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A Novel Fir Filter Based Approach for Performance Analysis of Rake Receiver

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Abstract: In wireless communication systems, the received signal is mainly obtained as the combination of various multipath signals. A Conventional CDMA Receiver ignores the multipath component and concentrates on the Direct Line Of Sight (LOS) component. The RAKE Receiver instead of completely eliminating multipath uses techniques to effectively utilize multipath to produce the desired signal. The objectives of the study are: 1) to implement the RAKE concept in a multi-user multipath Rayleigh fading environment; 2) to develop a trained-based filtering approach to achieve better Bit Error Ratio (BER), (3) to test data/image for RAKE filtering approach. RAKE Receiver has been simulated in MATLAB and its performance has been analyzed and compared with the Conventional CDMA Receiver. RAKE Receiver model using a novel Trained Based method is far superior to the Conventional CDMA Receiver (which uses LMS-Least Mean Square-algorithm for channel equalization) in terms of execution time and Bit Error Ratio (BER).

Key words: Code Division Multiple Access (CDMA), wireless communication system, RAKE receiver, trained-based filtering technique

INTRODUCTION

With the advancement in technology, the ability to communicate with people on the move has evolved remarkably. However, the transmission quality of the signal has deteriorated due to the modernization of urban cities with skyscrapers and other man-made obstacles. In a typical radio environment, transmitted signals arrive at the receiver through a direct unobstructed path, or multiple paths from reflection, diffraction and scattering due to surrounding objects. This multipath propagation causes the signal at the receiver to be distorted and to fade significantly.

Code Division Multiple Access (CDMA) is a spread spectrum technology which along with the RAKE receiver concept aids to minimize communication errors resulting from multipath effects. The spread spectrum technology aims to spread the information signal over a wider bandwidth to make jamming and interception more difficult. A RAKE receiver allows each arriving multipath signal to be individually demodulated and then combined to produce a stronger and more accurate signal (Pin Gan, 2002).

SYSTEM DESCRIPTION ALONG WITH TRAINED-BASED FILTERING TECHNIQUE

The entire CDMA Transmission and reception system with RAKE Receiver and a Trained-Based filtering module is shown in Fig. 1.

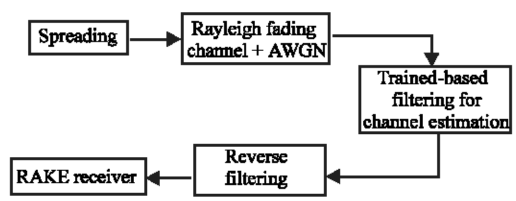

Fig. 1: Block diagram of trained based approach

The communication system as in Fig. 1 basically comprises of a CDMA Transmitter, Rayleigh fading channel with AWGN and a Receiver module. The receiver module comprises of a trained-based filtering section, reverse filtering section and a RAKE Receiver. This system has been analyzed in a multi-user multipath environment.

In CDMA Systems, a large number of users transmit simultaneously. They are differentiated by their unique spreading sequence. Each user sends different forms of information like audio, video, image, data etc (Huang, 2002). Walsh-Hadamard code have been used for spreading since it is an orthogonal code.

In DS-Spread Spectrum, each user is assigned a unique Walsh code. The data of each user which is to be transmitted is multiplied with its corresponding spreading code. The data which is modulated by the spreading code occupies more bandwidth than the data signal. The spread signal is then Binary Phase Shift Keyed and transmitted through the channel (Duel-Hallen *et al*., 1995).

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The channel is modeled as a Finite Impulse Response (FIR) Filter. Here the FIR (Finite Impulse Response) filter is modeled as Rayleigh Fading Channel. A multipath environment can be best characterized by a fading channel like Rayleigh fading channel. Additive White Gaussian Noise (AWGN) is present as background noise in the channel. The spread data of all the users is summed up in the channel. Since the RAKE Receiver has no prior knowledge of the channel parameters, there is a need to estimate the parameters (Sato and Ohtsuki, 2005). A novel trained-based filtering technique has been implemented to estimate the channel. Reverse Filtering is a technique used to counter the effects of the channel modeled as FIR Filter. It performs the reverse operation of a causal FIR Filter. With the knowledge of the channel impulse response h(n) and the user data that is obtained at the output of the channel, the data originally transmitted by the users can be found out. This is given as input to the RAKE Receiver. The idea behind the RAKE reception is that the signals propagating through different multipaths are received in the individual fingers of the RAKE receiver and the output from these fingers are coherently combined to provide the user data transmitted originally (Leus and Mudulodu, 2004).

CHANNEL MODEL

A communication channel refers to the medium used to convey information from a sender to a receiver. A channel can be modeled by calculating the processes which modify the transmitted signal. Such a channel can be considered as a filter that operates on the input signal. In our work, the channel has been modeled as a Finite Impulse Response (FIR) filter because of its numerous advantages.

Casual FIR filter can be realized as

$$y(n) = \sum_{k=0}^{M-1} h(k)x(n-k) \qquad (1)$$

In wireless communications, the channel is often modeled by a random attenuation (known as fading) of the transmitted signal, followed by additive noise. The fading channel considered in this work is Rayleigh fading channel. Rayleigh is a distributive function that is used to model the envelope of fading signals (Hong Lee and Jao Hyun Yi, 2000).

PROPOSED TECHNIQUES

Trained-based filtering technique for channel estimation: The Trained-based Filtering is the first module in the receiver. In this method, there is a predetermined training sequence which the receiver has knowledge about the sequence. The training sequence is a sum of the spreading sequences of all the users transmitting through the channel at that instant of time. This training sequence is passed through the channel whose parameters are to be estimated. The channel which is an FIR Filter acts upon this sequence. The training sequence also undergoes the fading effects of the channel and is acted upon by background AWGN. The signal thus received is given to the trained-based filtering module.

In the Trained-based filtering module, the training sequence which is the sum of all the spreading sequences of all users is generated dynamically. With the knowledge of the signal which has undergone the effects of the channel and the training sequence, the channel impulse response is calculated using the Eq. 1.

$$h(n) = \frac{1}{x(0)}\left(y(n) - \sum_{k=1}^{n} h(n-k)x(k)\right), n \le M \qquad (2)$$

where x (n) is the training signal,
y (n) is the signal at the output of the channel,
h (n) is the channel impulse response of the unknown channel.

Reverse filtering technique: Reverse Filtering is a technique used to counter the effects of the channel modeled as FIR Filter. It performs the reverse operation of a causal FIR Filter. With the knowledge of the channel impulse response h(n) and the user data that is obtained at the output of the channel, the data originally transmitted by the users can be found out. This method of reproducing the actual user data results in an enormous improvement in the BER at the RAKE Receiver (Haykin, 1999). The Reverse Filtering can be implemented using the Eq. 3.

$$x(n) = \frac{1}{h(0)}\left(y(n) - \sum_{k=1}^{M-1} x(n-k)h(k)\right) \qquad (3)$$

where x (n) is the User data,
y (n) is the signal at the output of the channel,
h (n) is the channel impulse response of the channel.
M is the order of the Filter.

The trained-based filtering module used for channel estimation and the reverse filtering module are incorporated in a CDMA system with a RAKE receiver.

PSEUDO CODE

```
/*Transmitter module*/
SET SNR
SET Spread_factor
READ total_users
GENERATE user_data of length data_length

/* Generating walsh spreading code*/
h = 1;
for i = 1 to log2 (spread_factor)
      h = [h h; h -h];
End
Spread_code = h;

/* Spreading user data*/
SET transmit_data to zero;
for user_number is 1 to total_user
      spread_data = user_data * spread_code;
      transmit_data = spread_data + transmit_data;
end

/* Multipath data generation*/
1st path = [0,transmit (1:length(transmit)-1)];
2n dpath = [0,0,transmit (1:length(transmit)-2)];

/*Adding all the multipath signals*/
transmit_data = transmit_data+1st path+2nd path;

/*Channel*/
/* Modeling the channel as a Rayleigh fading channel*/
ts = 1/1000; /* Sampling time*/
tau = [0 ts 2*ts]; /*Delay for each multipath*/
pb = [1 .99 .89]; /* Path gain of each multipath*/
channel = rayleighchan(ts,0,tau,pb); /* Defining channel*/

/* Adding AWGN */
transmit_data_with_noise = awgn(transmit_data, snr);

/*Passing the spread data through channel modeled as FIR Filter*/
data_through_channel = filter (channel,transmit_data_ with_ noise);

/* Receiver module*/

/*Trained-based filtering*/

/*Training for trained-based filtering*/
training_sequence = spreading code of each user;

/* Passing training sequence through the channel*/
atrainin = awgn(trainin,snr);
trainout = filter (channel, atrainin);

/*function "chann" for trained-based filtering calculates Channel Impluse Response 'channel_est'*/
channel_est = chann (trainin, trainout, channel_length);

/*END of trained-based filtering*/

/*Reverse filtering*/
/*Function "revchannel" performs reverse filtering on the incoming data*/
data_filtered = revchannel(data_through_channel, channel_est);

/*END of reverse filtering*/

/*Rake receiver section*/

START
/*Defining number of fingers*/
finger_total = No_of_multipaths;
for user_number is 1 to total_users
      /*receiving data from channel in each finger*/
            for finger_number is 1 to finger_total
                  finger_data = data_filtered;
            end

/*Multiplication with weightage factor of each finger*/
      weighted_data_from_finger 1 = finger 1_data * channel_impulse_response (1);
      weighted_data_from_finger 2 = finger 2_data * channel_impulse_response (2);
      weighted_data_from_finger 3 = finger 3_data * channel_impulse_response (3);

/* De-spreading operation performed on each set of data of length of spreading code*/
      data_from_finger 1 = weighted_data_from_finger 1 * spread_code (user_number);
      data_from_finger 2 = weighted_data_from_finger 2 * rotate(spread_code (user_number), 1);
      data_from_finger 3 = weighted_data_from_finger 1 * rotate (spread_code (user_number), 2);

/*performing integration over one bit interval*/
      output_data = data_from_finger 1 +
      data_from_finger 2 + data_from_finger 3;
      decoded_bit = signum (output_data);

REPEAT this process until all bits are decoded

/* End of RAKE Receiver */

/* Calculation of Bit Error Ratio (BER) */
      BER = No_of_bits_in_error /
      total_bits_transmitted;

/* END of program */
```

Functions used in the program

Signum (data)-It is a signum function which decodes values greater than or equal to 0 as 1 and rest as -1.

Rotate (data, number)-Rotates circularly the values in vector 'data' by 'number' times.

Chann (trainin, trainout, length_channel) – Function written to implement the following equation to calculate the channel impulse response.

$$h(n) = \frac{1}{x(0)}\left(y(n) - \sum_{k=1}^{n} h(n-k)x(k)\right) \text{Where } n \le M$$

Revchannel (data, channel)-Function written to implement the following equation to apply reverse filtering on the vector 'data'.

Rayleighchan (ts, dp, tau, pb)-MATLAB Function which simulates a Rayleigh fading channel.

Filter (c, data)-MATLAB Function that filters the values in vector 'data' with filter co-efficients 'c' defined by the 'Rayleighchan' function.

SIMULATION PARAMETERS

At the transmitter, input has been considered in the following formats: data which is a stream of 1s and -1s and image in bitmap or jpeg format and is spread using Walsh-Hadamard codes of spreading length 128.This spread data is transmitted through a multipath fading channel. A Rayleigh fading channel has been chosen for simulation purposes. The FIR (Finite Impulse Response) filter representing the channel is modeled as Rayleigh Fading Channel .The data is then passed through this Rayleigh Fading Channel and Additive White Gaussian Noise (AWGN) is also present as background noise. The amount of AWGN present in the channel is determined by the SNR value in dB. An estimate of the channel is evaluated using the novel Trained-Based filtering method. The PN Sequence of the users is passed through the channel as a training sequence for this filtering module. Applying the inverse filtering operation of the FIR filter and the estimated impulse response on the received data, the original spread data is obtained. Using RAKE Receiver which is assumed to have three fingers, de-spreading is done and the original data is retrieved.

SIMULATION RESULTS

The Fig. 2 gives a semilog graph which plots the BER values for various values of SNR (in dB).The parameters used: No. of users = 10, No. of bits/user = 30 and spreading gain = 128.

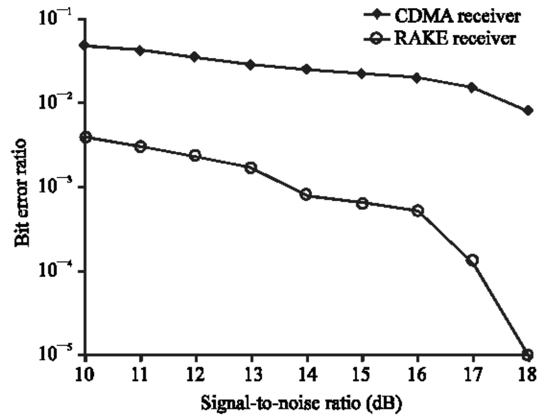

Fig. 2: Performance analysis of Rake/CDMA

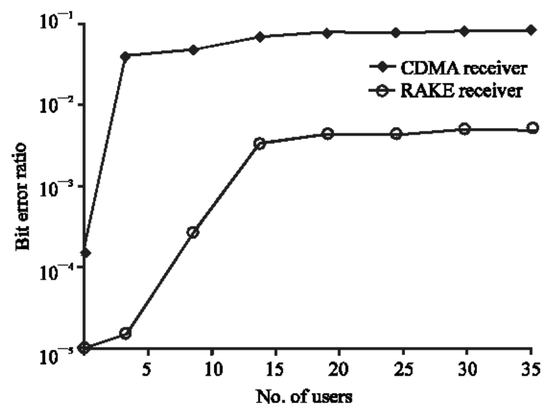

Fig. 3: Performance analysis w.r.t to users

From Fig. 2, it is clear that the BER value for the proposed RAKE Receiver with filtering technique tends to values of the order 10^{-5}. SNR is increased in steps of one and the values of BER were plotted. There is a marked difference of 10^{-3} in the BER values obtained from the RAKE Model and conventional CDMA Model. The Fig. 3 gives a semilog graph which plots the various BER values for different users. The parameters used: SNR = 17dB, No. of bits/user = 30 and spreading gain = 128.

From Fig. 3, it is evident that as the number of users increase, the increase in the BER values is less pronounced for the proposed model. Since the BER values are in the order of 10^{-5} there is an obvious capacity increase. Hence the proposed RAKE model with filtering technique with its low BER values is extremely suitable for practical use.

DISCUSSION AND CONCLUSION

The conventional CDMA Receiver and RAKE Receiver have been reviewed in the presence of Rayleigh fading and Additive White Gaussian Noise. A novel trained-based filtering technique which utilizes the concept of FIR has been introduced. An analysis of the receivers' performance has been made under the effects of Rayleigh fading channel in the presence of AWGN. The analysis was done by observing the trend in values of BER for various SNR values and different number of users. When SNR values were increased from 10 dB to 18 dB, for the RAKE Receiver model, BER values decreased to reach a minimum of 10^{-5}. This contrasts sharply to the BER values of the conventional CDMA model which is in the order of 10^{-2}. To demonstrate the improvement in the performance of a CDMA system with RAKE Receiver and trained-based filtering technique, bitmap image files were considered as input and complete retrieval of the images at the receiver was observed.

Simulations performed under the conditions specified by channel structure indicated that the trained-based filtering technique offers a significant performance improvement and capacity increase by achieving BER in the range of 10^{-4} and 10^{-5} which is highly appreciable under standard benchmark indicated in a host of literature studies. These simulations were carried out in multipath propagation conditions with a high level of Multiple Access Interference (MAI). This work can be extended to analyze the effects of various fading channels like Rician channel, Nakagami channel etc. The 1-D RAKE implementation can be extended to a 2-D space-time RAKE for better performance. Optimization techniques using neural networks can be incorporated to improve the Bit Error Ratio (BER).

REFERENCES

Duel-Hallen, A., J. Holtzman and Z. Zvonar, 1995. Multi user detection for CDMA systems. IEEE Personal Communications, April, 1995.

Haykin, S., 1999. Adaptive Fiter Theory. Prentice Hall of India, 3rd Edn.

Hong Lee, J. and J. Hyun Yi, 2000. RAKE receiver with adaptive interference cancellers for a DS-CDMA system in multipath fading channels. Proc. of the IEEE VTC2000 Fall, Boston, MA, USA., pp: 1216-1220.

Huang, X., 2002. Image coding for transmission over wireless CDMA channels. Ottawa-Carleton Institute of Electrical and Computer Engineering, School of Information Technology and Engineering, University of Ottawa, pp: 69-74.

Leus, G. and S. Mudulodu, 2004. An interference suppressing RAKE receiver for the CDMA downlink. IEEE Signal Processing Letters, Vol. 11.

Pin Gan, S., 2002. CDMA detection guided RAKE receiver. School of Information Technology and Electrical Engineering, The University of Queensland, pp: 1-28.

Sato, H. and T. Ohtsuki, 2005. Computational complexity and performance of RAKE receivers with channel estimation for DS-UWB. IEICE TRANS. Fundamentals, E88: 1202-1208.