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(54) **COLLABORATIVE BEAM FORMING OF BASE TRANSCEIVER STATIONS FOR REDUCING INTERFERENCE IN A WIRELESS MULTI-CELL NETWORK**

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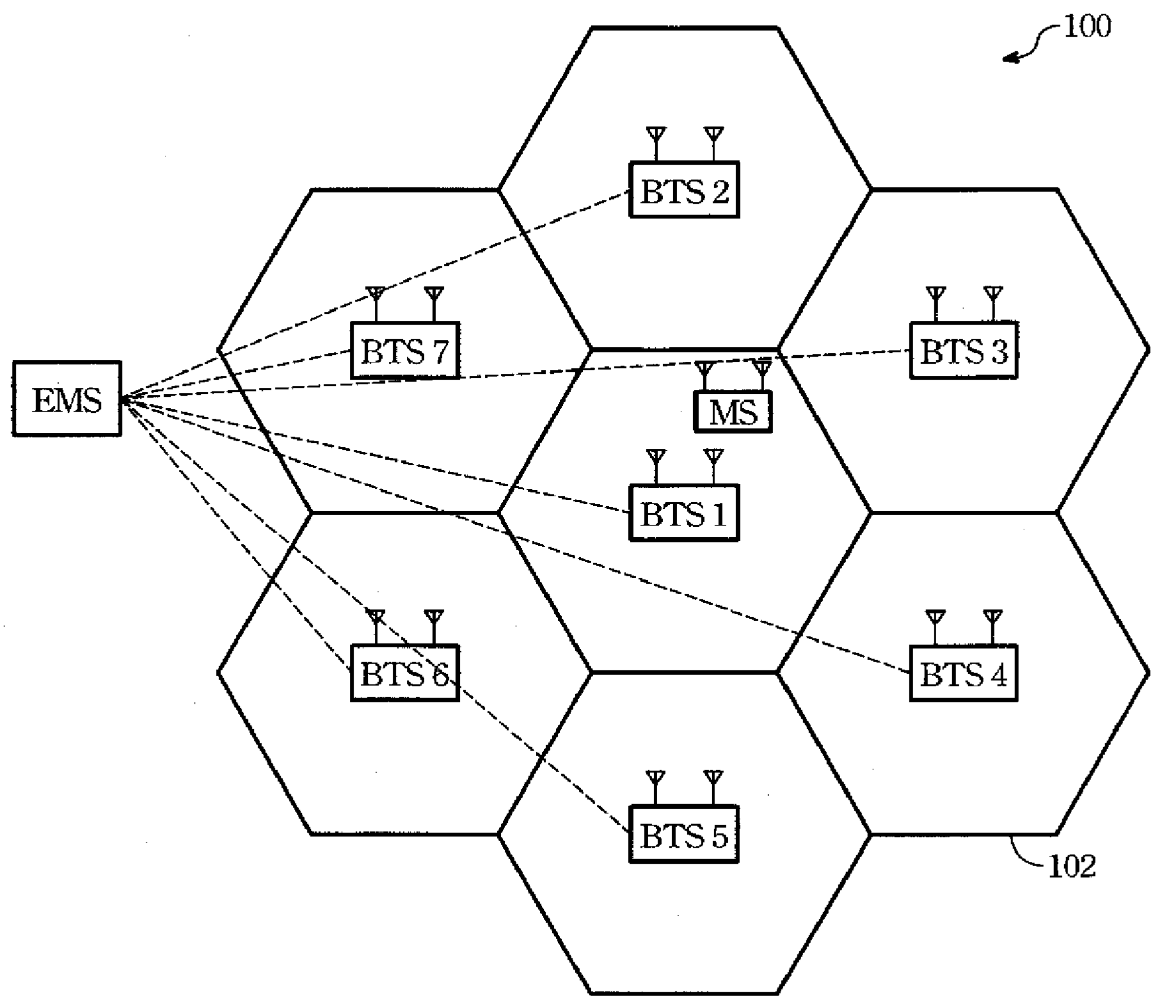
(57) **ABSTRACT**

A method of signal transmission and reception for a cellular wireless network includes steps of detecting signal strength of signals transmitted or received between a mobile station and a plurality of base transceiver stations; selecting a plurality of candidate serving base transceiver stations based on the detected signal strength; selecting a first group of serving base transceiver stations from the candidate serving base transceiver stations; and sending signals between the mobile station and the first group of serving base transceiver stations using beam forming technology to reduce interference received by the mobile station.



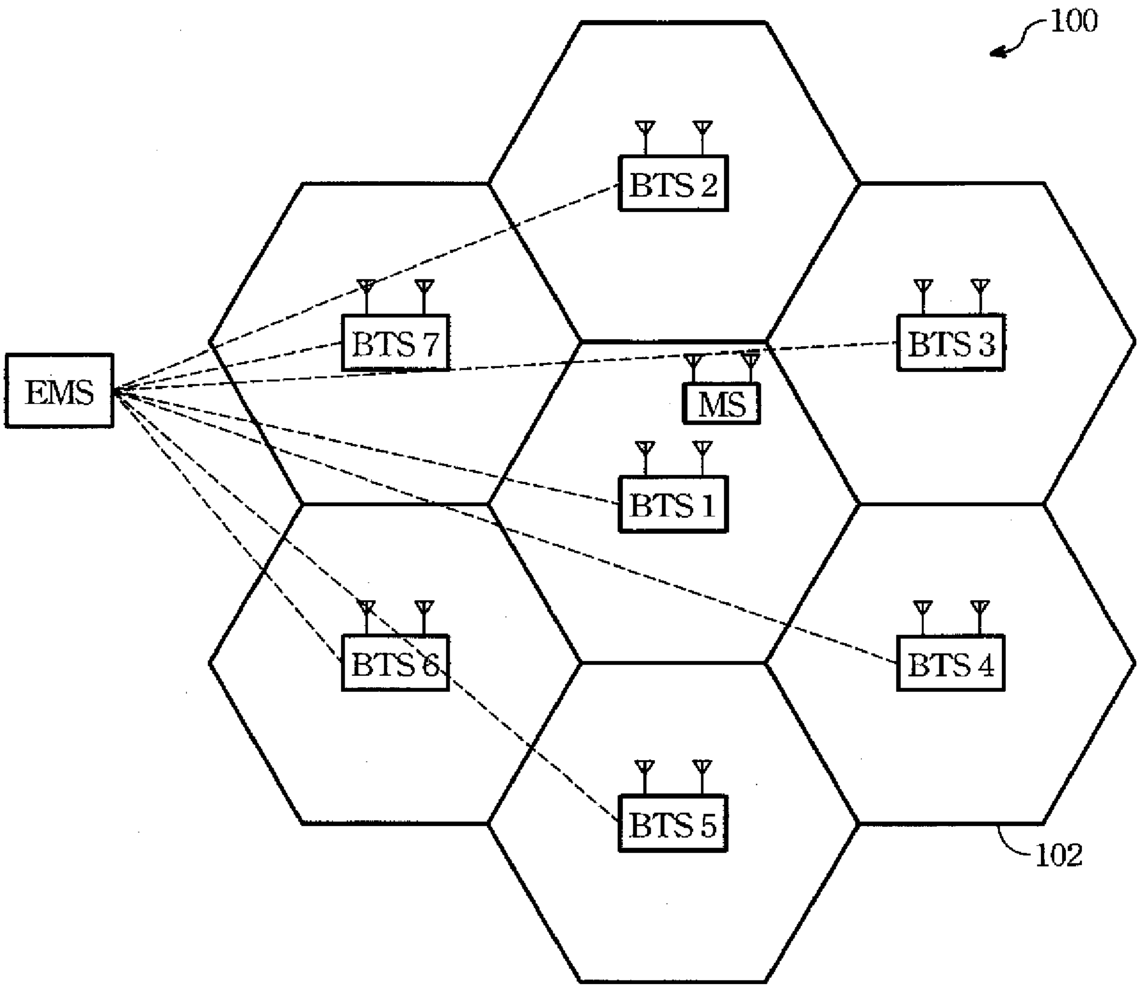


FIG.1

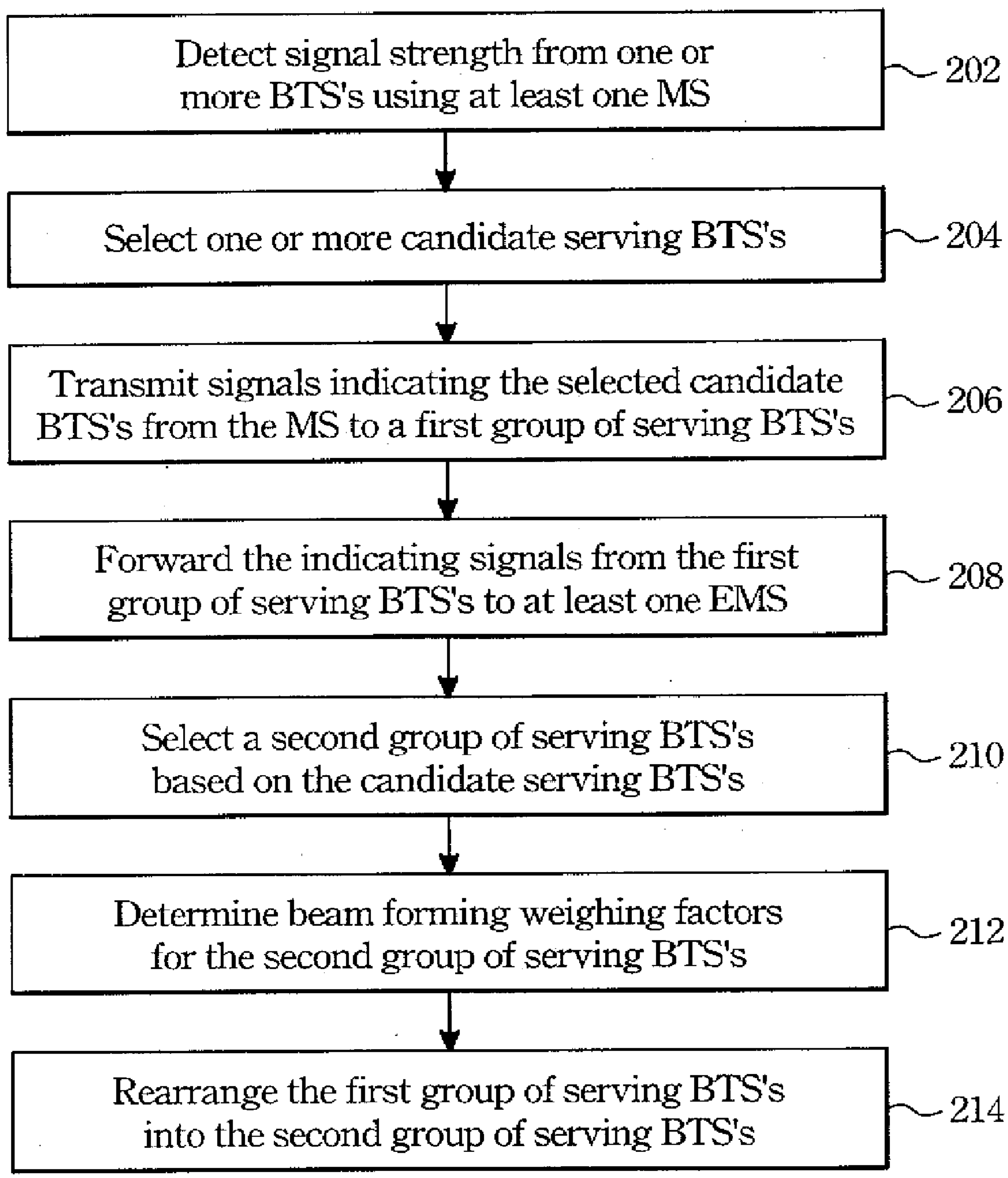

Detect signal strength from one or more BTS's using at least one MS
202
Select one or more candidate serving BTS's
204
Transmit signals indicating the selected candidate BTS's from the MS to a first group of serving BTS's
206
Forward the indicating signals from the first group of serving BTS's to at least one EMS
208
Select a second group of serving BTS's based on the candidate serving BTS's
210
Determine beam forming weighing factors for the second group of serving BTS's
212
Rearrange the first group of serving BTS's into the second group of serving BTS's
214

FIG. 2

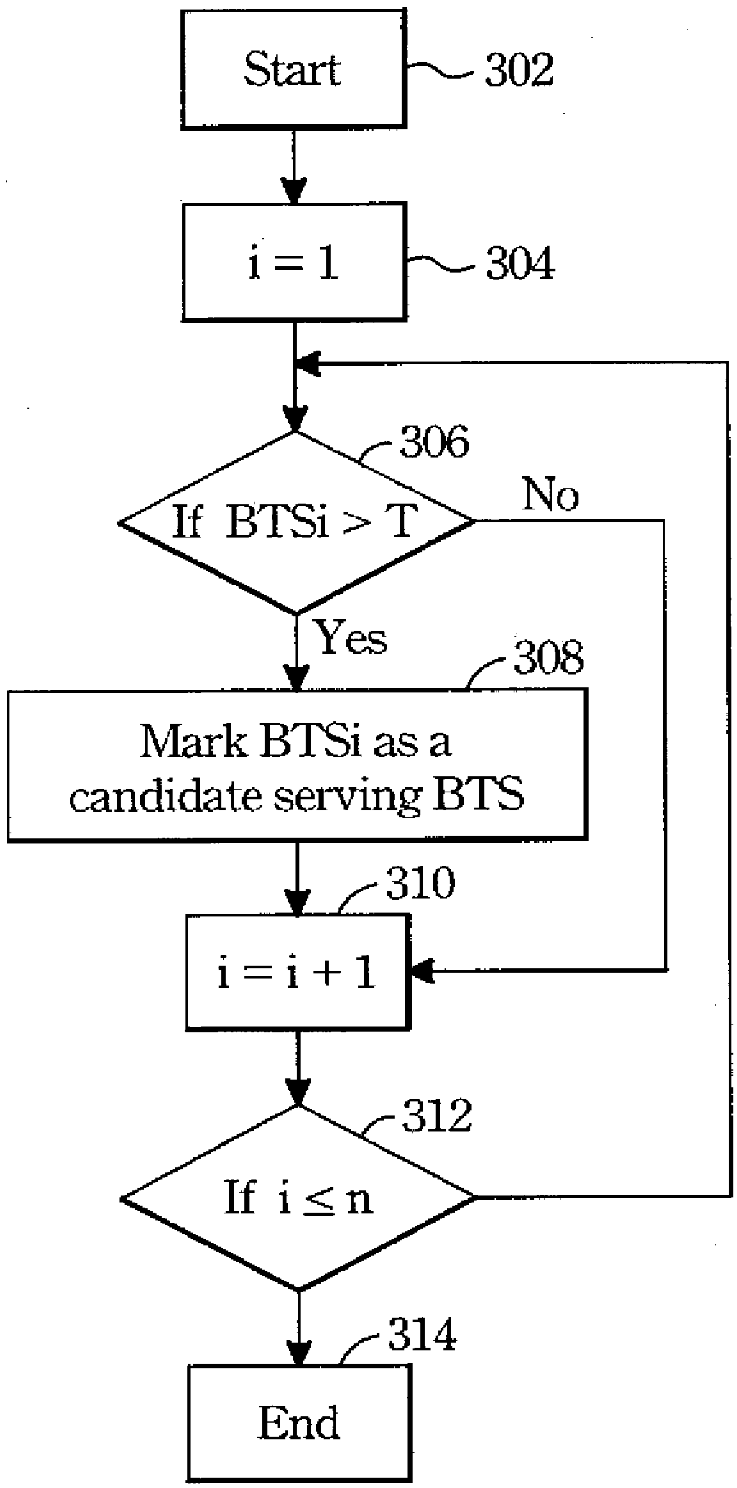

Start
302
i = 1
304
306
If BTSi > T
No
Yes
308
Mark BTSi as a candidate serving BTS
310
i = i + 1
312
If i ≤ n
314
End

FIG. 3

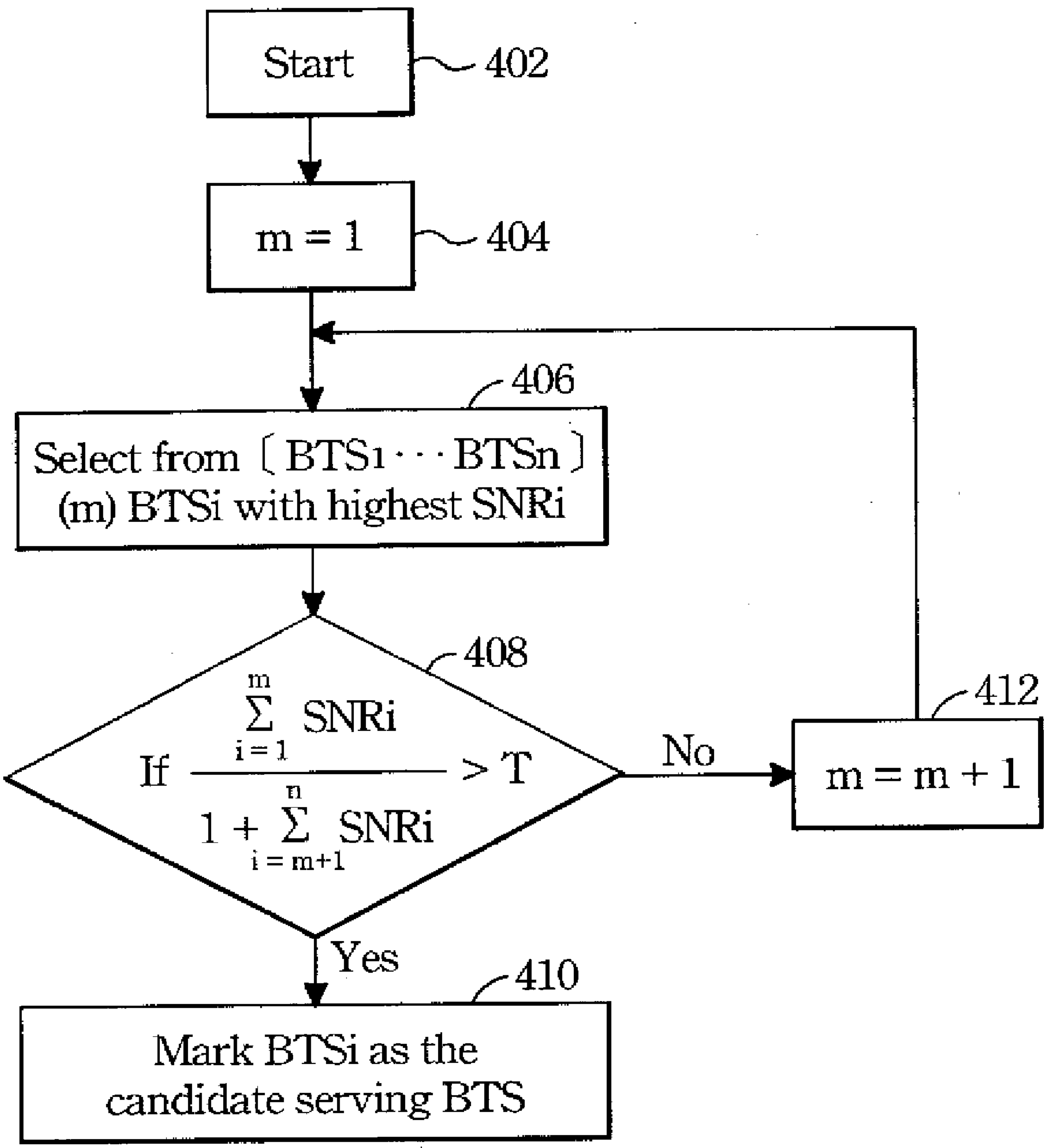

Start
402
m = 1
404
406
Select from [BTS1 · · · BTSn]
(m) BTSi with highest SNRi
408
If $\frac{\sum_{i=1}^{m} SNRi}{1 + \sum_{i=m+1}^{n} SNRi} > T$
No
412
m = m + 1
Yes
410
Mark BTSi as the
candidate serving BTS

FIG. 4

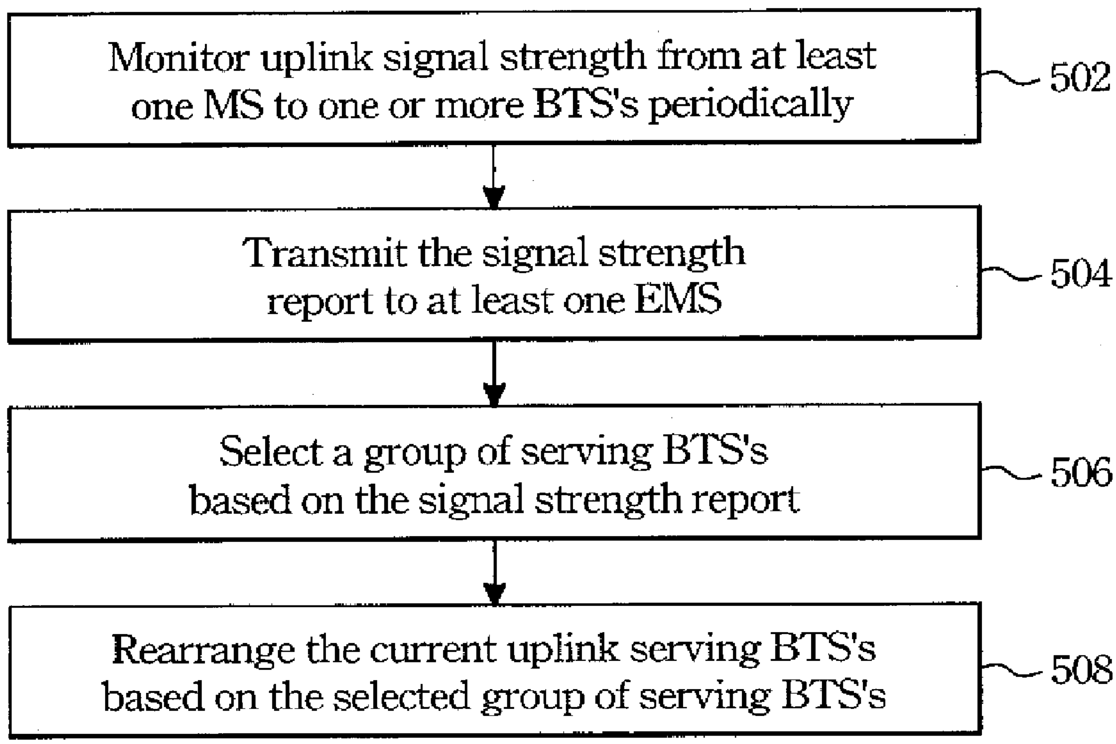

Monitor uplink signal strength from at least one MS to one or more BTS's periodically
502
Transmit the signal strength report to at least one EMS
504
Select a group of serving BTS's based on the signal strength report
506
Rearrange the current uplink serving BTS's based on the selected group of serving BTS's
508

FIG. 5

COLLABORATIVE BEAM FORMING OF BASE TRANSCEIVER STATIONS FOR REDUCING INTERFERENCE IN A WIRELESS MULTI-CELL NETWORK

BACKGROUND

[0001] The present application claims the benefit of U.S. Provisional Application Ser. No. 60/853,848, which was filed on Oct. 24, 2006 entitled "Wireless Multi-cell Interferences Reduction and Signal Strength Enhancement in Wireless Multi-cell Communications Through Adaptive Collaborative BTS Beam Forming and Dynamic BTS Selection."

[0002] The present invention relates generally to a wireless communication technology, and more particularly to collaborative beam forming of base transceiver stations (BTS's) for reducing interference and enhancing signal strength in a wireless multi-cell network.

[0003] A cellular wireless network is consisted of a plurality of cells, each of which is deployed with at least one BTS for transmitting and receiving signals to and from mobile stations (MS's) within the cell. Conventionally, signals transmitted and received in the network are carried by radio frequencies modulated with various technologies, such as frequency division multiple access (FDMA), time division multiples access (TDMA), code division multiple access (CDMA), orthogonal frequency division multiplexing (OFDM), and Orthogonal Frequency Division Multiple Access (OFDMA). In order to increase the capacity of the network, neighboring cells are usually assigned with various frequency bands that do not overlap for signal transmission and reception. One typical scheme of interference reduction is called frequency reuse where the same frequency band is used for multiple cells that do not neighbor with each other. A frequency reuse factor is defined as the rate at which the same frequency band can be used in the network. For example, a frequency reuse factor of seven means that seven different frequency bands are employed for a cellular wireless network to differentiate signal transmission and reception in neighboring cells.

[0004] One challenge facing the conventional cellular wireless network is interference that occurs when signals from a cell, ether a BTS or a MS, spill over to its neighboring cells. This limits signal capacity and coverage, thereby degrading the performance of the network. Moreover, the severity of interference depends on the frequency reuse factor employed by the network. The smaller the reuse factor, the more serious the interference.

[0005] Another challenge is the signal strength degradation due to radio wave propagation. For example, when a MS is distant from a BTS, or the communication link between the MS and the BTS is blocked by certain objects, the signal received by the MS or BTS can be very weak, thereby causing reliability issues for signal transmission.

[0006] As such, what is needed is a scheme that reduces the interference and enhances the signal strength for a cellular wireless network.

SUMMARY

[0007] The present invention discloses a method of signal transmission and reception for a cellular wireless network. In one embodiment of the invention, the method includes steps of detecting signal strength of signals transmitted or received between a mobile station and a plurality of base transceiver stations; selecting a plurality of candidate serving base transceiver stations based on the detected signal strength; selecting a first group of serving base transceiver stations from the candidate serving base transceiver stations; and sending signals between the mobile station and the first group of serving base transceiver stations using beam forming technology to reduce interference received by the mobile station.

[0008] The construction and method of operation of the invention, however, together with additional objectives and advantages thereof will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** illustrates a cellular wireless network where a plurality BTS's are deployed among a plurality of cells.

[0010] FIG. **2** illustrates a flowchart showing a method of downlink transmission in accordance with one embodiment of the present invention.

[0011] FIG. **3** illustrates a flowchart showing a method of determining serving BTS's for collaborative beam forming in accordance with one embodiment of the present invention.

[0012] FIG. **4** illustrates a flowchart showing a method of determining serving BTS's for collaborative beam forming in accordance with another embodiment of the present invention.

[0013] FIG. **5** illustrates a flowchart showing an uplink transmission in accordance with one embodiment of the present invention.

DESCRIPTION

[0014] This invention describes a method that reduces interference and enhances signal strength for a wireless cellular network. The following merely illustrates various embodiments of the present invention for purposes of explaining the principles thereof. It is understood that people skilled in the art will be able to devise various equivalents that, although not explicitly described herein, embody the principles of this invention.

[0015] FIG. **1** illustrates cellular wireless network **100** where a plurality of BTS's are deployed among a number of cells **102** making up an overall area of coverage in accordance with one embodiment of the present invention. Each BTS is designated with a predetermined frequency bandwidth for transmitting or receiving signals to or from a plurality of MS's within the cell, in which the BTS is deployed. A frequency reuse scheme can be used in the network **100** to assign neighboring BTS's with various frequency bands in order to increase its system capacity and frequency reuse efficiency. Each BTS or MS may be implemented with a plurality of antennas in order for supporting multiple-input multiple-output (MIMO) communications.

[0016] The BTS's are also linked to an element management system (EMS) that controls the BTS's to form uplinks and downlinks with the MS's, using a beam forming technology. For example, a MS located at the boundary of cells deployed with BTS **1**, BTS**2**, and BTS **3** transmits/receives signals to/from BST **1** as a primary source, with BTS **2** and BTS **3** as secondary sources if certain criteria. Beam forming will be performed for BTS **1**, BTS **2** and BTS **3**, such that

BTS **2** and BTS **3** become signal sources that strengthen the signals received by the MS, instead of sources of interference as they would have been, had they functioned according to conventional schemes.

[0017] FIG. **2** illustrates a flowchart explaining a method of downlink transmission for a wireless cellular network in accordance with one embodiment of the present invention. Referring simultaneously to FIGS. **1** and **2**, at step **202**, the MS detects signal strength of signals received from a number of BTS's, such as BTS **1**, BTS **2**, BTS **3**, and BTS **7**, located at its vicinity. At step **204**, the MS selects one or more candidate serving BTS's for potentially forming downlinks with the MS based on predetermined criteria taking into account of the detected signal strength. For example, the MS selects BTS **1**, BTS **2**, and BTS **3** as candidate serving BTS's for potentially forming downlinks with the MS if their corresponding signal strength is higher than a predetermined value, and disregards BTS **7** if its signal strength is lower than the predetermined value. It is noted that there are various criteria can be used for selecting the candidate serving BTS's. These criteria will be described in further detail in the following paragraphs.

[0018] At step **206**, the MS transmits signals containing information indicating the selected candidate serving BTS's to a first group of serving BTS's that currently form downlinks with the MS. These current serving BTS's may not be the same as the selected candidate serving BTS's. At step **208**, the information indicating the selected serving BTS's is forwarded by the current downlink serving BTS's to the EMS. For example, although the MS may select BTS **1**, BTS **2**, and BTS **3** as the candidates, it may transmit the indicating signals to BTS **1**, BTS **3**, and BTS **4** that currently communicate with the MS through downlink channels. BTS **1**, BTS **3** and BTS **4** then forward the information indicating that BTS **1**, BTS **2** and BTS **3** have been selected as candidate serving BTS's to the MS.

[0019] At step **210**, the EMS selects a second group of serving BTS's from the candidate serving BTS's based on the information forwarded by the current serving BTS's and on its own selection criteria, such as balancing system resources. The ESM also determines beam forming weighing factors for the selected second group of serving BTS's. For example, the MS may select BTS **1** and BTS **2** as the second group of serving BTS's and disregard BTS **3**, even though it is also one of the selected candidate serving BTS's.

[0020] At step **214**, the EMS transmits control signals containing information of the second group of the serving BTS's and their corresponding beam forming weighing factors to the current serving and candidate serving BTS's in order for rearranging the first group of the current serving BTS's into the second group of the selected serving BTS's for establishing new downlinks with the MS. For example, the control signals are transmitted from the EMS to BTS **1**, BTS **3**, and BTS **4**, the first group of current serving BTS's, and to BTS **2** and BTS **3**, the selected candidate serving BTS's. Since the second group of BTS's only includes BTS **1** and BTS **2**, the current serving BTS **3** and BTS **4** that do not belong to the second group are deactivated from serving the MS though downlink channels upon receiving the control signals. The BTS that belongs to the second group of serving BTS's, but do not belong to the first group of current serving BTS's, such as BTS **2**, is activated to form downlink channels with the MS upon receiving the control signals. A beam forming technology is performed for BTS **1** and BTS **2** to form downlink channels with the MS simultaneously, using the beam forming weighing factors determined by the EMS. It is understood that various implementations the beam forming schemes can be made without undue experimentation by people skilled in the art of telecommunications. As such, detailed description of such implementations is omitted from the present disclosure.

[0021] In this embodiment, the second group of serving BTS's then notify the MS of the rearrangement of BTS's through downlink channels. This can be done by transmitting one bit in the downlink message, using "1" to indicate that collaborative beam forming is employed, and "0" to indicate that only one BTS is serving the MS. It is noted that, as an alternative, the second group of serving BTS's can be simply activated to form downlink channels with the MS without utilization of any notification bit.

[0022] FIG. **3** illustrates a flowchart showing a process of determining serving BTS's for collaborative beam forming based on a predetermined criterion in accordance with one embodiment of the present invention. The process starts at step **302**, and then proceeds to step **304** where a variable i is set as 1. At step **306**, the signal strength received by the MS from the BTSi is compared to a predetermined threshold value T. If the signal strength is determined to be greater than the predetermined threshold value T, the process proceeds to step **308** where BTSi is marked as a candidate serving BTS. If the signal strength is determined to be smaller than the threshold vale T, the process proceeds to step **310** where the variable i is set to be equal to i+1. At step **312**, the value i is compared to a predetermined value n, which denotes, for example, a total number of BTS's in a predefined vicinity of the MS. If i is smaller or equal to n, the process goes back to step **306**. If i is greater than n, the process ends at step **314**. This process selects candidate BTS's based on the criterion that the selected BTS's have signal strength greater than a predetermined threshold.

[0023] FIG. **4** illustrates a flowchart showing a process of determining serving BTS's for collaborative beam forming based on a predetermined criterion in accordance with another embodiment of the present invention. The process starts at step **402**, and then proceeds to step **404** where a variable m is set as 1. At step **406**, a m number of BTS with the highest SNR is selected from a group of BTS's [BTS **1**, BTS **2**, . . . BTSn]. In case where m equals to 1, only one BTS with the highest SNR is selected from [BTS **1**, BTS **2**, . . . BTSn]. At step **408**, the SNRs of all the selected BTS's are added up and converted into the same metric as SNR. The result is compared to a predetermined threshold value T. If the result is greater than T, the process proceeds to step **410** where the selected BTS is marked as the candidate serving BTS's at step **410**. If the result is smaller than T, the process proceeds to step **412** where m is set to be m+1. This process selects candidate BTS's based on the criterion that the BTS's with the highest aggregate SNR that is greater than the predetermined threshold value are selected.

[0024] FIG. **5** illustrates a flowchart explaining a method of uplink transmission in accordance with one embodiment of the present invention. Referring simultaneously to FIGS. **1** and **5**, at step **502**, a number of BTS's at a predefined vicinity of the MS periodically monitors the signal strength received from the MS. At step **504**, information containing the signal strength report is transmitted to the EMS though a first group of current uplink serving BTS's. The EMS selects a second group of serving BTS's based on the signal strength report at step **506**. The current uplinks serving BTS's are rearranged based on the second group of the serving BTS's, using process steps similar to that for rearranging the downlink serving BTS's, at step **508**. It is noted that the uplink and downlink serving BTS's need not to be the same. It is also noted that the processes detailed in reference to FIGS. **3** and **4** can be used as criteria for selecting the uplink serving BTS's as well.

[0025] This method is a multi-cell interference reduction and signal enhancement technique based on adaptive collaborative BTS beam forming and dynamic BTS selection. It is applicable to any multiple access technologies, such as FDD, TDD, FDMA, TDMA, MC-CDMA, OFDM-MA and any combination of them.

[0026] The above illustration provides many different embodiments or embodiments for implementing different features of the invention. Specific embodiments of components and processes are described to help clarify the invention. These are, of course, merely embodiments and are not intended to limit the invention from that described in the claims.

[0027] Although the invention is illustrated and described herein as embodied in one or more specific examples, it is nevertheless not intended to be limited to the details shown, since various modifications and structural changes may be made therein without departing from the spirit of the invention and within the scope and range of equivalents of the claims. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the invention, as set forth in the following claims.

What is claimed is:

1. A method of signal transmission and reception for a cellular wireless network, comprising:

detecting signal strength of signals transmitted or received between a mobile station and a plurality of base transceiver stations;

selecting a plurality of candidate serving base transceiver stations based on the detected signal strength;

selecting a first group of serving base transceiver stations from the candidate serving base transceiver stations; and

sending signals between the mobile station and the first group of serving base transceiver stations using beam forming technology to reduce interference received by the mobile station.

2. The method of claim **1** wherein the candidate serving base transceiver stations are selected if their signal strength is greater than a predetermined threshold.

3. The method of claim **1** wherein the candidate serving base transceiver stations are selected if the candidate serving base transceiver stations have a combined signal to noise ratio greater than a predetermined threshold.

4. The method of claim **1** wherein the signal strength is associated with downlink signals received by the mobile station from the plurality of base transceiver stations.

5. The method of claim **4** further comprising transmitting signals containing information indicating the candidate serving base transceiver stations from the mobile station to current uplink serving base transceiver stations.

6. The method of claim **5** further comprising forwarding the indicating signals from the current uplink serving base transceiver stations to an element management server.

7. The method of claim **6** further comprising determining beam forming weighing factors for the first group of serving base transceiver stations, using the element management server.

8. The method of claim **7** further comprising transmitting a command signal containing information regarding the first group of base transceiver stations and the beam forming weighing factors from the element management server to the first group of serving base transceiver stations and current downlink serving base transceiver stations.

9. The method of claim **8** further comprising deactivating a first subset of base transceiver stations of the current downlink serving base transceiver stations from forming downlinks with the mobile station if the first subset of base transceiver stations do not belong to the first group of serving base transceiver stations.

10. The method of claim **9** further comprising activating a second subset of base transceiver stations of the first group of serving base transceiver stations to form downlinks with the mobile station if the second subset of base transceiver stations do not belong to the current downlink base transceiver stations.

11. The method of claim **10** further comprising sending a confirmation signal indicating whether beam forming among a plurality of base transceiver stations is performed.

12. The method of claim **1** wherein the signal strength is associated with uplink signals received by the plurality of base transceiver stations from the mobile station.

13. The method of claim **12** further comprising transmitting an uplink signal strength report from current uplink serving base transceiver stations to the element management server.

14. The method of claim **13** further comprising transmitting a command signal containing information regarding the first group of base transceiver stations from the element management server to the first group of serving base transceiver stations and the current uplink serving base transceiver stations.

15. The method of claim **14** further comprising deactivating a first subset of base transceiver stations of the current uplink serving base transceiver stations from forming uplinks with the mobile station if the first subset of base transceiver stations do not belong to the first group of serving base transceiver stations.

16. The method of claim **15** further comprising activating a second subset of base transceiver stations of the first group of base transceiver stations to form uplinks with the mobile station if the second subset of base transceiver stations do not belong to the current uplink base transceiver stations.

17. An element management server for controlling a plurality of base transceiver stations for transmitting downlink signals to at least one mobile station in a cellular wireless network, comprising:

means for selecting a first group of serving base transceiver stations from a plurality of candidate serving base transceiver stations provided by a mobile station based on signal strength received by the mobile station from a plurality of base transceiver stations; and

means for transmitting a command signal containing information regarding the first group of serving base transceiver stations to the first group of serving base transceiver stations and current downlink serving base transceiver stations for deactivating a first subset of base transceiver stations of the current downlink serving base transceiver stations from forming downlinks with the mobile station if the first subset of base transceiver stations do not belong to the first group of serving base transceiver stations, and for activating a second subset of base transceiver stations of the first group of serving base transceiver stations to form downlinks with the mobile station if the second subset of base transceiver stations do not belong to the current downlink base transceiver stations,

wherein the first group of serving base transceiver stations transmit downlink signals to the mobile station using a beam forming technology.

18. The element management server of claim **17** wherein the candidate serving base transceiver stations are selected if their signal strength is greater than a predetermined threshold.

19. The element management server of claim **17** wherein the candidate serving base transceiver stations are selected if the candidate serving base transceiver stations have a combined signal to noise ratio greater than a predetermined threshold.

20. An element management server for controlling a plurality of base transceiver stations for receiving downlink signals from at least one mobile station in a cellular wireless network, comprising:

means for selecting a first group of serving base transceiver stations from a plurality of candidate serving base transceiver stations provided by current uplink base transceiver stations based on signal strength received by the current uplink base transceiver stations from the mobile station; and

means for transmitting a command signal containing information regarding the first group of serving base transceiver stations to the first group of serving base transceiver stations and current uplink serving base transceiver stations for deactivating a first subset of base transceiver stations of the current uplink serving base transceiver stations from forming uplinks with the mobile station if the first subset of base transceiver stations do not belong to the first group of serving base transceiver stations, and for activating a second subset of base transceiver stations of the first group of serving base transceiver stations to form uplinks with the mobile station if the second subset of base transceiver stations do not belong to the current uplink base transceiver stations.

21. The element management server of claim **20** wherein the candidate serving base transceiver stations are selected if their signal strength is greater than a predetermined threshold.

22. The element management server of claim **20** wherein the candidate serving base transceiver stations are selected if the candidate serving base transceiver stations have a combined signal to noise ratio greater than a predetermined threshold.

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