IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676, p-ISSN: 2320-3331, Volume 16, Issue 1 Ser. II (Jan. – Feb. 2021), PP 21-33
www.iosrjournals.org

Performance Improvement of Satellite Networks Based On Fuzzy Logic Controller

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Abstract:
This study presents the performance improvement of satellite networks based on fuzzy logic controller. The satellite communication is an essential part of telecommunication systems which carries a large amount of data and telephone traffic in addition to television signals. At high frequency, satellite links are more sensitive to signal fades due to rain, especially in the tropical region. Rain attenuation can have a distorting effect on the quality of service (QoS) at higher frequencies that lead to excessive digital transmission error. This loss of signal is commonly referred to as signal attenuation. Rainfall data was obtained from the Nigerian Meteorological Agency for a period of ten (10) years for the purpose of estimating attenuation using ITU-R model and calculation of received signal level. Umuahia geographical location was considered as the choice of environment. Data was also obtained from Modern Communications Limited which was used to calculate Bit-error-rate and Network throughput. A developed model was used to interact with the input parameters to improve the quality of signal. The fuzzy logic system was added to mitigate rain attenuation in order to guarantee a certain level of signal quality. The simulated results show the effectiveness of the developed model and its ability to improve the quality of the satellite signal by 87% over Ku-band satellite communication in spite of rain attenuation.

***Key Word**: Satellite networks; Fuzzy logic controller; Rain attenuation; ITU-R model.*

Date of Submission: 04-02-2021 Date of Acceptance: 19-02-2021

I. Introduction

Satellite communications are essentially used for providing communication links between different areas on the Earth by receiving information from a transmitting earth station. Satellite communications play an important role globally in the telecommunications system. About 3,000 satellites are orbiting the Earth relaying continuous and discrete information bearing data, video and audio from one area/location to another in the world.

Satellite based communication networks at high frequencies are rapidly expanding. These high frequency operations have enabled a large number of available applications and services including communications, navigation, telemedicine, remote sensing, network sensors distribution, and access to internet without the use of wires. However, high frequency applications can generally result to large transmission problems because of atmospheric attenuations, [1].

Satellite communications were first used for military communications applications. These services, later on, were open to public for different usages such as long distance telephone network and television. Starting in 1990's, another task was added to satellite communication technology, which was the connection to the Internet through broadband data links. Thus, the satellite communication experience has shown that satellite applications can serve many military and civilian requirements, [2]

Satellite communications are cost effective, secure, reliable, and survivable. They can be easily identified as the best, being the only, solution to challenges of transmitting with highly mobile forces. Satellite communication system is mainly a communication package situated in earth orbit, in which the main purpose is to assist transmission of information from place to place via space. Satellites form an important part of global telecommunication systems which carry reasonable quantity of voice, video, and data traffic, and having some characteristics like covering wider areas of the earth, with the ability to provide instantaneous infrastructure particularly in underserved areas, as well as frequency reuse technique through On Board Processor (OBP), [3].

Satellites send signal using frequency bands. The most profitable bands presently used are C and Ku-bands. The application of a new band called Ka-band is expected to emerge in the nearest future. Generally C-band uses frequency bands of 4-6 GHz which is usually applied for constant services like mobile feeder links, Internet Trunking and Public Switched Network. Ku-band uses frequencies of 12-18 GHz range which is widely applied in constant services like VSAT, serving small businesses and corporate networks that use a small transceiver which is directly connected to the satellite in star system topology. Ku-band serves video distribution applications and Internet trunking, [4].

Application of larger bands like the Ku band for satellite services offers so many advantages which include congestion reduction in the lower bands that are been distributed within terrestrial connections; it propagates larger available bandwidths at higher bands, and offers lower cost application of spectrum conservation methods and a better utilization of the geostationary arc. [5] posited that the increase in radio wave propagation increases frequency due to severity of atmospheric impairments. It therefore implies that in depth idea of the propagation study influencing availability of the system and quality of signal in different bands are required.

Kurtz-Under band (Ku band) is a microwave frequency band which is used for satellite broadcasting and communication using frequencies of about 12GHz for terrestrial reception and 18GHz for transmission. Ku-band is mostly adopted for satellite services, mostly satellite to ground station applied in direct broadcast satellite television. Ku-band handles the challenge encountered in terrestrial microwave backhaul connections. Furthermore, it is known for its increase in power signals. Ku-band radio transmitter needs lesser power. Mostly, 0.9, 1.2, or 1.8m dish is applied for Ku-band operations. This is economical and could save much Capital Expenditure (CAPEX) and makes Ku-band best applicable for small networks, [6].

However, Ku-band is very much prone to rain fade and the attenuation caused by rain can be up to 10dB. Ku-band works better in small area for installation due to small size of dish is required and it is simple and easy to install. Moreover, Ku-band is suitable for satellite services which require a little bandwidth, as the device is cheaper. Ku-band can provide acceptable quality of service and communication speed, [7].

The effect of atmosphere is a primary issue when designing satellite-to-earth links operating at frequencies beyond 10GHz. Droplets of rain absorb and scatter radio waves, leading to signal attenuation and decrease in the system reliability and availability. It also causes one of the major fundamental problems on the communication satellite links performance, resulting to large variations in the signal power at the receiver end. Moreso, satellite services using 10GHz frequencies and beyond are influenced by different propagation impairments like attenuation caused by rain, attenuation caused by cloud, rain and ice depolarization, [8].

Rainfall causes attenuation of radio waves by absorption and by scattering of signal obtained from the wave and facilitate increase in the frequency that reduces the reliability and efficiency of the communication satellite link. Rain effects are dependent on frequency, rain rate, drop size distribution and drop shape, which are determined by the type of rain being witnessed in a particular region, [9].

Attenuation caused by rain is a primary source of impairment to information propagation at millimeter and microwave wavebands. These impairments become particularly severe at higher frequencies, especially beyond Ku-band. Because of this, it is very difficult to maximally utilize satellite based network resources which are affected by weather attenuations. Therefore, there is need to adequately study important attenuation factors which influence quality of service and the application of fuzzy logic can be deployed over the system to enhance received signal over satellite broadcasting.

Fuzzy Logic Controller

Fuzzy logic controller is a rule driven system where the controller uses fuzzy logic procedures to simulate human thinking in dealing with a complex system. Fuzzy logic controller is a better tool in dealing with processes that are very large to analyze, especially when the transmitted signals are interpreted quantitatively and uncertain in classification. The same situation is observed when the transmitted signals are combined with several impairments and employed multiple mitigation techniques are available. Fuzzy logic controller is a better tool to handle this complex situation because it consists of four compositions which are fuzzifier, fuzzy rule base, fuzzy inference system and defuzzier.

According to [10] modern Fuzzy Logic was initiated by Lofti Zadeth in the mid- 1960s to model those problems in which imprecise data must be used or in which the rules of inference are formulated in a very general way of making use of categories. Fuzzy Logic generally provides reliable and efficient representation for evaluation of irregularities and meaning representation of unclear concept presented in normal language, [11].

The application of fuzzy logic has been given high attention recently due to its worth in minimizing the requirement for ambiguous mathematical models in solving problems. Fuzzy logic uses linguistic terms which have to do with the little relationship between input and output variables. Hence, fuzzy logic method makes it simpler and easier to manipulate and proffer solutions to various problems, especially when the mathematical model is not properly known, or is difficult to solve.

Problem Statement

There are some basic effects of propagation abnormalities which affect the communication satellite systems performance. In a satellite communication, weather losses result from degradation of the satellite signals by hydrometers as they cross the earth's atmosphere. One of the losses encountered by satellite communication systems is rain attenuation. When higher frequencies are transmitted and received under heavy rain fall, signal degradation which is proportionate to the intensity of rain fall occurs, [12].

Rain leads to reduction of the transmitted signals with different degrees of severity, depending on the rain rate, size of raindrop, intensity of rain and the frequency of operation.

Attenuation due to rain is the primary cause of attenuation over Ku-band communication satellite; this is because the frequency of Ku-band is influenced in rhythm of rain attenuation. If there is a synchronization of both of them, the signal will be attenuated or lost. This is a major limitation that occurs in Ku-band when a high frequency is deployed, [13].

Satellite communications that suffer attenuation problems at high frequency sometimes could not be able to receive down link signal which conveys picture and sound. Therefore for signals to be properly received and transmitted during rain, attenuation and bit-error-rate should be reduced to the barest minimum so as to increase the received signal level and the network throughput thereby improving the quality of the satellite signal.

Rain Attenuation

Attenuation caused by rain is the dominant factor in path loss variation above 10GHz, and affects the transmission of electromagnetic signals in three ways namely;

it increases the system noise temperature
it changes polarization
it attenuates the signal

System Noise Temperature

The satellite to ground system noise temperature increases because of rain. The figure of merit of the ground location collect antenna is the proportion of the antenna gain to the device temperature G/T. The impact of rain is to make the system temperature higher and minimizes the figure of merit. The antenna temperature is the combined cloud temperature determined through the antenna gain. At an increased elevation angle, the clear sky temperature is basically about 25K since the antenna looks at cold space. However, the temperature of liquid water is about 300K.

Thus the rain effect increases the sky temperature noteworthy. Therefore, the noise accepted to the ground station receiving antenna increases and results to further signal reduction, [2].

Rain and Polarization

Rain affects signal polarization remarkably. Resulting from air resistance, a falling raindrop has the shape of a spheroid. Wind as well as other rotating pressure can make the rain drop to move round at statistical spreading of angles. Subsequently, the path length of transmission through the rain drop varies for various signal polarizations and the polarized received information is changed. For any given satellite service with double linear polarizations, the variation in polarization has two effects. First, there is loss in strength of the signal due to poor alignment of antenna component in relation to the orientation of bright sky expressed as

$$20\log(\cos\tau) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

where τ represent polarization tilt angle caused by the rain. Secondly, there is another obstruction noise caused by part of incoming signal in reverse polarization.

Attenuation

A major influence of rainfall is that attenuates the signal. The attenuation is due to absorption and scattering of electromagnetic waves by splashes of raindrop. The scattering diffuses the signal, but absorption is the vibration of the waves with molecules water. Absorption maximizes the energy of the molecules that corresponds to a little temperature increase, and causes reduction of signal energy. The attenuation increases as the wavelength approaches the size of water molecules, which is about 1.5 millimeters. The wavelength and frequency are related by

$$c = \lambda * f \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

where λ is the wavelength, f is the frequency, and c represents speed of light (approximately 3 x 108 m/s). For instance, for Ku-band satellite to ground frequency of 12 GHz, the wavelength is 25 millimeters, the wavelength is larger than the raindrop size.

Therefore, representing rain attenuation using standard method is

$$Lr=\alpha R\beta L = \Upsilon L \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

where R represents rain rate (mm/h), Lr represents rain attenuation (dB), L represents path length (km), and α and β represent empirical coefficients that is dependent upon frequency and polarization. γ represents the specific rain attenuation, and is expressed in dB/km. The path length is dependent upon the angle of elevation, the ground station latitude and the height of the rain layer. The rainfall rate is included into this equation due to the fact that it is used to measure the mean size of raindrops. When the rainfall rate increases, that is it rains heavily, the rain drops are larger and thus there is more attenuation. Rain models are different the way the effective path length L is calculated, (Nelson, 2000).

ITU-R Model

The ITU-R model is used worldwide, with huge range of frequencies with different elevation angles, for different rain climates. It is the most acceptable model by the international propagation community which is applied for calculating statistics of long term rain attenuation at higher frequencies in most of the regions, [14].
It was at the 25th Plenary Assembly held at Geneva in 1982 that the International Telecommunication Union first adopted a prediction of attenuation caused by rain. The model name is ITU-R P.618-11.This gives a summarized procedure for the computation of satellite path rain attenuation. The following parameters are needed for calculating attenuation.

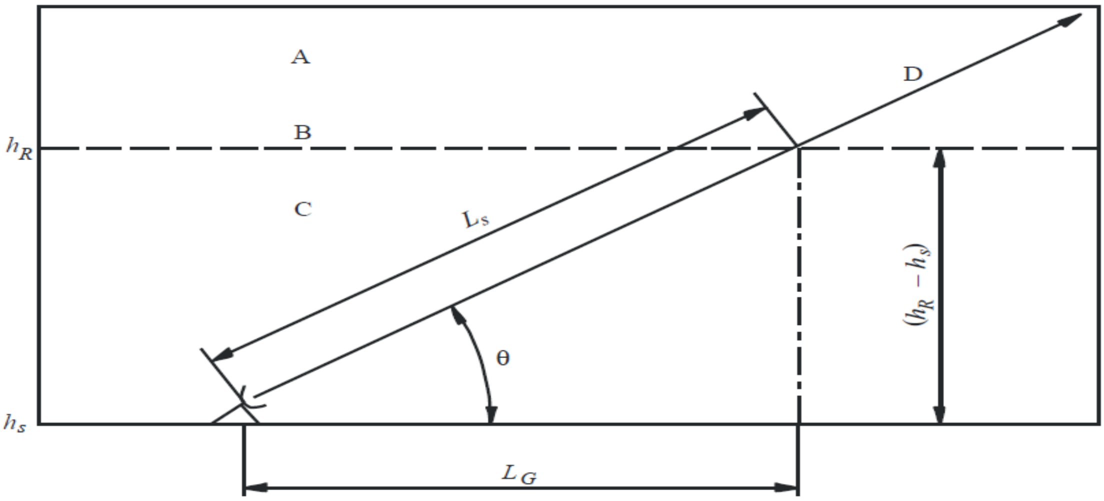


Figure 1: Schematic diagram for the attenuation prediction

A: Frozen precipitation, B: Rain height, C: Liquid precipitation, D: Earth space path,
hs: Earth station height above mean sea level(km) , Ө: Elevation angle (degrees),
Ø: Earth station latitude (degrees), F: working frequency (GHz),
Re: Effective radius of the earth (8500km), hR= Effective rain height (km),
R0.01: 0.01% of point rainfall rate (mm/hr) of average year for the location.
Ls = Slant path length (km), LG = Horizontal projection of the slant path (km).

II. Material And Methods

The materials used are essential for this study which includes the coaxial cable to connect their satellite antenna facilities to customer’s homes and their businesses. Rain gauge was used to measure the amount of liquid precipitation over a given period of time.

The compass used shows the direction relative to the geographical cardinal directions. The parabolic reflector antennas that use a parabolic reflector curved surfaces were used to direct the radio waves. Stopwatch was used to account for the period which the rainfall took place.

In the evaluation of the rain attenuation and characteristic in Umuahia, rain data for the site were obtained from Nigerian Meteorological Agency (NIMET) from (2009 – 2018). The location coordinates are (Latitude 5.5330N, Longitude 7.4830E).

Ku-band used for satellite broadcasting and communication uses a frequency of 18GHz and 12GHz for transmission and reception of signals.
The block diagram of a signal over Ku-band satellite communication is shown in figure 2.

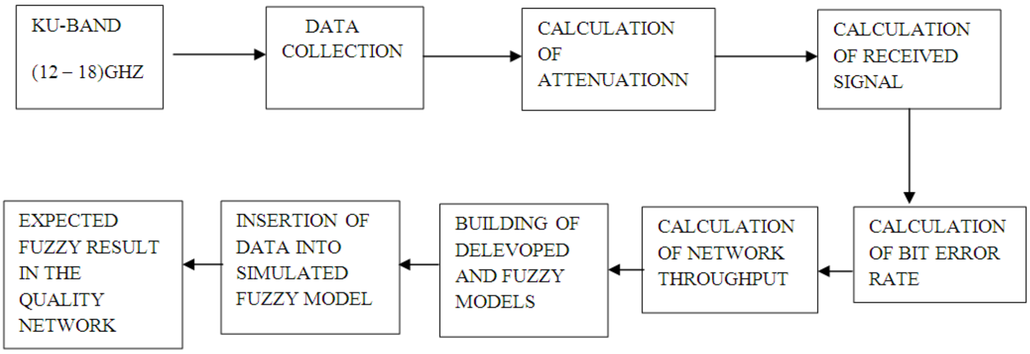


Figure 2: Block diagram of signal over Ku-band satellite communication

Ku-band is used for satellite broadcasting and communication. It uses 18GHz for transmission of signals and 12GHz for reception of signals. Rainfall data was obtained for a period of ten years (10 years). After obtaining the data, the data was arranged annually and put in a tabular form showing year, annual rainfall and average annual rainfall.

ITU model was used to calculate attenuation for ten years. The data obtained from the Modern communications Ltd. (MCL) operating at a frequency of 12.5GHz was used to calculate the bit-error rate and network throughput for this period. The calculated values were inserted into the fuzzy model for each year and the expected results were obtained in the quality network.

Table 1: Average annual rainfall accumulation for ten years (10 years)

YEAR	**ANNUAL RAINFALL (mm)**	**NO. OF DAYS**	**MEAN ANNUAL RAINFALL (mm/yr)**	**RAIN RATE**
2009	2060.1	147	14.0	26.9
2010	3350.3	110	30.5	33.9
2011	2560.9	120	21.3	30.5
2012	3560.8	101	35.3	35.5
2013	2135.8	132	16.2	28.1
2014	1798.6	135	13.3	26.5
2015	2676.6	132	20.3	30.0
2016	4322.7	107	40.4	36.9
2017	3379.8	115	29.4	33.4
2018	2728.6	108	25.3	32.1

The daily rainfall data will be converted to average/mean annual accumulation (M) in mm/year. To estimate rainfall rate with an integration time of one minute, $R_{0.01}$, it is suggested that it is derived from the value of M at the location of interest. Several techniques have been described for the estimation of $R_{0.01}$ from the long-term mean annual rainfall, M. Chebil's model appears suitable and it allows the usage of long-time mean annual accumulation, M, at the location . The power law of the model is given by

$$R_{0.01} = \propto M^{\beta} \qquad 4$$

where α and β are regression coefficients. In Chebil's model the regression coefficients are defined as α = 12.2903 and β = 0.2973.

Table 2: The attenuation and specific attenuation experienced each year using ITU-R Model.

YEAR	SPECIFIC ATTENUATION (dB/km)	ATTENUATION (dB)
2009	0.02552	0.1392
2010	0.02561	0.1397
2011	0.02557	0.1395
2012	0.02563	0.1398
2013	0.02553	0.1393
2014	0.02551	0.1392
2015	0.02556	0.1394
2016	0.02565	0.1399
2017	0.02561	0.1397
2018	0.02559	0.1396

RECEIVED SIGNAL LEVEL

Received signal level refers to the actual received signal level (usually measured in negative dBm) appeared at the antenna part of a satellite receiver from a remote transmitter.

The mathematical relationship between the received signal level of a satellite communication and rainfall rate is shown in equation 2;

$P = 16.57e^{-0.04363r} - 33.57$ 5

where P is the received signal level and r is the rainfall rate. The received signal level decreases as the rainfall rate increases.

The received signal level and rainfall rate experienced each year is shown in Table 3.

YEAR	**RAINFALL RATE (mm/hr)**	**RECEIVED SIGNAL LEVEL (dBm)**
2009	26.9	-28.4
2010	33.9	-29.8
2011	30.5	-29.2
2012	35.5	-30.0
2013	28.1	-28.7
2014	26.5	-28.4
2015	30.0	-29.1
2016	36.9	-30.3
2017	33.4	-29.7
2018	32.1	-29.5

DETERMINATION OF BIT ERROR RATE

Bit error rate is the fraction of bits lost or incorrect among all transmitted bits. Reduction in the QoS is caused by an increase in the BER of digital transmissions. In a communication system the quality of the transmission is usually quantified by either bit error rate (BER) or packet error ratio (PER), where a packet contains a number of bits. Bit error rate is the number of bits per unit time. Packet error ratio is the number of incorrectly received packets divided by the total number of received packets. It is the fraction of packet lost or packets containing bit errors among all transmitted packets. The receiver counts the successfully received packets among a known number of transmitted packets.

The relationship between BER and packet error rate (PER) is expressed as:

$PER = 1 - (1 - BER)^n$ ………………………………………………………….. 6

where n is the number of bits in the packet. Thus,

$BER = 1 - (1 - PER)^{1/n}$ ……………………………………………………. 7

DVB-S2 takes any input stream format including single or many MPEG/MPEG-2 transport streams (characterized by 188 byte packet) therefore, each packet contains 188 bytes.

Table 4 Computation of Packet error rate, Received signal level and Bit-Error-Rate.

YEAR	PACKET ERROR RATE	SIGNAL LEVEL	BIT ERROT RATE
2009	0.167	-28.4	0.0001215
2010	0.143	-29.8	0.0001030
2011	0.231	-29.2	0.0001746
2012	0.308	-30.0	0.0002447
2013	0.333	-28.7	0.0002692
2014	0.417	-28.4	0.0003587
2015	0.455	-29.1	0.0004039
2016	0.455	-30.3	0.0004039
2017	0.450	-29.7	0.0003974
2018	0.364	-29.5	0.0003009

DETERMINATION OF NETWORK THROUGHPUT

Network throughput is the rate at which packets are delivered successfully over a communication channel. It is normally measured in bits per second (bps) or data packets per second (pps). It is an indicator of the performance and quality of a network. Network throughput is affected by a number of factors which include network congestion and packet loss. Throughput is used to measure network efficiency and quality of service in the sense that a low throughput offers low network performance or bad network and high throughput offers high network performance or good network. Network throughput is calculated using equation 3.38

Throughput, $W = (1-BER)^n * \text{bit rate}$ ………………………………………….. 8

where n is the number of bits in the packet.

The bit rate is the number of bits that pass a given point in a telecommunication network in a given amount of time, usually a second. The bit rate obtained from MCL transmission office is 44.4Mbits/second.

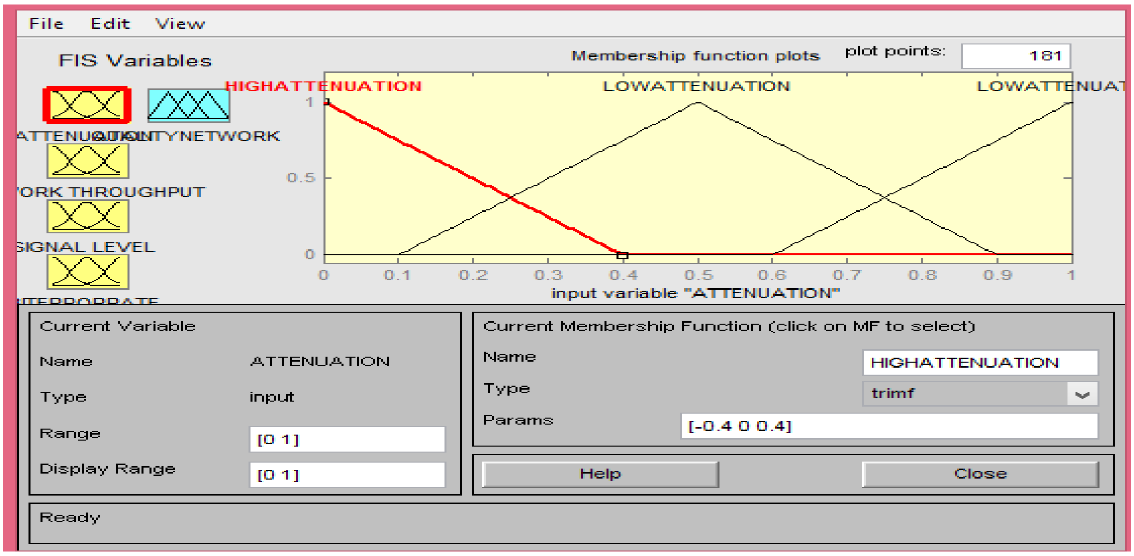
The network throughput experienced each year is shown in Table 5

YEAR	NETWORK THROUGHPUT (Mbps)
2009	36.99
2010	38.03
2011	34.14

2012	30.72
2013	29.61
2014	25.89
2015	24.18
2016	24.18
2017	24.42
2018	28.24

III. Result and Discussion

The results presents the membership functions (MFs) of attenuation, production output, received signal level, network throughput, bit-error rate. Rule base and rule viewer are also presented. The input space is sometimes referred to as the universe of discourse. The membership functions are selected for each fuzzy input and output variable based on the fuzzy set. The membership functions for attenuation, received signal level, network throughput, bit-error rate and the production output is shown in figures 3,4,5,6 and 7 respectively. The fuzzy model, rule base and ruler viewer are shown in figures 8, 9 and 10 respectively.



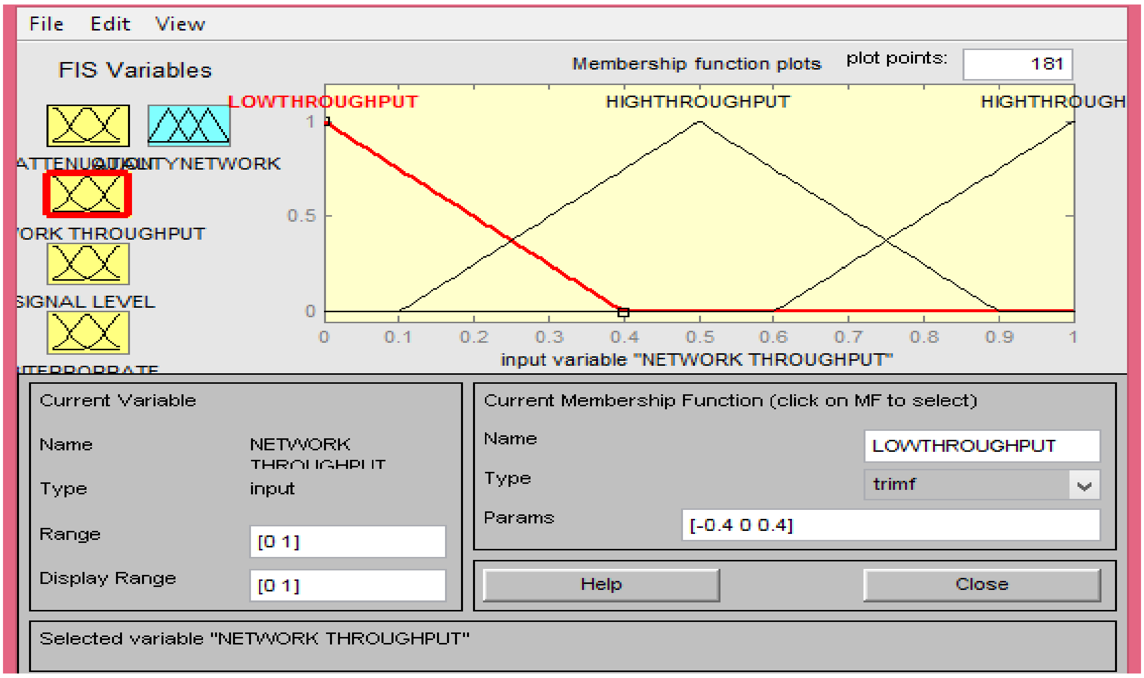
plot points: 181

Current Variable
Name ATTENUATION
Type input
Range [0 1]
Display Range [0 1]

Current Membership Function (click on MF to select)
Name HIGHATTENUATION
Type trimf
Params [-0.4 0 0.4]

Ready

Figure 3: Attenuation (input) membership function



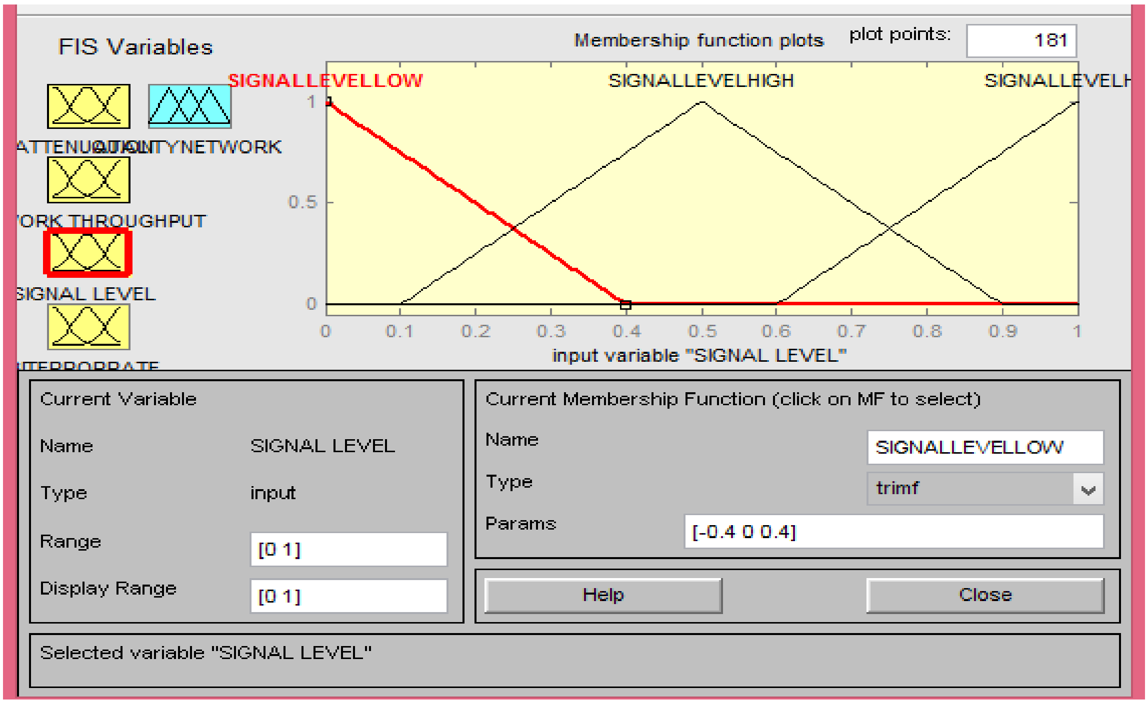
plot points: 181

Current Variable
Name NETWORK THROUGHPUT
Type input
Range [0 1]
Display Range [0 1]

Current Membership Function (click on MF to select)
Name LOWTHROUGHPUT
Type trimf
Params [-0.4 0 0.4]

Selected variable "NETWORK THROUGHPUT"

Figure 4: Network throughput (input) membership function



Current Variable

Name SIGNAL LEVEL

Type input

Range [0 1]

Display Range [0 1]

Current Membership Function (click on MF to select)

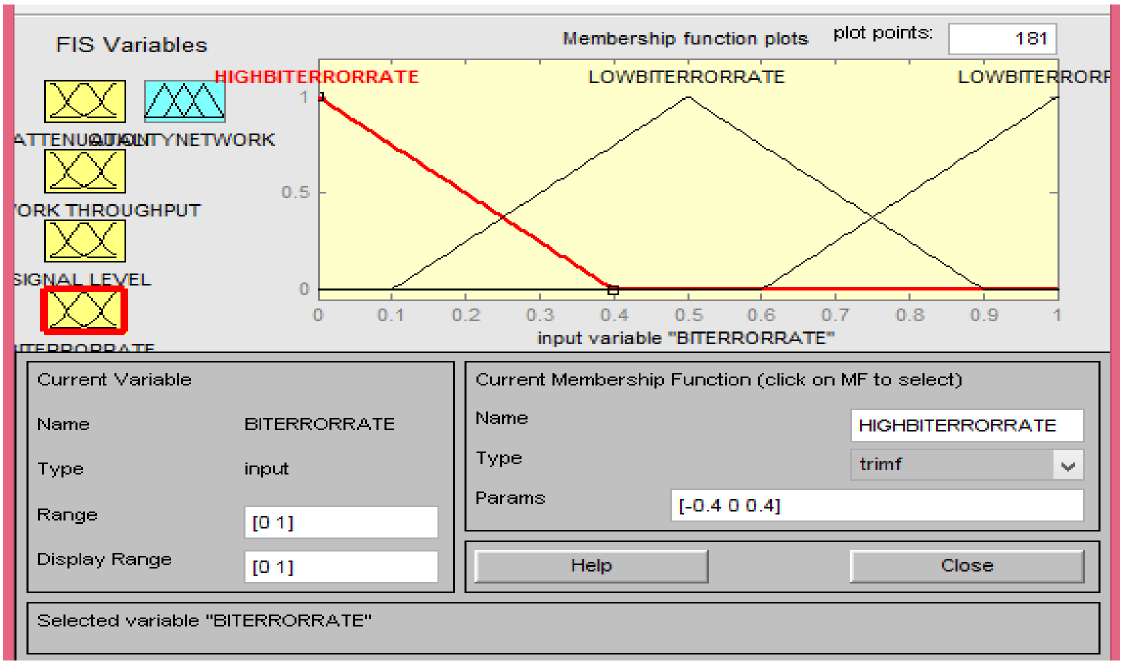
Name SIGNALLEVELLOW

Type trimf

Params [-0.4 0 0.4]

Selected variable "SIGNAL LEVEL"

Figure 5: Received signal level (input) membership function



Current Variable

Name BITERRORRATE

Type input

Range [0 1]

Display Range [0 1]

Current Membership Function (click on MF to select)

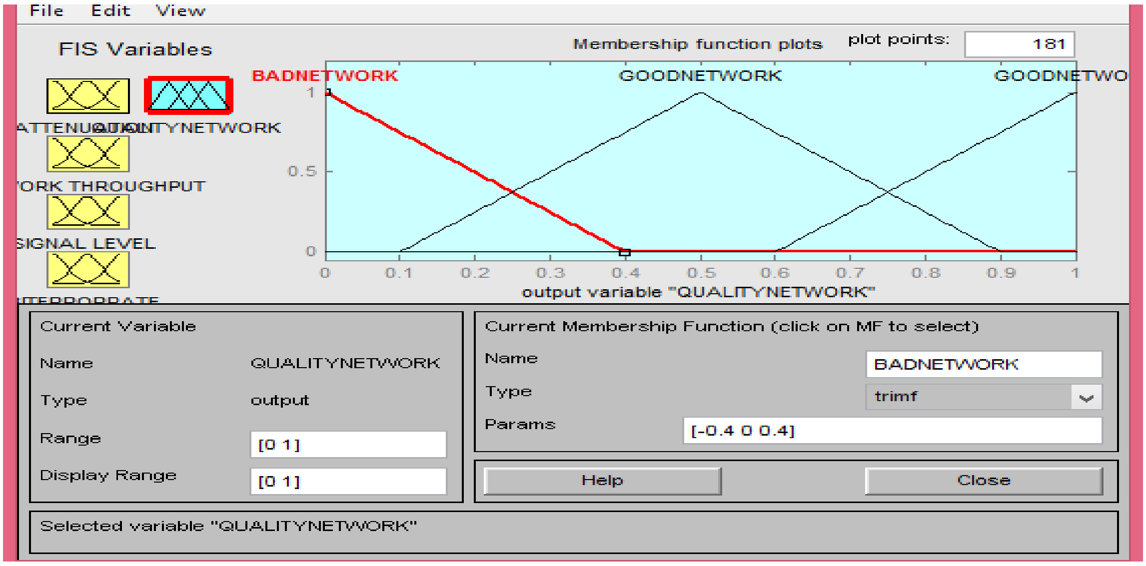
Name HIGHBITERRORRATE

Type trimf

Params [-0.4 0 0.4]

Selected variable "BITERRORRATE"

Figure 6: Bit error rate (input) membership function



plot points: 181

Current Variable
Name QUALITYNETWORK
Type output
Range [0 1]
Display Range [0 1]

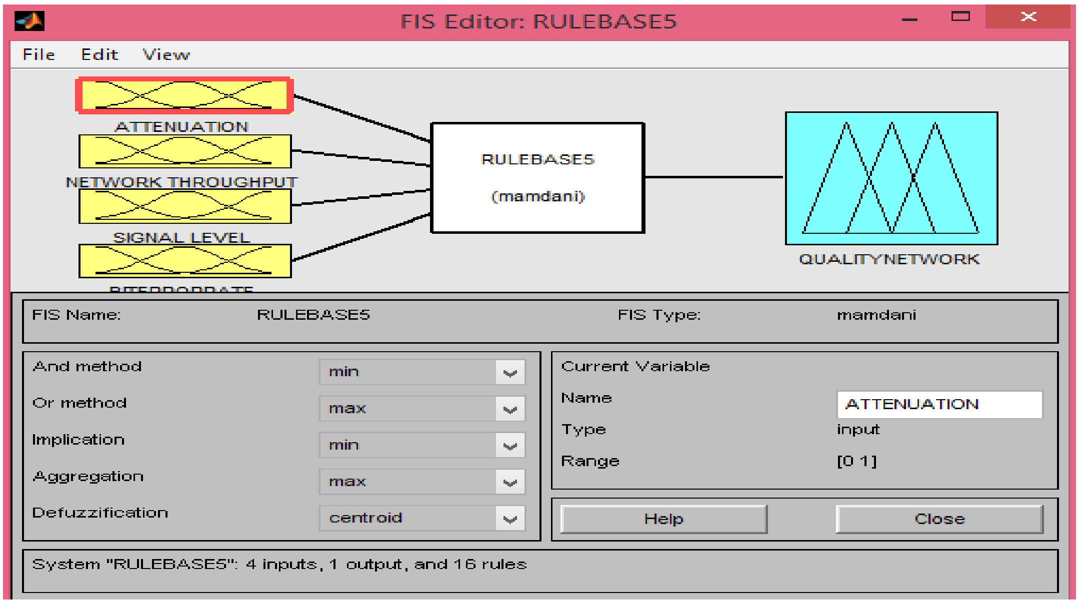
Current Membership Function (click on MF to select)
Name BADNETWORK
Type trimf
Params [-0.4 0 0.4]

Selected variable "QUALITYNETWORK"

Figure 7: membership function of the production output

BUILDING OF FUZZY LOGIC SIMULATION MODEL

The developed fuzzy model for the four inputs are multiplexed and these are send to the fuzzy logic controller with rule viewer, which process the whole information and produces a production output.



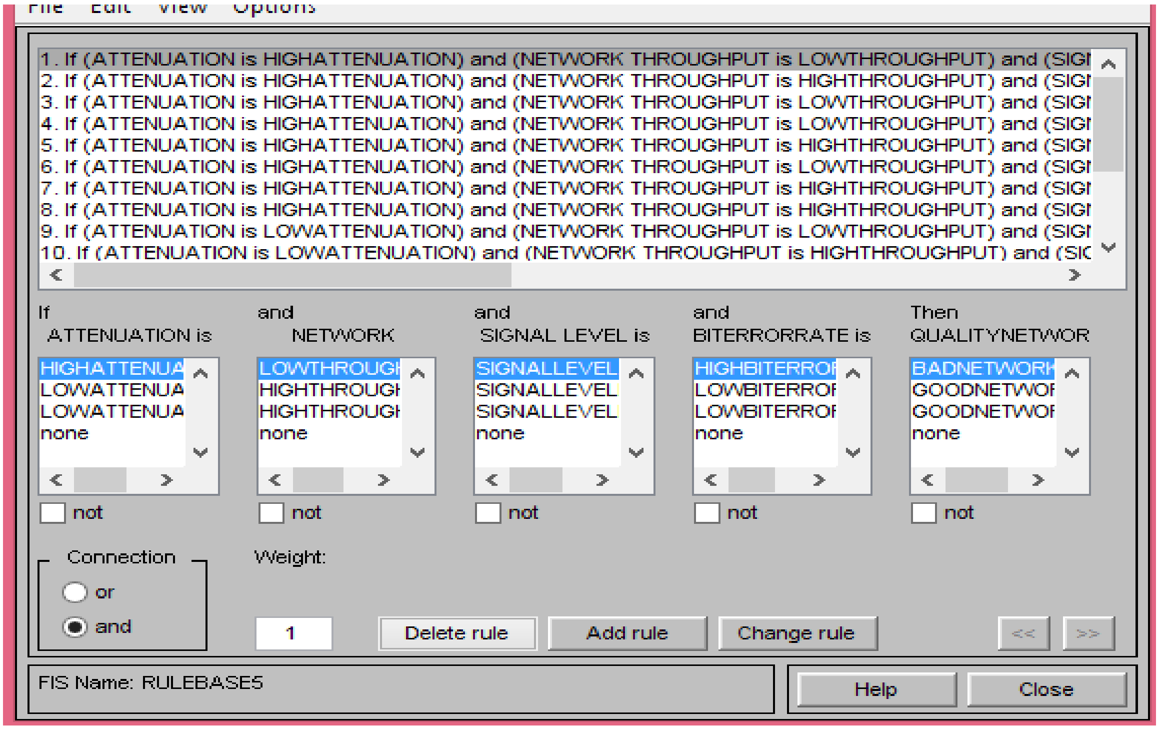
FIS Name: RULEBASE5
FIS Type: mamdani

And method min
Or method max
Implication min
Aggregation max
Defuzzification centroid

Current Variable
Name ATTENUATION
Type input
Range [0 1]

System "RULEBASE5": 4 inputs, 1 output, and 16 rules

Figure 8: Fuzzy inference systems (FIS)



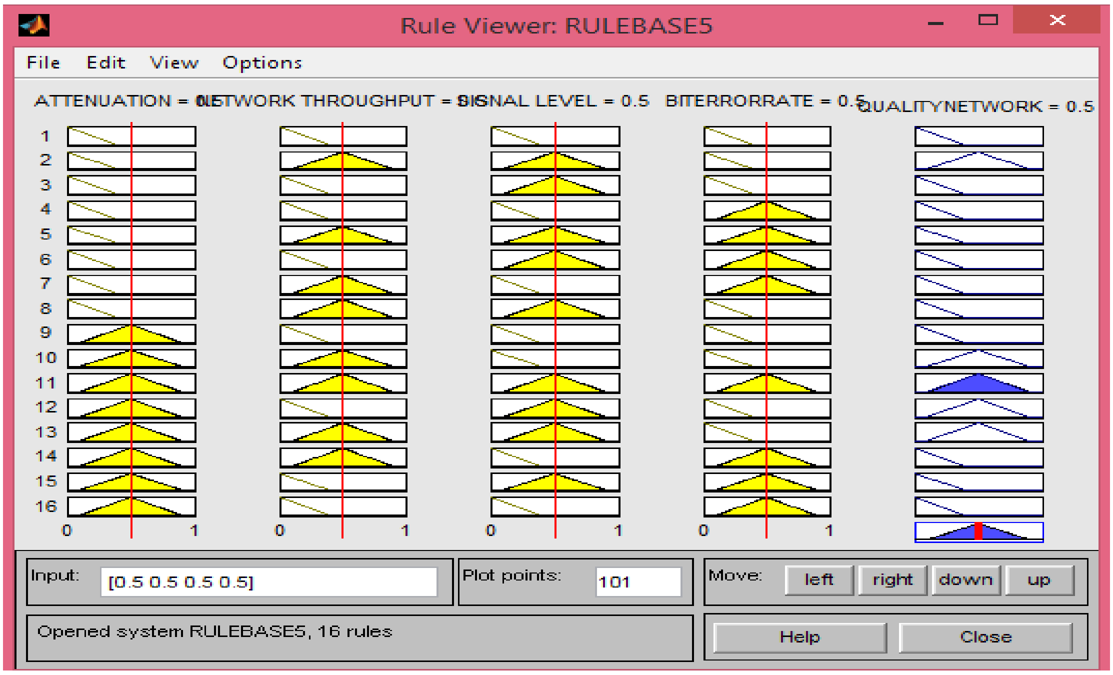
1. If (ATTENUATION is HIGHATTENUATION) and (NETWORK THROUGHPUT is LOWTHROUGHPUT) and (SIGI
2. If (ATTENUATION is HIGHATTENUATION) and (NETWORK THROUGHPUT is HIGHTHROUGHPUT) and (SIGI
3. If (ATTENUATION is HIGHATTENUATION) and (NETWORK THROUGHPUT is LOWTHROUGHPUT) and (SIGI
4. If (ATTENUATION is HIGHATTENUATION) and (NETWORK THROUGHPUT is LOWTHROUGHPUT) and (SIGI
5. If (ATTENUATION is HIGHATTENUATION) and (NETWORK THROUGHPUT is HIGHTHROUGHPUT) and (SIGI
6. If (ATTENUATION is HIGHATTENUATION) and (NETWORK THROUGHPUT is LOWTHROUGHPUT) and (SIGI
7. If (ATTENUATION is HIGHATTENUATION) and (NETWORK THROUGHPUT is HIGHTHROUGHPUT) and (SIGI
8. If (ATTENUATION is HIGHATTENUATION) and (NETWORK THROUGHPUT is HIGHTHROUGHPUT) and (SIGI
9. If (ATTENUATION is LOWATTENUATION) and (NETWORK THROUGHPUT is LOWTHROUGHPUT) and (SIGI
10. If (ATTENUATION is LOWATTENUATION) and (NETWORK THROUGHPUT is HIGHTHROUGHPUT) and (SIC

ATTENUATION is	NETWORK	SIGNAL LEVEL is	BITERRORRATE is	QUALITYNETWOR
HIGHATTENUA	LOWTHROUGI	SIGNALLEVEL	HIGHBITERROI	BADNETWORK
LOWATTENUA	HIGHTHROUGI	SIGNALLEVEL	LOWBITERROI	GOODNETWOI
LOWATTENUA	HIGHTHROUGI	SIGNALLEVEL	LOWBITERROI	GOODNETWOI
none	none	none	none	none

Weight: 1

FIS Name: RULEBASE5

Figure 9: Rule base of the fuzzy model



ATTENUATION = 0.5 NETWORK THROUGHPUT = 0.5 SIGNAL LEVEL = 0.5 BITERRORRATE = 0.5 QUALITYNETWORK = 0.5

Input: [0.5 0.5 0.5 0.5]

Plot points: 101

Opened system RULEBASE5, 16 rules

Figure 10: Rule viewer of the fuzzy model

Figure 11 shows the graph of attenuation and number of years for conventional and fuzzy logic controller.

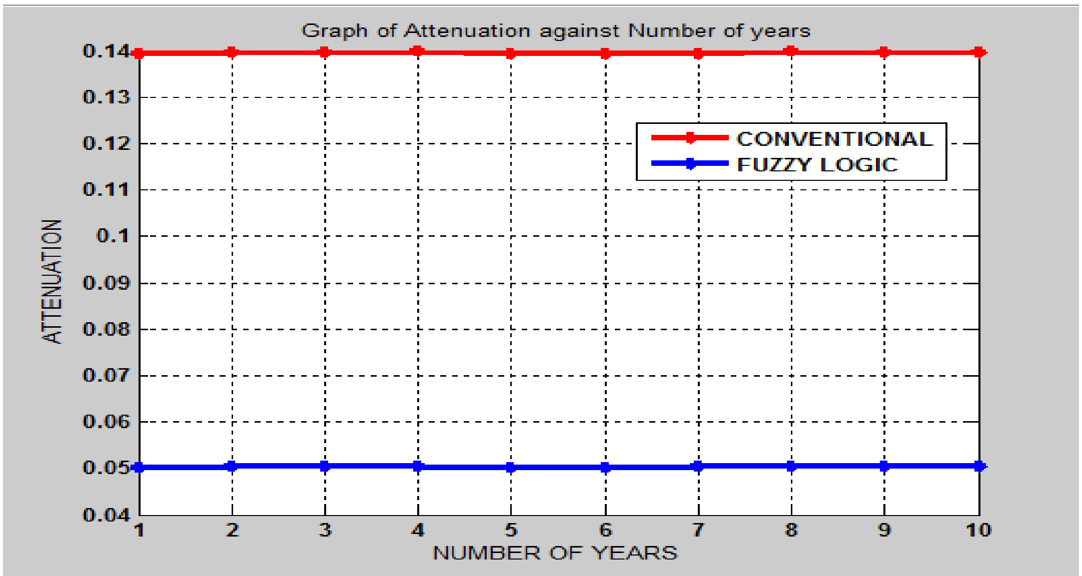


Figure 11: Graph of attenuation and number of years

In figure 11, it is observed that the fuzzy logic system gave the highest fuzzy controller attenuation value of 0.05044 while the conventional attenuation shows the highest attenuation value of 0.1399. These attenuations indicated that there was distortion of bad signal over Ku band satellite communication during conventional approach. Also, during fuzzy controller approach, a reliable signal was achieved with a reduced attenuation.

Figure 12 shows the graph of received signal level and number of years for conventional and fuzzy logic controller.

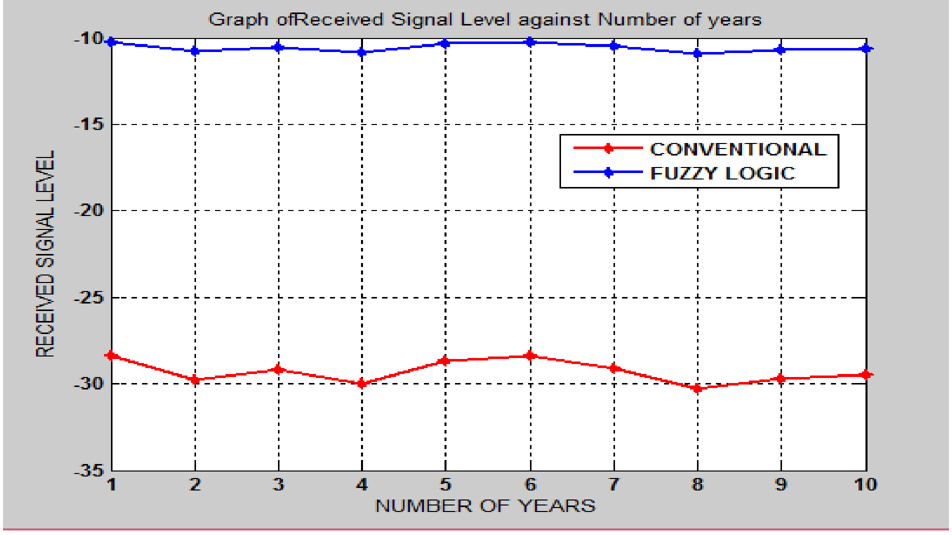


Figure 12: Graph of received signal level and number of years

In figure 12, the conventional received signal shows the highest received signal value of -30.3 and this resulted to network failure of signal over Ku band satellite communication. The fuzzy controller received signal indicated the highest received signal value of -10.92 and this provided a great improvement in signal level.

Figure 13 shows the graph of bit-error-rate and number of years for conventional and fuzzy logic controller.

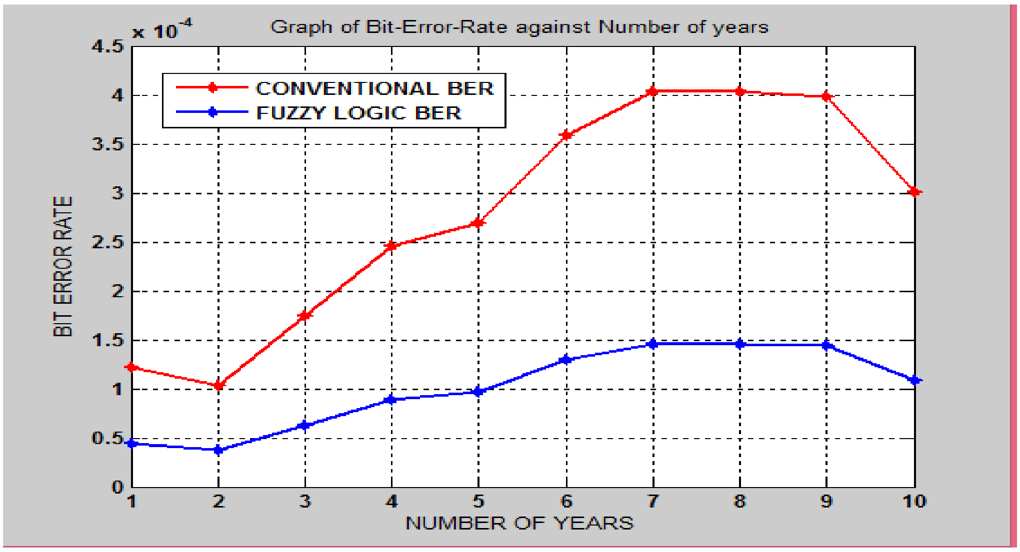


Figure 13: Graph of bit-error-rate and number of years

In figure 13, the fuzzy controller Bit-Error-Rate provided the highest bit-error rate of 0.0001456 which reduces the bit-error-rate while the conventional bit-error-rate gave the highest value of 0.00004039 which had a serious effect on the signal.

Figure 14 shows the graph of network throughput and number of years for conventional and fuzzy logic controller.

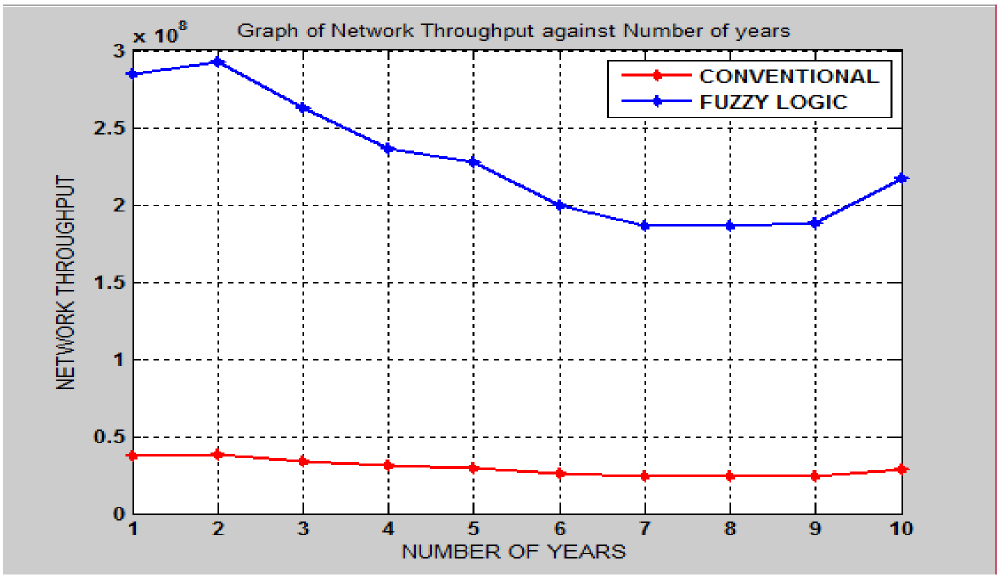


Figure 14: Graph of network throughput and number of years

From the graph, the fuzzy controller network throughput indicated the highest value of 292.5Mbps whereas the conventional network throughput provided the highest value of 38.03Mbps. This shows that there was a great improvement in fuzzy controller network throughput by 87% than the conventional network throughput.

IV. Conclusion

Signals over Ku-band satellite communication can be subjected to severe signal degradations due to rain attenuation because the attenuation increases as the wavelength approaches the size of a typical rain droplets (water particles) which is about 1.5millimeters.The signal fading caused by rain attenuation directly affects the Quality of Service in satellite communication and also affects the system availability especially at frequencies above 10GHz.

The results of the fuzzy logic approach are found to make significant improvement over that of conventional approach. This study also shows method of improving received signal for better reception to customers during rain attenuation by use of fuzzy logic system. The Simulated results have shown the effectiveness of the developed model and its ability to improve good QoS in spite of rain attenuation. The developed model using fuzzy logic system was able to improve the quality of the satellite signal by 87%.

References

[1]. Harb, K. Yu, F.R. and Abdul-Jauwad, S. (2012). "Performance evolution in satellite communication networks along markovian channel prediction," Journal of Wireless Networking and Communications, vol.2, no. 5,pp 143-157.

[2]. Vangli, H. (2010). "Construction of a Satellite Ground Station for Low Earth orbit Communication".

[3]. Jena, J. (2012)."A study of rain attenuation calculation and strategic power control for Ka-band satellite communication in India".

[4]. Kota, S. and Marchese, M. (2003). "Quality of service for satellite IP networks: a survey", International Journal of Satellite Communications and Networking, Vol. 21, No. 4–5, pp. 303–349.

[5]. Sarat, K.K. Vijaya, B.R.S. and Narayana, R. (2008)."Prediction of Ku Band Rain Attenuation Using Experimental Data and Simulations for Hassan, India," International Journal of Computer Science and Network Security, Vol. 8, No. 4.

[6]. Wikipedia, (2018). The free encyclopedia. Rain fade:https://en.wikipedia.org/wiki/Rain_fade

[7]. Satellite Communication. Retrieved from http://en.Wikipedia.org/wiki/link_communications, accessed 2018

[8]. Osahenvemwen, O.A. and Omorogiuwa, O. (2013). "Rain attenuation analysis from system operating at Ka and Ku frequency bands," American Journal of Advanced Research, vol. 1, pages 7-12.

[9]. Netharn, V. Prahmkaew, S. and Pongpadpinit, S. (2013). "Improve Receive Signal over Ku-Band Satellite Communications Based on Fuzzy Logic", International Journal of Scientific & Engineering Research, Volume 4, Issue 1.

[10]. Magadum, B.R. Suchitra, S.G. and Janzgamshetti, S.H. (2012)."Fuzzy Logic solution for Unit Commitment," International Journal of Scientific & Engineering Research, Vol. 3, Issue 4.

[11]. Abu-Jasser, A. (2011). "Solving the Unit Commitment Problem Using Fuzzy Logic," International Journal of Computer and Electrical Engineering and Information Technology (ReCCIT)

[12]. Singam, S. (2018). "High-throughput satellite technology optimizes operational efficiency and enables mission-critical communications," Communication and Subsea Cables.

[13]. Amruta, C. and Patane, R.D, (2015). "Performance Improvement of Intelligent weather system for satellite Networks," International Journal of Scientific and Research Publication, Vol.5, Issue 7.

[14]. ITU-R, (2001)."Propagation data and prediction methods required for the design of earth-space telecommunication systems," p.618-7, Geneva.

Odo, Kingsley O. "Performance Improvement of Satellite Networks Based On Fuzzy Logic Controller." *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)*, 16(1), (2021): pp. 21-33.