AMPLIFY and FORWARD COOPERATIVE DIVERSITY for SV MODEL BASED STANDARD UWB SYSTEM

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AMPLIFY and FORWARD COOPERATIVE DIVERSITY for SV MODEL BASED STANDARD UWB SYSTEM

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Abstract— ***Data rates and quality of service are limited by the fact that, for the duration of any given connection, they experience severe variation in signal strength. As reported any UWB system faces major challenges in achieving wide coverage without affecting the system performance. In this paper, a cooperative scheme in UWB is proposed so as to enhance the performance and coverage of UWB by using cooperation amongst UWB devices. BER performance analysis is provided for the cooperative UWB system with Amplify-and-Forward (AAF) cooperative protocol using different combining method. Further this work also analyses the performance of this protocol subject to positioning of relay between transmitter and receiver. The result indicates that AAF provides better performance over single link transmission.***

Keywords— AAF, SV Model, UWB, SNR, BER, ERC, FRC, SNRC, ESNRC

I. INTRODUCTION

In order to meet the demand of multi-rate multimedia communications, the next generation wireless system must employ advanced algorithms and techniques so as to enhance the data rates and guarantee to the quality of service (QoS) desired by various classes of traffic. Different techniques are currently being used to achieve this goal. Among these techniques, diversity is of primary importance due to the very nature of wireless environment [3]. Ultra Wide Band (UWB) technology demonstrates a great promise for high speed short range wireless communication. UWB system faces major challenges in achieving the desired performance and coverage due to low power transmission [2]. Spatial diversity relies on the principle that signal transmitted from geographically separated transmitters, and/or to geographically separated receivers, experience independent fading [3]. Cooperative diversity is a relatively new class of spatial diversity technique that is enabled by relaying and cooperative communication. Cooperative diversity result when cooperative communication is used primarily to leverage the spatial diversity available among distributed devices/ terminals. The major motivation here is to improve the reliability of communication in terms of outage probability or symbol/ bit error rate (SER/BER). In both cases, cooperation allow for tradeoff between target performance and required transmitted power. Cooperative communication exploits the broadcast nature of wireless medium and allows devices/ terminal to jointly transfer information to relaying. Relay can receive signal from the source transmission, process this received signal and transmit signal of their own so as to increase the capacity and/or improve reliability of end-to-end transmission between the source and destination terminals [8].

Section II presents the system model. S**ection III** provides SER/BER analysis for cooperative UWB system. **Section IV** simulation environment with result are discussed. **Section V** concludes the paper.

II. SYSTEM MODEL

A. *Channel Model*

The SV model distinguishes between “cluster arrival rates” and “ray arrival rates”. The first cluster starts by definition at time t=0, and the following rays are arriving with a rate given by a Poisson process with rate λ. The power of those rays decays exponentially with increasing delay from the first ray. The “cluster arrival rate”, which is smaller than the ray arrival rate, in turn determines when the next cluster has its origin. The rays within that cluster are again a Poisson process with rate λ[1]. Mathematically, the impulse response is described as

$$h_i(t) = X_i \sum_{l=0}^{L} \sum_{k=0}^{K} \propto_{k,l}^{i} \ \delta(t - T_l^i - \tau_{k,l}^i)$$

where
- $\{\propto_{k,l}^{i}\}$ are the multipath gain coefficients,
- $\{T_l^i\}$ is the delay of the l^{th} cluster,
- $\{\tau_{k,l}^i\}$ is the delay of the k^{th} multipath component relative to the l^{th} cluster arrival time (T_l^i),
- $\{X_i\}$ represents the log-normal shadowing, and i refers to the i^{th} realization.

Defining
- T_l = the arrival time of the first path of the l-th cluster;
- $\tau_{k,l}$ = the delay of the k-the path within the l-th cluster relative to the first path arrival time, T_l;
- Λ= cluster arrival rate;
- λ=ray arrival rate, i.e., the arrival rate of path within each cluster.

By definition, $\tau_{0,l} = 0$. The distribution of cluster arrival time and the ray arrival time are given by

$$p\,(T_l|T_{l-1}) = \Lambda \exp[-\Lambda\,(T_l - T_{l-1})], \qquad l > 0$$

$$p\,(\tau_{k,l}|\tau_{(k-l),1}) = \lambda \exp[-\lambda\,(\tau_{k,l} - \tau_{(k-l),1})], \qquad k > 0$$

The channel coefficients are defined as a product of small-scale and large-scale fading coefficients, i.e.,

$$\alpha_{k,l} = p_{k,l}\,\xi_l\;\beta_{k,l},$$

The behaviour of the (averaged) power delay profile is

$$E[|\xi_l\,\beta_{k,l}|^2] = \Omega_0\, e^{-T_l/\Gamma}\, e^{-\tau_{k,l}/\gamma}$$

which reflects the exponential decay of each cluster, as well as the decay of the total cluster power with delay. In the above equations, ξ_l reflects the fading associated with the l^{th} cluster, and $\beta_{k,l}$ corresponds to the fading associated with the k^{th} ray of the l^{th} cluster.

Finally, since the log-normal shadowing of the total multipath energy is captured by the term, X_i, the total energy contained in the terms $\{\propto_{k,l}^{i}\}$ is normalized to unity for each realization. This shadowing term is characterized by the following:

$$20\log10(X_i) \propto \mathrm{Normal}(0, \sigma_x^2).$$

B. *Block Fading*

In a fast fading channel, the channel characteristic changes within one burst of data. The block fading channel model takes this into consideration. The burst is broken up into smaller chunks called blocks, and thus can be assumed to have more or less a constant channel characteristic for block duration. Similarly in order to allow perfect estimation of channel characteristics the block length has to be long enough. The magnitude and the phase of the fading coefficient of the block are assumed to be known by the receiver. The possibility of high burst error cannot be ruled out in a block fading channel. Error correcting codes may not be capable of correcting this burst errors. The signal can be interleaved to get the errors distributed uniformly over the whole signal to prevent such occurrences. It is assumed that block interleaving and the coding exist. The only thing that is of interest is the average bit error ratio (BER). In order to reduce the computing time the block length of one is assumed without loss of generality.

C. *Non Cooperative Model (Direct Transmission)*

In a non cooperative UWB system, the source transmits data directly to the destination. In order to establish base-line performance under direct transmission the source transmits over channel (1). The signal is modulated using binary phase shift keying (BPSK). The signal quality received at the destination depends on the SNR of the channel and the way the signal is modulated. Theoretical BER for a single link transmission is defined as

$$P_b = \frac{1}{2}\left(1 - \sqrt{\frac{\overline{\gamma_b}}{1+\overline{\gamma_b}}}\right)$$

$\overline{\gamma_b}$ denotes the average signal-to-noise ratio, defined as $\overline{\gamma_b} = \frac{\xi}{2\sigma^2}E(a^2)$, where $E(a^2) = a^2$

D. *Cooperative Model*

To benefit from diversity, an interesting approach might be to build an ad-hoc network using another wireless device/ terminal as a relay**.** The cooperative UWB model of such a system is illustrated in Fig. II.1. Consider a two-user cooperation over UWB MB-OFDM system. Each user can act as a source or a relay. The cooperation strategy comprises two phases. In Phase 1, the source(S) sends the data to its destination (D), and the data is also received by the relay (R) as it is listening to this transmission. In Phase 2, the source is silent, while the relay helps forward the source data to the destination after processing. At the destination the two received signals are combined. Orthogonal channels are used for the two transmissions. Without loss of generality, this can be achieved using time divided channels, which is done in all the simulations in this paper.

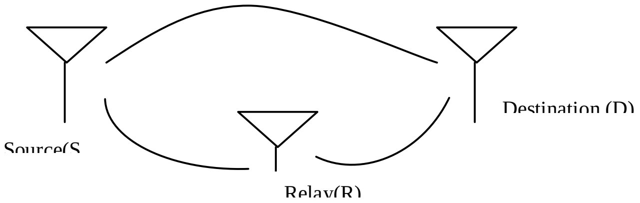

Fig. II.1: Direct data transmission and transmission through relay

III. SER/BER ANALYSIS FOR COOPERATIVE UWB SYSTEM

A. *Amplify and Forward (AAF) Protocol*

The general relaying allows sophisticated joint encoding in transmitting signal of the source and relay as well as intricate processing and decoding of the source signals at the relay and destination. Amplify and forward protocol is used when, the relay has only limited computing time/power available or the time delay, caused by the relay to de- and encode the message, has to be minimized. As expected the signal received at the relay is attenuated and hence required to be amplified before retransmission. This forms the basic idea behind AAF protocol. The disadvantage of this protocol is that the noise in the signal is amplified as well. Block wise amplification of the incoming signal is performed at the relay. Assuming that the channel characteristic can be estimated perfectly, the gain for the amplification can be calculated as follows. The power of the incoming signal is given by

$$\boldsymbol{E}[|\boldsymbol{y}_r^2|] = \boldsymbol{E}[|\boldsymbol{h}_{s,r}|^2]\boldsymbol{E}[|\boldsymbol{x}_s|^2] + \boldsymbol{E}[|\boldsymbol{z}_{s,r}|^2] = |\boldsymbol{h}_{s,r}|^2\boldsymbol{\xi} + \boldsymbol{2\sigma_{s,r}^2}$$

where s denotes the sender and r the relay. To send the data with the same power the sender did, the relay has to use a gain of

$$\beta = \sqrt{\frac{\xi}{|\boldsymbol{h}_{s,r}|^2\boldsymbol{\xi} + \boldsymbol{2\sigma_{s,r}^2}}}$$

This term has to be calculated for every block and therefore the channel characteristic of every single block needs to be estimated.

B. *Combining Type:*

i) *Equal Ratio Combining (ERC)*

If computing time is a crucial point, or the channel quality could not be estimated, all the received signals can just be added up. This is the easiest way to combine the signals, but the performance will not be that good in return.

$$y_d[n] = \sum_{i=1}^{k} y_{i,d}[n]$$

As only one relay station is used in simulation, the above equation is simplified to

$$y_d[n] = y_{s,d}[n] + y_{r,d}[n]$$

where $y_{s,d}$ and $y_{r,d}$ denote the received signal from the sender and the relay respectively.

ii) *Fixed Ratio Combining (FRC):*

A much better performance can be achieved, when fixed ratio combining is used. Instead of just adding up the incoming signals, they are weighted with a constant ratio, which will not change a lot during the whole communication. The ratio should represent the average channel quality and therefore should not take account of temporary influences on the channel due to fading or other effects. But influences on the channel, which change the average channel quality, such as the distance between the different stations, should be considered. The ratio will change only gently and therefore needs only a little amount computing time. The FRC can be expressed as

$$y_d[n] = \textstyle\sum_{i=1}^{k} w_{i,d} \cdot y_{i,d}[n],$$

where $w_{i,d}$ denotes weighting coefficient of the incoming signal $y_{i,d}$. Due to use of one relay station, the equation further simplifies to

$$y_d[n] = w_{s,d} \cdot y_{s,d}[n] + w_{s,r,d} \cdot y_{r,d}[n]$$

where $w_{s,d}$ and $w_{s,r,d}$ denotes the weight of the direct link and one of the multi-hop link respectively.

iii) Signal to Noise Ratio Combining (SNRC):

The quality of the link is determined by the SNR value. If this SNR is used to weight the received signal a much better performance can be achieved. The received signals can be expressed as

$$y_d[n] = \sum_{i=1}^{k} SNR_i \cdot y_{i,d}[n]$$

For one relay the equation can be simplified as

$$y_d[n] = SNR_{s,d} \cdot y_{s,d}[n] + SNR_{s,r,d} \cdot y_{r,d}[n]$$

Where $SNR_{s,d}$ and $SNR_{s,r,d}$ denotes the weight of the direct link and complete multi-hop link respectively. The estimation of the SNR of a multi-hop link using AAF or a direct link can be performed by sending a known symbol sequence in every block. The mechanism used for estimation of SNR using AAF is given below.

Using AAF, the received signal from the relay is

$$y_{r,d} = h_{r,d}x_r + z_{r,d} = h_{r,d}\beta(h_{s,r}x_s + z_{s,r}).$$

The received power will then be estimated as

$$E\left[\left|y_{r,d}\right|^2\right] = \beta^2\left|h_{r,d}\right|^2\left(\left|h_{s,r}\right|^2\xi + 2\sigma_{s,r}^2\right) + 2\sigma_{r,d}^2$$

Hence the SNR of one relay multi-hop link can be estimated as

$$SNR = \frac{\beta^2\left|h_{s,r}\right|^2\left|h_{r,d}\right|^2\xi}{\beta^2\left|h_{r,d}\right|^2 2\sigma_{s,r}^2 + 2\sigma_{r,d}^2}$$

iv) *Enhanced Signal to Noise Combining (ESNRC):*

Another credible combining method is to ignore an incoming signal when the other incoming channels have a much better quality. If the channels have more or less the same channel quality the incoming signals are treated equally. The same can be expressed as

$$y_d[n] = \begin{cases} y_{s,d}[n] & (SNR_{s,d}/SNR_{s,r,d} > 10) \\ y_{s,d}[n] + y_{s,r,d}[n] & (0.1 \le SNR_{s,d}/SNR_{s,r,d} \le 10) \\ y_{s,r,d}[n] & (SNR_{s,d}/SNR_{s,r,d} < 0.1) \end{cases}$$

Exact knowledge of channel characteristic is not required while using this combining method. An approximate channel quality is sufficient combine the signals. Equal ratio combining is further beneficial as it requires very less computing power.

IV SIMULATION ENVIRONMENT WITH RESULT

Following UWB channels parameters were consider for performance analysis.

Channel Type	Cluster arrival rate	Ray arrival rate	Cluster decay factor	Ray decay factor	SD of impulse response	SD for cluster fading	SD for Ray fading
CM1 (LOS)	0.0233	2.5	7.1	4.3	3.0	1.414	1.414
CM2 (NLOS)	0.4	0.5	5.5	6.7	3.0	1.414	1.414
CM3 (NLOS)	0.0667	2.1	14.0	7.9	3.0	1.414	1.414
CM4 (25 ns RMS delay spread bad multipath)	0.0667	2.1	24.0	12.0	3.0	1.414	1.414

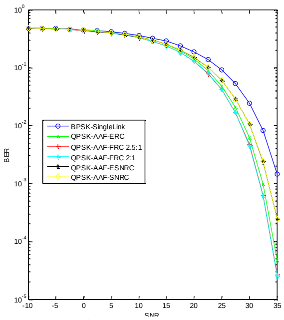

Fig.a.1: Different Combining types

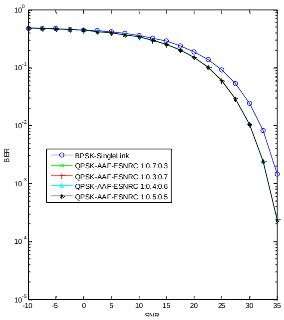

Fig. a.2: Benefits of Relay location

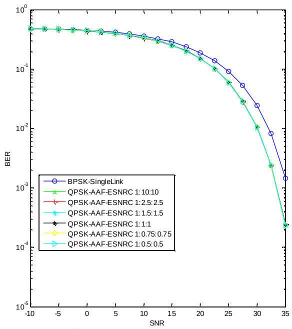

Fig. a.3: Effect of increasing distance

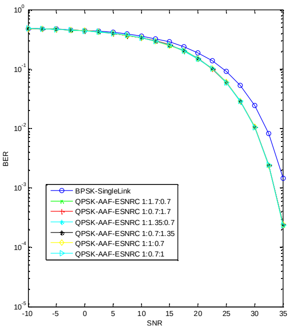

Fig. a.4: Relay close to Sender/Destination

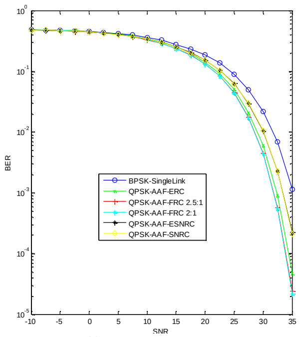

Fig. b.1: Different Combining types

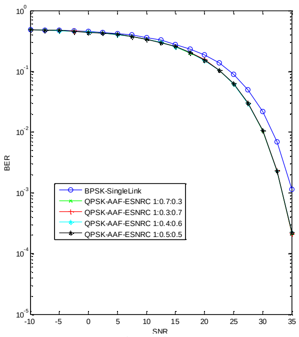

Fig. b.2: Benefits of Relay location

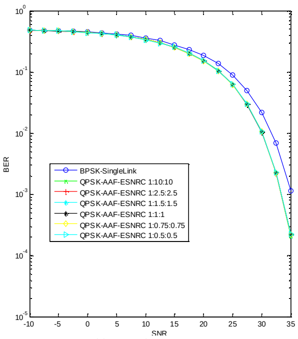

Fig. b.3: Effect of increasing distance

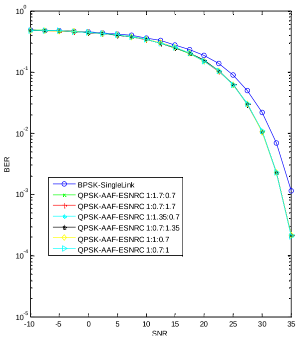

Fig. b.4: Relay close to Sender/Destination

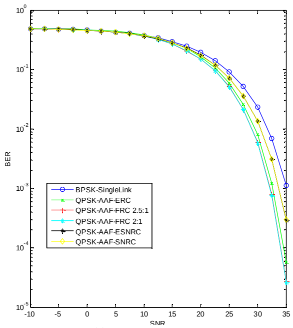

Fig. c.1: Different Combining types

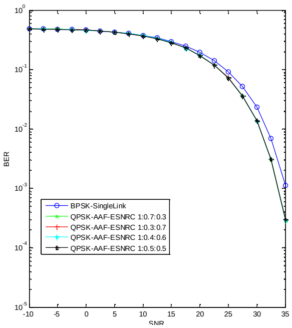

Fig.c.2: Benefits of Relay location

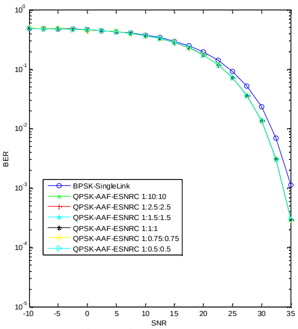

Fig.c.3: Effect of increasing distance

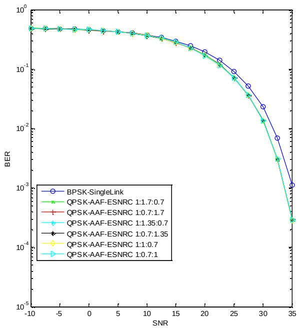

Fig.c.4: Relay close to Sender/Destination

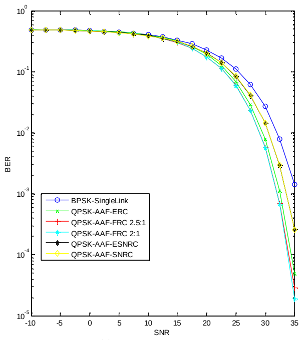

Fig.d.1: Different Combining types

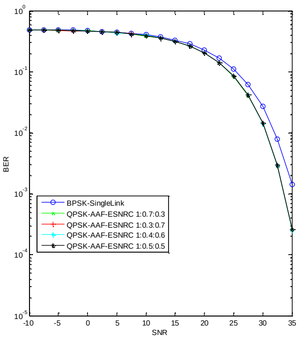

Fig. d.2: Benefits of Relay location

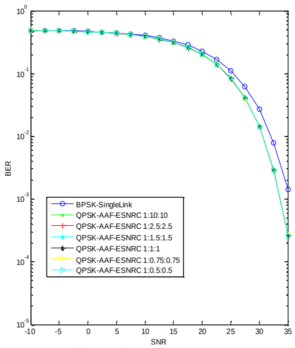

Fig.d.3: Effect of increasing distance

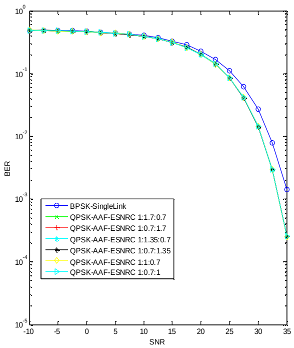

Fig. d.4: Relay close to Sender/Destination

The results are used to compare the benefits of different combining methods. FRC provides a much better performance as compared ERC as the direct link in general has a better quality over multi-hop link. The simulation results indicate best performance for FRC with ratio 2:1. As clearly seen the AAF diversity protocol provides better benefits as compared to direct link. The performance based on ERC combining shows advantages over direct link and is beneficial as is does not need any channel information except phase shift for combining. FRC to that extent may not be beneficial if some channel information is not available. The SNRC and ESNRC show similar performances. These combining methods have precise information about every single block but their performance is not significant as compared to FRC.

The effect of placement of relay between the sender and destination has been investigated. The position of relay does not reflect any difference in performance for UWB channel. However it derives huge benefit as compared to BPSK directly link. Positioning the relay at equidistance from sender and receiver is also investigated. This has been done to find the impact on performance. The results do not indicate any specific pattern due to the complex nature of indoor UWB channel. The arrangement where the relay is closer to either a sender or destination has been simulated. If relay is located roughly at same distance, the distance should not be much longer than direct link to get diversity benefits.

V CONCLUSION

This paper shows the possible advantage of using AAF cooperative diversity to enhance performance of wireless UWB communication system. The diversity is realized by developing an ad-hoc network using third terminal as relay. Two mechanisms of transmitting data i.e. direct link and through relay is demonstrated. The performance of different diversity combining method has been simulated. In AAF the equal ratio combining provides some benefits as compared to single link transmission. If knowledge of channel quality is known FRC can provide better diversity benefits as compared to ERC. Performance benefits to certain extent may be derived by placing relay near to source or destination.

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