Investigating Some Simulation Techniques for Wireless Communication System

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Abstract: This Paper seek to investigate the simulation techniques used for wireless communication systems The aim of the research is to provide a comprehensive list of various Network Simulators (General Purpose Simulators and Specific Simulators) which are available for researchers to do advanced research on Wireless Communication by reviewing the available simulation tools, highlighting the features of the simulators and using one of the best simulator to simulate and test wireless Network.. A review of NetTopo Simulator, Probabilistic Wireless Network Simulator (PROWLER), Matrix Laboratory (MATLAB)/Simulink, Platform for Integrated Communications and Control design, Simulation, Implementation and Modelling (PiccSIM), Laboratory Virtual Instrument Engineering Workbench (LabVIEW), Cisco Packet Tracer, Satellite Network Simulator 3 (SNS3), Systems Tool Kit (STK), Visual System Simulator (VSS) and Psimulator2 Network Simulator was presented along with their respective features with a sample wireless simulation. The investigated techniques will aid Computer and communication expert to select the most suitable tool for simulating and testing wireless communication Systems..
Keywords – Bluetooth, Broadcast, Communication, Microwave, Satellite

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I. Introduction

Simulation is an imitation of the operation of a real-world process or system. Computer simulation can be extremely valuable for understanding real world processes of wireless communication system. The area of Wireless Network is under rigorous research and development by various researchers across the globe to develop new algorithms, protocols and techniques to make wireless communication more efficient and reliable. Before live implementation, testing of the developed technique is required. Most of the time, testing and evaluating the protocols or theories proposed is not practically feasible through real experiments as it would be more complex, time consuming and even costly. So, to overcome this problem, "SIMULATORS and TESTBEDS are effective tools to test and analyze the performance of protocols and algorithms proposed [1].

The aim of this research is to provide comprehensive list of ten Network Simulators (General Purpose Simulators and Specific Simulators) which are available for researchers to do advanced research on Wireless Communication by reviewing the available simulation tools, highlighting the features of the simulators and using one of the best simulator to simulate and test a wireless System [1]. *The Network Simulators investigated are as follows*: NetTopo Simulator, Probabilistic Wireless Network Simulator (PROWLER), Matrix Laboratory (MATLAB)/Simulink, Platform for Integrated Communications and Control design, Simulation, Implementation and Modelling (PiccSIM), Laboratory Virtual Instrument Engineering Workbench (LabVIEW), Cisco Packet Tracer, Satellite Network Simulator 3 (SNS3), Systems Tool Kit (STK), Visual System Simulator (VSS) and Psimulator2 Network Simulator.

II. Wireless Communications System.

Wireless communication generally works through electromagnetic signals that are broadcast by an enabled device within the air, physical environment or atmosphere. The sending device can be a sender or an intermediate device with the ability to propagate wireless signals. The communication between two devices occurs when the destination or receiving intermediate device captures these signals, creating a wireless communication bridge between the sender and receiving device. Wireless communication has various forms, technology and delivery methods which include:

- Satellite communication
- Broadcast Radio
- Microwave Communication
- Mobile communication

- Wi-Fi
- Bluetooth communication
- Infrared communication
- WiMax and ZigBee

Although all of these communication technologies have different underlying architecture, they all lack a physical or wired connection between their respective devices to initiate and execute communication [2].

2,1 Satellite Communication
Satellite communication is one type of self-contained wireless communication technology, it is widely spread all over the world to allow users to stay connected almost anywhere on the earth. When the signal (a beam of modulated microwave) is sent near the satellite then, satellite amplifies the signal and sent it back to the antenna receiver which is located on the surface of the earth. Satellite communication contains two main components like the space segment and the ground segment. The ground segment consists of fixed or mobile transmission, reception and ancillary equipment and the space segment, which mainly is the satellite itself.

2.2 Broadcast Radio
The first wireless communication technology is the open radio communication to seek out widespread use, and it still serves a purpose nowadays. Handy multichannel radios permit a user to speak over short distances, whereas citizen's band and maritime radios offer communication services for sailors. Ham radio enthusiasts share data and function emergency communication aids throughout disasters with their powerful broadcasting gear, and can even communicate digital information over the radio frequency spectrum.

2,3 Microwave Communication
Microwave wireless communication is an effective type of communication, mainly this transmission uses radio waves, and the wavelengths of radio waves are measured in centimeters. In this communication, the data or information can be transfers using two methods. One is satellite method and another one is terrestrial method.

2,4 Mobile Communication Systems
The advancement of mobile networks is enumerated by generations. Many users communicate across a single frequency band through mobile phones. Cellular and cordless phones are two examples of devices which make use of wireless signals. Typically, cell phones have a larger range of networks to provide a coverage. But, Cordless phones have a limited range. Similar to GPS devices, some phones make use of signals from satellites to communicate.

2.5 Wi-Fi
Wi-Fi is a low power wireless communication that is used by various electronic devices like smart phones, laptops, etc. In this setup, a router works as a communication hub wirelessly. These networks allow users to connect only within close proximity to a router. WiFi is very common in networking applications which affords portability wirelessly. These networks need to be protected with passwords for the purpose of security, otherwise it will access by others.

2,6 Bluetooth Technology
The main function of the Bluetooth technology is that it permits you to connect a various electronic devices wirelessly to a system for the transferring of data. Cell phones are connected to hands free earphones, mouse, and wireless keyboard. By using Bluetooth device the information from one device to another device. This technology has various functions and it is used commonly in the wireless communication market.

2,7 Infrared Communication
Infrared wireless communication communicates information in a device or systems through IR radiation IR is electromagnetic energy at a wavelength that is longer than that of red light. It is used for security control, TV remote control and short range communications. In the electromagnetic spectrum, IR radiation lies between microwaves and visible light. So, they can be used as a source of communication.

2.8 WiMAX
There are wireless broadband systems that offer fast Web surfing without being getting connected through cable or DSL (Example of wireless broadband is WiMAX). Although WiMAX can potentially deliver data rates of more than 30 Megabits per second, yet the providers offer average 0 data rates of 6 Mbps and often deliver less, making the service significantly slower than the hard-wired broadband. The actual cost of the data available using WiMAX widely varies with the distance from the transmitter. WiMAX is also one of the versions of 4G wireless available in phones as Sprint's 4G technology.

2.9 Zig Bee
Zig Bee is a wireless communication standard designed to address the unique needs of low-power, low-cost wireless sensor, and control networks. ZigBee can be used almost anywhere, as it is easy to implement and requires little power to operate. Zigbee has been developed looking into the needs of the communication of data with a simple structure like the data from the sensors.

III. Simulation Techniques For Wireless Communication System

The essence of this research work is to assist researchers in choosing correct simulator to develop or test new algorithms, protocols and techniques in Wireless communication system, an explanation of various general purpose and specific purpose simulation tools is presented. The Simulation Tools for Wireless Network is as follows:

3.01   *NetTopo Simulator*

NetTopo is regarded as extensible cum integrated framework for simulating and visualizing wireless sensor networks. The basic objective behind design and development of NetTopo Simulator is to analyze various algorithms in WSN. With regard to simulation, users can define large number of parameters over sensor nodes like energy consumption, bandwidth management and NetTopo efficiently takes into consideration large-scale heterogeneous networks. NetTopo is an open source simulator and has been designed in Java language and has more than 80 Java classes and 11000 lines of code [3-4]. The following figure shows the GUI Interface of NetTopo Simulator:
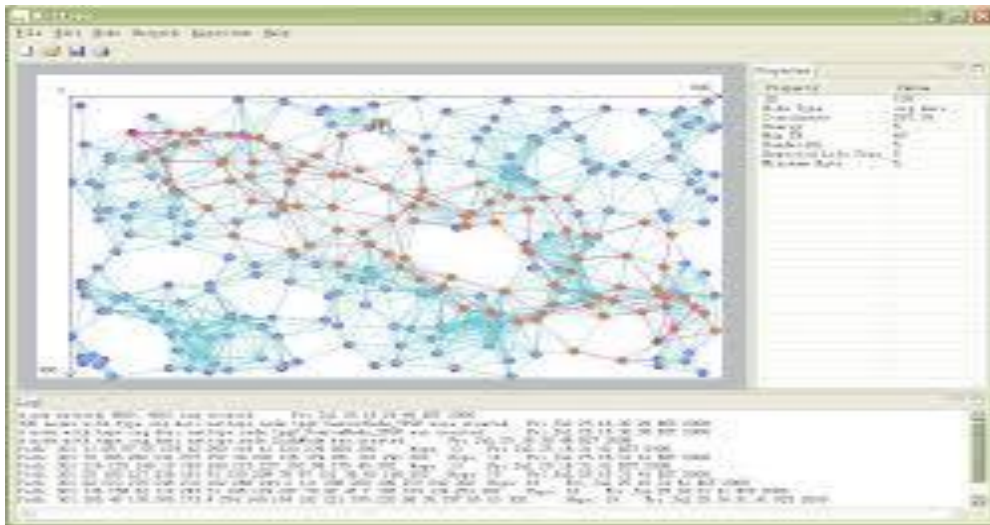

Figure 1. GUI of NetTopo Simulator

3.02   *Probabilistic Wireless Network Simulator (PROWLER)*

PROWLER is a probabilistic wireless network simulator capable of simulating wireless distributed systems, from the application to the physical communication layer. It is an event driven simulator for wireless sensor network runs under MATLAB and can operate either in deterministic or probabilistic mode [5]. The objective behind development of Prowler simulator was to simulate Berkeley MICA Mote operating on TinyOS and other general systems. Prowler was basically designed in MATLAB so it provides easy interface to prototype various applications and nice visualizations. An extension to Prowler is JProwler. JProwler is written in Java Language. The following figure shows the GUI Interface of the Simulator:
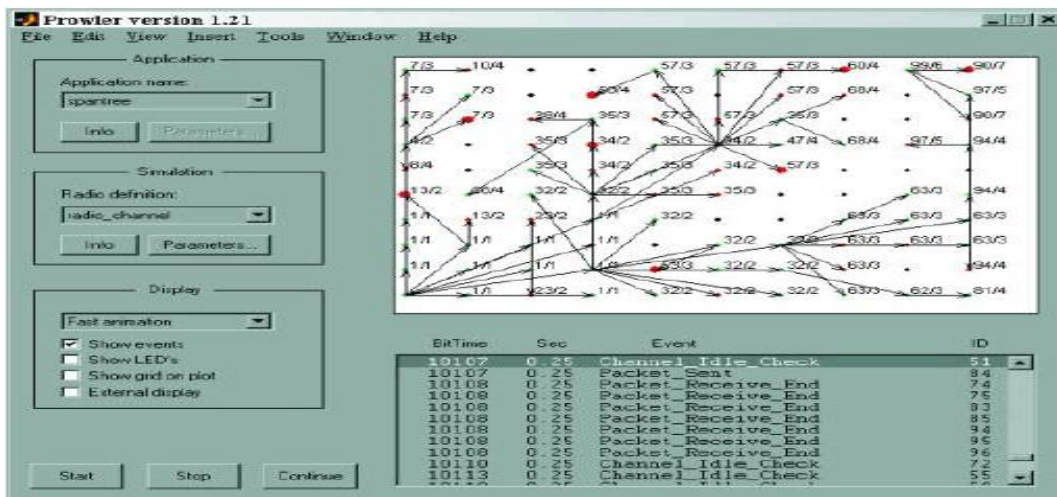

Figure 2. Prowler GUI

3.03   *Matrix Laboratory (MATLAB)/Simulink*

Matlab is a very high performance, varied feature rich computation and visualization tool comprising of thousands of features. It was built by Math works Inc. The Latest version currently available for download or purchase for Commercial purposes is MATLAB R2018a. The most important feature of MATLAB is its easy programming capability and easy platform for users to develop their own custom functions. MATLAB has various toolboxes like Aerospace, Control System Design, Fuzzy Logic, Symbolic Computations, Statistics, Communication and many others [6-8]. The following figure shows basic GUI of MATLAB R2018a software The following figure shows the GUI Interface of the Simulator:
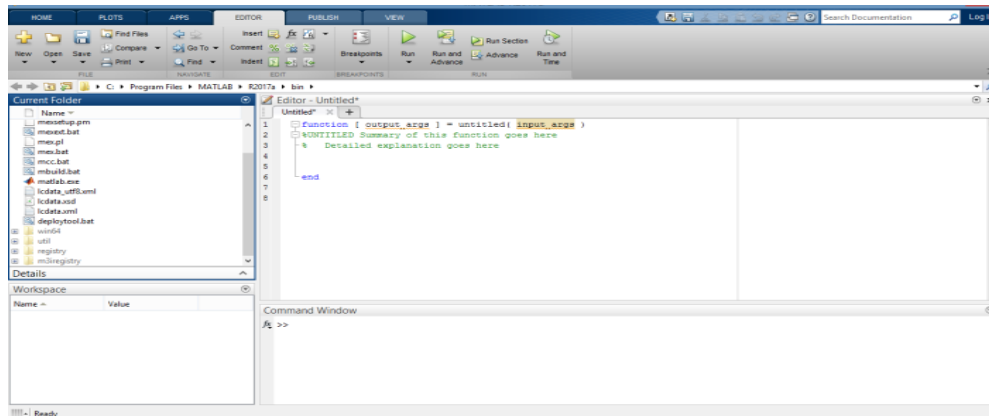

Figure 3. MATLAB R2018a GUI

Matlab is supported by another important software at its backend known as Simulink. Simulink supports both Linear and Non-Linear systems, modelled in continuous time, sampled time or mix of both. Simulink provides GUI for building block diagrams, drag and drop feature to design diagrams and its components. MATLAB and SIMULINK provides communication toolbox set to build a complete Wireless Network model system, Simulation procedure includes building the hardware architecture of transmitting nodes, modelling the communication channel and receiving node architecture.
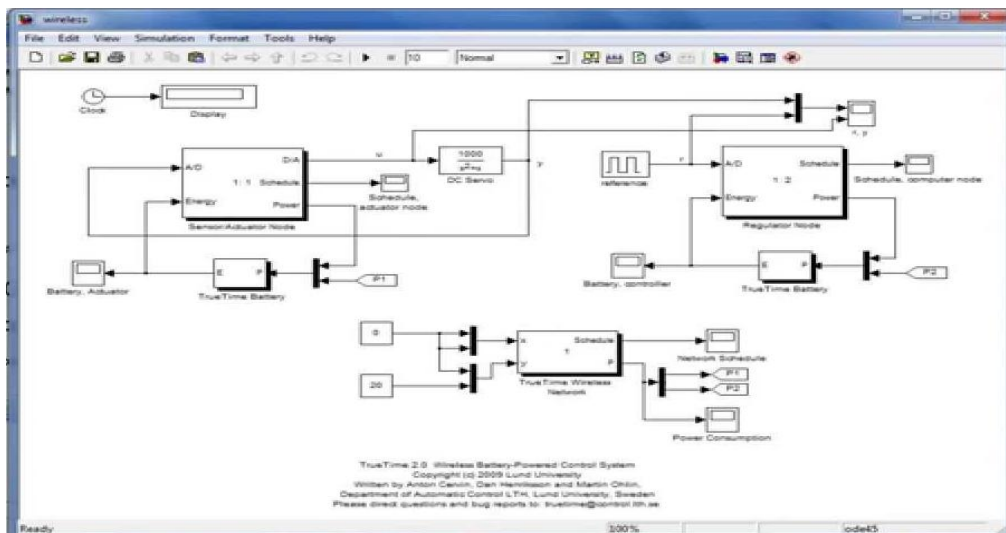

Figure 4. SIMULINK R2018a GUI

3.04   *Platform for Integrated Communications and Control design, Simulation, Implementation and Modelling (PiccSIM)*

The aim of PiccSIM is to deliver a complete toolset for design, simulation and implementation of wireless control systems. It is a co-simulation tool for networked control systems (NCS) and intended for research on NCS or WNCS. PiccSIM was developed by Wireless Sensor Network Research Group as joint venture between Department of Automation and Systems Technology and Department of Communications and Networking at Aalto University, Espoo, Finland. The idea behind the development of PiccSIM simulator was to make a complete toolset for design, simulation and implementation of Wireless Networked Control Systems (WiNCS) along with Network Controlled System (NCS). PiccSIM simulator comprise of Simulink (Used for

Simulating Dynamic System) and NS-2 (Used for Network Simulation). In addition to this, a GUI interface for modeling and designing the network and control system. With combination of Simulink and NS-2, PiccSIM can be known as PiccSIM Tool chain which can be used for designing and modelling real wireless nodes [9]. The following figure highlights PiccSIM Architecture:
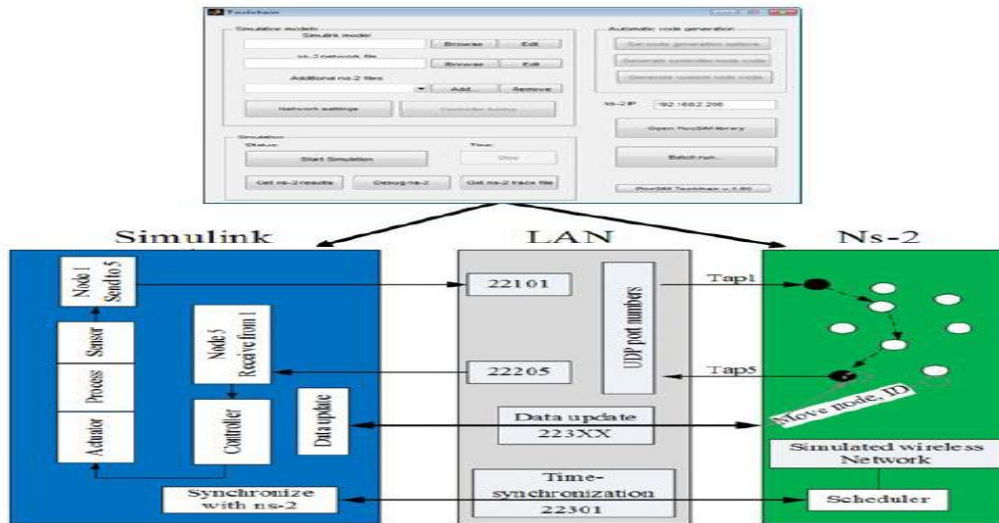

Figure 5. PiccSIM Architecture

3.05 *Laboratory Virtual Instrument Engineering Workbench (LabVIEW)*

LabVIEW provides a unique platform and development environment for visual programming language. It is product from National Instruments Inc. LabVIEW these days is most commonly used for data acquisition, instrument control and industrial automation. It supports various operating systems like Windows, Linux, UNIX and even Mac OS X. LabVIEW provides easy creation of user interfaces known as front panels into development. LabVIEW programs are called Virtual Instruments (Vis). Every VI has three components: Block Diagram, Front panel and Connector Panel. As LabVIEW comprise of various toolboxes like MATLAB. With LabVIEW WLAN module, one can add intelligence to NI wireless network via same graphical programming approach. With LabVIEW one can easily incorporate C code in the node for making routing and other all sorts of algorithms [10]. The following figure shows the GUI Interface of the Simulator:
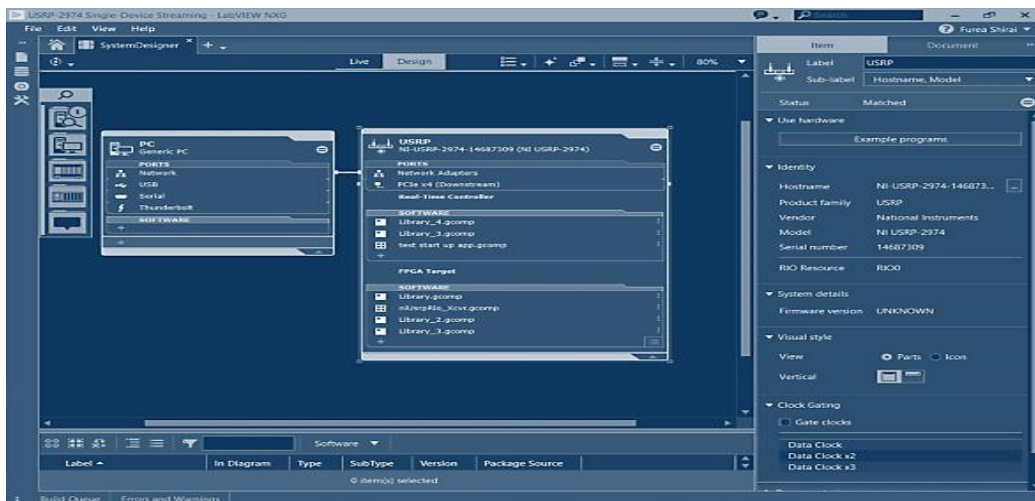

**Figure 6.** GUI of LabVIEW 2018

3.06 *Cisco Packet Tracer*

Packet Tracer is a cross-platform visual simulation tool designed by Cisco Systems that allows users to create network topologies and imitate modern computer networks. The software allows users to simulate the configuration of Cisco routers and switches using a simulated command line interface. Packet Tracer makes use of a drag and drop user interface, allowing users to add and remove simulated network devices as they see fit [11]. The most important features of Packet Tracer:

- Designs, builds and configures networks with drag-and-drop devices. Providing valuable hands-on experience that can be applied in the classroom and on the job.
- Supports the majority of protocols and technologies taught in several Networking Academy courses.
- Creates customized learning scenarios with the Activity Wizard. Adding instructional text for students as well as grading and real-time feedback, which provides an unlimited number of guided learning experiences. Activities can also be saved and shared with others in the Networking Academy community.
- Visualizes internal processes in real-time, such as dynamic data transfers and packet content expansion normally hidden on real devices.
- Opportunities to share ideas, best practices and discuss using Packet Tracer in the classroom with other instructors.

Offers multiuser and peer-to-peer real-time collaboration and competition for dynamic learning

- Authoring and localization of structured learning activities such as labs, demonstrations, quizzes, exams, remote instructor-student interactions and games.
- Supports feature expansion through external applications using an API. Enhancing Packet Tracer by adding on curriculum and assessment delivery, games, accessibility and interfacing with real equipment.
- You can run it on Microsoft Windows, Mac, and Linux.
- It allows basic routing with RIP< OSPF, EIGRP, BDP to the extents required by the CCNA.
- Starting with version 5.3, Packet Tracer supports the Border Gateway Protocol.
- Packet Tracer can also be used for collaboration.
- Starting with version 5.0., it supports a multi-user system that enables multiple users to connect multiple topologies over a network.
- The tool allows instructors to create activities for students to complete.
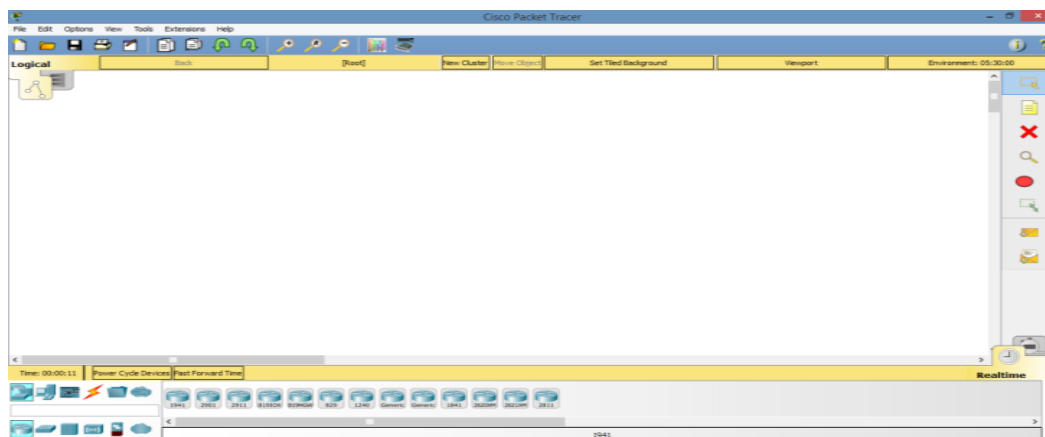
Figure 7. GUI of GNS3

3.07 *Satellite Network Simulator 3 (SNS3)*

SNS3 is a satellite network extension to Network Simulator 3 (ns-3) platform. SNS3 models a full interactive multi-spot beam satellite network with a geostationary satellite and transparent star (bent-pipe) payload. The reference satellite system consists of 72 spot-beams with an European coverage, 5 gateways and Ka-band frequencies. SNS3 is a dynamic system simulator, which works at a physical level burst resolution. Its use cases range from full network level performance to a single user Quality of Service verification. SNS3 is built to be modular and flexible to provide extensibility to different satellite communication networks and use cases.

SNS3 implements DVB-RCS2 (Digital Video Broadcast – Return Channel via Satellite – 2nd generation) and DVB-S2 (Digital Video Broadcasting – Satellite – 2nd generation) specifications in return and forward link [58]. Satellite network features include:
- Adaptive Coding and Modulation (ACM)
- Return and forward link scheduling
- Demand Assignment Multiple Access (DAMA): Constant Rate Allocation (CRA), Rate-Based Dynamic Capacity (RBDC), Volume-Based Dynamic Capacity (VBDC), Free Capacity Allocation (FCA)
- Random Access (RA): Slotted ALOHA and Contention Resolution Diversity Slotted ALOHA (CRDSA)
- Generic Stream Encapsulation (GSE)
- Return Link Encapsulation (RLE)

- Automatic Repeat reQuest (ARQ)
- Multi-beam satellite antenna gain patterns
- Packet-by-packet SNIR computation
- Packet-by-packet co-channel and intra-beam interference tracking
- Weather traces, Land-Mobile Satellite (LMS) channel
- Error models

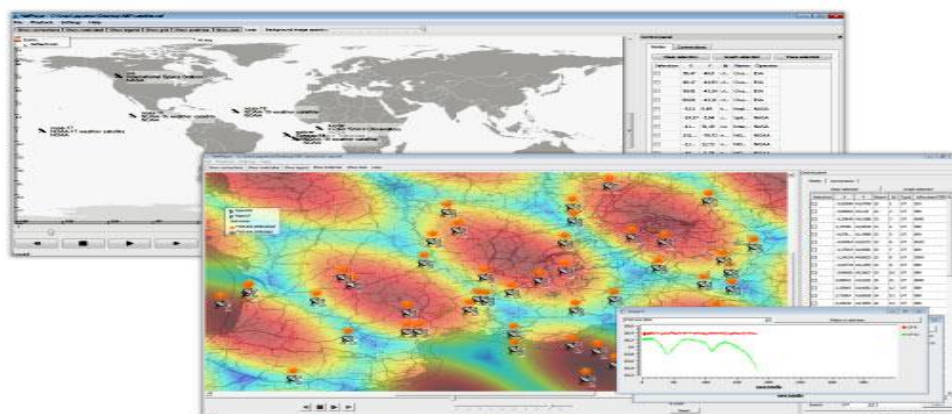The following figure shows the GUI Interface of the Simulator:

Figure 8: Satellite Network Simulator 3 GUI

3.08 *Systems Tool Kit (STK)*

Systems Tool Kit (formerly Satellite Tool Kit), often referred to by its initials STK, is a physics-based software package from Analytical Graphics, Inc. that allows engineers and scientists to perform complex analyses of ground, sea, air, and space assets, and share results in one integrated solution. At the core of STK is a geometry engine for determining the time-dynamic position and attitude of objects ("assets"), and the spatial relationships among the objects under consideration including their relationships or accesses given a number of complex, simultaneous constraining conditions. STK has been developed since 1989 as a commercial off the shelf software tool. Originally created to solve problems involving Earth-orbiting satellites, it is now used in the aerospace and defense communities and for many other applications [12]. The following figure shows the GUI Interface of the Simulator:
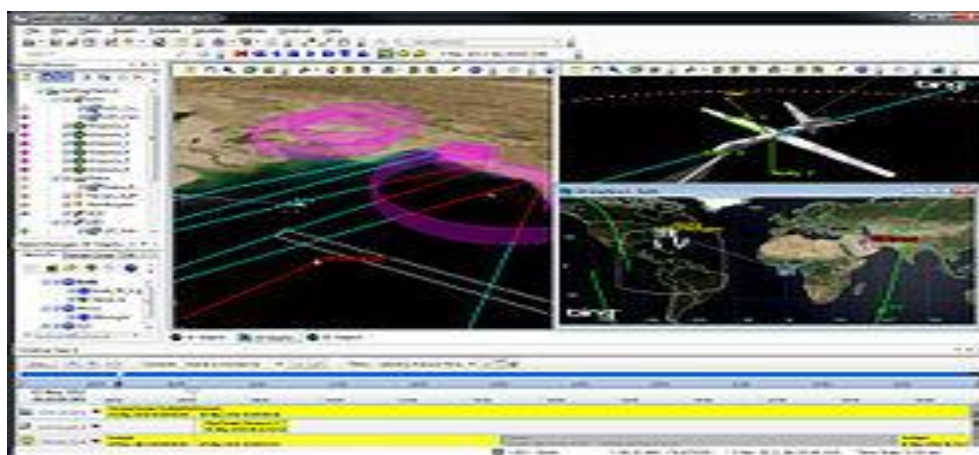

Figure 9: STK GUI

3.09 Visual System Simulator (VSS)

VSS software is the system-level simulation technology that's part of the NI AWR Design Environment platform. VSS is an RF and wireless communications and radar systems design solution, supporting realistic measurements of cascaded RF blocks, identifying the source of spurious products and simulating system metrics such as bit error rates all from a single system diagram. Designers of commercial and military transmitters and receivers are then able to quickly and easily create subsystem architectures and optimize their components for best overall performance. The latest release of NI AWR Design Environment platform, specifically the VSS software, provides new and enhanced capabilities. Highlights include:

Phased-Array Generator Wizard - Allows designers to quickly configure planar phased array or MIMO array systems, interactively modify the designs to achieve the desired behavior and then generate system diagrams and/or circuit schematics and EM structures for further, more rigorous analysis. The tool supports interactive specification of the layout, feed network settings, element antenna and RF link settings, gain tapers, and element failures.

Spatial Channel Models - Provides highly-accurate modeling of channel-specific propagation effects used in WINNER II and 3GPP spatial channel model (SCM) specifications. This capability supports more realistic link-budget analysis for rapid validation of end-to-end system performance and specification of individual component requirements.

Bus Support – Enables designers to efficiently implement parallel architectures by representing a large number of signal paths as separate instances, resulting in compact system diagrams that are easy to maintain and modify. This new capability is especially useful for massive MIMO and phased array designs, as they may consist of hundreds and even thousands of RF links and signal processing paths [13]. The following figure shows the GUI Interface of the Simulator:
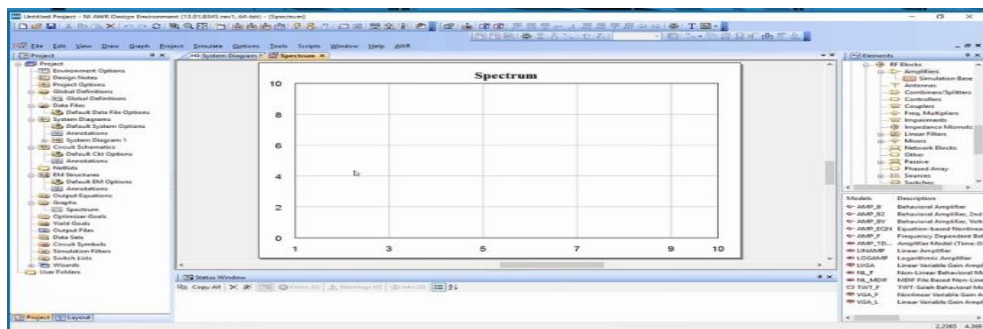

Figure 10: Visual System Simulator GUI

3.10 Psimulator2 Network Simulator

Psimulator2 is a basic graphical network simulator created and used by the Czech Technical University in Prague, Faculty of Information Technology to teach basic networking topics. It will run on any system that supports Java, including Windows, Mac OS, and Linux. Each node created in the Psimulator2 network is a Java program that implements the functionality of a host, switch, or router. Once a network simulation scenario is started, the user can connect to each virtual node using telnet and enter configuration or test commands. However, only a sub-set of normal networking functionality is supported by the software emulation the node [14].
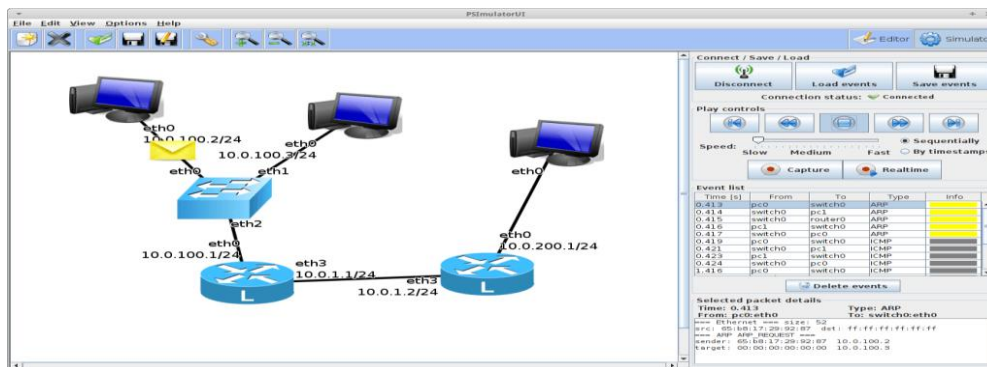

Figure 11. Psimulator2 Network Simulator GUI

The following Table is a summary of the various general parameters based performance comparison of Various Simulation Tools being highlighted in this research work.

Table 1: List of Widely Used Network Simulators

S/N	Name of Simulator	Simulator Type: (Discrete-Event/Trace-Driven)	Programming Language	License Type: Open Source or Commercial	Documentation Available (Yes/No)	Current Version	Developed by: (Company Name/ Research Group)	Official Website
1.	NetTopo	Discrete Event	Java	Open Source	Yes	1.0	Developed by Lei Shu	https://sites.google.com/site/leishuderi/nettopo
2	Prowler	Probabilistic Discrete Event	Matlab/Java	Open Source	Yes	1.24	Developed by NEST (Network Embedded Systems Technology)	http://www.isis.vanderbilt.edu/projects/nest/prowler
3	MATLAB	Discrete-Event	C/Java	Commercial	Yes	Matlab R2018a	Mathworks Inc.	https://www.mathworks.com
4.	PiccSIM	Discrete-Event	Matlab + NS-2	Open Source	Yes	1.6	Department of Automation and Systems Technology and Department of Communications and Networking at Aalto University	http://wsn.aalto.fi/en/tools/piccsim/
5.	LabVIEW	Discrete Event	C/C++/Java and others	Commercial	Yes	LabVieW 2018	National Instruments Inc.	www.ni.com/labview
6.	Cisco Packet Tracer	Event Trace	C/C++/Python and others	Open Source	Yes	Packet Tracer 7.2	Cisco Systems	https://www.netacad.com
7	SNS3	Discrete-Event	C++	Commercial	Yes	N/A	N/A	http://satellite-ns3.com/
8	STK	Discrete-Event	C, C++, C#, and others.	Commercial	Yes	STK 11.4.1	AGI	http://help.agi.com/stk/index.htm#releaseNotes/CurrentRelease.htm
9	VSS	Discrete-Event	C/C++/Java and others	Commercial	Yes	N/A	National Instruments Inc.	http://www.awrcorp.com/products/ni-awr-design-environment/visual-system-simulator-software
10	Psimulator 2	Event Trace	Java	Open Source	Yes	Psimulator 2	Roland Kuebert forked	https://www.brianlinkletter.com

IV. Conclusion

In this research work ten major Wireless Communication simulation tools were considered which are widely in used till date along with their comparison to guide researchers in choosing the appropriate simulation platform to carry out all sorts of Wireless based research. Considering various parameters in line with the performance of the numerous Wireless network simulators, Cisco Packet Tracer and GNS3 Simulator can be considered among the best simulators to carry out all sort of research in the area of Wireless Communication. With the help of simulation tools we can easily develop and test a new protocol for wireless networks. There are numerous advantages connected to this approach like easy implementation, low cost, analysis of real time results and even knowing the side effects and other effecting parameters on the entire network.

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