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RESEARCH ARTICLE

WIFI MIMO EMERGING TREND IN WIRELESS TECHNOLOGY

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Abstract — In radio, multiple-input and multiple-output, or MIMO (pronounced my-moh by some and me-moh by others), is the use of multiple antennas at both the transmitter and receiver to improve communication performance. It is one of several forms of smart antenna technology. MIMO technology has attracted attention in wireless communications, because it offers significant increases in data throughput and link range without additional bandwidth or increased transmit power. It achieves this goal by spreading the same total transmit power over the antennas to achieve an array gain that improves the spectral efficiency (more bits per second per hertz of bandwidth) and/or to achieve a diversity gain that improves the link reliability (reduced fading). Because of these properties, MIMO is an important part of modern wireless communication standards such as IEEE 802.11n (Wi-Fi), 4G, 3GPP Long Term Evolution, WIMAX and HSPA+.

Keywords —Wi-Fi, MIMO, transmitter, wireless, SIMO, MISO

I. INTRODUCTION OF MIMO

MIMO is an acronym that stands for Multiple Input Multiple Output. It is an antenna technology that is used both in transmission and receiver equipment for wireless radio communication. There can be various MIMO configurations. For example, a 2x2MIMO configuration is 2 antennas to transmit signals (from base station) and 2 antennas to receive signals (mobile terminal). [1]

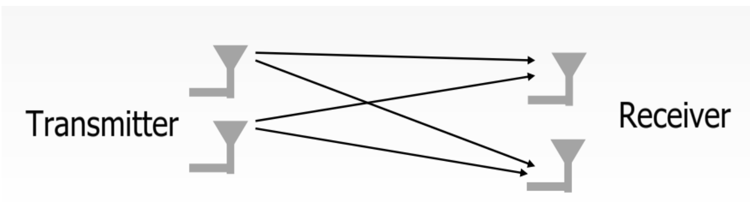


Fig 1. Basic MIMO Model

In the never-ending search for increased capacity in a wireless communication channel it has been shown that by using an MIMO (Multiple Input Multiple Output) system architecture it is possible to increase that capacity substantially. Usually fading is considered as a problem in wireless communication but MIMO channels uses the fading to increase the capacity.

MIMO systems transmits different signals from each transmit element so that the receiving antenna array receives a superposition of all the transmitted signals. All signals are transmitted from all elements once and the receiver solves a linear equation system to demodulate the message [2]. The idea is that since the receiver detects the same signal several times at different positions in space at least one position should not be in a fading dip.

If the transmitter has CSI (Channel State Information) then the transmitter can use the various techniques to optimize the power allocation between the antenna elements so that an optimal capacity is achieved.

When the CSI is supplied to the transmitter a decrease in spectral efficiency is unavoidable so therefore it is interesting to know in what cases it is important to have CSI and when the benefits are negligible. This will be answered after a series of measurements.

Consider two transmitting antennas where the first antenna is transmitting and the second does not. The electro-magnetic wave from the first antenna will induce a voltage in the other antenna and then the other antenna will also transmit a signal and so on, this is called "Mutual coupling". The Rayleigh-distribution is a well-known estimation of the PDF (Probability Density Function) of the fading statistics in a radio channel. Since the MIMO system architecture uses the independent fading between different antenna-elements perhaps it could be possible to increase the independent fading by using some sort of mixer in the channel so that the channel doesn't get stuck in state of low diversity gain [3]. There will be some experiments made with a retro-directive antenna that should work as a mixer.

II. INTRODUCTION TO WIFI

Wi-Fi, also spelled Wifi or WiFi, is a popular technology that allows an electronic device to exchange data or connect to the internet wirelessly using UHF radio waves. The name is a trademark name, and was stated to be a play on the audiophile term Hi-Fi. The Wi-Fi Alliance defines Wi-Fi as any "wireless local area network (WLAN) products that are based on the Institute of Electrical and Electronics Engineers' (IEEE) 802.11 standards". However, since most modern WLANs are based on these standards, the term "Wi-Fi" is used in general English as a synonym for "WLAN". Only Wi-Fi products that complete Wi-Fi Alliance interoperability certification testing successfully may use the "Wi-Fi CERTIFIED" trademark.[9]

Many devices can use Wi-Fi, e.g., personal computers, video-game consoles, smartphones, some digital cameras, tablet computers and digital audio players. These can connect to a network resource such as the Internet via a wireless network access point. Such an access point (or hotspot) has a range of about 20 meters (66 feet) indoors and a greater range outdoors. Hotspot coverage can comprise an area as small as a single room with walls that block radio waves, or as large as many square miles achieved by using multiple overlapping access points.

Depiction of a device sending information wirelessly to another device, both connected to the local network, in order to print a document. Wi-Fi can be less secure than wired connections (such as Ethernet) because an intruder does not need a physical connection. Web pages that use SSL are secure but unencrypted internet access can easily be detected by intruders. Because of this, Wi-Fi has adopted various encryption technologies. The early encryption WEP, proved easy to break. Higher quality protocols (WPA, WPA2) were added later. An optional feature added in 2007, called Wi-Fi Protected Setup (WPS), had a serious flaw that allowed an attacker to recover the router's password.[2] The Wi-Fi Alliance has since updated its test plan and certification program to ensure all newly certified devices resist attacks.

To connect to a Wi-Fi LAN, a computer has to be equipped with a wireless network interface controller. The combination of computer and interface controller is called a station. All stations share a single radio frequency communication channel. Transmissions on this channel are received by all stations within range. The hardware does not signal the user that the transmission was delivered and is therefore called a best-effort delivery mechanism [4]. A carrier wave is used to transmit the data in packets, referred to as "Ethernet frames". Each station is constantly tuned in on the radio frequency communication channel to pick up available transmissions.

A Wi-Fi-enabled device can connect to the Internet when within range of a wireless network which is configured to permit this. The coverage of one or more (interconnected) access points called hotspots can extend from an area as small as a few rooms to as large as many square miles. Coverage In the larger area may require a group of access points with overlapping coverage. Wi-Fi provides service in private homes, businesses, as well as in public spaces at Wi-Fi hotspots set up either free-of-charge or commercially, often using a captive portal webpage for access. Organizations and businesses, such as airports, hotels, and restaurants, often provide free-use hotspots to attract customers. Enthusiasts or authorities who wish to provide services or even to promote business in selected areas sometimes provide free Wi-Fi access. Outdoor public Wi-Fi technology has been used successfully in wireless mesh networks in London, UK.

Routers that incorporate a digital subscriber line modem or a cable modem and a Wi-Fi access point, often set up in homes and other buildings, provide Internet access and internetworking to all devices connected to them, wirelessly or via cable.

Similarly, there are battery-powered routers that include a cellular mobile Internet radio modem and Wi-Fi access point. When subscribed to a cellular phone carrier, they allow nearby Wi-Fi stations to access the Internet over 2G, 3G, or 4G networks. Wi-Fi also connects places that normally don't have network access, such as kitchens and garden sheds.[9]

III. PRINCIPLE OF MIMO

In traditional WLAN communications systems, both an access point end and a user end use only one antenna. The antenna system is named single-input and single-output system (SISO). C.E.Shannon proposed the following formula to calculate channel capacity in a SISO system.

$$C = B*\log^2 (1 + S/N) \qquad (1)$$

In the preceding formula, B stands for bandwidth of a channel and S/N stands for signal-to-noise-ratio. The formula for bandwidth utilization is as follows:

$$\Omega = \log^2 (1 + S/N) \qquad (2)$$

The preceding formula calculates the maximum rate of reliable communication in a channel with noises. Other technologies cannot provide a rate larger than the maximum rate no matter what modulation methods and channel coding methods are used.

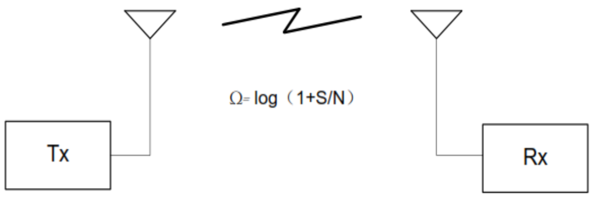


Fig 2. SISO wireless channel system

Install multiple antennas at the transmit or receive end. The antennas are considered independent of each other when antennas are far away from each other. Multiple independent channels are therefore constructed at the transmit or receive end. If a transmit end has N transmit antennas, a receive end has M receive antennas, and each stream of the M x N data streams are independent of each other in a wireless link, [5] the system capacity increases with the number of antennas according to the information theory. In a MIMO system, the channel capacity can be calculated using the following formula:

$$C = \min(M,N)* \log^2(1 + S/N) \qquad (3)$$

As shown in the formula, under ideal conditions, if the number of antennas is not limited, a MIMO system can provide infinite channel capacity.

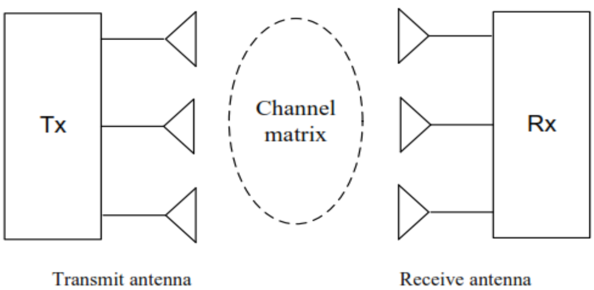
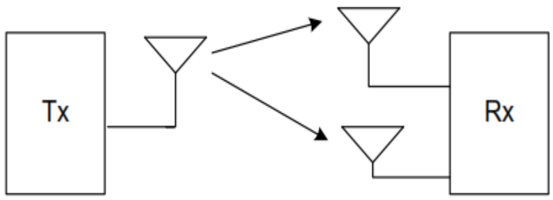


Fig 3. MIMO wireless channel system

As shown in Fig. 2, a MIMO system contains N transmit antennas and M receive antennas. The transmit data stream is divided into N substreams, and is transmitted through N antennas at the same time after modulation. Through scattering transmission in wireless channels, the parallel substreams are transmitted to the receiver from different paths and are received by M receive antennas. The receiver processes the substreams and restores the original data stream. Compared with traditional antenna systems, MIMO wireless communications systems transmit signals in multiple paths and construct multiple parallel transmission channels. Using the space-time block coding (STBC) technique, MIMO achieves transmit adversity and receive adversity, provides spatial multiplexing gain and spatial diversity gain, and improves channel capacity through parallel transmission channels. The MIMO technology is the most promising technology among emerging wireless communication technologies, and creates a significant way to high-speed transmission in wireless communications systems. In the MIMO technology the parallel N substreams are transmitted at the same time from the transmit end [6],[7].All transmit signals use the same bandwidth and no extra bandwidth is needed, improving available bandwidth. Therefore, the MIMO technology maintains the total transmit power of the transmit end, achieves best power allocation without increasing the transmit power of the system.[8]

IV. WORKING OF MIMO

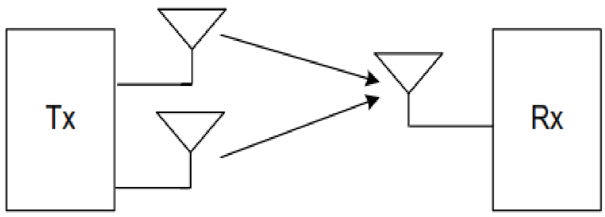
MIMO provides two mainstream technologies for wireless channels receive diversity and transmit diversity.
In receive diversity, the receiver uses more antennas than the transmitter (M > N). If the transmitter uses only one antenna (N = 1), the receive diversity is called SIMO. The following figure shows the simplest receive diversity that uses two receive antennas and one transmit antenna (SIMO, 1x2). SIMO requires no special coding technique and is easy to implement. The receiver needs only two radio channels for receiving two independent loss signals transmitted. The signal noise ratio (SNR) of received signals can be increased using methods such as diversity selection and maximal ratio combining (MRC). Diversity selection presents the strongest signal, while MRC combines two signals. In transmit diversity, the transmitter uses more transmit antennas than the receiver (M < N).



Transmitter Receiver

Fig 4. SIMO antenna configuration

When the receiver uses only one antenna, the transmit diversity is called MISO. The following figure shows simplest transmit diversity that uses two transmit antennas and one receive antenna (MISO, 2x1).



Transmitter Receiver

Fig 5. MISO antenna configuration

As shown in the figure, two antennas in the MISO system transmit corresponding data of the same signal. MISO uses the space time coding (STC) technology to improve the signal capability to prevent attenuation and increase the channel capacity. STC integrates the characteristics of diversity, coding, and modulating. The most attractive feature of STC is that it achieves space division multiple access (SDMA) by combing coding and matrix technologies. This improves the capability of the system to prevent signal attenuation. In addition, STC provides high quality data transmission at high rate for the transmit and receive diversity. In contrast to the non-STC coding system, the STC system supports high coding gain while ensuring bandwidth, improving the anti-interference and anti-noise capabilities. WLAN 802.11n uses space-time block coding (STBC) technology. STBC is a simple and optional transmit diversity mechanism defined in 802.11n. It provides a diversity gain that amounts to the gain obtained through MRC. However, if the total transmits power is limited; STBC is not competitive because STBC provides a little gain. STBC enables a low-cost device that requires low power and low data transmission rate to obtain high link performance using the assigned wireless channels. [7]

V. CONCLUSION

This document analyzes the MIMO technology in WLAN based on the Shannon's notion of channel capacity. The analysis result shows that the WLAN MIMO technology greatly improves the channel capacity and the increase of transmit and receive antennas helps improve system performance and reduce BER. A single transmit or receive antenna contributes a little to increase in the system gain. How to obtain and leverage the CSI is to be researched. In practice, a better choice is required for balance in addition to the system complexity and system performance.

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