

[0001] **METHOD, APPARATUS AND SYSTEM FOR IMPLEMENTING
MULTI-USER VIRTUAL MULTIPLE-INPUT MULTIPLE-OUTPUT**

[0002] **FIELD OF INVENTION**

[0003] The present invention is related to wireless communication systems. More particularly, the present invention is related to a method, an apparatus, and a system for implementing multi-user virtual multiple-input multiple-output (MIMO) techniques for wireless transmit/receive units (WTRUs) having one or more antennas.

[0004] **BACKGROUND**

[0005] In a conventional MIMO communication system, both a transmitter and a receiver employ multiple antennas for transmission and reception. With multiple antennas, multiple wireless channels may be established between the transmitter and the receiver. Generally, capacity and performance of the system are improved as the number of antennas increases.

[0006] For a virtual MIMO technique implemented in a conventional MIMO system involving two or more individual WTRUs, each WTRU is equipped with a single antenna to transmit independently onto the same sub-channel, or sub-carrier group (SBG). A base station, or scheduler, organizes the collaboration of two or more WTRUs to transmit on the same sub-channel or the SBG by scheduling the transmission of the WTRUs. However, in the conventional virtual MIMO system, a scheme, or solution, is not provided for WTRUs having more than one antenna.

[0007] Therefore, it would be desirable to provide a method for implementing virtual MIMO for WTRUs having two or more antennas.

[0008] **SUMMARY**

[0009] The present invention is related to a method, a base station, and a system for implementing multi-user virtual MIMO techniques for WTRUs having one or more antennas. The system includes a base station and at least one

WTRU having at least two antennas. The number of antennas of the base station is not less than the number of antennas at any of the WTRUs. The base station generates a channel matrix for the WTRUs and processes received signals from the WTRUs based on a measurement of the channel matrix. The WTRUs may perform transmit precoding, or eigen-beamforming using the channel matrix information. The WTRUs may also perform transmit diversity.

[0010] BRIEF DESCRIPTION OF THE DRAWINGS

[0011] A more detailed understanding of the invention may be had from the following description of a preferred embodiment, given by way of example and to be understood in conjunction with the accompanying drawings wherein:

[0012] Figure 1 shows a wireless communication system implementing virtual MIMO for WTRUs having two or more antennas in accordance with the present invention; and

[0013] Figure 2 is a block diagram of a base station configured in accordance with the present invention.

[0014] DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0015] When referred to hereafter, the terminology "WTRU" includes but is not limited to user equipment (UE), a mobile station, a fixed or mobile subscriber unit, a pager, a cellular telephone, a personal digital assistant (PDA), a computer, or any other type of user device capable of operating in a wireless environment. When referred to hereafter, the terminology "base station" includes but is not limited to a Node-B, a site controller, an access point (AP), or any other type of interfacing device capable of operating in a wireless environment.

[0016] The present invention is applicable to any wireless communication scheme that enables a WTRU to use more than one spatial stream, (i.e., an effective spatial channel). More specifically, the present invention is applicable to single carrier frequency division multiple access (SC-FDMA) MIMO transmission, orthogonal frequency division multiplex access (OFDMA) MIMO

transmission, or multi-carrier OFDMA MIMO transmission, where these transmission methods may use frequency hopping.

[0017] Figure 1 shows a wireless communication system 100 implementing virtual MIMO for WTRUs 120a, 120b having two or more antennas in accordance with the present invention. The system 100 includes a base station 110 and a plurality of WTRUs 120a, 120b. The base station 110 includes a plurality of antennas. At least one of the WTRUs 120a, 120b includes a plurality of antennas. It should be noted that Figure 1 shows two (2) WTRUs 120a, 120b, each having two (2) antennas, and a base station 110 having four (4) antennas as an example. It should be noted that any number of WTRUs may exist in the system 100, and the WTRUs 120a, 120b and the base station 110 may have any number of antennas.

[0018] The number (N_{rx}) of antennas at the base station 110 is equal to or greater than the number (N_{tx}) of antennas of any one of individual WTRUs 120a, 120b, which make up a virtual channel between the WTRUs 120a, 120b and the base station 110. It is well known that the capacity of the MIMO channel increases linearly with the minimum of N_{tx} and N_{rx} .

[0019] For example, the base station 110 may allocate a certain number of base station antennas, (at least the same number of antennas that each WTRU 120a, 120b includes), to each of the WTRUs 120a, 120b as shown by dotted circles in Figure 1 and generates an effective channel matrix for the channels between the base station 110 and the WTRUs 120a, 120b. The effective channel matrix, H_{eff} , from the WTRUs 120a, 120b to the base station 110 is written as follows:

$$H_{eff} = \begin{bmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{bmatrix}; \quad \text{Equation (1)}$$

where

$$H_{ij} = \begin{bmatrix} h_{i1} & h_{i2} \\ h_{j1} & h_{j2} \end{bmatrix}; \quad \text{Equation (2)}$$

where H_{ij} is a multipath channel matrix between the i-th WTRU and the j-th base station antenna group, and h_{11} , h_{12} , h_{21} , and h_{22} are channel coefficients for the two transmit antennas of each WTRU and the two receive antennas of each

base station antenna group, respectively. Equation (1) is an effective MIMO channel for multi-user virtual MIMO and Equation (2) is a single MIMO channel for a specific WTRU. It should be noted that in Equations (1) and (2), the example for two (2) antennas at the base station and the WTRU respectively was used. However, any combination of transmit and receive antennas where at least one of the WTRUs and the base station has more than one antenna may be considered. The matrix dimensions for Equations (1) and (2) will scale with the number of antennas used.

[0020] A spatial stream is equivalent to a scalar channel carried by the MIMO channel given by Equation (2). If Equation (3) is satisfied,

$$\begin{bmatrix} H_{11} & H_{21} \end{bmatrix} \begin{bmatrix} (H_{12})^* \\ (H_{22})^* \end{bmatrix} = 0, \quad \text{Equation (3)}$$

two equivalent $1(\text{Tx}) \times 2(\text{Rx})$ systems are established where each system comprises a scalar channel defined by the spatial stream.

[0021] Figure 2 is a block diagram of a base station 110 in accordance with the present invention. The base station 110 includes a plurality of antennas 122, a channel estimator 124, and a receiver 126. Other conventional components of the base station 110 are not shown in Figure 2 for simplicity. The base station 110 includes a number of antennas that is equal to or greater than the number of antennas of any one of WTRUs 120a, 120b being served by the base station 110 with the virtual MIMO scheme, (i.e., the base station 110 includes at least two (2) antennas). The channel estimator 124 generates a channel matrix for WTRUs 120a, 120b. The receiver 126 processes the signals from the WTRUs 120a, 120b using the channel matrix. The receiver 126 may use a linear minimum mean square error (LMMSE) technique to recover the data for each of the WTRUs 120a, 120b. With this scheme, the virtual MIMO technique can be extended to WTRUs having more than one antenna.

[0022] The WTRUs 120a, 120b may implement transmit eigen-beamforming, transmit precoding (either codebook-based or non-codebook-based), spatial multiplexing, diversity techniques including space time block coding (STBC), space frequency block coding (SFBC), cyclic delay diversity (CDD), or

combinations of these techniques. For the eigen-beamforming or transmit precoding, the base station may send a decomposed channel matrix, (i.e., V matrix obtained from decomposing the channel matrix by singular value decomposition (SVD) or similar operation), to the WTRUs. The system capacity is increased using a smaller number of MIMO antennas at the WTRU, (e.g., 2 antennas at the WTRU 120a, 120b).

[0023] Some WTRUs may only support one spatial stream. (i.e., having only one antenna), while the remainder of WTRUs may support more than one spatial stream, (i.e., having more than one antenna). With this scheme, the base station is given much more flexibility compared to single antenna virtual MIMO due to the added virtual channel dimensions. Potential reduced inter-cell interference is another benefit due to reduced transmission power requirements at the WTRU.

[0024] Embodiments.

[0025] 1. A method for implementing multi-user virtual MIMO in a wireless communication system including a base station and a plurality of WTRUs wherein the base station includes a plurality of antennas, and at least one of said WTRUs includes at least two antennas, the number of antennas of the base station being not less than the number of antennas of any of the WTRUs.

[0026] 2. The method of embodiment 1 comprising the base station generating a channel matrix for the WTRUs.

[0027] 3. The method of embodiment 2 comprising the base station processing received signals from the WTRUs using the channel matrix.

[0028] 4. The method as in any one of embodiments 2-3, wherein the WTRUs perform a transmit precoding using the channel matrix.

[0029] 5. The method as in any one of embodiments 2-4, wherein the WTRUs perform eigen-beamforming using the channel matrix.

[0030] 6. The method as in any one of embodiments 2-5, wherein the WTRUs perform transmit diversity.

[0031] 7. The method of embodiment 6, wherein the WTRUs perform at least one of STBC, SFBC, and CDD.

- [0032] 8. The method as in any one of embodiments 2-7, wherein at least one of the WTRUs supports only one spatial stream and the rest of the WTRUs support at least two spatial streams.
- [0033] 9. The method as in any one of embodiments 2-7, wherein the base station and the WTRUs implement SC-FDMA.
- [0034] 10. The method as in any one of embodiments 2-7, wherein the base station and the WTRUs implement OFDMA.
- [0035] 11. The method as in any one of embodiments 2-7, wherein the base station and the WTRUs implement MC-OFDMA.
- [0036] 12. A wireless communication system for implementing multi-user virtual MIMO.
- [0037] 13. The system of embodiment 12 comprising a plurality of WTRUs, at least one WTRU having at least two antennas.
- [0038] 14. The system of embodiment 13 comprising a base station, wherein the base station comprises a plurality of antennas, the number of the base station antennas being not less than the number of antennas of any of the WTRUs.
- [0039] 15. The system of embodiment 14 wherein the base station comprises a channel estimator for generating a channel matrix for the WTRUs.
- [0040] 16. The system of embodiment 15 wherein the base station comprises a receiver for processing signals transmitted from the WTRUs using the channel matrix.
- [0041] 17. The system as in any one of embodiments 15-16, wherein the WTRUs perform transmit precoding using the channel matrix.
- [0042] 18. The system as in any one of embodiments 15-17, wherein the WTRUs perform eigen-beamforming using the channel matrix.
- [0043] 19. The system as in any one of embodiments 15-18, wherein the WTRUs perform transmit diversity.
- [0044] 20. The system of embodiment 19, wherein the WTRUs perform at least one of STBC and SFBC.

- [0045] 21. The system as in any one of embodiments 13-20, wherein at least one of the WTRUs supports only one spatial stream and the rest of the WTRUs support at least two spatial streams.
- [0046] 22. The system as in any one of embodiments 13-21, wherein the base station and the WTRUs implement SC-FDMA.
- [0047] 23. The system as in any one of embodiments 13-21, wherein the base station and the WTRUs implement OFDMA.
- [0048] 24. The system as in any one of embodiments 13-21, wherein the base station and the WTRUs implement MC-OFDMA.
- [0049] 25. The system as in any one of embodiments 13-24, wherein the WTRUs selectively transmit the signals using one of a single stream MIMO and a multi-stream MIMO.
- [0050] 26. A base station for implementing multi-user virtual MIMO for a plurality of WTRUs wherein at least one WTRU has at least two antennas.
- [0051] 27. The base station of embodiment 26 comprising a plurality of antennas, the number of the base station antennas being not less than the number of antennas of any of the WTRUs.
- [0052] 28. The base station of embodiment 27 comprising a channel estimator for generating a channel matrix for the WTRUs.
- [0053] 29. The base station of embodiment 28 comprising a receiver for processing signals from the WTRUs using the channel matrix.
- [0054] 30. The base station of embodiment 29 wherein the receiver is configured to process the signals that are processed for transmit precoding by the WTRUs using the channel matrix.
- [0055] 31. The base station as in any one of embodiments 29-30, wherein the receiver is configured to process the signals that are processed for eigen-beamforming by the WTRUs using the channel matrix.
- [0056] 32. The base station as in any one of embodiments 29-31, wherein the receiver is configured to process the signals that are processed for transmit diversity by the WTRUs.

[0057] 33. The base station of embodiment 32, wherein the receiver is configured to process the signals that are processed for at least one of STBC, SFBC, and CDD by the WTRUs.

[0058] 34. The base station as in any one of embodiments 27-33, wherein at least one of the WTRUs supports only one spatial stream and the rest of the WTRUs support at least two spatial streams.

[0059] 35. The base station as in any one of embodiments 27-34, wherein the base station implements SC-FDMA.

[0060] 36. The base station as in any one of embodiments 27-34, wherein the base station implements OFDMA.

[0061] 37. The base station as in any one of embodiments 27-34, wherein the base station implements MC-OFDMA.

[0062] Although the features and elements of the present invention are described in the preferred embodiments in particular combinations, each feature or element can be used alone without the other features and elements of the preferred embodiments or in various combinations with or without other features and elements of the present invention. The methods or flow charts provided in the present invention may be implemented in a computer program, software, or firmware tangibly embodied in a computer-readable storage medium for execution by a general purpose computer or a processor. Examples of computer-readable storage mediums include a read only memory (ROM), a random access memory (RAM), a register, cache memory, semiconductor memory devices, magnetic media such as internal hard disks and removable disks, magneto-optical media, and optical media such as CD-ROM disks, and digital versatile disks (DVDs).

[0063] Suitable processors include, by way of example, a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs) circuits, any other type of integrated circuit (IC), and/or a state machine.

[0064] A processor in association with software may be used to implement a radio frequency transceiver for use in a wireless transmit receive unit (WTRU), user equipment (UE), terminal, base station, radio network controller (RNC), or any host computer. The WTRU may be used in conjunction with modules, implemented in hardware and/or software, such as a camera, a video camera module, a videophone, a speakerphone, a vibration device, a speaker, a microphone, a television transceiver, a hands free headset, a keyboard, a Bluetooth® module, a frequency modulated (FM) radio unit, a liquid crystal display (LCD) display unit, an organic light-emitting diode (OLED) display unit, a digital music player, a media player, a video game player module, an Internet browser, and/or any wireless local area network (WLAN) module.

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CLAIMS

What is claimed is:

1. A method for implementing multi-user virtual multiple-input multiple-output (MIMO) comprising:
 - allocating a subgroup of base station antennas to each of a plurality of wireless transmit/receive units (WTRUs);
 - generating a multipath channel matrix for each WTRU;
 - generating a MIMO channel matrix between antennas of the WTRUs and the base station antennas comprising the multipath channel matrices for each WTRU; and
 - processing received signals from the WTRUs using the MIMO channel matrix.
2. The method of claim 1 wherein a transmit precoding is performed using the MIMO channel matrix.
3. The method of claim 1 wherein eigen-beamforming is performed using the MIMO channel matrix.
4. The method of claim 1 wherein transmit diversity processing is performed.
5. The method of claim 4 wherein at least one of space time block coding (STBC), space frequency block coding (SFBC), and cyclic delay diversity (CDD) is performed.
6. The method of claim 1 wherein single carrier frequency division multiple access (SC-FDMA) is implemented.

7. The method of claim 1 wherein orthogonal frequency division multiple access (OFDMA) is implemented.
8. The method of claim 1 wherein multi-carrier orthogonal frequency division multiple access (MC-OFDMA) is implemented.
9. A base station for implementing multi-user virtual multiple-input multiple-output (MIMO) for a plurality of wireless transmit/receive units (WTRUs), the base station comprising:
 - a plurality of base station antennas;
 - a controller for allocating a subgroup of the base station antennas to each of a plurality of WTRUs;
 - a channel estimator for generating a multipath channel matrix for each WTRU, and generating a MIMO channel matrix between antennas of the WTRUs and the base station antennas comprising the multipath channel matrices for each WTRU; and
 - a transceiver for transmitting and receiving signals to and from the WTRUs using the MIMO channel matrix.
10. The base station of claim 9 wherein the transceiver is configured to implement transmit precoding using the MIMO channel matrix.
11. The base station of claim 9 wherein the transceiver is configured to perform eigen-beamforming using the MIMO channel matrix.
12. The base station of claim 9 wherein the transceiver is configured to perform transmit diversity processing.

13. The base station of claim 12 wherein the transceiver is configured to perform at least one of space time block coding (STBC), space frequency block coding (SFBC), and cyclic delay diversity (CDD).
14. The base station of claim 9 wherein the transceiver implements single carrier frequency division multiple access (SC-FDMA).
15. The base station of claim 9 wherein the transceiver implements orthogonal frequency division multiple access (OFDMA).
16. The base station of claim 9 wherein the transceiver implements multi-carrier orthogonal frequency division multiple access (MC-OFDMA).