US 20070041322A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2007/0041322 A1**

Choi et al. (43) **Pub. Date: Feb. 22, 2007**

(54) **RATE ADAPTATION USING SEMI-OPEN LOOP TECHNIQUE**

(76) Inventors: **Won-Joon Choi**, Santa Clara, CA (US); **Ning Zhang**, Santa Clara, CA (US); **Huanchun Ye**, Santa Clara, CA (US); **Jeffrey M. Gilbert**, Santa Clara, CA (US)

Correspondence Address:
BEVER HOFFMAN & HARMS, LLP
2099 GATEWAY PLACE
SUITE 320
SAN JOSE, CA 95110 (US)

(21) Appl. No.: **11/329,979**

(22) Filed: **Jan. 10, 2006**

Related U.S. Application Data

(60) Provisional application No. 60/643,459, filed on Jan. 12, 2005.

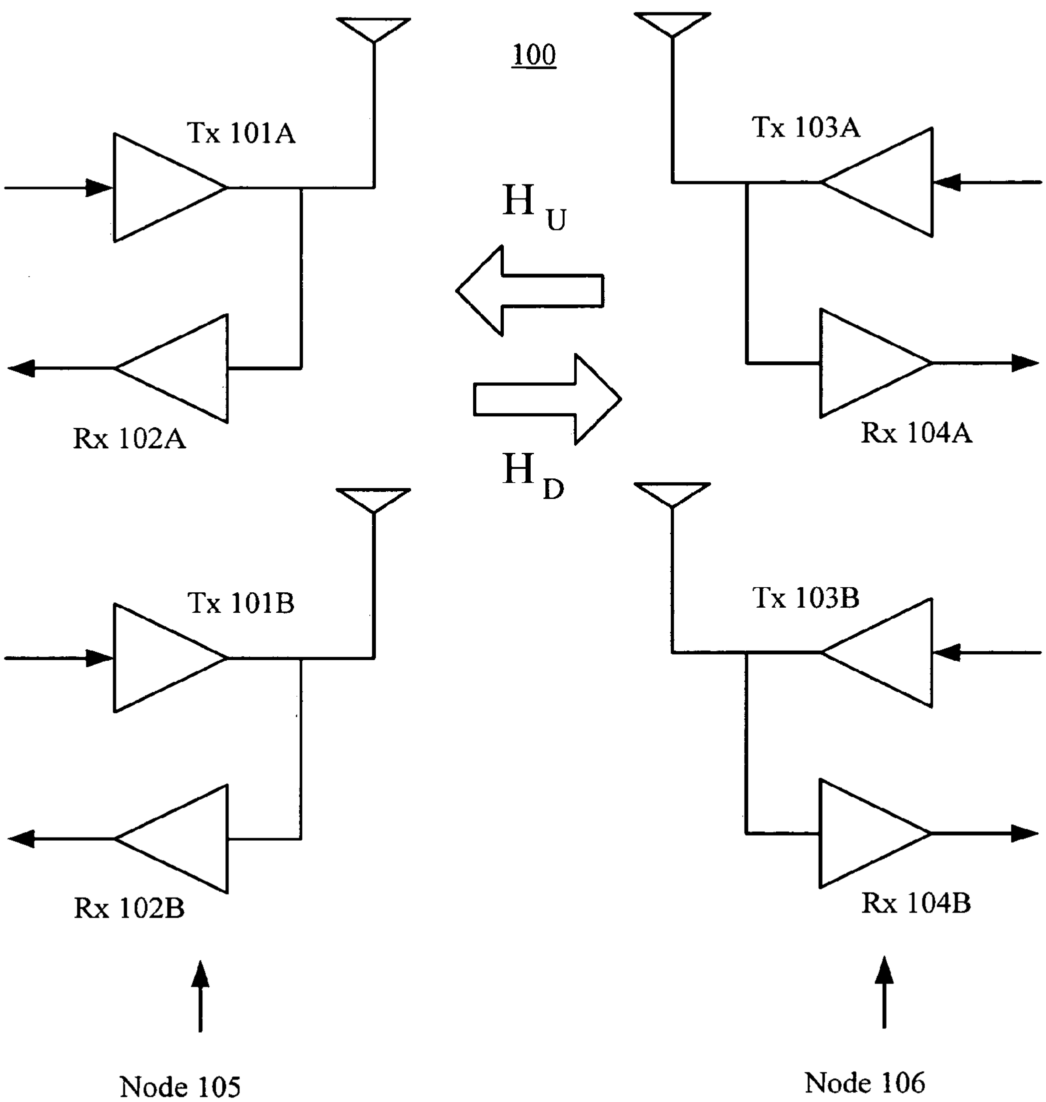
Publication Classification

(51) **Int. Cl.**
H04J 1/16 (2006.01)

(52) **U.S. Cl.** **370/235**; 370/252

(57) **ABSTRACT**

In a semi-open loop rate adaptation scheme for a multiple-input multiple-output (MIMO) system, a transmitter can advantageously use one or more quality metrics of an uplink as well as knowledge of device characteristics of both ends to perform fast and accurate rate adaptation.



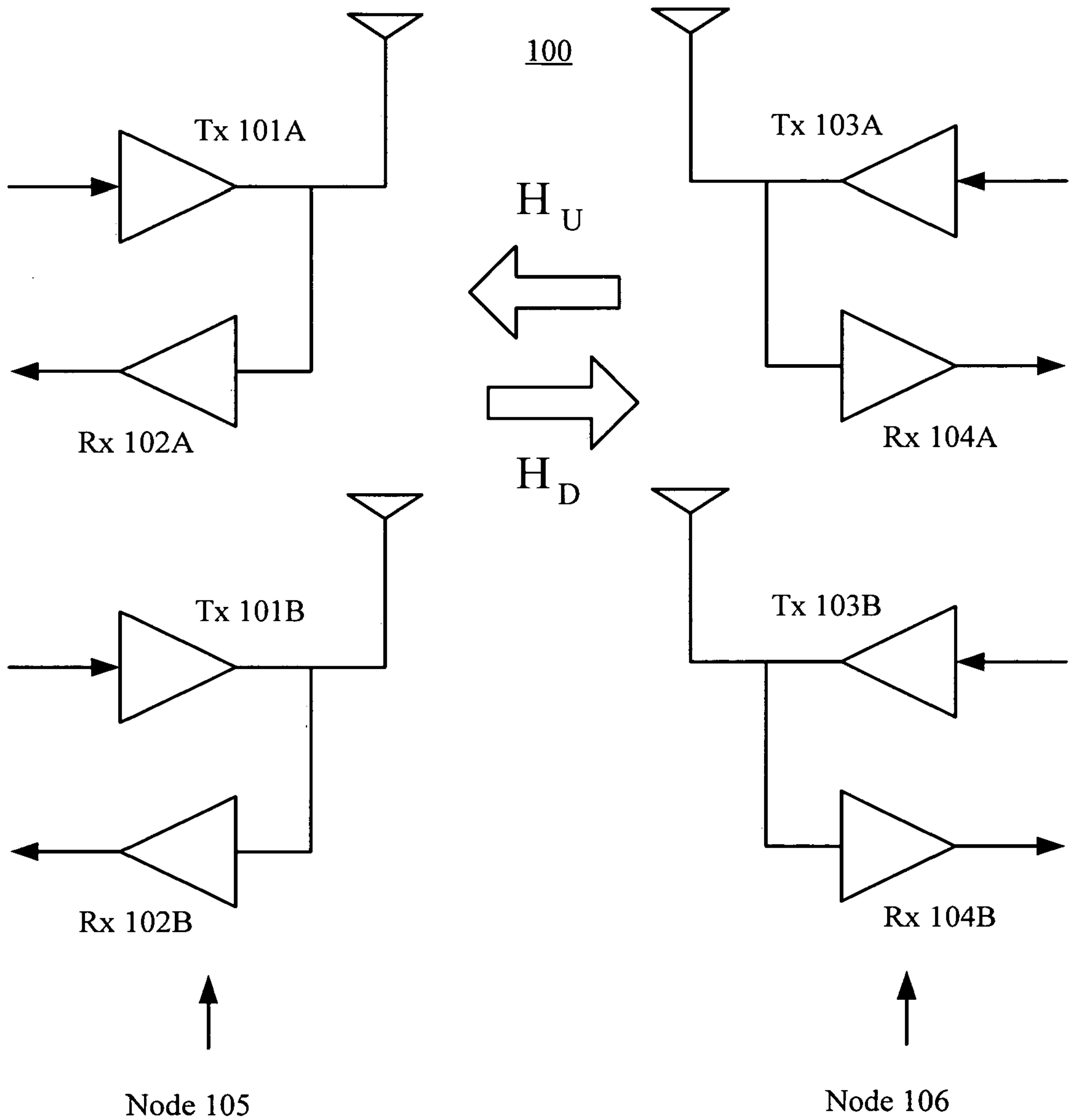

100
Tx 101A
Rx 102A
Tx 103A
Rx 104A
H U
H D
Tx 101B
Rx 102B
Tx 103B
Rx 104B
Node 105
Node 106

Figure 1

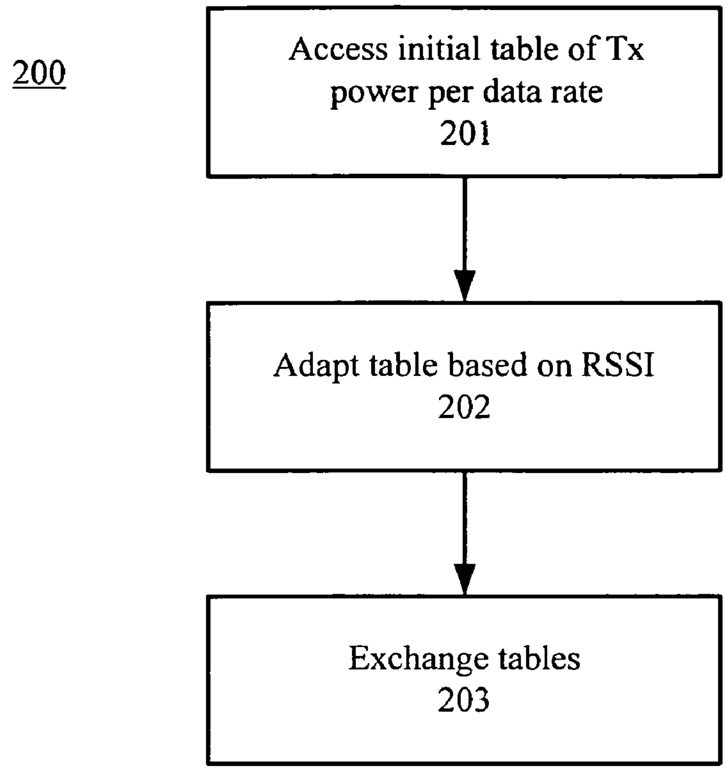


Figure 2

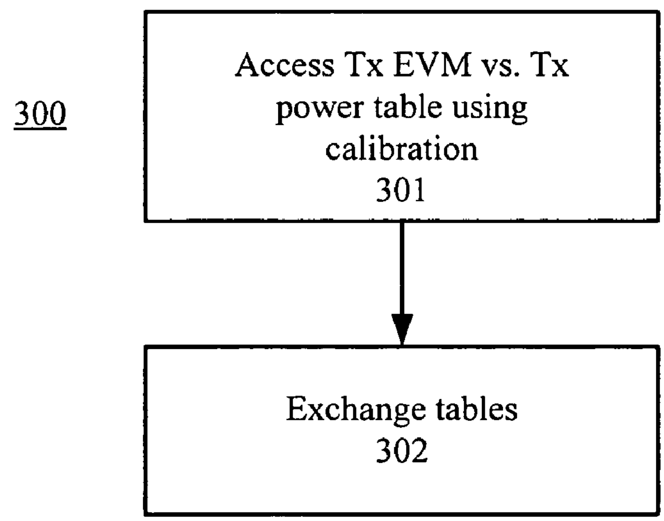


Figure 3

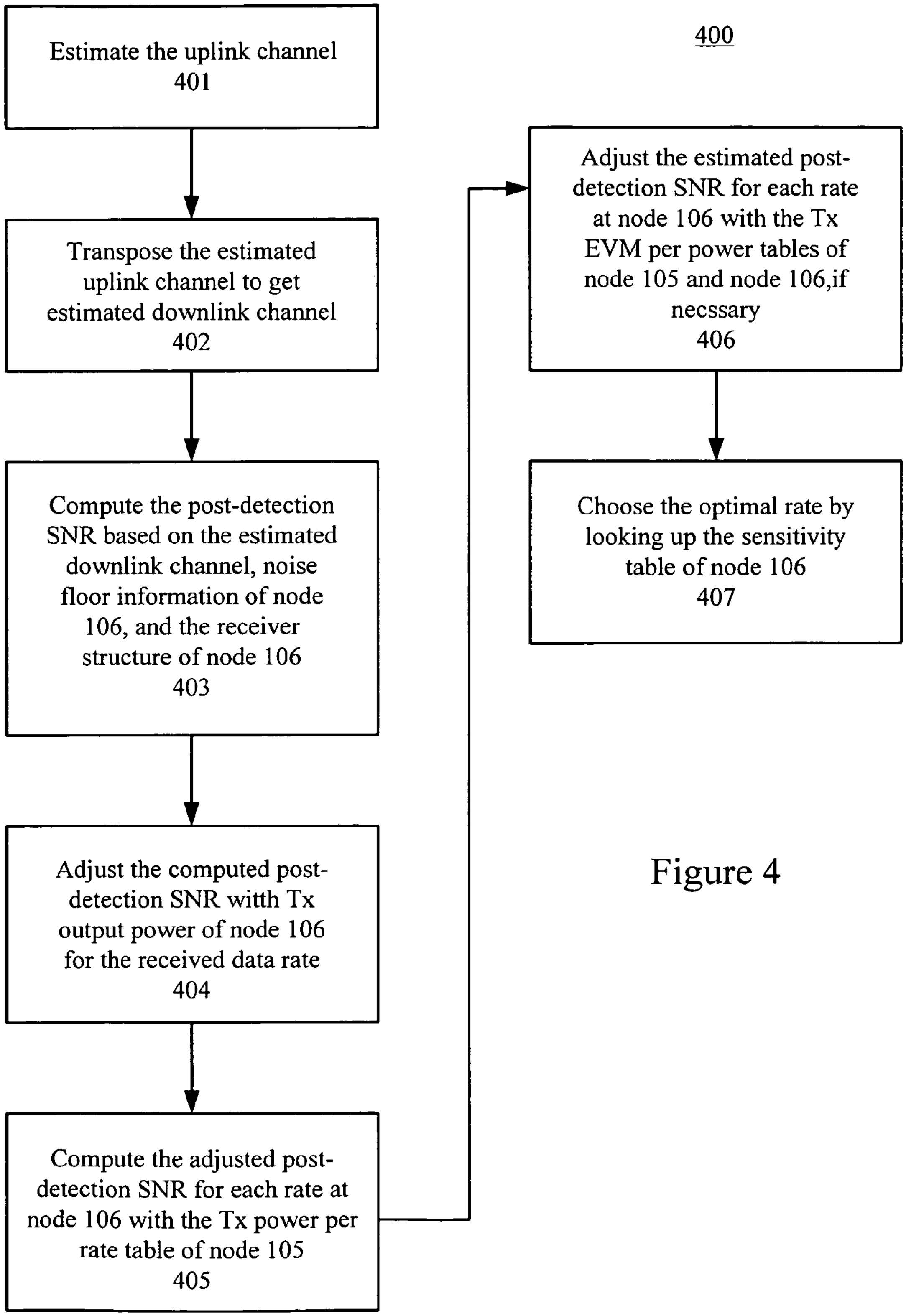

400
Estimate the uplink channel
401
Transpose the estimated uplink channel to get estimated downlink channel
402
Compute the post-detection SNR based on the estimated downlink channel, noise floor information of node 106, and the receiver structure of node 106
403
Adjust the computed post-detection SNR with Tx output power of node 106 for the received data rate
404
Compute the adjusted post-detection SNR for each rate at node 106 with the Tx power per rate table of node 105
405
Adjust the estimated post-detection SNR for each rate at node 106 with the Tx EVM per power tables of node 105 and node 106,if necssary
406
Choose the optimal rate by looking up the sensitivity table of node 106
407

Figure 4

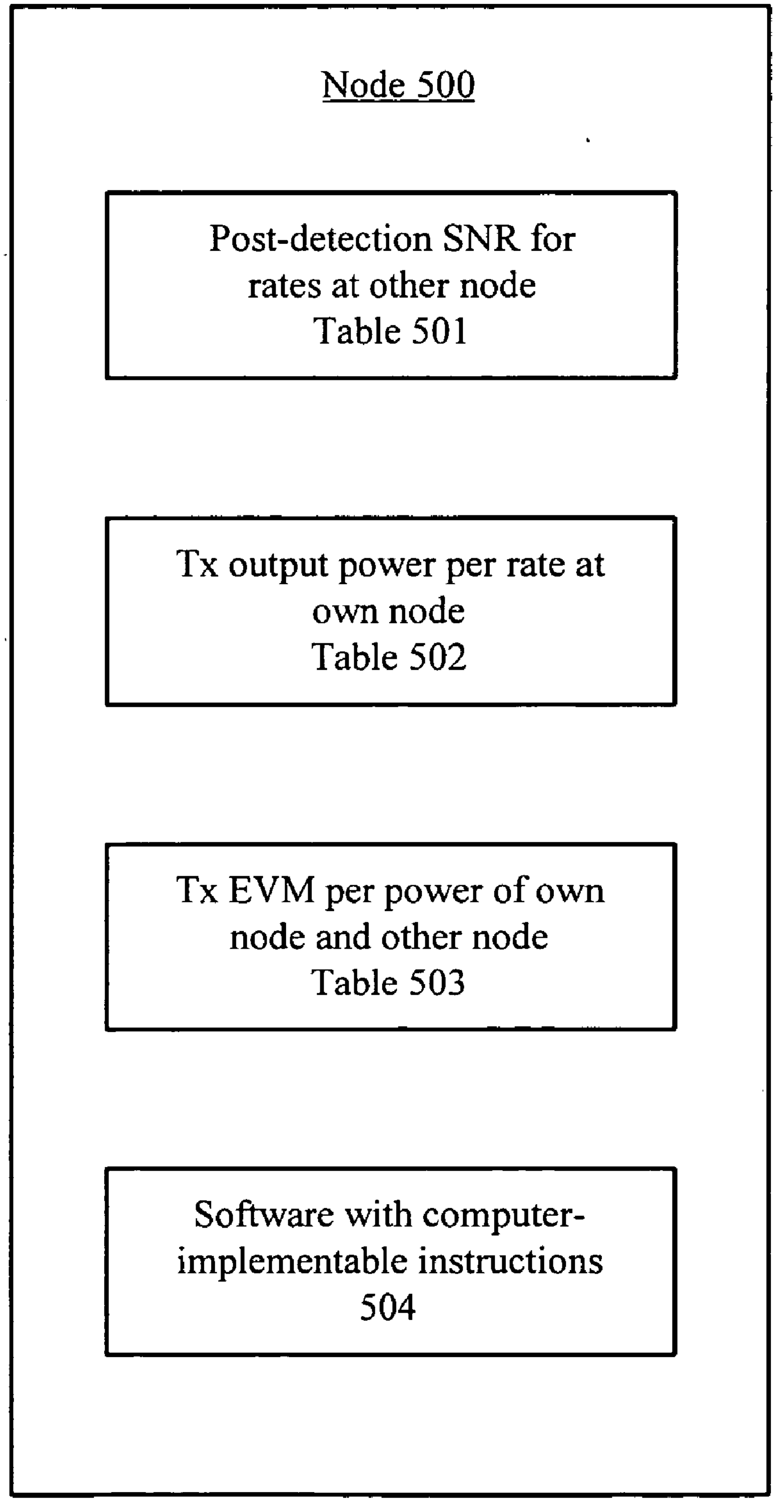

Node 500
Post-detection SNR for rates at other node Table 501
Tx output power per rate at own node Table 502
Tx EVM per power of own node and other node Table 503
Software with computer-implementable instructions 504

Figure 5

RATE ADAPTATION USING SEMI-OPEN LOOP TECHNIQUE

RELATED APPLICATIONS

[0001] This application claims priority of U.S. Provisional Patent Application 60/643,459, entitled "Rate Adaptation Using Semi-Open Loop Techniques" filed Jan. 12, 2005.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to rate adaptation in a wireless environment and in particular to using a semi-open loop technique to achieve an optimized rate.

[0004] 2. Related Art

[0005] Because the condition of a channel in a wireless environment varies over time, rate adaptation can be advantageously used to achieve optimized throughput in a system with multiple PHY (i.e. physical device) rates. Rate adaptation is especially important in a multiple-input multiple-output (MIMO) system because the number of streams introduces yet another dimension to the channel condition. In general, there are two categories of rate adaptation techniques: a closed-loop rate adaptation and an open-loop rate adaptation.

[0006] In the closed-loop rate adaptation, the intended receiver estimates some function of its receive signal (e.g. the channel state information (CSI)), and sends it back to the transmitter. The transmitter determines the optimized rate for its next transmission based on the feedback from the receiver. Unfortunately, this closed-loop rate adaptation has significant system overhead associated with determining the appropriate feedback.

[0007] In the open-loop rate adaptation, the transmitter uses trial and error to determine an optimized rate. Thus, the open-loop rate adaptation scheme does not incur any feedback overhead. However, because the transmitter receives no feedback from the receiver, the rate is typically slow to change and can result in errors as incorrect rates are selected.

[0008] Therefore, a need arises for a fast and accurate rate adaptation technique that minimizes system overhead.

SUMMARY OF THE INVENTION

[0009] A method for quickly and accurately adapting a rate in a multiple-input multiple-output (MIMO) system while minimizing system overhead is described. This system can include first and second nodes in which transmissions from the first node to the second node are on a "downlink channel" and transmissions from the second node to the first node are on an "uplink channel". Each node in the MIMO system can include multiple transmitters and receivers.

[0010] In this method, the first node can estimate the uplink channel using a packet sent by the second node to the first node. This uplink channel can be transposed to provide an estimated downlink channel. The first node can use transmitter and receiver characteristics from both the first and second nodes and the estimated downlink channel to accurately adapt the rate. Notably, the receiver characteristics can include the sensitivity of the second node.

[0011] In one embodiment, using the transmitter and receiver characteristics can include computing a post-detection signal to noise ratio (SNR) of the second node based on the estimated downlink channel, noise floor information from the second node, and a receiver structure of the second node. This post-detection SNR can be adjusted with a transmit output power of the second node for a received data rate of the packet. After the adjusting, an estimated post-detection SNR for each rate at the second node can be computed using the transmitter power per rate of the first node, thereby building a sensitivity table for the second node. If the transmitter EVM is not negligible, then the estimated post-detection SNR for each rate at the second node can be adjusted with a transmitter EVM per power of the first and second nodes.

[0012] The first node can use the sensitivity table to choose the optimized rate. In one embodiment, using the sensitivity table can include choosing the highest rate whose estimated post-detection SNR is larger than a threshold SNR.

[0013] A node that can quickly and accurately adapting its rate in a MIMO system is also described. This node includes various tables that can be accessed by software with computer-implementable instructions. Specifically, the node can include a table that indicates the post-detection SNR for rates at another node in the MIMO system. The node can further include a table that indicates transmitter output power per rate at the node as well as a table that indicates a transmitter EVM per power of the node and the other node. Notably, the node can further include software with computer-implementable instructions for accessing the above-described tables and performing the above-described steps.

BRIEF DESCRIPTION OF THE FIGURES

[0014] FIG. **1** illustrates a simplified multiple-input multiple-output (MIMO) system.

[0015] FIG. **2** illustrates one technique that can be used to obtain the transmit power information per data rate.

[0016] FIG. **3** illustrates a technique for accessing and using a transmitter EVM versus transmitter power table.

[0017] FIG. **4** illustrates an exemplary technique that can accurately evaluate the downlink quality of a channel in a MIMO system.

[0018] FIG. **5** illustrates a node including various tables that can be accessed by software with computer-implementable instructions.

DETAILED DESCRIPTION OF THE FIGURES

[0019] In a semi-open loop rate adaptation scheme for a multiple-input multiple-output (MIMO) system, a transmitter can advantageously use one or more quality metrics of an uplink as well as knowledge of transmitter/receiver characteristics of both nodes to perform fast and accurate rate adaptation. FIG. **1** illustrates a simplified MIMO system **100** in which the semi-open loop rate adaptation technique can be used. In MIMO system **100**, each transceiver includes a plurality of transmitters (Txs) and receivers (Rxs). For example, a first transceiver, referenced as node **105**, can include transmitters **101**A and **101**B as well as receivers **102**A and **102**B. A second transceiver, referenced as node

106, can include transmitters **103**A and **103**B as well as receivers **104**A and **104**B. Note that each transmitter/receiver pair, e.g. transmitter **101**A/receiver **102**A, shares an antenna.

[**0020**] MIMO system **100** can divide a data stream into multiple unique streams. Node **105** can modulate each of these multiple streams and then simultaneously transmit each stream through a different antenna in the same frequency channel. By leveraging multipath, i.e. reflections of the signals, each MIMO receive chain of node **106** can be a linear combination of the multiple transmitted data streams. Node **106** can separate these data streams using MIMO algorithms that rely on estimates of the channels between node **105** and **106**.

[**0021**] For purposes of understanding the semi-loop rate adaptation technique, a transmission from node **105** to node **106** is referenced herein as a "downlink" whereas a transmission from node **106** to node **105** is referenced as an "uplink". Note that the terms downlink and uplink merely describe the signal flow direction in a physical channel. Notably, the physical channels between node **105** and node **106** are reciprocal (i.e. exhibit the same characteristics) as long as both downlink and uplink channels use the same frequency. In a mathematical notation, channel reciprocity is represented by $H_D=H_U^T$, where H_D is the downlink channel (i.e. from node **105** to node **106**), and H_U is the uplink channel (i.e. from node **106** to node **105**).

[**0022**] With channel reciprocity, node **105** can estimate the uplink channel from the packets sent by node **106**, and transpose it to obtain the downlink channel, as long as the uplink and downlink packet use the same number of streams. For example, if an ACK (acknowledgment) packet is used as the uplink packet, then the ACK packet needs to be sent using the same number of streams as the downlink packet. (Note that an ACK packet may be sent using a data rate lower than that used to transmit a data packet. Additionally, the ACK packet may or may not be sent using the same power that is typically used for this lower rate.)

[**0023**] Notably, while the physical channel is reciprocal, the radio frequency (RF) circuits in nodes **105** and **106** may not be. Specifically, the optimized rate for the downlink from node **105** to node **106** should be a function of transmitter **101**A/**101**B, the channel from node **105** to node **106**, and receiver **104**A/**104**B. In contrast, the optimized rate of the uplink measured at node **105** should be a function of transmitter **103**A/**103**B, the channel from node **106** to node **105**, and receiver **102**A/**102**B.

[**0024**] Therefore, in accordance with one aspect of the invention, node **105** can use the transmitter and receiver characteristics of both nodes **105** and **106** to estimate the uplink quality and then compute the equivalent downlink quality. Nodes **105** and **106** can exchange these transmitter and receiver characteristics initially and/or periodically.

Transmitter Characteristics

[**0025**] In one embodiment, the transmitter characteristics can include the transmitter output power per data rate and the transmitter EVM (error vector magnitude) per transmitter output power. With respect to transmitter output power, the power amplifiers of transmitters **101**A/**101**B (node **105**) and **103**A/**103**B (node **106**) may be asymmetrical, thereby resulting in different transmit powers delivered by each node. Moreover, to add complexity to this asymmetry, the transmit power of a power amplifier can vary per rate and the tolerance of power amplifier non-linearity can depend on the data rate as well as power amplifier implementation specifics. Therefore, to accurately capture the equivalent downlink quality by estimating the uplink quality, node **105** should know the transmit power information per data rate for node **106**.

[**0026**] FIG. **2** illustrates one technique **200** that can be used to obtain the transmit power information per data rate. In step **201**, an initial table of transmitter power per data rate can be accessed. In one embodiment, this table can include the worst-case output power vs. rate characteristics. These characteristics can be determined through lab bench testing, for example. Therefore, in one embodiment, this information can be created in step **201**. In another embodiment, a vendor can provide this information, thereby allowing immediate use of the table.

[**0027**] In step **202**, this table can be slowly adapted, if necessary, based on receiver RSSI (receiver signal strength indicator) measurements. For example, in one embodiment, the transmit power for the highest rate can be reduced if an ACK RSSI is more than enough to improve a transmit EVM.

[**0028**] In step **203**, the transmit power information per data rate tables at the two nodes can be exchanged. That is, the downlink/uplink designation shown in FIG. **1** is from the perspective of node **105**. An opposite relationship can be defined from the perspective of node **106**. Thus, steps **201**, **202**, and **203** can be performed at each node in the wireless network. In one embodiment, the transmit power per data rate tables can be exchanged at an initial link setup. In another embodiment, these tables can be updated periodically during operation of the wireless network. Table 1 indicates exemplary transmit powers for various data rates (referenced as MCS**0**-MCS**7**).

TABLE 1

Transmit Power Per Data Rate

Data Rate (MCS)	Transmit Power (dBm)
MCS0	20
MCS1	20
MCS2	20
MCS3	18
MCS4	18
MCS5	17
MCS6	15
MCS7	14

[**0029**] With respect to transmitter EVM per transmitter output power, the transmitter EVM generally depends on the transmit power due to power amplifier non-linearity. Because transmitter EVM per transmit power is determined by the characteristics of the power amplifier and each node can use different power amplifiers, transmitter EVM information per transmit power can also be exchanged in one embodiment of the invention.

[**0030**] FIG. **3** illustrates a technique **300** for accessing and using a transmitter EVM versus transmitter power table. In step **301**, a transmitter EVM vs. transmitter power table can be accessed. In one embodiment, the transmitter EVM vs. transmitter power table can be created during manufacturing.

[0031] Note that this transmitter EVM vs. transmitter power table can include a temperature variation lookup. To use this temperature variation lookup, a temperature sensor can be positioned close to the power amplifier. The temperature difference between the sensor temperature and the room temperature (or, alternatively, the temperature at which the manufacturing calibration was done) can be used to lookup the EVM difference.

[0032] In one embodiment, the information in the transmitter EVM vs. transmitter power table can include an initial table based on the calibration temperature, a temperature correction table, and a current temperature. In one embodiment, part-to-part temperature variations can be calibrated during manufacturing, and an average temperature characteristic can be used for all parts. In this manner, only one temperature correction table, based on average temperature characteristics, need be generated.

[0033] In another embodiment, step **301** can include a continuous calibration during operation of the device. For example, if feedback from the receiver node is supported, then an EVM can be measured at the receiver node any time a packet is transmitted at any output power level. In one embodiment, to build a complete transmitter EVM vs. transmitter power table, the transmissions can cover all the possible output power levels being used within a given time window (during which the temperature change is negligible).

[0034] In step **302**, the tables can be exchanged at an initial link setup between the nodes. In one embodiment, the transmitter EVM vs. transmitter power table can be updated periodically during operation of the wireless network.

[0035] Note that the above-described transmitter output power per data rate table and the transmitter EVM per transmitter output power table can be combined into a single transmitter EVM per data rate table. Table 2 indicates EVMs for various data rates (referenced as MCS**0**-MCS**7**).

TABLE 2

EVM Per Data Rate

Data Rate (MCS)	Transmit power (dBm)
MCS0	−5
MCS1	−10
MCS2	−13
MCS3	−16
MCS4	−19
MCS5	−22
MCS6	−25
MCS7	−27

Receiver Characteristics

[0036] In accordance with one aspect of the invention, the receiver sensitivity, which can be defined as performance per rate, can also be exchanged. Note that the receiver architecture can determine the ease of defining the sensitivity for MIMO systems. In one embodiment, the SNR per stream can be defined after-an equalizer in the receiver chain, which is sometimes called "post-detection SNR", which advantageously measures the effect of the equalizer.

[0037] The post-detection SNR per stream can be calculated from the channel and the noise floor with a priori knowledge of the MIMO receiver. For example, if a linear receiver including an MMSE (minimum mean square error) detector is used, the post-detection SNR per stream can be derived as follows.

[0038] In the downlink transmission from node **105** to node **106**, the error covariance matrix of the linear MMSE receiver at node **106** can be defined by the equation:

$$R_e=\delta^2(H_D^*H_D+\delta^2 I)^{-1}$$

[0039] where δ^2 is the noise variance at a receiver of node **106**.

[0040] The post-detection SNR for a stream i can then be computed using the equation:

$$SNR_i = \frac{1}{r_{e,i}} - 1$$

[0041] where $r_{e,i}$ is the i^{th} diagonal element. (Note that R_e is an N×N matrix where N is the number of streams and the diagonal elements of the matrix are elements (1,1), (2,2), . . . (N,N) of R_e.)

[0042] The receiver sensitivity per rate table can be defined as the post-detection SNR per rate for a given PER (packet error rate). This table can be obtained through lab bench testing or updated periodically based on packet error statistics. In one embodiment, the receiver sensitivity per rate table can be divided into two parts: (1) post-detection SNR to SNR at the decision (i.e. the demodulator) device, and (2) the SNR at the decision device per rate for a given PER. A simple form of the first mapping could be a linear function with clipping (i.e. y=min(x,y_max), where y_max is the maximum SNR achievable in the system given the implementation loss). The second mapping can be obtained by simulations and/or lab bench testing, and will be updated periodically based on packet error statistics.

[0043] Note that the SNR at the decision device can be important because the post-detection SNR may not represent the full effects of circuit impairments (e.g. dynamic range, phase noise, etc.). The SNR at the decision device can be measured either by computing EVM with pilots (known signals) or by computing EVM with the data.

Rate Adaptation

[0044] FIG. **4** illustrates an exemplary technique **400** that node **105** (FIG. **1**) can use to evaluate the link quality from node **105** to node **106** (i.e. the downlink quality) by estimating the link quality from node **106** to node **105** (i.e. the uplink quality). In technique **400**, while relying on channel reciprocity, node **105** can calibrate the differences in Tx/Rx characteristics between node **105** and node **106** to assess a more accurate downlink quality.

[0045] In step **401**, node **105** can estimate the uplink channel using channel estimation (i.e. CSI) based on the preamble (i.e. training fields). In step **402**, node **105** can transpose the estimated uplink channel (i.e. by making row elements into column elements and vice versa) to get the downlink channel. In step **403**, node **105** can compute the post-detection SNR of node **106** based on the downlink channel, the noise floor information of node **106** (as measure by node **106** and provided to node **105**), and the receiver structure of node **106** (e.g. like the type of channel equalizer: MMSE equalizer or ZF equalizer, or another type of structure). In step **404**, node **105** can adjust the computed post-detection SNR with the transmitter output power of node **106** for the received data rate. In step **405**, node **105** can compute the post-detection SNR for each rate at node **106** with the transmitter power per rate table of node **105**, thereby building a sensitivity table for node **106**. In step **406** (in one embodiment, an optional step), node **105** can adjust the estimated post-detection SNR for each rate at node **106** with the transmitter EVM per power tables of node **105** and node **106**, if necessary (e.g. when the transmitter EVM is not negligible (e.g. if the EVM is more than 10 dB below the SNR). In step **407**, node **105** can choose the optimized rate by referring to the post-detection SNR per rate table of node **106**. In one embodiment, the optimized rate is the highest rate whose estimated post-detection SNR is larger than the required (i.e. the minimum SNR to get to less than 10% PER).

[**0046**] FIG. **5** illustrates a node **500** including various tables that can be accessed by software with computer-implementable instructions. Specifically, node **500** can include a table **501** that indicates the post-detection SNR for rates at node **106** (FIG. **1**). This table is also called a sensitivity table herein. Node **500** can further include a table **502**, which indicates transmitter output power per rate at node **105**, as well as a table **503**, which indicates a transmitter EVM per power of nodes **105** and **106**. Tables **501**, **502**, **503** can be stored using any standard memory devices or structures. Notably, node **500** can further include software **504** with computer-implementable instructions (residing on a computer-readable medium) for accessing tables **501**, **502**, and **503** and performing technique **400** (FIG. **4**).

Miscellaneous Probing

[**0047**] In accordance with one aspect of the invention, probing can be advantageously used to determine the optimized number of streams for the MIMO system, the guard intervals to be used for the packets forming those streams, and the bandwidth (i.e. 20/40 MHz) to be used.

[**0048**] The choice of the number of streams can significantly affect the success of rate adaptation. Notably, conventional channel estimation can readily determine that reducing the number of streams is appropriate. However, determining whether increasing the number of stream is appropriate can be difficult using standard techniques. In one embodiment, additional channel estimation can be performed using probes to determine if increasing the number of streams is appropriate. For example, to obtain more channel information, a device can periodically probe for a larger number of streams. As described above, if the uplink packet (e.g. an ACK packet) always uses the same number of streams as the downlink packet (e.g. a data packet), then the reverse channel can be advantageously estimated.

[**0049**] Orthogonal frequency division multiplexing (OFDM) can advantageously reduce multipath distortion in a MIMO system. Specifically, the densely packed subcarriers in the MIMO system are orthogonal to ensure non-interference even under multipath conditions. An OFDM symbol includes a fast Fourier transform (FFT) interval (from which the data is extracted) preceded by a guard interval. The guard interval can advantageously serve as a repository for echoes from the previous symbol, thereby preventing such echoes from adversely affecting the subsequent FFT interval. In one embodiment, the guard interval can be 800 ns in duration, which is commensurate with the longest indoor multipath. In another embodiment, the guard interval can be 400 ns in duration, which is commensurate with the longest indoor multipath of a home or small office environment. In yet another embodiment, the guard interval can be 1600 ns in duration, which is commensurate with the longest outdoor multipath. As used herein, the terms "half guard interval" and "full guard interval" refer to the 400 ns and 800 ns durations.

[**0050**] Because determining the appropriate guard interval is based on the operating environment (i.e. the delay spread of the channel) rather than fading, a rate table of various rates and their associated guard intervals can be developed over time. That is, the choice of guard interval can be different for each data rate because different data rates will have different sensitivities to multipath. Note that this rate table will depend on the environment, although the delay spread is assumed to be unchanged during the period. For example, in contrast to an outdoor environment, an indoor environment is relatively static.

[**0051**] In one embodiment, the guard interval choice can be determined by either measuring the channel flatness (e.g. how correlated is the channel from one bin to another bin. If the delay spread is small, then the channel variation is small. For example, a "0" delay spread channel is flat in the frequency domain. On the other hand, if the delay spread is large, then the channel varies significantly from bin to bin) directly (e.g. using channel estimations) and using this measurement as an index to determine which rates should use full guard intervals or reduced guard intervals. In another embodiment, packets can be sent with both full and reduced guard intervals. At this point, the EVMs associated with those packets and then the EVM difference between those two packets can be measured. The EVM difference can be used to determine if the impact to the EVM is sufficient to preclude the use of the most effective rates.

[**0052**] In one embodiment, the receiver that receives the packets can make this determination and provide feedback in a closed loop manner to the transmitter. In another embodiment, reciprocity can be used such that the uplink packets always use the same guard interval setting. In this case, the transmitter can estimate the flatness or EVM of the uplink packets when the downlink packets are sent using a different guard interval.

[**0053**] According to the IEEE 802.11 family of standards, which governs wireless communications, each frequency band includes a predetermined number of frequency channels. For example, the 2.4 GHz frequency band includes 14 channels, wherein each channel when occupied has a 22 MHz bandwidth and the center frequencies of adjacent channels are 5 MHz apart. In contrast, 5 GHz frequency band includes 12 channels, wherein each channel when occupied has a 20 MHz bandwidth and the center frequencies of adjacent channels are 20 MHz apart.

[**0054**] Notably, using a wider channel could advantageously increase capacity, i.e. the transfer rate. Specifically, a 40 MHz channel always has greater capacity than a 20 MHz channel, and increasingly so as the signal to noise ratio (SNR) increases. In one embodiment, the 20/40 MHz decision can be separate from the rate adaptation determination. There are three modes of operations: 40 MHz, mixed 40 MHz/20 MHz, and 20 MHz.

[0055] If no or minimal interference is present on the extension channel, then the device can operate in the 40 MHz mode. In this case, the receiver can perform dynamic 20/40 MHz detection on a packet-by-packet basis. In this mode, the transmitter can transmit 40 MHz packets unless certain conditions exist (e.g. the MAC times out due to 40 MHz CCA busy or multi-rate retry to send failing 40 MHz packets at 20 MHz). Note that 6 Mbps and 20 MHz is currently the last rate in the rate table.

[0056] If weak interference exists on the extension channel, then the device can operate in the mixed 20/40 MHz mode. In this case, the receiver can perform dynamic 20/40 MHz detection on a packet-by-packet basis. Note that although the transmitter can transmit 20 MHz packets, the carrier frequency can be set as if for 40 MHz transmission.

[0057] If heavy interference exists on the extension channel, then the device can operate solely in the 20 MHz mode. In this case, the carrier frequency can be set at the middle of the 20 MHz band, the receiver only detects 20 MHz packets, and the transmitter transmits only 20 MHz packets.

[0058] Switching between modes can be based on the long term sensing of extension channel activity. In one embodiment, switching between modes can be limited to be between the 40 MHz mode and the 40/20 MHz mixed mode or, alternatively, between the 40/20 MHz mixed mode and the 20 MHz mode.

[0059] Although illustrative embodiments of the invention have been described in detail herein with reference to the accompanying figures, it is to be understood that the invention is not limited to those precise embodiments. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed. As such, many modifications and variations will be apparent. For example, although a MIMO system is discussed in detail herein, semi-open technique **400** can be readily suited for any time division duplex (TDD) system. Accordingly, it is intended that the scope of the invention be defined by the following Claims and their equivalents.

1. A method for adapting a rate in a multiple-input multiple-output (MIMO) system, the system including a first node and a second node in which transmissions from the first node to the second node are on a downlink channel and transmissions from the second node to the first node are on an uplink channel, each node including multiple transmitters and receivers, the method for the first node comprising:

estimating the uplink channel using a packet sent by the second node to the first node;

transposing the uplink channel to provide an estimated downlink channel; and

using transmitter and receiver characteristics from the first and second nodes and the estimated downlink channel to accurately adapt the rate,

wherein the receiver characteristics include a sensitivity of the second node.

2. The method of claim 1, wherein the sensitivity of the second node includes a post-detection signal to noise ratio (SNR).

3. The method of claim 1, wherein the transmitter characteristics include an output power per data rate.

4. The method of claim 1, wherein the transmitter characteristics include an error vector magnitude (EVM) per output power.

5. The method of claim 1, wherein using the transmitter and receiver characteristics includes:

computing a post-detection signal to noise ratio (SNR) of the second node based on the estimated downlink channel, noise floor information from the second node, and a receiver structure of the second node.

6. The method of claim 5, wherein using the transmitter and receiver characteristics further includes:

adjusting the post-detection SNR with a transmit output power of the second node for a received data rate of the packet.

7. The method of claim 6, wherein using the transmitter and receiver characteristics further includes:

after the adjusting, computing an estimated post-detection SNR for each rate at the second node using the transmitter power per rate of the first node, thereby building a sensitivity table for the second node.

8. The method of claim 7, wherein using the transmitter and receiver characteristics further includes:

adjusting the estimated post-detection SNR for each rate at the second node with a transmitter EVM per power of the first and second nodes, if the transmitter EVM is not negligible.

9. The method of claim 7, wherein using the transmitter and receiver characteristics further includes:

choosing an optimized rate by using the sensitivity table for the second node.

10. The method of claim 9, wherein using the sensitivity table includes choosing a highest rate whose estimated post-detection SNR is larger than a threshold SNR.

11. A first node in a multiple-input multiple-output (MIMO) system, the system including a second node in which transmissions from the first node to the second node are on a downlink channel and transmissions from the second node to the first node are on an uplink channel, each node including multiple transmitters and receivers, the first node comprising software with computer-implementable instructions, the first node including:

instructions for estimating the uplink channel using a packet sent by the second node to the first node;

instructions for transposing the uplink channel to provide an estimated downlink channel; and

instructions for using transmitter and receiver characteristics from the first and second nodes and the estimated downlink channel to accurately adapt a rate,

wherein the receiver characteristics include a sensitivity of the second node.

12. The first node of claim 1, wherein the instructions for using the transmitter and receiver characteristics include:

instructions for computing a post-detection signal to noise ratio (SNR) of the second node based on the estimated downlink channel, noise floor information from the second node, and a receiver structure of the second node.

13. The method of claim 12, wherein the instructions for using the transmitter and receiver characteristics further include:

instructions for adjusting the post-detection SNR with a transmit output power of the second node for a received data rate of the packet.

14. The first node of claim 13, wherein the instructions for using the transmitter and receiver characteristics further include:

instructions for computing an estimated post-detection SNR for each rate at the second node using the transmitter power per rate of the first node, thereby building a sensitivity table for the second node.

15. The first node of claim 14, wherein the instructions for using the transmitter and receiver characteristics further include:

instructions for adjusting the estimated post-detection SNR for each rate at the second node with a transmitter EVM per power of the first and second nodes, if the transmitter EVM is not negligible.

16. The first node of claim 14, wherein the instructions for using the transmitter and receiver characteristics further include:

instructions for choosing an optimized rate by using the sensitivity table for the second node.

17. The first node of claim 16, wherein the instructions for using the sensitivity table include instructions for choosing a highest rate whose estimated post-detection SNR is larger than a threshold SNR.

18. A node in a multiple-input multiple-output (MIMO) system, the node comprising:

a first table that indicates a post-detection SNR for rates at another node in the MIMO system.

19. The node of claim 18, further including a second table that indicates transmitter output power per rate at the node.

20. The node of claim 19, further including a third table that indicates a transmitter EVM per power of the node and the other node.

21. The node of claim 20, further including software with computer-implementable instructions for accessing at least the first and second tables.

22. The node of claim 20, further including software with computer-implementable instructions for accessing the first, second, and third tables.

* * * * *