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ROLE OF DIVERSE DIVERSITY SCHEMES IN MIMO WIRELESS SYSTEM: A SURVEY

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***Abstract*- Diversity in MIMO (Multiple-Input Multiple-Output) wireless systems refers to a collection of schemes utilized to enhance the reliability and quality of wireless system. This scheme used the numerous antennas at the transmitter and/or receiver to diminish the harmful effects of multipath fading. Multipath fading is a common concern in wireless channels in which signals get multiple paths to arrive at the receiver, results interference and signal degradation. Hence receiver should incorporate some form of diversity, i.e., some less-attenuated replica of the transmitted signal in order to combat signal degradation. This paper describes basic concepts of the numerous diversity schemes.**

***Index Terms* - Almouti, STBC, Diversity, MIMO.**

1. INTRODUCTION

The wireless channel suffers from attenuation due to destructive and constructive addition of multipath in the propagation media. Signals can used several paths to reach the receiver due to reflections, diffraction, and scattering. This can lead to multipath fading, where the signal strength varies because of the constructive and destructive interference of the different signal paths. These attenuation effects could also vary with time due to user mobility, making wireless a challenging communication medium [1].

In general, multipath fading is described as the constructive/ destructive interference between signals arriving at the same antenna via different paths, and hence, with different delays and phases, resulting in random fluctuations of the signal level at the receiver. Multipath fading can cause rapid fluctuations in signal amplitude and phase, which can lead to issues like "ghosting" in analog TV broadcasts or fading of radio waves. It can make a radio signal too weak to be received adequately in certain areas. Multipath fading is critical for designing robust wireless communication systems that can deliver reliable signals in diverse environments [2]. Overall, multipath fading is a deterministic phenomenon that wireless networks must address to ensure stable and reliable communication, especially in environments with rich scattering or obstacles that cause reflection and diffraction of signals. The effects of multipath fading are [3]:

- Unreliability of Wireless Links: Multipath fading can cause large deviations from link quality predictions based on path loss models, contributing to the unreliability of wireless links.
- Signal Strength Variations: The signal strength can fluctuate rapidly due to the interference of multiple signal paths, which can result in a poor quality of service (QoS) and dropped connections.
- Inter-Symbol Interference (ISI): Multipath delay spread can cause ISI, where symbols in the transmitted signal overlap and interfere with each other, leading to errors in the received signal.
- Impact on Sensor Networks: In wireless sensor networks, multipath fading is a considerable issue as it can heavily influence the performance and reliability of the network

Diversity is a powerful communication receiver technique that provides wireless link improvement at a relatively low cost. Diversity techniques are used in wireless communications to mitigate the effect of fading over a radio channel. This scheme has transmitting numerous replicas' of a information stream across various antennas to utilize the a variety of received versions of the information, thus enhancing the reliability of information transfer. This technique is particularly effective in environments with scattering, reflection, refraction, and other forms of signal degradation, as well as thermal noise in the receiver [4].

2. TYPES OF DIVERSITY

In wireless System, diversity is an approach used to enhance signal quality and reliability. There are numerous kinds of diversity schemes, each utilizing different dimensions or resources to combat the effects of fading. The main diversity schemes are summarised as [5,6]:

- **Time Diversity:** Time diversity is based on the principle that the identical signal or components of a signal are transmitted over communication channel at different times. Therefore, ensures that even if one occasion of the signal contains fading, former case may not, permitting for a greater possibility of precise signal recovery. This can be implemented through a variety of ways such as repetition coding, where the same data is sent multiple times; Automatic Repeat Request (ARQ), where errors detected at the receiver trigger a retransmission request; and the combination of interleaving and coding, which spreads the data over time to minimize the impact of burst errors. The intervals between re-transmissions should be greater than the coherence time of the channel, which is the time duration over which the channel's properties do not change significantly. This ensures that the re-transmitted signals undergo statistically independent fading. Time diversity is mainly efficient in situations where the channel characteristics change rapidly over time, such as in mobile communications where the receiver or transmitter is moving. However, in stationary scenarios, like indoor wireless communication, its effectiveness is reduced as the channel characteristics do not vary much over time.
- **Frequency Diversity:** Frequency diversity is based on the method that signal distortions, such as fading, may affect one frequency component but not another. Hence utilizing numerous frequencies, the possibility of all frequencies have severe fading at the same time is decreased. This needs only one antenna but have a larger bandwidth (BW) and more receivers, which can increase costs. The variation in carrier frequency should be more than the coherence bandwidth to attain valuable diversity. This diversity can appreciably enhance the reliability of wireless systems, particularly in situations where the channel have frequency-selective fading. Hence it ensures that the identical data arrive at the receiver from statistically independent channels.
- **Space Diversity:** Space diversity, also known as spatial diversity, utilized several antennas to improve the quality and reliability of a wireless link. The technique is mainly efficient in urban and indoor situations where there is no clear line-of-sight (LOS) between the transmitter and receiver. It have two or more antennas that are physically separated from one another. The separation can be on the order of a wavelength or much larger, depending on the environment and the expected incidence of the incoming signal. In multipath situations, signals reflect off various objects and arrive at the receiving antenna with different phase shifts, time delays, attenuations, and distortions. These can destructively interfere with one another. Having multiple antennas allows the receiver to have several observations of the same signal, each experiencing a different interference environment. If one antenna is experiencing a deep fade, it is likely that another has a sufficient signal. Space diversity can be realized in several ways:
    - **Spatial Diversity**: It implements antennas with the same characteristics that are physically separated. The separation ensures that each antenna experiences independent fading conditions.
    - **Pattern Diversity**: It consists of two or more co-located antennas with different radiation patterns. This type allows for discrimination of a large portion of angle space and can provide a higher gain compared to a single omni-directional radiator.

The primary benefit of space diversity is to provide a robust link, decreasing the number of drop-outs and lost connections. It's especially beneficial for mobile communication as it allows multiple users to share a limited communication spectrum and avoid co-channel interference. Space diversity is a key component in the design of modern wireless systems, including cellular networks and Wi-Fi, to ensure stable and reliable communication in the presence of multipath fading and other signal degradations.

3. SPACE TIME BLOCK CODE (STBC):

In STBC, the Information stream is encoded in blocks, which are then distributed among spaced antennas and across time. While it is necessary to have multiple transmit antennas, having multiple receive antennas is optional, though it can enhance performance. The main objective of using STBC in Multiple Input Multiple Output (MIMO) systems is to improve the diversity gain and coding gain, which can lead to better error performance and higher data rates compared to conventional communication systems [7].

STBC is often represented by a matrix where each row represents a time slot and each column represents one antenna's transmissions over time. STBC differs from other MIMO (Multiple-Input Multiple-Output) techniques primarily in how it utilizes the multiple antenna elements to transmit and receive data. Here are some key differences [8]:

- **STBC** focuses on improving the reliability of transmission under fading environments by transmitting multiple copies of the same data symbol across multiple antennas. This technique uses algorithms at the receiver to combine all the copies of the received signals to extract the transmitted data efficiently without errors. It's characterized by a single input stream that is split into multiple streams for transmission.
- **Spatial Multiplexing (SM)**, another MIMO technique, transmits independent and separate copies of data symbols from each of the transmit antennas. These encoded data symbols are called streams, and they are transmitted over space and multiplexed in time. SM aims to increase the channel capacity by transmitting different data symbols simultaneously from multiple antennas.
- **Beam-forming** is a technique that uses the MIMO antenna array to direct the transmission or reception of signal in a particular direction. This is achieved by controlling the phase and amplitude of the signal at each transmitter, which can improve signal quality and range.
- **Spatial Diversity** involves transmitting the same signal from multiple antennas but with different coding or modulation schemes, or at different times or frequencies, to combat multipath fading and improve signal robustness.

In summary, while STBC aims to improve transmission reliability through diversity gain, techniques like SM and beam-forming seek to increase data rates and signal directionality. Each technique has its own advantages and is used based on the specific requirements of the communication system. STBC is particularly beneficial in scenarios where signal reliability is crucial, such as in environments with significant scattering and fading [9].

These diversity techniques can be combined with various combining methods at the receiver, such as selection combining, maximal-ratio combining, and equal gain combining, to further enhance signal quality and reliability. By employing these techniques, wireless networks can significantly mitigate the adverse effects of multipath fading and improve overall communication performance. STBC is designed to achieve transmit diversity and power gain without scarifying any more bandwidth. STBC is performed over two axis spatial (space) and temporal (time) axis for multiple antennas at different time. It is assumed that there are N transmit antennas and M receive antennas.

4. ALAMOUTI CODES

Alamouti coding is a space-time coding scheme that achieves transmit diversity in wireless communication systems. Proposed by Siavash Alamouti, these codes achieve transmit diversity by transmitting two copies of the same data symbol over two antennas in two consecutive time slots. They are simple to implement and provide diversity gain.

Transmit diversity aims to improve reliability by sending redundant copies of the same data symbol across multiple antennas. Alamouti coding achieves this using a simple technique. Alamouti coding is a foundational technique in MIMO systems, enhancing reliability and performance. The encoding of signal is done in space and time (space–time coding). The encoding, however, may also be done in space and frequency. Instead of two adjacent symbol periods, two adjacent carriers may be used (space–frequency coding).

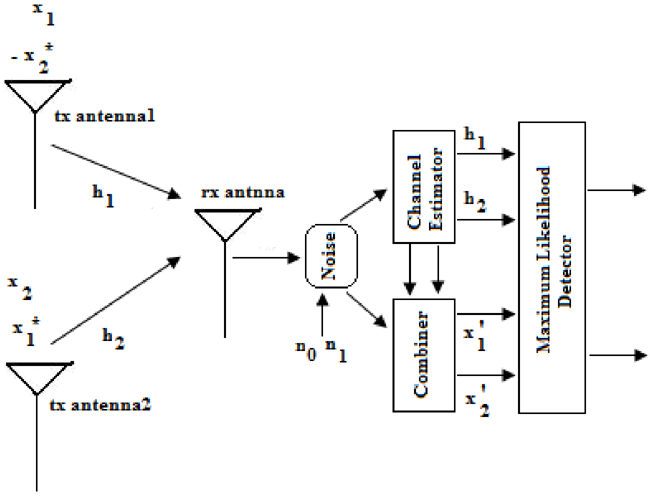

Figure 1: 2 Transmitter Diversity scheme with 1 Receiver

Consider we have a transmission sequence e.g. x_1, x_2, x_3.....x_n. In normal transmission, we send x_1 in first time slot, x_2 in second time slot and so on. However, Alamouti suggested that group the symbols into the group of two. In the first time slot send x_1 and x_2 from first and second antenna and $-x_2^*$ and x_1^* from first and second antenna at second time slot. In third time slot x_3 and x_4 from first and second antenna and there conjugates in fourth time slot and so on. Now the signal is transmitted through various channels. The channel experience by each transmit antenna is independent from the channel experienced by another antennas. For i^{th} transmitted antenna, the transmitted symbol is multiplied by h_i i.e. Rayleigh channel coefficient. The channel experienced between each transmit to receive antenna is randomly varying in time. However the channel is assumed to remain constant over two time slots. G2 represents a code which utilizes two transmit antennas and is defined by:

$$G2=\begin{bmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{bmatrix}$$

STBC is designed to achieve transmit diversity and power gain without scarifying any more bandwidth. STBC is performed over two axis spatial (space) and temporal (time) axis for multiple antennas at different time [10]. It is assumed that there are N transmit antennas and M receive antennas. The input source data bits are firstly modulated, and then carried into a space-time block encoder. Mapping from the modulated symbols to a transmission matrix, which is completed by the STBC encoder, is a key step in STBC systems. The input symbols of the encoder are divided into groups of several symbols. The number of symbols in a group is according to the number of transmit antennas. Different symbol columns are transmitted through different antennas separately and different symbol rows in different time slots.

5. CONCLUSION

The Multiple Input Multiple Output (MIMO) and Antenna diversity of wireless system plays an important role in space-time code design. This paper provides the overview and basic concept used for space-time block coding. Implementing diversity in wireless system, it is possible to efficiently combat the effects of multipath fading. The performance of the system is improved by providing the receiver with multiple copies of the data.

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