PSO Based Optimization Technique for Wireless Optical Communication

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ABSTRACT— ***Analysis of relay-assisted transmission to overcome fading effect in long range wireless optical communication channel considering atmospheric turbulence as a fading effect and implementing serial and parallel relaying configuration through particle swarm optimization(PSO) technique to find an optimized solution of relay locations so as to minimize the outage probability and improve the performance. Also, comparison is done by plotting outage probability function with different power margin values and number of relays used. The fading effect considered in this paper is mainly due to atmospheric turbulence and channel model which takes into account this effect of turbulence is induced log-normal fading model where the fading variance is distance-dependent in wireless optical system.***

Keywords– wireless optical systems, particle swarm optimization, relaying, fading channels

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1. INTRODUCTION

Recently, there has been increased interest in the use of optical wireless communication due to its large unregulated bandwidth ,and its immunity to interference caused by other electronic equipments. Most of the focus has gone to radio frequency wireless communication. Wireless optical links allow for greater mobility which excel at short-range [2]. It is advantageous over other competing technologies because the WOCs cost is on average about 10% of the cost of an optical fiber system. Second, WOC systems have a greater range i.e. systems can cover distances greater than a kilometer. Finally, this type of technology as opposed to radio links, does not require licensing in addition to not cause interference. These wireless optical systems are attractive to provide broadband services due to their inherent wide bandwidth, easy deployment and no license requirement. The access to broadband networks based on optical communications may be accomplished through passive optical networks (or PON‘s, which are based on the use of fiber optics) or via optical wireless communication systems. The WOC is a type of communications system that uses the atmosphere as a communications channel. The idea to employ the atmosphere as transmission media arises from the invention of the laser. Wireless radio frequency (RF) solutions alleviate most of the disadvantages of a fixed electrical connection.

Communication is theoretically possible as long as the line of sight between the transmitter and the receiver is clear, and as long as the transmitted power is high enough to overcome atmospheric attenuation. Despite the major advantages of WOC, its widespread use has been hampered by its rather disappointing performance for long-range links. For longer link ranges, atmospheric turbulence-induced fading becomes a major performance limiting factor in WOC systems. Atmospheric turbulences are the main source of noise in the channel [3]. To overcome this, relaying techniques are needed.

Cooperative diversity relaying (i.e. parallel relaying) is studied for mitigating signal power fluctuation due to multipath fading, and second one is multi-hop relaying (i.e. serial relaying)which is studied for alleviating signal attenuation due to path loss. Cooperative diversity has been recently introduced as an alternative way of realizing spatial diversity based on the observation that in a wireless RF channel, the signal transmitted by the source node is overheard by other nodes, which can be defined as relays. Multi-hop transmission is an alternative relay-assisted transmission scheme which employs the relays in a serial configuration. Such schemes are typically used to broaden the signal coverage for limited power transmitters and do not offer performance improvement against fading effects in wireless RF environments, i.e., it does not increase the diversity order.

To minimize outage probability, relay locations needs to be optimized. In this paper, we investigate the optimal relay placement problem for cooperative WOC systems. We consider log-normal distributed fading and formulate optimization problems based on the end-to-end outage probability to determine optimal relay locations using PSO (Particle swarm optimization). PSO is a global optimization method put forward originally by Doctor Kennedy and Eberhart in 1995. It is developed from swarm intelligence and is based on the research of bird and fish flock movement behavior. There is always a bird that can smell the food very well, having the better food resource information. Because they are transmitting the information, especially the good information at any time while searching the food from one place to another, conducted by the good information, the birds will eventually flock to the place where food can be found. The most optimist solution can be worked out in PSO algorithm by the cooperation of each individual. Due to its many advantages including its simplicity and easy implementation, the algorithm can be used widely in the fields such as function optimization, the model classification, machine study, neutral network training, the signal procession, vague system control, automatic adaptation control etc. The position of each particle in the swarm is affected both by the most optimist position during its movement (individual experience) and the position of the most optimist particle in its surrounding (near experience). Each particle can be shown by its current speed and position, the most optimist position of each individual and the most optimist position of the surrounding.

2. SYTEM MODEL AND OUTAGE PROBABILITY EXPRESSIONS

2.1 Channel Modeling with Relays

In serial relaying (Fig. 1), the source node transmits a BPPM signal to the closest relay node. The relay decodes the signal after direct detection, modulates it with BPPM, and retransmits it to the next relay. This continues until the source's data arrives at the destination node. In parallel relaying (Fig. 2), the source node is equipped with a multi-laser transmitter with each of the transmitter pointing out in the direction of a corresponding relay node. It transmits the same signal to *K* relay nodes and each relay decodes and retransmits the signal to the destination only if their received SNR exceeds a given decoding threshold. We consider an aggregated channel model where both distance-dependent path loss and turbulence-induced fading are taken into account [4]. The *path loss ratio* for an WOC link with length *d* can be expressed as

$$\ell(d) = A_{TX}A_{RX}e^{-\sigma d}/(\lambda d)^2 \qquad \text{-------------- (1)}$$

Where σ is the attenuation coefficient which is dependent on visibility. A_{TX}, A_{RX}, and λ are transmitter aperture area, receiver aperture area, and the optical wavelength, respectively [6]-[7]. Hence the fading log-amplitude χ is modeled as a Gaussian distributed random variable.

$$L(d) = \ell(d)/\ell(d_{S,D}) \qquad \text{-------------- (2)}$$

where L(d) denotes the *normalized path loss* with respect to the distance of the direct link between the source and the destination, i.e. $d_{s,d}$ We normalize the fading amplitude such that $\mu_x = -\sigma_x^2$. Besides the link length *d*, the log-amplitude variance depends on wave number (*k*), and refractive index structure constant (Cn^2) and is given by

$$\sigma_x^2 = \min\{0.124k^{7/6}\, Cn^2 d^{11/6}, 0.5\} \qquad \text{-------------- (3)}$$

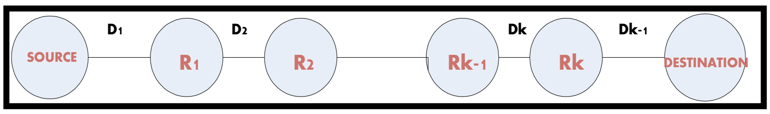

Fig. 1. Serial Relaying Technique

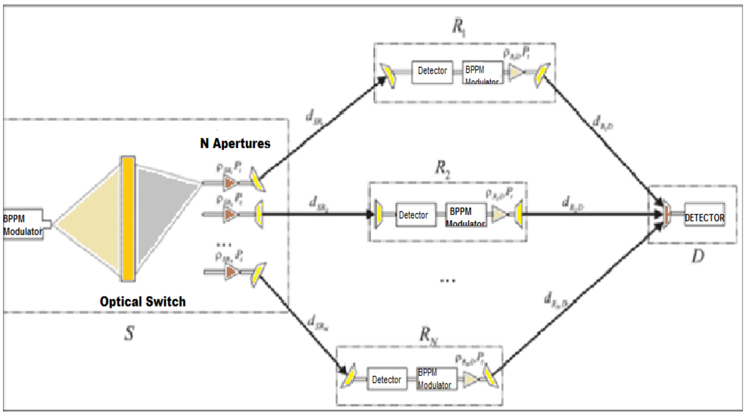

Fig. 2. Parallel Relaying Technique

2.2. Analysis of Outage Probability for WOC link

The outage probability is given by

$$P_{out}(R_o) = P_r\,(\gamma < \gamma_{th}) \qquad \text{-------------- (4)}$$

where γ_{th} and γ are instantaneous SNR and threshold SNR. If SNR exceeds threshold SNR, no outage happens and at receiver, signal decoding takes place with low probability error.

Power margin is given by $P_M = P_t/P_{th}$ where P_{th} is the transmission power required so that no outage happens while direct transmission from source to destination [5]. So the power margin is given by

$$P_M = \sqrt{P_t^2 R T_b^2 / N_o \gamma_{th}} \qquad \text{-------------- (5)}$$

The outage probability is given by

$$P_{out} = 1\text{-}\prod_{i=1}^{K+1}\left(1 - Q\left(\frac{\ln\left(\frac{L(d_i)P_M}{(K+1)+2\mu_x(d_i)}\right)}{2\sigma_x(d_i)}\right)\right) \qquad \text{-------------- (6)}$$

Let W(i) denote the i[th] possible set where received signal has been decoded and $d_{w(i)}$ denote the distances for the set of W(i).

Thus P_{out} is given as:

$$P_{out} = \sum_{i=1}^{2^k}\left[\prod_{j\in w(i)}\left(1 - Q\left(\frac{\ln\left(\frac{L(d_{s,j})P_M}{2K}\right)+2\mu_x(d_{s,j})}{\sigma_x(d_{s,j})}\right)\right)\times \prod_{j\in w(i)}\left(Q\left(\frac{\ln\left(\frac{L(d_{s,j})P_M}{2K}\right)+2\mu_x(d_{s,j})}{\sigma_x(d_{s,j})}\right)\right)\right]Q\left(\ln\left(\frac{P_M e^{\mu_\varepsilon}}{2K}\right)/\sigma_\varepsilon\left(\bar{d}_{W(i)}\right)\right)$$

-------------- (7)

Where $\mu_\varepsilon\left(\bar{d}_{W(i)}\right) = \ln\sum_{i\in W(i)} L\left(d_{i,D}\right) - \sigma_\varepsilon^2\left(\bar{d}_{W(i)}\right)$

$$\sigma_\varepsilon^2\left(\bar{d}_{W(i)}\right) = \ln\left(1 + \sum_{i\in W(i)} L^2\left(d_{i,D}\right)\frac{\left(e^{4\sigma_x^2}-1\right)}{\sum_{i\in W(i)} L\left(d_{i,D}\right)}\right)$$

3. OPTIMIZATION OF RELAY LOCATION AND MINIMISATION OF OUTAGE PROBABILITY

3.1. Serial Relaying

Let $d_1, d_2, \ldots$ and d_{K+1} denote these lengths to be optimized and define the following functions:- Where $\varphi(x) = 1 - Q(x)$ is the cumulative distribution function of the normal Gaussian distribution[5]

$$h(d_1, d_2, \ldots, d_{k+1}) \stackrel{\text{def}}{=} \prod_{i=1}^{k+1} \varphi(f(d_i)) \qquad \text{-------------- (8)}$$

$$g(d_1, d_2, \ldots, d_{k+1}) \stackrel{\text{def}}{=} \sum_{i=1}^{k+1} d_i \qquad \text{-------------- (9)}$$

$$\varphi(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} \exp\left(\frac{-t^2}{2}\right) dt \qquad \text{-------------- (10)}$$

Also $f(d_i)$ is defined as

$$f(d_i) = (\ln(L(d_i) P_M / (K+1)) + 2\mu_x(d_i)) / 2\sigma_x(d_i) \qquad \text{-------------- (11)}$$

thus optimization problem is

$$\max\ h(d_1, d_2, \ldots, d_{k+1})$$

$$\text{s.t. } g(d_1, d_2, \ldots, d_{k+1}) = d_{S,D}$$

3.2. Parallel Relaying

Let $d_{S,j}$ and $d_{j,D}$ source to relay and relay to destination distance . For optimization , relays are placed in direct path between source and destination [1]. The required functions have been defined as follows [8]:

$$z(d_{S;1}, d_{S;2}, \ldots, d_{S;K}, d_{1;D}, \ldots, d_{K;D}) \stackrel{\text{def}}{=} \sum_{i=1}^{2^k} \left[\prod_{j \in w(i)} \left(1 - Q\left(u(d_{s,j})\right)\right) \prod_{j \notin w(i)} Q\left(u(d_{s,j})\right) \right] \times Q\left(v(\bar{d}_{W(i)})\right) \qquad \text{-------------- (12)}$$

$$u(d_{s,j}) \stackrel{\text{def}}{=} \frac{\ln\left(\frac{L(d_{s,j}) P_M}{2K}\right) + 2\mu_x(d_{s,j})}{\sigma_x(d_{s,j})}$$

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

We can state the optimization problem as,

$$\min \quad z(d_{S1}, d_{S2}, \ldots, d_{SK}, d_{1,D}, \ldots, d_{K,D})$$

$$d_{S,j}, d_{j,D}, j=1,2,..,K \qquad \text{s.t } d_{S,j} + d_{j,D} = d_{S,D} \qquad j=1,2,\ldots,K$$

C. Parameters Of PSO

PSO is a population based stochastic method for optimization of function whose parameters are defined as follows [9]:

$V_i^{k+1} = wV_i^k + c_1\, rand_1(\ldots) \times (pbest_i - s_i^k) + c_2\, rand_2(\ldots) \times (gbest - s_i^k)$

w = wMax-[(wMax-wMin) x iter]/maxiter

$s_i^{k+1} = s_i^k + V_i^{k+1}$

where $\mathbf{v_i^k}$ and s_i^k are velocity and position of agent i at iteration k respectively and **w** is weighting function, $\mathbf{c_j}$ is weighting factor**,** pbest and gbest are personal best and global best of agent i at iteration k respectively.

D. Optimisation Using Algorithm PSO

1). Serial Realaying: As the function $f(d_i)$ is monotonically decreasing function , so we don't need to use any algorithm and solution can be found as

$$d_i = d_k$$

Therefore, the outage probability is minimized when the relays are placed at equal distance along the path between source to destination.

2). Parallel Relaying: The optimization problem is minimized using PSO in which random source to relay distance and relay to destination distance have been generated for K number of relays and then initial global and local best values have been initialized along with minimum value [10]. The minimum value has been updated for required number of iterations and corresponding optimized relay location has been found.

Also, with change in power margin , optimized and relay locations have been found corresponding to minimum outage probability as in Figure 3.

4. RESULTS AND DISCUSSIONS

In this section , we present numerical results for optimized relay locations . In this, we have considered λ= 1550 nm and atmospheric attenuation of 0.43 dB/km and refractive structure constant of $C_n^2=10^{-14}\,m^{-2/3}$.The link ranges considered are $d_{S,D}$=3 km and $d_{S,D}$=5 km. Figure demonstrates the end-to-end outage probability for WOC for parallel relaying for optimized and unoptimised relay locations(taking position of relay as halfway of distance between source to destination distance) for different number of relays. As optimization has yielded the same location for all relays , so only one value is provided for all number of relays. We present optimized outage performance for K=2,3 and

power margin of 0dB, 5 dB, 10dB, 15 dB. We have achieved performance improvement of 1.5dB, 1.7 dB for K=2,3. It is also observed that even with the use of random numbers as initial distance between source and destination , the optimized distance and minimized outage probability obtained is same for corresponding number of relays. The optimized relay location for different power margin values for K=2, 3 is shown in Table I.

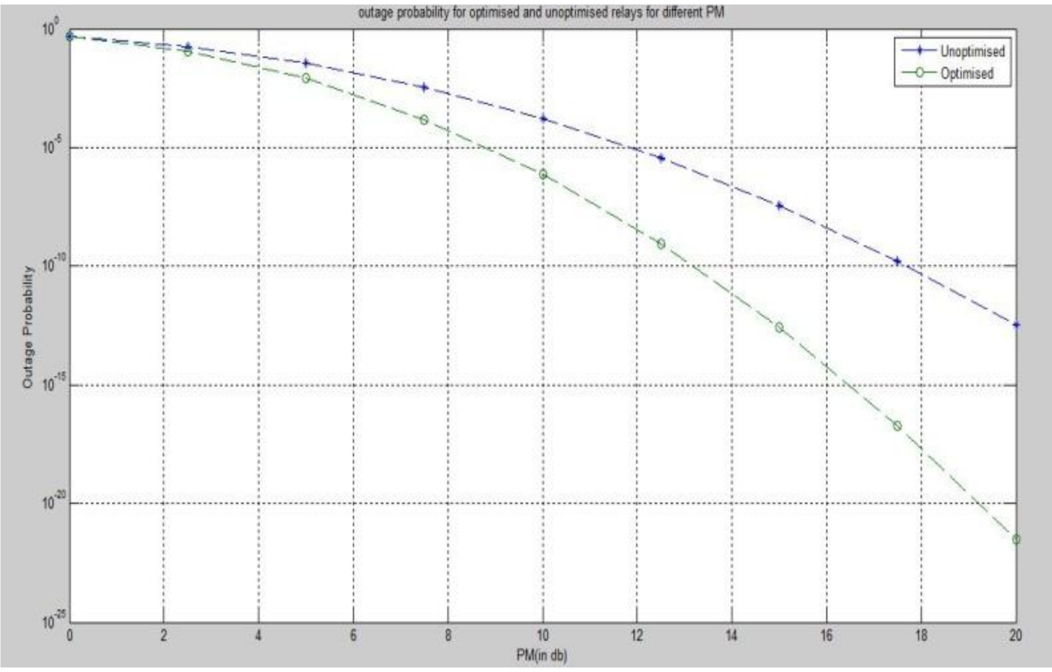

Fig. 3 Outage probability of parallel WOC relaying scheme for K=3 and $d_{S,D}$=5

PM(dB)	K=2	K=2	K=3	K=3
	$d_{S,D}$=3	$d_{S,D}$=5	$d_{S,D}$=3	$d_{S,D}$=5
0	0.3421	0.3562	0.3312	0.3223
5	0.3523	0.3671	0.3412	0.3515
10	0.3831	0.3944	0.3671	0.3721
15	0.3976	0.3998	0.3887	0.4024

Table I: Normalized Optimal Relay Locations

5. CONCLUSIONS

In this paper, we have examined the optimum relay placement for serial and parallel WOC relaying. Relay locations have been optimized for serial and parallel relaying. For serial relaying, the outage probability is minimized when the consecutive nodes are placed equi-distant along path from the source to destination while in case of parallel relaying, the outage probability is minimized when all the relays are placed at same location between source and destination along the direct link between source and destination and are closer to source.

6. REFERENCES

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