Simulation of the Effect of Interference and EIRP on the Qos of DVB-S2 and DVB-RCS2 Networks

Heskia Jefri Saputra[1] M. Faiz Alfatih[2] Sabri Alimi[3]
Aerospace Engineering Study Program, Sekolah Tinggi Teknologi Kedirgantaraan Yogyakarta, Bantul Regency, Province of Daerah Istimewa Yogyakarta, Indonesia[1,2,3]
Email: heskiajefrisaputra@gmail.com[1]

Abstract

The purpose of this study was to obtain the QoS value of the data sent from the user terminal to the gateway based on variations in antenna gain and to determine the effect of the level of interference caused by noise on the user's device on the quality of data reception. This research uses the NS3 software experimental method. Parameters analyzed include throughput, delay, PDR. This study uses quasi-experimental methods. The purpose of quasi-experimental research is pure experimental conditions in conditions where it is impossible to control or manipulate all relevant variables, namely estimating. The conclusion in this study has been successfully carried out simulating sending data packets using the NS3 simulator tools. Based on the simulations that have been carried out, several characteristics of the effect of antenna gain on the quality of data packet transmission are obtained. The simulations explain well that the values of throughput, delay, and PDR have increased so as to provide good service quality. Based on the simulations that have been carried out, several characteristics of the influence of the interference level that affect the user on the quality of sending data packets are obtained. The simulation explains well that the values of throughput, delay, and PDR experience stability so that the level of interference has no effect on users in sending packets. However, the values obtained are very good and have not decreased

Keywords: Simulation, Interference, EIRP, DVB-S2 and DVB-RSC2 Networks

INTRODUCTION

The rapid development of aerospace communication technology is closely related to the development of wireless network technology. Wireless communication systems provide convenience in terms of conveying information to be more dynamic (mobile). Wireless communication based on transmitter towers has drawbacks in the coverage area, an increase in coverage area can be obtained by using satellites as an intermediary.

Satellite communication in aircraft is one of the important aspects of network communication technology in the world of aviation. Communication systems that use satellites can be used for long-distance communications in the form of communications between aircraft and external parties (towers, other aircraft or ground stations). From the form of aircraft communication, it can be distinguished into voice communication (voice) and data communication (datalink). Satellite communication is the same as HF and VHF communication, however, satellite communication has a wider scope than HF and VHF communication. (Fatimah, 2017) DVB-S2 is a signal broadcast based on satellite reception and is a standard for determining modules, its use is widely used by most satellite operators around the world for television and data broadcasting services, the DVB-RCS2 standard complements DVB-S2 to provide satellite channels interactive and then efficiently support two-way applications (Niebla C.P., et al, 2006). Quality of Service (QoS) is a measurement method used to determine the quality of a network with the aim of providing a better and planned network service so that it can meet the needs of a service (Raj, 2019).

Communication network technology has been able to carry out the satellite communication process in the world of aviation so quickly. Understanding satellite communication in a network communication system requires an approach from various perspectives, one of which is through a simulation approach. The advantage gained is that it makes it easier to understand the satellite communication process and can also be used to understand various other aspects of the satellite communication mechanism. The obstacle faced is the limited use of open-source simulation software to help explain the satellite communication process. In this study using software based on NS-3.

Devices (components) on a satellite are usually well maintained and maintained, but on the other hand devices on the user's side are vulnerable to interference. This is then raised as a problem in this study, namely analyzing data service quality (QoS) on satellite communication networks based on DVB-RCS2 and DVB-S2 technology if there are differences in the gain value on the antenna of the user's device and if there is noise on the side of the user's device. The benefits obtained are knowing the condition of the user's device in order to produce the best QoS. Research Objectives: To obtain QoS values for data sent from the user terminal to the gateway based on variations in antenna gain. Knowing the influence of the level of interference caused by noise on the user's device on the quality of data reception.

Theoretical Basis

Aircraft Radio Systems

Communication systems provide convenience in terms of conveying information. Aircraft communication can be in the form of communication between aircraft and external parties (towers, other aircraft or ground stations). Or communication within the aircraft itself (cockpit to cabin and flight crew to passengers). From the form of aircraft communication, it can be distinguished into voice communication (voice) and data communication (datalink). The intermediary media used are cable (wire), Electromagnetic Waves (VHF, HF and satellite). (Fatima, 2017)

Satellite Communication Standards

A communications satellite is an artificial satellite installed in space for the purpose of telecommunication using radio at a microwave frequency. Most communications satellites use a geosynchronous or geostationary orbit, although some newer types use low Earth orbiting satellites. Frequency Band is Frequency Band or Frequency Range. The width or distance between the sides of the band is called bandwidth, so the frequency band contains channels sequentially from the left side of the band to the right border of the band. Due to lower frequency.

Table 1.Frequency

Frequency Range (GHz)	Name	Frequency Range (GHz)	Name
0.1 – 0.3	VHF	8.0 – 12.0	X
0.3 – 1.0	UHF	12.0 – 18.0	Ku
1.0 – 2.0	L	27.0 – 40.0	Ka
2.0 – 4.0	S	40.0 – 75.0	V
4.0 – 4.0	C	75.0 – 110.0	W

Source: (Lestariningati, 2012)

Among a number of frequencies allocated for satellite communications, the C-band and Ku-band frequencies are the most widely used frequencies for satellite communications. C-band frequencies are in the (4-8) GHz range while Ku-band frequencies are in the (12-18) GHz range. Apart from these two frequencies, the current frequency which is of special interest, especially among the telecommunications industry, is the Ka-band frequency which is in the (26.5-40) GHz range. Ka-band frequency has several advantages, one of which is greater bandwidth so that it can provide more service capacity. (Cornejo & Landeros, 2017)

Wireless Network

Wireless network is a communication technology that uses radio waves that travel in a vacuum (without a medium). Wireless network is the latest technology that is used as a substitute if environmental conditions do not allow using wired technology, in other words it can be an alternative. To replace cables, currently there are several ways to transmit data, namely via radio waves (Radio Frequency), infrared rays (Infrared), Bluetooth, microwaves (Microwave), and light waves (Lightwave Transmission). The use of radio waves is inseparable from the proof of Heinrich Hertz (1857 – 1894) that electro-magnetic waves move at the speed of light and electrical properties can be carried in these waves. All wireless data transmission technologies basically use waves, but with different frequencies, because of that difference, the speed and range of transmission vary. Wireless networks have advantages and disadvantages compared to wired networks. Advantages of wireless networks: Mobility, easy installation, flexibility of location, cost efficiency, broad coverage. (Duskarnaen & Nurfalah, 2017)

Network Simulator 3

A network simulator is a piece of software or hardware that predicts the behavior of a network and mimics the performance of a real network without representing the real network. Network Simulator 3 is a discrete-event network simulator, targeted primarily for research and educational purposes. NS-3 is free software, licensed under the GNU GPLv2 license, and publicly available for research, development, and use. The goal of the ns-3 project is to develop an open, simulation environment for research in the field of networking. ns-3 is primarily used on Linux systems, although support for FreeBSD, Cygwin (for Windows), and native Windows Visual Studio support is in development. NS-3 has its own advantages compared to other network simulators, namely having several scripts that can be developed according to the desired network requirements. Written in C++ and Python. However, the script presented is only a basic script, so users need to develop their own according to network needs. In terms of language structure, C++ on NS3 does look more complicated than the TCL language used on NS2. But NS3 is easier to use because it already contains libraries that we can call to meet our needs. The NS3 infrastructure itself supports the development of simulation models that are close to real conditions and have characteristics close to that of a network emulator. Besides being able to be used as a Simulator for IP-based Networks, NS3 can also be used as a Simulator for Non-IP-based Networks. Network Simulator 3 also has a tool that users can use to visualize their simulations. NetAnim is a tool created by Network Simulator 3 to visualize simulations created with Network Simulator 3. Just like Network Simulator 3, NetAnim runs on the Ubuntu operating system.

Network Performance

A network can be judged as good or bad quality from network performance measurements or commonly called Quality of Service (QoS). (Aprianto et al., 2020) Quality of Service (QoS) is a method of measuring how good a network is and is an attempt to define the characteristics and nature of a service. QoS is used to measure a set of performance attributes that have been specified and associated with a service. QoS refers to the ability of a network to provide better service to a given network traffic through different technologies. QoS offers the ability to define the attributes of the network services provided, both qualitatively and quantitatively.

C++ language

According to journal references (Ramadhana & Sujatmiko, 2017) the C++ language is a programming language used by programmers to write efficient, structured, object-oriented programs. In order to write and run C++ programs, you must have a text editor and a C++ compiler installed on your computer. A text editor is a software system that allows you to create and edit text files on your computer. Programmers use text editors to write programs in programming languages such as C++. A compiler is a software system that translates programs into machine language (called binary code) which can then be executed by a computer's operating system. The translation process is called program compilation. C++ compiler compiles C++ programs into machine language. Network Simulator 3 is based on the C++ language, meaning that all NS3 modules and constructs are built from C++. The C++ language is a programming language that can be said to be between a low-level language (a machine-oriented language) and a high-level language (a human-oriented language).

Script is a form of programming language that acts as a support or complement to a program. That is, program code with a scripting language will be inserted into a large or complex program code. CC in the .cc library means the header file from C, XML (Extensible Markup Language) is a computer language to simplify the process of exchanging and storing data. XML will store data in a simple text format, so that the data is understood by the server that receives the data without the need for changes in the XML. AWK (Aho, Weinberger, and Kernighan) is a special-purpose programming language designed for text processing and typically used as a data extraction and reporting tool.

Relevant Research

Table 2. Relevant Research

No	Name	Title	Research Result
1	Fathullah, Ida Nurcahyani	Simulation and comparative analysis of the performance of black hole attack mitigation techniques on the Mannet network	Black hole attack on the MANET network results in a decrease in performance. Indications of decline are seen in the QOS parameters, namely PDR, delay, and throughput. On the PDR, it decreased by about 11%; the delay increases by about 95 ms, and the throughput decreases by about 56 kbps. Changing nodes, the distance between nodes and the data rate can improve the performance of the MANET network affected by black hole attacks. Changing the node causes the delay to decrease to 107 ms. Changing the distance between nodes used can increase throughput to 472 kbps, packet delivery ratio to 93.63% and delay to 88.56 ms. Meanwhile, changing the data rate can increase throughput to 487 kbps and delay to 87 ms. The method of changing the distance between nodes has the best performance.
2	Kun Fayakun, Alfan Afandi, Fida Afifah, Harry Ramza	Comparative analysis of dvb-s2 signal margin measurements on the asiasat 9 satellite	The measurement process with the first method produces a link margin of 11.7 dB, 11.4 dB, and 11.6 dB, and produces an average value of 11.56 dB. While measurements using the second method produce a link margin of 11.6, 11.5 and 11.8 respectively and produce an average value of 11.63 dB. There is a difference of 0.07 dB, and this is very small, which can result in fluctuating gauge readings. This can prove that changes in the EIRP value on the satellite and changes in antenna pointing can be made, to prove the link margin value. From the measurements that have been carried out, it can be concluded that the two methods are feasible to be implemented in the measurement because using the ku-band frequency requires a large link margin to withstand rainfall. The greater the link margin indicates the better the quality of the communication. Finding a more accurate link margin value is obtained through the second measurement process by changing the elevation angle on the receiving antenna and it is easier

			to do compared to the first method which involves the satellite operator and permission from the operator as well as the technician from the satellite payload system.
3	Renato F. Lida, Pedro H. A. Trindade, Bruno Faria, Leonardo Aguayo, Alexander Wyglinski	A novel event-driven Simulation framework for dvb/rcs2 Performance characterization	This paper presents an event-driven system-level simulator with implementation details for PHY and MAC layers according to ETSI's DVB-RCS2 standard. We provide three example use cases for a working-proposed simulation framework to help evaluate and design GEO satellite systems with large area coverage in realistic scenarios. This proposed framework suggests two allocation strategies, and can be used in the future to test and evaluate new allocations. cation strategy. Additionally, the output is georeferenced and plotted on a scenario map. Finally the collision detection mechanism shows how this can affect the performance of the whole system form. The framework is also capable of providing an extensive set of results and KPIs, such as: Packet loss rate (PLR). The performance of other receivers will be presented in future works and code extensions to handle LEO trajectories are currently under development. The aim of this article is to focus on the behavior and analysis of DVB-RCS2. Code optimization is a topic of future research, as well as performance evaluation and code complexity.

RESEARCH METHOD

This study uses the NS3 software experimental method. Parameters analyzed include throughput, delay, PDR. This study uses quasi-experimental methods. The purpose of quasi-experimental research is pure experimental conditions in conditions where it is impossible to control or manipulate all relevant variables, namely estimating. The data collection method used as the basis for this research is in the form of primary data and secondary data. Primary data is data obtained directly from the simulations carried out, and secondary data is data obtained through intermediary media directly or indirectly such as books, journals, articles, and the internet as well as published and non-public archives as well as evidence existed. The research location is on the STTKD Campus. Research time: July 10 to September 25 2022. Equipment: Laptop. Materials: Xubuntu operating system; NS-3 software; NetAnim software; and VirtualBox Software.

Manufacturing Method

The first stage that will be carried out is the installation stage of NS-3.35 and the modules available at https://code.nsnam.org/ns-3-allinone which will be used for the simulation. Install the boos-devel library which will be used to run the openflow integration module, this module is needed so that the system runs optimally. The scenario in this simulation will be the process of sending data by the gateway to the user terminal and vice versa by sending data packets using one gateway, one satellite, one shipping terminal user with 10 simulation runs, this simulation will also use the antenna gain and noise specified in each packet sent to determine the effect of throughput, delay, packet delivery ratio in sending packets using NS-3.

RESEARCH RESULTS AND DISCUSSION

System Preparation

In the first stage the researcher installed the NS-3 version 3.35 and the modules that will be used. After successfully entering, as shown above, enter the ns-3.35 library and will execute several program commands. The first program command is to type the cd command to call the ns-3.35 library then type ls in the terminal to find out the contents of the library as a whole. The simulation process is run on the ns-3.35 library so that next time it will execute the command sudo ./waf distclean, this command will instruct the program to clean unnecessary temporary files in the waf. After executing the command above it shows the desired output, then it will execute the command ./waf –build-profile=optimized –enable-examples –enable-tests configure which functions to create a new profile for the simulation and to activate the test and sample modules and to configure the start of the program.

Executing commands on Waf from the local library, then waf will be reconfigured and create a new profile that will provide total system benefits when building a simulation system and double-checking for various module dependencies needed in the simulation in the profile created. From the output of the command ./waf –build-profile=optimized –enable-examples –enable-tests configure it can be seen that several ns-3 module options are not activated directly or require support from the underlying system to work properly and modules that are not activated directly requires further installation process. For example, to activate Openflow with NS3, the Openflow module must be downloaded and installed and configured so that it can be perfectly integrated with NS3. If this openflow module is not found, then the next command execution output that requires openflow module support will not run.

The system preparation process, in this case, is the NS-3 simulator program version NS-3.35, which will go through the final preparation stage, after which it will run the command ./test.py on the screen. this command will execute the ns-3 program to run a number of test units on waf, the execution of this command will take a while depending on the processor speed and the physical memory capacity of the laptop used, this command results in the command execution process as shown in the image below .

Data Package Delivery Simulation Scenario

This simulation uses the NS-3.35 simulator, in testing to run this simulation using one ground station and one user terminal which have their respective roles and one satellite is used, after all components are connected, the author will monitor network traffic. If the network traffic in the topology is as desired, the next step is to enter the parameters into the NS3 simulator to test the network that was created before. The parameters to be tested are throughput, delay, and packet delivery ratio. After getting the results of these QoS parameters by manipulating the antenna gain, the author will compare the results of these parameters so as to get the values of the three parameters with different antenna gains. In this process, 10 simulations will be carried out where details about the simulation can be seen in the following table:

Table 3. Simulation Scenario

Number of simulations	Source	Destinations	Description
5 times with antenna gain 28db, 29db, 30db, 33db, 35db	Ground Station	User Terminals	Looking for the effect of data rate on throughput, delay, and packet delivery ratio
5 times with antenna gain 28db, 29db, 30db, 33db, 35db	User Terminals	Ground Station	Looking for the effect of data rate on throughput, delay, and packet delivery ratio

Based on the scenario above, the data flow process that will be simulated is from the ground station to the satellite and then received by the user terminal and from the user terminal to the satellite and then received by the ground station. then build the topology implementation into the NS3 simulator, the topology that has been built will be built in NS3 to get the output of the topology path that has been made. The output results are then re-evaluated, to validate whether the paths in the topology that have been made are as desired or planned or have not fulfilled the previous system design.

After the topology is as desired, the next step is to enter parameters that can affect the final value of sending the data packet. In testing to obtain throughput, delay, and packet delivery ratio values, the initial parameters that will be used are the time or duration parameters used 20 seconds and the antenna gain is 45.2 db. Then it will compare the values of throughput, delay, and packet delivery ratio with 5 types of antenna gain with intervals of 28db, 29db, 30db, 33db, 35db. The selected interval corresponds to the DVB-S2 default.

Simulation Results

The following are the results of testing using the NS3 network simulation program that has been built in accordance with the scenarios that have been discussed, the initial parameters are 20 seconds of time and 45.2 db of antenna gain.

Delivery from User Terminal to Ground Station

After the topology path that has been built is in accordance with what is desired, the next step is to provide output results for the parameter values being tested. From the results of determining the parameter values that have been determined, the parameter values will be displayed regarding sending data packets from the user terminal to the ground station (RTN). The output of this packet delivery displays a number of parameters obtained in the form of throughput, delay, and packet delivery ratio from the results of the initial determination of Error! Reference source not found., then a number of these data to find a comparison of the parameter values obtained. The parameters obtained from the output results are throughput (in Kbps units), delay (in s units), and packet delivery ratio (in percentages). The values of throughput, delay and PDR parameters are compared based on the data rate given in the topology.

Table 4. Throughput Parameter Values

antenna gain	throughput	antenna gain	throughput
28 dBi	0 Kbps	33 dBi	59,7948 Kbps
29 dBi	1,86962 Kbps	35 dBi	59,8967 Kbps
30 dBi	28,0898 Kbps		

The results of the throughput parameter with changes in data rate (in Kbps units) The results of running with variations of antenna gain 35 dBi throughput show the speed of sending data packets, namely 59.8967 Kbps and the average throughput of the five variations, namely 29.9301 Kbps.

Table 5. Delay Parameter Values

antenna gain	Delay	antenna gain	Delay
28 dBi	0 s	33 dBi	0,683732 s
29 dBi	162,0825 s	35 dBi	0,560363 s
30 dBi	81,2796 s		

The results of the delay parameter with units of seconds, on the results of running with the antenna gain variation of 35 dBi the fastest delay from sending data packets is 0.560363 s and the average delay of the five variations is 48.9212s.

Table 6. PDR Parameter Values

antenna gain	PDR	antenna gain	PDR
28 dBi	0 %	33 dBi	57,04%
29 dBi	2,41748 %	35 dBi	57,65%
30 dBi	31,5537 %		

The results of the packet delivery ratio parameter with percent units, on the results of running with an antenna gain variation of 35 dBi the data packet delivery ratio is 57.65% and the average ratio of the five variations is 29.7322%.

Delivery from Ground Station to User Terminal

From the results of determining the parameter values that have been determined, the parameter values will be displayed regarding sending data packets from the ground station to the user terminal (FWD).

Table 7. Parameter Values with Antenna Gain

antenna gain	throughput	delay	packet delivery ratio
28 dBi	203,549 Kbps	0,263834 s	99,91 %
29 dBi			
30 dBi			
33 dBi			
35 dBi			

The results of running with five antenna gain variations, namely 28, 29, 30, 33, 35db, show throughput results of 203.549 Kbps with a delay of 0.263834 s and a packet delivery ratio of 99.91%.

Table 8. Parameter Values With Noise

Noise	throughput	delay	packet delivery ratio
0 db	203,549 Kbps	0,263834 s	99,91%
24,7 db			
49,4 db			

The results of running with five variations of noise, namely 0 db, 24.7 db, 49, 7 db, show throughput results of 203.549 Kbps with a delay of 0.263834 s and a packet delivery ratio of 99.91%. The results of the comparison of the parameter values from UT to the ground station show that the throughput value continues to increase based on the given data rate. For the delay value, there is a decrease in line with the increase in the given data rate and for the packet delivery ratio value it has increased while the parameter values from the ground station to ut show that the throughput, delay, packet delivery ratio values are fixed or there is no change. The following will give a graph of the throughput, delay, packet delivery ratio parameters tested with different antenna gain:

Throughput

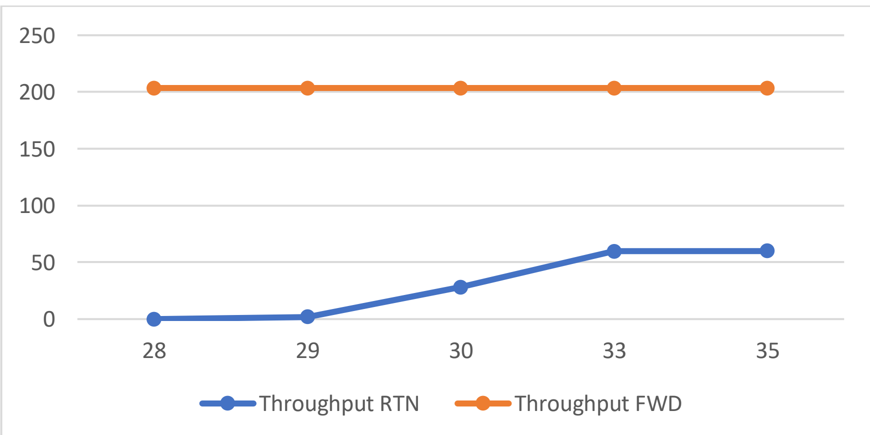

Figure 1. Graph of Changes in Throughput Parameter Values

From the graph in Figure 1, the RTN throughput has increased in speed and while the FDW throughput is stable where both throughputs have good quality of service, if the quality parameters decrease it will result in a decrease in network quality.

Delay

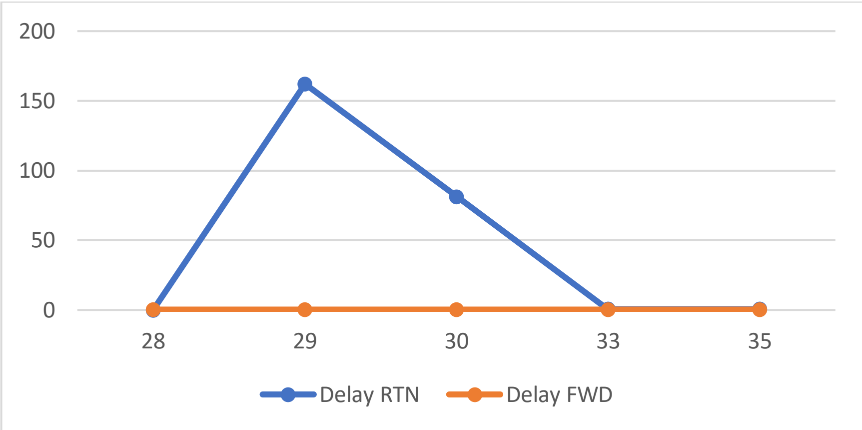

Figure 2. Graph of Changes in Delay Parameter Values

From the graph in Figure 2, the RTN delay has fluctuated because the antenna gain is 28 dBi, the delay has dropped or there is no data packet delivery at all after 29 dBi to 35 dBi has decreased, while the FWD delay has stabilized, from the table above it shows that the greater antenna gain the smaller the delay value that appears.

Packet Delivery Ratio (PDR)

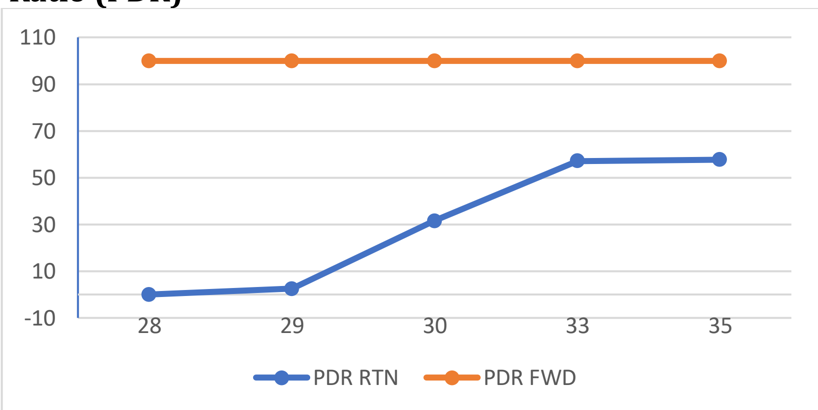

Figure 3. Graph of Changes in PDR Parameter Values

From the graph above the RTN packet delivery ratio shows that there is an increase, meaning that the greater the percentage of data packets sent will reduce the loss of data packets received, while the FWD packet delivery ratio is stable at 99.91%, which means it is very good because few data packets are lost.

CONCLUSION

Based on the research process that has been carried out in this study, a number of things are obtained as a conclusion: In this study, a simulation of sending data packets was successfully carried out using the NS3 simulator tools. Based on the simulations that have been carried out, several characteristics of the effect of antenna gain on the quality of data packet transmission are obtained. The simulations explain well that the values of throughput, delay, and PDR have increased so as to provide good service quality. Based on the simulations that have been carried out, several characteristics of the influence of the interference level that affect the user on the quality of sending data packets are obtained. The simulation explains well that the values of throughput, delay, and PDR experience stability so that the level of interference has no effect on users in sending packets. However, the values obtained are very good and have not decreased.

Suggestion: In general, there are a lot of research on network simulation using open source simulation software NS3, so similar research is still needed by comparing the results obtained in this study with other simulator tools, for example: OMNET++, SWAN, OPNET, Jist, and GloMoSiM . Besides that, the use of more complex data packet delivery scenarios will get better data to be able to conclude important things from the parameters measured in this study.

BIBLIOGRAPHY

Afandi, A., Afifah, F., Ramza, H., & Fayakun, K. (2019). Analisa Perbandingan Pengukuran Margin Sinyal Dvb-S2 Pada Satelit Asiasat 9. E - ISSN, jurnal kajian teknik elektro, April, 2014.

Aprianto, B., M. Ficky Duskarnaen, & Hamidillah Ajie. (2020). Analisis Quality of Service (Qos) Pada Jaringan Internet Smk Negeri 7 Jakarta. PINTER: Jurnal Pendidikan Teknik Informatika dan Komputer, 4(2), 32–36. https://doi.org/10.21009/pinter.4.2.6

Ariyanti, W. (2019). Pemodelan Dan Simulasi Instrumen Pesawat Vor/Dme (Vhf Omni-Directional Range/Distance Measuring Equipment) Sebagai Peralatan Navigasi Udara (Navaids) Pada Pesawat Terbang. Jurnal FIKI, IX(1), 2087–2372.

Banna, M. H. Al. (2017). Pengembangan Antenna Tracker Berbasis Global Positioning System (GPS) Untuk Komunikasi Pesawat Tanpa Awak. 74.

Basith, A. (2011). Optimalisasi Jaringan Topologi Star Dengan Algoritma Link-State Menggunakan Model Simulasi Graphical Network Simulator 3.

Caya, T. V., Syihabuddin, B., Elektro, F. T., Telkom, U., Orbit, L. E., & Rate, B. E. (2020). Simulasi Dan Analisis Penerimaan Sinyal Automatic Dependent Surveillance-Broadcast Dengan Satelit Orbit Rendah Simulation And Analysis Of Automatic Dependent Surveillance-Broadcast Signal Reception Over Low. 7(3), 9199–9206.

Cornejo, A., & Landeros, S. (2017). Simulation Model and Comparison for Satellite Links in Ku and Ka Bands for Standards-based on DVB-S2 and NS3. 14(4).

Cristina Parraga Niebla, ria Riera Diaz, Sandro Scalise, C., & Kissling. (2006). DVB-S2/RCS Suitability for the Provision of Air Traffic Management Services. 1–5.

Duskarnaen, M. F., & Nurfalah, F. (2017). Analisis, Perancangan, Dan Implementasi Jaringan Wireless Point To Point Antara Kampus A Dan Kampus B Universitas Negeri Jakarta. PINTER : Jurnal Pendidikan Teknik Informatika dan Komputer, 1(2), 134–141. https://doi.org/10.21009/pinter.1.2.6

Fatimah, S. (2017). Sistem Komunikasi. Journal of Chemical Information and Modeling, 53(9), 1689–1699.

Lestariningati, S. I. (2012). Jurnal Sistem Komputer Unikom – Komputika – Volume 1, No.1 - 2012. Jurnal Sistem Komputer Unikom, 1(2), 1–7.

Lisa, A. (2017). Rancang Bangun Sistem Monitoring Charger Aki Otomatis Menggunakan Komunikasi Wireless Rf Berbasis Mikrokontroler Atmega 328. 1–64.

Raj, J. S. (2019). Qos Optimization Of Energy Efficient Routing In Iot Wireless Sensor Networks. 01(01), 12–23.

Ramadhana, I., & Sujatmiko, B. (2017). Untuk Meningkatkan Kompetensi Kognitif Mata Kuliah Struktur Data Ilmi Ramadhana Bambang Sujatmiko Abstrak.

Salam, A. A., Luglio, M., Roseti, C., & Zampognaro, F. (2017). A burst - approach for transmission of TCP traffic over DVB - RCS2 links. 175–179.

Samudera, & Adji, M. (2019). Perancangan Radio Telemetry Monitoring System Pada Prototipe Pesawat Verpoly. 5–31.

Suyatmo, S., Prayitno, H., Hasnita, U., Idris, I., & Khair, R. (2019). Rancang Bangun Media Pembelajaran Avionic - Adf (Automatic Direction Finding System) Berbasis Multimedia Animasi Pada Atkp Medan. Jurnal Teknologi Informasi, 3(2), 222. https://doi.org/10.36294/jurti.v3i2.1218

Tri Nopiyani Damayanti, A. G. (2012). Analisis Kinerja Sistem Komunikasi Air Traffic Controller Pada Daerah Pemantauan Area Control Center (ACC) Bandara Soekarno Hatta. Jurnal ICT Peneltiain dan Penerapan Teknologi, 3(4), 28–36.

Tutorial, N. S. 3 A. (2021). ns-3 Tutorial.