Improvement in Error Reduction of Spatial Channel Model (SCM) by Exploiting Multi-user Diversity with the help of Omni-directional Antenna at BS

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ABSTRACT
This paper exploits the concept of diversity using Omni-directional antenna at BS, where different users are communicating with BS at the same time from different angles but having same frequency in flat fading and frequency selective environments. The opportunistic communication method has been implemented using Spatial channel model (SCM) developed by 3rd generation partnership project (3GPP). The main focus is on improving the performance of system by reducing bit error rate once multiple users are operating in frequency selective environments. The same objective has been achieved and is shown with the help of simulations that SCM provides an improvement by reduction in bit error rate (BER) thereby improving the performance of SCM system by using opportunistic communication method that exploits the spatial and time diversity that is offered by SCM. It has been shown with the help of simulations that while operating in frequency selective fading environment there is an improvement of 2-3 dB as compared to flat fading environment with more number of users that those operating in case of flat fading environment.

Keywords
Spatial channel model (SCM); Signal to Noise ratio (SNR); Additive white Gaussian noise (AWGN); Base station (BS); Mobile station (MS); Uniform Linear Array (ULA); Bit Error Rate (BER)

1. INTRODUCTION
A new form of diversity so called a spatial diversity has been proposed in [8][9] that provides the spatial diversity benefits to all those mobile users which do not have the capability of equipping with multiple antennas because of their size or may be because of some other constraints. In case of cooperation diversity scheme, one mobile station makes a partnership with other mobile station in order to transmit or receive the signals from/to a base station. This partner station serves as a relay that forwards the signal from source transmitter to the destination receiver and simulation results for mobile to mobile user implemented in Rayleigh channel are shown in [10] that use the technique of modified Method of exact Doppler spread. The main factors that distinguish the Amplify and Forward Relay channel from the Base station to Mobile station channel are: 1) the non Gaussian channel nature of the overall BS-relay-MS channel and 2) noise propagation from the relay to the receiver [11]. Consequently, the BS-relay-MS channel is quite different from the Bs-MS channel. Most of the authors have analyzed the performance of Amplify and Forward systems in terms of bit error rate (BER) and outage probability, under different assumptions for the amplifier gain [12]. However, they are assuming the perfect channel knowledge at the receiving end and in some cases at the relay also. Here in paper the opportunistic communication system is implemented that uses a novel network protocol, that only transmits to a user when the channel conditions to that particular user are good, whereas in case of traditional communications systems the resources are allocated according to the demands of user without considering the quality of a channel as a result channel capacity is lost when the channels get faded. Different cooperation protocols like amplify-and-forward, decode-and-forward [1][2] have been introduced for wireless networks.

In most of the existing cooperative communication in wireless systems the communication is based on the multi-hop systems, where the information from source is carried to the destination through other mobiles that acts as relay. This relaying operation overcomes the problem of path-loss that occurs because of large distances. This relay channel was introduced by Van der Meulen [3] and then investigated by Cover and El Gammal [4]. The research work carried out the analysis of three nodes such as source, relay and destination. Since in case of mobile channel the fading is considered to be a source of unreliability that needs to be mitigated at all cost and communication is considered to be a source of mitigating the fading in wireless networks by achieving spatial diversity. Relays are used to help the source by transferring the information to the destination but source needs to decide when to cooperate by taking the ratio between source-destination channel and source-relay channel conditions [5]. Here *in this paper concept of multiuser diversity is exploited by opportunistic communication*, where multiple users are communicating with common BS in the time varying fading channels while remaining in the same cell. It is assumed that channel state information is tracked at the receivers and fed back to the transmitters and then scheduling is based on the basis that a user with good channel conditions is only allowed to transmit to the BS. Here the diversity gain is achieved in a sense, that since many users are communicating with common BS via an independent varying channel so there are all the chances that a user may get a channel at an instant of time when the channel is at its peak. Traditionally the fading in a channel is considered to be a source of unreliability which must be mitigated. When multiple users are communicating simultaneously then transmission is scheduled by allocating a channel to users only when their channels are at peaks [6]. Therefore an opportunistic communication may be used to exploit the channel fluctuation where transmission only takes place when the channel is at its peak. *So here the performance of the system is then related to a channel condition when it is at peak rather than average conditions of the channel.*

From Figure 1.1 it is seen that opportunistic communication system allocates bandwidth dynamically based on conditions of the channel to individual users and all users with good channel conditions are dynamically allocated lots of bandwidth while users in deep fades are allocated little bandwidth. Since the fading is random so all users get their fair share of the bandwidth, hence the opportunistic communication systems can provide more capacity in fading channels as compared to traditional approach. In this case, a number of algorithms in various fading environments using Matlab Rayleigh and spatial channel models using Omni directional antenna at the BS have been developed that allow the users to communicate with common BS, depending upon the condition of the channel allocated to that particular user.

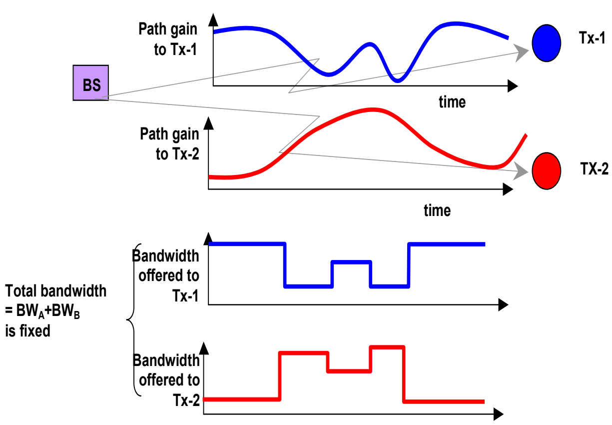

Figure 1.1: Allocation of Bandwidth

2. CHANNEL ALLOCATION BASED ON QUALITY

Here in this case a communication system considered dictates the environmental conditions where multiple users equipped with single antenna are communicating with common BS that is equipped with ULA of antenna elements. The opportunistic communication system provides the idea of multiuser diversity in the sense that in this system different users are operating over an independently fading channel, there is a chance that one of the users is likely to have very good channel condition at the instant of time. Whenever a particular user with good channel condition has been allocated a channel for the duration it remains at its peak, then that user has a chance of transmitting the maximum data to the BS. The resultant SNR of that particular user at the instant of time when the data is transferred can be written as:

$$SNR(t) = \max|h_k(t)|^2 \qquad (1.1)$$

Where, $k = 1 \cdots\cdots K$ i.e. the total number of users in a system

The resultant output of the system can be expressed as

$$y(t) = \sum_{k=1}^{K} h_k(t) x_k(t) + \mathbf{w}(t) \qquad (1.2)$$

Where, $h_k, x_k, \mathbf{w}$ are the channel gain, data transmitted and the additive white Gaussian noise respectively?

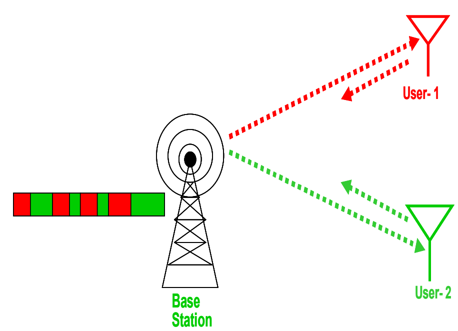

Figure 1.2: Channel allocation based on quality

Here in Figure 1.2 it is seen that both the users are placing a request to the BS for fair scheduling of resources depending on the Bandwidth and allocation of channel. So in this case the channel quality of the user k at the instant of time based on the requested data rate is represented as $R_k(t)$. This is the data rate that a user can support at the instant of time. The scheduling algorithm works on the principle that it keeps track of the average throughput denoted as $T_k(t)$ of every user in the previous interval of time t. In time slot t, the scheduling algorithm transmits with highest ratio of request to the throughput represented as:

$\frac{R_k(t)}{T_k(t)}$, where R_k is the request of the user placed to the BS while T_k is the throughput transferred to BS.

This scheduling of the users is done on the basis that whichever user has good channel conditions is allowed to transmit to the BS. The total throughput increases with the number of users in both the fixed and mobile environments. As the channel fades in both cases, the rate of variation is more in case of mobile channel as compared to fixed channel as a result the peaks are going to be higher in case of mobile channel environment, which determines the scheduling of the users. It can be stated that multiuser diversity is variable in case of mobile channel as compared to fixed channel where it is limited. The amount of multiuser diversity depends on the dynamic change in the fluctuation of channel characteristics.

Consider a system having *N* transmit antennas at the BS and let $h_{n,k}(t)$ is the gain from antenna *n* to the user *k* at the instant of time *t*. The block of symbols *x(t)* is transmitted in time slot *t* and the signal received by the k^{th} user during the time slot *t* is given by:-

$$y_k(t) = \sum_{n=1}^{N} \sqrt{\alpha_n(t)} e^{j\theta_n(t)} h_{n,k}(t) * x(t) \quad (1.3)$$

Where $n = 1 \cdots\cdots N$ is the number of transmit antennas, and overall channel gain seen by the receiver *k* is given by

$$h_k(t) = \sum_{n=1}^{N} \sqrt{\alpha_n(t)} e^{j\theta_n(t)} h_{n,k}(t) \quad (1.4)$$

Where, $\alpha_n(t)$ is the power allocated to each of the transmit antenna and $\theta_n(t)$ is the phase shift applied to the signal at each antenna. The fluctuation in the channel is achieved by varying these quantities ($\alpha_n(t)$ from 0 to 1 and $\theta_n(t)$ from 0 to 2π) over a time period *t*.

In case of single transmit antenna system, every receiver *k* feeds back the overall SNR i.e. $|h_k(t)|^2$ of its own channel to the BS and accordingly BS schedules the transmission to all users depending upon the quality of channel of a particular user. There could always be a possibility that the channels are symmetric having same quality with equal SNRs or asymmetric with different properties. The analysis for both types is carried out with the help of simulations to see the effect on BER performance.

3. SIMULATION OF SCM

Here spatial channel model (SCM) is used in uplink case where a signal being transmitted from MS is received by the BS that forms a broad spectrum beam in the direction of user thereby indicating the angle of arrival of that signal coming from particular MS. During each simulation run the fast fading of the channel is dictated by the mobility of MS. The information regarding state of the channel is given to BS from MS and then BS uses the schedulers to determine the direction of user where to transmit.

4. SCENARIO-I (FLAT FADING ENVIRONMENT)

This scenario dictates that two Mobile users MS-1(user 1) and MS-2(user 2) moving at a speed of 1.25m/s corresponding to a Doppler of 10Hz and carrier frequency of 2.4GHz are communicating with a common BS and each mobile user is operating at an independent path with BS. Two dice are rolled that determine which channel should transmit. When the channel is allocated to one transmitter, only that user is allowed to send across the data in frames depending upon the condition as and when the channel is allocated to that particular user and then AWGN is added to it. Here phase estimation is done at receiving end to compensate the phase distortion in the channel. The design parameters for simulation are given as:-

Parameters	***Value***	***Parameters***	***Value***
Number of frames sent	20,000	sampling time (t_s)	3.75E-3 sec
Number of bits/frame	10	Modulation order (*M*)	2
Total bits sent	200,000	Number of Paths	1
Modulation scheme	PSK	Number of Users	2
Doppler frequency (f_d (Hz))	10	Carrier frequency (f_c)	2.4GHz

Table 1-1: SCM flat fading Parameters (2-Users)

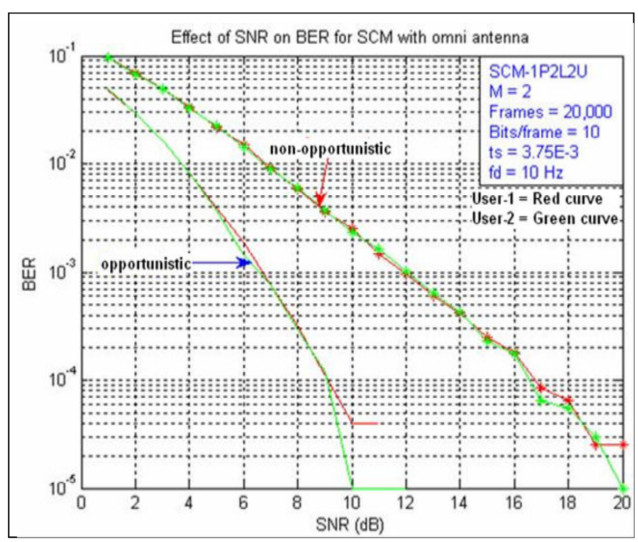

Figure 1.3: BER of 2xUsers with opportunistic communication using SCM

Parameters	***Value***	***Parameters***	***Value***
Number of frames sent	20,000	Number of Paths	2
Number of bits/frame	10	Number of Users	3
Total bits sent	200,000	Modulation scheme	PSK
Sampling time (t_s)	3.75E-3	Modulation order (*M*)	2
Doppler frequency (f_d Hz)	10	Carrier frequency (f_c)	2.4GHz

Table 1-2: SCM frequency selective fading parameters (2-Users)

4.1 Result Analysis

a. Characteristics of the channel coefficients are assumed to be constant while transmission of every frame.

b. In Figure 1.3 the curves of opportunistic communication system are compared with curves of non-opportunistic communication system.

c. The BER performance of an opportunistic communication system (Cooperation) is measured depending upon the condition of channel as to when the channel is given to Tx-1 or to Tx-2. The simulation results shown above dictate that if a data of about 0.2 million bits is sent across SCM, and then at SNR of 9 dB the BER of 10^{-4} in case of opportunistic communication system is achieved as compared to non-opportunistic system where same BER of 10^{-4} at SNR of about 17dB is achieved. So there is an improvement of 8dB with opportunistic system having same BER rate.

d. The BER performance of opportunistic communication system is improved depending upon the condition of channel as to when the channel is given to Tx-1 or to Tx-2. This is far better than that of non-opportunistic case and same is obvious from simulation results shown in Figure 1.3 above.

5. SCENARIO-II (MULTI-PATH FREQUENCY SELECTIVE ENVIRONMENT)

Here in this scenario three Mobile users MS-1(user 1), MS-2(user 2) and MS-3(user 3) moving at a speed of 1.25m/s corresponding to a Doppler of 10Hz and carrier frequency of 2.4GHz are communicating with a common BS, each mobile user is operating at independent link with symbol spaced delayed two paths/link with BS. Three dice are rolled that determine as to which channel should transmit. When the channel is allocated to a transmitter that user is allowed to send across the data in frames depending upon the condition as to when the channel is allocated to that particular user and AWGN is added to it. Once the data is sent across channel it gets attenuated or distorted, therefore an equalizer has been used at receiving end to compensate the phase distortion that occurs in the channel.

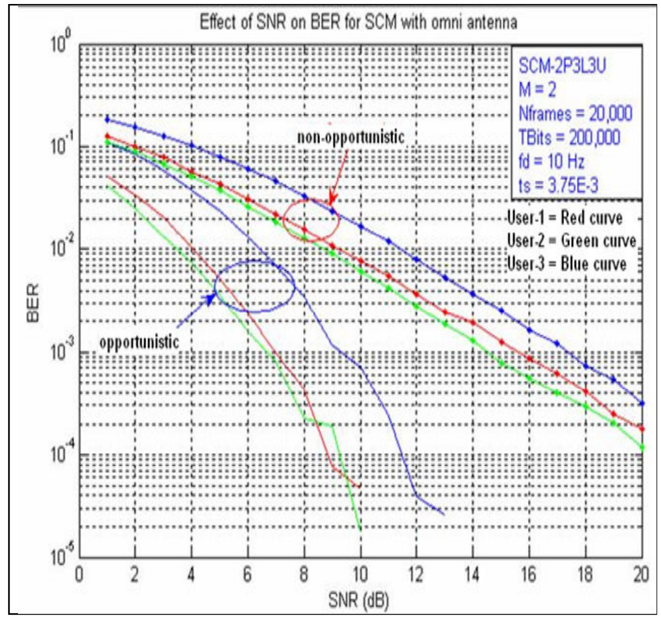

Figure 1.4: BER of 3xUsers using SCM

5.1 Result Analysis

a. From Figure 1.4 above it is observed that BER characteristics curves of all three users are better in opportunistic case than that of non- opportunistic environment as all users get the fair share of channel bandwidth allocation.

b. Amongst three users the BER performance of user-2 in green curve is better than user-1 and user-3 below SNR of 8dB, but after that BER performance of user-1 in red curve is better because of good channel conditions being offered to that user at that particular instant of time. The user-3 in blue curve does not get the good channel conditions, so its performance in terms of BER is poor as compared to other two users.

c. From the simulation results it is seen that with opportunistic communication technique employed the user-2 has BER of 10-3 at SNR of 7dB as compared to non opportunistic case where same user has same BER of 10-3 but at SNR of 15dB. So there is an improvement of 8dB when using an opportunistic communication system.

6. CONCLUSION

The performance of spatial channel models is compared by analyzing the BER of two systems using Opportunistic communication and non-Opportunistic communication techniques under flat fading and frequency selective fading environments using Omni-directional antenna at BS. It has been observed from simulation results analyzed above that SCM outperforms by exploiting the channel diversity in spatial and time domain using Opportunistic communication technique, where BER of 10^{-2} is achieved at SNR of 3 dB with Three users in case of frequency selective fading environments of SCM as compared to flat fading environments with two users having same BER but at SNR of 4dB. So there is an improvement of about 1dB once operating in frequency selective environment with more users as compared to flat fading environment with less number of users. This has been achieved due to spatial and time diversity offered by SCM that is being exploited by opportunistic communication technique.

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