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Performance Improvement of Free Space Optical Communication (FSO) Using the Innovative Relay Selection and Optimal Power Allocation Technique

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Abstract: Keeping in view the exponential growth in the telecommunication industry supported with large bandwidth technologies, the free space optical communication (FSO) seems a promising alternative solution. FSO transmits a modulated beam of light using line of sight propagation through the atmosphere for broadband communication. It is an emerging technology where we transfer signal wirelessly similar to optical fiber communication without using optical fiber. This paper exhibits the design of selecting relay and allocating power in optimized manner using the FSO communication approach. However, this technology suffers from various atmospheric effects. The proposed selective active relay protocol overcomes these effects by improving the performance of the link using compact data sharing through optical wireless channels. Here we use a scale free fitness network followed by water pouring Erbinium Doped Fiber Amplifier power allocation algorithm. We introduce African Buffalo Optimization algorithm to optimize the error and outage probability. Our proposed technique accomplished a different atmospheric effect of optical beam propagation at 1550nm. The Bit Error Rate and Q-factor under different weather conditions are examined. The central switching has been carried out in this work and proves much better than distributed switching as evident from the comparison made. The idea of the work is to mitigate the ill effects of atmospheric turbulence on the FSO channel using relay assistance. The numerical results depict that the proposed methodology is better tuned than the existing ones.

Keywords: Free Space Optical Communication, Scale Free Fitness Network, Water Pouring EDFA Algorithm, Atmospheric Conditions, African Buffalo Optimization Algorithm, Bit Error Rate , Q-facto

Commonly used acronyms

- FSO: Free space optics
- ABO: African Buffalo Optimization
- BER: Bit error rate
- EDFA: Erbinium doped fiber amplifier
- LOS: Line of sight
- LED: Light emitting diode
- VLC: Visible light communication
- QoS: Quality of service
- GBN-ARQ: Go back N and automatic repeat request
- AR: Adaptive rate
- OFDM: Orthogonal frequency division multiplexing
- WDM: Wavelength Division Multiplexing
- SNR: Signal to Noise Ratio
- DF: Decode and Forward
- AF: Amplify and Forward
- AWGN: Additive white Gaussian noise

1. Introduction

FSO communication is a technology of transmitting data from one point to another in the form of light waves wirelessly through the atmosphere. It makes use of visible and infrared (IR) light from the available light spectrum [1]. The inherent characteristic of unlicensed large bandwidth is the main advantage of this technology. The increasing demand for fast and secure data transmission essentially requires the technology with much higher bandwidth. FSO is a new paradigm for next generation wireless communication technology to provide seamless last and first mile connectivity. It is an optical technology having the potential of message transfer at about 10 Gbps of data rate.

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The multimedia data consisting of tone of voice, videotape message are transmitted under line of sight (LOS) machinery through bidirectional connectivity [2].
There is a connection between two or more points of interconnection [3], in which there are many applications in the remote communication networks [4]. FSO technology companies offer useful optical wireless connectivity with higher return on investment (ROI) and it provides a tap-proof communications with high speed [5]. It has some practical interest in communication partners, ground stations, satellites and high altitude platforms [6]. At present the net centric connectivity depends upon the available radio frequencies and as radio spectrum is limited, therefore FSO is the better alternative with regard to large bandwidth and security. It can be installed internationally with high return on investment, because of virtually unlimited unlicensed spectrum [7]. The maximum achievable speed through FSO technology with suitable mitigation technique is almost equal to the speed of light and is one of the attractive feature of this technology [8]. Imagine a technology that offers high speed connections with the incredible reliability at extremely low maintenance and less time to market [9]. FSO is a line of sight knowledge used with optical frequency connections, which can receive multimedia information on invisible shots of light [10]. This optical connection does not use high cost fiber optic cable and also does not need the investment on digging and spectrum licensing [11]. The use of lasers and LEDs is a simple idea of using at the transmitter end [12]. FSO technology also makes substantial use of the visible spectrum with the speed of light and is called VLC, where we receive both light and data simultaneously [13]. The Maxwel's electromagnetic wave equations are the basis of theory for both optical fiber and FSO communications [14]. There are a large number of applications which require very high speed and above all the security is the top priority and for them FSO is a very promising solution [15]. Building to building communications, mobile to backhaul connections, first and last mile connectivity and several other applications can be best treated with FSO technology [16]. The major challenge of this technique is the adverse effect of various weather conditions like snow, haze, rain, dust, mist and fog [17] and they ultimately result in fading in the channel [18]. The said technology paves a way towards the all optical communication with proper utilization of all optical devices [19-20].

This paper is an overview of the challenges to be responded with the suitable mitigation technique using suitable relay assistance [21-22]. A scale free network is taken into consideration with relay assisted FSO communication. The active relay selection is executed and power allocation is performed by Water Pouring EDFA algorithm. The atmospheric effects are involved and finally optimization is achieved by African Buffalo Optimization Algorithm. Fig. 1 depicts the basic block diagram of the FSO system.

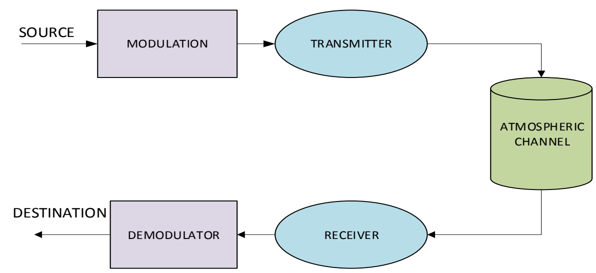

Figure1. Block diagram of FSO

The proposed methodology is based on the multiple relay assistance between a sender and a receiver. The relay selection technique is evolving around the concept of the SNR at each relay and the path selected is used for the data transmission and will continue till the SNR of the active path does not come below the set threshold at the destination. The results in terms of Q-factor, outage probability and BER are analyzed to depict the overall performances with the existing techniques. The graphics plotted from the obtained results and the numerical results achieved clearly suggest that the proposed technique is better than the existing ones.
Although, the sub-techniques involved in this study are pre-established, but the re-engineering of these techniques are being used to come with the proposed solution with appropriate tailoring and necessary modifications. The relay selection procedure incorporated to these sub-techniques for achieving the main objective is the novelty of this study.

2. RELATED WORK

Some of the recent literatures based on free space optical communication are described below:
The Statistical delay in the QoS along with joint power allocation and relaying link selection system for transmission of a multichannel rational FSO communication–based front haul is analyzed and evaluated. The total effective capacity of a front haul network is maximized subject to certain transmitting power budgets for both relay nodes and remote radio heads. Then, the relaying link selection and joint power allocation are devised as a miscellaneous integer non-linear programming problem. So, Md. Zoheb Hassan et al [23] proposed the method minimum weight matching and Lagrangian dual decomposition by using this technique they can improve the statistical delay of QoS and also the throughput in the presence of atmospheric unrest. The fading and pointing error is still the gap to be addressed.

Hoang et al [24] worked on FSO communication and modeled-cum-analyzed throughput of FSO systems using GBN-ARQ and AR transmission over the atmospheric turbulence channels. In their work, they worked on the error control issues under the time changeable behavior of the fading channels. The performance shows considerable improvement using suitable error control codes by Monte Carlo simulations.

Radio-over-free-space optics networks for further elastic frequency variety distribution and shortage of RF spectrum of lesser frequencies have been addressed with millimeter-wave broadcast in fiber-wireless. This focused on four parallel transmission indecent radio OFDM type channels and each carrying data of 20 Gbps. So, Angela Amphawan et al [25] introduced an optical millimeter mode division multiplex of spiral-phased Laguerre-Gaussian mode and Hermite-Gaussian mode using a spatial luminosity modulator to support 80 Gbps-160 Gbps data over a free space link of about 50 km.

In rural areas, scattering communication services is developed and the drudge center around two self-governing channels are broadcast, each carries 2.5 Gbps asymptotic achievable rate at the raised transmitted power and for various turbulent conditions in ideal mode set changes.

The said literature survey gives an impression that the FSO transmission is a workable solution to address the large bandwidth demand provided the optical link established is reliable in nature. Several methods had already been executed to address this issue and a certain level of reliability has been achieved. The proposed approach is aimed to improve the overall reliability with a better degree of performance.

The key contribution of our research is summarized below,

- A scale-free fitness network model is used to specify the transmitter and receiver channel.
- After that, selective active relay protocol is introduced.
- Then, water pouring EDFA algorithm is introduced for power allocation.
- Finally, the data error rates and outage probability are evaluated in atmospheric condition using African Buffalo Optimization (ABO).

information and 10 GHz radio signal then influenced the multipath signals. For this reason, Chaudhary, S. et al [26] proposed the mode-division multiplexing (MDM) of two winding staged Hermit Gaussian modes (HG00 and HG01) free-space optical (FSO) connects. Utilizing this strategy they can assess the temperate haze and haze.

Super-continuum range cut WDM free space optical scheme is surveyed at 2.5 Gbps information rate wakeful to the association distance of 5 KM and the Highly Nonlinear Fiber (HNLF) channel for the production of a high power wide range. To address this issue, Thakur, A. et al [27] developed the SC-SS-WDM and WDM for the FSO scheme under the rain, haze, and fog to improve versatile and minimal effort plot that can be executed well under climatic disturbance.

Direct discovery is considered in Spatial-mode multiplexing and FSO correspondence schemes. The rapid SMM FSO scheme is examined with commonly coherent channels where a specific laser cause by decreased line width is utilized at the transmitter. So, Huang. S and Safari, M. [28] grown commonly rational channels are an articulation for the total achievable rate are determined, to improve the maximal.

3. MAJOR CHALLENGES

A. *Atmospheric Effects*

The dynamic nature of atmospheric properties drops a considerable effect on the propagation of light (laser or LED) beams through the open atmosphere. The physical size of the suspended particles like water droplets, dust particles, and aerosols, etc. plays a decisive role in deciding the type of scattering and corresponding power distribution when a light beam encounters with these particles. The physical obstruction and the solar interference with the line of sight laser communication is the subject of concern. The various atmospheric properties lead an effect on the transmission of the laser beam before reaching to the destination.

The scattering caused by the water molecule and by the suspending particles, which occur in the natural physical obstruction form in the way of LOS (Light of sight) caused fluctuations in the power distribution process. The spreading of light beam occurs after it collides with a particle with proportionate size of the wave. The type of spreading occurs is decided by the wavelength of illumination.

- If the wavelength is greater than scattered size, then it is called Mie scattering.
- If the wavelength is less than scattered size, then it is called Rayleigh scattering.

B. Atmospheric Absorption

The light energy absorbed in the atmosphere is converted as internal energy of the absorbing molecules. The atmospheric gas molecules absorb the light energy usually in the distinct spectral regions. The absorption by the water droplets and by the sub-atomic events is of considerable attention.

C. Atmospheric Spreading

Climatic spreading is principally due to aerosol products like smoke, mist, and residue. Electromagnetic radiation (photons) gets spread by various particles in the earth's air. Spreading separate into three spaces is the capacity of the relationship between the wavelength and the span of the spreading operator (particles, atoms, and aerosols products). At that point, the Rayleigh spreading is exceedingly dependent on the wavelength.

- Scattering of blue wavelengths

The Rayleigh scattering is inversely proportional to the fourth power of the wavelength (λ^4) and, thereby, the shorter wavelengths like violet and blue scatter more. The clear sky with the low humidity and having aerosols present makes the blue light enough scattered and the scattered light comes to our eyes from all the directions in daylight.
Then, the photographers want to take clear panoramic photographs with black-and-white films use a yellow or red filter and it allows the less-scattered light to be captured on film in the pictures. The factor choosing the wavelength response to the satellite picture, typically exclude blue wavelength.

- Relative size of the scattering agent increases

The spreading processes are evolving toward Mie spreading. Depending upon the spreading probability, the spreading of wavelength decreases or it evolves well. In the Rayleigh spreading, the spreading occurs roughly in the equal directions, if the particle size increases, the likelihood of frontward spreading is increased. Mie spreading is consistent with the presence of water vapor and tiny particles of smoke, dust, and all particles comparable in size to the visible. Depend upon the shape and size distribution, concentration of spreading particle wavelength is varied in nature and the approach to assess the level of scattering is probabilistic in nature.

D. Atmospheric Turbulence

Atmospheric turbulence is a tiny irregularity in compactness, produce variation in the index of refraction is a small fluctuation in the direction of light proliferation (Snell's law) on the order of fractions in a million. It causes some power losses, owing to climate conditions and link fading. The weather condition of the atmospheric turbulence effects the phase fluctuation, beam spreading, beam broadening, and irradiance fluctuation by the alleviation diversity method, different modulation, coding method, and forward error correction method.

- Fog condition

The major trouble of FSO is a fog that consists of small water droplets with radii near the size of infrared wavelengths. The fog density affects the visibility range and it is an established study that the denser the fog more attenuation of the light beam. The attenuation is independent in the fog condition.

- Snow condition

Snowflakes are ice crystals that are in a variety of sizes and shapes. The snowstorm condition might attenuate the ray, but this effect for FSO can be coping as the extent of snowflakes is a large comparison to the operating wavelength. The quantity of attenuation in snow condition is 3-30 dB/km.

- Rain condition

Rain situation is distance-reducing on FSO, it is less than that other weather conditions owing to the large dissimilarity between the radius of raindrops and the wavelength of the FSO light source. Rain attenuation values are reasonable in nature.

- Clear weather condition

The FSO communication in clear weather shows better results in comparison to the other weather conditions. The attenuation level in the clear weather is very less and the attenuation factor value in the clear weather range is 3dB/km.

4. SYSTEM MODEL

FSO communication is an optical communication technology that is used to light propagation in free-space to wirelessly broadcast data for telecommunication. The atmospheric effects like temperature variation, rain, snow and fog are affecting the link performance. The effect by atmosphere is impacting the signal by scattering, link performance, and absorption. The power attenuation caused by fog is severe as compared to the attenuation caused by snow or rain. The basic working block of FSO is shown in fig. 2

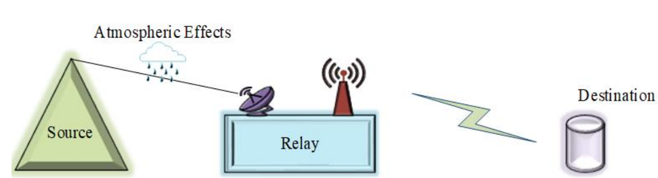

Figure 2 . Fundamental of FSO

Atmospheric turbulence affects the propagation of a beam of light in the channel in three different ways:

- Due to the scintillation index, the wavefront is distorted creates fluctuations in the intensity of the optical signal.
- Due to the diffraction of the laser beam, the diameter of the beam is smaller or equal to the size of eddies, which eventually leads to the beam wandering.
- Laser beam spreads outside the permissible limits because of Atmospheric turbulence. At that instant some problems arise and BER performance is reduced. The relay is used to reduce these effects in a controlled way.

5. PROPOSED METHODOLOGY

FSO communication is one of the interesting topics in wireless communication due to its number of merits. Since, it behaves badly in some situations because of dynamic atmospheric conditions. In this research, channel specification can be done using scale-free fitness network. Subsequently, water pouring EDFA algorithm is utilized to allocate the power for relay selection and it also evaluates the data rate and outage probability. To optimize the error and outage probability, we are using ABO algorithm. Fig. 3 shows the diagram of the proposed methodology.

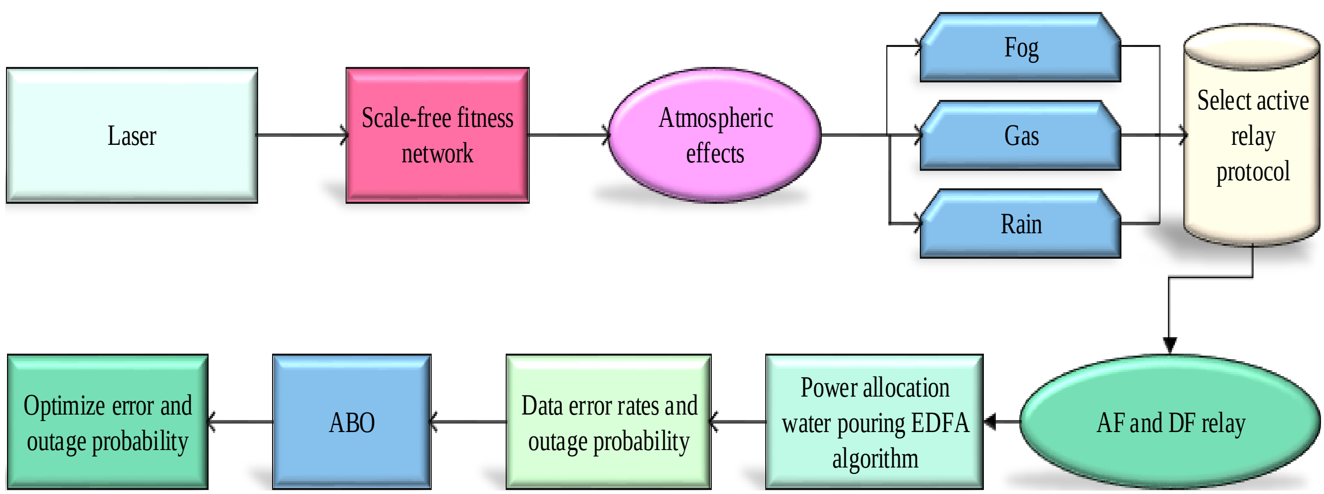

Figure3. Schematic Diagram of the Proposed Methodolog

A. Scale Free Fitness Network

The characteristic of the network remains independent on the number of nodes and hence, we are using a scale free fitness network. The scale-free fitness network follows the power law sharing and a node with higher-fitness acquires links at an advanced rate than less fit nodes. That is the part of $Q(l)$ being a node in the network having l connections to other nodes goes for bulky values of l is represented in Eqn.1.

$$Q(l) \approx l^{\alpha} \quad (1)$$

The fitness model links, linking nodes change over time depends on the fitness of the node. Moreover, the filter nodes are attracted to more links at the expense of less fit nodes. The scale-free fitness network is a degree allocation and is best captured by power law allocation. The average clustering coefficient is higher than predictable from a random network as well as average pathway span is smaller than predictable from a haphazard network.

A. Select Active Relay Protocol

Select the active relay protocol method is to improve the system performance. Relay method is coupled with AF and DF protocol and have been analyzed by the two-way relay protocol along with investigation of the BER performance in the shot noise. The RA Select active relay protocol uses optical amplify and forward strategy. In the relay assisted mode of FSO communication, various relays are installed between the transmitter and the receiver. The protocol adopted to select the active relay is based on retrieving the channel state information (CSI) of available paths. The relays usually used are solid-state relays and the working principle of the operating a switch is automatic. The second hand option with electromagnet relay along mechanically operated switch is seldom used. The relays are used to manage circuits are controlled by one signal and the path chosen with minimum losses takes over the information from the laser to the detector.

- Two Relay

Here we investigate the performance of the proposed system using two relays between the source and the destination. Both the relays are not involved in the transmission process simultaneously, as it is assumed that the path chosen makes use of one relay only at a time. The SNR of the active path should not fall below the threshold level set at the destination. The communication will continue through the active relay until the SNR comes down to the threshold level. Two relays are based on the

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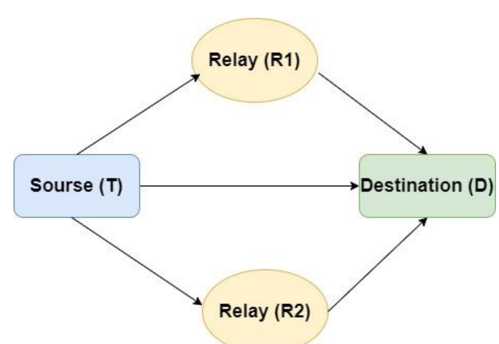

Figure 4. Two way relay in selective active protocol

The selective relay scheme is a power distribution as a substitute of dividing the power amongst all the FSO links, the power will be split only on either 1 link (T-E is the strongest) or on 2 links is $T - S_i$ and $Sj - E$. Where, i = j or i ≠ j.

The source node transmits the power proliferation through two relays before the detection at the destination. The system is believed by intensity modulation direct-detection (IM/DD) and optical transmitter is ON during the binary pulse position modulation (BPPM) bit interval means power distribution and OFF means another half that means non-power distribution. The receiver integrates the photocurrent over both power and non-power slot in the BPPM technique. The power at the receiver is the electrical power vector given by Eqn. (2),

$$s = \begin{bmatrix} s^t \\ s^o \end{bmatrix} = \begin{bmatrix} ST_b(q_t + q_c) + o^t \\ ST_c q_c + o^o \end{bmatrix} \quad (2)$$

Where s^t and s^o are receiving power and corresponding power and non power slot of BPPM pulse and q_t and q_c is optical power and background power to the photo detector.

The decoded power is given by E, it is the set of relays decoded successfully, means the received SNR is more than the threshold. Then, the optical power received and re-transmitted from the decoded set is given by Eqn. (3) and Eqn. (4).

$$s_{O+1} = \begin{bmatrix} s^t{}_{N+1} \\ s_{N+1} \end{bmatrix} \quad (3)$$

$$= \begin{bmatrix} ST_b(qh_{i,n+1} + q_c) + o^t{}_{N+1} \\ ST_c q_c + o^o{}_{N+1} \end{bmatrix} \quad (4)$$

The noise term is modeled by an AWGN with mean and variance of the noise caused by background radiation. The intensity of the light incident on the photo detector is sufficient to ensure the actual detection of the intended information sent from the source node. The source node transmits the same power to two relays, it is based on AF, and DF. In AF relay mode, the relay amplifies the signal before forwarding to the destination. In DF relay mode, the relay decodes the signal and re-modulates it before forwarding to the destination (see Fig.4).

C. *Decode-And-Forward (DF) and Amplified-And–Forward (AF)*

Decode-and-forward (DF) is a protocol for enhancing the performance in wireless cooperative communication in the relay network. The relay decodes the signal and re-encodes it, and then forwards to the destination. When encoded modulation is used this protocol makes detection and forwards the processed signal to the next hop or directly to the destination for final detection as the case demands. DF relaying decodes the signal with intended detection and re-modulates for further transmission. Here we perform the direction detection and modulation with BPPM technique with optical power P and retransmit to the subsequent relay. The received SNR exceeds the threshold to avoid the error propagation.

In AF transmission, the signals obtained from source are amplified without decoding and the relay forwards it to the destination with the assumption that the SNR is maintained and does not come down than the set threshold level to avoid the error generation. The signal from source to relay and relay to destination are expressed in Eqn. (5), Eqn. (6), and Eqn. (7) respectively.

$$A_1 = \alpha_1 T + Z_1 \quad (5)$$

$$A_2 = \alpha_2 T + Z_2 \quad (6)$$

$$A_3 = \alpha_3 \beta A_2 + Z_3$$
$$= \alpha_2 \alpha_3 \beta T + \alpha_3 \beta Z_2 + Z_3 \quad (7)$$

Where, β is the amplification factor. The maximal ratio combiner output at the destination is shown in Eqn.(8).

$$A_{1,3} = \frac{\alpha_1^{'}}{\sigma^2} A_1 + \frac{\alpha_2^{'} \alpha_3^{'} \beta}{\sigma^2 \left(|\alpha_3|^2 \beta^2 + 1 \right)} A_3 \quad (8)$$

The relay node receives power with direct detection and modulates by BPPM and retransmits to the destination. Power distribution in the AF and DF relay system is maximized to J_{AF+DF} . Then the ith DF relay node and jth AF relay has some power budgets $F_{DF}{}^{\max}$ and $F_{AF}{}^{\max}$ and the total obtainable power is limited to F_{total} is given by Eq(9) and Eq (10)

$$F_T + \sum_{j=1}^{SE} F_{DF,j} + \sum_{j=1}^{SB} F_{AF,j} \le F_{total}$$

(9)

$$F_S \le F_t^{\max}, \ , F_{DF,i} \le F_{DF}{}^{\max}, F_{AF,j} \le F_{AF}{}^{\max}$$

(10)

Therefore, the obtained result is shown in Eqn.(11), Eqn.(12), Eqn.(13), and Eqn.(14) that are subjected to Eqn.(9) and Eqn. (10).

$$J_{AF+DF} = \frac{1}{S_D + S_A + 1} \log_2 \left(1 + i^I i \right) \quad (11)$$

$$= \frac{1}{S_D+S_A+1}\times\log_2\left[1+F_t b_0+\sum_{j=1}^{S_d}F_{DF,}c_j+\sum_{k=1}^{S_B}\frac{F_T b_k F_{AF,k}c_k}{F_T b_k+F_{AF,k,c_k+1}}\right] \quad (12)$$

$$=\frac{1}{S_D+S_A+1}\times\log_2\left[1+F_T\left(\sum_{K=0}^{S}b_i\right)+\sum_{J=1}^{S_D}F_{DF.j}c_j-\sum_{k=1}^{S_A}\frac{F_T^{2}b_j+F_Tb_j}{F_Tb_k+F_{AF,K}c_k+1}\right] \quad (13)$$

$$\left[F_T\left(\sum_{K=0}^{S}b_i\right)+\sum_{J=1}^{S_D}F_{DF.j}c_j-\sum_{k=1}^{S_A}\frac{F_T^{2}b_j+F_Tb_j}{F_Tb_k+F_{AF,K}c_k+1}\right]$$

Max (14)

Solving the optimization problems (4) in a closed-form appears too difficult. However, if it relaxes the problem with a fixed pre-determined F_T then (13) can be estimated is shown in Eqn. (15), that are subjected to Eqn. (9) and Eqn (10),

$$\max\left[\sum_{J=1}^{S_D}F_{DF.j}c_j-\sum_{k=1}^{S_A}\frac{F_T^{2}b_j+F_Tb_j}{F_Tb_k+F_{AF,K}c_k+1}\right] \quad (15)$$

The same power is transmitted to the relay nodes by the source node, the problem is viewed as the Lagrangian optimization problem shown in Eqn. (16) and Eqn. (17),

$$M(F_{DF,i}..............F_{AF,K,\delta}) \quad (16)$$

$$\left[\sum_{J=1}^{S_D}F_{DF.j}c_j-\sum_{k=1}^{S_A}\frac{F_T^{2}b_j+F_Tb_j}{F_Tb_k+F_{AF,K}c_k+1}\right]+\frac{1}{\delta}\left(F_{total}-F_T-\sum_{j=1}^{S_D}F_{DF,j}-\sum_{k=1}^{S_A}F_{AF,k}\right) \quad (17)$$

Where, the Lagrange multiplier is set to $\left(\frac{1}{\delta^2}\right)$ to simplify and analyse the derivative of (16) with respect to zero is shown in Eqn.(18),

$$\frac{-c_k\left(F_K^{2}b_k^{2}+F_Tb_k\right)}{\left(F_Tb_k+F_{AF,k}c_k+1\right)^2}+\frac{1}{\delta^2}=0, k=1,2,3....S_A \quad (18)$$

Thus, the optimal power allocation is given in Eqn. (19),

$$\{F_{AF.k}\}_{K=1}^{S_A}=\left(\sqrt{\frac{F_T^{2}b_k^{2}+F_Tb_k}{c_j}}\delta-\frac{F_Tb_k+1}{c_k}\right)_0^{+} \quad (19)$$

Where δ is chosen to satisfy total power constraint shown in Eqn. (20),

$$\{F_{AF.k}\}_{K=1}^{S_A}=\left(\sqrt{\frac{F_T^{2}b_k^{2}+F_Tb_k}{c_j}}\delta-\frac{F_Tb_k+1}{c_k}\right)_O^{F_{AF}^{max}} \quad (20)$$

When the F_T (fixed transmit power) is high, the optimal power distribution is shown in Eqn. (21)

$$\{F_{AF.k}\}_{K=1}^{T_A}=\left(\frac{F_Tb_k}{\sqrt{c_j}}\delta-\frac{F_Tb_k}{c_k}\right)_O^{F_{AF}^{MAX}} \quad (21)$$

The derivative of (9) with respect to $\{F_{DF.j}\}_{j=11}^{S_D}$ to zero obtaining Eqn.(22),

$$\{c_j\}_{j=1}^{s_D}=\frac{1}{\delta^2} \quad (22)$$

From Eqn.(17), observe and obtain the maximum mutual information that is satisfying the two conditions which are shown in Eqn. (23) and Eqn. (24).

$$\{c_j\}_{J=1}^{s_D}=\frac{1}{\delta^2}=0, \quad (23)$$

$$\{c_j\}_{J=1}^{s_D}=\frac{1}{\delta^2}=\bar{c} \quad (24)$$

Where $\bar{c}$ is a non–negative rational number, shown in Eqn. (25)

$$\delta\longrightarrow\infty,$$

$$\delta=\frac{1}{\sqrt{\bar{c}}} \quad (25)$$

Substitute Eqn. (20) into Eqn. (17) can observe the AF and DF relay system with the optimal solution. When the transmiting power of the AF relay has the optimal power allocation, the performance of AF and DF relay system will be best shown in Eqn. (25).

D. Water–pouring EDFA algorithm is used in the digital message system for distributing the power among dissimilar channels in the multicarrier scheme and EDFA is a device that can amplify an optical signal. The EDFA fiber at the core is pumped with light from laser diodes. This category of setup in a telecommunication system can help in fiber communication. Then, the water-pouring theorem has proved its optimality for channels having AWGN and ISI. To assign power, presume torrential water into the container means the amount depends on the desired maximum average transmit power. After the water level is settled, the largest amount of water is the deepest section of the container. Additive White Gaussian Noise (AWGN) And Inter Symbol Interference (ISI)

The statistically random ratio of noise characterized by a wide frequency spectrum with regards to a signal SNR is the most common and well undeclared performance calculation characteristic of a digital message system shown in Eqn.(26).

$$SNR = \frac{signal\_power}{noise\_power} \quad (26)$$

The power distribution of water pouring EDFA algorithm is a method that efficiently distributes the power to different levels of various transmitters. The power distribution is calculated using Eqn. (27),

$$\sum_{j=1}^{s} \alpha_j^{opt} = NU \quad (27)$$

Where the α is optimum value of power that is allocated to FSO and mentioned in Eqn. (28),

$$\alpha_j^{opt} = \nu - \frac{\varepsilon - \frac{N_U O_p}{FT\mp}}{} \quad j= 1, 2,.., S$$

(28)

Where the j, ε is constant and O_p is noise power, $(y)_+$ is define assign that are represented in Eqn.(29),

$$(y)_+ = \begin{cases} y, if y \geq 0 \\ 0, if y < 0 \end{cases} \quad (29)$$

The water pouring EDFA algorithm scheme using the constant ε that is shown in Eqn.(30),

$$\varepsilon = \frac{N_t}{(s-q+1)}\left[1 + \frac{O_p}{F_t}\sum_{j=1}^{s-q+1}\frac{1}{\beta_j}\right] \quad (30)$$

SNR is represented in Eqn.(31),

$$SNR(j) = \frac{Q_{in}^{in}(j)1 - \Gamma^{-1}(j)}{2C_O iw1 - \Gamma^{-o}(j)} \quad (31)$$

Where, Q represents as power allocation and C represented as bit rate. Also, ISI is a form of distortion of α_j the signal in which one symbol interferes with succeeding symbols. This is an unwanted happening as the previous symbols have similar effect as noise, thus making the message less reliable.

E. African Buffalo Optimization

In the table, the $x.l$ represents the Waa (move on/explore) signals of the buffalos with meticulous reference to buffalo l ; $n.l$ is the maaa (stay to exploit); $x.k+1$ is the request for further exploration; $n.l+1$ represents a call for additional exploitation; $mq1$ and $mqs2$ are learning parameters.

1	**Objective function** $f(y)$ $f(y) = (\ y1, y2, \ldots\ldots yn\ )_\delta$
2	Initialization: randomly place (data rate) to nodes at the solution space;
3	Update the power fitness value using equation (32)
	$n.l+1 = n.l + mq1(ch\max.l) + mq2(cq\max.l)$ (32)
	Where $n.l$ and $x.l$ represents the exploration and exploitation moves respectively of the lth buffalo($l = 1,2,\ldots.N$); $lqs1$ and $lqs2$ are learning factors usually $[0,1]$
	$ch\max$ is the herd's best fitness and $cq\max$, the individual best (33)
4	Update the location of $l(cq\max$ and $ch\max$) using equation (33)
	$x.l+1 = \frac{x.l + n.l}{\pm 0.5}$ (34)
5	Is $ch\max$ updating? Yes, go to 6 steps. If No, go to 2 step
6	If the stop criterion is not met, go back to algorithm step3, else go to 7
7	Output best solution

ABO algorithm has three basic characteristics that are excellent memory, regular message and exceptional intelligence. The Waa calls the buffalo $(\ l = 1,2,....N\ );$ and buffalo move to investigate other graze areas at the time they are presently in unsafe or lacks adequate pasture is represented by $x.l$. Then, the Maa sound is asking the animals to stay on to exploit the present location because it has enough pasture and safe that is represented by $n.l.$ and Eqn. (33).

Where, $(\ n.l + 1\ )$ is the memory part that the animals are aware that they have relocated from their former position $(n.l)$ to a new one. The second character is representing the cooperative attributes of the animals $mq1(ch\max.l - x.l)$ that bring out the exceptional intelligence of these animals. This enables to take the decision on their search location for solution represented in Eqn. (34).

F. Data Rates And Outage Probability

Data rate and outage probability are important performance measuring parameters. Another term for data transfer rate is throughput and the outage probability is a chance that information rate is less than the required threshold rate. The outage probability gives a clear cut indication about the system performance. ABO algorithm has three basic characteristics that are excellent memory, regular message and exceptional intelligence. The Waa calls the buffalo $(\ l = 1,2,....N\ );$ and buffalo move to investigate other graze areas at the time they are presently in unsafe or lacks adequate pasture is represented by $x.l$. Then, the Maa sound is asking the animals to stay on to exploit the present location because it has enough pasture and safe that is represented by $n.l.$ and Eqn. (33).

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G. Data Rates And Outage Probability

Data rate and outage probability are important performance measuring parameters. Another term for data transfer rate is throughput and the outage probability is a chance that information rate is less than the required threshold rate. The outage probability gives a clear cut indication about the system performance.

6. RESULT AND DISCUSSION

The proposed approach is implemented with MATLAB version 2018b running on windows 7 platform. In this section, the data rate and outage probability in power allocation are calculated using water-pouring EDFA algorithm. Simulation results for scale free network, outage probability, noise and power level, different atmospheric turbulence and ergodic capacity using ABO for power allocation with AF and DF relay. The simulations in the Matlab platform are being carried out block-wise and each block is basically a sub-system of the whole process. The simulated sub-systems are run and connected together as per the proposed methodology. Finally, the complete devised system is run and expected results are generated.

A. Centralized and Decentralized Switch

Centralized and decentralized is the attention of power in the hands of a single person the decision took time. In our research, the centralized scale-free network is developed and the comparison of the centralized switch and decentralized switch proved better regarding a decision. The centralized switch has the greatest frequency range and average fitness in a scale-free network that is shown in fig. 5 and fig. 6.

The Outage probability and SNR in power allocation are calculated using the Water pouring EDFA algorithm that is shown in fig.7. Also, the optical input power and signal gain (dB) in power allocation shown in fig.8.

The number of channels (N) with Noise and power level in power allocation is shown in fig.9. Moreover, Propagation distance (m) with power loss (dB) in atmospheric turbulence are shown in fig.10.

Furthermore, with the increase in frequency (Decrease in wavelength), the data rate is generally enhanced. But, keeping in view the increase in losses and more atmospheric attenuation at certain frequencies is restricting the use of every higher frequency. The FSO communication is absolutely wavelength dependent and only the permissible optical windows are practically used. The relationship between wavelength of the signal coming from the transmitter and the date rate is illustrated in fig. 11.The correlation coefficient (dB) and Ergodic capacity in different atmospheric turbulence of the decentralized switch has a maximum and average fitness in a scale-free network that is shown in fig.12.

The alignment is one of the fundamental challenges in optical wireless communication and efficient alignment control is used to ensure the proper focusing of optical signal between the transmitter and receiver, so that the maximum power transmitted is captured by the intending optical receiver. Also, the average percentage of alignment using alignment control is shown in fig.13.

In the centralized mode of the switching, the sending and the receiving of the information is performed through the decentralized scheme does not require information to be passed through a single point. Outage probability and SNR in power allocation using the Water pouring EDFA algorithm are shown in fig.14.

Optical input power vs signal gain in power allocation using decentralization is shown in fig.15. The number of channels (N) and Noise and power level in power allocation using the Water pouring EDFA algorithm are shown in fig.16. Propagation distance (m) and power loss (dB) in atmospheric turbulence are shown in fig.17. The correlation coefficient (dB) and Ergodic capacity in different atmospheric turbulence are shown in fig.18.

The centralized and decentralized switch parameters of FSO like throughput, noise power, bit error rate, data rate, accuracy, wavelength and outage probability is represented in the table.1.

Moreover, the accuracy, outage probability, and BER of the centralized and decentralized switch is symbolized in fig.19.

The Q-factor and BER of the fog condition in the atmosphere is compared with existing approaches that are common point called as private server or hub. The

shown in the table.2. Moreover, the effective atmospheric condition is rain that is compared to existing techniques like CBSK and PRBS is represented in the table.3.

Furthermore, the comparison of throughput efficiency and channel distance of the existing techniques is mentioned in the table.4. Also, ergodic capacity is compared to existing techniques such as RF-FSO M-Distribution and Monte Z Carlo simulation is depicted in the table.5.

Table 4: Comparison of throughput efficiency with existing techniques

The quality factor of the fog and rain in the proposed approach is compared with RZ-DPSK and PRBS methods that provide high quality factor shown in fig.20.

Comparison of Ergodic capacity and SNR in ABO with RF-FSO M-Distribution and Monte Z Carlo simulation shown in fig. 21. Also, the comparison of throughput (Mbps) in ABO with GMTF (Greedy matching topology) and GBN-RQ is demonstrated in fig.22.

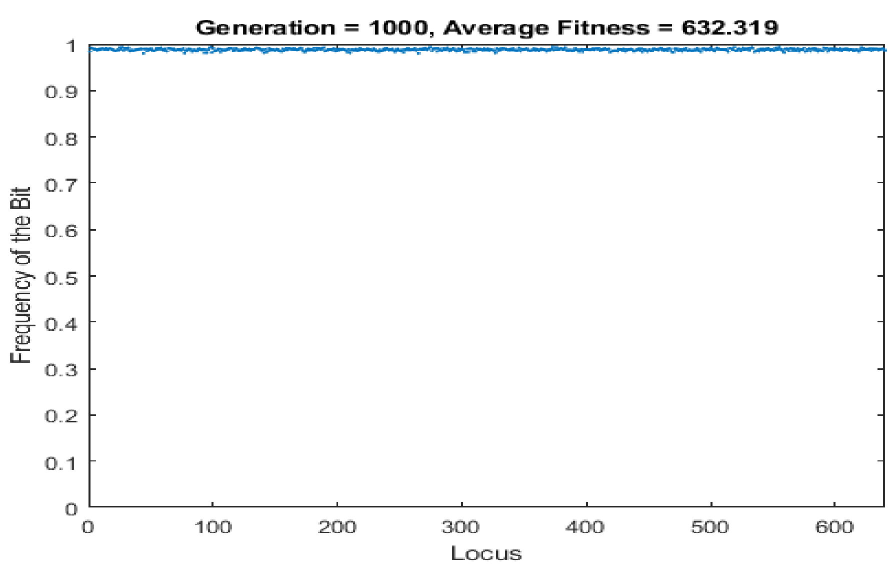

Figure 5. Frequency of scale free network

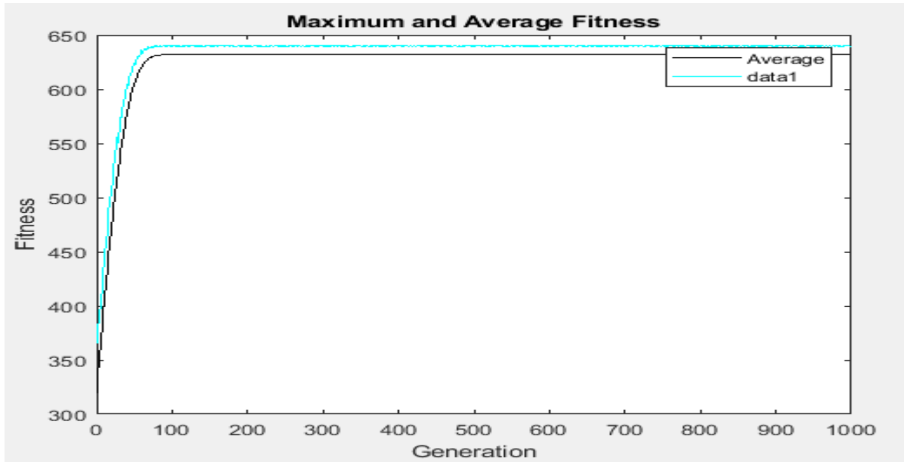

Figure 6. Average fitness in scale free network

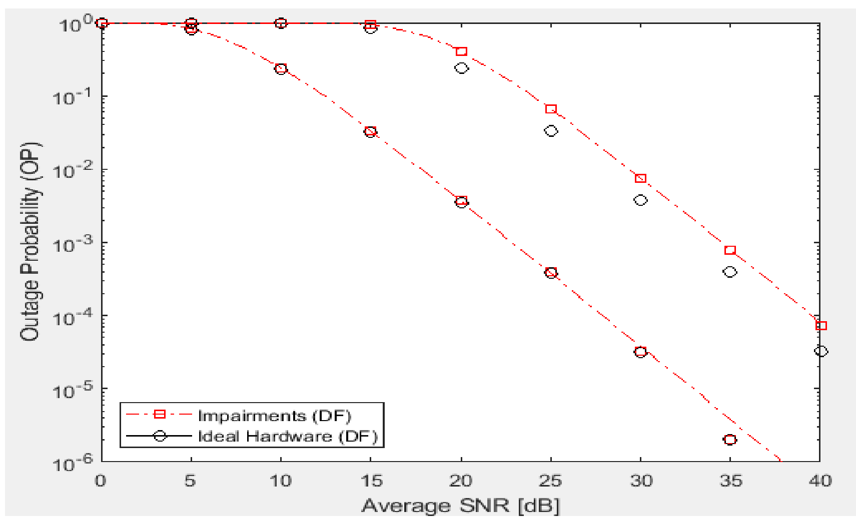

Figure 7. A Measure of Outage probability by Water pouring EDFA algorithm

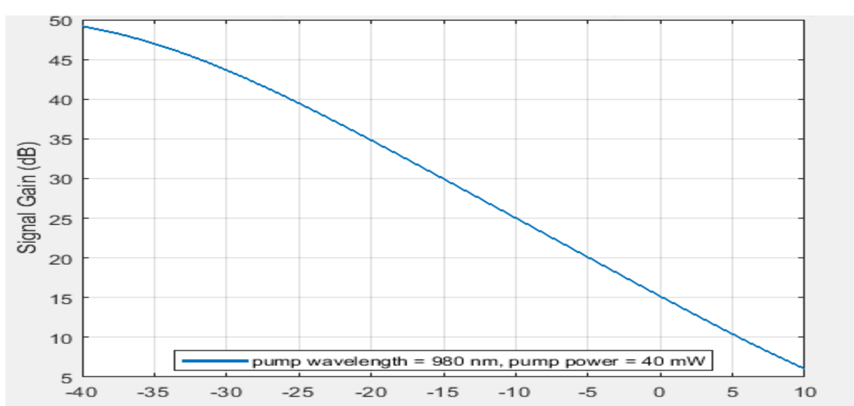

Figure 8. Optical input power and Signal gain

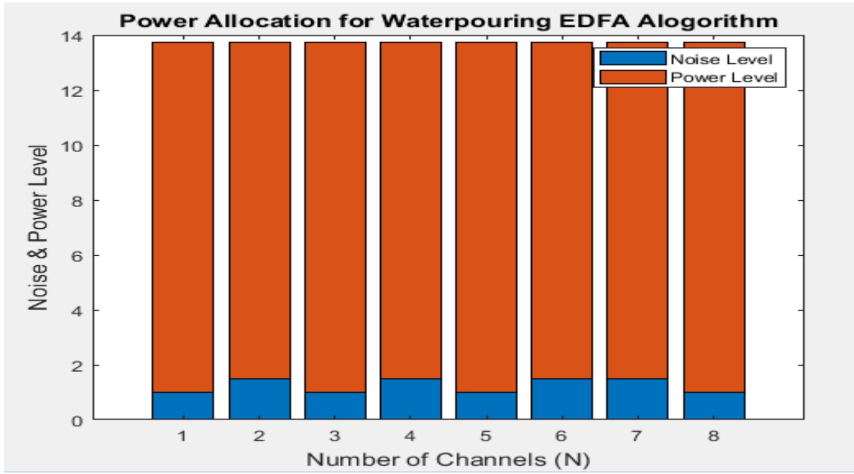

Figure 9. Noise and power level in power allocation using Water pouring EDFA algorithm

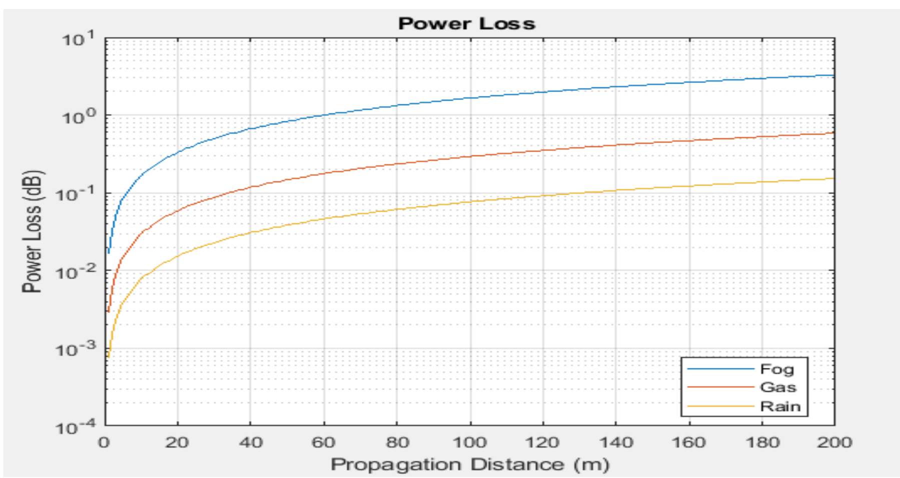

Figure 10. Power loss (dB) in Atmospheric turbulence

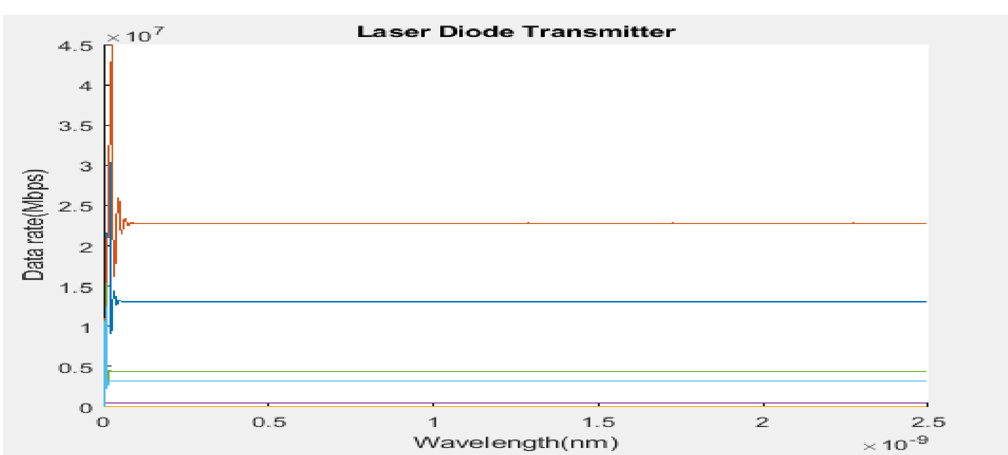

Figure 11. Wavelength and data rate in Laser diode transmitter

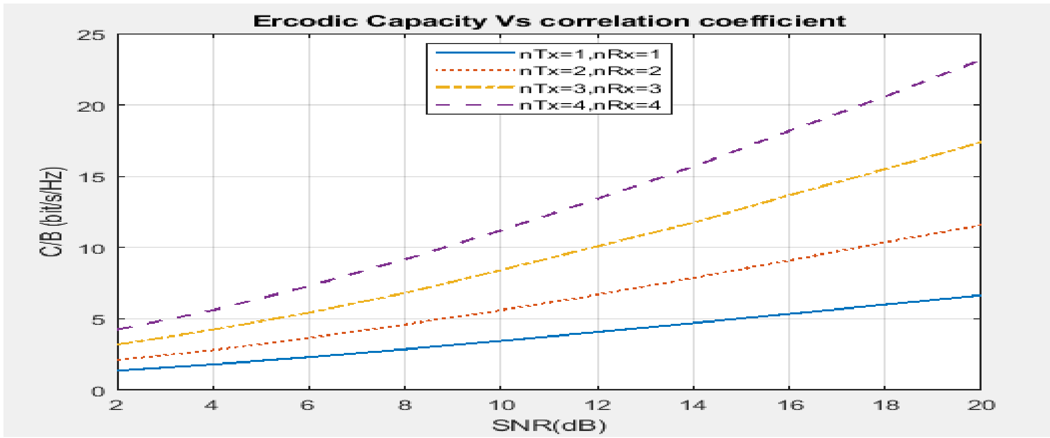

Figure 12. Correlation coefficient (dB) and ergodic capacity in different atmospheric range

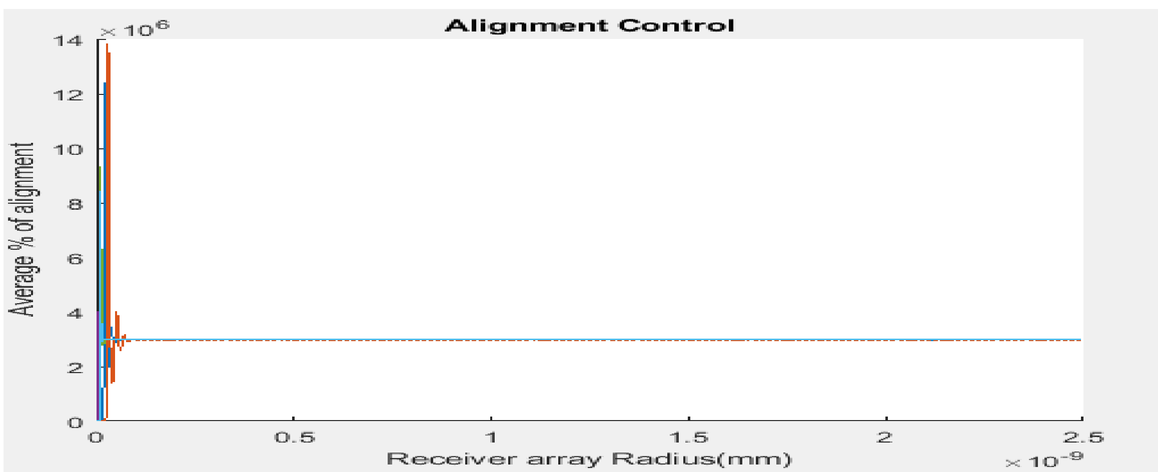

Figure 13. The Average percentage of alignment using alignment control.

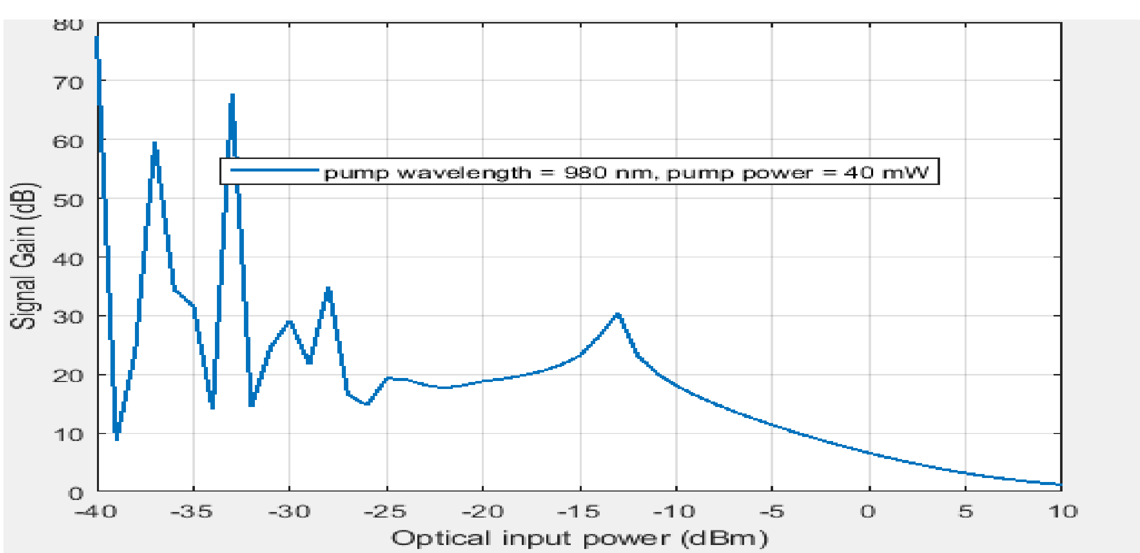

Figure 14. Optical input power vs signal gain in power allocation using decentralization

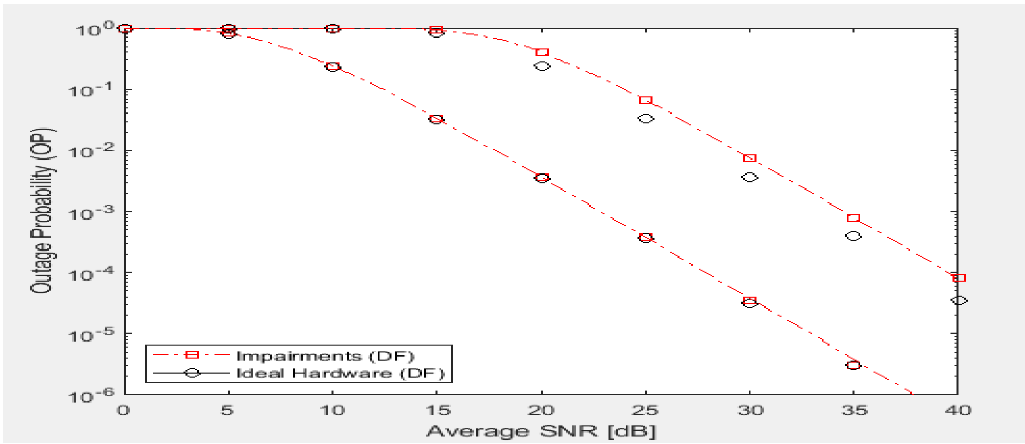

Figure 15. Average SNR(dB) vs outage probability of power allocation using decentralization

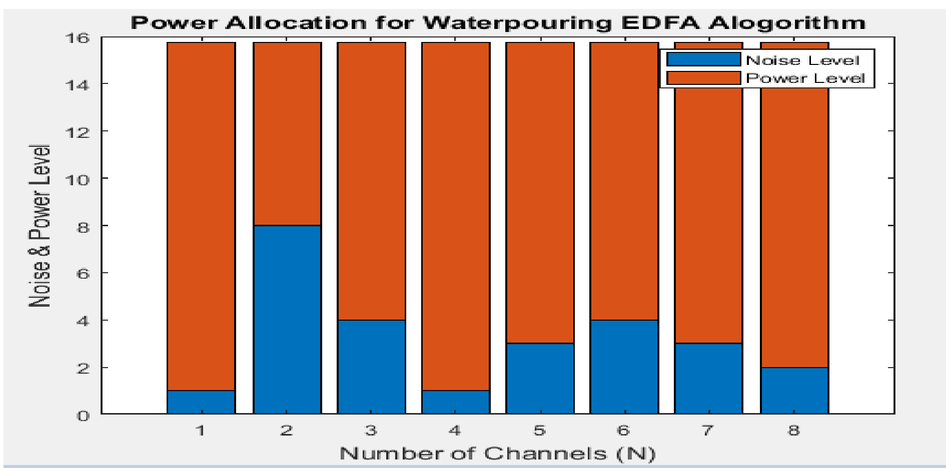

Figure 16. Noise and power level in power allocation using decentralization switch

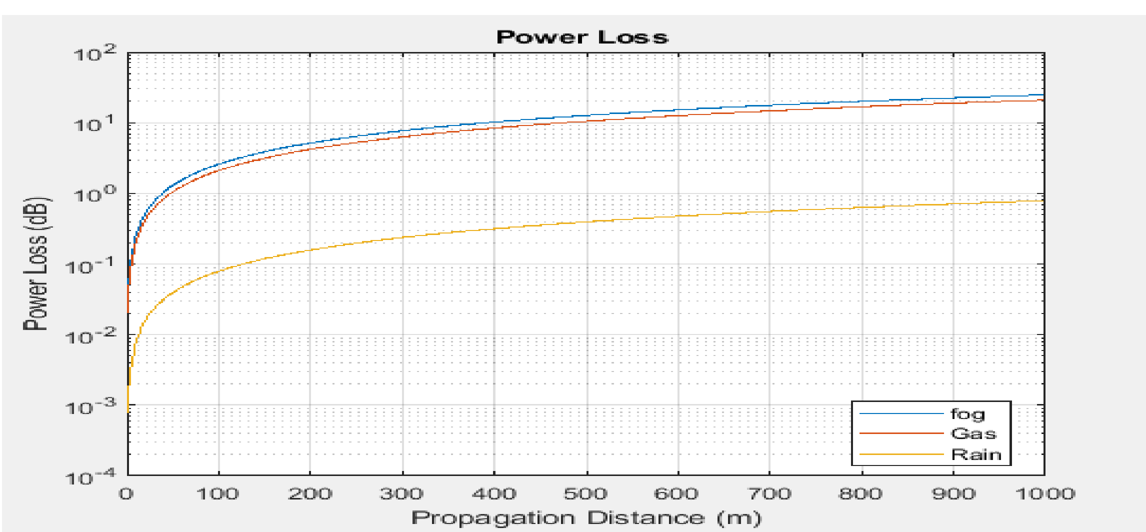

Figure 17. Propagation distance (m) vs power loss(dB)

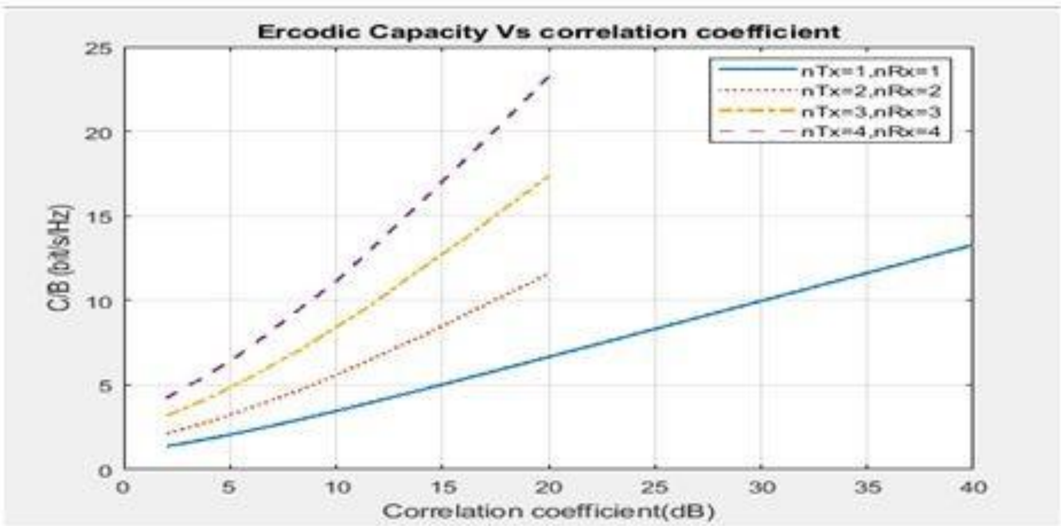

Figure 18. Correlation coefficient (dB) vs ergodic capacity in different atmospheric range

Table 1. Parameter of the FSO system

Centralized Switch		Decentralized Switch	
Outage Probability	0.52	Outage Probability	0.72
BER	0.2	BER	0.4
Throughput	23 Mbps	Throughput	20. 7 Mbps
Noise Power	10	Noise Power	10.5
Operating Wavelength	1550nm	Operating Wavelength	1550nm
Data Rate	3GHz	Data Rate	3GHz
Accuracy	94.05%	Accuracy	93%

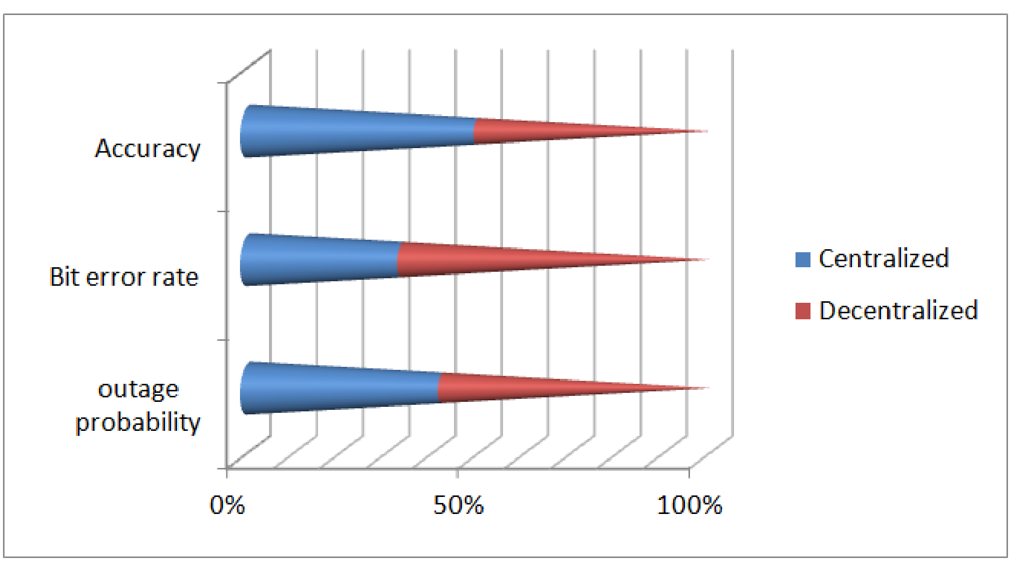

Figure 19. Comparision of the centralized and decentralized switch

Table2 . Comparison of fog with existing techniques

Fog	Quality Factor	BER
RZ-DPSK [29]	5.752	4.384x10-9
PRBS [30]	9.17	4.699x10-9
Proposed	10.641	3.273x10-9

Table 3. Comparison of rain with existing techniques

Rain	Quality factor	BER
CPSK [29]	5.77	1.39e-9
PRBS [30]	25	1.33e-144
Proposed	26	1.02e-8

Table 4. Comparison of throughput efficiency with existing techniques

Method	Throughput (Mbps)	Channel Distance (KM)
GMTF [31]	20	350
GBN-RQ [32]	6	200
Proposed	23	360

Table 5. Comparison of Ergodic capacity with existing techniques

Method	Ergodic Capacity (bits/s/Hz)	SNR (dB)
RF-FSO M-Distribution [33]	7	80
Monte Z Carlo Simulation [34]	6	80
Proposed	10	70

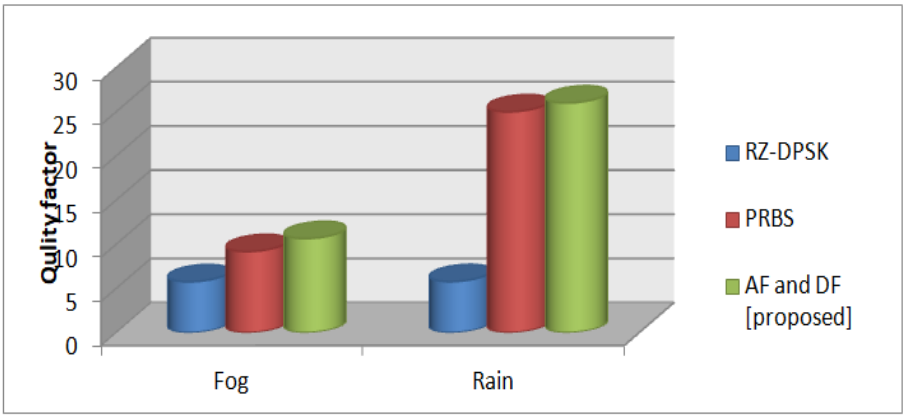

Figure 20. Comparison of quality factor with existing techniques

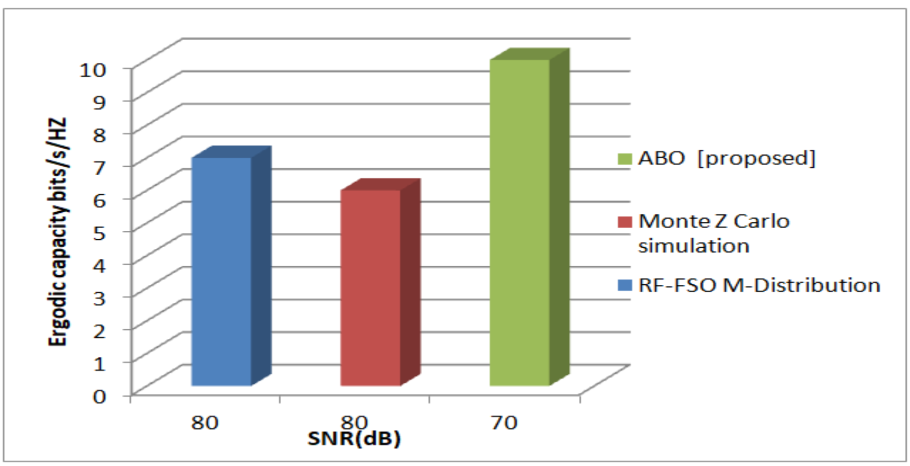

Figure 21. Comparison of Ergodic capacity and SNR in ABO with Existing techniques

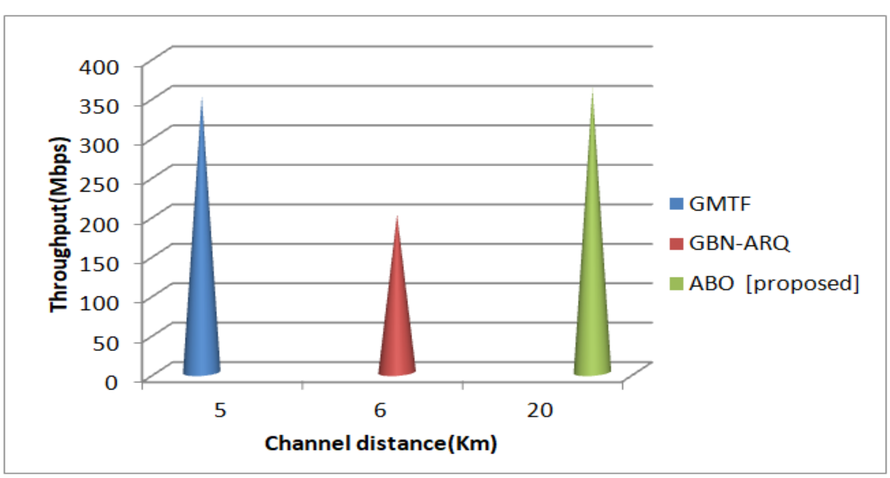

Figure 22. Comparison of throughput (Mbps) in ABO with Existing techniques

7. CONCLUSION

This approach investigated the transmission protocol for cooperative FSO for the channel model. For that, the selected active protocol is introduced for reducing the atmospheric effects in FSO. Also, the water pouring EDFA algorithm is used for power allocation. Moreover, ABO algorithm is used for optimization purpose. The detailed analysis done on various parameters clearly shows that the selective active protocol emerges with better performances than the existing ones. Hence, the proposed approach provides the highest throughput, ergodic capacity, and quality factor. Also, it achieved a low bit error rate compared to other techniques. The efficient implementation of these techniques with the concept of select active relay protocol has resulted in a workable approach to words using the FSO in practice.

8. FUTURE SCOPE

It is a well established fact that the all optical communication is taking an exponential growth like light –fidelity (Li-Fi), Optical fiber communication (OFC) and therefore optical wireless communication like FSO has a great market ahead.

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CONFLICT OF INTEREST

No conflict of interest is confirmed as verified by the authors.

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