A Survey on Single Relay Selection for co-operative Communication in Free Space Optical Communication

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Abstract— Multipath fading is one of the major obstacles for next generation wireless networks which limit the bandwidth requirement of services. There are many techniques found in literature to overcome the issues of multipath fading. However, co-operative communication is the major technique that has gained importance due to its ability to reduce fading. Co-operative communication is based on the relay selection technique using the channel state information at the source and relays. The main of relay based scheme is to achieve higher bandwidth efficiency. However, if the direct link between source to destination is proper and of high quality than there is no requirement to have relay based selection technique. The work in this thesis proposes a methodology to select optimal number of relays in order to achieve better transmission efficiency. Optical wireless communication (OWC) refers to transmission in unguided propagation media through the use of optical carriers, i.e., visible, infrared (IR), and ultraviolet (UV) bands.

Key words: Multipath Fading, FSO (Free space Optical), Co-operative Communication, SNR, BER (Bit Error Rate)

I. INTRODUCTION

Bridging the so-called “last mile” in communication networks has revived keen interest in free-Space Optics (FSO), also known as fiber-free or fibreless optics, which is a technology that transports data via laser technology. It is a line-of-sight technology that currently enables optical transmission up to 2.5 Gbps of data, voice and video through the air at long distances (4km), allowing optical connectivity without deploying fiber-optic cable or securing spectrum licenses. It is moving closer to being a realistic alternative to laying fiber in access networks.

Free Space Optics, the industry term for “Cable-free Optical Communication Systems”, is a line-of-sight optical technology in which voice; video and data are sent through the air (free space) on low-power light beams at speeds of megabytes or even gigabytes per second [1]. A free-space optical link consists of 2 optical transceivers accurately aligned to each other with a clear line-of-sight. Typically, the optical transceivers are mounted on building rooftops or behind windows. These transceivers consist of a laser transmitter and a detector to provide full duplex capability. It works over distances of several hundred meters to a few kilometers. Figure 1 shows 10 Gbps FSO link by MRV communication[1].

Fig. 1: 10Gbps FSO Link by MRV Communication, Feb 12,2013[1]

II. SURVEY ON FSO

Optical wireless communication has emerged as a viable technology for next generation indoor and outdoor broadband wireless applications. Applications range from short-range wireless communication links providing network access to portable computers, to last-mile links bridging gaps between end users and existing fiber optic communications backbones, and even laser communications in outer-space links [1]. Indoor optical wireless communication is also called wireless infrared communication, while outdoor optical wireless communication is commonly known as free space optical (FSO) communication. In applying wireless infrared communication, non-directed links, which do not require precise alignment between transmitter and receiver, are desirable. They can be categorized as either line-of-sight (LOS) or diffuse links. LOS links require an unobstructed path for reliable communication, whereas diffuse links rely on multiple optical paths from surface reflections. On the other hand, FSO communication usually involves directed LOS and point-to-point laser links from transmitter to receiver through the atmosphere. FSO communication over few kilometer distances has been demonstrated at multi-Gbps data rates.

FSO technology offers the potential of broadband communication capacity using unlicensed optical wavelengths. However, in-homogeneities in the temperature and pressure of the atmosphere lead to refractive index variations along the transmission path. These refractive index variations lead to spatial and temporal variations in optical intensity incident on a receiver, resulted in fading. In FSO communication, faded links caused by such atmospheric effects can cause performance degradation manifested by increased bit error rate (BER) and transmission delays.

FSO technology has also emerged as a key technology for the development of rapidly deployable, secure, communication and surveillance systems, which can cooperate with other technologies to provide a robust, advanced sensor communication network. However, the LOS requirement for optical links reduces flexibility in forming FSO communication networks. Compared with broadcast radio frequency (RF) networks, FSO networks do not have an obvious simple ability to distribute data and control information within the network.

The objective of the research work presented here is to answer the following questions regarding:

1) How to improve the performance of FSO links for long-range FSO communications
2) To enhance the reliability of FSO communication with efficient relay selection.
3) To reduce the Bit Error Rate (BER) in existing relay selection based FSO systems.

III. OVERVIEW OF CO-OPERATIVE COMMUNICATION

Multipath fading is one of the major obstacles for the next generation wireless networks, which require high bandwidth efficiency services. Time, frequency, and spatial diversity techniques are used to mitigate the fading phenomenon. Recently, cooperative communications for wireless networks have gained much interest due to its ability to mitigate fading in wireless networks through achieving spatial .Diversity, while resolving the difficulties of installing multiple antennas on small communication terminals. In cooperative communication, a number of relay nodes are assigned to help a source in forwarding its information to its destination, hence forming a virtual antenna array.

Various cooperative diversity protocols were proposed and analyzed by Laneman et al. described various techniques of cooperative communication, such as decodeand- forward, amplify-and- forward, selection relaying, and incremental relaying. It was shown that the first two schemes achieve bandwidth efficiency equal to 1/2 symbols per channel use (SPCU), while the other two schemes achieve higher bandwidth efficiency. In [3], a distributed space-time coded (STC) cooperative scheme was proposed, where the relays decode the received symbols from the source and utilize a distributed space-time code. Su et al. derived symbol error rate (SER) for single-relay decode-and-forward and amplify-and forward cooperative techniques in [4] and [5], respectively. In [6], Sadek et al. provided SER performance analysis for the decode-and-forward multi-node schemes.

There are various protocols proposed to choose the best relay among a collection of available relays in the literature. In, the authors proposed to choose the best relay depending on its geographic position, based on the geographic random forwarding (GeRaF) protocol proposed in [14]. In GeRaF, the source broadcasts its data to a collection of nodes and the node that is closest to the destination is chosen in a distributed manner to forward the source's data to the destination. In [5], the authors considered a best-select relay scheme in which only the relay, which has received the transmitted data from the source correctly and has the highest mean signal-to-noise ratio (SNR) to the destination node, is chosen to forward the source's data. In [5], a relay-selection scheme for singlerelay decode-and-forward cooperative systems was proposed. In this scheme, the source decides whether to employ the relay in forwarding its information or not, depending on the instantaneous values of the source-destination and source-relay channels gain.

The idea of cooperation was presented by van der Meulen in 1971, which established foundation of relay channel. Cooperative communication takes advantage of broadcast nature of the wireless medium where the neighboring nodes overhear the source's signals and relay the information to the destination.

Co-operative communication is similar to the relay channel model in some respects but differs significantly in that each wireless user is assumed to both transmit data as well as act as a cooperative agent for another user. In other words, cooperative signaling proto cols should be designed so that users can assist other users while still being able to send their own data.

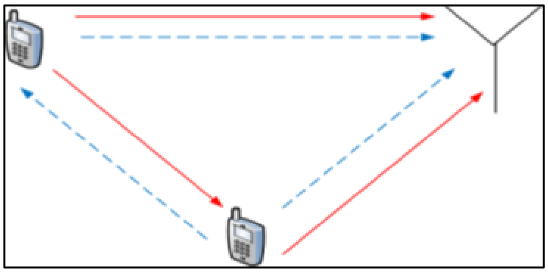

Fig. 2: In Cooperative Communication Each User is both a Source & a Relay

IV. RELAY SELECTION IN FSO

In wireless networks, nodes are constrained by their size, as well as power because they are powered by battery, with limited energy supply. So that it is crucial to transmit information with minimum power consumption in multi relay cooperative systems. All these works focus on the cooperation of one source with one relay or multi relay, which is known as single relay selection and multiple relay selection respectively.

In amplify & forward protocol, all relays are forced to cooperate and each relay has to use their full transmit power for cooperation. While in decode & forward protocol whether a relay would be able to decode depends on the channel quality between the transmitter and the relay. For the sack of simplicity we have considered decoding relays use their full transmit power for cooperation.

In single relay selection, only one relay can cooperate among all the relays in the network. Whereas in multiple relay selection, more than one relay can cooperate among all the relays in the network [9].

– System Model

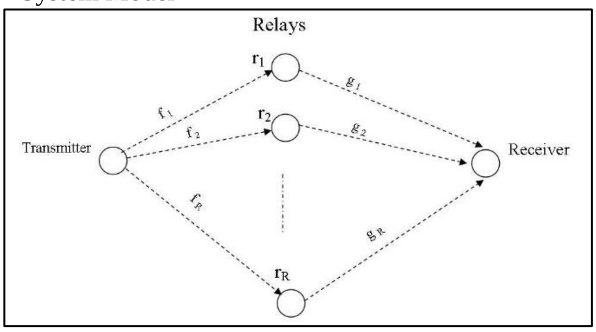

Fig. 3: Wireless Relay Network

Consider a relay network with one transmit-and-receive pair and R relays as depicted in Figure 3. Every relay has one antenna which can be used for both transmission and reception. Denote the channel from the transmitter to Relay I as fi and the channel from Relay i to the receiver as gi. Relay i knows its own channels fi and gi, and the receiver knows all channels f1. . . fR, g1, . . . , gR. Although the schemes proposed in this paper are valid for any channel statistics, for the diversity analysis, we assume that all channels are normalized i.e. Rayleigh random variables, i.e., CN (0, 1).
When only Relay i cooperates, the received SNR is

$$SNR_i = \frac{|f_i g_i|^2 PP_i}{1+|f_i|^2 P + |g_i|^2 P_i}$$

The received SNR at relay i shows, impacts of noise on the transmitted signal. Signal to noise ratio at relay i, depends on channel between transmitter to relay (fi,) channel between relay to receiver.(gi), transmission power used at transmitter (P) and transmission power used at relay (Pi).
Parametric relay selection can works as both single relay selection as well as multiple relay selection.

V. Diversity Orders of Single RS Schemes

In this section, we review some existing single RS schemes. As the diversity orders of many are unknown, our main contribution is the diversity derivation. In the derivation, we assume that all power levels have the same scaling, i.e., *P/Pi* is a constant. When only Relay i cooperates, the receive SNR is

$$SNR_i = \frac{|f_i g_i|^2 PP_i}{1+|f_i|^2 P + |g_i|^2 P_i}.$$

A. Best Relay Selection

In [12], [15]–[16], the relay whose path has the maximum SNR is selected. This is obviously the optimal single RS scheme. The error rate of this scheme is first discussed in [38], which uses an approximation on the cumulative density function of the receive SNR. Then, a rigorous upper bound on the error rate is given in [12]. Both show that this scheme has the full diversity order of R.

B. Nearest Neighbor Selection

In [13], [14], nearest neighbor selection is proposed, in which the relay that is the nearest to the base station cooperates. In both papers, DF is used and node spatial positions are considered. In our AF network with perfect channel information, we use this scheme by choosing the relay with the largest P|fi|2 or Pi|gi|2. Note that the original scheme is slightly modified to incorporate different relay power constraints. “The nearest relay” here is not necessarily the spatially nearest relay to the transmitter or receiver, but the relay with the strongest channel to the transmitter or receiver.

Theorem 1: The diversity order of the nearest neighbor relay selection is 1.

In this method, entire frame is divided into number of blocks of same size. This method is invariant to object motion. By computing the block motion, it is possible to enhance motion invariance.

C. Best Worse Channel Selection

For dual-hop protocols, each relay has two channels. In [14], [18], the best worse channel selection is used, in which the relay whose worse channel is the best is selected. The diversity-multiplexing trade-off of this scheme is analyzed in [18], in which the diversity analysis is based on the outage probability. To incorporate different relay power constraints, we modify the selection function to be min *{P|fi|^2, Pi|gi|^2}*. We work on the error rate and prove that it has full diversity.
Theorem 2: The best worse channel selection achieves the full diversity order of *R*.

D. Best Harmonic Mean Selection

In [18] and [17], the best harmonic mean selection is proposed, in which the RS function is chosen as the harmonic mean of the two channels’ qualities. The one with the largest mean cooperates. Symbol error rate of this scheme is analyzed in [39]. However, the derivation is not rigorous since an upper bound on the receive SNR is used. In this paper, we first modify the selection function to be $\left(P^{-1}|f_i|^{-2} + P_i^{-1}|g_i|^{-2}\right)^{-1}$ to incorporate the different relay power constraints, then give a rigorous upper bound on the error rate.

Theorem 3: The best harmonic mean selection achieves the full diversity order of *R*.

E. Simulation Results

For simulation of single relay selection as well as multiple relay selection technique, we have used MATLAB as software plat form. We have considered a network with 5 relays, 1 source and 1 destination. The channels are formed among all sources to all relays and relays to destination.

Channel type	iid CN(0,1)
Noise power	2 dB
Modulation scheme	BPSK
No. of symbols	10000
Normalization constant	√1/2

Table 1: Simulation Parameters

To check the BER performance one should consider number of symbols transmitted. Here we have considered 10000 symbols which are being transmitted from source to destination via single relay. Now the symbols are modulated and then they are transmitted at different power levels. We have considered the power levels from 0 to 15 dB with segment of 1. The BER is calculated by comparing the demodulation of received signal and reference transmitted signal. The plot of BER vs power is done. This process is repeated for all different single relay schemes and different number of relays as well.

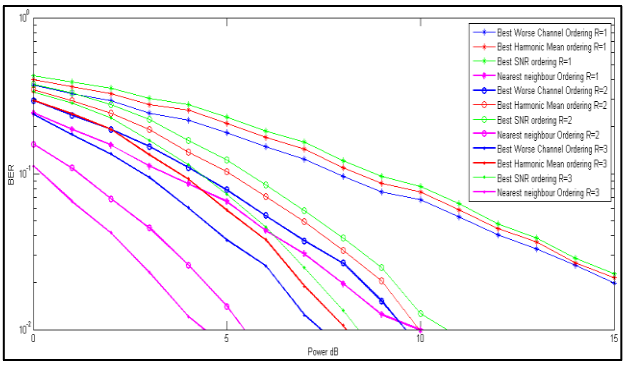

Fig. 4: Comparison of Four Single RS Schemes with Relays=1,2,3

Figure 4 shows the plot of BER versus power for four single relay schemes with varying number of relays from 1 to 3. From figure, it is clear that if we consider power level 5 db, for only Best SNR ordering scheme, we get BER 0.2285, 0.1236 and 0.0716, for Relays 1, 2 and 3 respectively in the network. So we can clearly observe that as the number of relays increases in the network, performance of the n/w will be better.

Similarly, If we consider power level 5 dB and relays keeping 2 in the network, we get BER 0.0844, 0.1084,0.1252 and 0.015 respectively for Best worse channel ordering, Best harmonic mean selection, Best SNR selection, Nearest neighbor selection.

It can be observed that, the performance of nearest neighbor selection is the best among all four schemes.

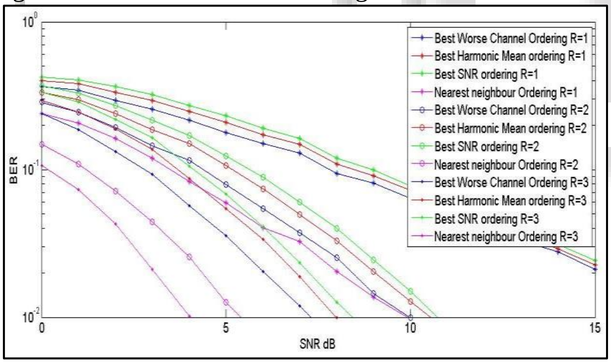

Figure 5. Comparison of four single RS schemes with relays=1,2,3

Figure 5 shows the plot of BER versus SNR for four single relay schemes with varying number of relays from 1 to 3. From figure, it is clear that if we consider SNR level 5 db, for only Best SNR ordering scheme, we get SNR 0.2311,0.1241 and 0.0685 ,for Relays 1,2 and 3 respectively in the network. So we can clearly observe that as the number of relays increases in the network, performance of the n/w increases.

Similarly, If we consider SNR level 5 dB and relays keeping 2 in the network, we get SNR 0.0685, 0.1064,0.1241 and 0.0127 respectively for Best worse channel ordering, Best harmonic mean selection, Best SNR selection, Nearest neighbor selection.

It can be observed that, the performance of Nearest neighbor selection is the best among all four schemes.

VI. CONCLUSION

In nearby future, FSO will become important and necessary medium of information exchange due to its advantages over fiber optics communication. Proper low cost design of transmitters is a viable and better option to prevent trenching and sunken cost of fiber optics. . The channel models for the free space optic link were studied in detail and different channel model. The simulations for all present day models were carried out using Matlab and the results presented. I introduce different relay selection methods in FSO and compare bit error rate of all four methods we conclude that nearest neighbor selection method gives good result and low BER with power and SNR.

VII. FUTURE WORK

Develop PSO algorithm for Free space optical communication to optimize relay selection to decrease BER in transmission.

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