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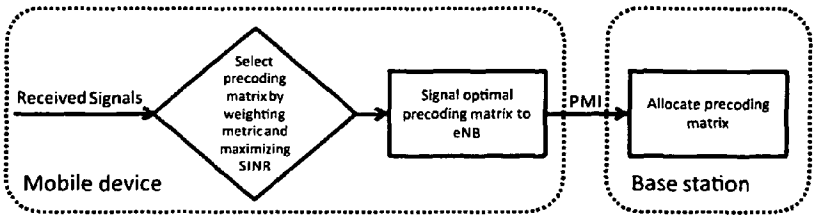

Fig. 3

(57) Abstract: The invention relates to a method to be carried out in a network of base stations and mobile devices, a mobile device for communicating in said network, a base station for communicating in said network, and the network itself. The method comprises the steps of: calculating a metric of a current precoding matrix and each matrix of a set of predefined precoding matrices maintained at a base station, wherein said current precoding matrix is currently being used by said base station to create a signal for a mobile device associated with the base station; selecting one matrix from the set such that interference from the base station to mobile devices in other cells deviate less from the current interference than with any other matrix from the set; and replacing the current pre - coding matrix with the selected matrix.

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„Inter-Cell-Interference Coordination Scheme for improved LTE system performance “

The invention relates to a computer-implemented method to be carried out in a network of base stations and mobile devices, a mobile device for communicating in said network, a base station for communicating in said network, and the network itself, a system, and an apparatus for improved transmission capacity in a wireless network, in particular in a single frequency network.

In a single frequency network, base stations transmit signals in the same spectrum. In a method known as beamforming, signal beams sent from a base station are configured to acquire a predefined shape and direction with time.

Depending on the current signal characteristics and on further factors such as distance of the mobile device to an associated base station and density of base stations etc., signals are always subject to interference at a certain level.

In order to perform beamforming, precoding matrices are maintained at base stations to specify signal properties. For example, a set of predefined precoding matrices, comprehensively referred to as a codebook, may be maintained at a base station for selection and for applying by said base station such that one precoding matrix is active at each time instance. The process of exchanging an active precoding matrix for another is referred to as reallocation.

Reallocation may be performed at regular intervals, such as with every transmission time interval (TTI) of LTE.

Selection of a new precoding matrix may be based on certain signal properties such as signal-

to-interference-plus-noise-ratio (SINR).

In N. Himayat, S. Talwar, A. Rao, and R. Soni: "Interference Management for 4G Cellular Standards", IEEE Communications Magazine, vol. 48, no.8 (August 2010), 86-92, data streams are weighted by a user, and a precoding matrix is selected from a codebook and multiplied with said data streams. The rationale of this reallocation is to transmit most of the transmission power in the direction of the mobile device corresponding to the users. Accordingly, a precoding matrix is selected for each mobile device such that the SINR is maximal when applying said precoding matrix. Subsequently, the resulting precoding matrix is indicated to the base station of the mobile device. Finally, the base station decides whether to accept the selection, and applies said precoding matrix.

A problem of the aforementioned approach is that a base station might interfere with a mobile device located in a neighbouring cell. Also, signals from multiple base stations may introduce interference at the mobile device. Thus, interference level at the mobile device is likely to significantly change abruptly upon changing a precoding matrix. This incurs problems at the mobile device to adapt to the changing signal, such as additionally required computing time. In effect, a lack of communication between said base stations leads to significant loss in overall system performance. The aforementioned problems may occur with mobile devices in proximity to an edge of a cell or further away from an edge. Even mobile devices in proximity to a base station may experience these problems.

Accordingly, the task underlying the present invention is improving system performance.

This task is solved by a computer-implemented method to be carried out in a network of base stations and mobile devices, comprising the steps of:

calculating a metric of a current precoding matrix and each matrix of a set of predefined precoding matrices maintained at a base station, wherein said current precoding matrix is currently being used by said base station to create a signal for a mobile device associated with the base station; selecting one matrix from the set such that interference from the base station to mobile devices in other cells deviates less from a current interference than with any other matrix from the set; and replacing the current precoding matrix with the selected matrix.

Said selecting may also comprise keeping signal strength to a maximum for the mobile device associated with the base station.

The metric may be calculated according to the formula

$$J_{corr}(B(i), B(i+1)) = \text{Trace}\{B(i)B(i)^{H}B(i+1)B(i+1)^{H}\}L,$$

wherein B(i) denotes the current precoding matrix, B(i+1) denotes the respective matrix from the set, and L denotes the number of data streams received at the mobile device associated with the base station. The superscript H denotes a Hermitian of the respective matrix, and Trace {} denotes the mathematical trace operation.

Preferably, the calculating further comprises calculating signal-to-interference-plus-noise-ratio J_{SINR}, and the selecting further comprises identifying the new matrix as

$$B(i+1)^{*} = \arg\max_{B(i+1)} (1-w)J_{SINR}(B(i+1)) + wJ_{corr}(B(i),B(i+1)),$$

wherein J_{SINR} () is a cost function indicating the possible SINR of a mobile device if B(i+1) was selected as B(i+1)*, and w denotes a weighting variable in the range of [0,1].

In a preferred embodiment, signal properties are measured at the mobile device associated with the base station prior to the calculating.

It is appropriate for the signal properties measured at the mobile device associated with the base station to include the signal-to-noise ratio.

The signal properties measured at the mobile device may include the interference level.

According to a preferred embodiment, the calculating is carried out at the mobile device.

Alternatively, the calculating is carried out at the base station.

Similarly, the selecting may be carried out at the mobile device or at the base station.

It is preferably provided that the result of the calculating is transmitted to the base station prior to selecting.

For embodiments which include the step of selecting to be carried out at the mobile device, the selected matrix is preferably transmitted to the base station.

In a typical implementation, the network is a single frequency network.

In a preferred embodiment, the network is a long term evolution (LTE) network.

The above task is also solved by a mobile device for communicating in a network of base stations and mobile devices, said mobile device preferably comprising at least one antenna, a processor and memory, and configured to calculate a metric of a current precoding matrix of each matrix of a set of predefined precoding matrices maintained at a base station, wherein said current precoding matrix is currently being used by said base station to create a signal for the mobile device; and transmit the result of the comparing to the base station.

According to a preferred embodiment, the mobile device is further configured to calculate said metric as $J_{corr}(B(i), B(i+1)) = \text{Trace}\{B(i)B(i)^{H}B(i+1)B(i+1)^{H}\}L$, wherein B(i) denotes the current precoding matrix, B(i+1) denotes the respective matrix from the set, superscript H denotes a Hermitian of the respective matrix, Trace denotes the mathematical trace operation, and L denotes the number of data streams received at the mobile device.

In addition, the mobile device may be configured to also calculate the signal-to-interference-plus-noise-ratio J_{SINR}.

According to another preferred embodiment, the mobile device may measure signal properties prior to the calculating.

In particular, signal properties measured at the mobile device may include the signal-to-noise-ratio.

The signal properties measured at the mobile device may include the interference level.

The task underlying the present invention is also solved by a base station for communicating in a network of base stations and mobile devices, said base station comprising at least one antenna and configured to calculate a metric of a current precoding matrix and each matrix of a set of predefined precoding matrices maintained at said base station, wherein said current precoding matrix is currently being used by said base station to create a signal for a mobile device associated with the base station; select one matrix from the set such that interference from the base station to mobile devices deviates less from the current signal properties than with any other matrix from the set; replace the current precoding matrix with the selected matrix.

The selecting may also include that a signal strength is kept to a maximum for the mobile device associated with the base station.

Advantageously, the base station may be configured to receive signal property measurements from the mobile station prior to comparing.

Said metric may be calculated as $J_{corr}(B(i), B(i+1))$ according to the above formula.

The base station may include the metric to make scheduling decisions.

In addition, the signal-to-interference-plus-noise-ratio J_{SINR} may be calculated, and the new matrix may be selected as $B(i+1)^*$ according to the formula above.

Further, the base station may additionally include a processor and memory.

A particular advantage of any of the aforementioned embodiments is that system performance is improved by avoiding abrupt changes of interference levels, thus allowing mobile devices – in particular mobile devices in other cells – to adapt to changing signals, especially interfering signals. The change of interference levels is kept to a minimum by selecting precoding matrices which preserve the current signal properties. This effect establishes a surprising effect in that the aforementioned advantage is gained even though no direct communication between base stations is required. Accordingly, a further advantage is that an overhead in communication is avoided.

A further advantage is that the invention is backwards-compatible with LTE in that no changes to LTE are required in order to deploy the invention.

Yet another advantage is increasing network throughput and higher spectral efficiency. Additionally, the invention is simple to understand, simple to implement, and generally simple to realize with the technical means provided in LTE and other contemporary networks.

Also, the disclosed invention may be implemented in a distributed manner, thereby relieving the base stations from calculating required metrics.

Further advantages and features of the invention will become clear from the following description of preferred embodiments, wherein references are made to the accompanying drawings, wherein

Figure 1 shows a schematic view of a network with base stations and mobile devices according to a preferred embodiment of the present invention,

Figure 2 shows a variant of the network according to figure 1, and

Figure 3 shows a flow diagram exemplifying a preferred embodiment of the claimed method.

With reference to figure 1, a wireless network 100 for carrying out a method according to a preferred embodiment of the present invention is presented. Said network 100 includes base stations 110, 120, and 130 which transmit and receive signals as indicated by arrows pointing to and from the respective base stations. Indicated by large hexagonal shapes are the cells defined by the signals transmitted by the respective base stations. For example, cell 170 corresponds to base station 130, while cell 180 corresponds to base station 120, and cell 190 corresponds to base station 110. Mobile devices 150, 160, and 140 are shown to be within the range of a respective one of the three base stations and typically receive signals from the base station that corresponds to the respective cell. The network may operate in multiple frequencies or in a single frequency. An example of a single frequency wireless network is Long Term Evolution (LTE). LTE is capable of simultaneously transmitting and receiving

multiple data streams by applying multiple antennas. Still, Quality of Service (QoS) is maintained at a high level.

According to a preferred embodiment illustrated in figure 3, mobile devices 140, 150, and 160 communicate via signals transmitted between the respective mobile device and the corresponding base station, said signals being configured according to a current precoding matrix which is used at a time instance i and which is denoted as B(i). A new precoding matrix B(i+1) may be selected for an upcoming time instance i+1. For example, a matrix may be selected from the codebook such that certain signal properties are achieved when applying said matrix in reallocation. More specifically, a metric may be calculated for each pair of precoding matrices (B(i), B(i+1)), wherein each of the precoding matrices in the codebook is used in place of B(i+1), and wherein said metric may be used to estimate the change of signal properties expected upon replacing the current precoding matrix with the respective matrix from the codebook. It is particularly advantageous to estimate said change at signal properties in neighbouring or even arbitrary cells. Such estimating may be based on knowledge of typical geometry alignment and size of cells expected in the vicinity of said base station. The metric may be used to compare the current precoding matrix with the respective codebook precoding matrix. Even further, comparing pairs of matrices may be based on the number of data streams received at the mobile device. According to a first embodiment, the metric is computed as

$$J_{corr}(B(i), B(i+i)) = \text{Trace}\{B(i)B(i)^{H}B(i+1)B(i+1)^{H}\}L,$$

wherein L is the number of data streams transmitted simultaneously, and Trace{} is the mathematical trace operation. According to a preferred embodiment, J_{corr} is within a range of [0,1]. Alternative ranges may be used.

In a subsequent step, the values obtained for J_{corr} for all different pairs of a current precoding matrix and precoding matrices from the codebook are compared and the codebook precoding matrix with an optimal J_{corr} value is selected. According to a preferred embodiment, the codebook precoding matrix may be selected such that signal properties at a mobile device in another cell, such as a neighbouring cell, deviate less from the current signal properties than with any other matrix in the set. More specifically, these signal properties may include a level

of interference a mobile device in another cell may be exposed to. In this embodiment, the precoding matrix is selected to minimize the deviation of the new interference level with respect to the current interference level.

In a preferred embodiment, further factors may influence selection of a codebook precoding matrix.

As an example, the optimal precoding matrix $B(i+1)^*$ may be defined as

$$B(i+1)^* = \arg\max_{B(i+1)} (1-w)J_{SINR}(B(i+1)) + wJ_{corr}(B(i),B(i+1)),$$

wherein $J_{SINR}(B(i+1))$ refers to the signal-to-interference-plus-noise ratio level to be expected with a respective codebook precoding matrix B(i+1), and w refers to a weighting variable in the range of [0,1]. For example, a value of w=0 will neglect the calculation as defined by J_{corr}, and will exclusively base the selection of an optimal precoding matrix on maximizing SINR. On the other hand, a value of w=1 will exclusively focus on minimizing changes of signal properties in neighbouring cells. Other values may be used to control the influence of J_{SINR} and J_{corr}.

In a preferred embodiment, steps may be taken to allow an operator to adjust w at each mobile device or each base station. In a particular embodiment, w may thus reflect the same value in all base stations of the network, or in a predefined subset of base stations.

According to a further embodiment, each base station includes a scheduler adapted to scheduling a given mobile device for reallocation at a particular time instance.

Prior to the steps outlined above, signal properties may be measured at the mobile device in order to achieve a more accurate result when comparing matrices. For example, properties such as the signal-to-noise ratio or the interference level may be measured in order to gain a better understanding of how the current precoding matrix actually influences certain signal properties. Specifically, measuring said signal properties prior to the remaining steps of the invention outlined above is advantageous in that it allows a better prediction on how an

individual precoding matrix influences signal properties, and simplifies implementing the comparison.

Calculating a metric may be performed at the mobile device or at the base station. Similarly, selection of an optimal codebook precoding matrix may be performed at the mobile device or at the base station. In one embodiment, metrics are calculated at the mobile device and transmitted to the base station which selects an optimal codebook precoding matrix. In an alternative embodiment, both metrics calculation and selection of a codebook precoding matrix is carried out at the mobile station, which transmits the result to the base station. In yet another embodiment, metrics calculation and codebook precoding matrix selection are carried out at the base station. The base station may finally reallocate the precoding matrix based on the selection.

The above-described automatic method may partially or as a whole be carried out by a mobile device which preferably comprises at least one antenna, a processor and memory. In one embodiment, the mobile device compares a current precoding matrix with each matrix of a set of predefined precoding measures maintained at a base station. The mobile device might also be configured to transmit the result of the comparison to the base station.

According to a further aspect of the invention, a base station is provided for communicating in a network of base stations and mobile devices, said base station comprising at least one antenna, a processor and memory, and configured to at least compare matrices as described in the method above, and to select one matrix from the base station's codebook. Finally, the base station may be configured to replace the current precoding matrix with the selected matrix. Any subset of the steps of the method described above may also or alternatively be carried out at the base station.

According to a further embodiment, each base station includes a scheduler adapted to scheduling a given mobile device for reallocation at a particular time instance.

An important technical effect is that the interference level imposed on a mobile device is prevented from varying significantly. Figure 2 shows base stations 210 and 220 which transmit signals within cells 270 and 280, respectively. Mobile devices 240 and 250 are

located close to the edges of each of these cells. Two arrows pointing from the base stations to mobile device 240 illustrate that this mobile device may receive signals from base station 210 but may be interfered by base station 220. This may be due to the proximity of the mobile station to the edge of the cell and may cause interference levels at the mobile device to significantly vary.

This variation of interference level negatively impacts signal reception. Variation of interference level at a mobile device indirectly depends on the precoding matrices applied at a base station in a different cell, such as in a neighbouring cell. By avoiding variation of interference level, the signal is improved. This is in contrast to prior art techniques which primarily build on improving signal quality directly. As is shown above, these prior art techniques are prone to drawbacks such as discontinuous changes in interference level, thus compromising the original objective of improving communication performance. At least according to a special embodiment of the invention, rather than short-sightedly aiming at gaining the best signal locally, selecting the new precoding matrix includes that interference level variation is kept to a minimum. In effect, system performance is improved.

Still with reference to figure 2, a specific example shall be discussed. In this example, a collection of 16 different vectors is maintained, each of which defining a respective precoding matrix. The definition uses for a precoding matrix B from a vector U_n may be

$$B = I-2\frac{U_n U_n^H}{U_n^H U_n},$$

wherein I is the 4x4 identity matrix, and U_n^H is the Hermitian of U_n. Other definitions may be used as well. Also, a different number of vectors may be maintained, and a collection of precoding matrices may be maintained directly in place of said vectors.

With regard to figure 2, mobile device 240 is associated with base station 210 and receives signals from said base station 210. Signal reception of mobile device 240 may be exposed to interference from base station 220. Base station 220 transmits signals according to a current precoding matrix B_{220}, and serves an associated mobile device 250 with data streams, such as a single data stream, L=1.

Current precoding matrix B_{220} may be defined by vector U_n. As an example, vector U_n may be represented by the tenth vector from the aforementioned collection of 16 vectors, and may be specified as $U_n=[1,1,1,-1]^T$.

Current precoding matrix B_{220} my thus be determined as

$$B_{220}(i) = \begin{pmatrix} 0,5 & -0,5 & -0,5 & 0,5 \\ -0,5 & 0,5 & -0,5 & 0,5 \\ -0,5 & -0,5 & 0,5 & 0,5 \\ 0,5 & 0,5 & 0,5 & 0,5 \end{pmatrix}$$

By applying $B = I-2\frac{U_n U_n^H}{U_n^H U_n}$.

In case that mobile device 250 requests a change of the current precoding matrix B_{220}, metrics are calculated for each pair of B_{220} and the respective precoding matrices defined by the 16 vectors. Specifically,

$$J_{corr}(B_{220}(i), B_{220}(i+i)) = \text{Trace}\{B_{220}(i)B_{220}(i)^H B_{220}(i+1)B_{220}(i+1)^H\}L,$$

and

$$J_{SINR}(B_{220}(i+1))$$

are calculated for each of the potential precoding matrices $B_{220}(i+1)$ which are defined by vectors U_n, respectively.

The table below exemplifies values obtained for J_{CORR} and J_{SINR} when using a typical set of precoding matrices.

$B_1(i+1) =$	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
J_{corr}	0,00	0,50	0,00	0,50	0,07	0,43	0,43	0,07	0,00	0,00	1,00	0,00	0,25	0,25	0,25	0,2
J_{SINR}	1.2	0.9	0.2	0.24	0,38	0.75	0,62	0,41	0,04	0,23	0.1	0,98	0,45	0,24	0,35	0,6
$J, w = 0.5$	0.6	0.7	0.1	0.37	0,225	0.59	0,525	0,24	0,02	0,115	0.55	0,49	0,35	0,245	0,3	0,4

Each column of the table indicates certain signal properties that would arise if the current precoding matrix was replaced by a precoding matrix indicated by the respective column.

If an optimal matrix was selected based on J_{CORR} only, the matrix with the highest value of J_{CORR} would be chosen because this value reflects minimal change of signal properties. In this example, matrix 10 would be chosen once more, because no change of signal properties would be incurred.

If an optimal matrix was selected based on signal strength J_{SINR} only, matrix 0 would have to be chosen due to the maximal value of 1,2.

A matrix to take account of both J_{CORR} and J_{SINR} may be provided as

$$B_{220}(i+1)^* = \arg \max_{B220(i+1)} (1-w)J_{SINR}(B_{220}(i+1)) + wJ_{corr}(B_{220}(i),B_{220}(i+1)).$$

In one example reflected by the table, w may be set to 0,5. As a result, neither matrix 10 or 0 would have to be chosen, but matrix 1 which yields a maximum value of 0,7.

The features in the foregoing description, in the claims and/or in the accompanying drawings may, both and in any combination thereof, be material for realising the invention in diverse forms thereof.

Reference List

100, 200	wireless network
110, 120, 130, 210, 220	base stations
140, 150, 160, 240, 250	mobile devices
170, 180, 190, 270, 280	cells of the networks

Claims

1. A method to be carried out in a network of base stations and mobile devices, comprising:

calculating a metric of a current precoding matrix and each matrix of a set of predefined precoding matrices maintained at a base station, wherein said current precoding matrix is currently being used by said base station to create a signal for a mobile device associated with the base station;

selecting one matrix from the set such that interference from the base station to mobile devices in other cells deviates less from a current interference than with any other matrix from the set; and

replacing the current precoding matrix with the selected matrix.

2. The method according to claim 1, wherein the selecting further comprises that signal strength is kept to a maximum for the mobile device associated with the base station.

3. The method according to claim 1, wherein the metric is calculated according to the formula

$$J_{corr}(B(i), B(i+1)) = \mathrm{Trace}\{B(i)B(i)^{H}B(i+1)B(i+1)^{H}\}L,$$

wherein B(i) denotes the current precoding matrix, B(i+1) denotes the respective matrix from the set of predefined precoding matrices, superscript H denotes a Hermitian of the respective matrix, Trace denotes the mathematical trace operation and L denotes the number of data streams received at the mobile device associated with the base station.

4. The method according to claim 4 3, wherein the calculating further comprises calculating signal-to-interference-plus-noise-ratio J_{SINR}, and the selecting further comprises identifying the new matrix as

$B(i+1)^* = \arg\max_{B(i+1)} (1-w)J_{SINR}(B(i+1)) + wJ_{corr}(B(i),B(i+1))$,

wherein w denotes a weighting variable in the range of [0,1].

5. The method according to any of the preceding claims 1 to 4, wherein signal properties are measured at the mobile device prior to the calculating.

6. The method according the claim 5, wherein the signal properties measured at the mobile device include the signal-to-noise ratio.

7. The method according to claim 5 or 6, wherein the signal properties measured at the mobile device include the interference level.

8. The method according to any of the preceding claims 1 to 7, wherein the calculating is carried out at the mobile device.

9. The method according to any of the preceding claims 1 to 7, wherein the calculating is carried out at the base station.

10. The method according to any of the preceding claims 1 to 9, wherein the selecting is carried out at the mobile device.

11. The method according to any of the preceding claims 1 to 9, wherein the selecting is carried out at the base station.

12. The method according to claim 8, wherein the result of the calculating is transmitted to the base station prior to the selecting.

13. The method according to claim 10, wherein the selected matrix is transmitted to the base station.

14. The method according to any of the preceding claims, wherein the network is a single frequency network.

15. The method according to any of the preceding claims, wherein the network is a Long Term Evolution (LTE) network.

16. A network of base stations and mobile devices, said network configured to carry out the method according to any of the preceding claims 1 to ~~16~~ 15.

17. A mobile device for communicating in a network of base stations and mobile devices, said mobile device comprising at least one antenna, a processor and memory, and configured to:

calculate a metric of a current precoding matrix and each matrix of a set of predefined precoding matrices maintained at a base station, wherein said current precoding matrix is currently being used by said base station to create a signal for the mobile device;

transmit the result of comparing to the base station.

18. The mobile device according to claim 17, wherein the metric is calculated according to the formula

$$J_{corr}(B(i), B(i+1)) = \text{Trace}\{B(i)B(i)^{H}B(i+1)B(i+1)^{H}\}L,$$

wherein B(i) denotes the current precoding matrix, B(i+1) denotes the respective matrix from the set of predefined precoding matrices, superscript H denotes a Hermitian of the respective matrix, Trace denotes the mathematical trace operation and L denotes the number of data streams received at the mobile device.

19. The mobile device according to claim 18, wherein the calculating further comprises calculating signal-to-interference-plus-noise-ratio J_{SINR}.

20. The mobile device according to any of the preceding claims 17 to 19, wherein the mobile device is further configured to measure signal properties prior to the calculating.

21. The mobile device according to claim 20, wherein the signal properties measured at the mobile device include the signal-to-noise ratio.

22. The mobile device according to claim 20 or 21, wherein the signal properties measured at the mobile device include the interference level.

23. A base station for communicating in a network of base stations and mobile devices, said base station comprising at least one antenna and configured to:

calculate a metric of a current precoding matrix and each matrix of a set of predefined precoding matrices maintained at said base station, wherein said current precoding matrix is currently being used by said base station to create a signal for a mobile device associated with the base station;

select one matrix from the set such that interference from the base station to signal mobile devices in other cells deviates less from the current interference than with any other matrix from the set; and

replace the current precoding matrix with the selected matrix.

24. The base station according to claim 23, wherein the selecting further comprises that signal strength is kept to a maximum for the mobile device associated with the base station.

25. The base station according to claim 23, wherein the base station is further configured to receive signal property measurements from the mobile station prior to the calculating.

26. The base station according to claim 23, wherein the base station is configured to use the metric for scheduling decisions.

27. The base station according to any of the preceding claims 23 to 26, wherein the metric is calculated according to the formula

$J_{corr}(B(i), B(i+1))= \text{Trace}\{B(i)B(i)^{H}B(i+1)B(i+1)^{H}\}L,$

wherein B(i) denotes the current precoding matrix, and B(i+1) denotes the respective matrix from the set of predefined precoding matrices, superscript H denotes a Hermitian of the respective matrix, Trace denotes the mathematical trace operation, and L denotes the number of data streams received at the mobile device.

28. The base station according to claim 27, wherein the calculating further comprises calculating signal-to-interference-plus-noise-ratio J_{SINR}, and the selecting further comprises identifying the new matrix as

$B(i+1)^{*}= \arg \max_{B(i+1)} (1-w)J_{SINR}(B(i+1)) + wJ_{corr}(B(i),B(i+1)),$

wherein w refers to a weighting variable in the range of [0,1].

29. The base station according to claim 27, further comprising a processor and memory.

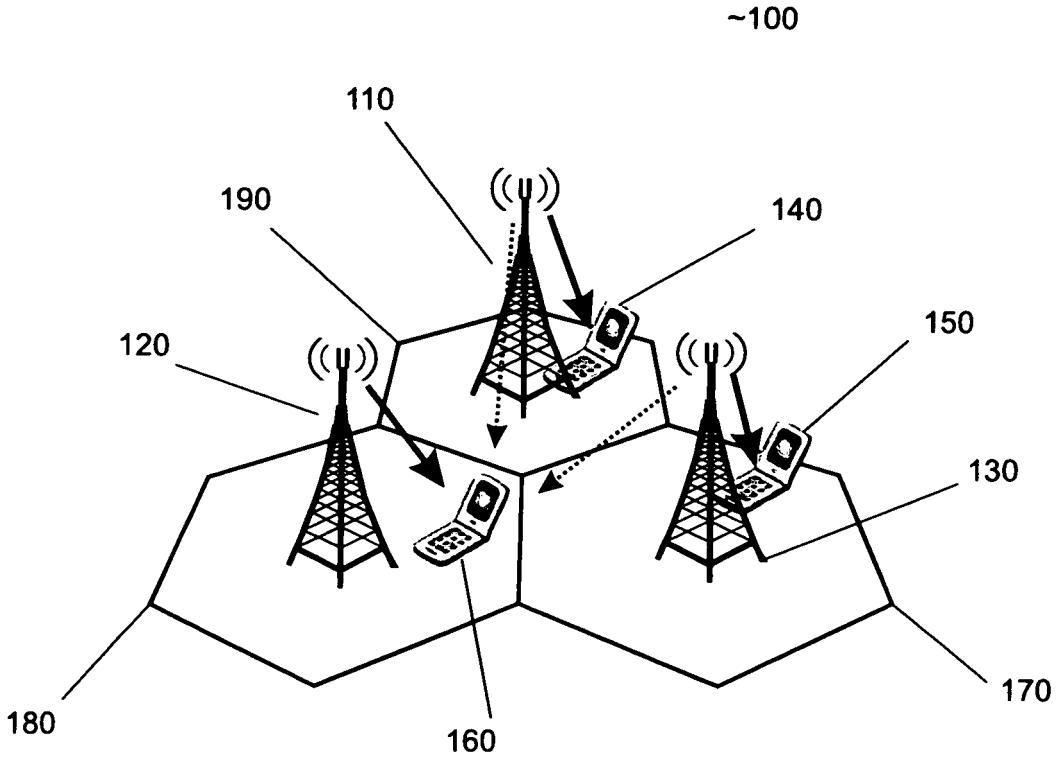

Fig. 1

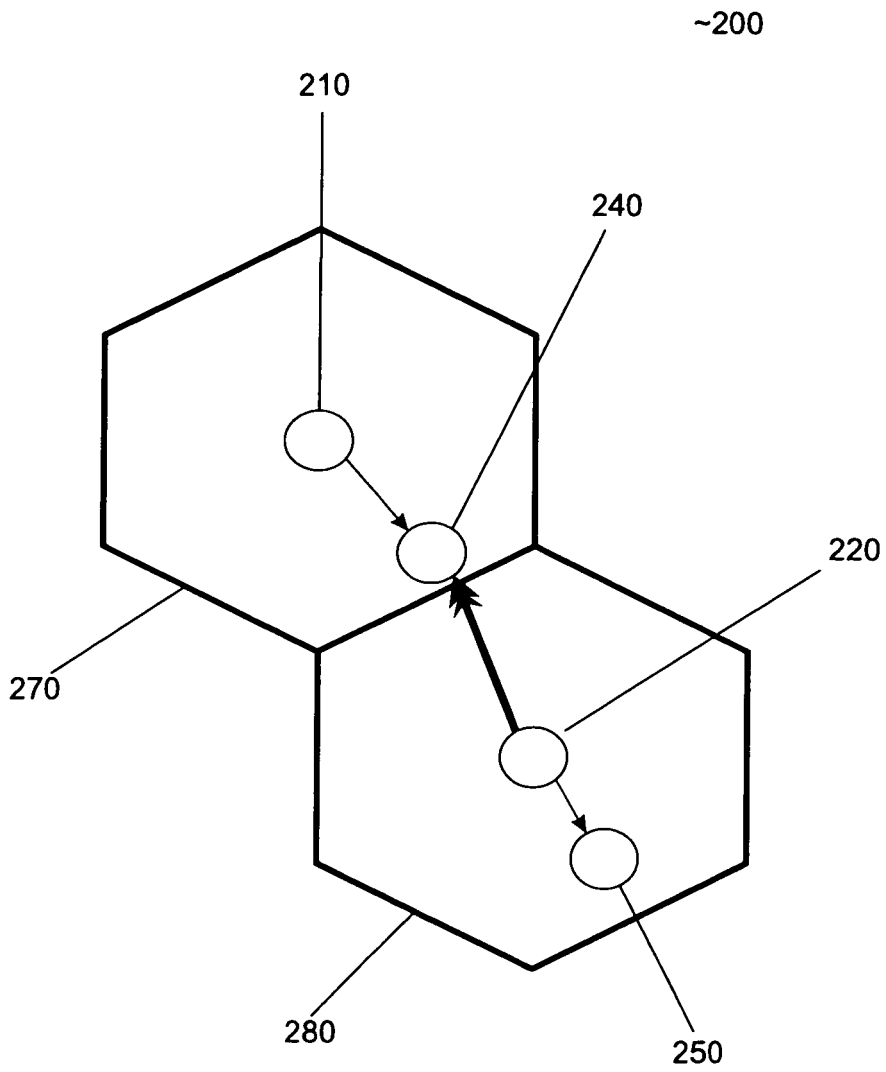

Fig. 2

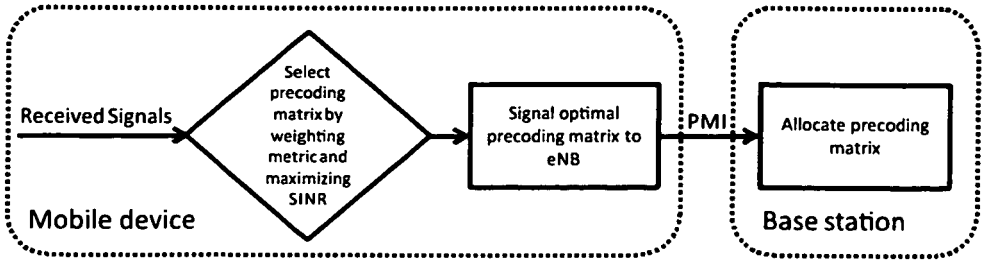
Received Signals
Select precoding matrix by weighting metric and maximizing SINR
Signal optimal precoding matrix to eNB
PMI
Allocate precoding matrix
Mobile device
Base station

Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/004004

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04B7/06 H04B7/04
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2006/176977 A1 (JAFARKHANI HAMID [US] ET AL) 10 August 2006 (2006-08-10)	17-22
A	abstract paragraph [0015] - paragraph [0021] paragraph [0051] -----	1,16,23
X	JIANN-CHING GUEY ET AL: "Signal Design for Transmitter Diversity Wireless Communication Systems Over Rayleigh Fading Channels", IEEE TRANSACTIONS ON COMMUNICATIONS, IEEE SERVICE CENTER, PISCATAWAY, NJ. USA, vol. 47, no. 4, 1 April 1999 (1999-04-01), XP011009388, ISSN: 0090-6778	17-22
A	abstract paragraph [IV.A] -----	1,16,23
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 March 2013	22/03/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Lustrini, Donato

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/004004

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	MENG WANG ET AL: "Dynamic Multi-User MIMO scheduling with limited feedback in LTE-Advanced", PERSONAL INDOOR AND MOBILE RADIO COMMUNICATIONS (PIMRC), 2012 IEEE 23RD INTERNATIONAL SYMPOSIUM ON, IEEE, 9 September 2012 (2012-09-09), pages 1627-1632, XP032272801, DOI: 10.1109/PIMRC.2012.6362609 ISBN: 978-1-4673-2566-0	17-22
A	abstract table Algorithm 1 -----	1,16,23

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2012/004004

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2006176977 A1	10-08-2006	EP 1846285 A2	24-10-2007
		KR 20070104356 A	25-10-2007
		US 2006176977 A1	10-08-2006
		WO 2006076527 A2	20-07-2006