ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

OPTIMIZATION OF WIRLESS OPTICAL COMMUNICATION SYSTEM WITH PLACEMENT OF RELAY USING SHUFFLED FROG LEAPING ALGORITHM

A. Jabeena, T. Jayabarathi, Palak Gupta, Geetashree Hazarika and Nibedan Bhawsinka
Vellore Institute of Technology, Tamil Nadu, India
E-Mail: ajabeena@vit.ac.in

ABSTRACT

Wireless Optical communication (WOC) is improved using relay assisted transmission which exploits multiple shorter hops that gives a better performance gain. Relay assisted transmission is utilized as a mitigation tool in combating atmospheric turbulence occurring in the communication channels. The main aim is to minimize the outage probability and optimize relay locations for parallel and serial FSO relaying. In this paper we address the major limiting factor for links measuring more than a kilometer; the error rate performances is dismal and therefore relay assisted transmission is employed to combat this shortcoming. The focus of this study is on considering the channel model, which takes into account both path-loss and turbulence-induced fading. The locations of the relay are found out using different algorithms and then compared to find out the best optimized result.

Keywords: wireless optical communication, outage probability, power margin, path loss.

1. INTRODUCTION

Wireless Optical communication is the transmission of optical signals through the atmosphere using Light Emitting Diodes and lasers. These systems offer high bandwidth, barrier to electromagnetic interference and can be used in a wide range of applications like in the wireless technology. A major hindrance in the FSO systems of today is the error rate performance in presence of atmospheric turbulence in communication links greater than a kilometre. Therefore to overcome this drawback we use relays, the devices that help exploit the fact that turbulence fading variance is distance dependent and yields improvements in performance by taking advantage of shorter hops. After every short hop there is a relay present that decodes the signal and amplifies it back, making it greater than the threshold value [1],[7]. If the signal from the output of the relay is less than the optimum threshold then an outage occurs.

1.1. Relay

A relay is a switching device that follows the fundamentals of electrical theory for performance of its operation. In general the switching mechanism is done mechanically by utilizing an electromagnet, but there are alternative operating principles that can be used. Relays are used when it is a requisite to monitor circuits with low-power signal, or when many circuits need a control by one signal.

1.2. Serial relay

This mode of relaying uses N number of relays allied between the direct paths of destination from the source. The source transmits of the signal which is intensity modulated and sent to the first relay. Assuming the DF (decode-and-forward) mode of relaying, subsequently direct detection, the signal is decoded with BPPM modulation by the relay, and then sent to the next relay for receiving. This continues until the data finally reaches the destination node. The DF technique used when the relay decodes the signal then modulates it, and retransmits if and only if the received signal-to-noise ratio (SNR) is greater than the pre decided decoding threshold. This threshold is essential for avoiding any propagation error [2].

In serial relaying scheme, the ith nodes received signal (i = 1, 2, . . . , N + 1) is given by:

$$r_i = \begin{bmatrix} r_i^{s} \\ r_i^{n} \end{bmatrix} = \begin{bmatrix} RT_b(P_{g_{i-1},i} + P_b) + n_i^{s} \\ RT_b P_b + n_i^{n} \end{bmatrix} \quad (1)$$

where r_i^n and r_i^s are signals that are received corresponding to the non-signal and signal BPPM time slots in the pulse. In above equation P is the average transmitted optical power for a particular transmit aperture, $g_{i-1,\ i}$ is the channel gain of the link that connects (i-1)th to ith nodes.

In serial relaying, P is expressed in terms of P_t that is the total transmitted power, given by $P=P_t/(N + 1)$. Now, $P_s=Pg_{i-1,\ i}$ where P_s is the optical signal power that is incident on the photo detector. Also, $g_{i,j}$ is the channel gain of the link connecting the ith and jth nodes. $L_{i,j}=(d_{i,j})/(d_{o,N+1})$ is the normalized path loss pertaining to the link connecting the ith and jth nodes with respect to the distance of direct link between source and destination that is $d_{o,N+1}$[1].

ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

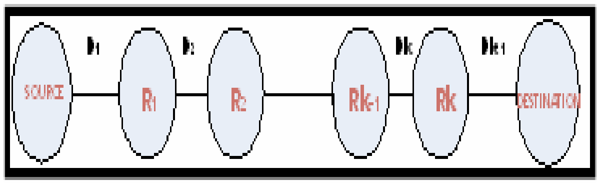

Figure-1. Serial relaying technique.

1.3. Parallel relay technique

In this mode of relaying, an N number of relays are used to link the source and the destination such that each of them can receive the signal directly from the source and then send it to the destination directly without any hindrance. Since it is impossible to broadcast the signal in a given WOC communication's manner, a multi-laser transmitter is used in which the lasers within the source point out to the node of relay. The N relays subsequently receive the same signal from the source node. Pertaining to the type of DF method of relaying, relays either decode or retransmit the signal to the destination. But, across the relays, block coding of distributed space-time is not needed because of the transmitting apertures from the orthogonal patterns of diffraction. In parallel relaying, the signal is caught by all the N relay nodes from the corresponding apertures that are transmitting.

The received signal at ith relay (i=1, 2 . . . N) is given as:

$$r_i = \begin{bmatrix} r_i^s \\ r_i^n \end{bmatrix} = \begin{bmatrix} RT_b(P_{g_{0,i}} + P_b) + n_i^s \\ RT_b P_b + n_i^n \end{bmatrix} \quad (2)$$

Here, $P=P_t / (2N)$ where P is the average optical power per transmitting aperture. It is obtained by dividing the total transmitted power with all the transmitting apertures in the configuration. As mentioned, the signal gets decoded then modulated using BPPM and retransmitted by the relay nodes to the destination. Let D denote the set of relays that have decoded the signal successfully. It is possible only when the received SNR is greater than the outage-threshold [2].

The superposition of the received optical powers from the decoded set gives the following results in the final received signal at the destination node:

$$r_{N+1} = \begin{bmatrix} r_{N+1}^s \\ r_{N+1}^n \end{bmatrix} = \begin{bmatrix} RT_b\left(\sum_{i\in D} P_{g_{i,N-1}} + P_b\right) + n_{N+1}^s \\ RT_b P_b + n_{N+1}^n \end{bmatrix} \quad (3)$$

Considering the average channel model and taking turbulence-induced by log-normal fading and path loss into use, the channel coefficient of a link of length d can be written as:

$$g = |\alpha|^2 L(d) \quad (4)$$

where $L(d) = \ell(d)/\ell(d_{S,D})$ denotes the normalized path loss w.r.t. the direct link distance between the source and the destination, $d_{S,D}$.

Here, $\ell(d) = e^{-\sigma d} A_{TX} A_{RX}/(\lambda d)^2$ where A_{TX} is the transmitter aperture area, A_{RX} is the receiver aperture area, λ and σ are the optical wavelength, and the attenuation coefficient, respectively.

Whereas, the log normally distributed fading amplitude is written as $|\alpha|=\exp(\chi)$ where the fading log amplitude χ is distributed normally with mean µx and variance σ2x. The fading amplitude is normalized such that E[|α|2] = 1 implying $\mu_x = -\sigma^2_x$, ensuring that the power average is not attenuated nor amplified by fading.

On the basis of Rytov theory, the log-amplitude variance is written by:

$$\sigma^2_x(d) = \min\{0.124 k^{7/6} C^2_n d^{11/6}, 0.5\} \quad (5)$$

where k is the wave number and C^2_n denotes the constant refractive index structure [1-3].

Note: In the present work we will not deal with serial relaying technique because if any link between the relays in serial relaying technique is broken, the whole system c7llapses.

The pictorial representation of the Technique of Parallel Relaying is given as:

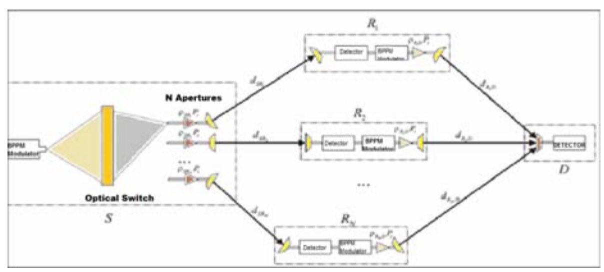

Figure-2. Parallel relaying technique.

2. OUTAGE ANALYSIS FOR PARALLEL RELAYING TECHNIQUE

Let us assume that the targeted transmission rate be denoted by R_0 and the equivalent SNR threshold is denoted by $\gamma_{th} = C^{-1}(R_0)$ in terms of instantaneous channel capacity for realization of fading channel. Hence, the probability of outage is given by $P_{out}(R_0) = P_r(\gamma < \gamma_{th})$. There is no outage in the case of SNR greater than γth and the signal is decoded at the receiver node with low probability of error [7].

Outage occurs in parallel relaying when the given conditions are true:

a) When the single relays properly decode the signal, for all the K-nodes
b) Multiple input single out put (MISO) link fails between relays and destination.

VOL. 8, NO. 7, JULY 2013 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

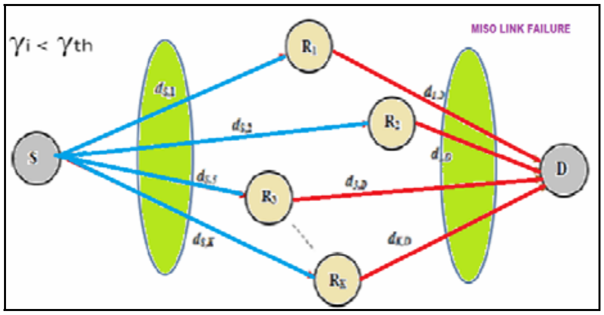

Figure-3. Outage conditions.

The decoded set consists of 2K number of possibilities and is defined as the set of relays that successfully decodes the signal. Let W(i) indicate the ith possible set, and $d_{W(i)}$ be the set of all the distances between the destination node and the relays in the decoded set , D, i.e., $d_{j,D}$ ε $d_{W(i)}$, for all j ε W(i).

The outage probability for such a configuration is given by:

$$P_{out} = \sum_{i=1}^{2^K} P_{out-p}(W(i)) = \sum_{i=1}^{2^K} \left[\prod_{j\in W(i)} \left(1 - Q\left(\frac{\ln\left(\frac{L(d_{S,j})P_M}{2K}\right) + 2\mu_\chi(d_{S,j})}{2\sigma_\chi(d_{S,j})}\right)\right) \times \prod_{j\notin W(i)} Q\left(\frac{\ln\left(\frac{L(d_{S,j})P_M}{2K}\right) + 2\mu_\chi(d_{S,j})}{2\sigma_\chi(d_{S,j})}\right)\right] Q\left(\frac{\ln\left(\frac{P_M e^{\mu_\xi}}{2K}\right)}{\sigma_\xi(\bar{d}_{W(i)})}\right) \quad (6)$$

Where

$$\mu_\xi(\bar{d}_{W(i)}) = \ln \sum_{i\in W(i)} L(d_{i,D}) - \sigma_\xi^2(\bar{d}_{W(i)}), \quad (7)$$

$$\sigma_\xi^2(\bar{d}_{W(i)}) = \ln\left(1 + \sum_{i\in W(i)} L^2(d_{i,D})(e^{4\sigma_\chi^2} - 1) \Big/ \left(\sum_{i\in W(i)} L(d_{i,D})\right)^2\right) \quad (8)$$

3. FITNESS OR OBJECTIVE FUNCTION

Finally the main aim in the present work is to reduce the outage probability and increase the power margin i.e., difference in received power and the incident power is more. For such a condition, we have to optimize the results by fixing and shifting the relay to different positions to get favourable output. The exact and optimized location of the relay can be obtained by implementing different algorithms such as Genetic Algorithm, Shuffled Frog Leaping Algorithm etc. The main concept behind all these algorithms are to randomly generate the positions of the relay, keep improvising them and finally obtain the best result. The manners in which improvisations are done are different in all the algorithms. Improvisations are done after analyzing the values obtained from the fitness function which determines the cost value, keeping in mind all the parameters like atmospheric turbulence etc and is specific to the given condition [1].

$$z(d_{S,1}, d_{S,2}, \ldots, d_{S,K}, d_{1,D}, \ldots, d_{K,D}) \stackrel{def}{=} \sum_{i=1}^{2^K} \left[\prod_{j\in W(i)} (1 - Q(u(d_{S,j}))) \prod_{j\notin W(i)} Q(u(d_{S,j})) \right] \times Q(v(\bar{d}_{W(i)})), \quad (9)$$

$$u(d_{S,j}) \stackrel{def}{=} \left(\ln\left(\frac{L(d_{S,j})P_M}{2K}\right) + 2\mu_\chi(d_{S,j})\right) / 2\sigma_\chi(d_{S,j}), \quad (10)$$

$$v(\bar{d}_{W(i)}) \stackrel{def}{=} \ln\left(\frac{P_M e^{\mu_\xi}}{2K}\right) / \sigma_\xi(\bar{d}_{W(i)}), \quad (11)$$

4. SHUFFLED FROG LEAPING ALGORITHM (SFLA)

In a nutshell, the SFLA fuses the benefits of the MAs, genetic-based, and the social behavior-centric PSO algorithms. In case of SFLA, the population comprises of a group of frogs as known as the solutions those are divided into subsets known as memeplexes. Different memeplexes are taken as varied cultures of frogs, where each performs a local search. And within every such memeplex, all the individual frogs hold different ideas, and are subjected to influence by the other ideas of the remaining frogs, and undergo evolution through memetic evolution. Following a fixed number of steps of memetic evolution, ideas pass among the memeplexes via a shuffling process. These shuffling processes and the local search go on till the set of defined convergence criteria are satisfied.

Firstly, an initial group of P frogs is obtained randomly. In S-dimensional problems having S variables, a frog, say i, is denoted by $X_i = (x_{i1}, x_{i2}, \ldots, x_{iS})$. Then, the frogs are sorted, descending order respective to their fitness. The entire population is then segregated into m number of memeplexes, each of them containing n frogs (mxn). Following this, the first frog sits in the first memeplex, then the second goes into the second memeplex, the m frog goes into the mth memeplex, and finally the frog m+1 sits back into the first memeplex. Within each of these memeplexes, the frogs having the worst and the best fitnesses are picked as X_w and X_b, respectively. Along with that, the globally best fitness is also identified as X_g. A similar process like PSO is applied to enhance the frog having the worst fitness in each cycle.

$$sd_{ITER} = \left(\frac{iter_{max} - iter}{iter_{max}}\right)^{pow} (sd_{max} - sd_{min}) + sd_{min} \quad (12)$$

And accordingly, the frog position, i.e., the worst fitness one is modified as follows:

Change in frog position, $(D_i) = \text{rand}(\ ) \times (X_b - X_w)$ (13)

New position, X_w = current position $X_w + D_i$; where $D_{max} \geq D_i \geq -D_{max}$. (14)

Here rand ( ) fetches a random number lying between 0 and 1 and D_{max} is the maximum allowed change in a frog's position. If this process gives rise to a better solution, the worst frog will be replaced otherwise the calculations are again repeated but now w.r.t. the global best frog (thus X_g replaces X_b). And, if no such improvement is available, a new solution is generated randomly as a replacement to that frog. This would continue for a fixed number of iterations. Thus, the main SFL parameters are: P, number of frogs, memeplexes, generations for every such memeplex right before shuffling, shuffling iterations, and the maximum step size [4-5].

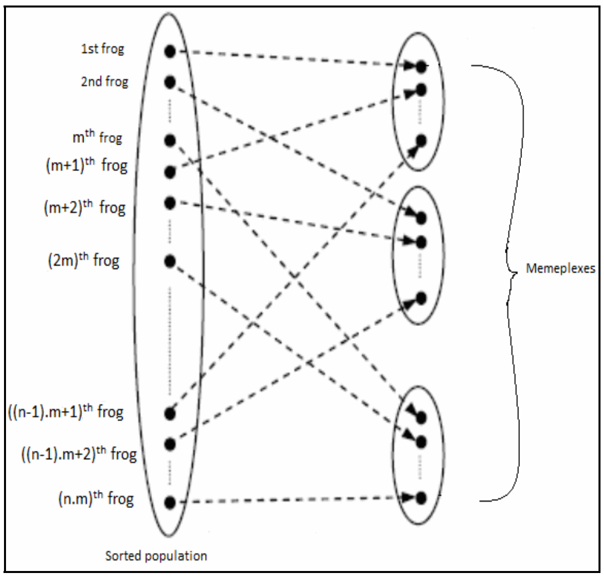

Figure-4. Dividing frog population in SFLA.

The comparatively clear and sorted picture of SFLA makes it less complicated, in terms of code complexity, with respect to genetic algorithm. Genetic algorithm seeks processes of reproduction to find the superior individuals, but here we are merely playing around with vulnerable ideas. Hence the SFLA procedure is accurate and fast while determining the location and the sizes. The ease of getting the output makes it preferable over the conventional genetic algorithm.

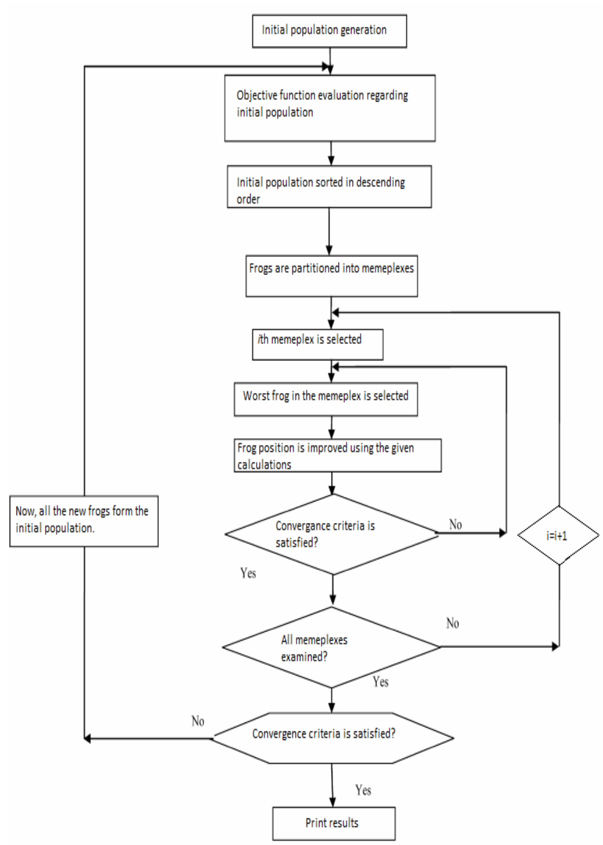

Figure-5. Flowchart for SFLA.

5. RESULTS AND COMPARISON

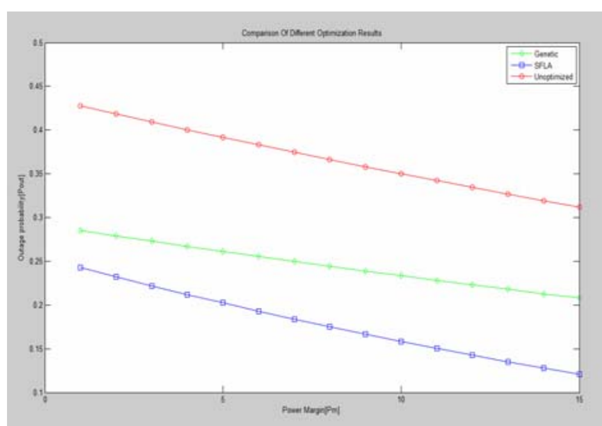

Figure-6. Outage probability vs power margin for 2 relays.

VOL. 8, NO. 7, JULY 2013 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

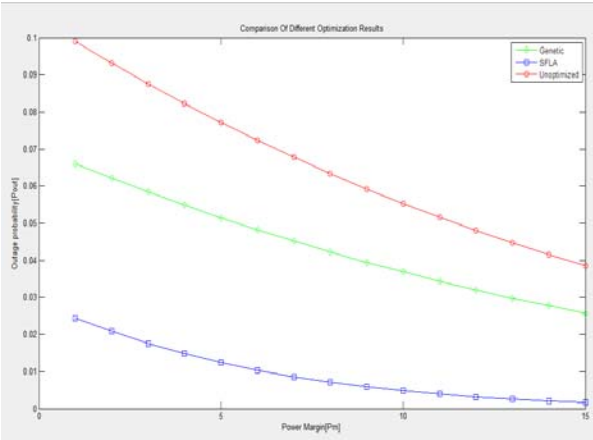

Figure-7. Outage probability vs power margin for 4 relays.

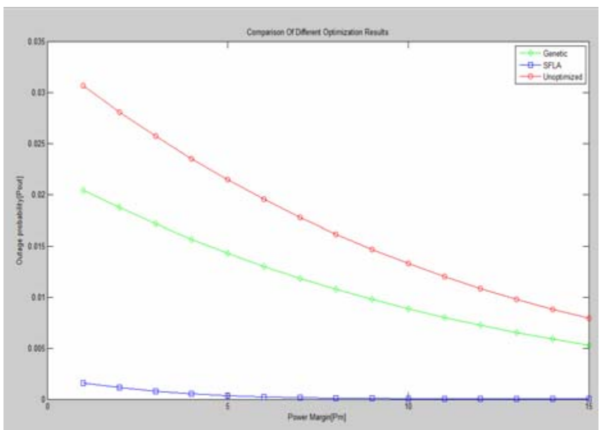

Figure-8. Outage probability vs power margin for 6 relays.

As the number of relays increases the outage probability decreases, and therefore it is recommended to use more number of relays in parallel technique [4-6].

Table-1. Optimized position obtained of 2 relays for genetic and SFL algorithm.

PM (DB)	Genetic algorithm		SFLA	
	(D=5km and K=2)			
	Position of relays w.r.t source (in KM)			
0	3.32487	2.83586	2.43483	1.46578
5	1.08148	2.80001	1.48652	0.85166
10	2.26959	4.38781	1.46651	0.84829
15	4.32204	2.81038	2.03641	2.34909
20	3.82427	3.91353	1.57954	1.85829

6. CONCLUSIONS

The problem statement involving the relay positions and the different convergence criteria is accessed through Genetic Algorithm and Shuffled Frog Leap Algorithm, i.e., getting the optimized relay positions. Results obtained from MATLAB implementation show that outputs of shuffled frog leaping have relative higher outage probability than the genetic algorithm, making them a preferable choice overall. Other reasons, making them a preferred choice, are the ease of their practical implementation and the lesser computational time.

The algorithms are studied as flow-charts, then the respective programs are coded. Both the algorithms use the fitness function to calculate the cost value to arrive into a conclusion. The primary aim is to minimize the fitness function to obtain optimized relay position. The outrage probability versus power margin is plotted for all the algorithms and the results are compared.

REFERENCES

[1] Mohammadreza A.Kashani1, Majid Safari, and Murat Uysal, "Optimal Relay Placement in Cooperative Free-Space Optical Communication Systems", 2012 IEEE Wireless Communications and Networking Conference: PHY and Fundamentals.

[2] Majid Safari, and Murat Uysal, "Relay assited free space optical communication", 2007 IEEE.

[3] Min Feng, Jun-Bo Wang, Ming Sheng, Ling-Ling Cao, Xiu-Xiu Xie Ming Chen, "Outage Performance for Parallel Relay-Assisted Free-Space Optical Communications in Strong Turbulence with Pointing Errors", 978-1-4577-1010-0/11 ©2011 IEEE.

[4] E. Afzalan1, M. A. Taghikhani2,*, M. Sedighizadeh1,2, "Optimal Placement and Sizing of DG in Radial Distribution Networks Using SFLA", International Journal of Energy Engineering 2012, 2(3): 73-77.

[5] Christopher R. Houck, Jeffery A. Joines, Michael G. Kay, "A Genetic Algorithm for Function Optimization: A Matlab Implementation".

[6] Book: "Practical Genetic Algorithms", Second Edition, by Randy L. Haupt and Sue Ellen Haupt.

[7] Nestor D. Chatzidiamantis, Diomidis S. Michalopoulosy, Emmanouil E. Kriezis, George K. Karagiannidis and Robert Schobery, "Relay Selection Protocols for Relay-Assisted Free-Space Optical Systems Vol. 5, No. 1/January 2013/J. Opt. Commun. Netw.