OPTICAL INTERNET: A COMPARATIVE ASSESSMENT ON TCP OVER OBS NETWORKS SIMULATION TOOLS

K.Muthuraj[1] and N.Sreenath[2], [1] Research Scholar, [2] Professor, Department of CSE, Pondicherry Engineering College

Abstract

Optical Internet has become the main conduit for all types of virtually sharing communications around the world as it continues its phenomenal growth of in traffic volumes and reaches using dedicated optical routers. A network simulator is a piece of software or hardware that predicts the behavior of a network, without an actual network is being present. Sufficient amount of research work done in network performance using these simulators and it is the most frequently used instruments, in comparison with analytical tools and in situ measurements. Optical burst switching (OBS) is a predominant switching technology for Optical network to cater the huge bandwidth demands and Transmission control protocol (TCP) is the prevailing mechanism to support the Internet. Hence TCP over OBS has become standard for Optical Internet and where the use of modeling and simulation tools is very important. This paper describes the comparative assessment study on various significant simulators on TCP over OBS networks, which is helpful for taking the best choice of simulation tools for academic and future research development on Optical Internet.

Keywords - Optical internet, TCP over OBS simulation tools, Network simulators, Network simulation tool.
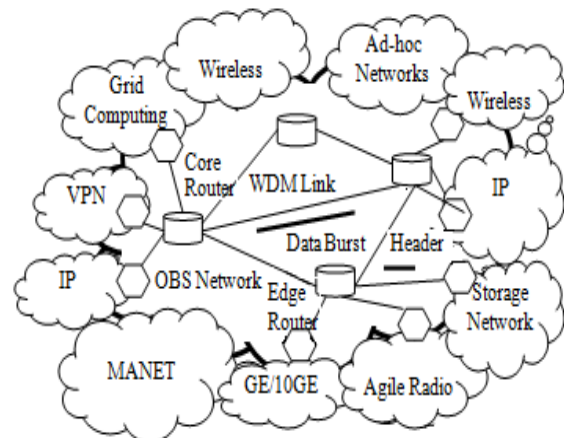
Introduction

The benefits of Optical Internet have been known for quite awhile; but it was not until the invention of wavelength division multiplexing (WDM) that the potential of fiber was fully realized. This divides the available bandwidth of the fiber into a number of separate wavelength channels and allows tens or hundreds of wavelength channels to be transmitted over a single optical fiber at a rate of 10 Gb/s/channel and beyond. This means that the data rate can reach 10 Tb/s in each individual fiber [1]. To carry IP traffic over WDM networks three switching technologies exist namely optical circuit switching (OCS), optical packet switching (OPS) and optical burst switching (OBS) [2]. Optical circuit switching, also known as lambda switching, can only switch at the wavelength level, and is not suitable for bursty internet traffic. Optical packet switching, which can switch at the packet

level with a fine granularity, is not practical in the foreseeable future. The two main obstacles are lack of random access optical buffers, and optical synchronization of the packet header and payload. Optical burst switching can provide fine granularity than optical circuit switching, and does not encounter the technical obstacles that optical packet switching faces. OBS is considered the most promising form of optical switching technology, which combines the advantages and avoids the shortcomings of OCS and OPS as tabulated in Table1 [3-4].

Table 1. Scope of Switching Technology

Technology	OBS	OPS	OCS
Bandwidth	High	High	Low
Latency	Low	Low	High
Buffering	-	Required	-
Overhead	Low	High	Low
Adaptively	High	High	Low
Switching Speed	High	Fast	Slow

The illustration of Optical Burst switched network in Optical Internet as shown in below Figure 1.

Figure 1. Illustration of Optical Internet

Optical Burst Switching Technology is not only supporting the increasing demands for bandwidth traffic but also

some sort of Quality of Service (QoS) and network security. Simulators are essential to evaluate how OBS technology has influenced the network performance. This analysis is to compare the support of the most relevant simulation tools in scientific and academic research, for specific features of TCP over OBS networks and other general capabilities also.

The remainder of this paper is organized as follows. The architecture of OBS and about in-band and out-of-band signaling with its functional diagram is described in Section 1. The Section 2 explains the TCP over OBS networks in Optical Internet. The Section 3 demonstrates the characteristics analyzed for each studied OBS simulation tool. Comparative study of the simulators is discussed in Section 4. Finally we conclude and notify the future work in Section 5.
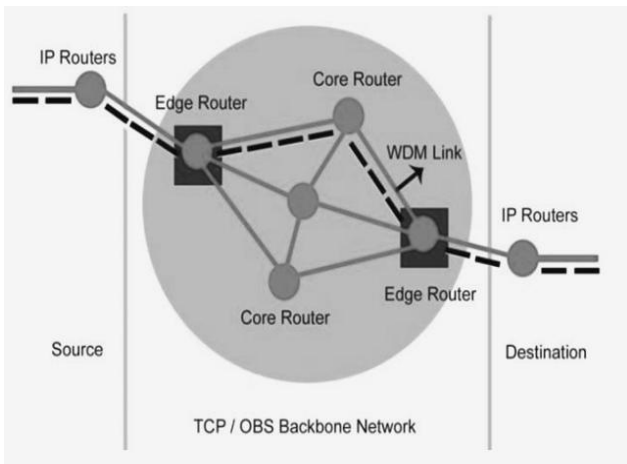
1. Architecture of OBS

Figure 2. Optical Burst Switching Architecture

In general, OBS network is composed of two types of routers, namely edge routers and core routers shown in Figure 2. Edge routers represent the electronic transit point between the burst-switched backbone and IP routers in an Optical Internet. The assembling of bursts from IP packets and disassembling of burst into IP packets is carried out at these edge routers. Core routers are connected to either edge routers or core routers. It transfers the incoming optical data into an outgoing link in the optical form without conversion of electronic form. In OBS, the basic switching entity is the burst which contains the number of encapsulated packets. For every burst there is a corresponding Burst Control Header (BCH) to establish a path from source to destination. BCH of a connection is sent prior to the transmission of Data Burst (DB) to specific offset time on the same wavelength channel is termed as an In band signaling shown in Figure 3.
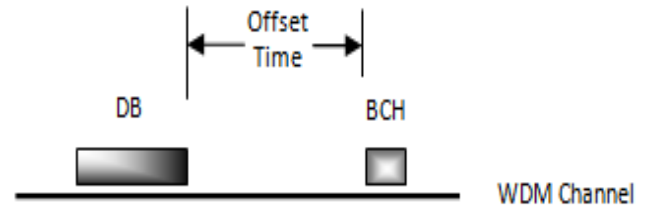

Figure 3. In – band Signaling

All BCH's of various connections are sent on the same control channel and their corresponding DBs will sent on the different channels with specific offset time named as out – of – band signaling is shown in Figure 4.
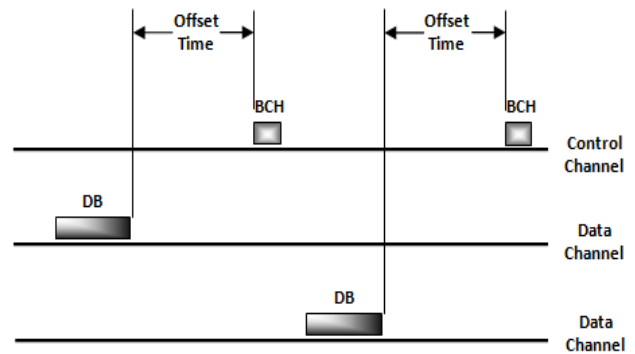

Figure 4. Out – of – band Signaling

The Offset time is the transmission time gap between the BCH and DB, which is used to allow the control part in intermediate core nodes to reserve the required resources for the onward transmission of bursts [5].
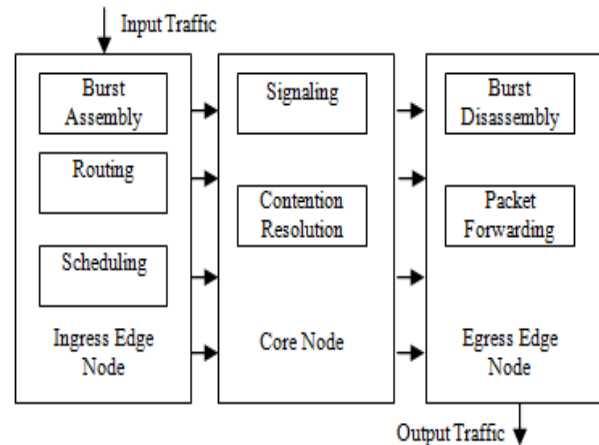

Figure 5. OBS Functional Diagram

The OBS functional diagram is shown in Figure 5. It describes the ingress node is responsible for burst assembly, routing, wavelength assignment and scheduling of burst at

the edge node. The core node is responsible for signaling and contention resolution. The egress edge node is responsible for disassembling the burst and forwarding the packets to the higher network layer.

2. TCP over OBS Networks

In a TCP/IP network, IP layer is involved in routing of packets, congestion control and addressing the nodes. When OBS is introduced into the network, it takes care of routing of data and congestion control. The routing information computed by IP layer need not be considered by OBS routers. It is because, the routes at the OBS are computed based on number of hops and wavelength availability. However, the addressing of the various nodes in the network does not take care by OBS by default. Hence the functionality of IP may be limited to addressing and packet formation. Due to above reasons, this proposal considers the stack TCP/OBS rather than TCP/IP/OBS shown in below Figure.6. [6].
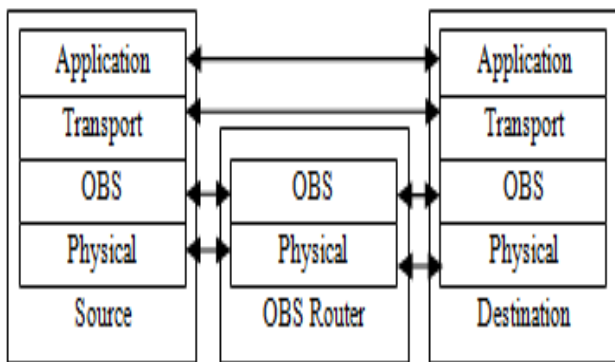

Figure 6. TCP over OBS Layer Architecture

3. Analysis of OBS Simulation Tools

It is very difficult for researchers to test the scenarios in the real world networks. Simulation is one of the important technologies in modern time. Simulation depicts the actual network by means of software. Simulation is very economical because it can carry out experiments without actual hardware. Next subsections present each simulator in detail which carried out TCP over OBS networks in Optical Internet.

A. NCTUns

NCTUns stands for National Chiao Tung University network Simulator. Harvard Network Simulator authored by S.Y.Wang is the predecessor of NCTUns, which was composed in 1999 [7]. NCTUns is one of the network simulator

and emulator capable of simulating various protocols used in both wired and wireless medium as described in Figure.7. Novel kernel re-entering methodology is the core technology used by NCTUns. It simulates many different and new types of networks. User can easily conduct network Simulations very quickly and easily by using the professional GUI environment provided in NCTUns. Topology used for the NCTUns is done by using a component topology editor [8].

The NCTUns uses a distributed architecture. Thus it helps to support remote simulations and concurrent simulations. Protocol modules can be easily enabled by using open-system architecture in NCTUns. Functionally, it is divided into eight separate components.
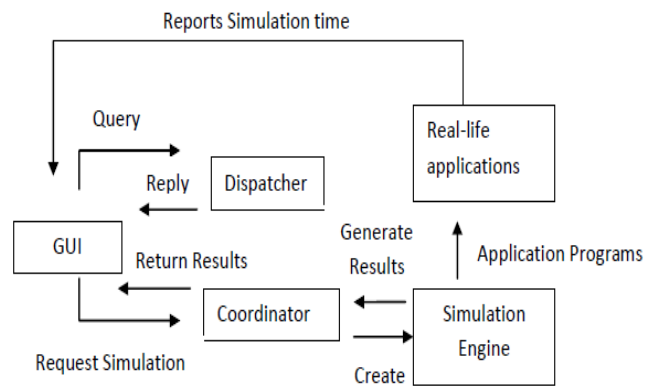

Figure 7. Architecture of NCTUns

A. 1. Advantages

- ✓ Users can easily perform the simulation studies using fully-integrated GUI environment.

- ✓ Network topology can be easily constructed using the topology editor.

- ✓ New protocol modules can be easily added to its simulation engine by using distributed and open-system architecture design which supports remote simulations and concurrent simulations.

- ✓ Simulating Single-hop Networks and Multi-hop Networks are the main features of the NCTUns.

A. 2. Disadvantages

- ▪ User has to set the parameters. So, programming is not possible here.

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- The main disadvantage is that manipulation has to be done at every node in the path or all nodes at the same time.

- It is not well suited for simulating the OBS networks.

B. ns2

It is the most popular network simulator used by researchers. It comes under discrete event simulator [9]. The upgraded version of the REAL Network Simulator is NS2, evolved in 1989 [10]. It mainly supports simulation of TCP, routing and multicasting protocols mostly in wired networks as shown in Figure. 8. This Simulator mainly works under C++, to define the protocol behaviors. Emulated network is also possible in NS2 simulator. With this facility, NS2 can be connected to a real network and can able to capture live packets.
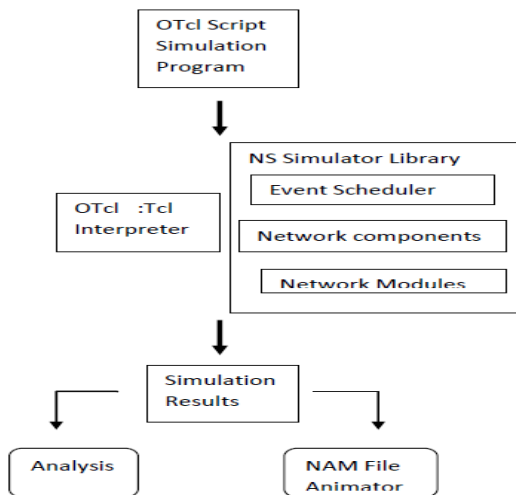

Figure 8. Architecture of ns2

ns2 is based on two languages, C++ to extend simulator and OTcl for configuration, manipulation [11]. Inputs have to be given by user to OTcl code to visualize the network. Further simulation and visualization can be done with the help of Nam file [12]. The main drawback is that Nam file cannot be used for accurate simulation analysis. Limitation is given for changing the node appearance. For plotting graph, external tools like Xgraph must be used [13]. One drawback is that NS2 needs to be recompiled every time when there is a change in user code.

B.1. Advantages

- Extensibility of network components is present in NS2

- It supports a wide range of Protocols.

- The main Advantage is that NS2 supports Emulation facility.

- Saving the CPU Resources when personalizing Trace Files.

B.2. Disadvantages

- Graphical User Interface is not well supported in NS2.

- Recompilation needs to be done every time when the user changes the code.

- Very difficult to analyze and understand the code.

- Performance will be reduced when the number of nodes increases.

- Not well suited for the Optical components when not patched with some other protocols.

- When the number of nodes increases, it will lead to decrease the simulation time.

C. OPNET

OPNET stands for OPtimized Network Engineering Tool. It was founded by OPNET Technologies. It is initially proposed in 1986 and after that developed by Massachusetts Institute of Technology in 1987 [14]. Programming Language used here is C++. OPNET has the capability of simulating heterogeneous networks. More number of editors are included in Graphical User Interface to create, modify, verify analysis and displays the simulation results. The important feature of OPNET is that simulation models can be built using hierarchical fashion. Many numbers of pre-defined types of nodes are present. Nodes contain set of transmission and reception modules. The functions of various levels in OPNET are described in below Table 2.

Table 2. Functions of various levels in OPNET

Level	Functions
Network Level	Handles Topology Modeling and overall configuration
Node Level	Internal Structures of the nodes like Transmitters and Receivers.
Process Level	Functionalities of Node Level

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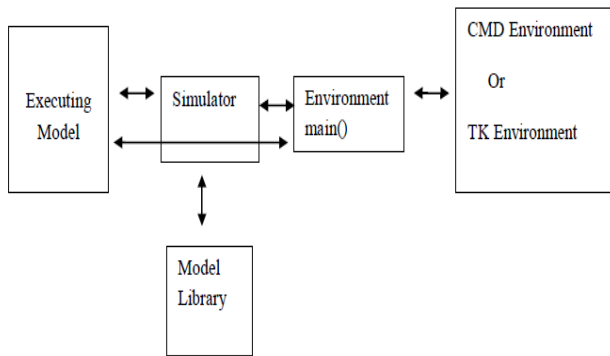|	Devices.
Proto-C Level	Source Code

C.1. Advantages

- ✓ Different Routing Protocols are supported by the OPNET

- ✓ There are many features available in the OPNET which supports the Quality of Service.

- ✓ Extensibility of the new protocols is very high in OPNET and supports GUI.

C.2. Disadvantages

- ▪ Not well suited for Optical layer components.

- ▪ The cost of license is very expensive.

- ▪ Not supports the analytical analysis and on-line analysis of Output data.

D. OMNET++

Objective Modular Network Testbed (OMNeT++) is a discrete event simulator tool. Mostly OMNeT++ supports the wireless and mobile simulations [15]. The architecture of the OMNeT++ is composed based as shown in Figure. 9..

Figure 9. Architecture of OMNET++

C++ language is used here. Components, Modules are programmed using the C++ and C++ class library are used to carry out the topology discovery, statistics collection. High level language called Network Description is used here. It is used to assemble the individual components. Kernel library

contains Graphical Network Editor (GNED), a NED compiler, command line. OMNeT++ model consists of Modules. Modules communicate via message passing by sending and receiving messages. Each Module is able to generate, read or react to messages. Modules consist of parameters which are used to customize the behavior of the Modules

D.1. Advantages

- ✓ OMNeT++ provides the powerful GUI.

- ✓ GUI makes the tracing and debugging much easier than other simulators.

- ✓ Credibility of the system is well supported.

- ✓ Hardware requirements are moderate in OMNeT++ system.

- ✓ New Features and Protocols can be supported through Modules.

D.2. Disadvantages

- ▪ It does not offer a great variety of protocols.

- ▪ The user cannot able to work with their significant background if they want to test their own protocol in different environments.

- ▪ Poor Documentation and poor analysis of typical performance measure.

E. OBSns

OBSns is one of the extensions to the NS2 simulator. DAWN Networking Research Lab from University of Maryland released the OBSns. OBSns is an event-driven simulator built on NS2. Predecessor to the OBS ns is OIRC OBSns [16]. As from the name, it is mostly used to simulate the Burst switching Networks. To run the OBS simulation, it is necessary to create OTcl script. This OBSns provides more features of extended list of OTcl parameters with default values. These parameters are used to specify details about OBS, such as the delay used of in FDL at end of link, the size of BHP and DB overhead, the burst timeout, the maximum burst size, the offset time for class and the edge node

electronic buffer size. Based on available documentation and our experiments, it was not possible to determine which resource reservation protocols are supported in this simulator. OBS-ns simulation output is written to statistics and trace files which can be processed using whatever tools the

user desires, but in order to facilitate the process of getting results from the raw data, this simulator offers the possibility to plot graphs that analyze the throughput, delay and loss rate[17].

E.1. Advantages

- ✓ The cost of the license is free

- ✓ Provides extended list of OTcl parameters with default values.

E.2. Disadvantages

- ▪ OBSns simulator implements only the shortest path routing Mechanisms.

- ▪ There is no Better Protocols supported for the OBSns.

- ▪ Lack of providing better documentation.

F. nOBS

ns2 based OBS (nOBS) mainly used for simulating the Optical layer components. Any Routing can be simulated using nOBS. Extending version of NS2 version 2.27 is used to develop the nOBS [18-19]. Since, nOBS mainly concentrate on Optical layer components, the nodes and links are modified into Optical Nodes and Optical Links. nOBS enables performance analysis of OBS networks with wavelength converters and FDLs carrying TCP traffic. It implements various Burst Assembly, Scheduling and Routing Algorithms. One of the first NS2 based OBS network is OWns. It uses the older version of NS2.OIRC OBSns is a redesigned version of OWns. OBSns does not allow simulating a network structure composed of OBS Networks. The main advantage of the nOBS is that it simulate general OBS network topologies composed of Optical Clouds. Basically for a TCP connection there will be addressed classifier at the node entrance. This address classifier is replaced by classifier in nOBS.

F.1. Advantages

- ✓

- ✓ nOBS uses the Just-Enough-Time (JET) reservation Protocol.

- ✓ The routing of the bursts within the OBS network is performed in nOBS using minimum-hop path between the ingress node and egress node.

- ✓ Differentiation of the TCP segments from the Optical bursts.

- ✓ The User can able to specify the number of Fiber Delay Lines and Wavelength Converters at each node.

F.2. Disadvantages

- ▪ The user cannot able to understand coding easily in short time of period.

- ▪ Sometimes Burst losses will take place due to the increase in the number of assemblers per destination node.

- ▪ Cannot use with the Reservation Protocol Tell and Wait (TAW), because it depends on Acknowledgements of destination.

G. GLASS/SSFnet

Lighwave Agile Switching Simulator (GLASS) is a Java– based network [20]. Simulation tool is used to facilitate the evaluation of routing, restoration and signaling protocols in and optical environments. It is also used to study the behavior of algorithms and protocols. SSFNet as shown in below Figure. 10. It is the basic framework by means of handling discrete events, the ability to run on multiprocessors and the scalability to large numbers of nodes. SSFNet provides many network protocols. GLASS uses the Data Modeling Language (DML). DML is used to design the topology and derive scripts for the simulation scenarios. GLASS Simulator extends the SSFNet components with an implementation of MPLS, optical components such as Optical Cross Connects (OXC), edge routers, optical links, fibers. One of the important design goals of the GLASS has been the modularity.

of features including graphical visualization, support for disk serialization of topologies and execution of common graph algorithms. It is thanks to these core packages that the user can rapidly develop and test network planning procedures through the construction of simulation models [21].
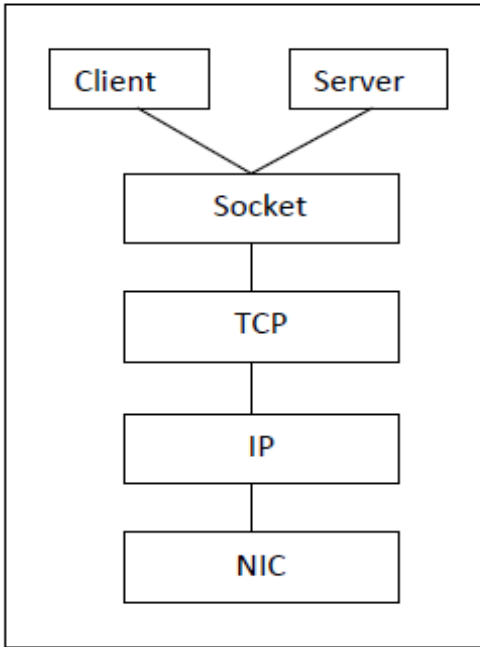
Figure 10. SSFNet Graph

G.1. Advantages

✓ User can choose their Modular structure of their choice.

✓ Data modeling language usage in the GLASS designs the topology.

✓ Provides fast restoration from the Optical Link failures.

G.2. Disadvantages

▪ Documentation is currently not adequate

▪ The validity of the Modules is not yet verified.

▪ Simulation result reporting is not adequate.

H. JAVOBS

The JAVANCO framework is programmed within the Java 1.6.0 platform, using the popular Java programming language. It has been conceived to provide a coherent object oriented structure that is able to properly represent graph and network topologies in a compelling yet versatile way. Over this fundamental structure, several packages offer a variety
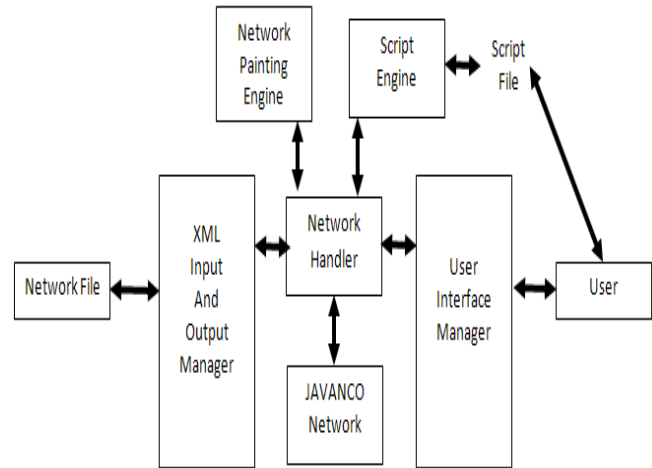

Figure 11. Architecture of JAVOBS

Figure.11. shows a general representation depicting the architecture of JAVANCO. The cornerstone of its architecture is the Network Handler object, in charge of both organizing the references towards each object composing the graph (i.e. layers, links and nodes) and providing access to several managers and engines (e.g. user interface manager, serialization manager, script engine). JAVANCO permits to load and save files that describe network topologies and their components. Taking advantage of this description format, it is easy to associate several attributes to any element present in a network topology (e.g. the capacity in a link). JAVANCO embeds a script engine which allows calling any functionality of the framework and dispenses the user to write complete Java classes. It also supports different kinds of user interfaces.

4. Comparisons of OBS Simulators

In this section we summaries the network simulators of OBS in the Table 3a and 3b. It has seven simulators compared with each other using some of the features.

Table 3a. Comparisons of OBS Simulators

Simulators	Scalability	Credibility	GUI	Language
NCTUns	Small	No	Yes	C++
NS2	Medium	Satisfactory	Yes	C++ & OTcl
OPNET	Large	Satisfactory	Yes	C++
OM-NET++	Small	Excellent	Yes	C++
OBSns	Large	No	No	C++
nOBS	Large	Excellent	Yes	C++ & OTcl

| GLASS/ SSFNet | Medium | No | Yes | Java |
| JAVOBS | Large | Yes | Yes | Java |

Table 3b. Comparisons of OBS Simulators

Simulators	Extendibility	Support for Optical Components	Cost of License
NCTUns	Yes	Not Supported	Free
NS2	Fully Supported	Less Support	Free
OPNET	Fully Supported	Not Supported	Expensive
OM-NET++	Fully Supported	Partially	Free
OBSns	No	Supported	Free
nOBS	Fully Supported	Fully Supported	Free
GLASS/ SSFNet	Partially Supported	Not Supported	Free
JAVOBS	Yes	Yes	Trial

5. Conclusion and Future work

Optical Burst Switching will become the most widely used technology in mere future in Optical Internet because of its speed and as it provides an end to end optical path between communication parties and appears as a good solution to be the infrastructure of the next generation networks. So the current stage of their studies simulation is essential to evaluate the behavior, performance and to help to improve them. We described the network Simulator that supports the Optical Internet (NCTUns, NS2, OPNET, OMNeT++, OBSns, nOBS, GLASS/SSFNet and JAVOBS) features, advantages and disadvantages. However, some work remains to be done, since it does not support any kind of animation or real time viewing of the simulation, and its user interface and output analysis are not user friendly.

The above work can be extended making the simulator validation, for example by verifying that each of the simulators implementations accurately the OBS network model in Optical Internet, devices and subsystems (entities). This is our interest for future work.

Acknowledgments

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Biographies

K. MUTHURAJ received the B.E. degree in Computer science and Engineering from the Madurai Kamaraj University, Madurai, Tamilnadu, India, in 2000, the M.E. degree in Computer science and Engineering from the Anna University Chennai, Tamilnadu, India, in 2008, respectively. Currently, He is a research scholar and pursuing Ph.D degree at Pondicherry Engineering College, puducherry, India. His research areas include Optical Internet, Computer Networks, and Network Security.

DR. N. SREENATH received the B. Tech. degree in Electronics and Communication Engineering from the JNTU College of Engineering, Ananthapur, Andrapradesh, India, in 1987, the M.Tech. Degree in Computer science and Engineering from the University of Hyderabad, Hydrabad, India, in 1990, and the Ph.D. degree in Computer science and Engineering from the IIT Madras, Chennai, Tamilnadu, India, in 2003, respectively. Currently, He is a Professor of Computer science and Engineering Department at Pondicherry Engineering College, Puducherry, India. His teaching and research areas include High speed networks and Optical networks.