Integrating Orthogonal Frequency Division Multiplexing [Ofdm] And Multiple Input Multiple Output [Mimo] as Joint Transmission Scheme

[1]Syed Ahsan, [2]Muhammad Shahbaz, [3]Syed Athar Masood

[1,2]Department of Computer Science, University of Engineering and Technology, Lahore
[3] Department of Engineering Management, NUST College of E&ME, Rawalpindi Pakistan
[1] ahsancs@hotmail.com; [2] m.shahbaz@uet.edu.pk, [3]atharmasood2000@hotmail.com

Abstract: Wireless medium is a hostile propagation medium suffering from multipath fading and interference from other sources. Time Diversity and Frequency Diversity provide provides effective methods to mitigate fading and interference, this improving link robustness. Spatial Diversity provides link reliability without compromising on spectral efficiency. Space-time-coding provides potentially increased robustness and capacity by exploiting the fact that multiple antennas can be used in both transmitting and receiving equipments. This spatial multiplexing technique is termed as Multiple-Input-Multiple-Out ["MIMO"]. Most of the previous work in the area of "MIMO" wireless has been restricted to narrowband systems. Orthogonal-Frequency-Division-Multiplexing ["OFDM"] significantly reduces receiver complexity in wireless broadband systems. The use of "MIMO" technology in combination with "OFDM" seems to be an attractive solution for future broadband wireless systems. This paper is aimed at looking at possible integration of "MIMO" with "OFDM" and establishing improvements it has to offer for wireless networks. Various schemes that employ multiple antennas at the transmitter and receiver are being considered to improve the range and performance of communication systems. [Syed Ahsan, Muhammad Shahbaz, Syed Athar Masood. Integrating Orthogonal Frequency Division Multiplexing and Multiple Input Multiple Output as Joint Transmission Scheme. Journal of American Science 2011;7(7):24-27]. (ISSN: 1545-1003). http://www.americanscience.org.

Keywords: Time Diversity, Frequency Diversity, OFDM, MIMO

1. Introduction:

"MIMO" happens to be the most suitable multiple antenna technology for large deployments of commercial networks. It offers a linear increase in throughput with every pair of antennas added at transmit and receive ends of the system. It increases throughput simply by exploiting spatial dimension by increasing number of unique spatial paths between the two ends of a wireless network. An environment rich in multipath (like dense urban morphology and in-building coverage) makes it most appropriate for multiple antenna array implementations.

"OFDM" is a significantly efficient modulation scheme. It ensures spectral efficiency by dividing a broadband channel into multiple sub-channels. Each of the frequencies is an integer multiple of a fundamental frequency. This ensures that even though the sub-channels overlap they do not interfere with each other. The use of IFFT and FFT for modulation and demodulation results in computationally efficient "OFDM" modems..

"MIMO-OFDM" combines "OFDM" and "MIMO" techniques thereby achieving spectral efficiency and increased throughput. A "MIMO-OFDM" system transmits independent "OFDM" modulated data from multiple antennas simultaneously. At the receiver, after "OFDM" demodulation, "MIMO" decoding on each of the sub-channels extracts the data from all the transmit antennas on all the sub-channels. This paper provides a focus on various aspects of their integration.

Although both "MIMO" and "smart antenna" systems employ multiple antennas spaced as far apart as practical but "MIMO" and smart antenna systems are fundamentally different.

Smart antennas enhance conventional, one-dimensional radio systems. Commonly they use dynamic / static beam-forming to concentrate the signal energy on the main path and receive diversity to capture the strongest signal at any given moment. Note that beam-forming and receive combining are only multipath mitigation techniques, and do not multiply data throughput over the wireless channel. Both have demonstrated improvements in performance incrementally in point-to-point applications. "MIMO" is a paradigm shift, dramatically changing responses to multipath propagation. While receive-combining and beam-forming increase spectral efficiency one or two b/s/Hz at a time; "MIMO" multiplies the b/s/Hz.

"MIMO-B" has following key characteristics:

- Higher throughput
- Improvement in Spectral Efficiency
- Higher Frame / Slot Utilization
- It is based on Spatial Multiplexing [SM]

SM achieves higher throughput by transmitting independent data streams on different transmit branches simultaneously and at the same carrier frequency. Receiver equipment recovers parallel streams of data. This technique requires multiple antennas at receiving end to ensure adequate performance.

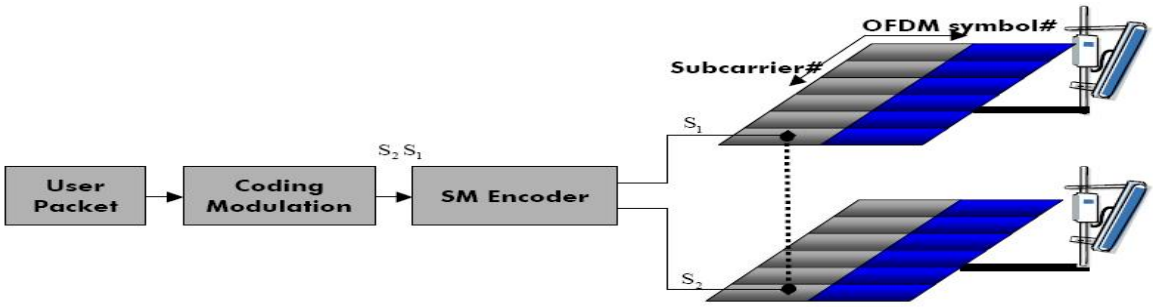

Fig-1: "MIMO-B": SM Architecture [5]

2. COMPARATIVE STUDY: MIMO-B vs. Channel-Bonding [CB]

Channel-bonding is one of the most direct methods of increasing throughput. It multiplies throughput by combining two or more radio channels. But this technique consumes increased bandwidth. In some cases, lack of available bandwidth can limit the use of this technique. Also that use of increased bandwidth can cause interference on air-interface. In other cases, benefits may be reduced due to technical challenges.

Although both "MIMO" and CB can multiply throughput but there are two key differences between the approaches. Although CB increases throughput and capacity, it may reduce range slightly whereas "MIMO" enhances all three performance attributes simultaneously. And while CB increases throughput by consuming more bandwidth, it results may result in higher interference to other channels. On the contrary, "MIMO" increases spectral efficiency by multiplying throughput in the same bandwidth. [6]

"MIMO" based products will outperform smart-antenna and CB based products. ""MIMO"" based products can make judicious use of smart antennas and CB to offer even more benefits.

MIMO – OFDM INTEGRATION

"MIMO" can be used with any modulation or access technique. Today, most digital radio systems use TDMA, CDMA, or ""OFDM"".

TDMA systems transmit bits over a narrowband channel using time slots to segregate bits for different users. CDMA systems transmit bits over a wideband channel using codes to segregate bits for different users. "OFDM" is also a wideband system, but unlike CDMA which spreads the signal continuously over the entire channel, "OFDM" employs multiple, discrete, lower data rate sub-channels.

"MIMO" can be used with any of above mentioned access techniques. However research shows that implementation is much simpler—particularly at high data rates—for "MIMO-OFDM".

Most of the previous work in the area of "MIMO" wireless has been restricted to narrowband systems. Broadband "MIMO" channels offer higher capacity and frequency diversity due to delay spread apart from spatial diversity. "OFDM" significantly reduces receiver complexity in wireless broadband systems. Thus integration of "MIMO" and "OFDM" seems to be an efficient method of achieving higher data rates and robustness for future broadband wireless systems.

3. WORKING PRINCIPLE OF MIMO-OFDM INTEGRATION

Up-link:

- Mobile Subscriber Station [MSS] starts by transmitting pilot sequences for the channel estimation.
- The scheduler in Base Station [BS] assigns the required resources in the space-frequency domain to MSS such that the

desired quality-of-service requirements can be met. Each spatial and frequency channel should at least have individual modulation, steered by the link adaptation unit.

- Power control is realized using the joint space-frequency pre-processing after modulation.
- Finally, the signals are passed through an IFFT, modulated onto the carrier and transmitted over the air. In principle, the corresponding units are used in reversed order at the BS.
- Following the classical system approach, most of signal processing efforts in "MIMO" systems except power control and rate adaptation are performed by BS.

Down-link:

- BS requests MSS to transmit in uplink direction pilot sequences for the channel estimation and interference scenario faced by MSS.
- Using channel reciprocity, the channel state information from the up-link is then correspondingly used to steer the space-frequency pre-coding and to schedule the data transport in the space-frequency domain at BS. This maximize throughput and to minimize latency of the individual users.
- The data is pre-coded, which means that the "MIMO" processing is already done at BS, so that only minor post-processing is required at the MSS, such as scaling, demodulation and decoding.
- The data streams to be multiplexed in space shall already arrive spatially separated at the MSS antennas.

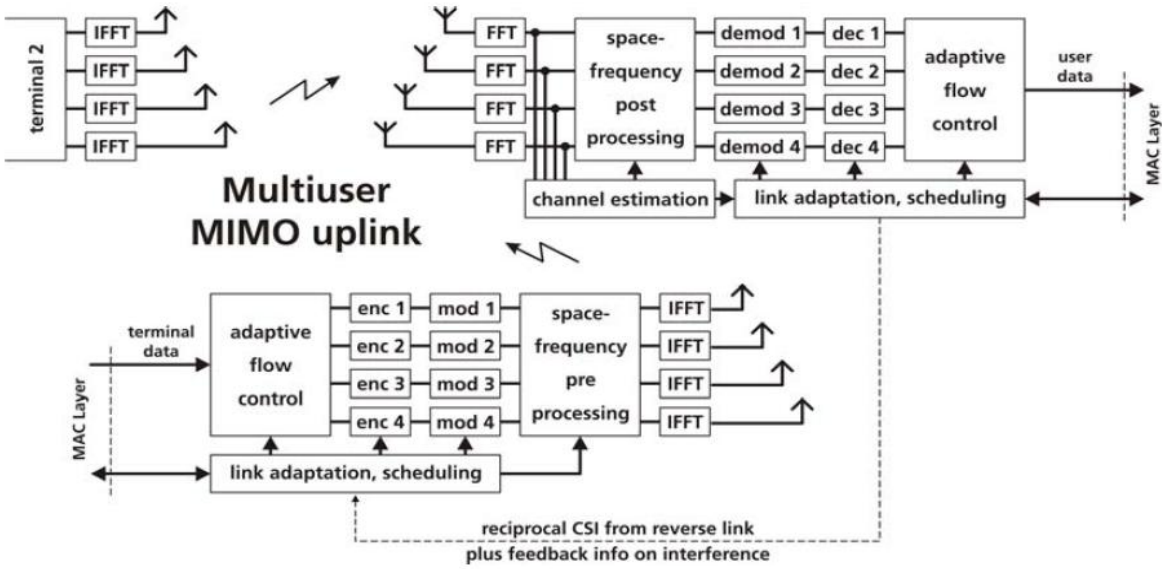

Fig-3.1: "MIMO-OFDM" Transceiver Block Diagram [8]

Duplex Recommendation:

Time Division Duplex (TDD) mode allows reusing channel state information from downlink to uplink and vice versa. Thus offering flexibility in terms of signal processing shifting. This enables design of user terminals with high data rates offered at lower costs. Moreover, link adaptation becomes more optimal.

Hence it is recommended to use TDD for all "MIMO-OFDM".

REFERENCES

[1] A. Paulraj, R. Nabar, D. Gore: "Introduction to Space-Time Wireless Communications", Published May 2003, ISBN: 0521826152.

[2] Courtesy Alcatel-Lucent Malaysia [WiMAX R&D Wing-2009].

[3] "MIMO Technology is Today's Most Significant Advance in Wireless Communications", Datacomm Research Company, Research Alert, February, 2005

[4] Courtesy Datacomm Research Company

[5] Courtesy Alcatel-Lucent Malaysia [WiMAX R&D Wing-2009]
[6] "Spatio-Temporal Coding for Wireless Communications" Cioffi, J.M. Global Telecommunications Conference, 1996: vol. 3, 18-22 Nov. 1996.
[6] H. Bolcskei "Space frequency coded broadband OFDM systems", in proc. of IEEE Wireless Communications and Networking Conference (WCNC) 2000, Vol. 1, 2000.
[7] N. Chayat, "Tentative Criteria for Comparison of Modulation Methods", Tech. Rep. IEEE, Nov. 2003
[8] Courtesy Alcatel-Lucent Malaysia [WiMAX R&D Wing-2009]
[9] W. Xiang, T. Pratt, and X. Wang, "A software radio test-bed for four-transmitter four-receiver space-time coding OFDM wireless LAN," IEEE Communications Magazine, vol. 42, 2004.
[10] W. Xiang, D. Waters, T. G. Pratt, J. Barry, and B. Walkenhorst, "Implementation and experimental results of a three-transmitter three-receiver OFDM/BLAST test-bed," IEEE Communications Magazine, vol. 42, 2004.
[11] W. Xiang, T. Pratt, and X. Wang, "A software radio test-bed for two-transmitter two-receiver space-time coding OFDM wireless LAN," IEEE Communications Magazine, vol. 42, 2004.
[12] G. D. Golden, C. J. Foschini, R. A. Valenzuela, and P.W.Wolniansky, "Detection algorithm and initial laboratory results using V-BLAST space-time communication architecture," Electronics Letters, vol. 35, 2003.
[13] H. Sampath, S. Talwar, J. Tellado, V. Erceg, and A. Paulraj, "A fourth-generation MIMO-OFDM broadband wireless system: design, performance, and field trial results," IEEE Communications Magazine, vol. 40, 2002.
[14] R. J. Piechocki, P. N. Fletcher, A. R. Nix, C. N. Canagarajah, and J. P. McGeehan, "Performance evaluation of BLAST-OFDM enhanced Hiperlan/2 using simulated and measured channel data," Electronics Letters, vol. 37, 2001.
[15] M. D. Batariere, J. F. Kepler, T. P. Krauss, S. Mukthavaram, J. W. Porter, and F. W. Vook, "An experimental OFDM system for broadband mobile communications," in Proceedings of 54th IEEE Vehicular Technology Conference (VTC '01), vol. 4, Atlantic City, NJ, USA, October 2001.
[16] J. W. Wallace, B. D. Jeffs, and M. A. Jensen, "A real-time multiple-antenna element test-bed for MIMO algorithm development and assessment," in Proceedings of IEEE Antennas and Propagation Society International Symposium, vol. 2, pp. Monterey, California, USA, June 2004.
[17] As described in Datacomm Research's report, "Wireless Machine-to-Machine: an In-depth Study of Applications and Vertical Markets," published July 16, 2004.
[18] "MIMO products boost 802.11g nets," Craig Mathias, Network World.

4/22/2011