

Investigation into strengths and weaknesses of freeware network simulation tools for educational purposes

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### **Title:**

Investigation into strengths and weaknesses of freeware network simulation tools for educational purposes

### **Academic Questions:**

1. Which is the best tool networking simulation tool/package for students and teachers of level 5, Level 6 ?

### **Aims:**

1. To investigate into the strength and weakness of the Network simulating tools.
2. To compare the weakness and strength of the simulation tools for teaching network.
3. Recommend network simulation tool for level 5 and 6 module for educational purposes.
4. Create a simulated network to assess each tool.

### **Objectives:**

1. Assess the performance of different simulation tools for teaching.
2. Design different network topologies using various types of nodes such as end hosts, hubs, network bridges, routers, optical link-layer devices and investigate the strengths and weaknesses.
3. Comparing the tools and features in terms of their suitability for teaching.

4. Produce a report with recommendations.

## **Introduction**

The point of this venture is to cover few freeware network simulation tools used by universities and students, and to select two of them for deep investigation and comparison to see which one tool is most appropriate for learning at level 5. The OPNET and GNS3 Simulation programming bundles, which are uninhibitedly accessible in PC labs, will be depicted in detail.

The contrasts between test systems will be examined by making case situations and applying each of the test systems to and acquiring the results. Test systems OPNET and GNS3 will be contrasted with a genuine system with assess the exactness and ease of use of the two. Some basic examinations of reproduced system movement on a picked topology will be completed. Consequences of the recreation techniques will be researched with a correlation with see circumstances each of the apparatuses will be (Prokkola, 2006).

## **Background:**

Simulation can be characterized as an endeavour to anticipate the conduct of a few frameworks by reproducing PC organizes that looks like the framework being concentrated on.

In this venture organize test systems will be utilized to reproduce arrange frameworks from which information will be moved crosswise over amongst hubs and expectations on lining, deferrals and preparing activities of the framework recreated. In this venture, four test systems, OPNET, NS-3, and will be utilized examinations made to choose the best to teach at level 5.

Keeping in mind the end goal to pick reproduction apparatuses, correlation is produced using various recreation instruments that are effortlessly accessible for people in general. The examination made to the instruments deliver a proposal of which apparatus is to be picked in various study situations (Expósito et al, 2010).

Arrange test systems have been utilized to consider the conduct of system models and conventions. The outcomes have been the premise of creating system design and steering conventions. This is accomplished by altering the correspondence channels of the hubs and conduct of the system hubs. The succession of occasion's structures the directing conduct of hubs that will be broke down and used to assemble PC systems.

Arrange Simulators are imperative I their conspicuous use in ventures, examine and in Instructive organizations. Business instruments like OPNet modeler, ns-3 test systems are prevalent in the exploration area (Nizar et al, 2000).

## **Methodology:**

Research methodology generally reflects the processes followed to achieve the desired objectives associated with a research. In this project work detailed investigation will be made on the strengths as well as weaknesses of network simulation tools available freely as freeware for educational usages.

For gaining the initial understanding over the most widely used freeware simulation tools detailed literature review will be carried out. This includes collecting critical and relevant information and data from different sources such as verified online articles, journal papers, books, conference proceedings etc. Then the identified network simulation tools will be analysed in details in terms of strength and weaknesses based on detailed literature reviews.

It is also imperative for this project to validate the literature findings. As the analysed simulation tools are freeware effectiveness of these tools will be through simulations. Suitable test cases for simulating each of these tools will be prepared and subsequently simulations will be carried out. This hands-on experience of the freeware network simulation tools will validate all the strengths and weaknesses reported in literature.

## **Artefact (Proposed):**

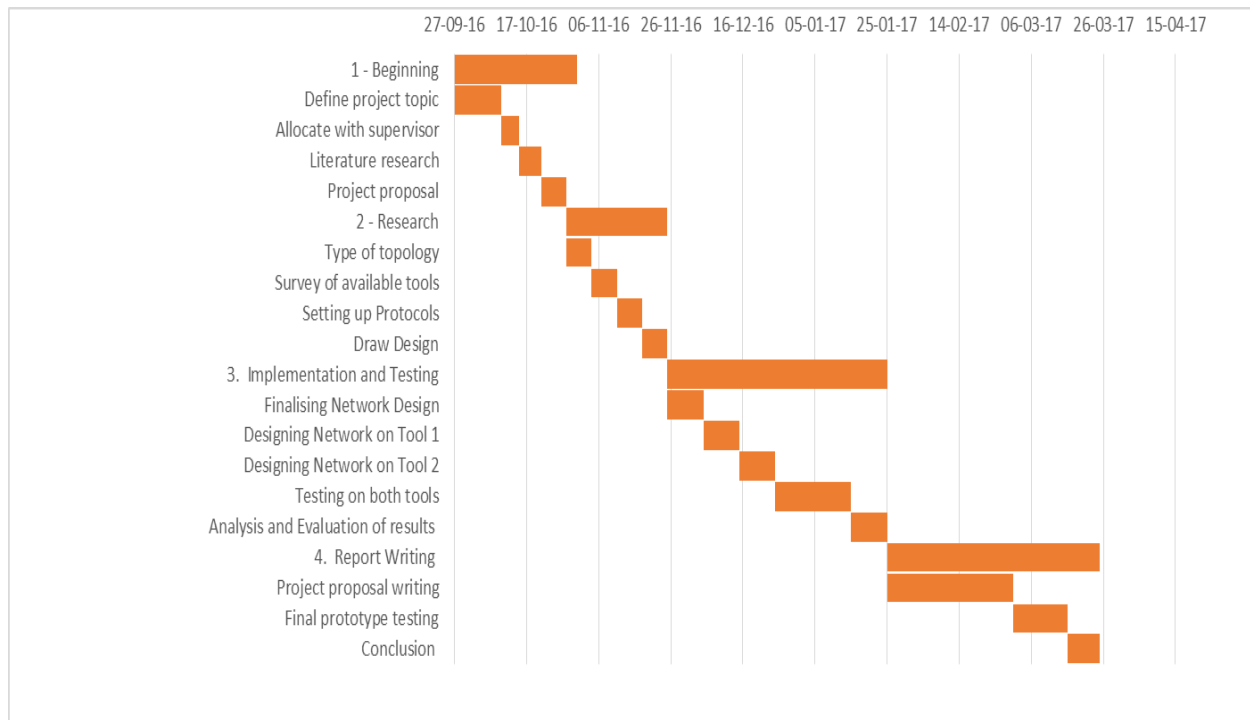
The final artefact will be a full simulated network that is working in both of the tools. At this stage a suggestion of the most appropriate tool for teaching is identified with explaining.

The waterfall development cycle will be used to successfully develop the artefact. The artefact will go through three stages; design, development, and test.

1. Design will be as follows
  - a. Network planning parameter setup
  - b. By choosing the topology and the devices for the network.
2. Development of network to implement the designed network on the simulation tool.
3. Test
  - a. Usability of the tool
  - b. Ranking the tool

The details of the final artefact will be presented in the final report. The main aim of the project is to suggest the most appropriate tool for teaching with explaining and documentation.

## **Gantt Chart**



## Literature Review

### Initial Review of few existing freeware Network simulators:

In this research, we are going to survey and compare 6 open-source network simulation tools to find out which one of these 6 suits best for the students studying at level 5 or 6. We are going to compare these tools on the basis of literature available on these tools to find out the advantages and disadvantages of using these tools. Following are the tools selected for the comparison.

#### 1. NS-2 (Network Simulator 2):

NS-2 is one of the most Network Simulator. It was developed by Lawrence Berkeley Laboratory at the University of California, Berkeley, as part of the Virtual InterNetwork Testbed (VINT) project. NS-2 is object-oriented discrete-event network simulator and is written using C++ language and OTcl is used for command and configuration interface.

The main advantage of this tool is its free availability and can be used various operating systems. A number of Published research papers with NS-2 code are available which can be used by other Master's or PhD. Level students by further building upon existing codes for network modelling and network performance evaluation.

The major weakness of NS-2 is the output is a raw data that needs to be processed using other scripting tools (Fall, 2011). NS-2 is also not very easy to learn because of its text-based

interface, although the tutorials by Gries (2011) are very helpful, but still due its split-programming model, it is difficult to learn.

## **2. NS-3 Simulators:**

NS-3 is the most recent adaptation of the ns arrangement which was made for an indistinguishable reason from ns-1 and ns-2 (research and educating). NS-3 has included element that adjusts to situations material to ebb and flow organizing research which permit approval and alterations from research group. These elements empower dynamic assessments, testing and upgrading of the product to be initiated by the specialists, clients and program designers (Siraj et al, 2012).

GNS3 is an open source Graphical Network Simulator which is intended to take a shot at Windows, XP Mac and Linux working frameworks. It can be downloaded effectively from GNS3 website. GNS3 is in a perfect world intended to work with Cisco IOS and it is best utilized for learning and testing purposes and in labs environment. For understudies concentrating on for a Cisco examinations, for example, CCNA, CCNP and CCIE, it is the device they find extremely helpful. GNS3 does not break down system execution. It is helpful in that you can make a reproduction arrange you need to outline. A virtual recreation of a current system with GNS3 will empower one to view all areas of the system to incorporate gadgets, for example, principle switches, switches and PC hubs. This will empower blunders in the current system to be analyzed and arrangements created and actualized. Setting up a GNS3 virtual system will empower parcels to be caught utilizing Wireshark (Nizar et al, 2000).

In downloading the product, the GNS3 set up wizard will start and will lead the establishment effectively. GNS3 relies on upon various different projects to run. These incorporate WinPCAP, Dynamips and Qemu. These can be introduced in their default organization to begin with however can be designed at a later stage. WinPCAP is utilized by GNS3 to speak with genuine systems.

### **GNS3 Features:**

GNS3 has the accompanying elements that make it an imperative instrument in recreation and imitating:

- Design complex system topologies
- Emulation of Cisco switch stages
- Connection of the recreated systems to this present reality
- Packet catch utilizing Wireshark (Linkleter, 2013)



### **3. OPNET:**

OPNET is an Optimised Network Engineering Tool. It is a general purpose, discrete event, object-oriented network simulator. It can be used to develop comprehensive environments for wide range of specifications to simulate and analyse the performance of computer and data communication networks. Opnet is used both commercially and for academic research purposes that gives it the advantage of upgrading its system on the basis of inputs from both the sectors.

#### **Main features:**

1. Quick discrete occasion recreation motor
2. Parcel of part library with source code
3. Protest arranged demonstrating
4. Various leveled demonstrating environment
5. Adaptable remote recreations bolster
6. 32-bit and 64-bit graphical UI
7. Adjustable remote demonstrating
8. Discrete Event, Hybrid, and Analytical recreation
9. 32-bit and 64-bit parallel recreation piece
10. Matrix registering support
11. Incorporated, GUI-based investigating and examination
12. Open interface for incorporating outer part libraries (Pan, 2014)

#### **OPNET Application and Profile Modelling:**

The motivation behind this is to exhibit how to fabricate applications that will be utilized as a part of OPNET to manufacture activity. I will demonstrate to relate those applications with their specific gatherings. I will have 2 Groups of clients on my system. I will call these Group 1 and Group 2. Amass 1 will utilize HTTP and FTP, and Group 2 will utilize HTTP, Database, and Voice (Prokkola, 2006).

### **4. OmNet++:**

OmNet++ is an open source, Component based simulator with GUI Support. The major advantage if OmNet++ is it supports both generic as well as flexible architecture which makes it the first choice for many applications such as IT networks, hardware architecture, and other business processes, although it is primarily used for network communications (Pan, 2011). Its main features are its component-based architecture and reusable modules that can be combined in many ways. The OMNeT++ components include (Omnet, n.d.):

1. Simulation kernel library
2. Compiler for the NED topology description language (nedc)
3. Graphical network editor for NED files ( GNED )
4. GUI for simulation execution, links into simulation executable ( Tkenv )
5. Command-line user interface for simulation execution ( Cmdenv )
6. Graphical output vector plotting tool ( Plove )
7. Graphical output scalars visualization tool ( Scalars )
8. Model documentation tool (opp\_neddoc)
9. Utilities (random number seed generation tool, makefile creation tool, etc.)
10. Documentation, sample simulations, etc.

### **5. GloMoSim:**

GloMoSim is a library-based parallel simulator. University of California at Los Angeles developed it for mobile wireless networks (GloMoSim, 2011). It is written in PARSEC which is an extension for C language for parallel programming purposes. Because it is a scalable simulator, it can be used for model and simulate large scale networks with thousands of nodes. Its major advantage remains supporting thousands of nodes and ability to execute simulations on number of machines. It was initially designed to simulate both wireless and wired networks, but currently it only works with wireless networks only

### **6. NetSim:**

NetSim can be used both for commercial and academic purposes by downloading the respective version. It can be used to model and simulate variety of network configurations or protocols, both wired and wireless, TCP/IP, and asynchronous transfer mode switches (Tetcos, n.d.). Its use is limited to academic and research purposes. NetSim applications include:

- Detailed performance study of wired and wireless networks.
- Effect of relative positioning of stations on network performance
- Realistic signal propagation modelling.
- Transmission of deferral mechanisms
- Investigation of collision handling and detection processes (Chang, 1999).

### **Cisco Packet Tracer**

The use of simulation tools is fast becoming the approach to learn and also test a prototype implementation for various technologies. The packet tracer tool provides a visualization tool and also network simulation platform which can be used study the impact of connected



different network topologies. The tool also allows user to configure routes and also emulate a command line interface for switching (Cisco Networking Academy, 2016).

## Psimulator2

The simulation tool is used for teaching basic networking topics at different universities by the faculty of information technology. The tool is a basic network simulator with graphical interfaces which can run on any operating system that supports Java.

The tool consists of nodes which act as routes, host or switch that is essentially a Java implementation. The start of simulation allows the connection possibility to user to connect to virtual nodes with telnet and then configure by entering test commands. The software however only supports some of the functionalities in a normal network.

The simulation tool consists of a front end and back end implementation. The front end like in most cases is the GUI which allows the creation of topology of network that is shown in the figure. The start of simulation marks the network packet animation start on the interface which is quite simple. The simulation is run by the back end implementation which uses the information provided by front end GUI in the form of xml file.

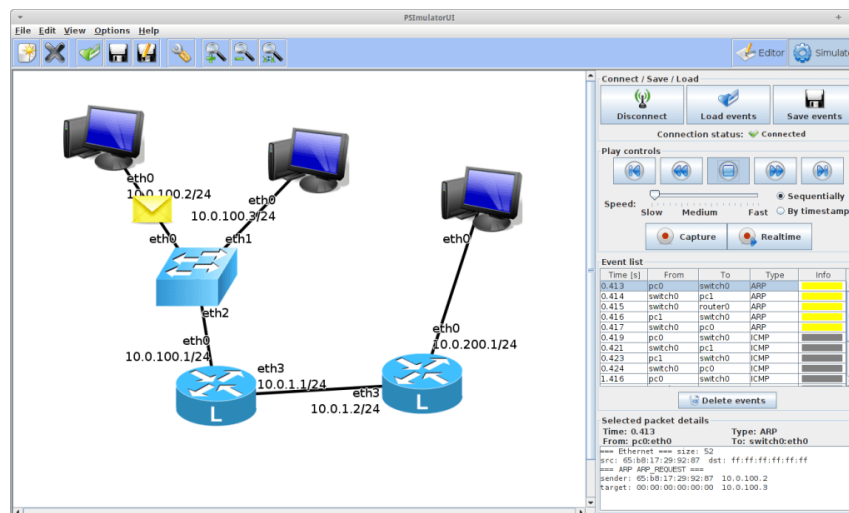


Figure 2 Front end GUI for PSimulator2 (Open-Source Routing and Network Simulation, 2016)

The tool also has the possibility to run the front end part and back end part on separate systems. However, majority of the uses of the tool have the complete tool running on single computer. The front end and back end work together to carry out a network simulation. There is possibility to run various scenarios of simulation. The following steps are general steps to carry out simulation on the tool. The front end of the tool needs to be start. The topology with nodes and links needs to be created. The topology needs to be saved so that suitable xml file is created. The simulation back end is to be loaded so that the xml nodes can be used for running the simulation. The front end simulation is then connection to back end so that the

networking features can be shown by the tool in form of emulations (Open-Source Routing and Network Simulation, 2016).

### **Networking Simulation – Basic Concepts**

It is important to understand a number of basic ideas from the network simulation domain. There are several terms which might lead to confusions in the interpretation and this needs to be thus clarified with examples. The basic idea of the network simulator and network simulations will be discussed further with the discussion of difference between emulations and simulations.

### **Simulator and Network Simulations**

The purpose of the network simulators is to realise the behaviour of real world networks through models. The system features are realized in the form of a model and then the model parameters can be changed to change the behaviour and thus different system and test results can be obtained. It is much cheaper to realize changes in the model output by changing parameters than changing implementations in real world implementations. This allows a large number of ideas and tests to be carried out without large cost when compared to actual implementations. The network simulations however are not 100% accurate. The exact details and real world implementations and sporadic errors are not present in the model. The modelling accuracy and the desired test for the user should match in order to have the realization of the network under study and the impact of changes in the operation (A Survey of Network Simulation Tools: Current Status and Future Development, 2016).

### **Differences in Emulation and Simulation**

As discussed earlier, it is also important to realize the difference between the emulations and simulations. The interaction between the different components on the network is implemented in the form of models and thus the behaviour of network is replicated in the simulation environment. The components used for the modelling can be network nodes such as physical links, routers or packets along with the end-hosts which are linked by use of equations that are related. The model can also be prepared by just making the recording of the behaviour from a real world implementation and using the recording as the output of respective element in the environment. The offline tests can then be performed on the data from the simulation experiments and the observation of protocols and network can be made. Different parameter combinations of environmental parameters and the configuration conditions can be input to the simulation environment to carry out the study. The simulation

tool for networks can also be linked with different services and application to find the performance of the nodes in the networks which is a good utility worth noticing.

The term emulation however implies the simulation of a network to understand and study its performance of the optimizations or changes carried out. The unique feature of such implementations is that the systems can be connected to the emulator and perform as they would in the real implementation. The emulator thus performs the function of emulating the network connecting the nodes but it does not perform the function of node behaviour calculation. There are several network emulation tools and some of them discussed earlier are the NS2 which is a limited functionality emulator that is used quite widely. There is also another emulator called as WANSim which is the emulator for bridged Wireless area network that works by using the functionality from linux (A Survey of Network Simulation Tools: Current Status and Future Development, 2016).

### **Network Simulator Types**

The types of simulators available in the market can be classified on different criterions depending on the complexity of their implementations or the cost of the simulators.

### **Cost of Simulators**

The criteria for classification of simulators is the involved cost. Some simulators are available commercially which means that there needs to be license fees or cost which needs to be paid by the users to the installation of tool and working. The license fees is dependent on the packages which the user should install depending on the simulation details and requirements. OPNET is one of the examples of such commercial tools. There are several advantages and disadvantages to the use of OPNET tool. The documentation of the tool is updated and it is maintained quite consistently. Proper documentation of the tool is one of the disadvantages of freely available simulation tools as they do not deploy people to maintain documentation. The problem gets aggravated in the case of different update versions with new features in which case it become difficult for user to understand and find different in the old and updated versions.

The main advantage of open source simulation tools is that all the code is visible to the user and anyone to everyone can contribute to the development by discovery of bugs and applying fixes. The interface can also be developed fast. The flexibility with the tool is also lot more with the adoption of most recent technologies faster compared to commercial simulation. The fast development and improvement of open source simulators comes with the last of systematic approaches and documentations which can after the life time and applicability of

the open source tools. Some of the open source tools discussed are NS2, NS3 and NS2- wiki (Christhu, 2013).

### **Complexity of simulator implementation**

A number of network simulators are available in the market current with different levels of complexity of implementation. A simulator allows the replication of network topologies and also creating a scenario with the definition of nodes on the network. The links between the traffic and the network nodes also needs to be defined. The complex implementations of simulation tools allow the user to define all the aspects of the network traffic parameters. The implementations also have graphical representation which make it easier to identify the traffic process on network. The simpler implementations of simulation tools provide text based outputs or less visual interfaces which is difficult to interpret results from and requires further post processing implementations. There are also applications that provide the framework for writing programs which allow the user in the application creation that acts the environment for network testing (Christhu, 2013).

### **Types of networks**

A network can be defined as the linkage of two or more computers that are connected with each other for sharing data, exchanging files along with establishing electronic communication. In a network, the computers might be connected with radio waves, telephone lines, infrared light beam, cables and many more (Horvath, 2011). The network could be both wired or wireless as per the requirement of geographical area. The wireless and wired communication is established through different types of networks such as LAN (Local Area Network), MAN (Metropolitan Area Network), WAN (Wide Area Network) and PAN (Personal Area Network).

**LAN:** It established a communication between more than two computers, which is often required within home or office buildings. LAN aids in sharing files and limited in size, which covers an area not more than a mile (McNamara, 2014). LAN requires wiring that include single cable connecting each devices for providing high speed from 10 Mbps to 10 Gbps. LAN consists of ring, bus and star topology along with using certain protocol for transferring files. Figure 1 shows that LAN network that uses switch for establishing a communication between different electronic devices.

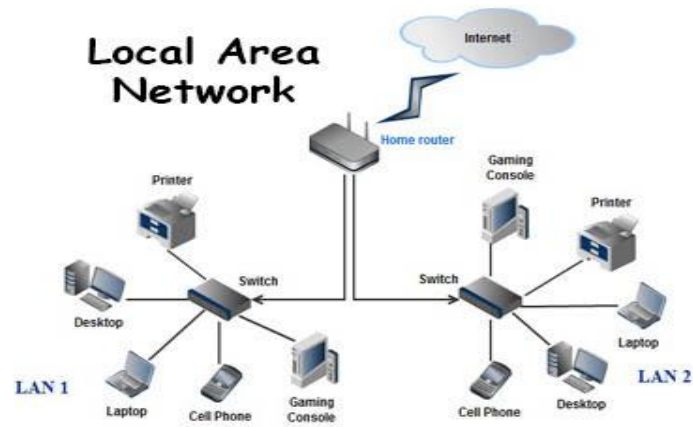


Figure 3: Local Area Network (Schweitzer, 2015)

**MAN:** It covers a large campus or a city due to its large computer network. It is high-speed network, which covers an area between 5 to 50 kilometres (Abts and Kim, 2010).

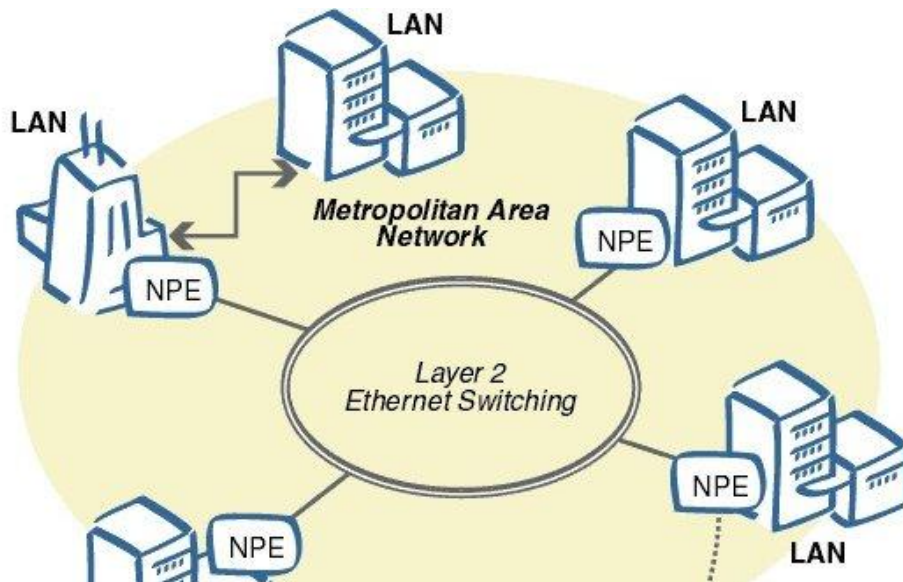
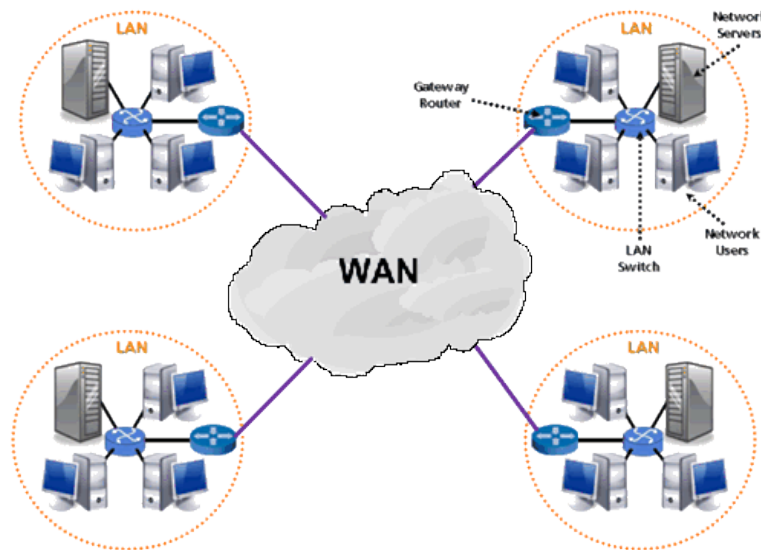


Figure 4: MAN Network (Lusher, 2012)



**WAN:** this network covers large geographical areas such as continent or a country and offers high-speed to the users (Iversen, 2014). WAN network includes various LAN connected together through different devices such as routers, switches, bridges or gateways.



*Figure 5: WAN Network (Merkow, 2014)*

**PAN:** These networks are limited to a certain area of few meters and could be wired or wireless in nature (Nejad, 2014). Communication among computer devices can be established through PAN and it also includes telephones.

### **Type of programs**

For developing a communication between the computer devices in a network, programming is the most important task (Ebbers, 2015). The network programs are of different types such as IP (Internet Protocol) addressing, TCP/IP (Transport Control Protocol/Internet Protocol), JAVA Socket programming and TCP/IP Socket programming.

**TCP/IP Socket programming:** Socket and serversocket, which are two vital classes of Java.net, will be used for creating server and client program. For listening to client's request, the server program will create a certain program and for connection request, a new socket will be created for exchanging data where client uses input and output streams (Fall and Stevens, 2011). The below figure demonstrates the steps incorporated in the creation of server and client programming based on socket.

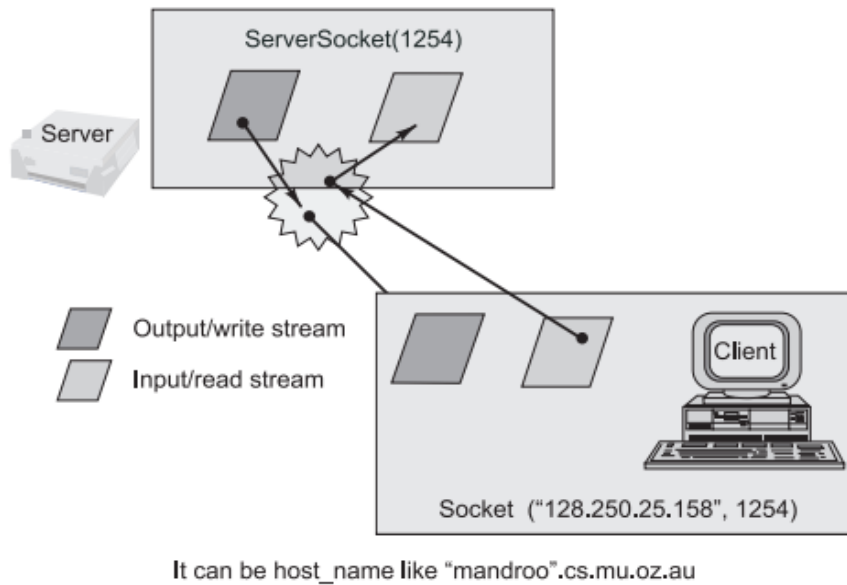


Figure 6: Socket-based server and client programming (Rogers, 2012)

## Types of technologies

The networking world has the tendency to carried way with new technologies (Evdokimov and Fabian, 2011). There are various technologies, which are used in the computer networks such as Internet of Things (IoT) and cloud virtualisation.

**Internet of things:** It is a system of interconnected computing devices, objects, people or digital or mechanical machines, which uses unique identifiers (McEwen, 2013). These devices are provided with the ability of transferring data over network without human-to-computer or human-to-human interaction.

**Clouds of virtualisation:** This is an essential technology, which permits the sharing of single application among multiple users. Moreover, the virtualisation concerns with the creation of virtual version of storage device, desktop, network resources and a server. Virtual machine manager (VMM) is automatically installed on the server system in case of server virtualisation (van Sinderen and Shishkov, 2012). In addition, storage virtualisation in cloud computing primarily done for the recovery and back-up process which enables grouping of physical storage from multiple storage networks. Clouds of virtualisation are improved technology that enables control on servers' platforms and application. Moreover, it divides the single server into multiple servers to balance the load.

## Servers

Different serves performs diverse task and operations based on its configuration and software that is essential to communicate with the clients. Application server, FTP server,

communication server and web server are various network serves which enable improved and effective connectivity (Ebbbers, 2012). Communication server manages common interaction network involving E-mail, firewall, and remote access. Further, application servers play an important role as eliminates the need for installing software on every workstation.

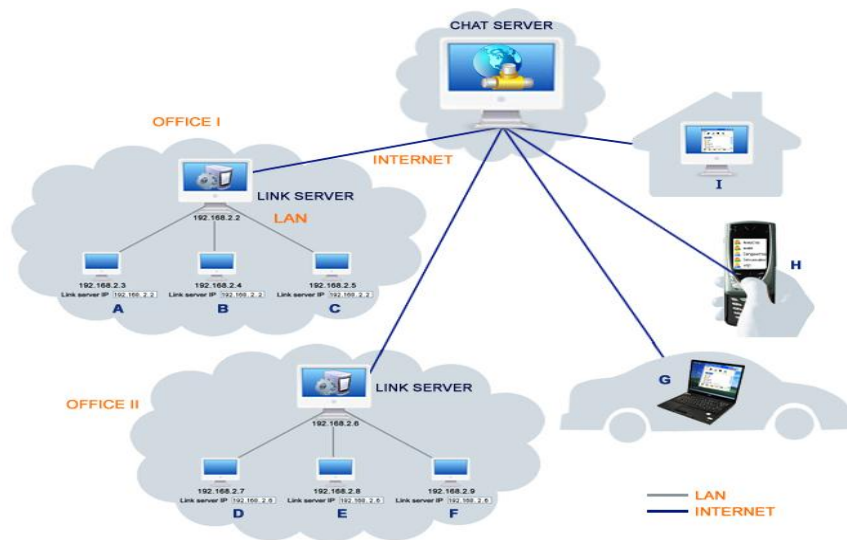


Figure 7: Communication Server: (Wizzard, 2013)

Apart from this, chat servers and fax servers are other servers that facilitate real time discussion capabilities. Fax servers are crucial as it provides opportunity to the organisations to reduce the incoming and outgoing telephonic calls. Moreover, chat servers impart exchange of data among internet users such as newsgroup (Herring and Stein, 2013). Web server is important due to its ability to serve the static content to a web browser. This server displays the file to a user’s web browser by loading the file from a disk. Another essential server is proxy server that filters the request, share connection and improve the performance by connecting web browser and external server.

### Type of VPN

Virtual Play Network (VPN) is provides a better way to create a secure connection by passing the communication and internet traffic through a secure tunnel. Site to site VPN and remote access VPN are important VPN, which facilitates the organisation by offering effectives services and operations (Hooper, 2012). Moreover, site to site VPN is also called route to route VPN that connect the networks of different office location at a time. Apart from this, hybrid VPN is expensive virtual play network, which offer higher flexibility and reliability. It also admits the connection from multiple VPN clients with more efficiency.

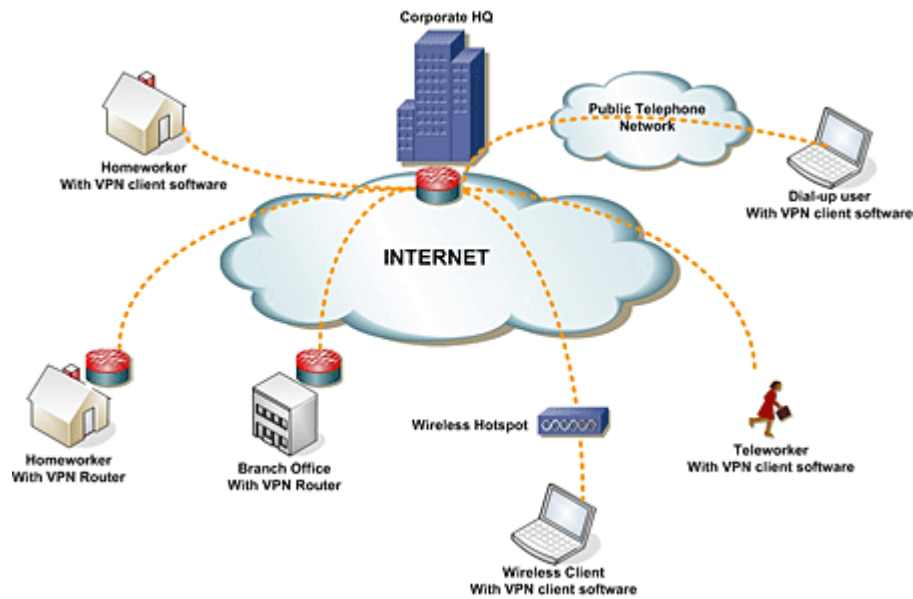


Figure 8: Virtual Play Network (VPN): (Shayan, 2016)

Apart from this, secure socket layer (SSL) is another VPN that enable secure accessible through https over web browser. Moreover, it adopts the web browser as a client application due to which it does not require installation of any software. IPSec (Internet protocol security) primarily based on two modes including tunnelling and transport modes (Snader, 2015). It is a trusted protocol, which is designed for control IP traffic. It is expensive and time-consuming mode of require a number of software installation to work. Further, the most scalable and flexible option for remote access is multi-protocol label switching (MPLS) which easily connected the two sites by using same ISP tuned VPS.

## Methodology

### Riverbed Modeller

The simulation tool chosen for this project is Riverbed Modeller formerly referred to as Optimized Network Engineering Tools (OPNET). This tool was developed by Alain Cohen, Marc Cohen and Steven Baraniuk while working on their graduate project for a networking course, this was later transformed into a commercial software later on. (OMICS International, 2014)

Riverbed modeller is a very useful tool set to design and simulate large network environment as it has lots of networking and communication equipment in its object pallet tools. Riverbed modeller is purposely used for application performance management, planning, engineering, operations, research and development (Anand Nayyar, Rajeshwar Singh, 2015)

Riverbed modeler is quite easy to use as it is mainly a graphical user interface software which allows users to simply drag and drop network devices onto the interface and configure them as needed for network simulation. Riverbed modeler is available in 32 and 64 bit versions which can be installed in both Windows and Linux environments.

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