design and authentic changes prior to the implementation [32].

Riverbed Modeler is a commercial research oriented network simulation environment tool for network simulation and modeling. OPNET allows users to design and study communication networks with proper scalability and flexibility. OPNET lets the user to visually design the network. OPNET gives the graphical structure of the network components and the actual network design [33].

The availability and reliability of network communication topologies are analyzed using OPNET and also the simulation and modeling of different condition. To record and understand

the data transfer performance OPNET software is used and this is accomplished mainly by investigating the delay characteristics, latency, throughputs and data rate under different network configurations [32].

Different IP networks such as ATM, SONET/SDH comparative performance analysis can be done in OPNET. The change in the type of IP network does not affect immunity besides their individual delay performance. Quality of Service parameters such as tunneling, and priority queuing can be examined in OPNET in order to enhance the time delivery performance thereby minimizing packet loss of messages and jitter. This can all be archived in OPNET modeler which is used to carry out simulation and modeling [34].

OPNET modeler can be used to model DNP3 to enhance and analyze DNP3 protocol performance. OPNET is the industry's leading environmental for network simulation and modeling, allowing to study and design communication networks, applications, protocols and devices with unmatched scalability and flexibility [35].

IEC61850 protocol is a new protocol which can be used to enhance the real-time performance of a network and Basic analysis of Substation data flow can be evaluated using OPNET software [36]

In this project OPNET would be used to evaluate the existing DNP3 protocol and then compare it to the IEC61850 in terms of performance. From this analysis the better performing protocol could be recommended for implementation on existing SCADA systems.

1.4.10 RELATED RESEARCH WORK

1.4.10.1 IEC 61850 Research Work

The protocol IEC 61850 was created to standardize communication for Substation devices so that all devices from different manufacturers could communicate using the same protocol in power utilities [22]. The IEC 61850 standard is a foundation of engineering networks for Substation Automation by having a set of standard formats [23]. The IEC 61850 is used to achieve interoperability of intelligent electronic devices in the communication method of power-based networks [24]. The communication architecture of the IEC 61850 has more

benefits from Ethernet communication technology, and it gives it more flexibility [22]. Substations use IEC 61850 for Substation automation, protection function and data acquisition, it is an Ethernet based protocol. Ethernet based communications can handle more data, are faster and more reliable as compared to hardware-based communication protocols. Engineers came up with the solution of IEC 61850 protocol in order to solve the problem of interoperability of relays from different manufactures. The IEC 61850 protocol covers all the relay functions such as control, monitoring and protection. This protocol introduces a new way of communication at an Electrical Substation network. IEC 61850 standard has brought innovation to the engineering technique of Substation protection, integration of devices, control, monitoring and testing [25]. Models for Substation automation, protection and control systems are provided by the IEC 61850. The models provided by IEC 61850 are stored in an XML language format that enables the exchange of information with other devices and systems. The Substation Configuration Language (SCL) schema that permits any manufacturer configuration tool to interpret the IEC 61850 files made by a different manufacturer is defined in the standard [26]. GOOSE and SV messages can be used in IEC 61850 protocol over Ethernet [36].

The paper in [37] applies the concept of Active distribution Networks (ADN) to low voltage networks. The study in [38] presents a mathematical model of communication in an Active Distribution System (ADS) Substation. There, seven types of IEC 61850 messages were used in the study. The analysis and performance evaluation of the ADS model was done in different scenarios. The conclusion was that priority tagging enhances the ADS Substation Communication Network (SCN). This is because it reduces the SV within the bay network and enhances the performance by reducing end to end delay [38]. In [39] the authors say that limiting the cycle within the bay reduces the data flow on a VLAN scheme and improves network performance. This study is done in OPNET to simulate a mathematical model for data flow. Simulations done in [40] show that networks with heavy traffic shall use IED's and switches with priority tagging. Three-layer system communication architecture for smart microgrids has been modelled in OPNET and the results indicate that communication performance of the access layer network improves on a 2000m plain radius as shown in [41]. The star and ring configuration systems have been simulated and compared in OPNET environment and the star system performed better than the ring system [42].

1.4.10.2 DNP3 Research Work

DNP3 allows expansion and evolution without compromising reliability and interoperability of the protocol as it follows an object-oriented approach. DNP3 can be modelled by using the ns-2 network simulation tool as was done in [17]. DNP3 uses three layers of the OSI model: the application layer, data link layer and physical layer. The structure of DNP3 is shown in [18]. DNP3 in a network environment involves encapsulation of data frames from the data link layer within the transport layer. In [43] an Automatic Circuit Recloser (ACRs) is used to combine communications via serial ports, one port is used for SCADA DNP3 the other for engineering access connections. The building of a DNP3 message begins at the application layer all the way to the link layer. The DNP3 data link layer frame, which has a size of 292 bytes, is encapsulated unto a TCP segment. The TCP segment is 556 bytes long. The TCP/IP packet has source and destination IP address for inclusion. There are 20 bytes for the IP header and 20 bytes for the TCP. The payload is about 1460 bytes the details of which are given in [44]. The DNP3 protocol is modelled in [44] using ns-2 software, while in this paper we carry out the modelling of DNP3 in a substation grid using OPNET.

A split protocol design can be used to increase the speed response time for DNP3 devices as shown in [45]. The split protocol can be implemented in a utility network with high traffic. In [46] protocols from SCADA systems such as DNP3 are migrated to a smart grid protocol design.

An automatic network protection framework for DNP3 over TCP/IP is presented in [47]. Their system is capable of detecting old and new attacks.

The Constrain Application Protocol (CoAP) which is a web transfer protocol is combined with DNP3 for Machine-to-Machine (M2M) communication to be achieved in a smart grid, this is reported in [48]. CoAP can increase interoperability in a SCADA system.

An evaluation of the DNP3 performance in an IEEE 802.11g wireless ad hoc network, encapsulated in TCP/IP is done in [49]. Results show there that DNP3 is useful for low cost smart grid applications.

In [50] we see a communication system that multiplexes DNP3 traffic. This happens because several Master Terminal Units (MTUs) use the same Remote Terminal Units (RTUs). This is done to ensure that master stations can share access to the same network of remote terminal

units prior to commissioning. OPNET [51] can be used to simulate and model DNP3 in a smart grid

1.4.10.3 OPNET Research Work

In this study OPNET was used to study the performance of different MAC layer parameters by modelling beacon enable 802.15.4 networks [52]. In [53] OPNET was used to research a network delay in a Substation communication security. OPNET software was used to simulate parallel redundancy protocol and the check the reliability of the network. OPNET results indicated that the built architecture can rapidly restore communication and effectively improve network dependability when typical network level and link level faults occur [54].

OPNET software was used to model IEC61850 Substation communication and study different factors affecting end to end delay. Intelligent electronic devices of a Substation level network were modelled in OPNET [55]. OPNET Riverbed application was used to analyse the performance of WLAN 802.11g/n standard. When comparing the results of 802.11n and 802.11g in OPNET, the results showed that 802.11n has better performance than 802.11g standard [56].

1.5 Methodology

Methodology steps are the following.

- Installation and running of OPNET software
- Modelling of Substation communication model on OPNET.
- Configuration of DNP3 protocol on OPNET.
- Configuration of IEC 61850 protocol stack on OPNET.

CHAPTER 2

2 DNP3 Protocol Opnet Modelling

Figure 2.1 is a block diagram of the substation communication network model. The block diagram depicts the components of the model and the communication path to the devices.

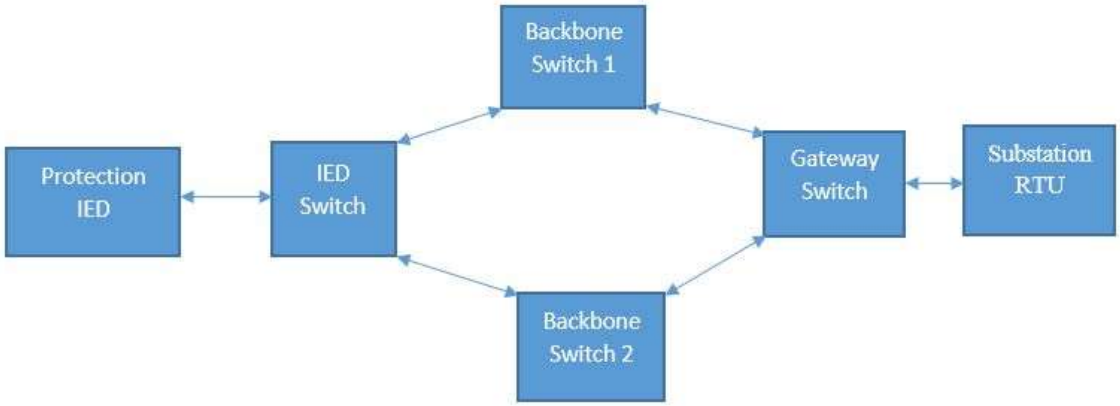

Figure 2.1 Substation communication network model block diagram

This DNP3 model was modelled in OPNET.The Substation Communication Network Model in figure 2.2 has 10 nodes that simulate protection IED relays, 10 Ethernet switches that simulate protection relay switches, two backbone switches that are redundant to each other, one gateway switch and one Substation Remote Terminal Unit (RTU). The cable linking the protection IED's to the IED Switch is a 100BaseT cable. The cable linking the backbone switch, IED switch, gateway switch and the Substation RTU is a 1000BaseX cable. The Substation RTU is basically modelled by a server in OPNET.

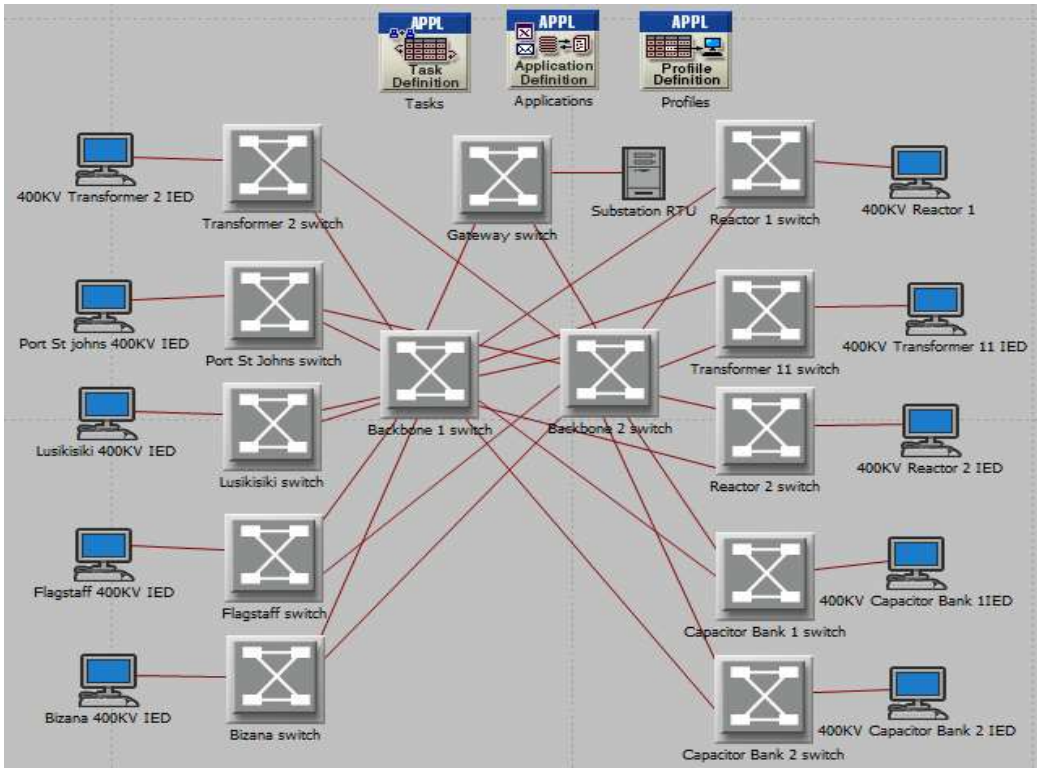

Figure 2.2 OPNET Substation Communication Network Model [57]

Application definition is where the configuration of the DNP3 over TCP/IP is configured. There is one row that has been selected, this provides the definition for one application. This application defined is TCP/IP as can be seen in figure 2.3.

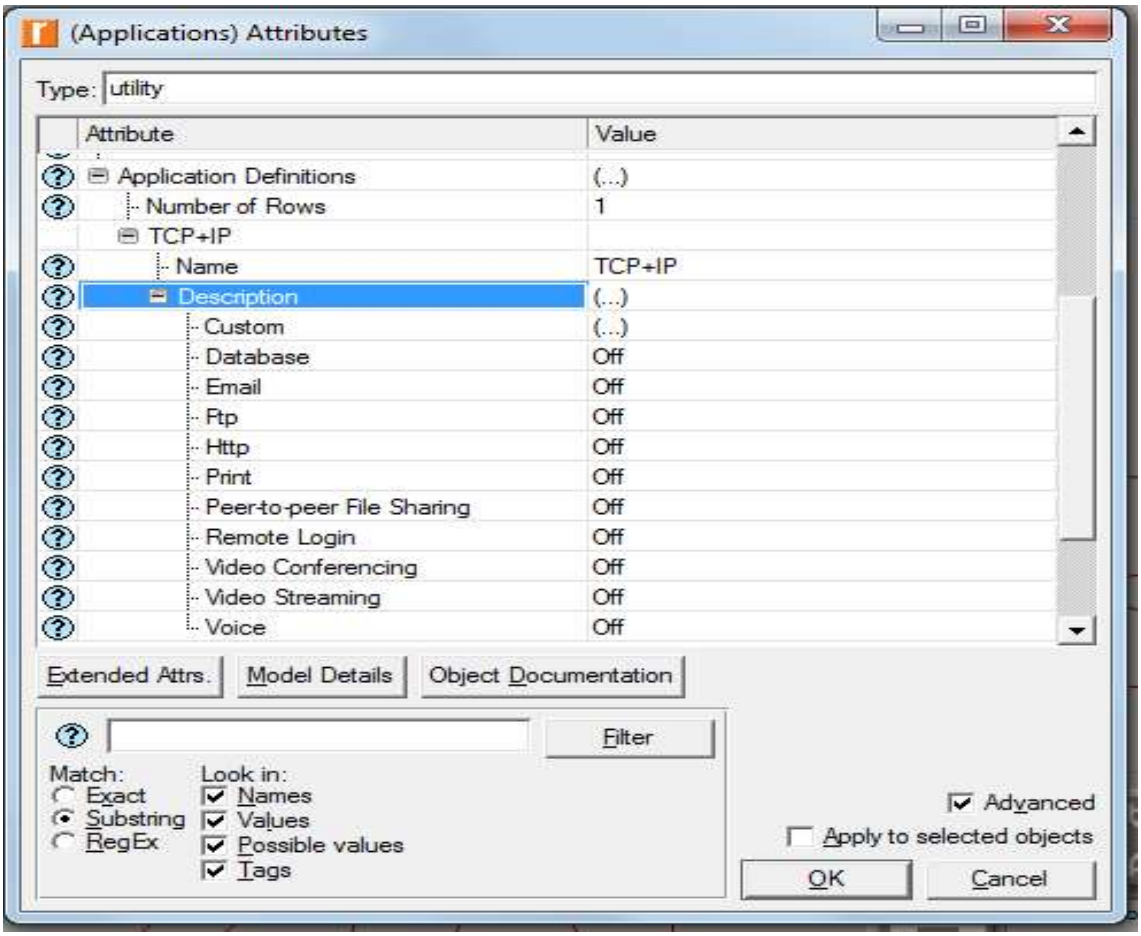

Figure 2.3 Application definitions

Figure 2.4 shows the manual configuration table for the setting of the DNP3 over IP characteristics. The generation of the traffic between the source and destination is selected using this table. The request and response sequence is also selected from this table. The transport protocol is selected from this table.

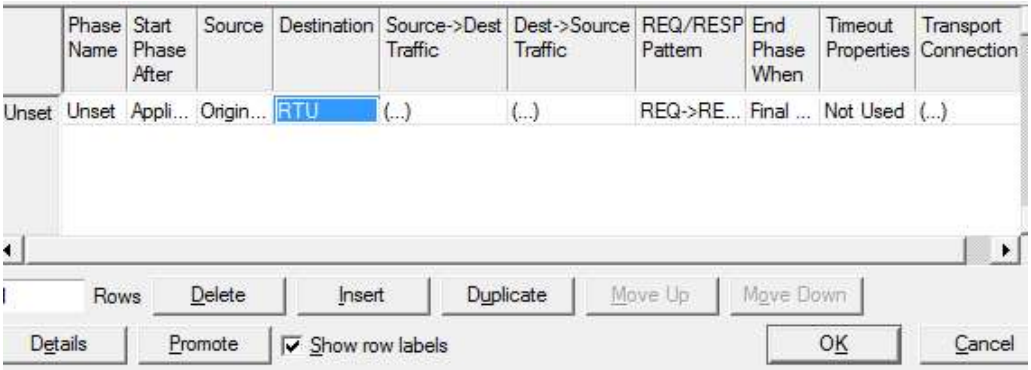

Figure 2.4 Manual configuration table for DNP3

IED Traffic characteristics in figure 2.5 are set as follows: initialization time is set to 50 ms, request count is set to 3 seconds, inter-request time is set to 1 second, request packet size is set to 3222 bytes [58,59], packet per request is set to 3222 bytes and inter-packet time is set to 1 second.

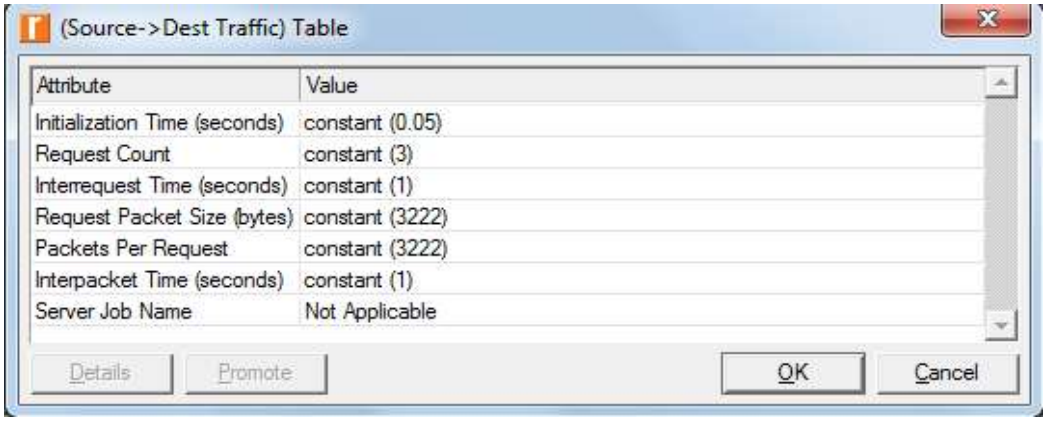

Figure 2.5 IED Traffic characteristics

Substation RTU traffic characteristics in figure 2.6 are set as follows: request processing time is set to 50 ms, response packet size is 1024 [51,60], packet per response is 1024 and inter-packet time is set at 1 second.

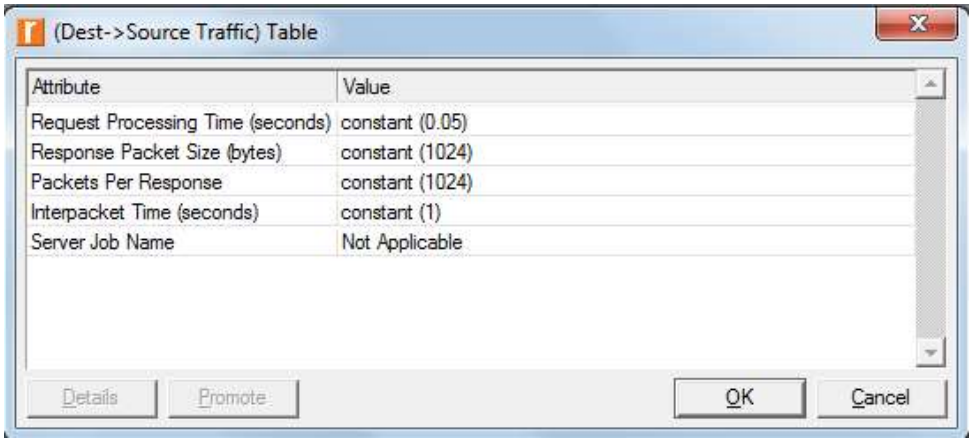

Figure 2.6 Substation RTU Traffic characteristics

CHAPTER 3

3 IEC61850 Protocol Opnet Modelling

Figure 3.1 is a block diagram of the substation communication network model. The block diagram shows the components of the model and the communication path to the devices.

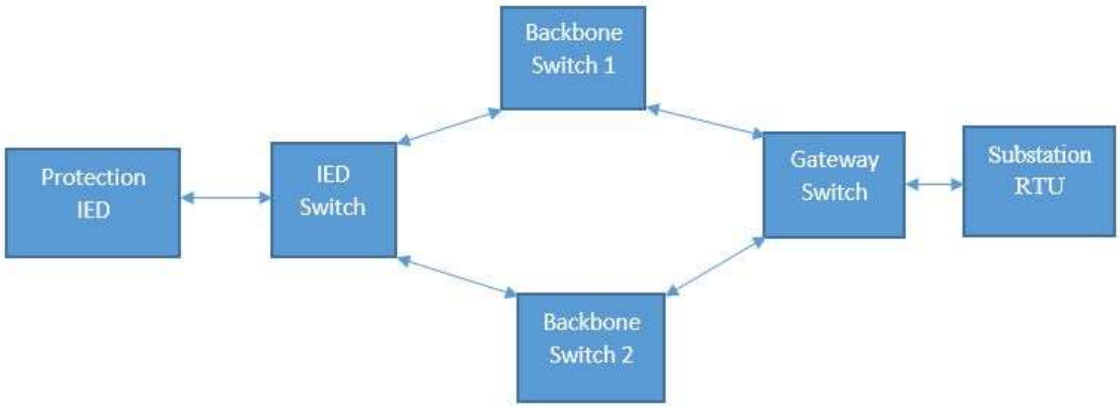

Figure 3.1 Substation communication network model block diagram

The Substation Communication Network Model in figure 3.2 has 10 nodes that simulate protection IED relays, 10 Ethernet switches that simulate protection relay switches, two backbone switches that are redundant to each other, one gateway switch and one Substation Remote Terminal Unit (RTU). The cable linking the protection IED's to the IED Switch is a 100BaseT cable. The cable linking the backbone switch, IED switch, gateway switch and the

Substation RTU is a 1000BaseX cable. The Substation RTU is basically modelled by a server in OPNET.

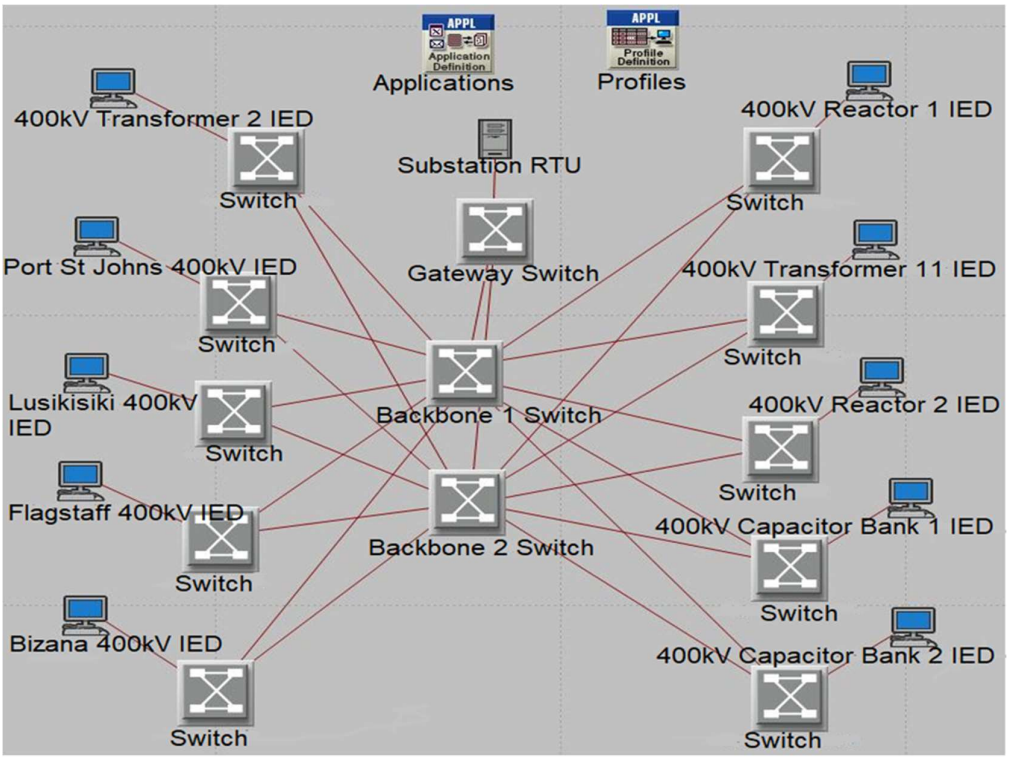

Figure 3.2 OPNET Substation Communication Network Model [61]

The Application attributes are first defined in OPNET, this is where the protocol stack of the IEC 61850 is configured as can be seen in figure 3.3. All the message types (GOOSE, GSSE, MMS and Time Sync) to be used are configured here.

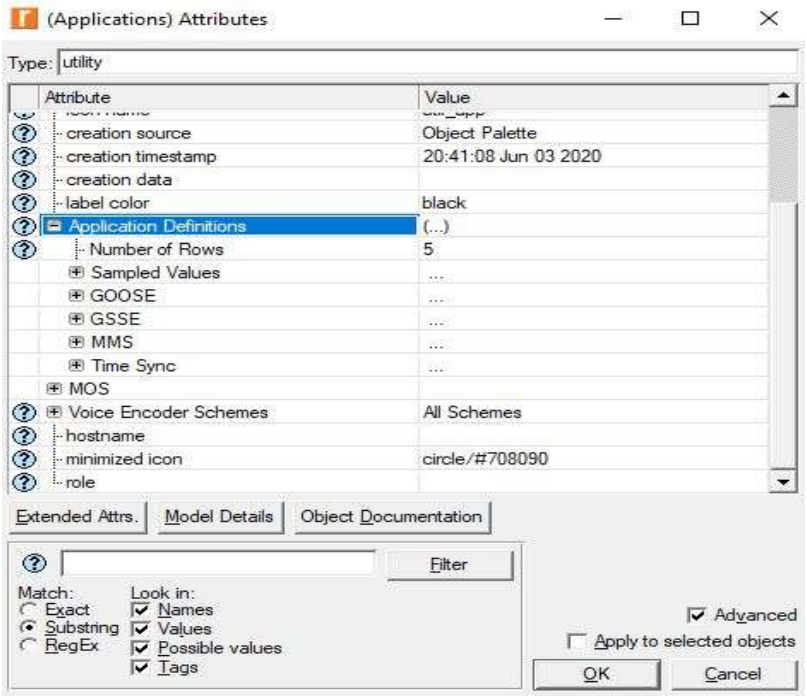

Figure 3.3 OPNET Profile settings

Figure 3.4 shows OPNET Profile settings, this is where IEC 61850 protocol timing settings are done.

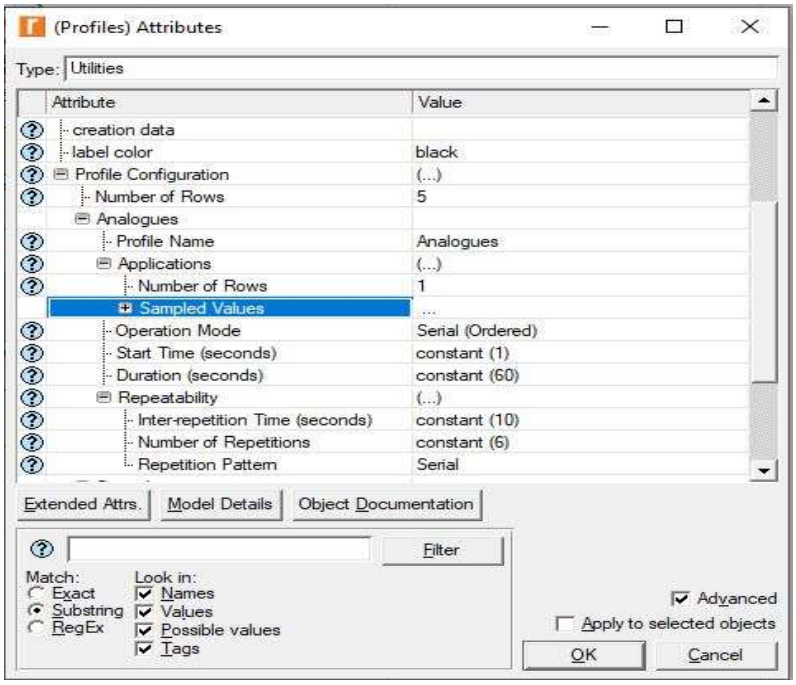

Figure 3.4 OPNET Profile settings

Figure 3.5 shows the settings for IED Traffic as well as the configuration for the packet size and the interarrival time. These settings are further expanded in Figure 3.6 and Figure 3.7 respectively.

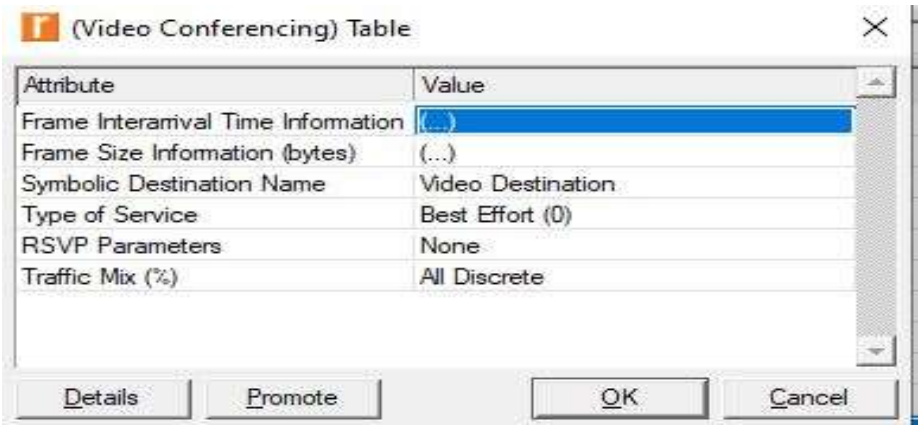

Figure 3.5 IED Traffic characteristics Configuration

Sample values set at 15 frames/sec [62]. Controls/GOOSE packets are set to 204 bytes, indications/GSSE packets set to 144 bytes, Alarms/MMS packets set to 144 bytes, time sync packets set to 219 bytes Analogues/SV packets set to 219 bytes [38, 39, 63] as can be seen in figure 3.6. Timing is set in figure 3.7.

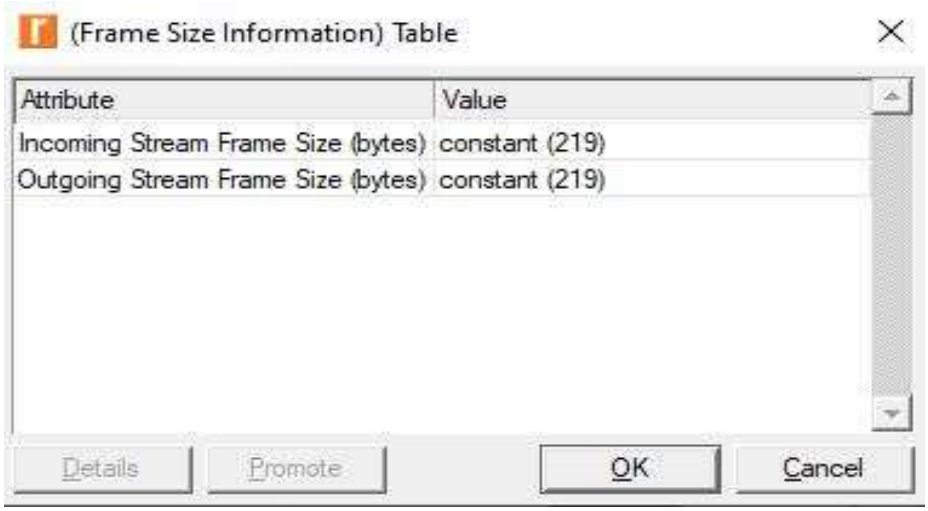

Figure 3.6 IED Packet size setting

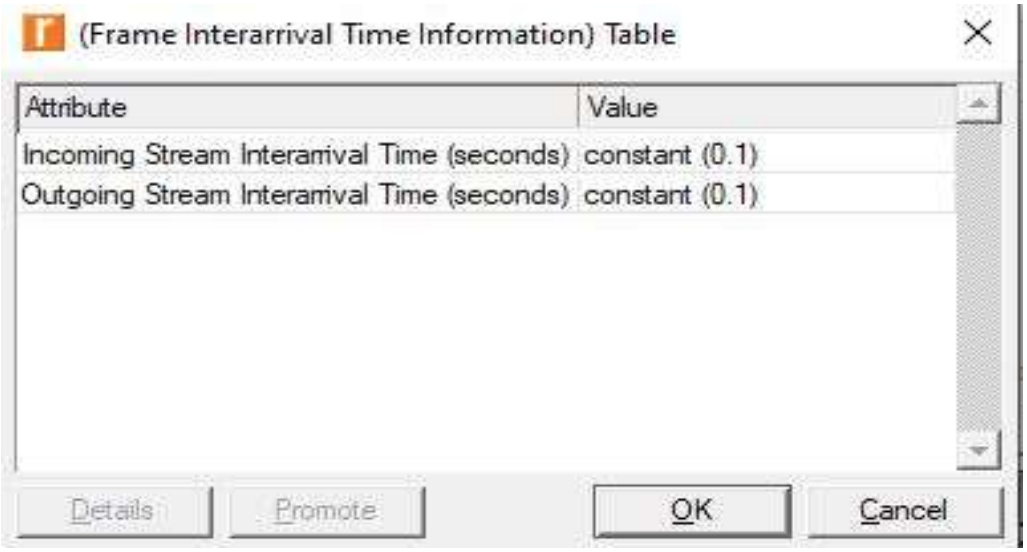

Figure 3.7 IED Frame interarrival setting

CHAPTER 4

4 Results and Analyses

4.1 DNP3 Results

The DNP3 protocol results were taken at different levels of the network load on the Substation communication network model. The first measurement was taken when 10 percent of the devices were online. The second measurement was taken when 50 percent of the devices were online. The third when 90 percent of the devices were in service and the fourth when all the devices were in service. Time delay, network load and throughput were extracted from the model and analysed. The analysed results will determine the performance of the DNP3 protocol model at an electrical substation network. It can be seen in Figure 4.1 that as the number of devices online increases the number of load packets increases.

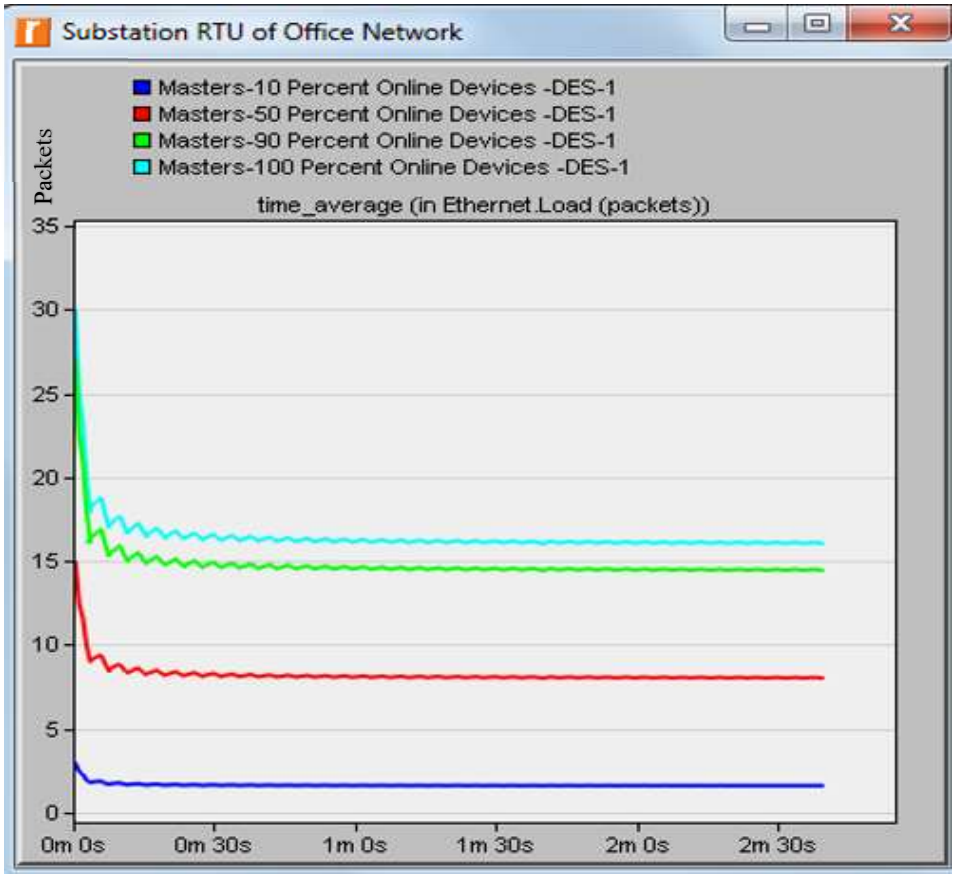

Figure 4.1 Ethernet load packets [57]

Figure 4.2 shows the Ethernet load packets per second distribution with different percentage of IED devices online. The load on the network at 10% of the IED devices online is 3 packets/sec, at 50% is 10 packets/sec, at 90% is 18 packets/sec and at 100% is 20 packets/sec.

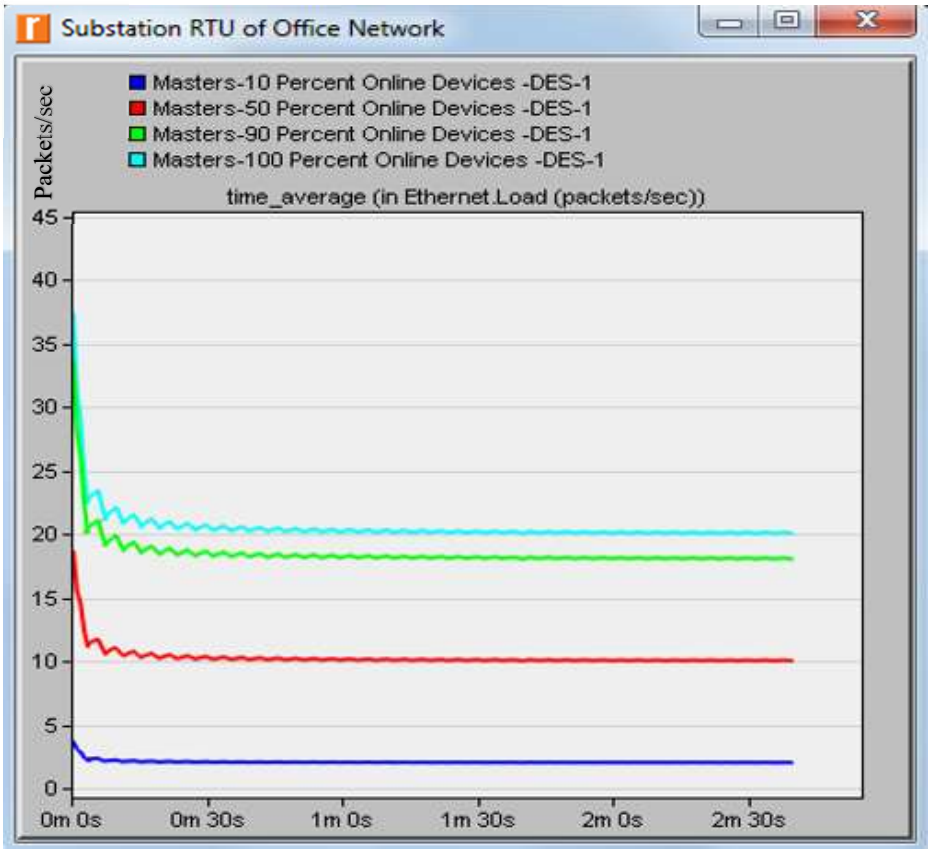

Figure 4.2 Ethernet load packets/sec

Figure 4.3 shows the received Ethernet packets at the substation RTU end. In the figure it can be seen that with an increase in the number of devices online there is also an increase in traffic received.

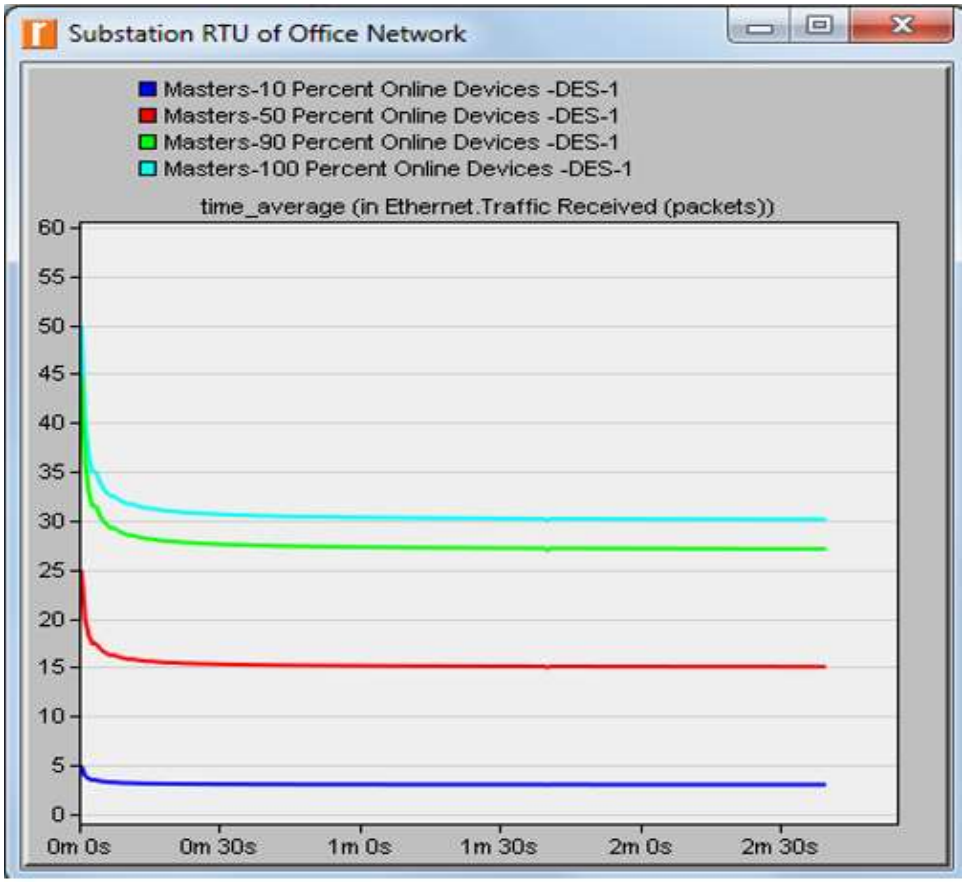

Figure 4.3 Ethernet traffic received packets

Figure 4.4 shows the IP traffic sent from the 400 KV transformer IED. Figure 4.5 shows the IP traffic received at the substation RTU end as seen in the model in figure 2.2. These figures show that with an increase in the number of devices online there is an increase in the traffic on the network. The figures also show that the sent traffic is less than the received traffic. It is because the substation RTU in the model is receiving data from multiple devices at the same time as they come online.

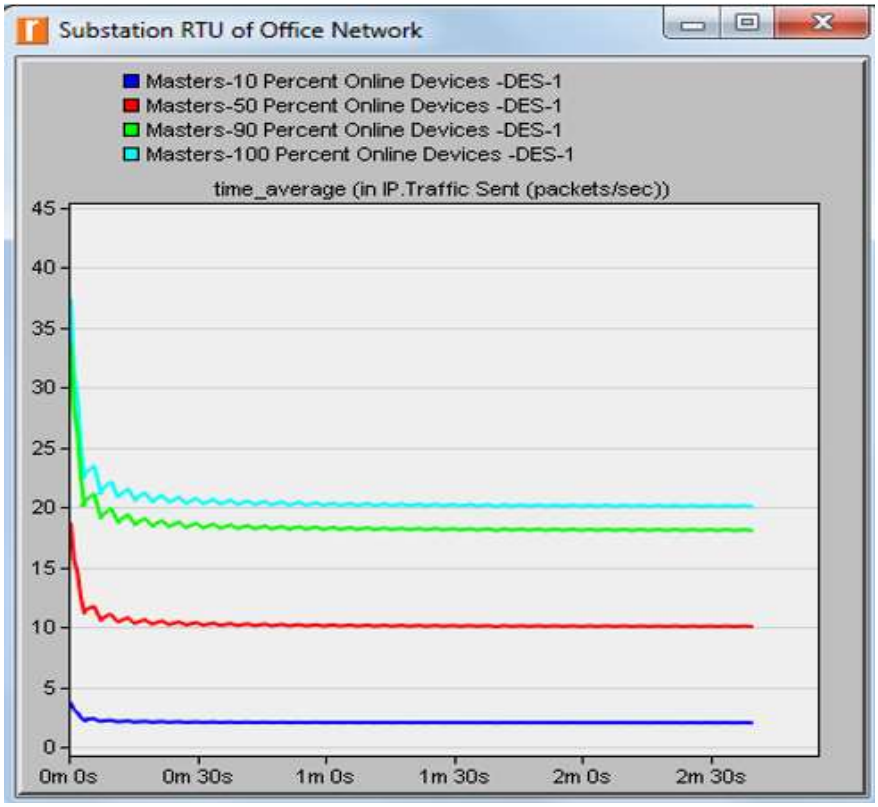

Figure 4.4 IP traffic sent packets/sec from the 400 KV transformer IED end

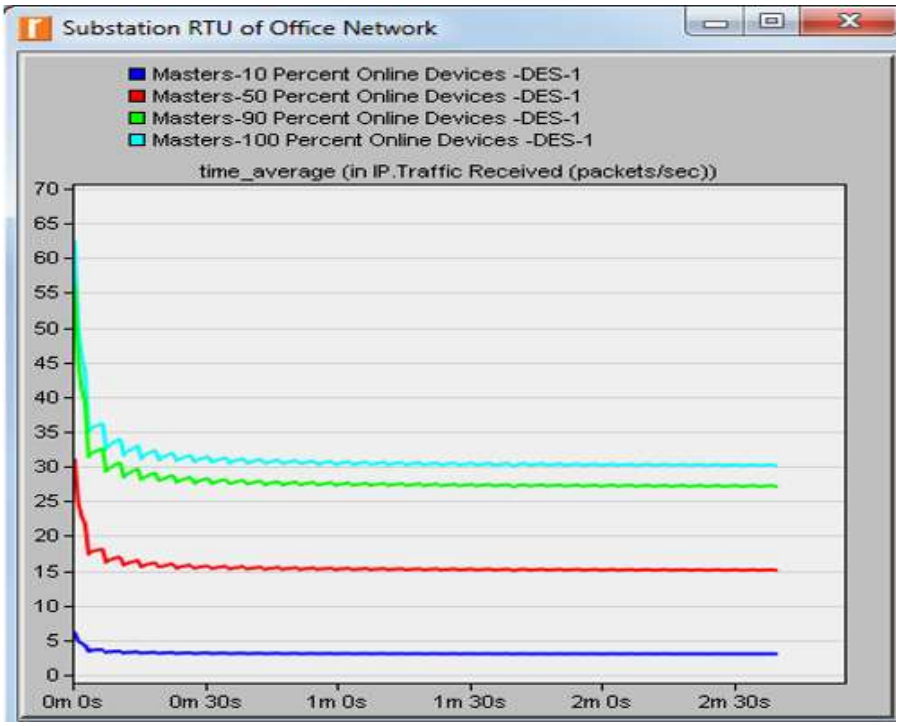

Figure 4.5 IP traffic received packets/sec at the Substation RTU end

Figure 4.6 shows the sent and received traffic between the 400 KV transformer protection IED and the IED switch. From the figure it can be seen that the sent traffic is more than the received traffic. The reason for this is that on the same link there is data losses along the line therefore the received data should be less than the sent data.

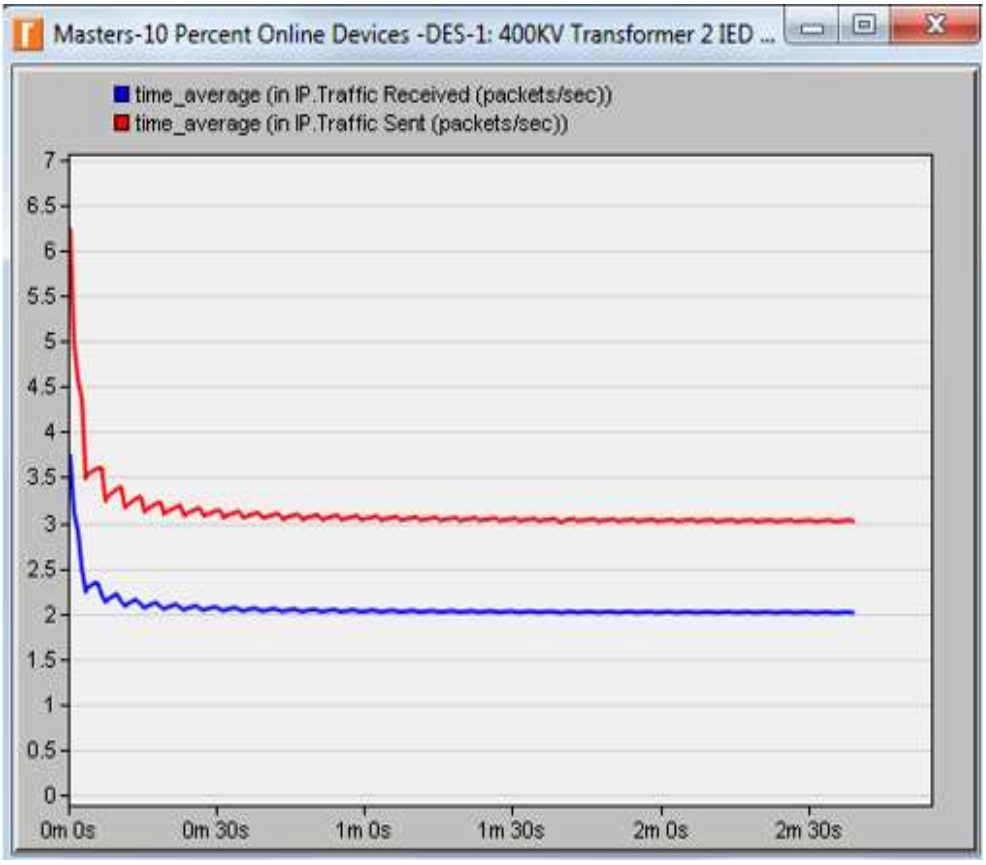

Figure 4.6 Traffic received and sent packets/sec at 400KV Transformer IED end.

Figure 4.7 shows Ethernet delay for the model and that with an increase in devices online, there is also an increase in time delay. Figure 4.7 shows that the time delay ranges between (0.160 – 0.2) ms.

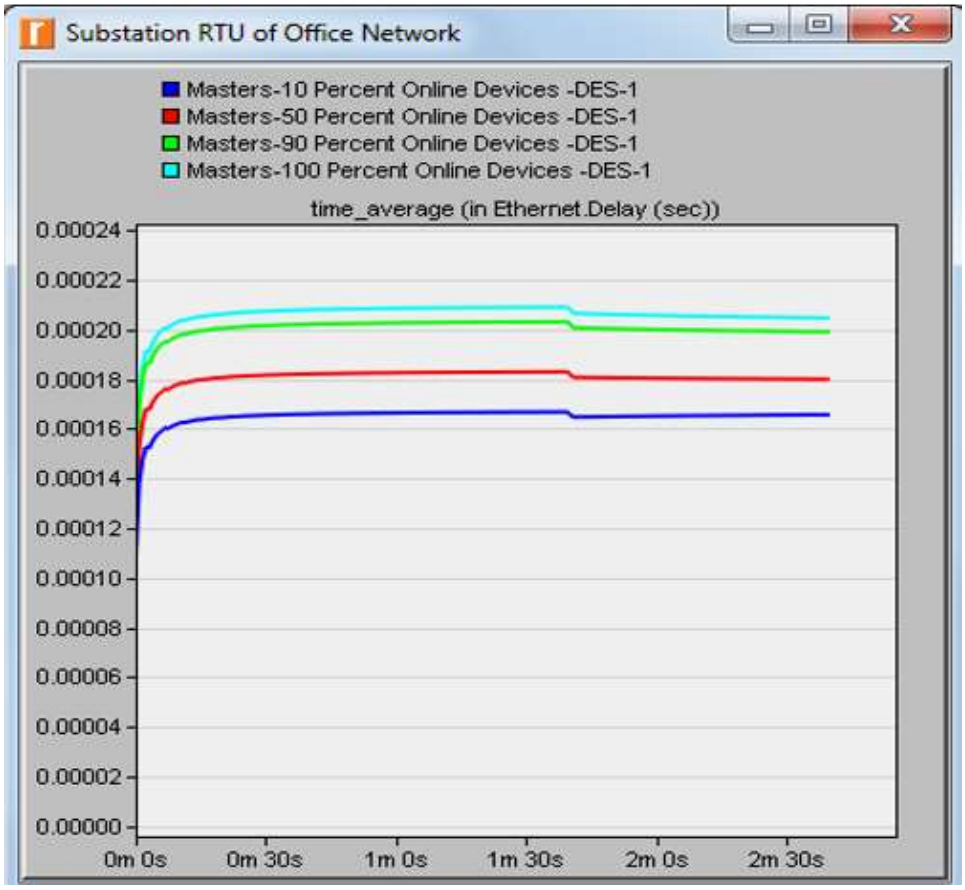

Figure 4.7 Ethernet delay/sec

Figure 4.8 shows the sent throughput from the transformer IED, while figure 4.9 shows the received throughput at the substation RTU unit end. Both figures show that with an increase in the number of devices online, there is a corresponding increase in data throughput. The figures also show that the throughput is stable therefore the network model is operating correctly. In the figures it can be seen that the DNP3 protocol can carry data from (20-350) kbps. These figures show that the received throughput exceeds the sent throughput because the substation RTU receives data from several devices coming online.

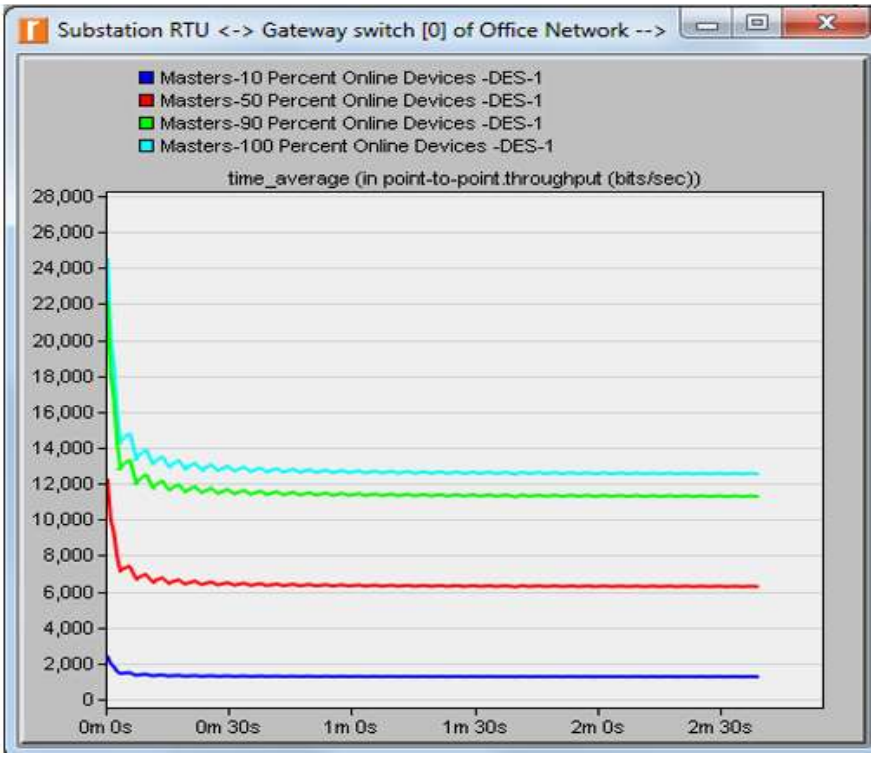

Figure 4.8 Sent throughput (bps)

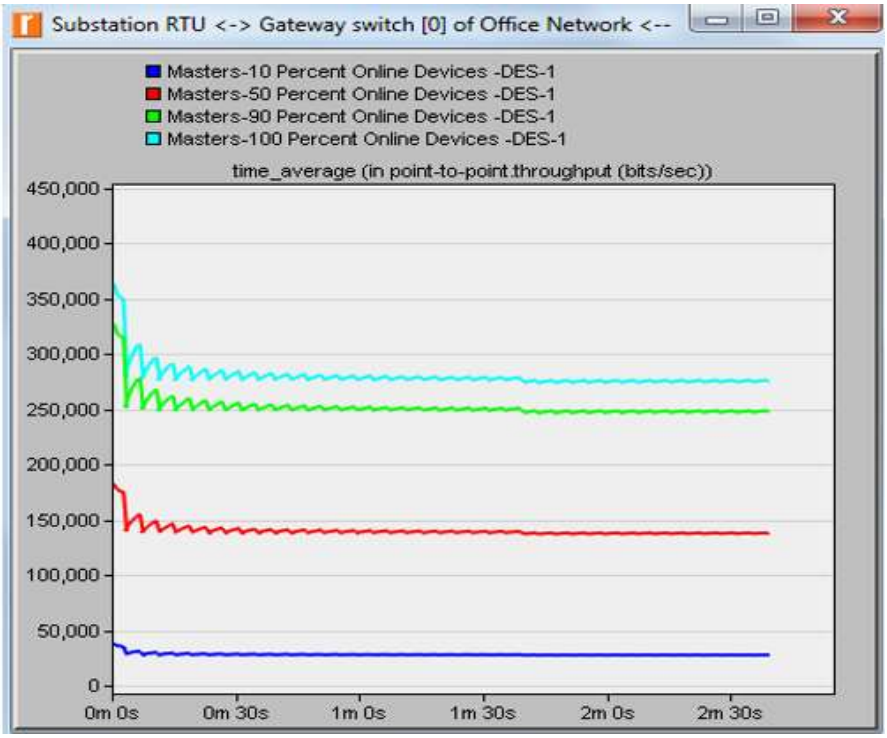

Figure 4.9 Received throughput (bps)

The tables below summarizes the Ethernet delay and load on the network. This is determined at 10%, 50%, 90% and 100% of the devices online. The tables indicates that the Ethernet delay tends to saturate to some extent as you increase the number of devices online. The delay is in the region of 200 μs for these networks.

Table 4.1 DNP3 Online devices

10% Online	**Minimum**	**Average**	**Maximum**
Ethernet Delay	14.001µs	165.65 µs	167.33 µs
Load Packets	1	1.6050	3
50% Online			
Ethernet Delay	18.771 µs	179.89 µs	184.68 µs
Load Packets	5	8.0250	15
90% Online			
Ethernet Delay	29.327 µs	198.98 µs	203.66 µs
Load Packets	9	14.445	27
100% Online			
Ethernet Delay	32.327 µs	204.55 µs	209. µs
Load Packets	10	16.050	30

4.1.1 DNP3 during Maintenance Results

DNP3 communication protocol simulation during Maintenance. The traffic and time delay between the 400kV transformer 11 IED and substation RTU on the model were monitored during the simulation. Figure 4.10 shows the received and sent traffic by the substation RTU. The substation RTU received more traffic and sent less traffic because the Substation RTU is receiving data from all the Substation communication model devices and the Substation RTU only send traffic when its requesting data from the IEDs or when it is sending a control command. The substation RTU has a steady traffic for two minutes and then at two minutes and forty seconds it has a sharp increase in traffic that is because of the alarms it receives from the 400kV Transformer 11 IED during maintenance.

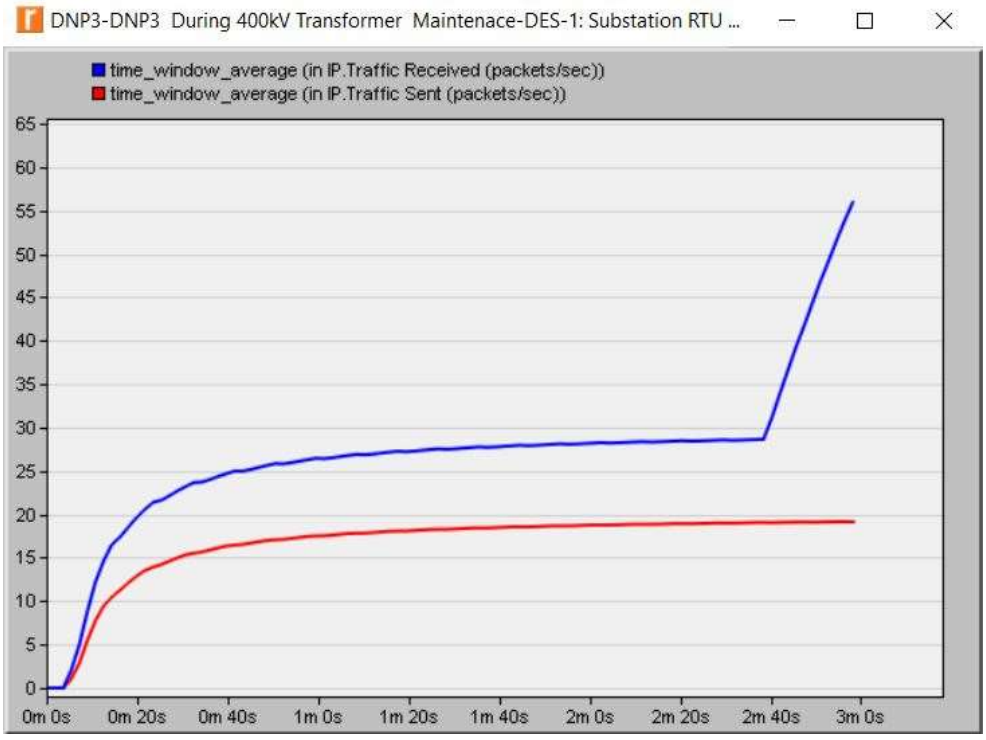

Figure 4.10 Received and Sent Traffic at Substation RTU end

Figure 4.11 shows the sent and received traffic by the 400kV Transformer 11 IED. The 400kV Transformer 11 IED sent more traffic to the Substation RTU and received less traffic from the Substation RTU. The 400kV Transformer 11 IED has more sent traffic because it sent more data to the Substation RTU. The Substation RTU request data from the 400kV Transformer 11 IED and the IED responds by sending all the data to the substation RTU, that is why the 400KV Transformer has more sent traffic and less received traffic. The 400kV Transformer has a steady sent and received traffic for two minutes and a sharp increase in sent traffic that is caused by the alarms sent by the 400kV Transformer 11 IED to the Substation RTU during the 400kV Transformer 11 IED maintenance.

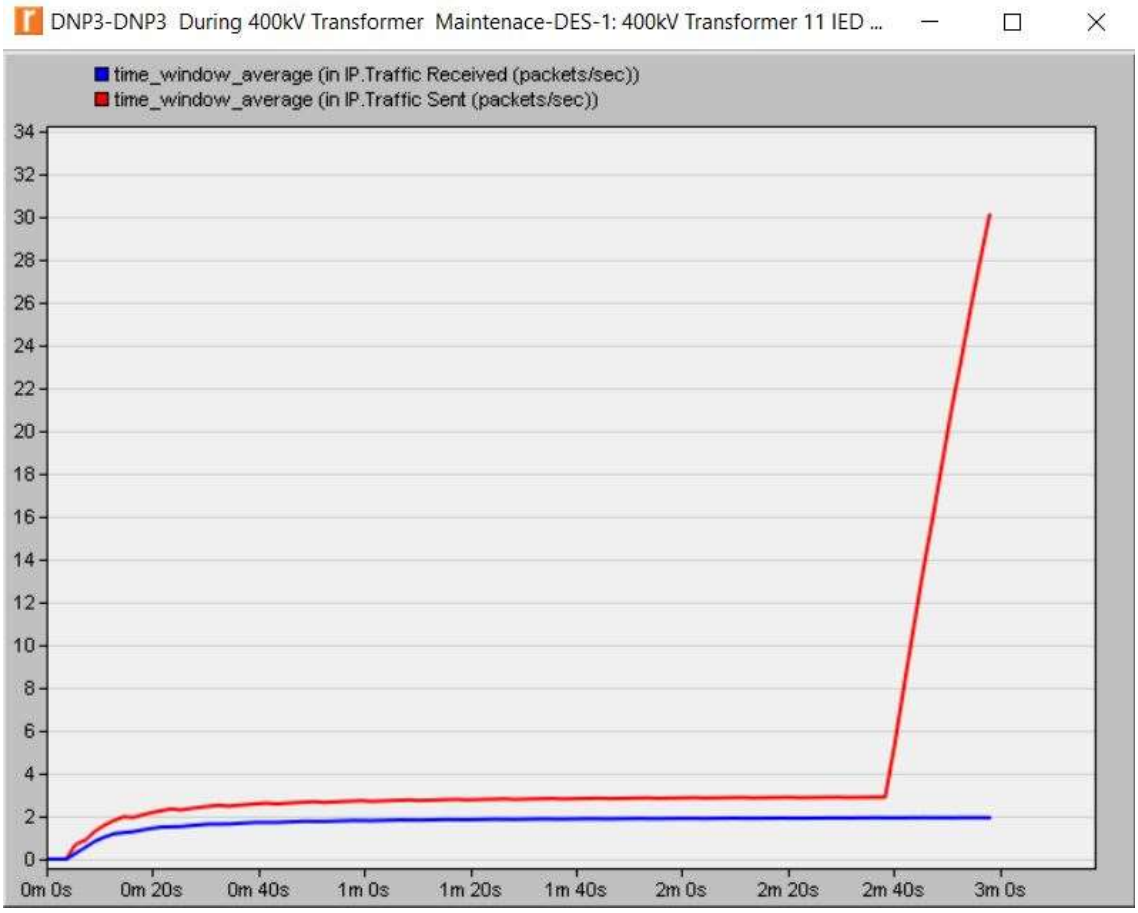

Figure 4.11 Received and sent Traffic at the Transformer 11 IED end

Figure 4.12 shows the Substation RTU time delay when it is communicating with the 400kV Transformer 11 IED and there is a delay of 160 μs.

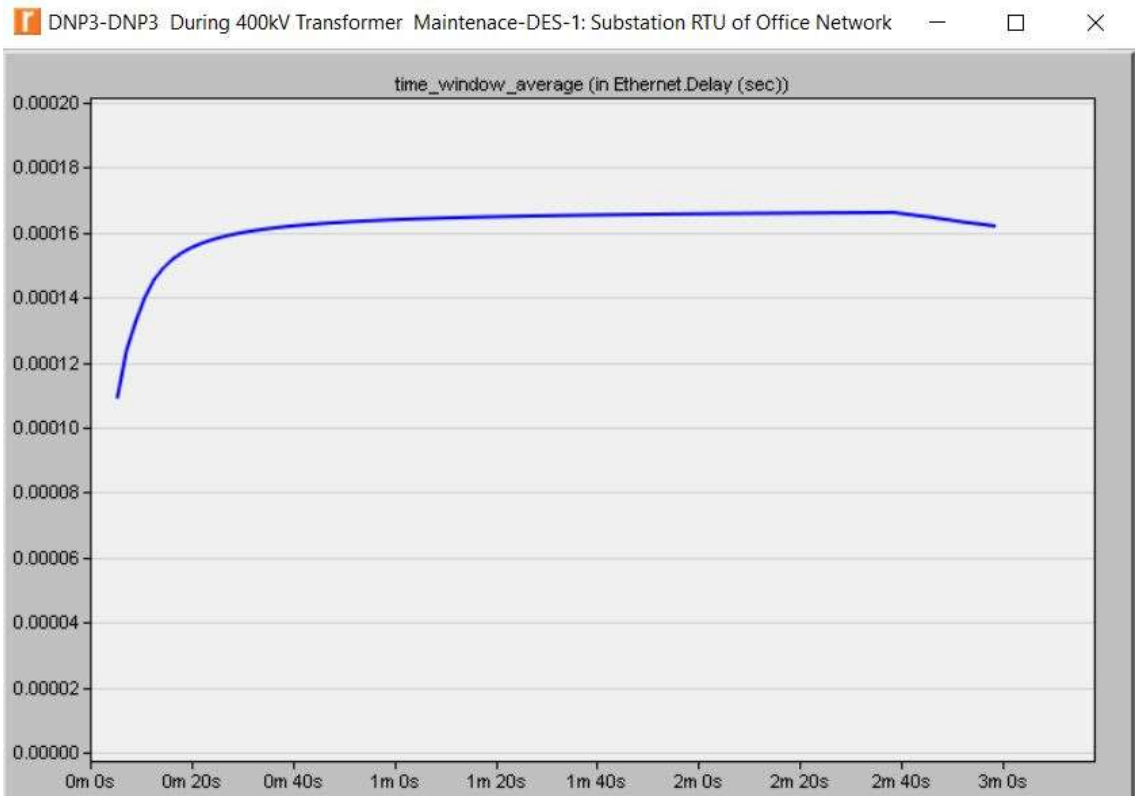

Figure 4.12 Time delay at Substation RTU end

Figure 4.13 shows a time delay when the 400kV Transformer is communicating with the Substation RTU there is delay of 17 µs.

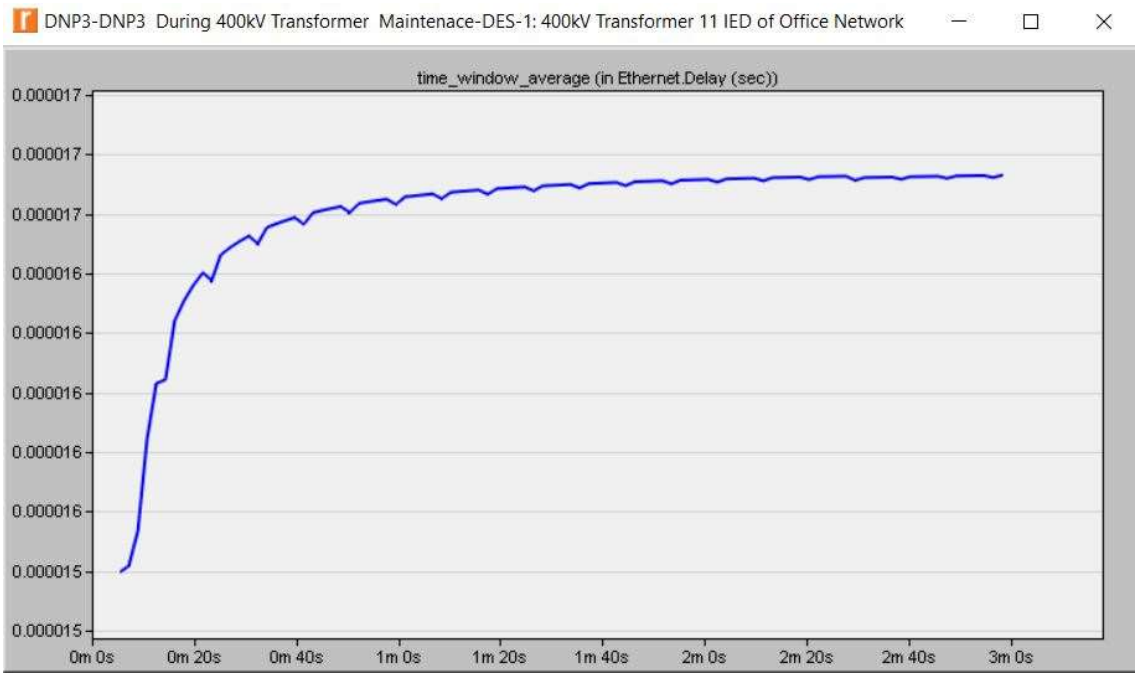

Figure 4.13 Time delay at Transformer 11 IED end

Figure 4.14 shows the Substation RTU received throughput, it has a steady increase in the received throughput and a sharp increase at 2 minutes and forty seconds. Figure 4.15 shows a 400kV Transformer 11 IED sent throughput it has a steady increase in the sent traffic at two minutes and forty seconds it has a sharp increase in sent throughput. The sharp increase in received throughput on the Substation RTU and a Sharp increase in sent throughput on the 400kV Transformer 11 IED shows the balance and validates the model. The throughput ranges between (20 – 450) kbps.

Figure 4.14 Substation RTU Throughput RX

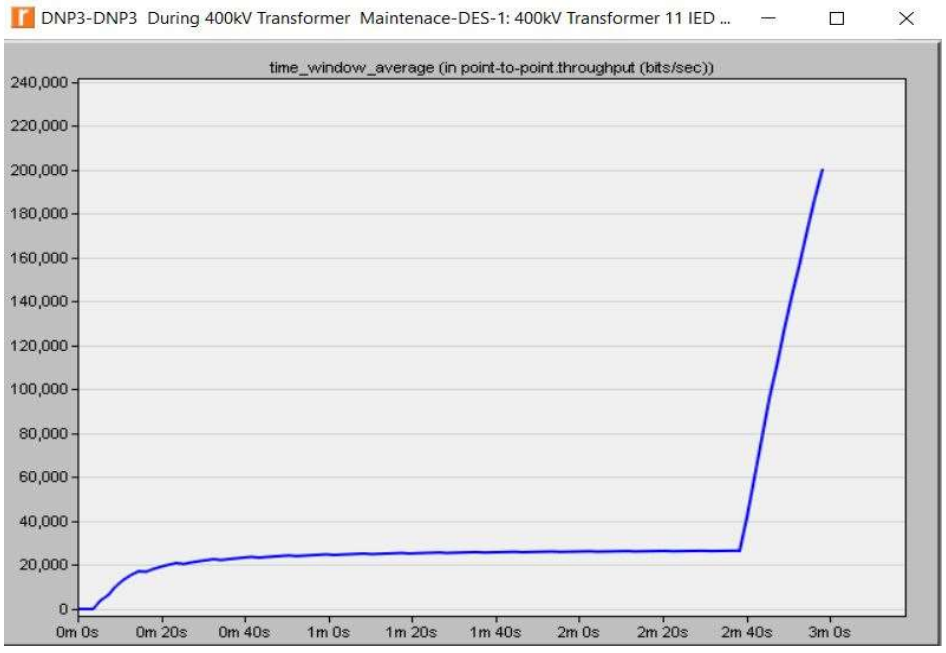

Figure 4.15 400kV Transformer Througput TX

Figure 4.16 and figure 4.17 shows Transformer 11 IED received Throughput and Substation RTU sent Throughput respectively. There is a steady sent and received throughput between the 400kV Transformer and the Substation RTU and this proves that the model is stable.

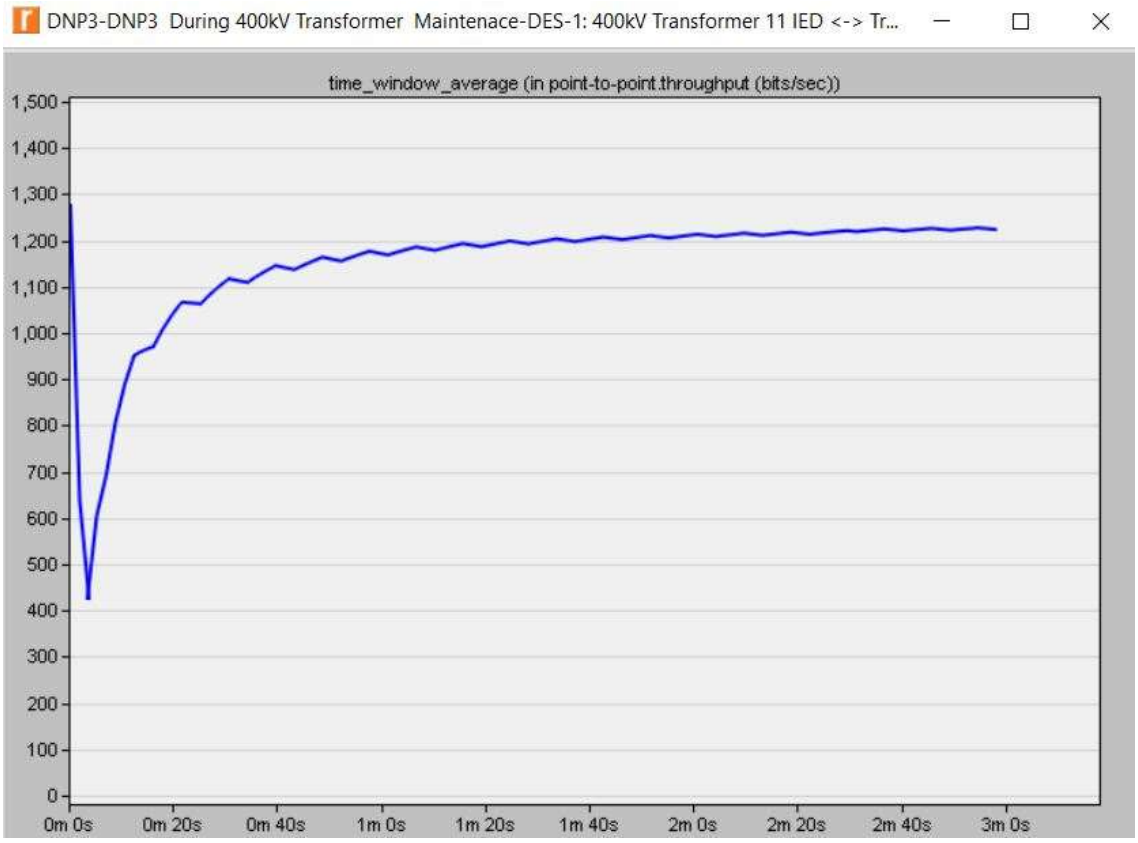

Figure 4.16 Transformer 11 IED Throughput RX

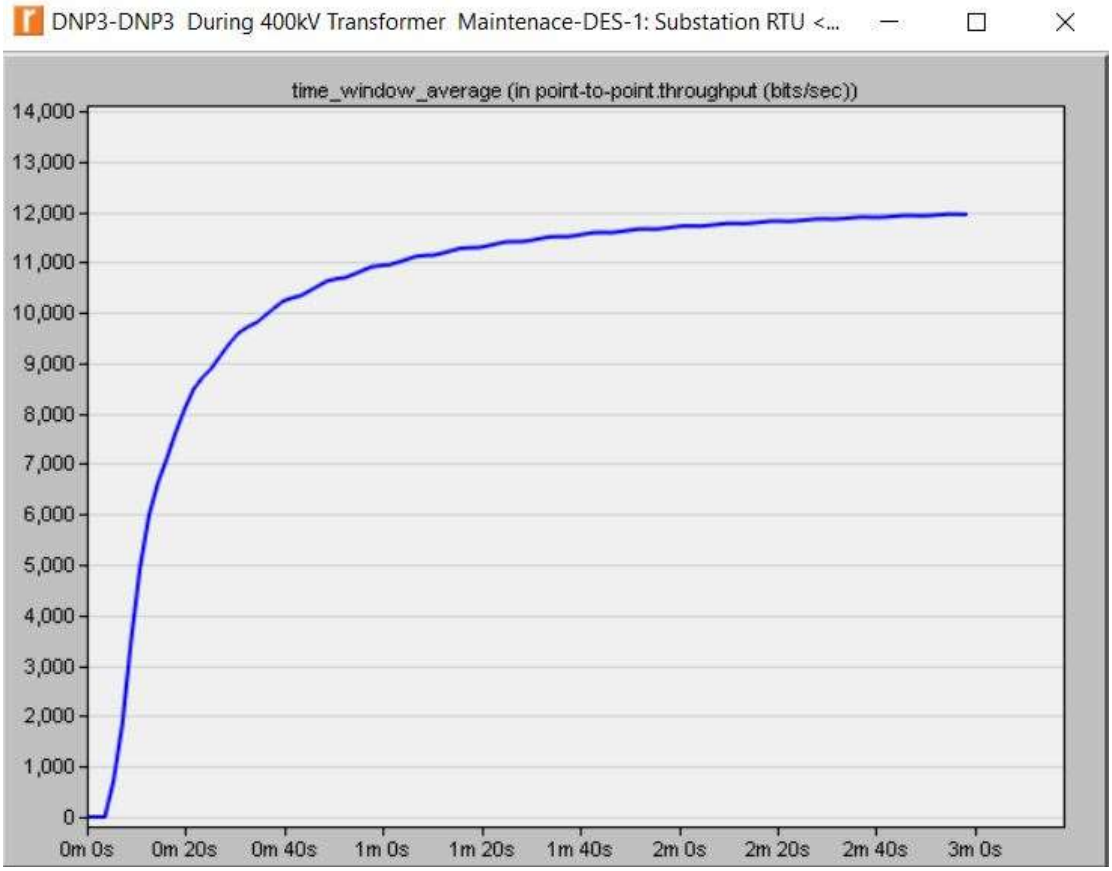

Figure 4.17 Substation RTU Throughput TX

4.2 IEC61850 RESULTS

The results are based on three scenarios namely; normal operation of the Substation, maintenance of specific equipment and Buszone operation (Busbar protection). The scenarios simulate maintenance traffic on an IEC 61850 protocol based communication network and monitor whether the Generic Object Oriented System (GOOSE), Sample Values (SV), Generic Substation State Events (GSSE) and Manufacturing Message Specification (MMS) messaging over the network meet the IEC 61850 standard transfer time requirements. A Busbar fault at an Electrical Substation affects a lot of equipment and can cause tripping on the busbar which will break the circuit as a protection mechanism [64]. The Busbar connects all the bays at an Electrical Substation [65], when there is a busbar fault all the bays and alarms trip at the same time. Indications are sent to the RTU, this creates a huge traffic within a short space of time, at the same time controls are sent to breakers to trip. The Buszone operation simulates the busbar trip and it will check if GOOSE, SV, GSSE and MMS messages meet the IEC 61850 standard

transfer time for this operation. Normal operation of the Substation is also simulated and monitors the same IEC 61850 standard transfer time that was monitored for the maintenance and Buszone Operations.

The packet delay analyses are the delay for the GOOSE, GSSE, MMS and SV messages. The throughput at the Transformer IED end and the throughput at the Substation RTU end are also analysed.

Figure 4.18 shows the traffic received at the Substation RTU shown in the model. During normal operation of the IED's there is a steady traffic received by the RTU from the 400 kV transformer. There is a slight increase in traffic received at the RTU during maintenance of the 400kV Transformer 11, this is caused by the alarm and control packets sent by the single 400 kV Transformer 11 during testing and maintenance. During Buszone operation there is a huge increase in traffic received at the RTU end, this is caused by the alarm and indication packets coming from all the IED devices on the busbar at the same time. The alarm and indication packets are sent to the Substation RTU.

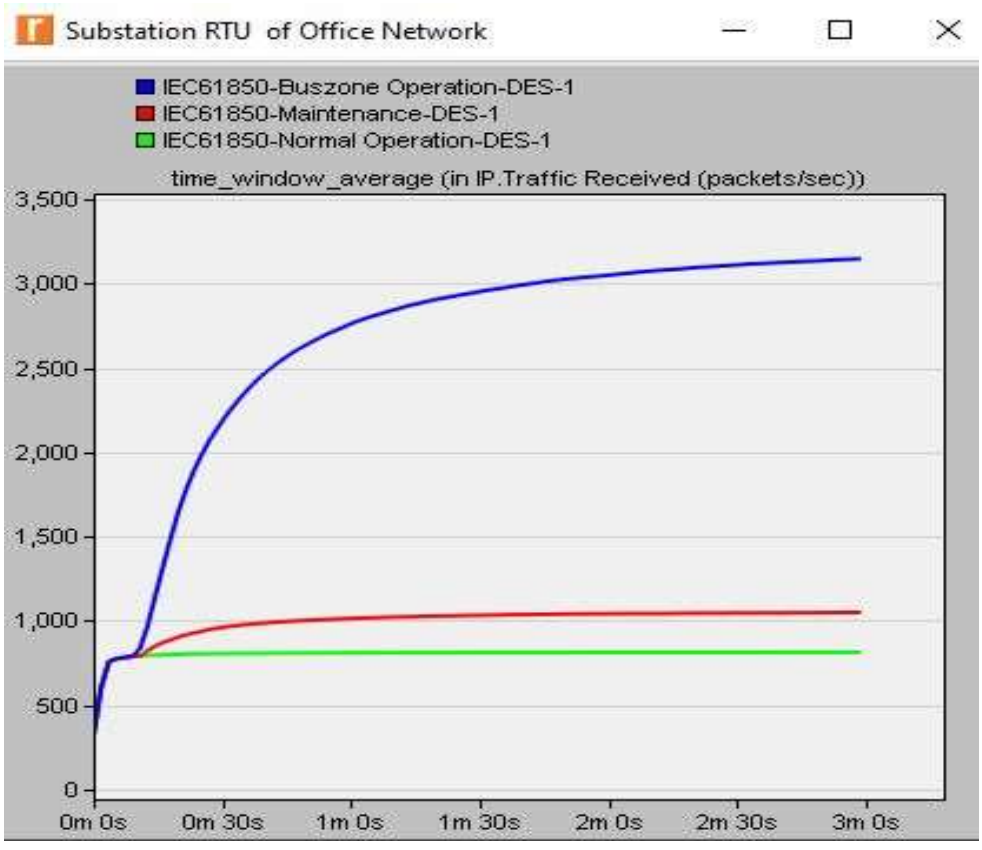

Figure 4.18 IP Traffic Received packets/sec at RTU end

Figure 4.19 shows the traffic sent by 400kV Transformer 11 IED during different scenarios. At normal operation there is steady traffic sent. During Buszone (alarm and indication packets) and transformer maintenance (alarm and control packets) operations there is a huge increase in the traffic sent from the single 400 kV transformer unit because of the extra packets sent to the RTU. The maintenance operation sends slightly more traffic than Buszone operation from the single entity 400 kV transformer 11, this is because the maintenance operation consists of alarm and control packets for maintenance purposes, while the Buszone operation from the single 400 kV transformer 11 consists mainly of alarm and indicator packets. It is during feedback from the RTU that control signals are sent to the busbar breakers to trip during Buszone operation.

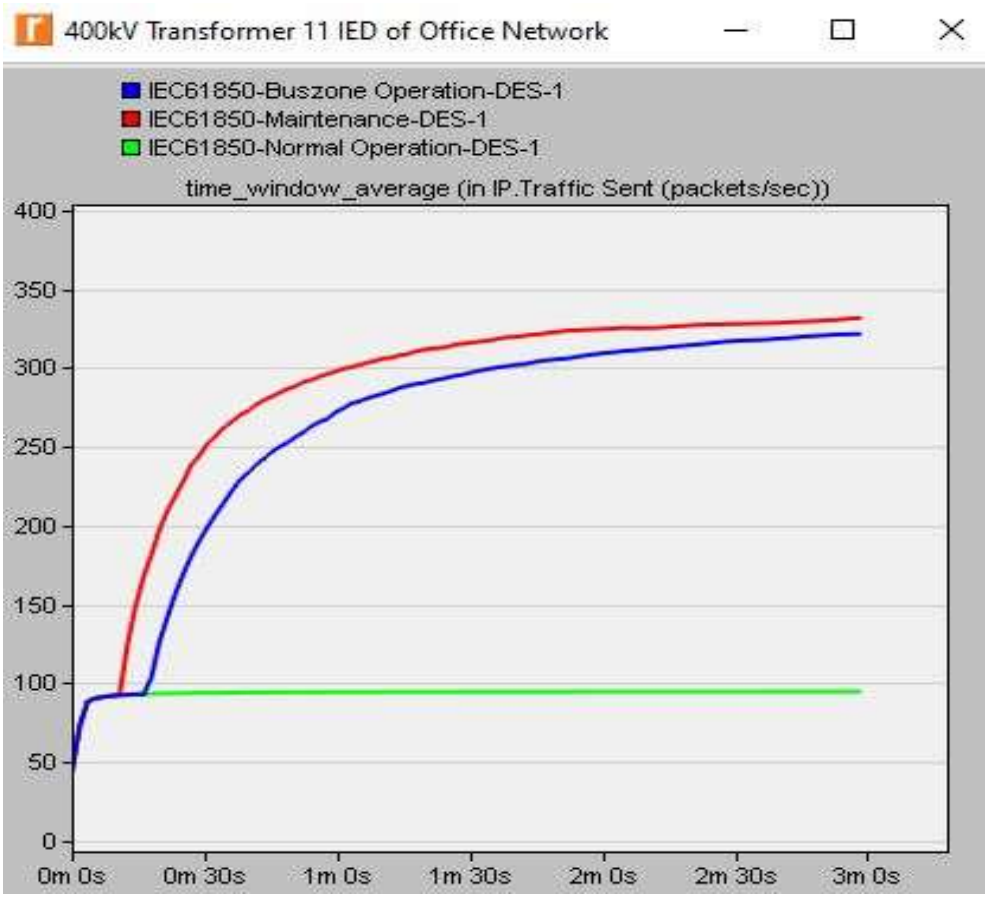

Figure 4.19 IP Traffic Sent packets/sec 400 kV Transformer 11 IED end

Figure 4.20 shows Ethernet delay at different levels of operation on the SCN. Time delay increased during Buszone operation because there is more activity (communication) from all the IED's on the busbar as compared to the maintenance and normal operation.

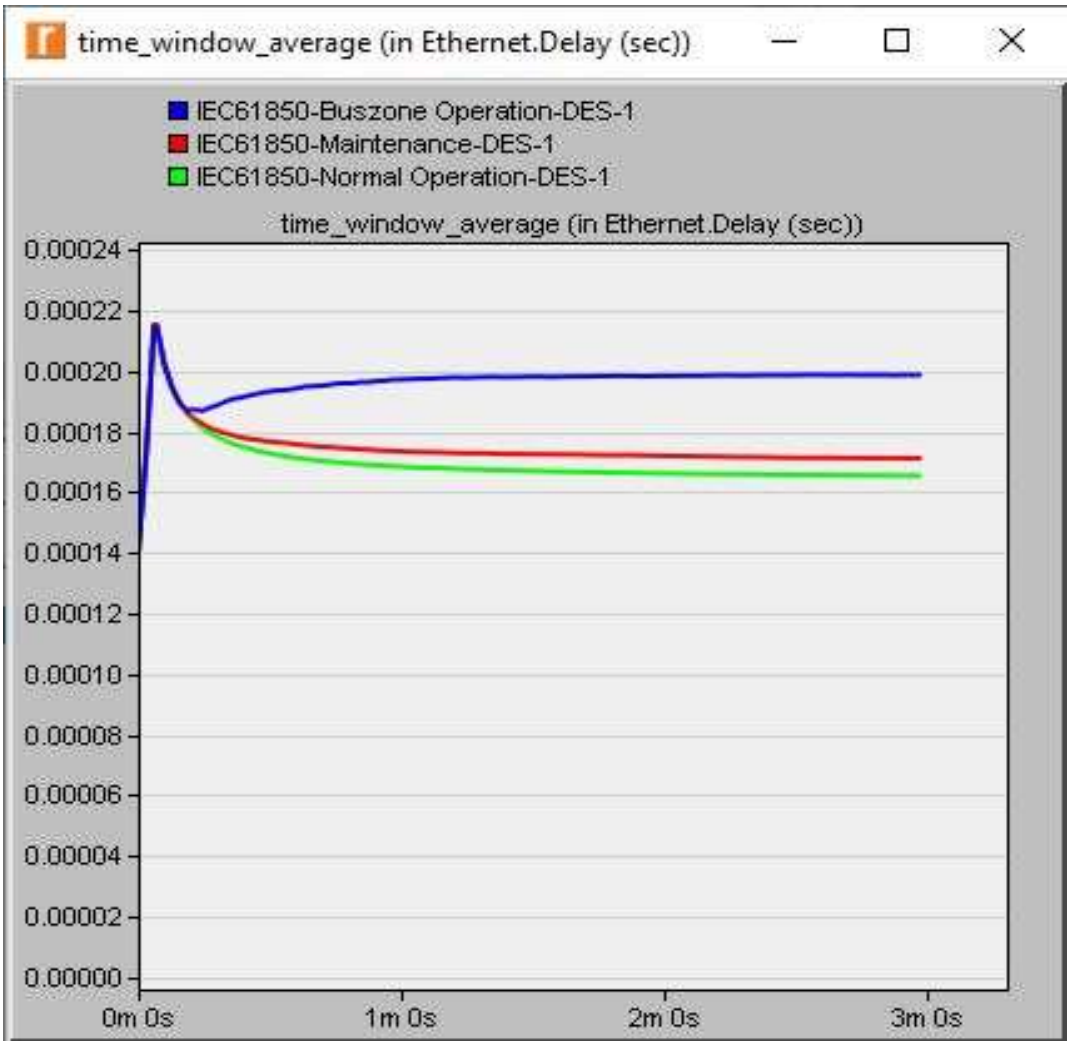

Figure 4.20 Ethernet delay/sec

Figure 4.21 shows received throughput in (bps) at the Substation RTU end and figure 4.22 shows the sent throughput in (bps) from the single 400kV Transformer 11 IED. There is a corresponding relationship in throughput data between the two figures, also the two figures show a stable throughput which indicates the model is operating correctly and data packets are not being dropped. The received throughput at the RTU end exceeds the sent throughput from the 400 kV transformer IED. This is because the RTU receives data from all the devices on the network.

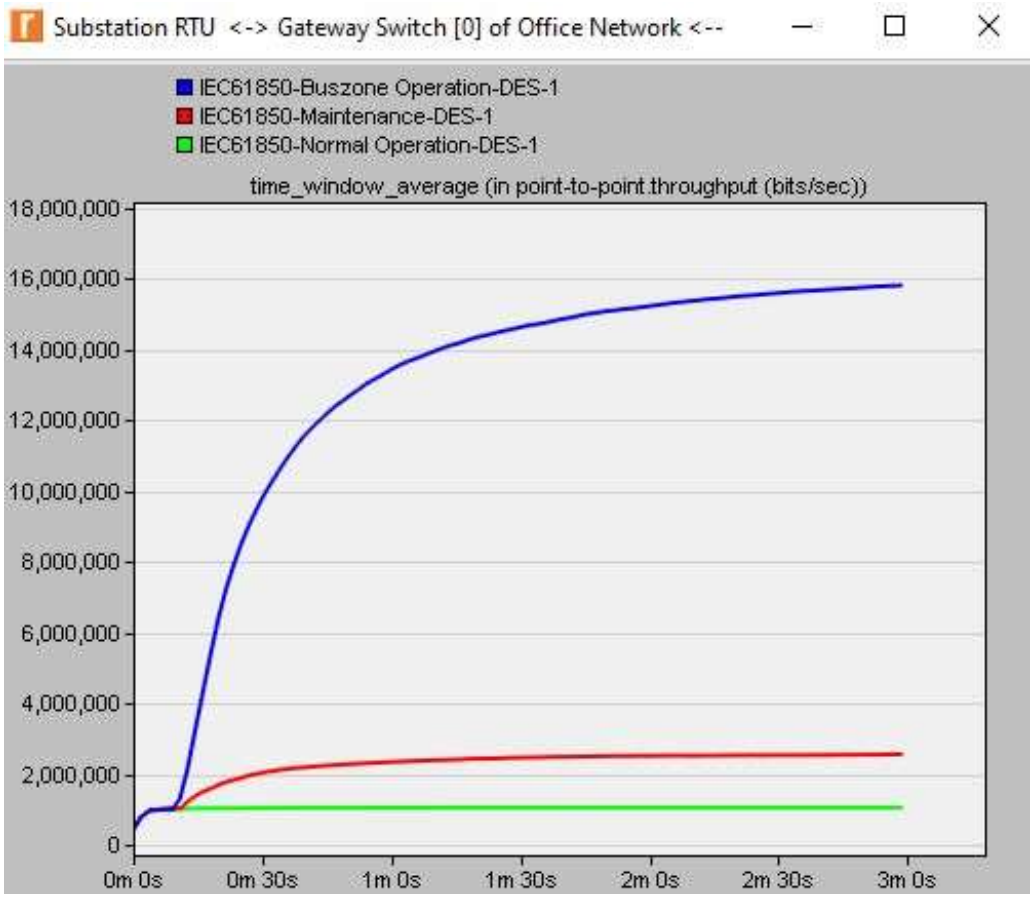

Figure 4.21 Received throughput in (bps) at the Substation RTU end

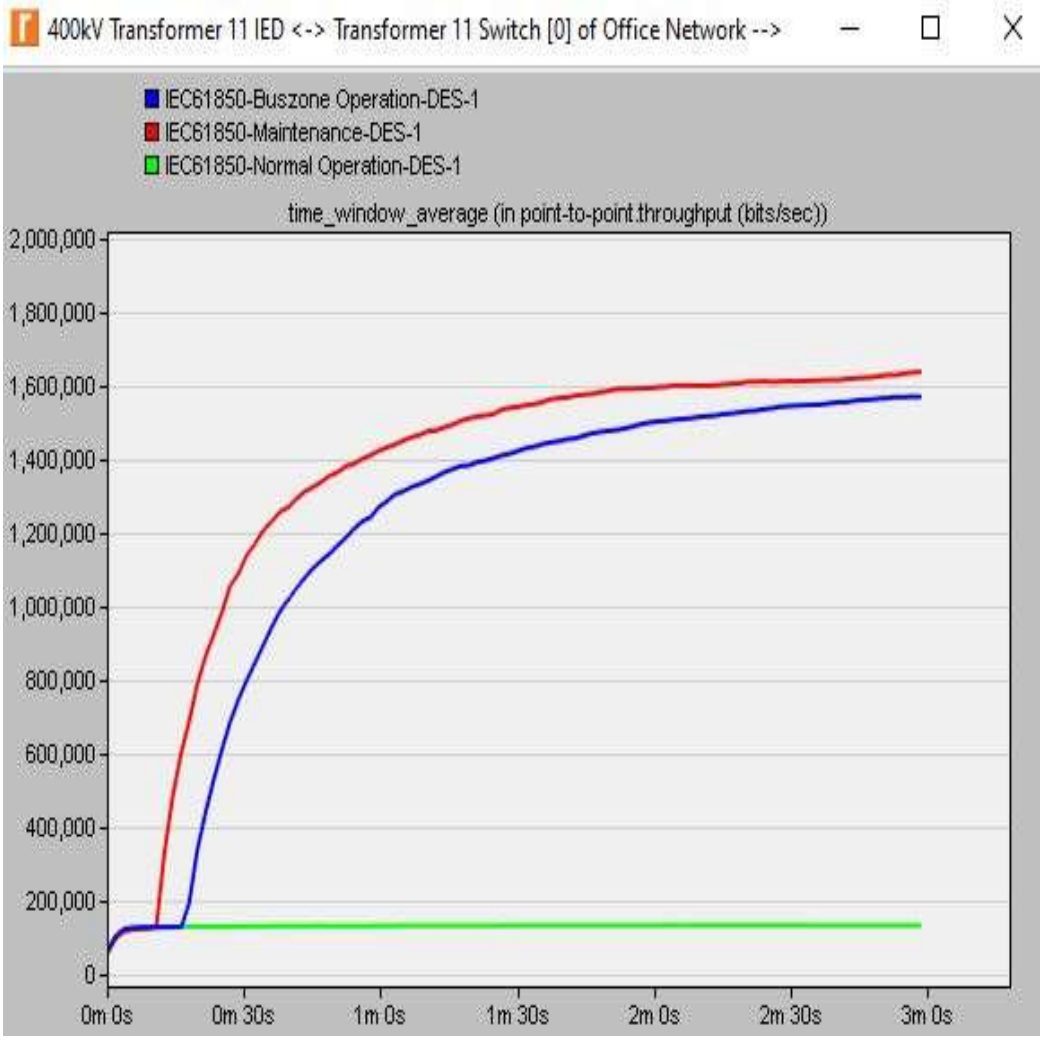

Figure 4.22 Sent throughput in (bps) from the 400 kV Transformer 11 IED

Studies done in [38] show that GOOSE messages average delay is 65.2 μs. Studies done using C programming shows the end to end delay for GOOSE messages is 58 μs [66]. Simulations done on network simulator (ns) shows MMS delay as 0.925 ms [67]. The tables below shows end to end delay captured at different scenarios for the GOOSE, GSSE, MMS and SV messages. Maximum end to end delay for GOOSE messages meets the IEC 61850 standard in all the scenarios. The maximum end to end delay for GOOSE messages is approximately 0.12 ms. The maximum delay for GOOSE messages in the IEC 61850 standard is 1 ms as in [29, 42]. Maximum end to end delay for GSSE messages meets the IEC 61850 standard in all the scenarios. The maximum end to end delay for GSSE messages is approximately 0.4 ms. The maximum delay for GSSE on the IEC 61850 standard is 10 ms [29 42]. Maximum end to end delay for SV meets the IEC 61850 standard in all the scenarios. The maximum end to end delay

for SV messages is approximately 0.145 ms. Maximum delay for SV in the IEC 61850 standard is 10 ms [29, 42]. The maximum delay for MMS does not meet the IEC 61850 standard in all the scenarios, for example it fails in type 2 message of the IEC 61850 standard. However, the MMS messages meets the requirements for the type 5 message of the IEC 61850 standard. The maximum delay for event/alarms (type 5) messages in the IEC 61850 standard is 1000 ms or slightly more as in [29, 42, 68].

Table 4.2 Summary of diferent scenarios performance

Normal operation	**Minimum packet delay**	**Average packet delay**	**Maximum packet delay**
GOOSE/Controls	52.04µs	53.90µs	112.71µs
GSSE/Indications	420.21µs	428.02µs	438.34µs
MMS/Alarms	111 330µs	157 640µs	1 019 000µs
SV/Analogues	142.08µs	142.66µs	145.81µs
Maintenance			
GOOSE/Controls	52.04µs	56.93µs	117.07µs
GSSE/Indications	410.51µs	426.67µs	438.34µs
MMS/Alarms	98 850µs	157 970µs	1 183 600µs
SV/Analogues	136.03µs	142.23µs	145.81µs
Buszone operation			
GOOSE/Controls	52.05µs	66.54µs	128.68µs
GSSE/Indications	311.54µs	332.45µs	348.98µs
MMS/Alarms	123 830µs	151 600µs	462 800µs
SV/Analogues	132.31µs	139.40µs	146.22µs

4.2.1 IEC61850 Faulty Backbone Switch Network performance

The IEC61850 faulty backbone switch network performance is a simulation modelling a scenario where one of the backbone switches have failed and analysing the effect of the network delay and throughput. Figure 4.23 shows the network delay time for normal operation with two backbone switches operating at the same time, normal operation is depicted by a red line and figure 4.23 also shows when one backbone switch has failed depicted by the blue line. The delay time for the network during normal operation is 80 µs and when there is a faulty backbone switch the delay time on average is 100 µs.

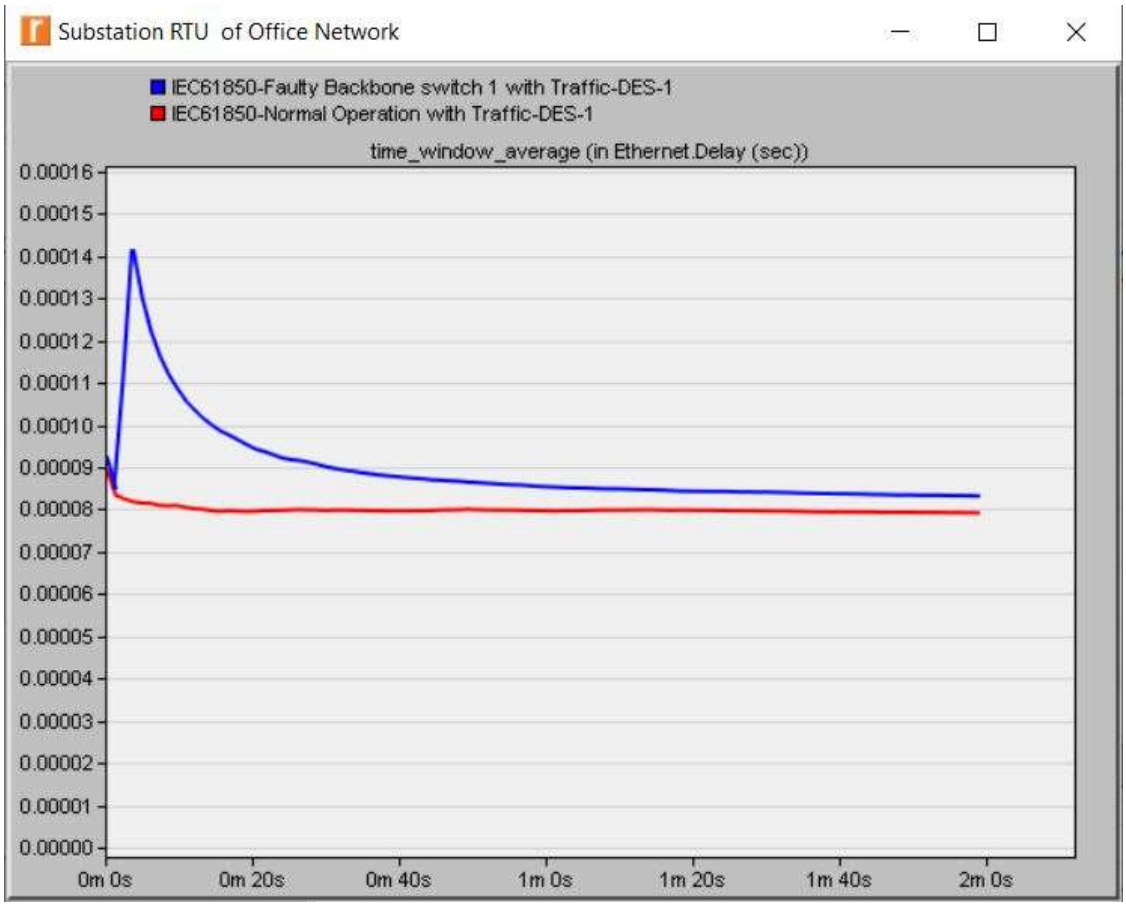

Figure 4.23 Ethernet delay for backbone switches

Figure 4.24 shows the sent throughput during operation with one faulty backbone switch and normal operation with two healthy backbone switches. When the network is operating with one

backbone switch the is a low throughput and in normal operation with two backbone switches the throughput is high .

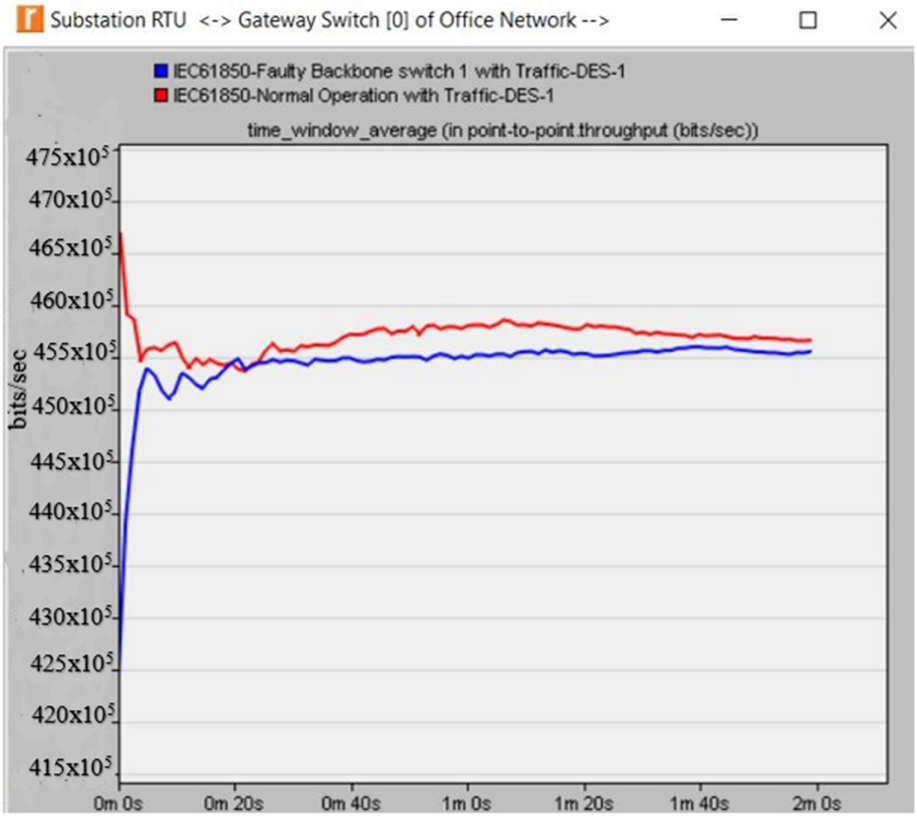

Figure 4.24 Sent Throughput in bps

Figure 4.25 shows the received throughput at the backbone switch during one faulty switch operation and the scenario when two switches are healthy in a normal operation. It is the received throughput at the backbone switch before failure occurs hence the matching value.

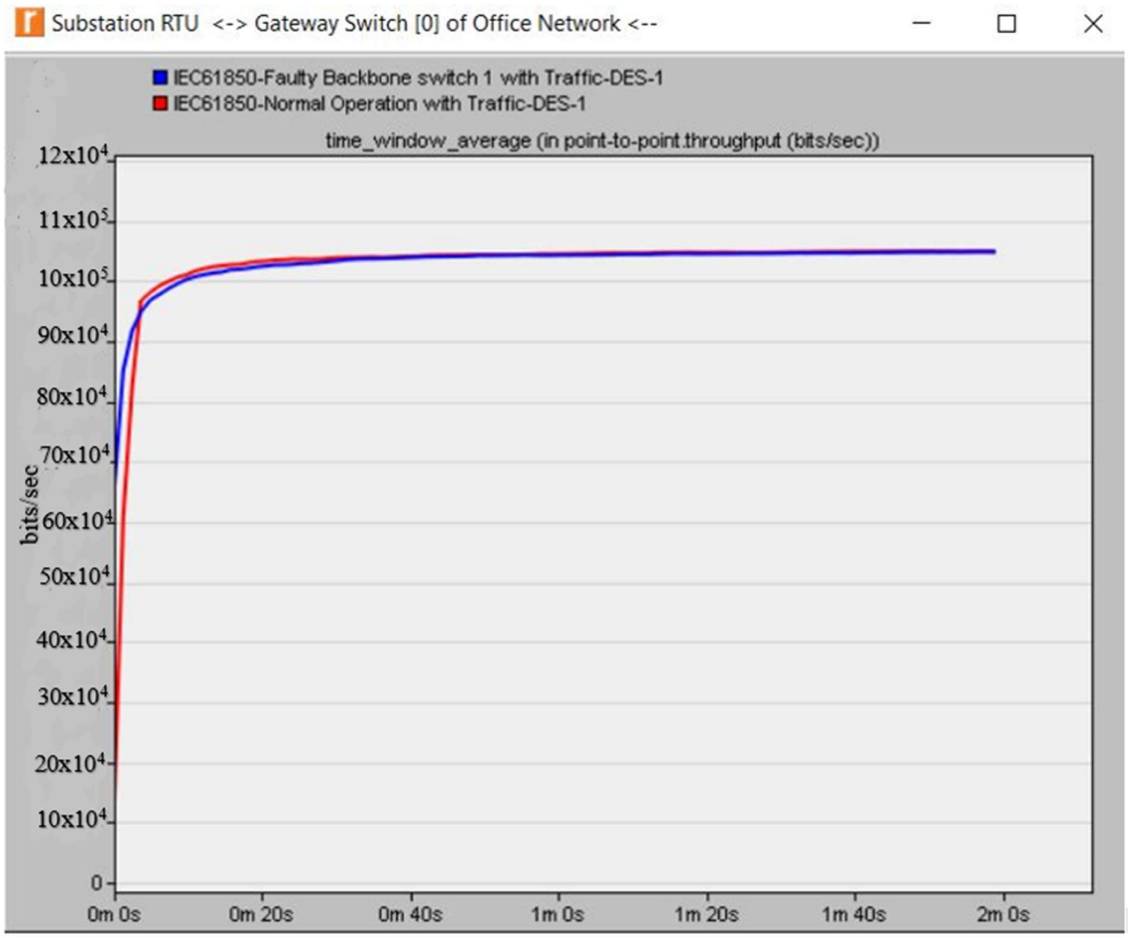

Figure 4.25 received throughput in bps

Figure 4.26 shows the queuing delay at the transmitting end (Tx) during the scenario when there is one faulty switch and the scenario when two switches are healthy in a normal operation. The queuing delay in normal operation is 0.7 µs and when there is a faulty

backbone switch is 1.25 µs. The queuing delay during normal operation is less than when there is a faulty switch.

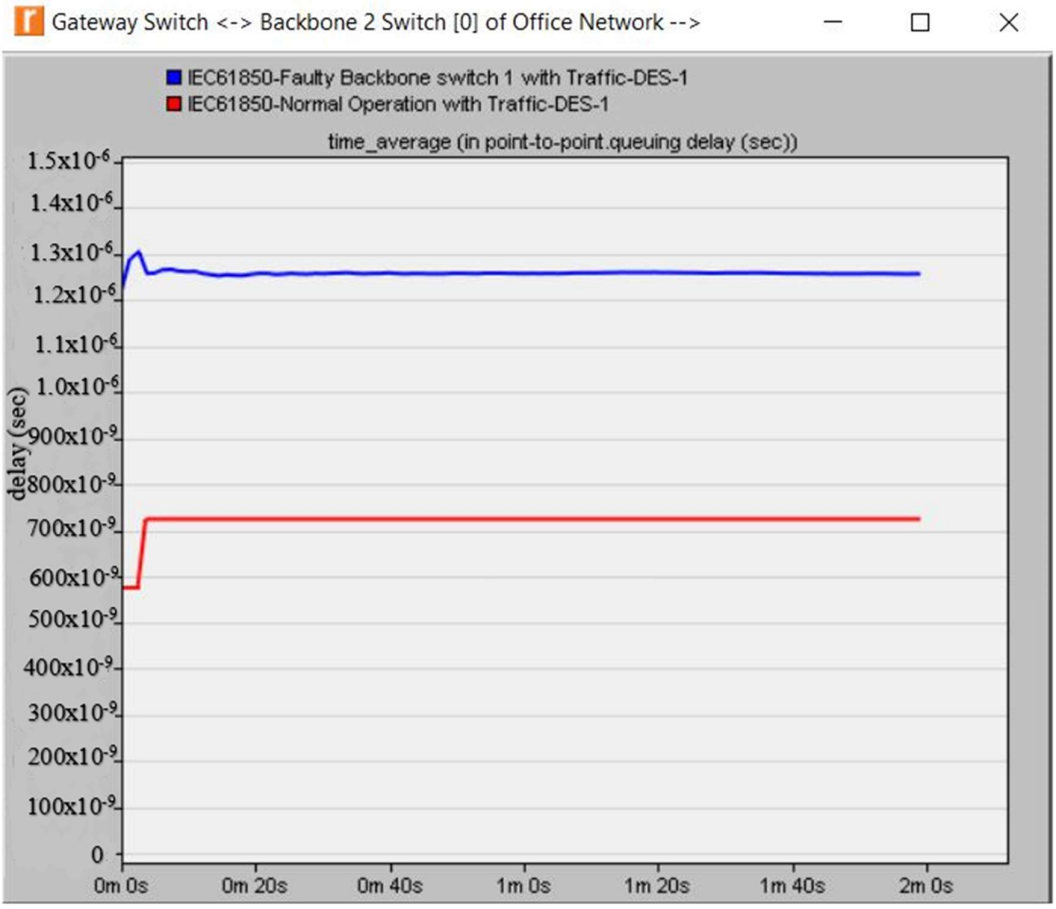

Figure 4.26 Queing delay Tx

Figure 4.27 shows the queing delay at the received end (Rx) during healthy and unhealthy switch operation. The delay is 0.59 µs for normal operation and 1.3 µs for a faulty switch condition.

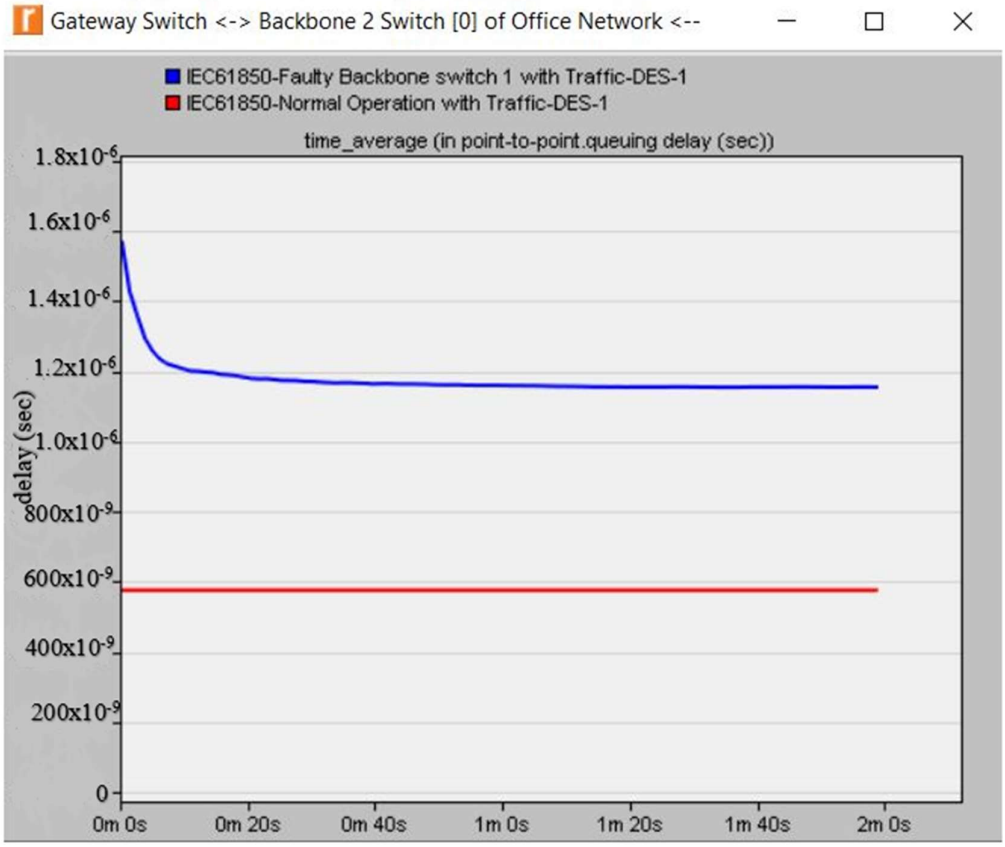

Figure 4.27 Queuing delay Rx

CHAPTER 5

5 Conclusion and Recommendations

5.1 Conclusion

The Eastern Cape Operating Unit is using DNP3 protocol on their Substation SCADA system.

The simulation of the Substation communication network model using DNP3 protocol applied over the model with Ethernet in OPNET. The modelling shows that DNP3 has a data rate in in the range of (20 – 450) kbps and a delay in the range of 0.2 ms. In addition, it has been observed in the simulation that with an increase in the number of IED devices in the substation network there is an increase in the Ethernet delay and the packet load on the network. It can be concluded that when designing a substation communication network, the packet load on the network must be taken into consideration if a quick response is required as in a smart grid system.

The simulation of the Substation communication network model using IEC 61850 protocol is configured in OPNET

The results of the simulation show that with an increase in traffic there is a corresponding increase in the end to end packet delay. The increase in end to end packet delay does not affect the IEC 61850 standard requirements of messaging and data transfer time when it comes to GOOSE, GSSE and SV messages. The model cannot be used for type 2 messages of the IEC 61850 standard, since it failed the message and transfer time requirements of type 2 MMS messages.

In general, the MMS message is best used for large packets and in scenarios where timing and long delay will not affect the performance of the system. Since the throughput of the IEC 61850 standard is in the range of (1.6 – 16) Mbps, and delay values such as 80 µs it can be used in power utilities such as ESKOM in South Africa to carry large data packets for IED's. The model can be used to predict network behaviour when preparing to do maintenance and fault finding in a SCADA based Electrical Substation using the IEC 61850 protocol for communication.

The network end to end delay time for DNP3 protocol is in milliseconds and IEC 61850 protocol is in micro seconds based on the fact that the minimum throughtput for DNP3 is 2 kbps and IEC 61850 is 200 kbps. When simulating the IEC 61850 protocol since the delay was determined to be in micro seconds this is good for Substation monitoring alarms and sending control commands to plant equipment.

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5.2 **Recommendation**s

High processing Substation RTU would be recommended when designing a Substation communication network since the RTU communicates with all the IEDs in the Substation.

OPNET proved to be a valuable tool for simulation of network devices and monitoring the network performance without building an actual network which would be very expensive to build.

Since the throughput for IEC is in Mbps and the throughput for DNP3 is in kbps and the delay for the IEC 61850 protocol is shorter than for the DNP3 protocol we recommend to ESKOM to implement the IEC 61850 protocol in their network infrastructure for power substation grids.

In the end the research achieved a “ONE” hypothesis as was suggested or predicted.

REFERENCES

[1] J.Ranyane, "Substation Control Systems Refurbishment Strategy" Eskom Standard. Jan, 2015.

[2] D. Bailey and E. Wright, Practical SCADA for Industry. Perth: IDC Technologies, 2003, pp. 1-18.

[3] S.A. Boyer Supervisory Control and Data Acquisition, 3rd ed. USA: The Instrumentation, Systems and Automation Society, 2004, pp. 9-12.

[4] D.J.Kang and R.J Robles, "Compartmentalization of Protocols in SCADA Communication". International Journal of Advanced Science and Technology, vol. 8, pp. 27-36, Jul 2009.

[5] R. Jiang, R. Lu, J.Luo, C.Lai and X.Shen (2014, August). "Efficient self-healing group key management with dynamic revocation and collusion resistance for SCADA in smart grid". Security and Communication Networks [Online]. vol. 8, pp. 1026-1039.

[6] L. Fen, "SCADA for Dummies" Eskom Distribtion, East London. Nov, 2011.

[7] G. Clark, D. Reynders and S. Mackay, "Practical DNP3, IEC 60870.5 & Moden SCADA Communication Systems". South Africa: IDC Technologies, 2010, 17-35.

[8] P. Malindi C2.4. Class Lecture: "Introduction to Communication Systems". Faculty of Engineering and Technology, Walter Sisulu University, East London, South Africa, Jul. 28, 2012.

[9] S. Haykin, Communication Systems, 4th ed. New Jersey: John Wiley & Sons, Inc, 2001, pp. 1-40.

[10] B.A. Forouzan TCP/IP Protocol Suite, 4th ed. New York: The Mcgraw-Hill Companies, Inc, 2010, pp. 28-29.

[11] B. Hossein, Handbook of Computer Networks: LANs, MANs, WANs, the Internet, and Global, Cellular, and Wireless Networks, vol. 2, New Jersey: John Wiley & Sons, Inc, 2008, pp. 388-406.

[12] D.Wetteroth, OSI Reference Model For Telecommunications. New york: The Mcgraw-Hill Companies, Inc, 2003, pp. 2-5.

[13] K. P. Brand. Class Lecture: "Communication Principles and IEC 61850".ABB University, Switzerland, Apr, 2006.

[14] A.S. Tanenbaum, Computer Networks 4th ed.New Jersey: Prentice Hall PTR Upper Saddle River, New Jersey, 2003, pp. 38-42.

[15] J.V. Prakash, White paper: “Advantages of the DNP3 Communication Protocol in Water and Wastewater Telemetry Systems”. Semaphore, Jan, 2012.

[16] J. Ekanayake, K. Liyanage, J.Wu, A.Yokoyama and N. Jenkins. Smart Grid: Technology and Applications. United Kingdom: A John Wiley & Sons, Ltd. 2012, pp. 45-56.

[17] T.P.Neeraja, P.Sivraj and K.K. Sasi (2015, Aug). “Sensor Based Communication Network for WACS with DNP3”. Procedia Technology [Online]. vol 21, pp. 76-81. Aug, 2015.

[18] L.Cheng, “Study and Application of DNP3.0 in Scada System”. Int Conf. on Electronic and Mechanical Engineering and Information Technology, Dongying, China, August 12-14, 2011, pp.4563-4566.

[19] E.D Knapp, Industrial Network Security: Securing Critical Infrastructure Networks for Smart Grid, SCADA and Other Industrial Control Systems, USA: Elsevier Inc, 2011, pp. 56-68.

[20] H. Zhang, Y. Li and H. Zhu (2011, Aug). “Development for Protocol Conversion Gateway of Profibus and Modbus”. Procedia Engineering [Online]. vol. 15, pp. 767–771.

[21] Honeywell, “Industrial Communication Protocols” Safety and Productivity Solutions, [Online]. Honeywell, Aug, 2016.

[22] P. Terwiesch, C. Rytoft, H.E Meier, H. Bawa, P. Reinhardt and A. Moglestue.” Special Report IEC 61850”. The corporate technical journal [Online]. Aug, 2010.

[23] C. Yang, V. Dubinin and V. Vyatkin, "Automatic Generation of Control Flow from Requirements for Distributed Smart Grid Automation Control", in IEEE Transactions on Industrial Informatics, vol. 16, no. 1, pp. 403-413, Jan. 2020.

[24] Z. Zhu, W. Gao, B. Xu, J. Cheng and J. Ye, "Application of IEC61850 for Communication of Distribution Gird Automation," IEEE Sustainable Power and Energy Conference (iSPEC), Beijing, China, November 20-24, 2019, pp. 1395-1400.

[25] A. Pal and R. Dash. “A Paradigm Shift in Substation Engineering: IEC 61850 Approach”. Procedia Technology [Online]. vol 21, pp. 8–14. Aug, 2015.

[26] IEEE Substation Committee. “IEEE Recommended Practice for Implementing an IEC 61850-Based Substation Communications, Protection, Monitoring and Control System”. IEEE USA, 2017.

[27] M. Adamiak, D. Baigent and R. Mackiewicz., “IEC 61850 Communication Networks and Systems in Substations, an overview for users. Protection and Control Journa [Online]. Vol 8, pp. 61-68, Jun. 2009.

[28] R. B. Scarselli, L. F. Soares and I. M. Moraes, "Evaluating Cryptographic Algorithms in IEC 61850 Networks", 10th International Conference on Networks of the Future (NoF), Rome, Italy, October 1-3, 2019, pp. 9-16.

[29] N. H. Ali, B. B. M. Ali, O. Basir, M. L. Othman and F. B. Hashim, "WLAN oriented optimization of process bus in IEC 61850-based substation communication network", 3rd International Renewable and Sustainable Energy Conference (IRSEC), Marrakech, December 10-13, 2015, pp. 1-6.

[30] J. Zhang, C.A Gunter. LAB4309 Class Lecture “IEC 61850 Communication Networks and Systems in Substations” University of Illinois. ILLINOIS, USA, Mar, 2011.

[31] IEC 61850-1. Communication networks and systems in substations-Part 7-1:Basic communication structure for substation and feeder equipment –Principles and models. 2003.

[32] N. Das, H. Modi and S. Islam, "Investigation on architectures for power system communications between substations using IEC 61850," 2014 Australasian Universities Power Engineering Conference (AUPEC), Perth, WA, 28 Sep - 1 Oct, 2014, pp. 1-6.

[33] Sonika, A. Arora, K. Vats and N. Rani. “OPNET based investigation and Simulation Evaluation of WLAN Standard with Protocols using Different QoS”. International Journal of Computer Science and Mobile Computing [Online]. vol 3, no 6, pp. 852-861, Jun, 2014.

[34] I. Ali and S. M. S Hussain. “Control and management of distribution system with integrated DERs via IEC61850 based communication”. Engineering Science and Technology, an International Journal [Online]. vol 20, pp. 956-964. Dec, 2016.

[35] M. T. O. Amanullah, A. Kalam and A. Zayegh. “Development of information embedded power system using OPNET”. Australian journal of electrical and electronics engineering, vol. 4, no. 3, pp. 211-215, Jan, 2007.

[36] N. H. Ali, B. M. Ali, M. A. Abdala, M. L. Othman and F. B. Hashim. “Comparisons process-to-bay level peer to peer network delay in IEC61850 Substation communication systems”. Journal of Electrical Systems and Information Technology [Online] vol 1, pp. 266-275. Dec, 2014.

[37] S. Repo et al, "Active distribution network concept for distributed management of low voltage network", IEEE/PES Innovative Smart Grid Technologies Europe (ISGT Europe), October 6-9, 2013, pp. 1-5.

[38] T. S. Ustun, M. A. Aftab, I. Ali and S. M. S. Hussain, "A Novel Scheme for Performance Evaluation of an IEC 61850-Based Active Distribution System Substation", in IEEE Access, vol. 7, pp. 123893-123902, 2019.

[39] Z. Zhang, X. Huang, B. Keune, Y. Cao and Y. Li, "Modeling and Simulation of Data Flow for VLAN-Based Communication in Substations", in IEEE Systems Journal, vol. 11, no. 4, pp. 2467-2478, Dec. 2017.

[40] T. S. Sidhu and Y. Yin, "Modelling and Simulation for Performance Evaluation of IEC61850-Based Substation Communication Systems", in IEEE Transactions on Power Delivery, vol. 22, no. 3, pp. 1482-1489, July 2007.

[41] X. Yang, Y. Wang, Y. Zhang and D. Xu, "Modeling and Analysis of Communication Network in Smart Microgrids", 2nd IEEE Conference on Energy Internet and Energy System Integration (EI2), Beijing, October 20-22, 2018, pp. 1-6.

[42] Xin Yang, N. Das and S. Islam, "Analysis of IEC 61850 for a reliable communication system between substations", Australasian Universities Power Engineering Conference (AUPEC), Hobart, TAS, 29 Sep – 3 Oct, 2013, pp. 1-6.

[43] H. Hung, “Automatic Circuit Recloser (ACR) communications using P25 RMU (Radio Modem Unit)”, Dissertation submitted to the University of Southern Queensland, 2016.

[44] A. Ortega, A.A. Shinoda and C.M. Schweitzer, “Performance Analysis of Smart Grid Communication Protocol DNP3 over TCP/IP in a Heterogeneous Traffic Environment”, IEEE Colombian Conf. Communications and Computing, Medellin Colombia, May 22-24, 2013.

[45] A. Richard. and P.A. Kubi, “Design and performance of a split protocol architecture on Distributed Network Protocol 3”, IEEE International Conference on Electro Information technology, Lincoln, USA, May 14-17, 2017.

[46] X. Lu, Z. Lu, W. Wang and J. Ma, "On Network Performance Evaluation toward the Smart Grid: A Case Study of DNP3 over TCP/IP," 2011 IEEE Global Telecommunications Conference - GLOBECOM 2011, Houston, December 5-9, TX, USA, 2011, pp. 1-6.

[47] J. Bai, S. Hariri and Y.A. Nashif, “A Network Protection Framework for DNP3 over TCP/IP Protocol”, IEEE/ACS 11th International Conference on Computer Systems and Applications, Doha, Qatar, November 10-14, 2014, pp. 9-15.

[48] I.J. Shin, D.S. Eom and B.K. Song, “The CoAP-based M2M Gateway for Distribution Automation System using DNP3.0 in Smart Grid Environment”, IEEE International Conference on Smart Grid Communications, Miami, USA, November 2-5, 2015, pp. 713-718.

[49] A. Ortega, C. M. Schweitzer, A. A. Shinoda and A. V. Ortega, "Simulation of the DNP3 protocol over TCP/IP on a network IEEE 802.11g ad-hoc with smart meter," 2016 IEEE ANDESCON, Arequipa, October 19-2, 2016, pp. 1-4.

[50] J.C.C. Zecena and V.L.O. Molina, “Hydra-A DNP3 multiplexing platform for SCADA system switchover”, IEEE 24th International Conference on Electronics, Electrical Engineering and Computing, Cusco, Peru, Aug. 15-18, 2017, pp. 1-4.

[51] A.S. Sethi and V.Y. Hnatyshin, “The Practical OPNET User Guide for Computer Network Simulation”, New York, Taylor and Francis Group, LLC, 2019, pp. 1-528. ISBN 9780367380953.

[52] S. Biswas, "Simulation model of beacon enabled 802.15.4 networks with OPNET modeler," 2017 International Electrical Engineering Congress (iEECON), Pattaya, 2017, pp. 1-4.

[53] F. Fang, D.H. WANG, X.H. XUAN, J.H. XIE, and Q. Chen. “Application research of hmac in intelligent substation communication security,”2018 International Conference on Electrical, Control, Automation and Robotics (ECAR), Xiamen, China, September 16-17, 2018 pp. 261-264.

[54] W. Yue, Z. Xu and Z. Dapeng, "A High-reliability Network Architecture Based on Parallel Redundancy Protocol," 2019 14th International Conference on Computer Science & Education (ICCSE), Toronto, ON, Canada, August 19-21, 2019, pp. 43-46.

[55] N. Das, W. Ma and S. Islam, "Comparison study of various factors affecting end-to-end delay in IEC 61850 substation communications using OPNET," 2012 22nd

Australasian Universities Power Engineering Conference (AUPEC), Bali, Indonesia, September 26-29, 2012, pp. 1-5.

[56] D. Maraj and A. Maraj, "Performance analysis of WLAN 802.11g/n standards using OPNET (Riverbed) application," 2015 57th International Symposium ELMAR (ELMAR), Zadar, Croatia, September 28-30, 2015, pp. 129-132.

[57] D. Njova, K. Ogudo and P. Umenne, "Packet Analysis of DNP3 protocol over TCP/IP at an Electrical Substation Grid modelled in OPNET," 2020 IEEE PES/IAS PowerAfrica, Nairobi, Kenya, August 25-28, 2020, pp. 683-687.

[58] G. Clarke, D. Reynders and E. Wright, “Practical Modern SCADA Protocols: DNP3, 60870.5 and Related Systems”, IDC Technologies, England, 2004. PP.166-168.

[59] S. Kwon, H. Yoo and T. Shon, "RNN-based Anomaly Detection in DNP3 Transport Layer," 2019 IEEE International Conference on Communications, Control, and Computing Technologies for Smart Grids (SmartGridComm), Beijing, China, October 21-24, 2019, pp. 1-7.

[60] M. Marian, A. Cusman, F. Stîngă, D. Ionică and D. Popescu, "Experimenting With Digital Signatures Over a DNP3 Protocol in a Multitenant Cloud-Based SCADA Architecture," in IEEE Access, vol. 8, pp. 156484-156503, 2020.

[61] D. Njova, K. Ogudo and P. Umenne, “Analysis of the IEC 61850 protocol when used for communication during maintenance operation in an electrical substation grid” ICONIC '20: Proceedings of the 2nd International Conference on Intelligent and Innovative Computing Applications September 2020 Article No.: 45 Pages 335 -341.

[62] T. Amare, C. M. Adrah and B. E. Helvik, "A Method for Performability Study on Wide Area Communication Architectures for Smart Grid", 7th International Conference on Smart Grid (icSmartGrid), Newcastle, Australia, December 9-11, 2019, pp. 64-73.

[63] J. Hong, R. Karnati, C. -W. Ten, S. Lee and S. Choi, "Implementation of Secure Sampled Value (SeSV) Messages in Substation Automation System," in IEEE Transactions on Power Delivery, Early acess, Februay, 2021, pp. 1-9.

[64] P. Rajagopal and S. Sayapogu, "Effective utilization of SCADA for substation protection and control applications," 13th International Conference on Development in Power System Protection (DPSP), Edinburgh, England, March 7-10, 2016, pp. 1-5.

[65] H. Purwanto, H. Prasetia and I. Firdaus, "Implementation of Over Current Relays with Non-Cascade Scheme on Medium Voltage Switchgear as Busbar Protection Study Case in PT PLN (Persero) UIT JBB," 2nd International Conference on High Voltage Engineering and Power Systems (ICHVEPS), Denpasar, Bali, Indonesia, October 1-4, 2019, pp. 1-4.

[66] D. P. d. Mattos et al., "IEC 61850 Packet Generator for Testing Substation Communication", IEEE PES Asia-Pacific Power and Energy Engineering Conference (APPEEC), Macao, Macao, December 1-4, 2019, pp. 1-5.

[67] S. M. S. Hussain, M. A. Aftab, F. Nadeem, I. Ali and T. S. Ustun, "Optimal Energy Routing in Microgrids With IEC 61850 Based Energy Routers", in IEEE Transactions on Industrial Electronics, vol. 67, no. 6, pp. 5161-5169, June 2020.

[68] R. Loenders, D. Van Hertem, J. Beerten, G. Chaffey and L. Yang, "Testing reliability performance of IEC61850-based digital substations," 15th International Conference on Developments in Power System Protection (DPSP 2020),liverpool, England, March 9-12, 2020, pp. 1-7.

APPENDICES

Appendix A DNP3 XML

10 Percent Online Devices

<?xml version="1.0"?>
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50 Percent Online Devices

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value="Disabled" name="IMEP Route Injection"/><promoted-attribute value="Specify..." name="TORA Animated Destination RID"/><promoted-attribute value="10" name="TORA IMEP Animation Refresh Interval"/><promoted-attribute value="Disabled" name="TORA IMEP Efficiency"/><promoted-attribute value="100" name="TORA IMEP Packet Delivery Cache Update"/><promoted-attribute value="Disabled" name="TORA Infinite Loop Prevention"/><promoted-attribute value="1150" name="TORA Max Communication Distance"/><promoted-attribute value="Default" name="TORA Mode of Operation"/><promoted-attribute value="Do Not Export Reports" name="H323 Call Reports"/><promoted-attribute value="End of Simulation" name="H323 Reporting End Time"/><promoted-attribute value="Beginning of Simulation" name="H323 Reporting Start Time"/><promoted-attribute value="CS6" name="IGMP Message DSCP"/><promoted-attribute value="CS6" name="PIM Message DSCP"/><promoted-attribute value="Default" name="IP Dynamic Routing Protocol"/><promoted-attribute value="Auto Addressed" name="IP Interface Addressing Mode"/><promoted-attribute value="Not Used" name="IP Routing Table Export/Import"/><promoted-attribute value="Flow Analysis" name="IP Routing Table Source"/><promoted-attribute value="IPv6" name="IP Version Preference"/><promoted-attribute value="Consider" name="IPv6 Configuration"/><promoted-attribute value="Disabled" name="IPv6 Interface Address Export"/><promoted-attribute value="0.8" name="Interface Buffer Congestion Threshold"/><promoted-attribute value="20" name="Routing Activity Idle Timer"/><promoted-attribute value="RSVP" name="LSP Signaling Protocol"/><promoted-attribute value="CS6" name="RIP Message DSCP"/><promoted-attribute value="Auto" name="TCP Real Payload Support"/></promoted-attribute-list><selected-run-list><selected-run id="0"/></selected-run-list><traffic-trend growth-rate="10" method="regular-simple" import-options="nothing" storage-method="each-simulation" time-gap="1.0" units="month" count="1"/></simset></simset-list></simulation-sequence>

During 400kV Transformer Maintenance

<?xml version="1.0"?>
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name="IPv6 Configuration"/><promoted-attribute value="Disabled" name="IPv6 Interface Address Export"/><promoted-attribute value="0.8" name="Interface Buffer Congestion Threshold"/><promoted-attribute value="20" name="Routing Activity Idle Timer"/><promoted-attribute value="RSVP" name="LSP Signaling Protocol"/><promoted-attribute value="CS6" name="RIP Message DSCP"/><promoted-attribute value="Auto" name="TCP Real Payload Support"/></promoted-attribute-list><selected-run-list><selected-run id="0"/></selected-run-list><traffic-trend growth-rate="10" method="regular-simple" import-options="nothing" storage-method="each-simulation" time-gap="1.0" units="month" count="1"/></simset></simset-list></simulation-sequence>

Appendix B IEC61850 XML

Buszone Operation

<?xml version="1.0"?>
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value="conservative" type="enumerated" name="packet sharing"/><attribute value="1" type="toggle" name="generate packet info report"/></simset-attributes><promoted-attribute-list><promoted-attribute value="Enabled" name="ARP Sim Efficiency"/><promoted-attribute value="Enabled" name="IGMP Sim Efficiency"/><promoted-attribute value="Disabled" name="IPv6 ND Simulation Efficiency"/><promoted-attribute value="Enabled" name="LACP Simulation Efficiency"/><promoted-attribute value="Enabled" name="PIM-SM Sim Efficiency"/><promoted-attribute value="Enabled" name="RIP Sim Efficiency"/><promoted-attribute value="65" name="RIP Stop Time"/><promoted-attribute value="Enabled" name="RIPng Sim Efficiency"/><promoted-attribute value="65" name="RIPng Stop Time"/><promoted-attribute value="Enabled" name="Switch Sim Efficiency"/><promoted-attribute value="<Primary Model Directory>" name="Application Tracking Directory"/><promoted-attribute value="Do Not Export" name="Custom Application 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Normal Operation

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Maintenance

<?xml version="1.0"?>
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name="packet sharing"/><attribute value="1" type="toggle" name="generate packet info report"/></simset-attributes><promoted-attribute-list><promoted-attribute value="Enabled" name="ARP Sim Efficiency"/><promoted-attribute value="Enabled" name="IGMP Sim Efficiency"/><promoted-attribute value="Disabled" name="IPv6 ND Simulation Efficiency"/><promoted-attribute value="Enabled" name="LACP Simulation Efficiency"/><promoted-attribute value="Enabled" name="PIM-SM Sim Efficiency"/><promoted-attribute value="Enabled" name="RIP Sim Efficiency"/><promoted-attribute value="65" name="RIP Stop Time"/><promoted-attribute value="Enabled" name="RIPng Sim Efficiency"/><promoted-attribute value="65" name="RIPng Stop Time"/><promoted-attribute value="Enabled" name="Switch Sim Efficiency"/><promoted-attribute value="<Primary Model Directory>" name="Application Tracking Directory"/><promoted-attribute value="Do Not Export" name="Custom Application Tracing"/><promoted-attribute value="Disabled" name="GNA API Safe Mode"/><promoted-attribute value="Disabled" name="RTP API Safe Mode"/><promoted-attribute value="1" name="Background Traffic Start Delay"/><promoted-attribute value="Enabled" name="Hybrid Simulation Efficiency"/><promoted-attribute value="Disabled" name="Link Usage Report"/><promoted-attribute value="Enabled" name="Tracer Packet Redundancy"/><promoted-attribute value="2" name="Tracer Packets Per Interval"/><promoted-attribute value="1.0" name="Traffic Scaling Factor"/><promoted-attribute value="Background Traffic" name="Traffic Scaling Mode"/><promoted-attribute value="Do Not Include" name="Traffic from LSP Loads"/><promoted-attribute value="Include" name="Traffic from Link Loads"/><promoted-attribute value="Include" name="Traffic from Traffic Flows"/><promoted-attribute value="Do Not Include" name="Traffic from VC Loads"/><promoted-attribute value="Disabled" name="DHCP Logging"/><promoted-attribute value="Enabled" name="DSR Record Routes"/><promoted-attribute value="Disabled" 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Support"/></promoted-attribute-list><attr-info-list><attr-info type="toggle" name="ARP Sim Efficiency"><value value="0"/></attr-info><attr-info type="string" name="Application Tracking Directory"><value value=""/></attr-info><attr-info type="double" name="Background Traffic Start Delay"><value value="0.0"/></attr-info><attr-info type="integer" name="Custom Application Tracing"><value value="0"/></attr-info><attr-info type="toggle" name="DHCP Logging"><value value="0"/></attr-info><attr-info type="toggle" name="DSR Record Routes"><value value="0"/></attr-info><attr-info type="toggle" name="DSR Routes Export"><value value="0"/></attr-info><attr-info type="integer" name="GNA API Safe Mode"><value value="0"/></attr-info><attr-info type="double" name="GRP Quadrant Size"><value value="0.0"/></attr-info><attr-info type="toggle" name="GRP Record

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IEC 61850 Fault Backbone Switch XML

<?xml version="1.0"?>
<simulation-sequence base-id="1"><OPNET-info OPNET-model-data-version="17.5.B" OPNET-patchlevel="7" OPNET-release="17.5.A"/><simset-list><simset anim-enabled="no" id="0"><simset-attributes><attribute value="scenario" type="string" name="name"/><attribute value="IEC61850-Faulty Backbone switch 1 with Traffic" type="typed file" name="network" spectype="4"/><attribute value="IEC61850-Faulty Backbone switch 1 with Traffic" type="typed file" name="probe file" spectype="27"/><attribute value="IEC61850-Faulty Backbone switch 1 with Traffic" type="string" name="vector file" spectype="29"/><attribute value="120" type="double" name="duration"/><attribute value="IEC61850-Faulty Backbone switch 1 with Traffic" type="string" name="anim hist" spectype="40"/><attribute type="textlist" name="SLA probe files"/><attribute type="textlist" name="Report probe files"/><attribute value="seconds" type="string" name="duration units"/><attribute value="1" type="integer" name="number sim processors"/><attribute value="Poptimized" type="string" name="kernel_type"/><attribute value="conservative" type="enumerated" name="packet sharing"/><attribute value="1" type="toggle" name="generate packet info report"/></simset-attributes><promoted-attribute-list><promoted-attribute value="Enabled" name="ARP Sim Efficiency"/><promoted-attribute value="Enabled" name="IGMP Sim Efficiency"/><promoted-attribute value="Disabled" name="IPv6 ND Simulation Efficiency"/><promoted-attribute value="Enabled" name="LACP Simulation Efficiency"/><promoted-attribute value="Enabled" name="PIM-SM Sim Efficiency"/><promoted-attribute value="Enabled" name="RIP Sim Efficiency"/><promoted-attribute value="65" name="RIP Stop Time"/><promoted-attribute value="Enabled" name="RIPng Sim Efficiency"/><promoted-attribute value="65" name="RIPng Stop Time"/><promoted-attribute value="Enabled" name="Switch Sim Efficiency"/><promoted-attribute value="<Primary Model Directory>" name="Application Tracking Directory"/><promoted-attribute value="Do Not Export" name="Custom Application Tracing"/><promoted-attribute value="Disabled" name="GNA API Safe Mode"/><promoted-attribute value="Disabled" name="RTP API Safe Mode"/><promoted-attribute value="1" name="Background Traffic Start Delay"/><promoted-attribute value="Enabled" name="Hybrid Simulation Efficiency"/><promoted-attribute value="Disabled" name="Link Usage Report"/><promoted-attribute value="Enabled" name="Tracer Packet Redundancy"/><promoted-attribute

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value="0.0"/></attr-info><attr-info type="integer" name="Switch Sim Efficiency"><value value="0"/></attr-info><attr-info type="string" name="TCP Real Payload Support"><value value=""/></attr-info><attr-info type="integer" name="TORA Animated Destination RID"><value value="0"/></attr-info><attr-info type="integer" name="TORA IMEP Animation Refresh Interval"><value value="0"/></attr-info><attr-info type="toggle" name="TORA IMEP Efficiency"><value value="0"/></attr-info><attr-info type="double" name="TORA IMEP Packet Delivery Cache Update"><value value="0.0"/></attr-info><attr-info type="toggle" name="TORA Infinite Loop Prevention"><value value="0"/></attr-info><attr-info type="integer" name="TORA Max Communication Distance"><value value="0"/></attr-info><attr-info type="integer" name="TORA Mode of Operation"><value value="0"/></attr-info><attr-info type="integer" name="Tracer Packet Redundancy"><value value="0"/></attr-info><attr-info type="integer" name="Tracer Packets Per Interval"><value value="0"/></attr-info><attr-info type="double" name="Traffic Scaling Factor"><value value="0.0"/></attr-info><attr-info type="integer" name="Traffic Scaling Mode"><value value="0"/></attr-info><attr-info type="toggle" name="Traffic

from_LSP_Loads"><value value="0"/></attr-info><attr-info type="toggle" name="Traffic from Link Loads"><value value="0"/></attr-info><attr-info type="toggle" name="Traffic from Traffic Flows"><value value="0"/></attr-info><attr-info type="toggle" name="Traffic from VC Loads"><value value="0"/></attr-info></attr-info-list><selected-run-list><selected-run id="0"/></selected-run-list><traffic-trend growth-rate="10" method="regular-simple" import-options="nothing" storage-method="each-simulation" time-gap="1.0" units="month" count="1"/></simset></simset-list></simulation-sequence>

Appendix C DNP3 Script

10 PERCENT ONLINE	
Static Environment Attribute Confirmations	**Traffic Script**
----------Name---------- --Source--- ------Value- ef cmd line "DNP3-10 Percent Online Devices-DES-1" force_posix_locale default TRUE handle_exception default TRUE handle_exception_extended default TRUE mem_clear default 0 mem_opt.compact_pools default TRUE mem_opt.pool_small_blocks default TRUE mem_opt.grow_pool_planks default TRUE mem_optimize default TRUE mem_shred default FALSE tfile_dir_cache_file default opnet_dir_cache tfile_dir_cache default use noprompt cmd line TRUE opnet_dir env. file "C:\\Program Files\\Riverbed EDU" opnet_user_home shell var C:\Users\Ngonini preferences_default_save_location env. file Local verbose_session_log default FALSE java_prog config file "C:\\Program Files\\Riverbed EDU\\17.5.A\\jre7_modeler_ae\\JRE\\bin\\java.exe" java_prog64 default java 3dnv default FALSE 3dnv.cleanup_at_the_end default TRUE 3dnv.fed_file_name default <null> 3dnv.federation_name default OPNET_3DNV 3dnv.history_file default <null> 3dnv.hla_standard default "DOD 1.3" 3dnv.initialization_delay default 1 3dnv.mapping_argument default <null> 3dnv.mapping_library default opnet_3dnv_default_mapping 3dnv.max_request_rate default 0 3dnv.rpr_fom_version default 1 anim_attempts default 5 anim_hist default <null> anim_host default localhost anim_port default 0 anim_timeout default 3 anim_view env. file FALSE antenna.spherical_model default Mathematical attr_reqs_file default <null> auto_disk_space_threshold default 1000 automation_lock_max_wait_time default 60 beep_count_confirm default 1 beep_count_error default 2 bind_shobj_flags default <null> bind_shobj_flags_32bit default <null> bind_shobj_flags_64bit default <null> bind_shobj_flags_devel default /DEBUG bind_shobj_flags_optim default <null> bind_shobj_libs default <null> bind_shobj_libs_32bit default <null>	"_locale":"C "anim_view": "false" "Application Tracking Directory": "<Primary Model Directory>" "ARP Sim Efficiency": "Enabled" "Background Traffic Start Delay": "150" "comp_trace_info": "kernel-based" "Custom Application Tracing": "Do Not Export" "default_site_position_cache_time_granularity": "0.0" "des.log_severity_filter": "-1" "DHCP Logging": "Disabled" "DSR Record Routes": "Enabled" "DSR Routes Export": "Disabled" "duration": "150.0" "GNA API Safe Mode": "Disabled" "GRP Quadrant Size": "2000" "GRP Record Routes": "Disabled" "GRP Routes Export": "Disabled" "H323 Call Reports": "Do Not Export Reports" "H323 Reporting End Time": "End of Simulation" "H323 Reporting Start Time": "Beginning of Simulation" "Hybrid Simulation Efficiency": "Enabled" "IGMP Message DSCP": "CS6" "IGMP Sim Efficiency": "Enabled" "IMEP Route Injection": "Disabled" "Interface Buffer Congestion Threshold": "0.8" "IP Dynamic Routing Protocol": "Default" "IP Interface Addressing Mode": "Auto Addressed" "IP Routing Table Export/Import": "Not Used" "IP Routing Table Source": "Flow Analysis" "IP Version Preference": "IPv6" "IPv6 Configuration": "Consider" "IPv6 Interface Address Export": "Disabled" "IPv6 ND Simulation Efficiency": "Disabled" "LACP Simulation Efficiency": "Enabled" "Link Usage Report": "Disabled" "log_endsim_perf": "true" "log_file": "DNP3-10 Percent Online Devices-DES-1" "LSP Signaling Protocol": "RSVP" "max_log_entries": "200" "num_collect_values": "100" "ot_file": "DNP3-10 Percent Online Devices-DES-1" "ov_file":"DNP3-10 Percent Online Devices-DES-1" "parallel_sim.event_execution_time_window": "0.0" "parallel_sim.mem_balance_interval": "100,000" "parallel_sim.num_processors": "1" "PIM Message DSCP": "CS6" "PIM-SM Sim Efficiency": "Enabled" "probe": "DNP3-10 Percent Online Devices" "realtime_ratio": "0.0" "RIP Message DSCP": "CS6" "RIP Sim Efficiency": "Enabled"

```
bind_shobj_libs_64bit                    default    <null>
bind_shobj_libs_devel                    default    <null>
bind_shobj_libs_optim                    default    <null>
bind_shobj_prog                          default    bind_so_msvc
check_newer_process_model_files          default    TRUE
comp.no_fin_required_for_state_vars      default    FALSE
comp_flags_32bit                         default    <null>
comp_flags_64bit                         default    /GS-
comp_flags_c++_specific                  default    <null>
comp_flags_c_specific                    default    <null>
comp_flags_common                                   env. file    "/W3
/D_CRT_SECURE_NO_DEPRECATE
/IC:\\PROGRA~1\\RIVERB~1\\175~1.A\\models\\std\\include"
comp_flags_devel                         default    "/Z7 /Od"
comp_flags_mt                            default    <null>
comp_flags_optim                         default    "/Ox /Ob2
/DOPD_NO_DEBUG /DOPD_INLINE_KPS"
comp_globals_export                      default    FALSE
comp_object_files_without_source                    default
allow_with_warning
comp_per_process_errors                  default    TRUE
comp_prog                                default    comp_msvc
comp_prog_cpp                            default    comp_msvc
comp_trace_info                          env. file  kernel-based
console_exit_pause                       default    FALSE
cosim                                    default    <null>
cosimulation_optimization_mode           default    none
debug_mk                                 default    FALSE
default_site_position_cache_time_granularity env. file  0
des.log_severity_filter                  env. file  -1
diag_enable                              default    FALSE
display_timezone_string                  default    FALSE
duration                                 env. file  150
edit_lock_mode                           default    FALSE
endsim_memstats                          default    FALSE
etrace_diff                              default    <null>
etrace_dump                              default    <null>
etrace_end_time                          default    1e+100
etrace_start_time                        default    0
event_order_method                       default    strict
event_speed_parameter                    default    100000
file_read_abort_suppress                 default    FALSE
format_event_ids_with_1000s_separator    default    TRUE
format_ici_ids_with_1000s_separator      default    TRUE
format_object_ids_with_1000s_separator   default    TRUE
format_packet_ids_with_1000s_separator   default    TRUE
format_process_ids_with_1000s_separator  default    TRUE
fully_serialized_event_execution_ids     default    TRUE
fully_serialized_ici_ids                 default    TRUE
fully_serialized_packet_ids              default    TRUE
geocentric_model                         default    right_sphere
invalid_link_notification                default    TRUE
kernel_type                              env. file  optimized
license_broker_host                      default    <null>
license_broker_port                      default    <null>
license_expiration_warning_interval      default    3
license_group                            default    <null>
license_http_proxy_password              default    <not set>
license_http_proxy_port                  default    80
license_http_proxy_server                default    <null>
license_http_proxy_user                  default    <null>
license_http_server                      default    license01.opnet.com
license_http_use_proxy                   default    FALSE
license_password                         default    <not set>
license_port                             default    port_a
license_server                           default    localhost
license_server_standalone                default    FALSE
```

```
"RIP Stop Time":    "65"
"RIPng Sim Efficiency":        "Enabled"
"RIPng Stop Time":             "65"
"Routing Activity Idle Timer":             "20"
"RTP API Safe Mode":           "Disabled"
"seed":    "128"
"sim_packet_sharing":          "conservative"
"sim_time_quantum":            "0.0"
"site_position_cache_size":    "3"
"Switch Sim Efficiency":       "Enabled"
"TCP Real Payload Support":"Auto"
"tmm_simulate":     "false"
"TORA Animated Destination RID":     "Specify..."
"TORA IMEP Animation Refresh Interval":        "10"
"TORA IMEP Efficiency":     "Disabled"
"TORA IMEP Packet Delivery Cache Update":
          "100"
"TORA Infinite Loop Prevention":        "Disabled"
"TORA Max Communication Distance":
          "1150"
"TORA Mode of Operation": "Default"
"Tracer Packet Redundancy":"Enabled"
"Tracer Packets Per Interval":"2"
"Traffic from Link Loads":     "Include"
"Traffic from LSP Loads":      "Do Not Include"
"Traffic from Traffic Flows": "Include"
"Traffic from VC Loads":       "Do Not Include"
"Traffic Scaling Factor":      "1.0"
"Traffic Scaling Mode":        "Background Traffic"
"update_interval":   "500,000"
"verbose_cell_size_report":    "false"
"verbose_event_report":        "false"
"verbose_event_timing_report":             "false"
"verbose_load":      "true"
"verbose_packet_report":       "true"
"verbose_parallel_speedup_report":       "false"
"verbose_sim":       "true"
```

license_server_standalone_diagnose default FALSE license_username default <null> livelock_thresh default 8192 log_endsim_perf env. file TRUE log_file env. file "DNP3-10 Percent Online Devices-DES-1" log_time_precision default 12 manage_loanable_licenses default FALSE max_idle_time_microseconds default 1 max_log_entries env. file 200 memstat_autogen default <null> mtn_warn_int default 3 named_locks default FALSE net_name cmd line "DNP3-10 Percent Online Devices" num_collect_values env. file 100 num_err default 10 ot_file env. file "DNP3-10 Percent Online Devices-DES-1" ot_file.default_format default write_many ot_mem_size default 4 ov_autogen default <null> ov_diff_tolerance default 5 ov_file env. file "DNP3-10 Percent Online Devices-DES-1" ov_mem_size default 16 parallel_sim.event_execution_time_window env. file 0 parallel_sim.mutex_rank_ignore default FALSE per_module_random_stream default FALSE probe env. file "DNP3-10 Percent Online Devices" probe_error_enable default FALSE probe_start_time default -1 probe_stop_time default -1 prof_output default console prof_output_separator default <null> prof_track_func default <null> prof_track_recurse default TRUE psnone_tda.bu.closure.closure default TRUE psnone_tda.bu.collision.num_colls default 0 psnone_tda.bu.ecc.pk_accept default TRUE psnone_tda.bu.error.num_errors default 0 psnone_tda.bu.propdel.prop_delay default 0 psnone_tda.bu.txdel.tx_delay default 0 psnone_tda.pt.ecc.pk_accept default TRUE psnone_tda.pt.error.num_errors default 0 psnone_tda.pt.propdel.prop_delay default 0 psnone_tda.pt.txdel.tx_delay default 0 psnone_tda.ra.ber.ber default 0 psnone_tda.ra.bkgnoise.bkgnoise default 0 psnone_tda.ra.chanmatch.match_status default valid psnone_tda.ra.closure.closure default TRUE psnone_tda.ra.ecc.pk_accept default TRUE psnone_tda.ra.error.actual_ber default 0 psnone_tda.ra.error.num_errors default 0 psnone_tda.ra.power.rcvd_power default -1 psnone_tda.ra.propdel.end_propdel default 0 psnone_tda.ra.propdel.start_propdel default 0 psnone_tda.ra.ragain.rx_gain default 0 psnone_tda.ra.snr.snr default 1000 psnone_tda.ra.tagain.tx_gain default 0 psnone_tda.ra.txdel.tx_delay default 0 radio_transmission_defer_packet_duplication default TRUE radio_transmission_on_demand_receiver_groups default FALSE rand_gen_type default Linear-Congruential rand_num_ext_res default TRUE	

raw_err default FALSE realtime_ratio env. file 0 rec_err_suppress default FALSE record_gstats default FALSE repositories env. file stdmod script_mode default none script_name default odb_script seed env. file 128 sim_packet_sharing env. file conservative sim_process_priority default normal sim_time_quantum env. file 0 site_position_cache_size env. file 3 sitl_realtime_ratio_check default TRUE sla_compute_all_violations default FALSE split_start_radio_transmission default FALSE timezone default "Local Timezone" tmm_data_directory default <obsolete> tmm_data_type default "USGS DEM" tmm_display_degrees default FALSE tmm_include_antenna_height default FALSE tmm_load_as_needed default TRUE tmm_pathloss_cache_size default 2 tmm_prop_model default <null> tmm_prop_param default <null> tmm_propagation_specification default <null> tmm_propagation_zone_ratio default 0 tmm_propagation_zone_resolution default 100 tmm_simulate env. file FALSE tmm_terrain_cache_size default 10 tmm_terrain_specification default <null> tmm_use_cache default TRUE tmm_verbose default FALSE update_interval env. file 500000 updates_in_seconds default FALSE user_lock_devname default <null> verbose_load env. file TRUE verbose_mk default FALSE verbose_sim env. file TRUE warning_suppress default FALSE	

50 PERCENT ONLINE	
Static Environment Attribute Confirmations	**Traffic Script**
----------Name---------- --Source--- ------Value---- ef cmd line "DNP3-50 Percent Online Devices-DES-1" force_posix_locale default TRUE handle_exception default TRUE handle_exception_extended default TRUE mem_clear default 0 mem_opt.compact_pools default TRUE mem_opt.pool_small_blocks default TRUE mem_opt.grow_pool_planks default TRUE mem_optimize default TRUE mem_shred default FALSE tfile_dir_cache_file default opnet_dir_cache tfile_dir_cache default use noprompt cmd line TRUE opnet_dir env. file "C:\\Program Files\\Riverbed EDU" opnet_user_home shell var C:\Users\Ngonini preferences_default_save_location env. file Local verbose_session_log default FALSE	"_locale":"C" "anim_view": "false" "Application Tracking Directory": "<Primary Model Directory>" "ARP Sim Efficiency": "Enabled" "Background Traffic Start Delay": "150" "comp_trace_info": "kernel-based" "Custom Application Tracing": "Do Not Export" "default_site_position_cache_time_granularity": "0.0" "des.log_severity_filter": "-1" "DHCP Logging": "Disabled" "DSR Record Routes": "Enabled" "DSR Routes Export": "Disabled" "duration": "150.0" "GNA API Safe Mode": "Disabled" "GRP Quadrant Size": "2000" "GRP Record Routes": "Disabled" "GRP Routes Export": "Disabled" "H323 Call Reports": "Do Not Export Reports" "H323 Reporting End Time": "End of Simulation" "H323 Reporting Start Time": "Beginning of Simulation" "Hybrid Simulation Efficiency": "Enabled"

```
java_prog                                   config file "C:\\Program
Files\\Riverbed
EDU\\17.5.A\\jre7_modeler_ae\\JRE\\bin\\java.exe"
java_prog64                                 default     java
3dnv                                        default     FALSE
3dnv.cleanup_at_the_end                     default     TRUE
3dnv.fed_file_name                          default     <null>
3dnv.federation_name                        default     OPNET_3DNV
3dnv.history_file                           default     <null>
3dnv.hla_standard                           default     "DOD 1.3"
3dnv.initialization_delay                   default     1
3dnv.mapping_argument                       default     <null>
3dnv.mapping_library                                    default
opnet_3dnv_default_mapping
3dnv.max_request_rate                       default     0
3dnv.rpr_fom_version                        default     1
anim_attempts                               default     5
anim_hist                                   default     <null>
anim_host                                   default     localhost
anim_port                                   default     0
anim_timeout                                default     3
anim_view                                   env. file   FALSE
antenna.spherical_model                     default     Mathematical
attr_reqs_file                              default     <null>
auto_disk_space_threshold                   default     1000
automation_lock_max_wait_time               default     60
beep_count_confirm                          default     1
beep_count_error                            default     2
bind_shobj_flags                            default     <null>
bind_shobj_flags_32bit                      default     <null>
bind_shobj_flags_64bit                      default     <null>
bind_shobj_flags_devel                      default     /DEBUG
bind_shobj_flags_optim                      default     <null>
bind_shobj_libs                             default     <null>
bind_shobj_libs_32bit                       default     <null>
bind_shobj_libs_64bit                       default     <null>
bind_shobj_libs_devel                       default     <null>
bind_shobj_libs_optim                       default     <null>
bind_shobj_prog                             default     bind_so_msvc
check_newer_process_model_files             default     TRUE
comp.no_fin_required_for_state_vars         default     FALSE
comp_flags_32bit                            default     <null>
comp_flags_64bit                            default     /GS-
comp_flags_c++_specific                     default     <null>
comp_flags_c_specific                       default     <null>
comp_flags_common                                       env. file   "/W3
/D_CRT_SECURE_NO_DEPRECATE
/IC:\\PROGRA~1\\RIVERB~1\\175~1.A\\models\\std\\include"
comp_flags_devel                            default     "/Z7 /Od"
comp_flags_mt                               default     <null>
comp_flags_optim                                        default     "/Ox /Ob2
/DOPD_NO_DEBUG /DOPD_INLINE_KPS"
comp_globals_export                         default     FALSE
comp_object_files_without_source                        default
allow_with_warning
comp_per_process_errors                     default     TRUE
comp_prog                                   default     comp_msvc
comp_prog_cpp                               default     comp_msvc
comp_trace_info                             env. file   kernel-based
console_exit_pause                          default     FALSE
cosim                                       default     <null>
cosimulation_optimization_mode              default     none
debug_mk                                    default     FALSE
default_site_position_cache_time_granularity env. file  0
des.log_severity_filter                     env. file   -1
diag_enable                                 default     FALSE
display_timezone_string                     default     FALSE
```

```
"IGMP Message DSCP":        "CS6"
"IGMP Sim Efficiency":      "Enabled"
"IMEP Route Injection":     "Disabled"
"Interface Buffer Congestion Threshold":        "0.8"
"IP Dynamic Routing Protocol":      "Default"
"IP Interface Addressing Mode":     "Auto
Addressed"
"IP Routing Table Export/Import":   "Not Used"
"IP Routing Table Source":  "Flow Analysis"
"IP Version Preference":    "IPv6"
"IPv6 Configuration":       "Consider"
"IPv6 Interface Address Export":    "Disabled"
"IPv6 ND Simulation Efficiency":    "Disabled"
"LACP Simulation Efficiency":       "Enabled"
"Link Usage Report":        "Disabled"
"log_endsim_perf": "true"
"log_file":         "DNP3-50    Percent    Online
Devices-DES-1"
"LSP Signaling Protocol":   "RSVP"
"max_log_entries": "200"
"num_collect_values":       "100"
"ot_file": "DNP3-50 Percent Online Devices-DES-1"
"ov_file":"DNP3-50 Percent Online Devices-DES-1"
"parallel_sim.event_execution_time_window":    "0.0"
"parallel_sim.mem_balance_interval":   "100,000"
"parallel_sim.num_processors":      "1"
"PIM Message DSCP":         "CS6"
"PIM-SM Sim Efficiency":    "Enabled"
"probe":  "DNP3-50 Percent Online Devices"
"realtime_ratio":    "0.0"
"RIP Message DSCP":         "CS6"
"RIP Sim Efficiency":       "Enabled"
"RIP Stop Time":   "65"
"RIPng Sim Efficiency":     "Enabled"
"RIPng Stop Time":          "65"
"Routing Activity Idle Timer":          "20"
"RTP API Safe Mode":        "Disabled"
"seed":    "128"
"sim_packet_sharing":       "conservative"
"sim_time_quantum":         "0.0"
"site_position_cache_size":    "3"
"Switch Sim Efficiency":    "Enabled"
"TCP Real Payload Support":"Auto"
"tmm_simulate":    "false"
"TORA Animated Destination RID":    "Specify..."
"TORA IMEP Animation Refresh Interval":     "10"
"TORA IMEP Efficiency":     "Disabled"
"TORA IMEP Packet Delivery Cache Update":
        "100"
"TORA Infinite Loop Prevention":    "Disabled"
"TORA Max Communication Distance":
        "1150"
"TORA Mode of Operation": "Default"
"Tracer Packet Redundancy": "Enabled"
"Tracer Packets Per Interval":"2"
"Traffic from Link Loads":    "Include"
"Traffic from LSP Loads":    "Do Not Include"
"Traffic from Traffic Flows": "Include"
"Traffic from VC Loads":    "Do Not Include"
"Traffic Scaling Factor":    "1.0"
"Traffic Scaling Mode":     "Background Traffic"
"update_interval":  "500,000"
"verbose_cell_size_report":    "false"
"verbose_event_report":     "false"
"verbose_event_timing_report":      "false"
"verbose_load":     "true"
"verbose_packet_report":    "true"
```

```
duration                                  env. file   150
edit_lock_mode                            default     FALSE
endsim_memstats                           default     FALSE
etrace_diff                               default     <null>
etrace_dump                               default     <null>
etrace_end_time                           default     1e+100
etrace_start_time                         default     0
event_order_method                        default     strict
event_speed_parameter                     default     100000
file_read_abort_suppress                  default     FALSE
format_event_ids_with_1000s_separator     default     TRUE
format_ici_ids_with_1000s_separator       default     TRUE
format_object_ids_with_1000s_separator    default     TRUE
format_packet_ids_with_1000s_separator    default     TRUE
format_process_ids_with_1000s_separator   default     TRUE
fully_serialized_event_execution_ids      default     TRUE
fully_serialized_ici_ids                  default     TRUE
fully_serialized_packet_ids               default     TRUE
geocentric_model                          default     right_sphere
invalid_link_notification                 default     TRUE
kernel_type                               env. file   optimized
license_broker_host                       default     <null>
license_broker_port                       default     <null>
license_expiration_warning_interval       default     3
license_group                             default     <null>
license_http_proxy_password               default     <not set>
license_http_proxy_port                   default     80
license_http_proxy_server                 default     <null>
license_http_proxy_user                   default     <null>
license_http_server                       default     license01.opnet.com
license_http_use_proxy                    default     FALSE
license_password                          default     <not set>
license_port                              default     port_a
license_server                            default     localhost
license_server_standalone                 default     FALSE
license_server_standalone_diagnose        default     FALSE
license_username                          default     <null>
livelock_thresh                           default     8192
log_endsim_perf                           env. file   TRUE
log_file                                  env. file   "DNP3-50 Percent
Online Devices-DES-1"
log_time_precision                        default     12
manage_loanable_licenses                  default     FALSE
max_idle_time_microseconds                default     1
max_log_entries                           env. file   200
memstat_autogen                           default     <null>
mtn_warn_int                              default     3
named_locks                               default     FALSE
net_name                                  cmd line    "DNP3-50 Percent
Online Devices"
num_collect_values                        env. file   100
num_err                                   default     10
ot_file                                   env. file   "DNP3-50 Percent Online
Devices-DES-1"
ot_file.default_format                    default     write_many
ot_mem_size                               default     4
ov_autogen                                default     <null>
ov_diff_tolerance                         default     5
ov_file                                   env. file   "DNP3-50 Percent
Online Devices-DES-1"
ov_mem_size                               default     16
parallel_sim.event_execution_time_window  env. file   0
parallel_sim.mutex_rank_ignore            default     FALSE
per_module_random_stream                  default     FALSE
probe                                     env. file   "DNP3-50 Percent
Online Devices"
probe_error_enable                        default     FALSE
```

```
"verbose_parallel_speedup_report":      "false"
"verbose_sim":      "true"
```

```
probe_start_time                        default    -1
probe_stop_time                         default    -1
prof_output                             default    console
prof_output_separator                   default    <null>
prof_track_func                         default    <null>
prof_track_recurse                      default    TRUE
psnone_tda.bu.closure.closure           default    TRUE
psnone_tda.bu.collision.num_colls       default    0
psnone_tda.bu.ecc.pk_accept             default    TRUE
psnone_tda.bu.error.num_errors          default    0
psnone_tda.bu.propdel.prop_delay        default    0
psnone_tda.bu.txdel.tx_delay            default    0
psnone_tda.pt.ecc.pk_accept             default    TRUE
psnone_tda.pt.error.num_errors          default    0
psnone_tda.pt.propdel.prop_delay        default    0
psnone_tda.pt.txdel.tx_delay            default    0
psnone_tda.ra.ber.ber                   default    0
psnone_tda.ra.bkgnoise.bkgnoise         default    0
psnone_tda.ra.chanmatch.match_status    default    valid
psnone_tda.ra.closure.closure           default    TRUE
psnone_tda.ra.ecc.pk_accept             default    TRUE
psnone_tda.ra.error.actual_ber          default    0
psnone_tda.ra.error.num_errors          default    0
psnone_tda.ra.power.rcvd_power          default    -1
psnone_tda.ra.propdel.end_propdel       default    0
psnone_tda.ra.propdel.start_propdel     default    0
psnone_tda.ra.ragain.rx_gain            default    0
psnone_tda.ra.snr.snr                   default    1000
psnone_tda.ra.tagain.tx_gain            default    0
psnone_tda.ra.txdel.tx_delay            default    0
radio_transmission_defer_packet_duplication  default    TRUE
radio_transmission_on_demand_receiver_groups  default
FALSE
rand_gen_type                           default    Linear-Congruential
rand_num_ext_res                        default    TRUE
raw_err                                 default    FALSE
realtime_ratio                          env. file  0
rec_err_suppress                        default    FALSE
record_gstats                           default    FALSE
repositories                            env. file  stdmod
script_mode                             default    none
script_name                             default    odb_script
seed                                    env. file  128
sim_packet_sharing                      env. file  conservative
sim_process_priority                    default    normal
sim_time_quantum                        env. file  0
site_position_cache_size                env. file  3
sitl_realtime_ratio_check               default    TRUE
sla_compute_all_violations              default    FALSE
split_start_radio_transmission          default    FALSE
timezone                                default    "Local Timezone"
tmm_data_directory                      default    <obsolete>
tmm_data_type                           default    "USGS DEM"
tmm_display_degrees                     default    FALSE
tmm_include_antenna_height              default    FALSE
tmm_load_as_needed                      default    TRUE
tmm_pathloss_cache_size                 default    2
tmm_prop_model                          default    <null>
tmm_prop_param                          default    <null>
tmm_propagation_specification           default    <null>
tmm_propagation_zone_ratio              default    0
tmm_propagation_zone_resolution         default    100
tmm_simulate                            env. file  FALSE
tmm_terrain_cache_size                  default    10
tmm_terrain_specification               default    <null>
tmm_use_cache                           default    TRUE
tmm_verbose                             default    FALSE
```

update_interval env. file 500000 updates_in_seconds default FALSE user_lock_devname default <null> verbose_load env. file TRUE verbose_mk default FALSE verbose_sim env. file TRUE warning_suppress default FALSE	

90 PERCENT ONLINE	
Static Environment Attribute Confirmations	**Traffic Script**
----------Name---------- --Source--- ------Value---- ef cmd line "DNP3-90 Percent Online Devices-DES-1" force_posix_locale default TRUE handle_exception default TRUE handle_exception_extended default TRUE mem_clear default 0 mem_opt.compact_pools default TRUE mem_opt.pool_small_blocks default TRUE mem_opt.grow_pool_planks default TRUE mem_optimize default TRUE mem_shred default FALSE n" tfile_dir_cache_file default opnet_dir_cache tfile_dir_cache default use noprompt cmd line TRUE opnet_dir env. file "C:\\Program Files\\Riverbed EDU" opnet_user_home shell var C:\Users\Ngonini preferences_default_save_location env. file Local verbose_session_log default FALSE java_prog config file "C:\\Program Files\\Riverbed EDU\\17.5.A\\jre7_modeler_ae\\JRE\\bin\\java.exe" java_prog64 default java 3dnv default FALSE 3dnv.cleanup_at_the_end default TRUE 3dnv.fed_file_name default <null> 3dnv.federation_name default OPNET_3DNV 3dnv.history_file default <null> 3dnv.hla_standard default "DOD 1.3" 3dnv.initialization_delay default 1 3dnv.mapping_argument default <null> 3dnv.mapping_library default opnet_3dnv_default_mapping 3dnv.max_request_rate default 0 3dnv.rpr_fom_version default 1 anim_attempts default 5 anim_hist default <null> anim_host default localhost anim_port default 0 anim_timeout default 3 anim_view env. file FALSE antenna.spherical_model default Mathematical attr_reqs_file default <null> auto_disk_space_threshold default 1000 automation_lock_max_wait_time default 60 beep_count_confirm default 1 beep_count_error default 2 bind_shobj_flags default <null> bind_shobj_flags_32bit default <null> bind_shobj_flags_64bit default <null>	"_locale":"C" "anim_view": "false" "Application Tracking Directory": "<Primary Model Directory>" "ARP Sim Efficiency": "Enabled" "Background Traffic Start Delay": "150" "comp_trace_info": "kernel-based" "Custom Application Tracing": "Do Not Export" "default_site_position_cache_time_granularity": "0.0" "des.log_severity_filter": "-1" "DHCP Logging": "Disabled" "DSR Record Routes": "Enabled" "DSR Routes Export": "Disabled" "duration": "150.0" "GNA API Safe Mode": "Disabled" "GRP Quadrant Size": "2000" "GRP Record Routes": "Disabled" "GRP Routes Export": "Disabled" "H323 Call Reports": "Do Not Export Reports" "H323 Reporting End Time": "End of Simulation" "H323 Reporting Start Time": "Beginning of Simulation" "Hybrid Simulation Efficiency": "Enabled" "IGMP Message DSCP": "CS6" "IGMP Sim Efficiency": "Enabled" "IMEP Route Injection": "Disabled" "Interface Buffer Congestion Threshold": "0.8" "IP Dynamic Routing Protocol": "Default" "IP Interface Addressing Mode": "Auto Addressed" "IP Routing Table Export/Import": "Not Used" "IP Routing Table Source": "Flow Analysis" "IP Version Preference": "IPv6" "IPv6 Configuration": "Consider" "IPv6 Interface Address Export": "Disabled" "IPv6 ND Simulation Efficiency": "Disabled" "LACP Simulation Efficiency": "Enabled" "Link Usage Report": "Disabled" "log_endsim_perf": "true" "log_file": "DNP3-90 Percent Online Devices-DES-1" "LSP Signaling Protocol": "RSVP" "max_log_entries": "200" "num_collect_values": "100" "ot_file": "DNP3-90 Percent Online Devices-DES-1" "ov_file":"DNP3-90 Percent Online Devices-DES-1" "parallel_sim.event_execution_time_window": "0.0" "parallel_sim.mem_balance_interval": "100,000" "parallel_sim.num_processors": "1" "PIM Message DSCP": "CS6" "PIM-SM Sim Efficiency": "Enabled" "probe": "DNP3-90 Percent Online Devices"

```
bind_shobj_flags_devel                    default    /DEBUG
bind_shobj_flags_optim                    default    <null>
bind_shobj_libs                           default    <null>
bind_shobj_libs_32bit                     default    <null>
bind_shobj_libs_64bit                     default    <null>
bind_shobj_libs_devel                     default    <null>
bind_shobj_libs_optim                     default    <null>
bind_shobj_prog                           default    bind_so_msvc
check_newer_process_model_files           default    TRUE
comp.no_fin_required_for_state_vars       default    FALSE
comp_flags_32bit                          default    <null>
comp_flags_64bit                          default    /GS-
comp_flags_c++_specific                   default    <null>
comp_flags_c_specific                     default    <null>
comp_flags_common                         env. file  "/W3
/D_CRT_SECURE_NO_DEPRECATE
/IC:\\PROGRA~1\\RIVERB~1\\175~1.A\\models\\std\\include"
comp_flags_devel                          default    "/Z7 /Od"
comp_flags_mt                             default    <null>
comp_flags_optim                          default    "/Ox /Ob2
/DOPD_NO_DEBUG /DOPD_INLINE_KPS"
comp_globals_export                       default    FALSE
comp_object_files_without_source                     default
allow_with_warning
comp_per_process_errors                   default    TRUE
comp_prog                                 default    comp_msvc
comp_prog_cpp                             default    comp_msvc
comp_trace_info                           env. file  kernel-based
console_exit_pause                        default    FALSE
cosim                                     default    <null>
cosimulation_optimization_mode            default    none
debug_mk                                  default    FALSE
default_site_position_cache_time_granularity env. file  0
des.log_severity_filter                   env. file  -1
diag_enable                               default    FALSE
display_timezone_string                   default    FALSE
duration                                  env. file  150
edit_lock_mode                            default    FALSE
endsim_memstats                           default    FALSE
etrace_diff                               default    <null>
etrace_dump                               default    <null>
etrace_end_time                           default    1e+100
etrace_start_time                         default    0
event_order_method                        default    strict
event_speed_parameter                     default    100000
file_read_abort_suppress                  default    FALSE
format_event_ids_with_1000s_separator     default    TRUE
format_ici_ids_with_1000s_separator       default    TRUE
format_object_ids_with_1000s_separator    default    TRUE
format_packet_ids_with_1000s_separator    default    TRUE
format_process_ids_with_1000s_separator   default    TRUE
fully_serialized_event_execution_ids      default    TRUE
fully_serialized_ici_ids                  default    TRUE
fully_serialized_packet_ids               default    TRUE
geocentric_model                          default    right_sphere
invalid_link_notification                 default    TRUE
kernel_type                               env. file  optimized
license_broker_host                       default    <null>
license_broker_port                       default    <null>
license_expiration_warning_interval       default    3
license_group                             default    <null>
license_http_proxy_password               default    <not set>
license_http_proxy_port                   default    80
license_http_proxy_server                 default    <null>
license_http_proxy_user                   default    <null>
license_http_server                       default    license01.opnet.com
license_http_use_proxy                    default    FALSE
```

```
"realtime_ratio":     "0.0"
"RIP Message DSCP":          "CS6"
"RIP Sim Efficiency":        "Enabled"
"RIP Stop Time":    "65"
"RIPng Sim Efficiency":      "Enabled"
"RIPng Stop Time":           "65"
"Routing Activity Idle Timer":            "20"
"RTP API Safe Mode":         "Disabled"
"seed":    "128"
"sim_packet_sharing":        "conservative"
"sim_time_quantum":          "0.0"
"site_position_cache_size":  "3"
"Switch Sim Efficiency":     "Enabled"
"TCP Real Payload Support": "Auto"
"tmm_simulate":     "false"
"TORA Animated Destination RID":     "Specify..."
"TORA IMEP Animation Refresh Interval":       "10"
"TORA IMEP Efficiency":     "Disabled"
"TORA IMEP Packet Delivery Cache Update":
          "100"
"TORA Infinite Loop Prevention":      "Disabled"
"TORA Max Communication Distance":
          "1150"
"TORA Mode of Operation": "Default"
"Tracer Packet Redundancy": "Enabled"
"Tracer Packets Per Interval":"2"
"Traffic from Link Loads":     "Include"
"Traffic from LSP Loads":     "Do Not Include"
"Traffic from Traffic Flows": "Include"
"Traffic from VC Loads":      "Do Not Include"
"Traffic Scaling Factor":     "1.0"
"Traffic Scaling Mode":       "Background Traffic"
"update_interval":   "500,000"
"verbose_cell_size_report":   "false"
"verbose_event_report":       "false"
"verbose_event_timing_report":            "false"
"verbose_load":     "true"
"verbose_packet_report":      "true"
"verbose_parallel_speedup_report":      "false"
"verbose_sim":      "true"
```

```
license_password                          default     <not set>
license_port                            default     port_a
license_server                           default     localhost
license_server_standalone                  default     FALSE
license_server_standalone_diagnose          default     FALSE
license_username                          default     <null>
livelock_thresh                          default     8192
log_endsim_perf                           env. file   TRUE
log_file                                  env. file   "DNP3-90 Percent
Online Devices-DES-1"
log_time_precision                        default     12
manage_loanable_licenses                    default     FALSE
max_idle_time_microseconds                  default     1
max_log_entries                           env. file   200
memstat_autogen                           default     <null>
mtn_warn_int                             default     3
named_locks                              default     FALSE
net_name                                 cmd line    "DNP3-90 Percent
Online Devices"
num_collect_values                          env. file   100
num_err                                 default     10
ot_file                                 env. file   "DNP3-90 Percent Online
Devices-DES-1"
ot_file.default_format                    default     write_many
ot_mem_size                              default     4
ov_autogen                               default     <null>
ov_diff_tolerance                         default     5
ov_file                                  env. file   "DNP3-90 Percent
Online Devices-DES-1"
ov_mem_size                              default     16
parallel_sim.event_execution_time_window     env. file   0
parallel_sim.mutex_rank_ignore              default     FALSE
per_module_random_stream                  default     FALSE
probe                                    env. file   "DNP3-90 Percent
Online Devices"
probe_error_enable                        default     FALSE
probe_start_time                         default     -1
probe_stop_time                          default     -1
prof_output                             default     console
prof_output_separator                      default     <null>
prof_track_func                          default     <null>
prof_track_recurse                        default     TRUE
psnone_tda.bu.closure.closure              default     TRUE
psnone_tda.bu.collision.num_colls          default     0
psnone_tda.bu.ecc.pk_accept               default     TRUE
psnone_tda.bu.error.num_errors             default     0
psnone_tda.bu.propdel.prop_delay           default     0
psnone_tda.bu.txdel.tx_delay              default     0
psnone_tda.pt.ecc.pk_accept               default     TRUE
psnone_tda.pt.error.num_errors             default     0
psnone_tda.pt.propdel.prop_delay           default     0
psnone_tda.pt.txdel.tx_delay              default     0
psnone_tda.ra.ber.ber                    default     0
psnone_tda.ra.bkgnoise.bkgnoise            default     0
psnone_tda.ra.chanmatch.match_status        default     valid
psnone_tda.ra.closure.closure              default     TRUE
psnone_tda.ra.ecc.pk_accept               default     TRUE
psnone_tda.ra.error.actual_ber             default     0
psnone_tda.ra.error.num_errors             default     0
psnone_tda.ra.power.rcvd_power             default     -1
psnone_tda.ra.propdel.end_propdel          default     0
psnone_tda.ra.propdel.start_propdel        default     0
psnone_tda.ra.ragain.rx_gain              default     0
psnone_tda.ra.snr.snr                    default     1000
psnone_tda.ra.tagain.tx_gain              default     0
psnone_tda.ra.txdel.tx_delay              default     0
radio_transmission_defer_packet_duplication  default     TRUE
```

radio_transmission_on_demand_receiver_groups default FALSE rand_gen_type default Linear-Congruential rand_num_ext_res default TRUE raw_err default FALSE realtime_ratio env. file 0 rec_err_suppress default FALSE record_gstats default FALSE repositories env. file stdmod script_mode default none script_name default odb_script seed env. file 128 sim_packet_sharing env. file conservative sim_process_priority default normal sim_time_quantum env. file 0 site_position_cache_size env. file 3 sitl_realtime_ratio_check default TRUE sla_compute_all_violations default FALSE split_start_radio_transmission default FALSE timezone default "Local Timezone" tmm_data_directory default <obsolete> tmm_data_type default "USGS DEM" tmm_display_degrees default FALSE tmm_include_antenna_height default FALSE tmm_load_as_needed default TRUE tmm_pathloss_cache_size default 2 tmm_prop_model default <null> tmm_prop_param default <null> tmm_propagation_specification default <null> tmm_propagation_zone_ratio default 0 tmm_propagation_zone_resolution default 100 tmm_simulate env. file FALSE tmm_terrain_cache_size default 10 tmm_terrain_specification default <null> tmm_use_cache default TRUE tmm_verbose default FALSE update_interval env. file 500000 updates_in_seconds default FALSE user_lock_devname default <null> verbose_load env. file TRUE verbose_mk default FALSE verbose_sim env. file TRUE warning_suppress default FALSE	

100 PERCENT ONLINE	
Static Environment Attribute Confirmations	**Traffic Script**
----------Name---------- --Source--- ------Value---- ef cmd line "DNP3-100 Percent Online Devices-DES-1" force_posix_locale default TRUE handle_exception default TRUE handle_exception_extended default TRUE mem_clear default 0 mem_opt.compact_pools default TRUE mem_opt.pool_small_blocks default TRUE mem_opt.grow_pool_planks default TRUE mem_optimize default TRUE mem_shred default FALSE tfile_dir_cache_file default opnet_dir_cache tfile_dir_cache default use noprompt cmd line TRUE	"_locale":"C" "anim_view": "false" "Application Tracking Directory": "<Primary Model Directory>" "ARP Sim Efficiency": "Enabled" "Background Traffic Start Delay": "150" "comp_trace_info": "kernel-based" "Custom Application Tracing": "Do Not Export" "default_site_position_cache_time_granularity": "0.0" "des.log_severity_filter": "-1" "DHCP Logging": "Disabled" "DSR Record Routes": "Enabled" "DSR Routes Export": "Disabled" "duration": "150.0" "GNA API Safe Mode": "Disabled" "GRP Quadrant Size": "2000" "GRP Record Routes": "Disabled"

```
opnet_dir                                   env. file    "C:\\Program
Files\\Riverbed EDU"
opnet_user_home                          shell var   C:\Users\Ngonini
preferences_default_save_location          env. file   Local
verbose_session_log                        default     FALSE
java_prog                                   config file "C:\\Program
Files\\Riverbed
EDU\\17.5.A\\jre7_modeler_ae\\JRE\\bin\\java.exe"
java_prog64                               default     java
3dnv                                     default     FALSE
3dnv.cleanup_at_the_end                    default     TRUE
3dnv.fed_file_name                        default     <null>
3dnv.federation_name                       default     OPNET_3DNV
3dnv.history_file                         default     <null>
3dnv.hla_standard                         default     "DOD 1.3"
3dnv.initialization_delay                 default     1
3dnv.mapping_argument                      default     <null>
3dnv.mapping_library                                          default
opnet_3dnv_default_mapping
3dnv.max_request_rate                      default     0
3dnv.rpr_fom_version                       default     1
anim_attempts                             default     5
anim_hist                                default     <null>
anim_host                                 default     localhost
anim_port                                 default     0
anim_timeout                               default     3
anim_view                                 env. file   FALSE
antenna.spherical_model                    default     Mathematical
attr_reqs_file                           default     <null>
auto_disk_space_threshold                  default     1000
automation_lock_max_wait_time              default     60
beep_count_confirm                        default     1
beep_count_error                          default     2
bind_shobj_flags                          default     <null>
bind_shobj_flags_32bit                     default     <null>
bind_shobj_flags_64bit                     default     <null>
bind_shobj_flags_devel                     default     /DEBUG
bind_shobj_flags_optim                     default     <null>
bind_shobj_libs                           default     <null>
bind_shobj_libs_32bit                      default     <null>
bind_shobj_libs_64bit                      default     <null>
bind_shobj_libs_devel                      default     <null>
bind_shobj_libs_optim                      default     <null>
bind_shobj_prog                           default     bind_so_msvc
check_newer_process_model_files            default     TRUE
comp.no_fin_required_for_state_vars        default     FALSE
comp_flags_32bit                          default     <null>
comp_flags_64bit                          default     /GS-
comp_flags_c++_specific                    default     <null>
comp_flags_c_specific                      default     <null>
comp_flags_common                                    env. file    "/W3
/D_CRT_SECURE_NO_DEPRECATE
/IC:\\PROGRA~1\\RIVERB~1\\175~1.A\\models\\std\\include"
comp_flags_devel                          default     "/Z7 /Od"
comp_flags_mt                             default     <null>
comp_flags_optim                                 default     "/Ox /Ob2
/DOPD_NO_DEBUG /DOPD_INLINE_KPS"
comp_globals_export                       default     FALSE
comp_object_files_without_source                                default
allow_with_warning
comp_per_process_errors                    default     TRUE
comp_prog                                 default     comp_msvc
comp_prog_cpp                              default     comp_msvc
comp_trace_info                           env. file   kernel-based
console_exit_pause                         default     FALSE
cosim                                    default     <null>
cosimulation_optimization_mode             default     none
```

```
"GRP Routes Export":          "Disabled"
"H323 Call Reports":          "Do Not Export Reports"
"H323 Reporting End Time":    "End of Simulation"
"H323 Reporting Start Time":          "Beginning of
Simulation"
"Hybrid Simulation Efficiency":       "Enabled"
"IGMP Message DSCP":          "CS6"
"IGMP Sim Efficiency":        "Enabled"
"IMEP Route Injection":       "Disabled"
"Interface Buffer Congestion Threshold":          "0.8"
"IP Dynamic Routing Protocol":        "Default"
"IP Interface Addressing Mode":       "Auto
Addressed"
"IP Routing Table Export/Import":     "Not Used"
"IP Routing Table Source":    "Flow Analysis"
"IP Version Preference":      "IPv6"
"IPv6 Configuration":         "Consider"
"IPv6 Interface Address Export":      "Disabled"
"IPv6 ND Simulation Efficiency":      "Disabled"
"LACP Simulation Efficiency":         "Enabled"
"Link Usage Report":          "Disabled"
"log_endsim_perf": "true"
"log_file":          "DNP3-100      Percent      Online
Devices-DES-1"
"LSP Signaling Protocol":     "RSVP"
"max_log_entries": "200"
"num_collect_values":         "100"
"ot_file": "DNP3-100 Percent Online Devices-DES-1"
"ov_file":"DNP3-100 Percent Online Devices-DES-1"
"parallel_sim.event_execution_time_window":   "0.0"
"parallel_sim.mem_balance_interval":  "100,000"
"parallel_sim.num_processors":        "1"
"PIM Message DSCP":           "CS6"
"PIM-SM Sim Efficiency":      "Enabled"
"probe":  "DNP3-100 Percent Online Devices"
"realtime_ratio":     "0.0"
"RIP Message DSCP":           "CS6"
"RIP Sim Efficiency":         "Enabled"
"RIP Stop Time":   "65"
"RIPng Sim Efficiency":       "Enabled"
"RIPng Stop Time":            "65"
"Routing Activity Idle Timer":        "20"
"RTP API Safe Mode":          "Disabled"
"seed":    "128"
"sim_packet_sharing":         "conservative"
"sim_time_quantum":           "0.0"
"site_position_cache_size":   "3"
"Switch Sim Efficiency":      "Enabled"
"TCP Real Payload Support":"Auto"
"tmm_simulate":    "false"
"TORA Animated Destination RID":    "Specify..."
"TORA IMEP Animation Refresh Interval":       "10"
"TORA IMEP Efficiency":       "Disabled"
"TORA IMEP Packet Delivery Cache Update":
          "100"
"TORA Infinite Loop Prevention":      "Disabled"
"TORA Max Communication Distance":
          "1150"
"TORA Mode of Operation": "Default"
"Tracer Packet Redundancy":"Enabled"
"Tracer Packets Per Interval":"2"
"Traffic from Link Loads":    "Include"
"Traffic from LSP Loads":     "Do Not Include"
"Traffic from Traffic Flows": "Include"
"Traffic from VC Loads":      "Do Not Include"
"Traffic Scaling Factor":     "1.0"
"Traffic Scaling Mode":       "Background Traffic"
```

```
debug_mk                                    default     FALSE
default_site_position_cache_time_granularity env. file   0
des.log_severity_filter                     env. file   -1
diag_enable                                 default     FALSE
display_timezone_string                     default     FALSE
duration                                    env. file   150
edit_lock_mode                              default     FALSE
endsim_memstats                             default     FALSE
etrace_diff                                 default     <null>
etrace_dump                                 default     <null>
etrace_end_time                             default     1e+100
etrace_start_time                           default     0
event_order_method                          default     strict
event_speed_parameter                       default     100000
file_read_abort_suppress                    default     FALSE
format_event_ids_with_1000s_separator       default     TRUE
format_ici_ids_with_1000s_separator         default     TRUE
format_object_ids_with_1000s_separator      default     TRUE
format_packet_ids_with_1000s_separator      default     TRUE
format_process_ids_with_1000s_separator     default     TRUE
fully_serialized_event_execution_ids        default     TRUE
fully_serialized_ici_ids                    default     TRUE
fully_serialized_packet_ids                 default     TRUE
geocentric_model                            default     right_sphere
invalid_link_notification                   default     TRUE
kernel_type                                 env. file   optimized
license_broker_host                         default     <null>
license_broker_port                         default     <null>
license_expiration_warning_interval         default     3
license_group                               default     <null>
license_http_proxy_password                 default     <not set>
license_http_proxy_port                     default     80
license_http_proxy_server                   default     <null>
license_http_proxy_user                     default     <null>
license_http_server                         default     license01.opnet.com
license_http_use_proxy                      default     FALSE
license_password                            default     <not set>
license_port                                default     port_a
license_server                              default     localhost
license_server_standalone                   default     FALSE
license_server_standalone_diagnose          default     FALSE
license_username                            default     <null>
livelock_thresh                             default     8192
log_endsim_perf                             env. file   TRUE
log_file                                    env. file   "DNP3-100 Percent
Online Devices-DES-1"
log_time_precision                          default     12
manage_loanable_licenses                    default     FALSE
max_idle_time_microseconds                  default     1
max_log_entries                             env. file   200
memstat_autogen                             default     <null>
mtn_warn_int                                default     3
named_locks                                 default     FALSE
net_name                                    cmd line    "DNP3-100 Percent
Online Devices"
num_collect_values                          env. file   100
num_err                                     default     10
ot_file                                     env. file   "DNP3-100 Percent
Online Devices-DES-1"
ot_file.default_format                      default     write_many
ot_mem_size                                 default     4
ov_autogen                                  default     <null>
ov_diff_tolerance                           default     5
ov_file                                     env. file   "DNP3-100 Percent
Online Devices-DES-1"
ov_mem_size                                 default     16
parallel_sim.event_execution_time_window    env. file   0
```

```
"update_interval":   "500,000"
"verbose_cell_size_report":    "false"
"verbose_event_report":        "false"
"verbose_event_timing_report":          "false"
"verbose_load":      "true"
"verbose_packet_report":       "true"
"verbose_parallel_speedup_report":      "false"
"verbose_sim":       "true"
```

```
parallel_sim.mutex_rank_ignore              default     FALSE
per_module_random_stream                    default     FALSE
probe                                    env. file   "DNP3-100 Percent
Online Devices"
probe_error_enable                          default     FALSE
probe_start_time                           default     -1
probe_stop_time                            default     -1
prof_output                               default     console
prof_output_separator                       default     <null>
prof_track_func                            default     <null>
prof_track_recurse                         default     TRUE
psnone_tda.bu.closure.closure               default     TRUE
psnone_tda.bu.collision.num_colls           default     0
psnone_tda.bu.ecc.pk_accept                 default     TRUE
psnone_tda.bu.error.num_errors              default     0
psnone_tda.bu.propdel.prop_delay            default     0
psnone_tda.bu.txdel.tx_delay                default     0
psnone_tda.pt.ecc.pk_accept                 default     TRUE
psnone_tda.pt.error.num_errors              default     0
psnone_tda.pt.propdel.prop_delay            default     0
psnone_tda.pt.txdel.tx_delay                default     0
psnone_tda.ra.ber.ber                      default     0
psnone_tda.ra.bkgnoise.bkgnoise             default     0
psnone_tda.ra.chanmatch.match_status        default     valid
psnone_tda.ra.closure.closure               default     TRUE
psnone_tda.ra.ecc.pk_accept                 default     TRUE
psnone_tda.ra.error.actual_ber              default     0
psnone_tda.ra.error.num_errors              default     0
psnone_tda.ra.power.rcvd_power              default     -1
psnone_tda.ra.propdel.end_propdel           default     0
psnone_tda.ra.propdel.start_propdel         default     0
psnone_tda.ra.ragain.rx_gain                default     0
psnone_tda.ra.snr.snr                      default     1000
psnone_tda.ra.tagain.tx_gain                default     0
psnone_tda.ra.txdel.tx_delay                default     0
radio_transmission_defer_packet_duplication  default     TRUE
radio_transmission_on_demand_receiver_groups            default
FALSE
rand_gen_type                           default     Linear-Congruential
rand_num_ext_res                            default     TRUE
raw_err                                  default     FALSE
realtime_ratio                            env. file   0
rec_err_suppress                            default     FALSE
record_gstats                              default     FALSE
repositories                              env. file   stdmod
script_mode                                default     none
script_name                                default     odb_script
seed                                     env. file   128
sim_packet_sharing                          env. file   conservative
sim_process_priority                       default     normal
sim_time_quantum                            env. file   0
site_position_cache_size                    env. file   3
sitl_realtime_ratio_check                   default     TRUE
sla_compute_all_violations                  default     FALSE
split_start_radio_transmission              default     FALSE
timezone                                 default     "Local Timezone"
tmm_data_directory                          default     <obsolete>
tmm_data_type                              default     "USGS DEM"
tmm_display_degrees                         default     FALSE
tmm_include_antenna_height                  default     FALSE
tmm_load_as_needed                         default     TRUE
tmm_pathloss_cache_size                     default     2
tmm_prop_model                             default     <null>
tmm_prop_param                             default     <null>
tmm_propagation_specification               default     <null>
tmm_propagation_zone_ratio                  default     0
tmm_propagation_zone_resolution             default     100
```

tmm_simulate env. file FALSE tmm_terrain_cache_size default 10 tmm_terrain_specification default <null> tmm_use_cache default TRUE tmm_verbose default FALSE update_interval env. file 500000 updates_in_seconds default FALSE user_lock_devname default <null> verbose_load env. file TRUE verbose_mk default FALSE verbose_sim env. file TRUE warning_suppress default FALSE	

During 400kV Transformer Maintenance	
Static Environment Attribute Confirmations	**Traffic Script**
----------Name---------- --Source--- ------Value---- ef cmd line "DNP3-DNP3 During 400kV Transformer Maintenace-DES-1" force_posix_locale default TRUE handle_exception default TRUE handle_exception_extended default TRUE mem_clear default 0 mem_opt.compact_pools default TRUE mem_opt.pool_small_blocks default TRUE mem_opt.grow_pool_planks default TRUE mem_optimize default TRUE mem_shred default FALSE tfile_dir_cache_file default opnet_dir_cache tfile_dir_cache default use noprompt cmd line TRUE opnet_dir env. file "C:\\Program Files\\Riverbed EDU" opnet_user_home shell var C:\Users\Ngonini preferences_default_save_location env. file Local verbose_session_log default FALSE java_prog config file "C:\\Program Files\\Riverbed EDU\\17.5.A\\jre7_modeler_ae\\JRE\\bin\\java.exe" java_prog64 default java 3dnv default FALSE 3dnv.cleanup_at_the_end default TRUE 3dnv.fed_file_name default <null> 3dnv.federation_name default OPNET_3DNV 3dnv.history_file default <null> 3dnv.hla_standard default "DOD 1.3" 3dnv.initialization_delay default 1 3dnv.mapping_argument default <null> 3dnv.mapping_library default opnet_3dnv_default_mapping 3dnv.max_request_rate default 0 3dnv.rpr_fom_version default 1 anim_attempts default 5 anim_hist default <null> anim_host default localhost anim_port default 0 anim_timeout default 3 anim_view env. file FALSE antenna.spherical_model default Mathematical attr_reqs_file default <null> auto_disk_space_threshold default 1000 automation_lock_max_wait_time default 60 beep_count_confirm default 1 beep_count_error default 2 bind_shobj_flags default <null>	"_locale":"C" "anim_view": "false" "Application Tracking Directory": "<Primary Model Directory>" "ARP Sim Efficiency": "Enabled" "Background Traffic Start Delay": "150" "comp_trace_info": "kernel-based" "Custom Application Tracing": "Do Not Export" "default_site_position_cache_time_granularity": "0.0" "des.log_severity_filter": "-1" "DHCP Logging": "Disabled" "DSR Record Routes": "Enabled" "DSR Routes Export": "Disabled" "duration": "180.0" "GNA API Safe Mode": "Disabled" "GRP Quadrant Size": "2000" "GRP Record Routes": "Disabled" "GRP Routes Export": "Disabled" "H323 Call Reports": "Do Not Export Reports" "H323 Reporting End Time": "End of Simulation" "H323 Reporting Start Time": "Beginning of Simulation" "Hybrid Simulation Efficiency": "Enabled" "IGMP Message DSCP": "CS6" "IGMP Sim Efficiency": "Enabled" "IMEP Route Injection": "Disabled" "Interface Buffer Congestion Threshold": "0.8" "IP Dynamic Routing Protocol": "Default" "IP Interface Addressing Mode": "Auto Addressed" "IP Routing Table Export/Import": "Not Used" "IP Routing Table Source": "Flow Analysis" "IP Version Preference": "IPv6" "IPv6 Configuration": "Consider" "IPv6 Interface Address Export": "Disabled" "IPv6 ND Simulation Efficiency": "Disabled" "LACP Simulation Efficiency": "Enabled" "Link Usage Report": "Disabled" "log_endsim_perf": "true" "log_file": "DNP3-DNP3 During 400kV Transformer Maintenace-DES-1" "LSP Signaling Protocol": "RSVP" "max_log_entries": "200" "num_collect_values": "100" "ot_file": "DNP3-DNP3 During 400kV Transformer Maintenace-DES-1" "ov_file":"DNP3-DNP3 During 400kV Transformer Maintenace-DES-1" "parallel_sim.event_execution_time_window": "0.0" "parallel_sim.mem_balance_interval": "100,000"

```
bind_shobj_flags_32bit default <null>
bind_shobj_flags_64bit default <null>
bind_shobj_flags_devel default /DEBUG
bind_shobj_flags_optim default <null>
bind_shobj_libs default <null>
bind_shobj_libs_32bit default <null>
bind_shobj_libs_64bit default <null>
bind_shobj_libs_devel default <null>
bind_shobj_libs_optim default <null>
bind_shobj_prog default bind_so_msvc
check_newer_process_model_files default TRUE
comp.no_fin_required_for_state_vars default FALSE
comp_flags_32bit default <null>
comp_flags_64bit default /GS-
comp_flags_c++_specific default <null>
comp_flags_c_specific default <null>
comp_flags_common env. file "/W3
/D_CRT_SECURE_NO_DEPRECATE
/IC:\\PROGRA~1\\RIVERB~1\\175~1.A\\models\\std\\include"
comp_flags_devel default "/Z7 /Od"
comp_flags_mt default <null>
comp_flags_optim default "/Ox /Ob2
/DOPD_NO_DEBUG /DOPD_INLINE_KPS"
comp_globals_export default FALSE
comp_object_files_without_source default
allow_with_warning
comp_per_process_errors default TRUE
comp_prog default comp_msvc
comp_prog_cpp default comp_msvc
comp_trace_info env. file kernel-based
console_exit_pause default FALSE
cosim default <null>
cosimulation_optimization_mode default none
debug_mk default FALSE
default_site_position_cache_time_granularity env. file 0
des.log_severity_filter env. file -1
diag_enable default FALSE
display_timezone_string default FALSE
duration env. file 180
edit_lock_mode default FALSE
endsim_memstats default FALSE
etrace_diff default <null>
etrace_dump default <null>
etrace_end_time default 1e+100
etrace_start_time default 0
event_order_method default strict
event_speed_parameter default 100000
file_read_abort_suppress default FALSE
format_event_ids_with_1000s_separator default TRUE
format_ici_ids_with_1000s_separator default TRUE
format_object_ids_with_1000s_separator default TRUE
format_packet_ids_with_1000s_separator default TRUE
format_process_ids_with_1000s_separator default TRUE
fully_serialized_event_execution_ids default TRUE
fully_serialized_ici_ids default TRUE
fully_serialized_packet_ids default TRUE
geocentric_model default right_sphere
invalid_link_notification default TRUE
kernel_type env. file optimized
license_broker_host default <null>
license_broker_port default <null>
license_expiration_warning_interval default 3
license_group default <null>
license_http_proxy_password default <not set>
license_http_proxy_port default 80
license_http_proxy_server default <null>
license_http_proxy_user default <null>
```

```
"parallel_sim.num_processors": "1"
"PIM Message DSCP": "CS6"
"PIM-SM Sim Efficiency": "Enabled"
"probe": "DNP3-DNP3 During 400kV Transformer
Maintenace"
"realtime_ratio": "0.0"
"RIP Message DSCP": "CS6"
"RIP Sim Efficiency": "Enabled"
"RIP Stop Time": "65"
"RIPng Sim Efficiency": "Enabled"
"RIPng Stop Time": "65"
"Routing Activity Idle Timer": "20"
"RTP API Safe Mode": "Disabled"
"seed": "128"
"sim_packet_sharing": "conservative"
"sim_time_quantum": "0.0"
"site_position_cache_size": "3"
"Switch Sim Efficiency": "Enabled"
"TCP Real Payload Support": "Auto"
"tmm_simulate": "false"
"TORA Animated Destination RID": "Specify..."
"TORA IMEP Animation Refresh Interval": "10"
"TORA IMEP Efficiency": "Disabled"
"TORA IMEP Packet Delivery Cache Update":
"100"
"TORA Infinite Loop Prevention": "Disabled"
"TORA Max Communication Distance":
"1150"
"TORA Mode of Operation": "Default"
"Tracer Packet Redundancy": "Enabled"
"Tracer Packets Per Interval": "2"
"Traffic from Link Loads": "Include"
"Traffic from LSP Loads": "Do Not Include"
"Traffic from Traffic Flows": "Include"
"Traffic from VC Loads": "Do Not Include"
"Traffic Scaling Factor": "1.0"
"Traffic Scaling Mode": "Background Traffic"
"update_interval": "500,000"
"verbose_cell_size_report": "false"
"verbose_event_report": "false"
"verbose_event_timing_report": "false"
"verbose_load": "true"
"verbose_packet_report": "true"
"verbose_parallel_speedup_report": "false"
"verbose_sim": "true"
```

```
license_http_server                    default    license01.opnet.com
license_http_use_proxy                 default    FALSE
license_password                       default    <not set>
license_port                           default    port_a
license_server                         default    localhost
license_server_standalone              default    FALSE
license_server_standalone_diagnose     default    FALSE
license_username                       default    <null>
livelock_thresh                        default    8192
log_endsim_perf                        env. file  TRUE
log_file                               env. file  "DNP3-DNP3 During
400kV Transformer Maintenace-DES-1"
log_time_precision                     default    12
manage_loanable_licenses               default    FALSE
max_idle_time_microseconds             default    1
max_log_entries                        env. file  200
memstat_autogen                        default    <null>
mtn_warn_int                           default    3
named_locks                            default    FALSE
net_name                               cmd line   "DNP3-DNP3 During
400kV Transformer Maintenace"
num_collect_values                     env. file  100
num_err                                default    10
ot_file                                env. file  "DNP3-DNP3 During
400kV Transformer Maintenace-DES-1"
ot_file.default_format                 default    write_many
ot_mem_size                            default    4
ov_autogen                             default    <null>
ov_diff_tolerance                      default    5
ov_file                                env. file  "DNP3-DNP3 During
400kV Transformer Maintenace-DES-1"
ov_mem_size                            default    16
parallel_sim.event_execution_time_window   env. file  0
parallel_sim.mutex_rank_ignore         default    FALSE
per_module_random_stream               default    FALSE
probe                                  env. file  "DNP3-DNP3 During
400kV Transformer Maintenace"
probe_error_enable                     default    FALSE
probe_start_time                       default    -1
probe_stop_time                        default    -1
prof_output                            default    console
prof_output_separator                  default    <null>
prof_track_func                        default    <null>
prof_track_recurse                     default    TRUE
psnone_tda.bu.closure.closure          default    TRUE
psnone_tda.bu.collision.num_colls      default    0
psnone_tda.bu.ecc.pk_accept            default    TRUE
psnone_tda.bu.error.num_errors         default    0
psnone_tda.bu.propdel.prop_delay       default    0
psnone_tda.bu.txdel.tx_delay           default    0
psnone_tda.pt.ecc.pk_accept            default    TRUE
psnone_tda.pt.error.num_errors         default    0
psnone_tda.pt.propdel.prop_delay       default    0
psnone_tda.pt.txdel.tx_delay           default    0
psnone_tda.ra.ber.ber                  default    0
psnone_tda.ra.bkgnoise.bkgnoise        default    0
psnone_tda.ra.chanmatch.match_status   default    valid
psnone_tda.ra.closure.closure          default    TRUE
psnone_tda.ra.ecc.pk_accept            default    TRUE
psnone_tda.ra.error.actual_ber         default    0
psnone_tda.ra.error.num_errors         default    0
psnone_tda.ra.power.rcvd_power         default    -1
psnone_tda.ra.propdel.end_propdel      default    0
psnone_tda.ra.propdel.start_propdel    default    0
psnone_tda.ra.ragain.rx_gain           default    0
psnone_tda.ra.snr.snr                  default    1000
psnone_tda.ra.tagain.tx_gain           default    0
```

psnone_tda.ra.txdel.tx_delay default 0 radio_transmission_defer_packet_duplication default TRUE radio_transmission_on_demand_receiver_groups default FALSE rand_gen_type default Linear-Congruential rand_num_ext_res default TRUE raw_err default FALSE realtime_ratio env. file 0 rec_err_suppress default FALSE record_gstats default FALSE repositories env. file stdmod script_mode default none script_name default odb_script seed env. file 128 sim_packet_sharing env. file conservative sim_process_priority default normal sim_time_quantum env. file 0 site_position_cache_size env. file 3 sitl_realtime_ratio_check default TRUE sla_compute_all_violations default FALSE split_start_radio_transmission default FALSE timezone default "Local Timezone" tmm_data_directory default <obsolete> tmm_data_type default "USGS DEM" tmm_display_degrees default FALSE tmm_include_antenna_height default FALSE tmm_load_as_needed default TRUE tmm_pathloss_cache_size default 2 tmm_prop_model default <null> tmm_prop_param default <null> tmm_propagation_specification default <null> tmm_propagation_zone_ratio default 0 tmm_propagation_zone_resolution default 100 tmm_simulate env. file FALSE tmm_terrain_cache_size default 10 tmm_terrain_specification default <null> tmm_use_cache default TRUE tmm_verbose default FALSE update_interval env. file 500000 updates_in_seconds default FALSE user_lock_devname default <null> verbose_load env. file TRUE verbose_mk default FALSE verbose_sim env. file TRUE warning_suppress default FALSE	

Appendix D IEC 61850 Script

Buszone Operation	
Static Environment Attribute Confirmations	**Traffic Script**
----------Name---------- --Source--- ------Value------ ef cmd line "IEC61850-Buszone Operation-DES-1" force_posix_locale default TRUE handle_exception default TRUE handle_exception_extended default TRUE mem_clear default 0 mem_opt.compact_pools default TRUE mem_opt.pool_small_blocks default TRUE mem_opt.grow_pool_planks default TRUE mem_optimize default TRUE mem_shred default FALSE tfile_dir_cache_file default opnet_dir_cache tfile_dir_cache default use noprompt cmd line TRUE	"_locale":"C" "anim_hist": "IEC61850-Buszone Operation-DES-1" "anim_view": "false" "Application Tracking Directory": "<Primary Model Directory>" "ARP Sim Efficiency": "Enabled" "Background Traffic Start Delay": "1" "comp_trace_info": "kernel-based" "Custom Application Tracing": "Do Not Export" "default_site_position_cache_time_granularity": "0.0" "des.log_severity_filter": "-1" "DHCP Logging": "Disabled" "DSR Record Routes": "Enabled" "DSR Routes Export": "Disabled"

```
opnet_dir                                   env. file   "C:\\Program
Files\\Riverbed EDU"
opnet_user_home                             shell var   C:\Users\Ngonini
preferences_default_save_location           env. file   Local
verbose_session_log                         default     FALSE
java_prog                                   config file "C:\\Program
Files\\Riverbed
EDU\\17.5.A\\jre7_modeler_ae\\JRE\\bin\\java.exe"
java_prog64                                 default     java
3dnv                                        default     FALSE
3dnv.cleanup_at_the_end                     default     TRUE
3dnv.fed_file_name                          default     <null>
3dnv.federation_name                        default     OPNET_3DNV
3dnv.history_file                           default     <null>
3dnv.hla_standard                           default     "DOD 1.3"
3dnv.initialization_delay                   default     1
3dnv.mapping_argument                       default     <null>
3dnv.mapping_library                                    default
opnet_3dnv_default_mapping
3dnv.max_request_rate                       default     0
3dnv.rpr_fom_version                        default     1
anim_attempts                               default     5
anim_hist                                   env. file   "IEC61850-Buszone
Operation-DES-1"
anim_host                                   default     localhost
anim_port                                   default     0
anim_timeout                                default     3
anim_view                                   env. file   FALSE
antenna.spherical_model                     default     Mathematical
attr_reqs_file                              default     <null>
auto_disk_space_threshold                   default     1000
automation_lock_max_wait_time               default     60
beep_count_confirm                          default     1
beep_count_error                            default     2
bind_shobj_flags                            default     <null>
bind_shobj_flags_32bit                      default     <null>
bind_shobj_flags_64bit                      default     <null>
bind_shobj_flags_devel                      default     /DEBUG
bind_shobj_flags_optim                      default     <null>
bind_shobj_libs                             default     <null>
bind_shobj_libs_32bit                       default     <null>
bind_shobj_libs_64bit                       default     <null>
bind_shobj_libs_devel                       default     <null>
bind_shobj_libs_optim                       default     <null>
bind_shobj_prog                             default     bind_so_msvc
check_newer_process_model_files             default     TRUE
comp.no_fin_required_for_state_vars         default     FALSE
comp_flags_32bit                            default     <null>
comp_flags_64bit                            default     /GS-
comp_flags_c++_specific                     default     <null>
comp_flags_c_specific                       default     <null>
comp_flags_common                                       env. file   "/W3
/D_CRT_SECURE_NO_DEPRECATE
/IC:\\PROGRA~1\\RIVERB~1\\175~1.A\\models\\std\\include"
comp_flags_devel                            default     "/Z7 /Od"
comp_flags_mt                               default     <null>
comp_flags_optim                            default     "/Ox /Ob2
/DOPD_NO_DEBUG /DOPD_INLINE_KPS"
comp_globals_export                         default     FALSE
comp_object_files_without_source                        default
allow_with_warning
comp_per_process_errors                     default     TRUE
comp_prog                                   default     comp_msvc
comp_prog_cpp                               default     comp_msvc
comp_trace_info                             env. file   kernel-based
console_exit_pause                          default     FALSE
cosim                                       default     <null>
```

```
"duration":                 "180.0"
"GNA API Safe Mode":        "Disabled"
"GRP Quadrant Size":        "2000"
"GRP Record Routes":        "Disabled"
"GRP Routes Export":        "Disabled"
"H323 Call Reports":        "Do Not Export Reports"
"H323 Reporting End Time":  "End of Simulation"
"H323 Reporting Start Time":                "Beginning of
Simulation"
"Hybrid Simulation Efficiency":             "Enabled"
"IGMP Message DSCP":        "CS6"
"IGMP Sim Efficiency":      "Enabled"
"IMEP Route Injection":     "Disabled"
"Interface Buffer Congestion Threshold":    "0.8"
"IP Dynamic Routing Protocol":              "Default"
"IP Interface Addressing Mode":             "Auto
Addressed"
"IP Routing Table Export/Import":           "Not Used"
"IP Routing Table Source":  "Flow Analysis"
"IP Version Preference":    "IPv6"
"IPv6 Configuration":       "Consider"
"IPv6 Interface Address Export":            "Disabled"
"IPv6 ND Simulation Efficiency":            "Disabled"
"LACP Simulation Efficiency":               "Enabled"
"Link Usage Report":        "Disabled"
"log_endsim_perf":"true"
"log_file":                 "IEC61850-Buszone    Operation-
DES-1"
"LSP Signaling Protocol":   "RSVP"
"max_log_entries": "200"
"num_collect_values":       "100"
"ot_file": "IEC61850-Buszone Operation-DES-1"
"ov_file":"IEC61850-Buszone Operation-DES-1"
"parallel_sim.event_execution_time_window":  "0.0"
"parallel_sim.mem_balance_interval":         "100,000"
"parallel_sim.num_processors":               "1"
"PIM Message DSCP":         "CS6"
"PIM-SM Sim Efficiency":    "Enabled"
"probe":  "IEC61850-Buszone Operation"
"realtime_ratio":    "0.0"
"RIP Message DSCP":         "CS6"
"RIP Sim Efficiency":       "Enabled"
"RIP Stop Time":   "65"
"RIPng Sim Efficiency":     "Enabled"
"RIPng Stop Time":          "65"
"Routing Activity Idle Timer":              "20"
"RTP API Safe Mode":        "Disabled"
"seed":   "128"
"sim_packet_sharing":       "conservative"
"sim_time_quantum":         "0.0"
"site_position_cache_size":  "3"
"Switch Sim Efficiency":    "Enabled"
"TCP Real Payload Support":"Auto"
"tmm_simulate":    "false"
"TORA Animated Destination RID":    "Specify..."
"TORA IMEP Animation Refresh Interval":     "10"
"TORA IMEP Efficiency":     "Disabled"
"TORA IMEP Packet Delivery Cache Update":
          "100"
"TORA Infinite Loop Prevention":    "Disabled"
"TORA Max Communication Distance":
          "1150"
"TORA Mode of Operation": "Default"
"Tracer Packet Redundancy":"Enabled"
"Tracer Packets Per Interval":"2"
"Traffic from Link Loads":  "Include"
"Traffic from LSP Loads":   "Do Not Include"
```

cosimulation_optimization_mode default none debug_mk default FALSE default_site_position_cache_time_granularity env. file 0 des.log_severity_filter env. file -1 diag_enable default FALSE display_timezone_string default FALSE duration env. file 180 edit_lock_mode default FALSE endsim_memstats default FALSE etrace_diff default <null> etrace_dump default <null> etrace_end_time default 1e+100 etrace_start_time default 0 event_order_method default strict event_speed_parameter default 100000 file_read_abort_suppress default FALSE format_event_ids_with_1000s_separator default TRUE format_ici_ids_with_1000s_separator default TRUE format_object_ids_with_1000s_separator default TRUE format_packet_ids_with_1000s_separator default TRUE format_process_ids_with_1000s_separator default TRUE fully_serialized_event_execution_ids default TRUE fully_serialized_ici_ids default TRUE fully_serialized_packet_ids default TRUE geocentric_model default right_sphere invalid_link_notification default TRUE kernel_type env. file optimized license_broker_host default <null> license_broker_port default <null> license_expiration_warning_interval default 3 license_group default <null> license_http_proxy_password default <not set> license_http_proxy_port default 80 license_http_proxy_server default <null> license_http_proxy_user default <null> license_http_server default license01.opnet.com license_http_use_proxy default FALSE license_password default <not set> license_port default port_a license_server default localhost license_server_standalone default FALSE license_server_standalone_diagnose default FALSE license_username default <null> livelock_thresh default 8192 log_endsim_perf env. file TRUE log_file env. file "IEC61850-Buszone Operation-DES-1" log_time_precision default 12 manage_loanable_licenses default FALSE max_idle_time_microseconds default 1 max_log_entries env. file 200 memstat_autogen default <null> mtn_warn_int default 3 named_locks default FALSE net_name cmd line "IEC61850-Buszone Operation" num_collect_values env. file 100 num_err default 10 ot_file env. file "IEC61850-Buszone Operation-DES-1" ot_file.default_format default write_many ot_mem_size default 4 ov_autogen default <null> ov_diff_tolerance default 5 ov_file env. file "IEC61850-Buszone Operation-DES-1" ov_mem_size default 16	"Traffic from Traffic Flows": "Include" "Traffic from VC Loads": "Do Not Include" "Traffic Scaling Factor": "1.0" "Traffic Scaling Mode": "Background Traffic" "update_interval": "500,000" "verbose_cell_size_report": "false" "verbose_event_report": "false" "verbose_event_timing_report": "false" "verbose_load": "true" "verbose_packet_report": "true" "verbose_parallel_speedup_report": "false" "verbose_sim": "true"

```
parallel_sim.event_execution_time_window     env. file   0
parallel_sim.mutex_rank_ignore               default     FALSE
per_module_random_stream                     default     FALSE
probe                                    env. file   "IEC61850-Buszone
Operation"
probe_error_enable                         default     FALSE
probe_start_time                         default     -1
probe_stop_time                          default     -1
prof_output                              default     console
prof_output_separator                      default     <null>
prof_track_func                          default     <null>
prof_track_recurse                       default     TRUE
psnone_tda.bu.closure.closure              default     TRUE
psnone_tda.bu.collision.num_colls          default     0
psnone_tda.bu.ecc.pk_accept                default     TRUE
psnone_tda.bu.error.num_errors             default     0
psnone_tda.bu.propdel.prop_delay           default     0
psnone_tda.bu.txdel.tx_delay               default     0
psnone_tda.pt.ecc.pk_accept                default     TRUE
psnone_tda.pt.error.num_errors             default     0
psnone_tda.pt.propdel.prop_delay           default     0
psnone_tda.pt.txdel.tx_delay               default     0
psnone_tda.ra.ber.ber                    default     0
psnone_tda.ra.bkgnoise.bkgnoise            default     0
psnone_tda.ra.chanmatch.match_status       default     valid
psnone_tda.ra.closure.closure              default     TRUE
psnone_tda.ra.ecc.pk_accept                default     TRUE
psnone_tda.ra.error.actual_ber             default     0
psnone_tda.ra.error.num_errors             default     0
psnone_tda.ra.power.rcvd_power             default     -1
psnone_tda.ra.propdel.end_propdel          default     0
psnone_tda.ra.propdel.start_propdel        default     0
psnone_tda.ra.ragain.rx_gain               default     0
psnone_tda.ra.snr.snr                    default     1000
psnone_tda.ra.tagain.tx_gain               default     0
psnone_tda.ra.txdel.tx_delay               default     0
radio_transmission_defer_packet_duplication  default     TRUE
radio_transmission_on_demand_receiver_groups           default
FALSE
rand_gen_type                          default     Linear-Congruential
rand_num_ext_res                         default     TRUE
raw_err                                default     FALSE
realtime_ratio                           env. file   0
rec_err_suppress                         default     FALSE
record_gstats                            default     FALSE
repositories                             env. file   stdmod
script_mode                              default     none
script_name                              default     odb_script
seed                                   env. file   128
sim_packet_sharing                         env. file   conservative
sim_process_priority                     default     normal
sim_time_quantum                         env. file   0
site_position_cache_size                 env. file   3
sitl_realtime_ratio_check                default     TRUE
sla_compute_all_violations               default     FALSE
split_start_radio_transmission           default     FALSE
timezone                               default     "Local Timezone"
tmm_data_directory                       default     <obsolete>
tmm_data_type                            default     "USGS DEM"
tmm_display_degrees                      default     FALSE
tmm_include_antenna_height               default     FALSE
tmm_load_as_needed                       default     TRUE
tmm_pathloss_cache_size                  default     2
tmm_prop_model                           default     <null>
tmm_prop_param                           default     <null>
tmm_propagation_specification            default     <null>
tmm_propagation_zone_ratio               default     0
```

tmm_propagation_zone_resolution default 100 tmm_simulate env. file FALSE tmm_terrain_cache_size default 10 tmm_terrain_specification default <null> tmm_use_cache default TRUE tmm_verbose default FALSE update_interval env. file 500000 updates_in_seconds default FALSE user_lock_devname default <null> verbose_load env. file TRUE verbose_mk default FALSE verbose_sim env. file TRUE warning_suppress default FALSE	

Normal Operation	
Static Environment Attribute Confirmations	**Traffic Script**
----------Name---------- --Source--- ------Value------ ef cmd line "IEC61850-Normal Operation-DES-1" force_posix_locale default TRUE handle_exception default TRUE handle_exception_extended default TRUE mem_clear default 0 mem_opt.compact_pools default TRUE mem_opt.pool_small_blocks default TRUE mem_opt.grow_pool_planks default TRUE mem_optimize default TRUE mem_shred default FALSE tfile_dir_cache_file default opnet_dir_cache tfile_dir_cache default use noprompt cmd line TRUE opnet_dir env. file "C:\\Program Files\\Riverbed EDU" opnet_user_home shell var C:\Users\Ngonini preferences_default_save_location env. file Local verbose_session_log default FALSE java_prog config file "C:\\Program Files\\Riverbed EDU\\17.5.A\\jre7_modeler_ae\\JRE\\bin\\java.exe" java_prog64 default java 3dnv default FALSE 3dnv.cleanup_at_the_end default TRUE 3dnv.fed_file_name default <null> 3dnv.federation_name default OPNET_3DNV 3dnv.history_file default <null> 3dnv.hla_standard default "DOD 1.3" 3dnv.initialization_delay default 1 3dnv.mapping_argument default <null> 3dnv.mapping_library default opnet_3dnv_default_mapping 3dnv.max_request_rate default 0 3dnv.rpr_fom_version default 1 anim_attempts default 5 anim_hist default <null> anim_host default localhost anim_port default 0 anim_timeout default 3 anim_view env. file FALSE antenna.spherical_model default Mathematical attr_reqs_file default <null> auto_disk_space_threshold default 1000 automation_lock_max_wait_time default 60 beep_count_confirm default 1 beep_count_error default 2	"_locale":"C" "anim_view": "false" "Application Tracking Directory": "<Primary Model Directory>" "ARP Sim Efficiency": "Enabled" "Background Traffic Start Delay": "1" "comp_trace_info": "kernel-based" "Custom Application Tracing": "Do Not Export" "default_site_position_cache_time_granularity": "0.0" "des.log_severity_filter": "-1" "DHCP Logging": "Disabled" "DSR Record Routes": "Enabled" "DSR Routes Export": "Disabled" "duration": "180.0" "GNA API Safe Mode": "Disabled" "GRP Quadrant Size": "2000" "GRP Record Routes": "Disabled" "GRP Routes Export": "Disabled" "H323 Call Reports": "Do Not Export Reports" "H323 Reporting End Time": "End of Simulation" "H323 Reporting Start Time": "Beginning of Simulation" "Hybrid Simulation Efficiency": "Enabled" "IGMP Message DSCP": "CS6" "IGMP Sim Efficiency": "Enabled" "IMEP Route Injection": "Disabled" "Interface Buffer Congestion Threshold": "0.8" "IP Dynamic Routing Protocol": "Default" "IP Interface Addressing Mode": "Auto Addressed" "IP Routing Table Export/Import": "Not Used" "IP Routing Table Source": "Flow Analysis" "IP Version Preference": "IPv6" "IPv6 Configuration": "Consider" "IPv6 Interface Address Export": "Disabled" "IPv6 ND Simulation Efficiency": "Disabled" "LACP Simulation Efficiency": "Enabled" "Link Usage Report": "Disabled" "log_endsim_perf": "true" "log_file": "IEC61850-Normal Operation-DES-1" "LSP Signaling Protocol": "RSVP" "max_log_entries": "200" "num_collect_values": "100" "ot_file": "IEC61850-Normal Operation-DES-1" "ov_file":"IEC61850-Normal Operation-DES-1" "parallel_sim.event_execution_time_window": "0.0" "parallel_sim.mem_balance_interval": "100,000"

```
bind_shobj_flags                        default    <null>
bind_shobj_flags_32bit                  default    <null>
bind_shobj_flags_64bit                  default    <null>
bind_shobj_flags_devel                  default    /DEBUG
bind_shobj_flags_optim                  default    <null>
bind_shobj_libs                         default    <null>
bind_shobj_libs_32bit                   default    <null>
bind_shobj_libs_64bit                   default    <null>
bind_shobj_libs_devel                   default    <null>
bind_shobj_libs_optim                   default    <null>
bind_shobj_prog                         default    bind_so_msvc
check_newer_process_model_files         default    TRUE
comp.no_fin_required_for_state_vars     default    FALSE
comp_flags_32bit                        default    <null>
comp_flags_64bit                        default    /GS-
comp_flags_c++_specific                 default    <null>
comp_flags_c_specific                   default    <null>
comp_flags_common                       env. file  "/W3
/D_CRT_SECURE_NO_DEPRECATE
/IC:\\PROGRA~1\\RIVERB~1\\175~1.A\\models\\std\\include"
comp_flags_devel                        default    "/Z7 /Od"
comp_flags_mt                           default    <null>
comp_flags_optim                        default    "/Ox /Ob2
/DOPD_NO_DEBUG /DOPD_INLINE_KPS"
comp_globals_export                     default    FALSE
comp_object_files_without_source        default
allow_with_warning
comp_per_process_errors                 default    TRUE
comp_prog                               default    comp_msvc
comp_prog_cpp                           default    comp_msvc
comp_trace_info                         env. file  kernel-based
console_exit_pause                      default    FALSE
cosim                                   default    <null>
cosimulation_optimization_mode          default    none
debug_mk                                default    FALSE
default_site_position_cache_time_granularity env. file  0
des.log_severity_filter                 env. file  -1
diag_enable                             default    FALSE
display_timezone_string                 default    FALSE
duration                                env. file  180
edit_lock_mode                          default    FALSE
endsim_memstats                         default    FALSE
etrace_diff                             default    <null>
etrace_dump                             default    <null>
etrace_end_time                         default    1e+100
etrace_start_time                       default    0
event_order_method                      default    strict
event_speed_parameter                   default    100000
file_read_abort_suppress                default    FALSE
format_event_ids_with_1000s_separator   default    TRUE
format_ici_ids_with_1000s_separator     default    TRUE
format_object_ids_with_1000s_separator  default    TRUE
format_packet_ids_with_1000s_separator  default    TRUE
format_process_ids_with_1000s_separator default    TRUE
fully_serialized_event_execution_ids    default    TRUE
fully_serialized_ici_ids                default    TRUE
fully_serialized_packet_ids             default    TRUE
geocentric_model                        default    right_sphere
invalid_link_notification               default    TRUE
kernel_type                             env. file  optimized
license_broker_host                     default    <null>
license_broker_port                     default    <null>
license_expiration_warning_interval     default    3
license_group                           default    <null>
license_http_proxy_password             default    <not set>
license_http_proxy_port                 default    80
license_http_proxy_server               default    <null>
```

```
"parallel_sim.num_processors":          "1"
"PIM Message DSCP":                     "CS6"
"PIM-SM Sim Efficiency":                "Enabled"
"probe":                                "IEC61850-Normal Operation"
"realtime_ratio":                       "0.0"
"RIP Message DSCP":                     "CS6"
"RIP Sim Efficiency":                   "Enabled"
"RIP Stop Time":                        "65"
"RIPng Sim Efficiency":                 "Enabled"
"RIPng Stop Time":                      "65"
"Routing Activity Idle Timer":          "20"
"RTP API Safe Mode":                    "Disabled"
"seed":                                 "128"
"sim_packet_sharing":                   "conservative"
"sim_time_quantum":                     "0.0"
"site_position_cache_size":             "3"
"Switch Sim Efficiency":                "Enabled"
"TCP Real Payload Support":             "Auto"
"tmm_simulate":                         "false"
"TORA Animated Destination RID":        "Specify..."
"TORA IMEP Animation Refresh Interval": "10"
"TORA IMEP Efficiency":                 "Disabled"
"TORA IMEP Packet Delivery Cache Update":
                                        "100"
"TORA Infinite Loop Prevention":        "Disabled"
"TORA Max Communication Distance":
                                        "1150"
"TORA Mode of Operation":               "Default"
"Tracer Packet Redundancy":             "Enabled"
"Tracer Packets Per Interval":          "2"
"Traffic from Link Loads":              "Include"
"Traffic from LSP Loads":               "Do Not Include"
"Traffic from Traffic Flows":           "Include"
"Traffic from VC Loads":                "Do Not Include"
"Traffic Scaling Factor":               "1.0"
"Traffic Scaling Mode":                 "Background Traffic"
"update_interval":                      "500,000"
"verbose_cell_size_report":             "false"
"verbose_event_report":                 "false"
"verbose_event_timing_report":          "false"
"verbose_load":                         "true"
"verbose_packet_report":                "true"
"verbose_parallel_speedup_report":      "false"
"verbose_sim":                          "true"
```

```
license_http_proxy_user                    default     <null>
license_http_server                        default     license01.opnet.com
license_http_use_proxy                     default     FALSE
license_password                           default     <not set>
license_port                               default     port_a
license_server                             default     localhost
license_server_standalone                  default     FALSE
license_server_standalone_diagnose         default     FALSE
license_username                           default     <null>
livelock_thresh                            default     8192
log_endsim_perf                            env. file   TRUE
log_file                                   env. file   "IEC61850-Normal
Operation-DES-1"
log_time_precision                         default     12
manage_loanable_licenses                   default     FALSE
max_idle_time_microseconds                 default     1
max_log_entries                            env. file   200
memstat_autogen                            default     <null>
mtn_warn_int                               default     3
named_locks                                default     FALSE
net_name                                   cmd line    "IEC61850-Normal
Operation"
num_collect_values                         env. file   100
num_err                                    default     10
ot_file                                    env. file   "IEC61850-Normal
Operation-DES-1"
ot_file.default_format                     default     write_many
ot_mem_size                                default     4
ov_autogen                                 default     <null>
ov_diff_tolerance                          default     5
ov_file                                    env. file   "IEC61850-Normal
Operation-DES-1"
ov_mem_size                                default     16
parallel_sim.event_execution_time_window   env. file   0
parallel_sim.mutex_rank_ignore             default     FALSE
per_module_random_stream                   default     FALSE
probe                                      env. file   "IEC61850-Normal
Operation"
probe_error_enable                         default     FALSE
probe_start_time                           default     -1
probe_stop_time                            default     -1
prof_output                                default     console
prof_output_separator                      default     <null>
prof_track_func                            default     <null>
prof_track_recurse                         default     TRUE
psnone_tda.bu.closure.closure              default     TRUE
psnone_tda.bu.collision.num_colls          default     0
psnone_tda.bu.ecc.pk_accept                default     TRUE
psnone_tda.bu.error.num_errors             default     0
psnone_tda.bu.propdel.prop_delay           default     0
psnone_tda.bu.txdel.tx_delay               default     0
psnone_tda.pt.ecc.pk_accept                default     TRUE
psnone_tda.pt.error.num_errors             default     0
psnone_tda.pt.propdel.prop_delay           default     0
psnone_tda.pt.txdel.tx_delay               default     0
psnone_tda.ra.ber.ber                      default     0
psnone_tda.ra.bkgnoise.bkgnoise            default     0
psnone_tda.ra.chanmatch.match_status       default     valid
psnone_tda.ra.closure.closure              default     TRUE
psnone_tda.ra.ecc.pk_accept                default     TRUE
psnone_tda.ra.error.actual_ber             default     0
psnone_tda.ra.error.num_errors             default     0
psnone_tda.ra.power.rcvd_power             default     -1
psnone_tda.ra.propdel.end_propdel          default     0
psnone_tda.ra.propdel.start_propdel        default     0
psnone_tda.ra.ragain.rx_gain               default     0
psnone_tda.ra.snr.snr                      default     1000
```

psnone_tda.ra.tagain.tx_gain default 0 psnone_tda.ra.txdel.tx_delay default 0 radio_transmission_defer_packet_duplication default TRUE radio_transmission_on_demand_receiver_groups default FALSE rand_gen_type default Linear-Congruential rand_num_ext_res default TRUE raw_err default FALSE realtime_ratio env. file 0 rec_err_suppress default FALSE record_gstats default FALSE repositories env. file stdmod script_mode default none script_name default odb_script seed env. file 128 sim_packet_sharing env. file conservative sim_process_priority default normal sim_time_quantum env. file 0 site_position_cache_size env. file 3 sitl_realtime_ratio_check default TRUE sla_compute_all_violations default FALSE split_start_radio_transmission default FALSE timezone default "Local Timezone" tmm_data_directory default <obsolete> tmm_data_type default "USGS DEM" tmm_display_degrees default FALSE tmm_include_antenna_height default FALSE tmm_load_as_needed default TRUE tmm_pathloss_cache_size default 2 tmm_prop_model default <null> tmm_prop_param default <null> tmm_propagation_specification default <null> tmm_propagation_zone_ratio default 0 tmm_propagation_zone_resolution default 100 tmm_simulate env. file FALSE tmm_terrain_cache_size default 10 tmm_terrain_specification default <null> tmm_use_cache default TRUE tmm_verbose default FALSE update_interval env. file 500000 updates_in_seconds default FALSE user_lock_devname default <null> verbose_load env. file TRUE verbose_mk default FALSE verbose_sim env. file TRUE warning_suppress default FALSE	

Maintenance	
Static Environment Attribute Confirmations	**Traffic Script**
----------Name---------- --Source--- ------Value------ ef cmd line IEC61850-Maintenance-DES-1 force_posix_locale default TRUE handle_exception default TRUE handle_exception_extended default TRUE mem_clear default 0 mem_opt.compact_pools default TRUE mem_opt.pool_small_blocks default TRUE mem_opt.grow_pool_planks default TRUE mem_optimize default TRUE mem_shred default FALSE tfile_dir_cache_file default opnet_dir_cache tfile_dir_cache default use	"_locale":"C" "anim_view": "false" "Application Tracking Directory": "<Primary Model Directory>" "ARP Sim Efficiency": "Enabled" "Background Traffic Start Delay": "1" "comp_trace_info": "kernel-based" "Custom Application Tracing": "Do Not Export" "default_site_position_cache_time_granularity": "0.0" "des.log_severity_filter": "-1" "DHCP Logging": "Disabled" "DSR Record Routes": "Enabled" "DSR Routes Export": "Disabled" "duration": "180.0"

```
noprompt                                cmd line    TRUE
opnet_dir                                   env. file   "C:\\Program
Files\\Riverbed EDU"
opnet_user_home                         shell var   C:\Users\Ngonini
preferences_default_save_location           env. file   Local
verbose_session_log                     default     FALSE
java_prog                                   config file "C:\\Program
Files\\Riverbed
EDU\\17.5.A\\jre7_modeler_ae\\JRE\\bin\\java.exe"
java_prog64                             default     java
3dnv                                    default     FALSE
3dnv.cleanup_at_the_end                 default     TRUE
3dnv.fed_file_name                      default     <null>
3dnv.federation_name                    default     OPNET_3DNV
3dnv.history_file                       default     <null>
3dnv.hla_standard                       default     "DOD 1.3"
3dnv.initialization_delay               default     1
3dnv.mapping_argument                   default     <null>
3dnv.mapping_library                                default
opnet_3dnv_default_mapping
3dnv.max_request_rate                   default     0
3dnv.rpr_fom_version                    default     1
anim_attempts                           default     5
anim_hist                               default     <null>
anim_host                               default     localhost
anim_port                               default     0
anim_timeout                            default     3
anim_view                               env. file   FALSE
antenna.spherical_model                 default     Mathematical
attr_reqs_file                          default     <null>
auto_disk_space_threshold               default     1000
automation_lock_max_wait_time           default     60
beep_count_confirm                      default     1
beep_count_error                        default     2
bind_shobj_flags                        default     <null>
bind_shobj_flags_32bit                  default     <null>
bind_shobj_flags_64bit                  default     <null>
bind_shobj_flags_devel                  default     /DEBUG
bind_shobj_flags_optim                  default     <null>
bind_shobj_libs                         default     <null>
bind_shobj_libs_32bit                   default     <null>
bind_shobj_libs_64bit                   default     <null>
bind_shobj_libs_devel                   default     <null>
bind_shobj_libs_optim                   default     <null>
bind_shobj_prog                         default     bind_so_msvc
check_newer_process_model_files         default     TRUE
comp.no_fin_required_for_state_vars     default     FALSE
comp_flags_32bit                        default     <null>
comp_flags_64bit                        default     /GS-
comp_flags_c++_specific                 default     <null>
comp_flags_c_specific                   default     <null>
comp_flags_common                           env. file   "/W3
/D_CRT_SECURE_NO_DEPRECATE
/IC:\\PROGRA~1\\RIVERB~1\\175~1.A\\models\\std\\include"
comp_flags_devel                        default     "/Z7 /Od"
comp_flags_mt                           default     <null>
comp_flags_optim                            default     "/Ox /Ob2
/DOPD_NO_DEBUG /DOPD_INLINE_KPS"
comp_globals_export                     default     FALSE
comp_object_files_without_source                    default
allow_with_warning
comp_per_process_errors                 default     TRUE
comp_prog                               default     comp_msvc
comp_prog_cpp                           default     comp_msvc
comp_trace_info                         env. file   kernel-based
console_exit_pause                      default     FALSE
cosim                                   default     <null>
```

```
"GNA API Safe Mode":        "Disabled"
"GRP Quadrant Size":        "2000"
"GRP Record Routes":        "Disabled"
"GRP Routes Export":        "Disabled"
"H323 Call Reports":        "Do Not Export Reports"
"H323 Reporting End Time": "End of Simulation"
"H323 Reporting Start Time":        "Beginning of
Simulation"
"Hybrid Simulation Efficiency":     "Enabled"
"IGMP Message DSCP":        "CS6"
"IGMP Sim Efficiency":      "Enabled"
"IMEP Route Injection":     "Disabled"
"Interface Buffer Congestion Threshold":        "0.8"
"IP Dynamic Routing Protocol":      "Default"
"IP Interface Addressing Mode":     "Auto
Addressed"
"IP Routing Table Export/Import":   "Not Used"
"IP Routing Table Source":  "Flow Analysis"
"IP Version Preference":    "IPv6"
"IPv6 Configuration":       "Consider"
"IPv6 Interface Address Export":    "Disabled"
"IPv6 ND Simulation Efficiency":    "Disabled"
"LACP Simulation Efficiency":       "Enabled"
"Link Usage Report":        "Disabled"
"log_endsim_perf": "true"
"log_file":         "IEC61850-Maintenance-DES-1"
"LSP Signaling Protocol":   "RSVP"
"max_log_entries": "200"
"num_collect_values":       "100"
"ot_file": "IEC61850-Maintenance-DES-1"
"ov_file":"IEC61850-Maintenance-DES-1"
"parallel_sim.event_execution_time_window":    "0.0"
"parallel_sim.mem_balance_interval":    "100,000"
"parallel_sim.num_processors":      "1"
"PIM Message DSCP":         "CS6"
"PIM-SM Sim Efficiency":    "Enabled"
"probe":  "IEC61850-Maintenance"
"realtime_ratio":    "0.0"
"RIP Message DSCP":         "CS6"
"RIP Sim Efficiency":       "Enabled"
"RIP Stop Time":    "65"
"RIPng Sim Efficiency":     "Enabled"
"RIPng Stop Time":          "65"
"Routing Activity Idle Timer":      "20"
"RTP API Safe Mode":        "Disabled"
"seed":    "128"
"sim_packet_sharing":       "conservative"
"sim_time_quantum":         "0.0"
"site_position_cache_size":    "3"
"Switch Sim Efficiency":    "Enabled"
"TCP Real Payload Support":"Auto"
"tmm_simulate":     "false"
"TORA Animated Destination RID":    "Specify..."
"TORA IMEP Animation Refresh Interval":     "10"
"TORA IMEP Efficiency":     "Disabled"
"TORA IMEP Packet Delivery Cache Update":
        "100"
"TORA Infinite Loop Prevention":    "Disabled"
"TORA Max Communication Distance":
        "1150"
"TORA Mode of Operation": "Default"
"Tracer Packet Redundancy": "Enabled"
"Tracer Packets Per Interval":"2"
"Traffic from Link Loads":      "Include"
"Traffic from LSP Loads":       "Do Not Include"
"Traffic from Traffic Flows": "Include"
"Traffic from VC Loads":    "Do Not Include"
```

cosimulation_optimization_mode default none debug_mk default FALSE default_site_position_cache_time_granularity env. file 0 des.log_severity_filter env. file -1 diag_enable default FALSE display_timezone_string default FALSE duration env. file 180 edit_lock_mode default FALSE endsim_memstats default FALSE etrace_diff default <null> etrace_dump default <null> etrace_end_time default 1e+100 etrace_start_time default 0 event_order_method default strict event_speed_parameter default 100000 file_read_abort_suppress default FALSE format_event_ids_with_1000s_separator default TRUE format_ici_ids_with_1000s_separator default TRUE format_object_ids_with_1000s_separator default TRUE format_packet_ids_with_1000s_separator default TRUE format_process_ids_with_1000s_separator default TRUE fully_serialized_event_execution_ids default TRUE fully_serialized_ici_ids default TRUE fully_serialized_packet_ids default TRUE geocentric_model default right_sphere invalid_link_notification default TRUE kernel_type env. file optimized license_broker_host default <null> license_broker_port default <null> license_expiration_warning_interval default 3 license_group default <null> license_http_proxy_password default <not set> license_http_proxy_port default 80 license_http_proxy_server default <null> license_http_proxy_user default <null> license_http_server default license01.opnet.com license_http_use_proxy default FALSE license_password default <not set> license_port default port_a license_server default localhost license_server_standalone default FALSE license_server_standalone_diagnose default FALSE license_username default <null> livelock_thresh default 8192 log_endsim_perf env. file TRUE log_file env. file IEC61850-Maintenance-DES-1 log_time_precision default 12 manage_loanable_licenses default FALSE max_idle_time_microseconds default 1 max_log_entries env. file 200 memstat_autogen default <null> mtn_warn_int default 3 named_locks default FALSE net_name cmd line IEC61850-Maintenance num_collect_values env. file 100 num_err default 10 ot_file env. file IEC61850-Maintenance-DES-1 ot_file.default_format default write_many ot_mem_size default 4 ov_autogen default <null> ov_diff_tolerance default 5 ov_file env. file IEC61850-Maintenance-DES-1 ov_mem_size default 16 parallel_sim.event_execution_time_window env. file 0	"Traffic Scaling Factor": "1.0" "Traffic Scaling Mode": "Background Traffic" "update_interval": "500,000" "verbose_cell_size_report": "false" "verbose_event_report": "false" "verbose_event_timing_report": "false" "verbose_load": "true" "verbose_packet_report": "true" "verbose_parallel_speedup_report": "false"

```
parallel_sim.mutex_rank_ignore              default     FALSE
per_module_random_stream                    default     FALSE
probe                                  env. file   IEC61850-Maintenance
probe_error_enable                          default     FALSE
probe_start_time                           default     -1
probe_stop_time                            default     -1
prof_output                               default     console
prof_output_separator                       default     <null>
prof_track_func                           default     <null>
prof_track_recurse                         default     TRUE
psnone_tda.bu.closure.closure               default     TRUE
psnone_tda.bu.collision.num_colls           default     0
psnone_tda.bu.ecc.pk_accept                 default     TRUE
psnone_tda.bu.error.num_errors              default     0
psnone_tda.bu.propdel.prop_delay            default     0
psnone_tda.bu.txdel.tx_delay                default     0
psnone_tda.pt.ecc.pk_accept                 default     TRUE
psnone_tda.pt.error.num_errors              default     0
psnone_tda.pt.propdel.prop_delay            default     0
psnone_tda.pt.txdel.tx_delay                default     0
psnone_tda.ra.ber.ber                      default     0
psnone_tda.ra.bkgnoise.bkgnoise             default     0
psnone_tda.ra.chanmatch.match_status        default     valid
psnone_tda.ra.closure.closure               default     TRUE
psnone_tda.ra.ecc.pk_accept                 default     TRUE
psnone_tda.ra.error.actual_ber              default     0
psnone_tda.ra.error.num_errors              default     0
psnone_tda.ra.power.rcvd_power              default     -1
psnone_tda.ra.propdel.end_propdel           default     0
psnone_tda.ra.propdel.start_propdel         default     0
psnone_tda.ra.ragain.rx_gain                default     0
psnone_tda.ra.snr.snr                      default     1000
psnone_tda.ra.tagain.tx_gain                default     0
psnone_tda.ra.txdel.tx_delay                default     0
radio_transmission_defer_packet_duplication  default     TRUE
radio_transmission_on_demand_receiver_groups            default
FALSE
rand_gen_type                           default     Linear-Congruential
rand_num_ext_res                            default     TRUE
raw_err                                 default     FALSE
realtime_ratio                            env. file   0
rec_err_suppress                            default     FALSE
record_gstats                             default     FALSE
repositories                              env. file   stdmod
script_mode                               default     none
tmm_propagation_specification               default     <null>
tmm_propagation_zone_ratio                  default     0
tmm_propagation_zone_resolution             default     100
tmm_simulate                              env. file   FALSE
tmm_terrain_cache_size                      default     10
tmm_terrain_specification                   default     <null>
tmm_use_cache                             default     TRUE
tmm_verbose                               default     FALSE
update_interval                           env. file   500000
updates_in_seconds                          default     FALSE
user_lock_devname                           default     <null>
verbose_load                              env. file   TRUE
verbose_mk                                default     FALSE
verbose_sim                               env. file   TRUE
warning_suppress                            default     FALSE
```