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DIVERSITY ANALYSIS IN WIFI SYSTEM

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ABSTRACT

Wi-Fi, a Wireless Local Area Network technology has solely conquered the arena of short range wireless broadband systems. To support the existing system and to further enhance the measure of performance in multipath fading environment, Wi-Fi technology is intertwined with space diversity technique which is implemented using Alamouti coding and is then introduced with interleaving/scrambling technique to take the benefit of time diversity. Diversity technique has been an essential factor in improving the quality of the wireless system's operation by providing performance almost equivalent to that of the least distorted path among various multi paths at any given time and thereby accounting for the fading effect caused in corruptive communication channels. This paper discusses the performance of space diversity techniques in Wi-Fi by comparing their Bit Error Rate (BER). Various channel models are taken into account to simulate the real time scenario of a noisy unreliable wireless environment.

Keywords – *WiFi, WLAN, MIMO, MISO, Diversity, STBC*

1. INTRODUCTION AND RELATED WORK

Wireless LANs based on the IEEE 802.11 standards have been a resounding success. Wi-Fi, short for Wireless Fidelity is a wireless digital communication system, operating in 2.4GHz ISM band with channel bandwidth of 25MHz is intended for LANs with coverage of few hundred feet. Multipath propagation, an inherent nature of wireless channels causes the signal to distort and fade significantly. The received signals have random phase and amplitude which when combined, causes fluctuations in the signal strength inducing fading and signal distortion. The multipath fading can be effectively combated by g diversity technique. Diversity is a powerful communication technique that provides wireless link improvement by transmitting multiple versions of the same signal over multipath channels that experience independent fading [1]. Alternatively a combiner is used to sum all the signals coherently resulting in the production of a better estimate of the original signal. The IEEE 802.11 standard supports a variety of options for multiple antenna techniques including diversity, Smart Antenna Systems (SAS) and Multiple Input Multiple Output (MIMO) systems.

Several prior studies have reported diversity schemes for potential MIMO applications in various wireless s technologies. Paper [2] discussed the facilities of diversity techniques in CDMA based mobile networks. Several papers [3,4] proposed solutions to overcome the issues in multipath propagation using diversity techniques deployed only at the transmitter or at the receiver of OFDM, CDMA and WiMAX Systems. This paper demonstrates the idea of introducing transmit and receive diversity in the physical layer of IEEE 802.11 WiFi network. The application of 802.11n standard as a low interference sensitivity wireless interface, to improve the performance of the 802.11a based wireless networks is investigated in [5]. The improvement in data rate in wireless networks is demonstrated in[6]. The survey paper[7] compares the wireless protocols of 802.11 Blue Tooth and WiFi nodes and reported the data rate and respective source and channel coding scheme . Bluetooth EDR Modeling is done in [8] and physical layer is implemented with

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prescribed IEEE standard and did not address the MIMO concepts.

Some of the relevant issues of the LTE/4G wireless technologies [9] with respect to the physical layer considerations are,

*Adaptive and reconfigurable coding and modulation, reconfigurable space time coding
*antenna array signal processing
*reconfigurable SDR and Cognitive Radio technology
*Channel Modeling
*Advanced Multiple Accessing Techniques

These schemes emphasize on MIMO technique and can be categorized to facilitate their implementation in base band and/or in RF section of transceivers. The diversity schemes in the base band signal level at the physical layer may be implemented with several versions. In the IEEE standards and amendments of WLAN not all the diversity schemes are been proposed. We propose to include diversity with respect to time, code and space with bit interleaving, DSSS and space time block codes. Hence the data to be transmitted in the wireless network is scattered in various dimensions and the impact of long term and short term fading due to the multipath channels are compensated. The receiver is able to reconstruct the intelligence of the information from the received corrupted replica of transmitted signal. By introducing diversity at the receiving end with combining techniques and implementing Maximum Likelihood function, the wireless node is able to get the best estimate from various versions of arrived signal. Despite the numerous benefits of wireless network such as support for mobility, dynamic topology, device portability, etc., the wireless technology is highly vulnerable to data security threats and multipath interference. Security issues are handled in the upper layers and multipath propagation which is one of the basic characteristics of wireless communication is to be addressed in the physical layer. Our work investigates the improvement in SNR for the MIMO configuration with time diversity, code diversity and space diversity in the physical layer of basic WLAN standard. These diversity schemes are exploited with scrambling and bit interleaving, spread spectrum technique and Space Time Block codes respectively. The performance of simple 1 X 1 transceiver is compared with 1X2 and 2X2 modes of WiFi architecture.

2. SYSTEM DESCRIPTION

A. Transmitter model

The signal power, channel bandwidth and the power spectral density of the receiver noise are the factors which determine the value of E_b/N_o.

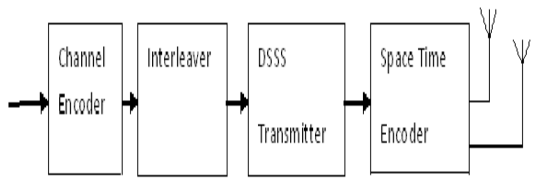

Fig.1. Transmitter model of the Wi-Fi system

The schematic diagram of transmitter model of WiFi System is shown in fig.1.The role of channel coding is to increase the reliability of transmission in a noise effective channel by lowering the frequency of error events. As per the standard, for the simulation of physical layer of Wi-Fi 802.11b, convolutional codes are used as channel error control scheme. These are non systematic binary codes and thel encoder operates on the incoming message bits sequentially in a serial manner [10]. The encoder of the binary convolutional code with rate 1/n is considered as a finite state machine. It consists of an M-stage shift register with connections to n modulo 2 adders and a multiplexer that serializes the output to the adders. An L-bit message sequence produces a coded output sequence of length n (L+M) bits. The code rate is given by

$$R = L / n (L+M) \quad \text{bits/symbol}$$

Another important parameter to be considered is the constraint length (K) of the convolutional encoder which is the number of shifts over which the message bit can influence the encoder output. In an encoder with M stage shift registers the memory of the encoder equals m message bits and K=M+ 1 shifts are required for a message bit to enter the shift register and come out finally.

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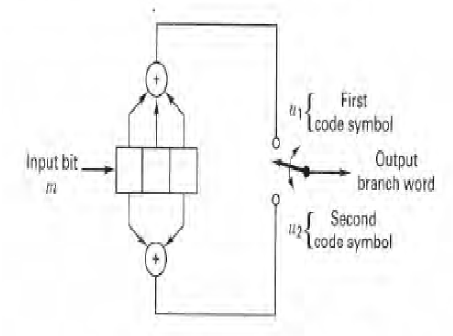

Fig.2. Schematic diagram for convolutional Encoder

Diagrammatic Representations are used to portray the structural properties of convolutional encoder. We have adopted Trellis tree representation for convolutional coding. This encoded data is then fed to interleaver, which scrambles the data in a non contiguous manner so that no adjacent symbols are from the same code word. This is done so that even if noise corrupts one bit of data, the other bits can be used to retrieve the original data which enhances the performance of the system by mitigating the burst errors that may occur when data travels in a corruptive multipath environment. The IEEE 802.11b data is encoded using DSSS (Direct Sequence Spread Spectrum) technology which is the most widely recognized form of spread spectrum technique. DSSS technique involves spreading of the message signal over larger bandwidth using a direct sequence [11]. To achieve most of the claims made for the spread spectrum, it is necessary that the bandwidth over which the message is spread be very much greater than the bandwidth of the message itself and thereby the transmitted signal takes up more data rate and bandwidth than the information signal that is being modulated. This is achieved by directly coding the digital data at a much higher frequency. The higher rate, pseudo random codes are deterministically generated using shift registers which includes modulo-2 adders and feedback operation but have properties similar to random sequences. The DSSS process is performed by XOR-ing the interleaved message signal with a Pseudo-Noise (PN) digital signal which is an 11-bit sequence that satisfies certain mathematical properties like Run length and Correlation. This makes the PN modulated information signal ideal for modulating radio waves using one of the many modulation techniques available.

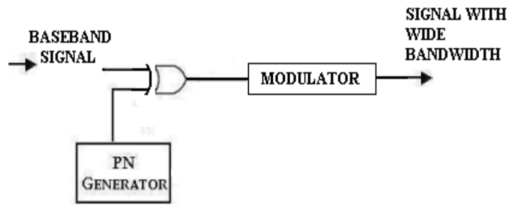

Fig.3. DSSS transmitter block

The spreading process causes the message signal to be replaced with a very wide bandwidth signal. The wide bandwidth provided by the PN code allows the signal power to drop below the noise threshold without loss of information.

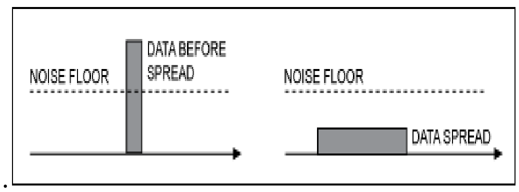

Fig.4. Schematic diagram of DSSS signal Spectrum

As per the standards of IEEE 802.11b, QPSK (Quadrature Phase Shift Keying) where four rotations (45°, 135°, 225° and 315°) are used to encode 2 bits of information in the same space, is used and this modulation has an added advantage ,as it increases the data rate, thereby causing reduction in the available process gain. The process gain is reduced because for a given PN code rate, the bandwidth which sets the process gain is halved due to the two-fold increase in information transfer.

Table No.1.Technological Aspects of WiFi

	WiFi(802.11b)
Primary Application	WLAN
Frequency Band	2.5 GHz ISM Band
Bandwidth	25 MHz
Modulation	QPSK
FEC	Convolutional Codes

The result is that systems in a spectrally quiet environment benefit from the possible increase in data transfer rate. As the coverage range of Wi-Fi is limited to some hundreds of meters the interference is comparatively low when compared with WMAN applications. So the Direct Sequence Spread Spectrum technique

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using QPSK modulation in Wi-Fi system is found to have the acceptable performance. This spectrum technique is used for a variety of reasons, including the establishment of secure communication, increasing resistance to natural interference and jamming, and to prevent spurious detection.

B. Diversity Technique

Diversity, a key technique which exploits the inherent multipath nature of wireless channel is used in Wi-Fi technology to mitigate the transmission errors. It provides wireless link improvement at relatively low cost.

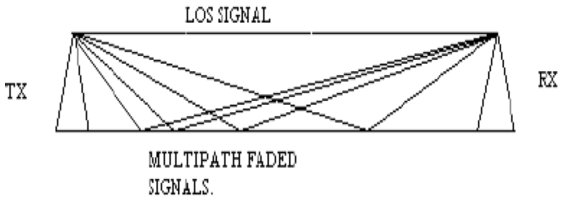

Fig.5. Multipath propagation

Space diversity also known as antenna diversity is one of the most widely used diversity techniques in wireless systems. In this technique, multiple antennae are used either at transmitter side or at receiver side or at both sides. Diversity schemes at the transmitter side and receiver side can provide high diversity gain as well as increased rates. Multiple versions of the same signal which endured independent fading arrive at the receiver side when multiple antennae are used at the transmitter side. The receiver antennae, after combining the independently faded versions of the signal the resultant signal exhibits considerably small amount of fading. If independent signals are transmitted simultaneously, then each one of them traverses independent path and a certain amount of correlation between these symbols transmitted over the channel is attained by using coding techniques like space time block code, having low receiver complexities. Alamouti code is the only orthogonal space time block code which takes two time-slots to transmit two symbols where diversity gain is achieved without loss in bandwidth efficiency[12]. Alamouti code can be generalized to an arbitrary number of antennae. If two antennae are deployed at the transmitter side, at a given symbol period, two symbols are simultaneously transmitted from the two antennae. The signal transmitted from antenna one (A0) is denoted by S0 and from antenna two (A1) denoted by S1. During the next symbol period signal $-S1^*$ is transmitted from antenna A0, and $S0^*$ signal is transmitted from antenna A1 where * is the complex conjugate operation. Let the two time slots be denoted as t and t+T. The Alamouti code matrix is given as

	Antenna 0	Antenna 1
Symbol period 0	S0	-S1*
Symbol period 1	S1	S0*

Table.2. Alamouti code matrix

C. Single Input Single Output (SISO) Technique

SISO is the conventional scheme adopted in which only one antenna is present in the transmitter as well as the receiver side. The signal that is transmitted through the single antenna takes multiple paths of propagation and the received signals obtained after traveling in different path are displaced with respect to one another, in time and spatial domain. When these signals are combined at the receiver side with a single antenna it results in destructive interference. So the SISO scheme has a major constraint in the form of fading, associated with it.

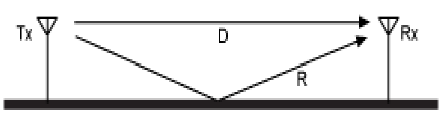

Fig.6. Schematic diagram for SISO scheme

D. Multiple Input Single Output (MISO) diversity technique

MISO comes under the category of transmit diversity where multiple antennae are used at the transmitter side and a single antenna at the receiver side. The purpose of this scheme is not to increase the system capacity but to improve the error rate performance of the system. As the error rate performance increases, higher modulation schemes can be used which means that each symbol can carry more amounts of data

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thereby leading to improved system capacity. Due to independent fading in multipath environment replicas of the same signal transmitted at different time slots undergo different fading. Therefore there is a probability for few versions of the transmitted signal to experience least fading and at the receiver side when combining all the received signals the least faded ones, accounts for the improved SNR associated with MISO scheme when compared to SISO scheme.

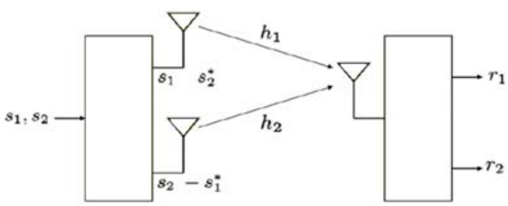

Fig.7. Schematic diagram for transmit diversity

E. Multiple Input Multiple Output (MIMO) diversity technique

In the MIMO scheme, diversity is adopted both at the transmitter side and receiver side thereby commingling the advantage of both the diversity techniques. This technique dramatically increase the capacity of the wireless channels and the throughput of the systems by employing multiple antennae at both the transmitter and receiver side[13]. Multiple versions of the same signal are transmitted simultaneously through multiple antennae which are deployed at the transmitter side. By the use of multiple antennae at the receiver side, when one antenna sees the signal null, one of the other antennae may see the signal peak, thereby the highest achievable SNR is always available at the receiver side which eventually leads to reduction in the consequences of fading.

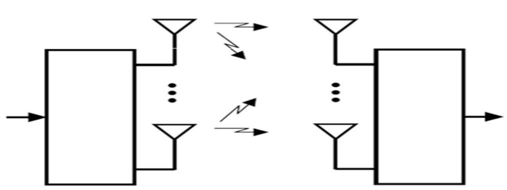
Fig.8. Schematic diagram for MIMO scheme

F. Receiver model

The purpose of any communication system is to properly receive the transmitted data so proper detectors and decoders have to be deployed at the receiver side. The receiver side of this Wi-Fi system consists of a de-spreading block, demodulator, deinterleaver and Viterbi decoder which is used for decoding the convolutional coded data which is shown in fig.9

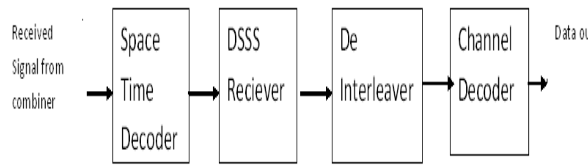

Fig .9.Receiver model of the Wi-Fi system

After the signal reception the signals are combined using Maximum Likelihood decision rule to obtain the signal estimate.
The received signal vector is:

$$r_t = (r_t^1, r_t^2, \ldots, r_t^{nr})$$
$$r_t = H_t x_t + n_t$$

If two antennae are used at the transmitting side then by denoting the channel response from Tx1 to the receiver as h_1 and the channel response from Tx2 to the receiver as h_2, the received signal samples corresponding to the symbol periods t and t+T can be written as:

$$r_1 = h_1 s_1 + h_2 s_2 + n_1$$
$$r_2 = h_1 s_2^* - h_2 s_1^* + n_2$$

where n_1 and n_2 are the additive noise terms.
The receiver computes the following signals to estimate the symbols s_1 and s_2:

$$x_1 = h_1^* r_1 - h_2 r_2^* = (|h_1|^2+|h_2|^2)s_1 + h_1^* n_1 - h_2 n_2^*$$
$$x_2 = h_2^* r_1 - h_1 r_2^* = (|h_1|^2+|h_2|^2)s_2 + h_2^* n_1 - h_1 n_2^*$$

These expressions clearly show that x_1 and x_2 can be sent to a Maximum Likelihood detector to estimate symbol s_1 and symbol s_2 without interference. The estimated signal is then fed to the de-spreading block. For de-spreading to work correctly, transmitted and received sequences must be synchronized. A de-spreading operation reconstitutes the information into its original bandwidth. The output signal is maximum when the estimated signal and the PN signal generated at the receiver side exactly correlates with one another. The correlated signal is then filtered

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and then this de-spread signal is sent to a QPSK demodulator.

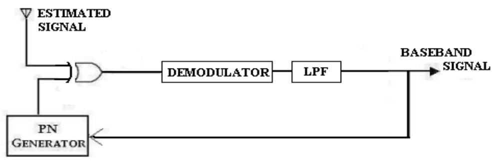

Fig.10. DSSS receiver block

After demodulation, deinterleaving is done. The deinterleaved data is then imparted to the Viterbi decoder .The function of Viterbi decoder is to estimate the path traversed through the Trellis and correspondingly decode the data. After Viterbi decoding the original message is obtained

3. BER COMPARISON RESULTS

An important measure of performance used for comparing these receiver models is the Bit Error Rate (BER). BER performance can be compared by plotting the graph between BER and E_b/N_o values which is precisely presented here. Fig. 11, 12 and 13 show the BER comparison graph of the case C and D, D and E and all the cases respectively. The BER comparison graphs demonstrate the performance of the three diversity techniques against multipath fading.

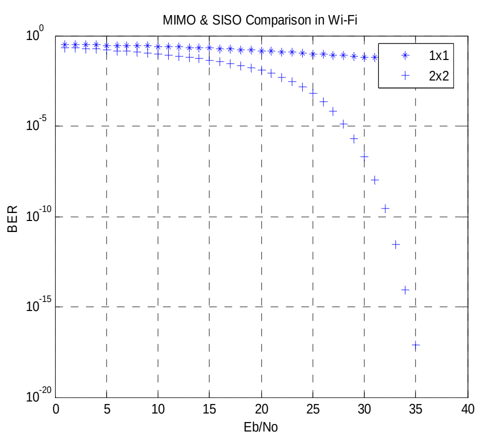

Fig.11. Comparison of BER for case C and case D

It is observed that there is a marked increase in performance which can be attributed to the use of multiple antenna at both transmitter and receiver side leads to better receives the weak faded signal, as observed in performance rather than using a single antenna at transmitter and receiver side. This is due to the fact that , by using a single antenna scheme, the cumulative density of SNR decreases with fading effect.

In case D, diversity technique is deployed only in the transmitter side and there is only a single antenna in the receiver side, so improvement in the SNR is not appreciable when compared to MIMO scheme using multiple antennae at the receiver side.

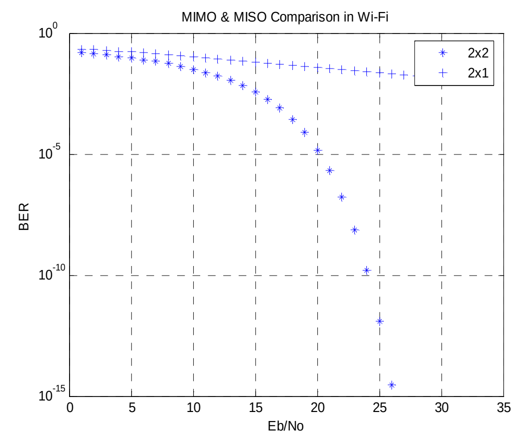

Fig.12. Comparison of BER for case D and case E

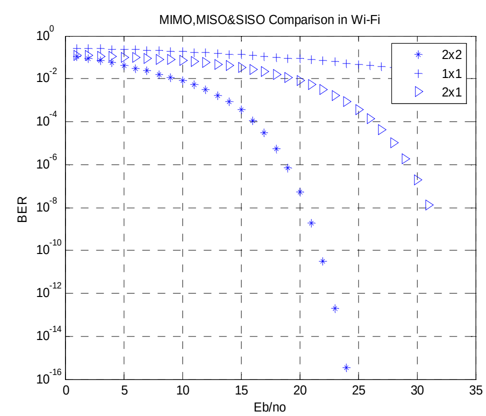

Fig.13.Comparison of BER between all the cases

By increasing the number of antennae at transmitter and receiver side, due to independent fading, even when faced with a worst case situation wherein most of the receiver antennae

the case of urban environment, there is a

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probability that an antenna receives the least faded signal and thereby reducing the Bit Error Rate dramatically when compared to MISO and SISO schemes.

4. CONCLUSION

Space diversity technique vastly improves the performance of wireless systems by effectually combating against fading experienced by a signal in a multipath fading environment, and in this paper the various space diversity techniques have been discussed. In a multipath fading scenario diversity techniques would to some extent surpass the limitations enforced due to fading and help in production of a better estimate of the original signal. Another fact observed is that the introduction of diversity techniques does not increase the data overhead. The comparison BER graphs for each technique, revealing that the MIMO technique gives least BER and exhibits optimum performance. Thereby enabling Wi-Fi integrated with MIMO diversity scheme to prevail best over other broadband wireless technologies and making it an effective WLAN system.

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