Title: TRAFFIC AWARE COMMON PILOT CONFIGURATION

Abstract: The present invention relates to a method for downlink common pilot configuration for a base station serving a first set of User Equipments UEs and a second set of UEs, wherein the first set of UEs consists of 4-branch MIMO capable UEs and the second set of UEs consists of 4-branch MIMO mode incapable UEs. The method comprises the steps of determining (S410) information related to the UEs served by the Base Station BS; and configuring (S420) transmission of at least one common pilot from the BS to the served UEs based on the determined UE related information. In an example 4-branch MIMO system, at most 4 common pilots are configurable to be transmitted, and at least one common pilot is a two common pilots newly introduced into a legacy system. The present invention also relates to a base station configured for performing the method for downlink common pilot configuration and a computer readable storage medium. (Figure 4b)

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TRAFFIC AWARE COMMON PILOT CONFIGURATION

TECHNICAL FIELD

The disclosure relates to wireless communication systems, and more particularly, to a scheme of common pilot configuration.

BACKGROUND

Unless otherwise indicated herein, the approaches described in this section are not prior art to the claims in this application and are not admitted to be prior art by inclusion in this section.

The 2-branch downlink MIMO was introduced for HSDPA in 3rd Generation Partnership Project (3GPP) Standard Release 7. Then, 3GPP more focused on the carrier aggregation for the High Speed Downlink Packet Access (HSDPA) evolution. Dual-carrier HSDPA was introduced into 3GPP Standard Release 8. Further, the standardization of 4-carrier HSDPA and dual-carrier High Speed Uplink Packet Access (HSUPA) was almost finished. In 3GPP Standard Release 11, 8-carrier HSDPA was accepted as a work item in 3GPP.

Compared to the carrier aggregation, multiple antenna technology more helps to improve the frequency utilization efficiency as well as the coverage. In good channel conditions, the data transmission in a high rank channel increases the peak data rate. In bad channel conditions, the beam forming gain in a low rank channel improves the coverage. Presently, only 2-branch Multiple Input Multiple Output (MIMO) was specified for HSDPA. Compared to the up to 8-layer data transmission in Long-Term Evolution (LTE) downlink, the number of branch in MIMO transmission of HSDPA can be further increased. In 3GPP RAN1-65 meeting, it was proposed to introduce the 4-branch MIMO for HSDPA (cf. Reference [1]).

For downlink, there are control channels and data channels. For HSDPA, the downlink physical channel that carries data is High Speed Physical Downlink Shared Channel (HS-PDSCH). The spreading factor is 16, and any other spreading factor is not allowed. There are mainly two types of pilot designs being discussed in 3GPP, common pilots only, and common pilots plus shared demodulation pilots. These two types of pilot options are described in detail below.
> OPTION 1: COMMON PILOTS ONLY

Fig. 1 exemplifies the structure of 4-branch MIMO with common pilots only. There are one Primary Common Pilot Channel (CPICH) (P-CPICH) plus x (0-3) Secondary CPICHs (S-CPICH), which are used for data demodulations over High Speed Downlink Shared Channel (HS-DSCH) and High Speed Shared Control Channel (HS-SCCH), Channel Quality Indicator (CQI) estimation, and Pre-coding Matrix Indicator (PMI) and rank selection. Dependent on the number of S-CPICHs, there can be multiple orthogonal patterns for the P-CPICH and/or S-CPICH. As shown in Fig. 1, there are in total four common pilots, two P-CPICH patterns and two S-CPICH patterns. The two P-CPICH patterns are orthogonal to each other, and the two S-CPICH patterns are orthogonal to each other. Non-MIMO User Equipments (UEs) can use the default P-CPICH pattern, or one S-CPICH pattern configured for data demodulations and CQI estimation. 2-branch MIMO UEs can be configured to use the two orthogonal P-CPICH patterns, or one P-CPICH pattern plus one S-CPICH pattern. 4-branch MIMO UEs (i.e., the UE configured in 4-branch MIMO modes) will use all these four common pilots.

> OPTION 2: COMMON PILOTS PLUS SHARED DEMODULATION PILOTS (SDPS)

Fig. 2 exemplifies the structure of 4-branch MIMO with common pilots plus SDPs. There are still four common pilots, which can be any of the cases mentioned in Option 1. The UEs in legacy modes (i.e., non-MIMO UEs and 2-branch MIMO UEs) may operate in the same way as mentioned in Option 1. The 4-branch MIMO UEs uses common pilots for CQI, PMI and rank estimation. The channel estimation for the data demodulations of the 4-branch MIMO UEs relies on the 4 SDPs.

For any option, the common pilots are required to get the raw channel for pre-coding matrix, rank estimation and CQI measurement.

Compared to 2-branch MIMO, there are two additional common pilots (i.e., the 3-rd and the 4-th common pilots) for spatial channel estimation, which mean additional power consumption and interference. The 4-branch MIMO capable UEs, in the following also denominated as new UEs, can support up to 4 antenna ports. In case of good channel conditions, the 4-branch MIMO capable UEs can be served with up
to 4 data-stream transmission. In case of bad channel conditions, the 4-branch MIMO capable UEs can benefit from beam forming transmission with a low rank channel. While for legacy UEs (i.e., non-MIMO UEs and 2-branch MIMO UEs), for instance, the non-MIMO UEs can only support single antenna port and the 2-branch MIMO UEs can support up to 2 antenna ports. For non-MIMO UEs, only one CPICH is used for channel estimation and CQI measurement, and the other three common pilots are useless but consume the transmit power and generate interference. For 2-branch MIMO UEs, the last two CPICHs are not used. Such impact can be severer if the additional common pilots are transmitted with higher powers.

According to the current studies, there is around 30% loss for 2-branch MIMO or non-MIMO UE if the 3-rd and 4-th common pilots are set to -13 dB relative to the maximum downlink power.

**SUMMARY**

According to the present disclosure, a traffic aware common pilot configuration scheme is proposed to adapt and configure the transmission of at least one common pilot according to the traffic conditions in order to optimize the system performance.

In a first embodiment of the present disclosure, there is provided a method for downlink common pilot configuration for a base station serving a first set of User Equipments UEs and a second set of UEs, wherein the first set of UEs consists of 4-branch MIMO capable UEs and the second set of UEs consists of 4-branch MIMO mode incapable UEs. The method includes steps of: determining information related to the User Equipments (UEs) served by the Base Station (BS); and configuring transmission of at least one common pilot from the BS to the served UEs based on the determined UE related information.

In accordance with an aspect of the present disclosure, the step of determining information related to the UEs served by the BS includes the further steps of: selecting a metric representative of downlink data traffic for the UEs; determining for the first set of UEs a first value of the selected metric and for the second set of UEs a second value of the selected metric; calculating a ratio from the first and second values; and comparing the ratio to one or more ratio thresholds associated with a set of predefined power setting schemes applicable to the selected metric.

In accordance with a further aspect of the present disclosure, the step of configuring
transmission of at least one common pilot from the BS to the served UEs based on
the determined UE related information includes the further steps of: selecting a power
setting scheme from the predefined power setting schemes, and adjusting
transmission power of the at least one downlink common pilot in accordance with the
selected power setting scheme.

In accordance with yet an aspect of the present disclosure, the steps for downlink
common pilot configuration are repeated when the transmission power of the at least
one downlink common pilot has been adjusted.

In an example, the first value is the number of 4-branch Multiple Input Multiple Output
(MIMO) capable UEs having active downlink data traffics and the second value is the
number of 4-branch MIMO incapable UEs having active downlink traffic and the ratio
is a number ratio calculated as the first value to the sum of the first and the second
value; and if the number ratio is higher than a first number ratio threshold a first
number ratio power setting scheme is selected which is configured to transmit the at
least one common pilot to support 4-branch MIMO transmission, and otherwise, it is
configured not to transmit the at least one common pilot; and/or if the number ratio is
higher than a second number ratio threshold, a second number ratio power setting
scheme is selected which is configured to transmit the at least one common pilot with
a higher power, and otherwise, it is configured to transmit the at least one common
pilot with a lower power; and/or it is configured to transmit the at least one common
pilot with a power proportional to the calculated number ratio.

In another example, the first value is the total data rate of 4-branch MIMO capable
UEs having active downlink data traffics and the second value is the 4-branch MIMO
capable UEs having active downlink data traffics and the second value is the
4-branch MIMO incapable UEs having active downlink data traffics, the ratio is a rate
ratio calculated as the first value to the sum of the first and second value; and if the
rate ratio is higher than a first rate ratio threshold, a first rate ratio power setting
scheme is selected which is configured to transmit the at least one common pilot, and
otherwise, it is configured not to transmit the at least one common pilot to support
4-branch MIMO transmission; and/or if the rate ratio is higher than a second rate ratio
threshold, a second number ratio power setting scheme is selected which is
configured to transmit the at least one common pilot with a higher power, and
otherwise, it is configured to transmit the at least one common pilot with a lower
power; and/or it is configured to transmit the at least one common pilot with a power
proportional to the calculated rate ratio.

In still another example, the ratio is a satisfaction ratio of 4-branch MIMO capable UEs or 4-branch MIMO incapable UEs, and if the satisfaction ratio of 4-branch MIMO incapable UEs is higher than a first satisfaction ratio threshold and/or if the satisfaction ratio of 4-branch MIMO capable UEs is lower than a first satisfaction ratio threshold, a first satisfaction ratio power setting scheme is selected which is configured to transmit the at least one common pilot to support 4-branch MIMO transmission, and otherwise, it is configured not to transmit the at least one common pilot; and/or if the satisfaction ratio of 4-branch MIMO incapable UEs is higher than a second satisfaction ratio threshold and/or if the satisfaction ratio of 4-branch MIMO capable UEs is lower than a second satisfaction ratio threshold, a second satisfaction ratio power setting scheme is selected which is configured to transmit the at least one common pilot with a higher power, and otherwise, it is configured to transmit the at least one common pilot with a lower power; and/or it is configured to transmit the at least one common pilot with a power proportional to the calculated satisfaction ratio of 4-branch MIMO incapable UEs or reciprocal to the calculated satisfaction ratio of 4-branch MIMO capable UEs.

In this case, the satisfaction ratio of 4-branch MIMO capable UEs or 4-branch MIMO incapable UEs is calculated as a weighted sum of satisfactions according to different QoS traffics respectively.

In yet another example, the first value is a total downlink power for 4-branch MIMO capable UEs and the second value is the total downlink power for 4-branch MIMO incapable UEs, the ratio is a power ratio calculated as the first value to the sum of the first and second value, and if the power ratio is higher than a first power ratio threshold, a first power ratio power setting scheme is selected which is configured to transmit the at least one common pilot to support 4-branch MIMO transmission, and otherwise, it is configured not to transmit the at least one common pilot; and/or if the power ratio is higher than a second power ratio threshold, a second power ratio power setting scheme is selected which is configured to transmit the at least one common pilot with a higher power, and otherwise, it is configured to transmit the at least one common pilot with a power proportional to the calculated power ratio.

In still yet another example, the first value is a total buffered data for 4-branch MIMO
capable UEs and the second value is a total buffered data for 4-branch MIMO incapable UEs in a transmission buffer of the BS and the ratio is a buffered data ratio calculated as the first value to the sum of the first and second value; and a first buffered data power setting scheme is selected wherein if the buffered data ratio is higher than a first buffered data ratio threshold, it is configured to transmit the at least one common pilot to support 4-branch MIMO transmission, and otherwise, it is configured not to transmit the at least one common pilot; and/or a second buffered data power setting scheme is selected wherein, if the buffered data ratio is higher than a second buffered data ratio threshold, it is configured to transmit the at least one common pilot with a higher power, and otherwise, it is configured to transmit the at least one common pilot with a lower power; and/or it is configured to transmit the at least one common pilot with a power proportional to the calculated buffered data ratio.

As another example, the first value is a total number of downlink channels allocated to 4-branch MIMO capable UEs and the second value is a total number of downlink channels allocated to 4-branch MIMO incapable UEs and the ratio is a channel number ratio calculated as the first value to the sum of the first and second value; and if the channel number ratio is higher than a first channel number ratio threshold, a first channel number ratio power setting scheme is selected which is configured to transmit the at least one common pilot to support 4-branch MIMO transmission, and otherwise, it is configured not to transmit the at least one common pilot; and/or if the channel number ratio is higher than a second channel number ratio threshold, a second channel number ratio power setting scheme is selected which is configured to transmit the at least one common pilot with a higher power, and otherwise, it is configured to transmit the at least one common pilot with a lower power; and/or it is configured to transmit the at least one common pilot with a power proportional to the calculated channel number ratio.

As still another example, geometries of 4-branch MIMO capable UEs enable selection of one or more power setting schemes configured to transmit the at least one common pilot with a power determined based on the lowest geometry among the 4-branch MIMO capable UEs; and/or configured to transmit the at least one common pilot with a power determined based on a predetermined nth higher geometry among the 4-branch MIMO capable UEs; and/or configured to transmit the at least one common pilot with a power determined based on a predetermined percentile higher geometry among the 4-branch MIMO capable UEs.
Furthermore, a transmission pattern of the at least one common pilots can be configurable based on at least one of the calculated number ratio, the calculated rate ratio, the calculated satisfaction ratio, the calculated power ratio, the calculated buffered data ratio, the calculated channel number ratio, the calculated geometries.

Additionally, the method may further include: notifying the common pilot configuration by broadcasting to all the served UE; or notifying the common pilot configuration by broadcasting to all the 4-branch MIMO capable UEs, e.g., over High Speed Downlink Shared Channel (HS-DSCH), and/or e.g., by using one common Radio Network Temporary Identifier (RNTI).

Alternatively, the method may further include: notifying the common pilot configuration by using a High Speed Shared Control Channel (HS-SCCH) order, and/or e.g., by using one common RNTI, and/or by reusing a channelization code allocated to E-DCH Absolute Grant Channel (E-AGCH) and/or E-DCH Relative Grant Channel (E-RGCH).

In some examples, at most 4 common pilots are configurable to be transmitted, and the at least one common pilot is two common pilots newly introduced into a legacy system.

In a second embodiment of the present disclosure, there is provided a computer-readable storage medium having computer-readable instructions to facilitate configuration of at least one common pilot from a BS to a UE stored thereon, that are executable by a computing device to carry out the method according to the first embodiment of the present disclosure.

In a third embodiment of the present disclosure, there is provided a BS including: a transmitter configured to transmit at least one common pilot to a first set of UEs and to a second set of UEs served by the BS, wherein the first set of UEs consists of 4-branch MIMO capable UEs and the second set of UEs consists of 4-branch MIMO mode incapable UEs; a determination unit configured to determine information related to the served UEs; and a configuration unit configured to configure transmission of the at least one common pilot by the transmitter based on the determined UE related information.

In accordance with an aspect of the present disclosure, the first determination unit comprises a selection unit for selecting a metric representative of downlink data traffic
for the UEs. A first determination subunit is configured for determining for the first set of UEs a first value of the selected metric and a second determination subunit is configured for determining for the second set of UEs a second value of the selected metric. The first determination unit further comprises a ratio calculation unit for calculating a ratio from the first and second values and a comparing unit for comparing the ratio to one or more ratio thresholds associated with a set of predefined power setting schemes applicable to the selected metric.

In accordance with a further aspect of the present invention, the configuration unit comprises a selection unit for selecting a power setting scheme from the set of predefined power setting schemes and a power adjustment unit configured to adjust the transmission power in the transmitter for the at least one common pilot in accordance with the selected power setting scheme.

In an example, the first determination subunit is a number determination subunit and the first value is a number of 4-branch MIMO capable UEs; the second determination subunit is a number determination subunit and the second value is a number of 4-branch MIMO incapable UEs and the ratio calculation unit for calculating a ratio from the first and second values is a number ratio calculation unit arranged to calculate a number ratio as the first value to the sum of the first and second values; the selection unit is configured to select a first number ratio power setting scheme and to trigger the power adjustment unit to adjust transmission power so that if the number ratio is higher than a first number ratio threshold, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot to support 4-branch MIMO transmission, and otherwise, the power adjustment unit is configured to trigger the transmitter not to transmit the at least one common pilot; and/or the selection unit is configured to select a second number ratio power setting scheme and to trigger the power adjustment unit to adjust transmission power so that if the number ratio is higher than a second number ratio threshold, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a higher power, and otherwise, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a lower power; and/or the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a power proportional to the determined number ratio.

In another example, the first determination subunit is a rate determination subunit and
the first value is a number of 4-branch Multiple Input Multiple Output MIMO capable UEs; the second determination subunit is a rate determination subunit and the second value is a number of 4-branch MIMO incapable UEs; and the ratio calculation unit is a rate ratio calculation unit for calculating a ratio from the first and second values as the first value to the sum of the first and second values; the selection unit is configured to select a first number ratio power setting scheme and to trigger the power adjustment unit to adjust transmission power so that and if the rate ratio is higher than a first rate ratio threshold, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot to support 4-branch MIMO transmission, and otherwise, the power adjustment unit is configured to trigger the transmitter not to transmit the at least one common pilot; and/or the selection unit is configured to select a second number ratio power setting scheme and to trigger the power adjustment unit to adjust transmission power so that if the rate ratio is higher than a second rate ratio threshold, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a higher power, and otherwise, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a lower power; and/or the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a power proportional to the determined rate ratio.

In still another example, the first determination subunit is a satisfaction determination subunit and the first value is a total satisfaction of 4-branch MIMO capable UEs; the second determination subunit is a satisfaction determination subunit and the second value is a total satisfaction of 4-branch MIMO incapable UEs; and the ratio calculation unit is a satisfaction ratio calculation unit for calculating a satisfaction ratio from the first and second values; the selection unit is configured to select a first satisfaction ratio power setting scheme and to trigger the power adjustment unit to adjust transmission power so that if the satisfaction ratio of 4-branch MIMO incapable UEs is higher than a first satisfaction ratio threshold and/or if the satisfaction ratio of 4-branch MIMO capable UEs is lower than a first satisfaction ratio threshold, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot to support 4-branch MIMO transmission, and otherwise, the configuration unit is configured to trigger the transmitter not to transmit the at least one common pilot; and/or the selection unit is configured to select a second satisfaction ratio power setting scheme and to trigger the power adjustment unit to adjust transmission power so that if the satisfaction ratio of 4-branch MIMO
incapable UEs is higher than a second satisfaction ratio threshold and/or if the satisfaction ratio of 4-branch MIMO capable UEs is lower than a second satisfaction ratio threshold, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a higher power, and otherwise, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a lower power; and/or the configuration unit is configured to trigger the transmitter to transmit the at least one common pilot with a power proportional to the determined satisfaction ratio of 4-branch MIMO incapable UEs or reciprocal to the determined satisfaction ratio of 4-branch MIMO capable UEs.

In this case, the satisfaction ratio calculation unit is configured to calculate the satisfaction ratio of 4-branch MIMO capable UEs or 4-branch MIMO incapable UEs as a weighted sum of satisfactions according to different QoS traffics respectively.

In yet another example, the first determination subunit is a power determination subunit and the first value is a total downlink power for 4-branch Multiple Input Multiple Output MIMO capable UEs; the second determination subunit is a total power determination subunit and the second value is a total downlink power for 4-branch MIMO incapable UEs; and the ratio calculation unit is a power ratio calculation unit arranged to calculate the power ratio as the first value to the sum of the first and second values; and; the selection unit is configured to select a first power ratio power setting scheme and to trigger the power adjustment unit to adjust transmission power so that if the power ratio is higher than a first power ratio threshold, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot to support 4-branch MIMO transmission, and otherwise, the power adjustment unit is configured to trigger the transmitter not to transmit the at least one common pilot; and/or the selection unit is configured to select a second power ratio power setting scheme and to trigger the power adjustment unit to adjust transmission power so that if the power ratio is higher than a second power ratio threshold, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a higher power, and otherwise, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a lower power; and/or the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a power proportional to the determined power ratio.

In still yet another example, the first determination subunit is a buffered data ratio
determination subunit configured to determine a total buffered data for 4-branch MIMO capable UEs; the second determination subunit is a buffered data determination subunit configured to determine a total buffered data for 4-branch MIMO incapable UEs; the ratio calculation unit is a buffered data ratio calculation unit arranged to calculate the power ratio as the first value to the sum of the first and second values; and the selection unit is configured to select a first buffered data ratio power setting scheme and to trigger the power adjustment unit to adjust transmission power so that if the buffered data ratio is higher than a first buffered data ratio threshold, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot to support 4-branch MIMO transmission, and otherwise, the power adjustment unit is configured to trigger the transmitter not to transmit the at least one common pilot; and/or if the buffered data ratio is higher than a second buffered data ratio threshold, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a higher power, and otherwise, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a lower power; and/or the configuration unit is configured to trigger the transmitter to transmit the at least one common pilot with a power proportional to the determined buffered data ratio.

As another example, the first determination subunit is a channel number ratio determination subunit configured to determine a total number of downlink channels allocated to 4-branch MIMO capable UEs; the second determination subunit comprises a channel number determination subunit configured to determine a total number of downlink channels allocated to 4-branch MIMO incapable UEs; the ratio calculation unit is a channel number ratio calculation unit arranged to calculated the channel number ratio as the first value to the sum of the first and second values; the selection unit is configured to select a first channel number ratio power setting scheme and to trigger the power adjustment unit to adjust transmission power so that if the channel number ratio is higher than a first channel number ratio threshold, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot to support 4-branch MIMO transmission, and otherwise, the power adjustment unit is configured to trigger the transmitter not to transmit the at least one common pilot; and/or if the channel number ratio is higher than a second channel number ratio threshold, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a higher power, and otherwise, the power adjustment unit is configured to trigger the transmitter to
transmit the at least one common pilot with a lower power; and/or the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a power proportional to the determined channel number ratio.

As still another example, the first determination subunit comprises a geometry determination subunit configured to determine geometries of 4-branch MIMO capable UEs; and the ratio calculation unit is a geometry calculation unit; arranged to calculate a geometry ratio as the geometries of 4-branch MIMO capable UEs; and the selection unit is configured to select a geometry ratio power setting scheme and to trigger the power adjustment unit to trigger the transmitter to transmit the at least one common pilot with a power determined based on the lowest geometry among the 4-branch MIMO capable UEs; and/or the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a power determined based on a predetermined nth higher geometry among the 4-branch MIMO capable UEs; and/or the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a power determined based on a predetermined percentile higher geometry among the 4-branch MIMO capable UEs.

Furthermore, a transmission pattern of the at least one common pilots by the transmitter can be configurable by the power adjustment unit based on at least one of the calculated number ratio, the calculated rate ratio, the calculated satisfaction ratio, the calculated power ratio, the calculated buffered data ratio, the calculated channel number ratio, the calculated geometry ratios.

Additionally, the base station may further include: a notification unit configured to notify the common pilot configuration configured by the configuration unit by using a HS-SCCH order, and/or e.g., by using one common RNTI, and/or by reusing a channelization code allocated to E-AGCH and/or E-RGCH.

In some examples, at most 4 common pilots are configurable by the configuration unit to be transmitted by the transmitter, and the at least one common pilot is two common pilots newly introduced into a legacy system.

The embodiments of the present disclosure at least lead to the following benefits and advantages:

- Reduction of the power consumption and interference of the additional
common pilots;
- Optimization of the system performance with mixed new and legacy UEs; and/or
- Trade-off between the experience of the legacy and new UEs in 4-branch MIMO capable network.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features of this disclosure will become more fully apparent from the following description and appended claims, taken in conjunction with the accompanying drawings. Understanding that these drawings depict only several embodiments in accordance with the disclosure and are, therefore, not to be considered limiting of its scope, the disclosure will be described with additional specificity and detail through use of the accompanying drawings.

Fig. 1 exemplifies the structure of 4-branch MIMO with common pilots only.

Fig. 2 exemplifies the structure of 4-branch MIMO with common pilots plus SDPs.

Fig. 3a shows a schematic diagram of a BS facilitating the common pilot configuration scheme according to one example of the present disclosure.

Fig. 3b shows a schematic diagram of a BS facilitating the common pilot configuration scheme according to another example of the present disclosure.

Fig. 4a shows a flowchart of a method for common pilot configuration according to another example of the present disclosure.

Fig. 4b shows a flowchart of a method for common pilot configuration according to a further example of the present disclosure.

Fig. 5 shows a flowchart of a method for common pilot configuration according to still another example of the present disclosure, in which $R_{s,t,e}$ and $R_{s,t}$ are jointly used to determine the transmission of the additional common pilots.
DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative examples or embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other examples or embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented here. It will be readily understood that aspects of this disclosure, as generally described herein, and illustrated in the figures, can be arranged, substituted, combined, and designed in a wide variety of different configurations, all of which are explicitly contemplated and make part of this disclosure.

The present disclosure is exemplified in the context of WCDMA-HSDPA system as the 4-branch MIMO mode is introduced, while the similar principles and algorithms can be simply extended to even higher rank or other wireless communication systems, such as WCDMA, CDMA2000 and LTE systems.

In the present disclosure, a UE in 4-branch MIMO mode (i.e., a 4-branch MIMO capable UE) is referred to as a new UE, and a UE in non-MIMO or 2-branch MIMO mode (i.e., a 4-branch MIMO incapable UE) is referred to as a legacy UE. The two newly introduced common pilots (i.e., the 3rd and the 4th common pilots) are referred as additional common pilots.

In practice, as a first aspect, there are mixed legacy UEs and new UEs in the same network. The new UEs can benefit from the 4 common pilots transmission with either beam forming in case of low rank transmission or spatial multiplex gain in case of high rank transmission. While the performances of the legacy UEs are affected due to the generated interference and the power consumption by the additional common pilots.

As a second aspect, there are different traffic type for both legacy UEs and new UEs. For 4-branch MIMO UEs with only low bit-rate traffics, the benefits from high rank spatial multiplexing and or beam forming are marginal.

As a third aspect, there can be different ratio of legacy UEs relative to new UEs. The overall benefits from 4-branch transmission relative to the cost of the power
consumption and the generated interference are different under different ratios of legacy UEs to new UEs.

As mentioned above, the benefits from 4-branch transmission in the system perspective are different in different situations if we consider the gain for the new UEs and the cost of the legacy UEs. In case there are high data traffics from 4-branch capable UEs, the benefit is higher by means of 4-branch beam forming in a low rank transmission and/or spatial multiplexing in a high rank transmission. However, when there is a high ratio of traffics from legacy UEs, the performance degradation for the legacy UEs is rather considerable due to the power consumption of the additional common pilots (i.e., the 3-rd and 4-th CPICHS) and the overall system performance can be degraded as a consequence. It is therefore worth to consider some conditional configurations of the transmission of the additional common pilots in case of 4-branch MIMO capable networks.

With the above considerations, methods and base stations to adapt and configure the transmission of the additional common pilot transmission according to the traffic situation are needed in order for the optimization of the system performance.

In some embodiments of the present disclosure, schemes to conditionally turn on/off additional common pilots, and/or conditionally adjust the power setting and the transmission patterns of the additional common pilots are proposed to optimize the system performance when there are mixed new UEs and legacy UEs. With the adaptation of the addition common pilots, the system performance can be optimized and/or the user experiences of the legacy UEs and new UEs can be balanced.

The configuration (or the adaptation) of the additional common pilots can be notified by a Radio Network Controller (RNC) node and/or a Base Station (BS) (e.g., Node B) to UEs.

Fig. 3a and 3b show schematic diagrams of base stations BS 300 facilitating the common pilot configuration scheme according to examples of the present disclosure. Fig. 4a and 4b show flowcharts 400 of methods for common pilot configuration according to other examples of the present disclosure.

As shown in Fig. 3a and 3b, the BS 300 includes a transmitter 310, a determination unit 320 and a configuration unit 330, and optionally a notification unit 340 (in dotted block).
The transmitter 310 is configured to transmit up to 4 common pilots (Option 1 or Option 2) to UEs served by the BS. The determination unit 320 is configured to determine information related to the served UEs. The configuration unit 330 is configured to configure transmission of each of the up to 4 common pilots by the transmitter 310 based on the UE related information determined by the determination unit 320. The optional notification unit 340 may notify the common pilot configuration to the UEs served by the BS.

The common pilot configuration may include conditionally turn on/off at least one common pilot (especially the additional common pilots), and/or conditionally adjust the power setting and the transmission patterns of at least one common pilot (especially, the additional common pilots).

Also, as shown in Fig. 3a and 3b, the determination unit 320 may include some subunits for determining different pieces of the UE related information. For example, in the disclosure of Figure 3a, the determination unit 320 may include a number ratio determination subunit 3210, a rate ratio determination subunit 3220, a satisfaction ratio determination subunit 3230, a power ratio determination subunit 3240, a buffered data ratio determination subunit 3250, a channel number ratio determination subunit 3260, and/or a geometry determination subunit 3270. These subunits are used independently or coordinately, which will be deliberated later.

Figure 3b, discloses an aspect of a base station BS 300 including a determination unit 320 and a configuration unit 330. The determination unit 320 includes a selection unit 321 for selecting a metric representative of downlink data traffic for the UEs. A first determination subunit 322 is included for determining a first value for the first set of UEs, i.e. the 4-branch MIMO capable UEs. Determination of a second value for a second set of UEs is performed in a second determination subunit 323, i.e. determination for the 4-branch MIMO incapable UEs. A ratio calculation unit 324 is provided for calculating a ratio from the first and second values. A comparison of the ratio to one or more ratio thresholds associated with a set of predefined power setting schemes applicable to the selected metric is performed in a comparing unit 325.

As illustrated in Fig. 3b, the previously mentioned ratio determination subunit 3210, a rate ratio determination subunit 3220, a satisfaction ratio determination subunit 3230, a power ratio determination subunit 3240, a buffered data ratio determination subunit 3250, a channel number ratio determination subunit 3260, and/or a geometry
determination subunit 3270 could be part of the ratio calculation unit 324. However, these subunits can also be arranged as independent units or included in any of the other subunits of the determination unit 320 or have a distributed configuration so that said ratio determination subunits or geometry determination subunit are virtual subunits distributed amongst all or a selection of the selection unit 321, the first determination subunit 322, the second determination subunit, the ratio calculation unit 324 or the comparing unit 325. The various ratio determination subunits are used independently or coordinately, as will be deliberated in the following disclosure.

Referring to Fig. 4a, a flowchart 400 of a method for common pilot configuration according to aspects of the present disclosure is shown. In step S410, the determination unit 320 determines information related to the UEs served by the BS 300, wherein the UEs served by the BS 300 includes a first set of User Equipments UEs and a second set of UEs. The first set of UEs consists of 4-branch MIMO capable UEs and the second set of UEs consist of 4-branch MIMO incapable UEs. In step S420, the configuration unit 330 configures transmission of at least one common pilot (especially, the additional common pilots) from the BS 300 to the served UEs based on the determined UE related information.

In Fig. 4b, aspects of a method for common pilot configuration is shown, disclosing further optional details in the step of determining S410 information related to the UEs served by the BS 300 and in the step of configuring transmission of at least one common pilot from the BS to the served UEs based on the determined UE related information. The optional steps S411-S414 in the method step S410 of determining UE related information can be performed prior to performing the optional steps S421-S422 during the step of configuring transmission of a common pilot from the BS to the served UEs based on the determined UE related information. The steps can also be performed independent of any performance of the optional steps S421-S422.

The optional details of determining UE related information includes selecting S411 a metric representative of downlink data traffic for the UEs. As will be explained in the following, such a metric could be a number ratio, a rate ratio, a satisfaction ratio a power ratio, a buffered data ratio, a channel number ratio or a geometry or any other type of metric representative of downlink data traffic for the UEs. Thus, one or more of said metrics can be used to tradeoff the gain of the new UEs, 4-branch MIMO capable UEs, and the loss of the legacy UEs, 4-branch MIMO incapable UEs, and/or save the power for the transmission of the additional common pilots by conditionally configure
the transmission of additional common pilots.

Exemplifying disclosures will be provided in the following for each the metrics listed above.

Following the selection S411 of a metric, a first value of the selected metric for the first set of UEs and a second value of the selected metric for the second set of UEs are determined. In step S413, a ratio is calculated from the first and second values. The UE related information is the result of a comparison S414 of the ratio to one or more ratio thresholds associated with a predefined power setting schemes applicable to the selected metric.

Following the step of comparing S414, transmission of at least one common pilot from the BS to the served UEs is configured in step S420 based on the UE related information from the comparison.

Optionally, the step of configuring S420 transmission of at least one common pilot from the BS to the served UEs based on the determined UE related information could include a step of selecting S421 a power setting scheme from the set of predefined power setting schemes. The transmission power of the at least one downlink common pilot is adjusted S422 in accordance with the selected power setting scheme.

According to a further aspect of the invention, the steps S410, S411-S414 and S420, S421-S422 for downlink common pilot configuration are repeated when the transmission power of the at least one downlink common pilot has been adjusted in step S422.

In the following detailed description 4-branch MIMO capable UEs will be denoted as new UEs and 4-branch MIMO incapable UEs will be denoted as legacy UEs.

\[ R_{U,E}, \text{ a number ratio of the number of new UEs or legacy UEs to the summed number of new UEs and legacy UEs} \]

The UEs which are included to calculate RUE are the UEs that have any active downlink data traffic. One example to calculate RUE of new UEs may be

\[ RUE = \frac{N_{new}}{N_{new} + N_{legacy}} \]

where \( N_{new} \) is the number of new UEs with active downlink traffic, and \( N_{legacy} \) is the number of legacy UEs with active downlink traffic.
For example, the number ratio determination subunit 321 0 can be used to calculate RUE.

A higher RUE of new UEs means that a higher gain from 4-branch MIMO transmission can be expected.

A certain high threshold of RUE (referred to as RuE.thres.H) can be predefined. If RUE of new UEs is higher than RuE.thres.H, it is worth to pursue the gain from the 4-branch transmission at the cost of the performance degradation of the legacy UEs. Hence, the transmission of the additional common pilots can be enabled and the 4-branch transmission may be applied for the new UEs.

A certain low threshold of RUE (referred to as RuE.thres.L, lower than RuE.thres.H in order for reducing Ping-Pong) can be predefined. If RUE of new UEs is lower than RuE.thres.L, it is worth to ensure the performance of the legacy UEs with single or 2-branch transmission at the cost of the possible performance degradation of the new UEs. In this case, the additional common pilots are turned off and all UEs run in legacy modes. Then, the new UEs fall back to the legacy transmission mode.

Or, instead of simply turning on/off the transmission of the additional common pilots, the additional common pilots can be transmitted with a power determined based on the RUE. For instance, if RUE of new UEs is higher than RuE.thres.H, the additional common pilots can be transmitted with a higher power; if RUE of new UEs is lower than RuE.thres.H but higher than RuE.thres.L, the additional common pilots can be transmitted with a lower power; and if RUE of new UEs is lower than RuE.thres.L, the additional common pilots can be turned off.

Or, instead of the stepped power configuration, the additional common pilots can be transmitted with a power proportional to the RUE. That is, if the RUE of new UEs is higher, then the power is higher; and if RUE of new UEs is lower, then the power is lower.

\[ R_{rate} = \text{a rate ratio of a total data rate of new UEs or legacy UEs to a summed total data rate of new UEs and legacy UEs} \]

The UEs which are included to calculate \( R_{rate} \) are the UEs that have any active downlink data traffic. The total data rate of new/legacy UEs means the
summed data rate of all new/legacy UEs. \( R_{rate} \) of new UEs can be calculated by the following formula:

\[
R_{rate} = \frac{\sum_{i=1}^{N_{new}} Rate_{new,i}}{\sum_{i=1}^{N_{new}} Rate_{new,i} + \sum_{j=1}^{N_{legacy}} Rate_{legacy,j}}
\]

where \( Rate_{new,i} \) is a downlink data rate of new UE \( i \) and \( Rate_{legacy,j} \) is a downlink rate of legacy UE \( j \).

For example, the rate ratio determination subunit 3220 can be used to calculate \( R_{rate} \).

Compared to \( R_{UE} \), this metric can more precisely improve the system throughput. The schemes to enable/disable and/or adjust the transmission of the additional common pilots are similar as \( R_{UE} \) based examples.

\( R_{sat} \) a satisfaction ratio of legacy/new UEs

The satisfaction definition can be defined for each traffic type due to the different QoS requirement. For both legacy and new UEs, there can be multiple traffic types. A certain function can be drawn to define an overall satisfaction metric for new / legacy UEs separately:

\[
R_{sat} = f(N_{traffic_1}, Sat_{traffic_1}, \ldots, N_{traffic_i}, Sat_{traffic_i}, \ldots, N_{traffic_P}, Sat_{traffic_P})
\]

where \( N_{traffic,i} \) is the number of UEs with traffic \( i \), \( Sat_{traffic,i} \) is the satisfaction ratio of UEs with traffic \( i \), \( P \) is the number of available traffic types.

As one example:

\[
R_{sat} = \left( \sum_{i=1}^{P} k_i N_{traffic,i} Sat_{traffic,i} \right) / \sum_{i=1}^{P} N_{traffic,i}
\]

where \( k_i \) is the coefficient which is determined by the QoS requirement of traffic \( i \) or the policy from the operator.

For example, the satisfaction ratio determination subunit 3230 can be used to
calculate $R_{sa,t}$ for new UEs and legacy UEs respectively.

The schemes to enable/disable and/or adjust the transmission of the additional common pilots are similar as RUE based examples.

This metric, as well as any metric disclosed in the present disclosure, can be used coordinately with any other mentioned metric or metrics to determine the configuration of the transmission of the additional common pilots. The mentioned parameters can be used in a combined style accordingly in various different ways.

An example of a flowchart 500 to jointly use $R_{rate}$ and $R_{sa,t}$ to determine the transmission of the additional common pilots is illustrated in Fig. 5. The $R_{rate}$ and $R_{sa,t,oid}$ of legacy UEs are determined first in step S510 (one example of step S410 in Fig. 4). If $R_{rate}$ of legacy UEs is lower than a predetermined threshold (i.e., $R_{rate,thres,L}$, the total data rate of new UEs is relative high compare to that of legacy UEs), it is regarded that the new UEs are worth to be protected (step S520: YES). Further, in step S530, the satisfaction ratio $R_{sa,t,oid}$ of legacy UEs is compared to a predetermined threshold (i.e., $R_{sa,t,thres,L,oid}$). If $R_{sa,t,oid}$ of legacy UEs is higher than $R_{sa,t,thres,L,oid}$ (step S530: NO), it can be decided that the legacy UEs need not to be specially protected. When the two conditions are fulfilled (step S520: YES & step S530: NO), the configuration unit 330 configures the transmitter 310 to enable the transmission of the additional common pilots (step S540), which means 4-branch MIMO can be supported for the new UEs. On the other hand, if $R_{sa,t,oid}$ of legacy UEs is lower than $R_{sa,t,thres,L,oid}$ (step S530: YES), it can be decided that the legacy UEs need to be specially protected. When the two conditions are fulfilled (step S520: YES & step S530: YES), the configuration unit 330 configures the transmitter 310 to disable the transmission of the additional common pilots (step S550), and the new UEs fall back to the legacy modes. Additionally, if $R_{rate}$ of legacy UEs is not lower than the predetermined threshold $R_{rate,thres,L}$ it proceeds directly to step S550 to disable the transmission of the additional common pilots.

$R_{power}$, a power ratio of a total downlink power for new UEs or legacy UEs to a summed total downlink power for new UEs and legacy UEs

The UEs which are included to calculate $R_{power}$ are the UEs that have any active downlink data traffic. The total downlink power for new/legacy UEs means
the summed downlink power of all new/legacy UEs. $R_{\text{power}}$ of new UEs can be calculated by the following formula:

$$R_{\text{power}} = \frac{\sum_{i=1}^{N_{\text{new}}} Power_{\text{new},i}}{\left( \sum_{i=1}^{N_{\text{new}}} Power_{\text{new},i} + \sum_{j=1}^{N_{\text{legacy}}} Power_{\text{legacy},j} \right)}$$

where $Power_{\text{new},i}$ is a downlink power for new UE $i$ and $Power_{\text{legacy},j}$ is a downlink power for legacy UE $j$.

For example, the power ratio determination subunit 3240 can be used to calculate $R_{\text{power}}$.

The schemes to enable/disable and/or adjust the transmission of the additional common pilots are similar as RUE based examples.

$R_{\text{data}}$, a buffered data ratio of a total buffered data for new UEs or legacy UEs to a summed total buffered data for new UEs and legacy UEs in a transmission buffer of the BS

The total buffered data for new/legacy UEs in the transmission buffer of the BS means the summed buffered data amount of all new/legacy UEs. $R_{\text{data}}$ of new UEs can be calculated by the following formula:

$$R_{\text{data}} = \frac{\sum_{i=1}^{N_{\text{new}}} Data_{\text{new},i}}{\left( \sum_{i=1}^{N_{\text{new}}} Data_{\text{new},i} + \sum_{j=1}^{N_{\text{legacy}}} Data_{\text{legacy},j} \right)}$$

where $Data_{\text{new},i}$ is a buffered data amount for new UE $i$ in the transmission buffer and $Data_{\text{legacy},j}$ is a buffered data amount for legacy UE $j$ in the transmission buffer.

For example, the buffered data ratio determination subunit 3250 can be used to calculate $R_{\text{data}}$.

The schemes to enable/disable and/or adjust the transmission of the additional common pilots are similar as RUE based examples.
The UEs which are included to calculate $R_{\text{channel\_number}}$ are the UEs that have any active downlink data traffic. The total number of HS-PDSCH channels allocated to new/legacy UEs means the summed number of HS-PDSCH channels allocated to all new/legacy UEs. $R_{\text{channel\_number}}$ of new UEs can be calculated by the following formula:

$$ R_{\text{channel\_number}} = \frac{\sum_{i=1}^{N_{\text{new}}} \text{Channel}_{\text{new},i}}{\left( \sum_{i=1}^{N_{\text{new}}} \text{Channel}_{\text{new},i} + \sum_{j=1}^{N_{\text{legacy}}} \text{Channel}_{\text{legacy},j} \right)} $$

where $\text{Channel}_{\text{new},i}$ is the number of HS-PDSCH channels allocated to new UE $i$ and $\text{Channel}_{\text{legacy},j}$ is the number of HS-PDSCH channels allocated to legacy UE $j$.

For example, the channel number ratio determination subunit 3260 can be used to calculate $R_{\text{channel\_number}}$.

The schemes to enable/disable and/or adjust the transmission of the additional common pilots are similar as RUE based examples.

**Geometries of new UEs**

The geometries of new UEs can be either achieved from the UE reports or indirectly estimations from the CQI reports from the UEs. High geometry of new UE means that a lower transmit power of the additional common pilots is required to ensure the good enough channel estimation. Based on this metric, the transmit power of the additional common pilots can be conditionally adjusted rather than to simply enable/disable the transmission of the additional common pilots. There are various ways to adjust the transmit power of the additional common pilots. One simple example to adjust the transmit power of the additional common pilots based on the lowest geometry of the new UEs. Another attractive way is to adjust the transmit power of the additional common pilots...
pilots based on the $n^{\text{th}}$ ($n$ can be predefined) higher geometry among the new UEs. Still another attractive way is to adjust the transmit power of the additional common pilots based on the $x$ ($x$ can be predefined) percentile higher geometry among the new UEs.

For example, the geometry determination subunit 3270 can be used to calculate geometries of new UEs.

The schemes to enable/disable and/or adjust the transmission of the additional common pilots are similar as RUE based examples.

Furthermore, a transmission pattern of the additional common pilots by the transmitter 310 are configurable by the configuration unit 330 based on at least one of the above metrics (such as, the determined number ratio $\text{RUE}$, the determined rate ratio $R_{\text{rate}}$, the determined satisfaction ratio $R_{s_{u}}$, the determined power ratio $R_{\text{power}}$, the determined buffered data ratio $R_{d_{u}}$, the determined channel number ratio $R_{\text{channel\_number}}$, and the determined geometries).

The common pilot configuration configured by the configuration unit 330 can be notified by the notification unit 340 (i.e., BS based notification). In this example, the BS (Node B) can make use of High Speed Shared Control Channel (HS-SCCH) order. One common Radio Network Temporary Identifier (RNTI) can be pre-defined per cell for the served new users. Then the network can inform all the UEs about the configuration of the additional common pilots with one HS-SCCH order and one transmission of such HS-SCCH order. Similarly, the Node B can also reuse the channelization code allocated to E-DCH Relative Grant Channel (E-RGCH) and/or E-DCH Absolute Grant Channel (E-AGCH), i.e., a new channel is defined for sending the configuration of the additional common pilots to share code with current common channels, such as E-RGCH and/or E-AGCH. The new UEs can demodulate and know the new configuration of the additional common pilots. The mentioned channel can be transmitted over the legacy antenna modes only.

Additionally, the common pilot configuration can be notified from Radio Network Controller (RNC). In this example, one method is to broadcast the configuration of the additional common pilots. This method is doable but has the following limitations:

- This method may result in a larger overhead of broadcasting message
This content of the message needs to be handled by the RNC, which may have a large delay, and thus fast adaptation of the additional common pilots is difficult.

Another method can be certain smart broadcasting over signaling radio bearer. One instance is to broadcast the configuration of the additional common pilots over HS-DSCH. One common RNTI can be pre-defined per cell for all the served new users. The new UEs can know the signaling by detecting the common RNTI.

As mentioned above, the configuration can be

- turn on/off the additional pilots based on some conditions, or turn on/off additional pilots periodically or semi-persistently;
- the power setting of the additional pilots; and/or
- the transmission patterns of the additional common pilots.

Other arrangements of the present disclosure include software programs performing the steps and operations of the method embodiments, which are firstly generally described and then explained in detail. More specifically, a computer program product is such an embodiment, which comprises a computer-readable medium with a computer program logic encoded thereon. The computer program logic provides corresponding operations to provide the above described common pilot configuration scheme when it is executed on a computing device. The computer program logic enables at least one processor of a computing system to perform the operations (the methods) of the embodiments of the present disclosure when it is executed on the at least one processor. Such arrangements of the present disclosure are typically provided as: software, codes, and/or other data structures provided or encoded on a computer-readable medium such as optical medium (e.g. CD-ROM), soft disk, or hard disk; or other mediums such as firmware or microcode on one or more ROM or RAM or PROM chips; or an Application Specific Integrated Circuit (ASIC); or downloadable software images and share database, etc., in one or more modules. The software, hardware, or such arrangements can be mounted on computing devices, such that one or more processors in the computing device can perform the technique described by the embodiments of the present disclosure. Software process operating in combination with e.g. a group of data communication devices or computing devices in other entities can also provide the nodes and host of the present disclosure. The
nodes and host according to the present disclosure can also be distributed among a plurality of software processes on a plurality of data communication devices, or all software processes running on a group of mini specific computers, or all software processes running on a single computer.

There is little distinction left between hardware and software implementations of aspects of systems; the use of hardware or software is generally (but not always, in that in certain contexts the choice between hardware and software can become significant) a design choice representing cost vs. efficiency tradeoffs. There are various vehicles by which processes and/or systems and/or other technologies described herein can be effected (e.g., hardware, software, and/or firmware), and that the preferred vehicle will vary with the context in which the processes and/or systems and/or other technologies are deployed. For example, if an implementer determines that speed and accuracy are paramount, the implementer may opt for a mainly hardware and/or firmware vehicle; if flexibility is paramount, the implementer may opt for a mainly software implementation; or, yet again alternatively, the implementer may opt for some combination of hardware, software, and/or firmware.

The foregoing description gives only embodiments of the present disclosure and is not intended to limit the present disclosure in any way. Thus, any modification, substitution, improvement or like made within the spirit and principle of the present disclosure should be encompassed by the scope of the present disclosure.

ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>3GPP</td>
<td>3rd Generation Partnership Project</td>
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<tr>
<td>BS</td>
<td>Base Station</td>
</tr>
<tr>
<td>CDMA2000</td>
<td>Code Division Multiple Access 2000</td>
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<tr>
<td>CQI</td>
<td>Channel Quality Indicator</td>
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<tr>
<td>E-DCH</td>
<td>Enhanced Dedicated Channel</td>
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<tr>
<td>E-AGCH</td>
<td>E-DCH Absolute Grant Channel</td>
</tr>
<tr>
<td>E-RGCH</td>
<td>E-DCH Relative Grant Channel</td>
</tr>
<tr>
<td>HSDPA</td>
<td>High Speed Downlink Packet Access</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>HSUPA</td>
<td>High Speed Uplink Packet Access</td>
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<td>HS-DSCH</td>
<td>High Speed Downlink Shared Channel</td>
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<tr>
<td>HS-PDSCH</td>
<td>High Speed Physical Downlink Shared Channel</td>
</tr>
<tr>
<td>HS-SCCH</td>
<td>High Speed Shared Control Channel</td>
</tr>
<tr>
<td>LTE</td>
<td>Long-Term Evolution</td>
</tr>
<tr>
<td>MIMO</td>
<td>Multiple Input Multiple Output</td>
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<tr>
<td>PMI</td>
<td>Pre-coding Matrix Index</td>
</tr>
<tr>
<td>P-CPICH</td>
<td>Primary Common Pilot Channel</td>
</tr>
<tr>
<td>QoS</td>
<td>Quality of Service</td>
</tr>
<tr>
<td>RNTI</td>
<td>Radio Network Temporary Identifier</td>
</tr>
<tr>
<td>SDP</td>
<td>Shared Demodulation Pilot</td>
</tr>
<tr>
<td>S-CPICH</td>
<td>Secondary Common Pilot Channel</td>
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<tr>
<td>UE</td>
<td>User Equipment</td>
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<tr>
<td>WCDMA</td>
<td>Wideband Code Division Multiple Access</td>
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CLAIMS

1. A method for downlink common pilot configuration for a base station serving a first set of User Equipments UEs and a second set of UEs, wherein the first set of UEs consists of 4-branch MIMO capable UEs and the second set of UEs consists of 4-branch MIMO mode incapable UEs, the method comprising steps of:
   determining (S410) information related to the UEs served by the Base Station BS; and
   configuring (S420) transmission of at least one common pilot from the BS to the served UEs based on the determined UE related information.

2. The method according to claim 1, wherein the step of determining (S410) information related to the UEs served by the BS includes:
   selecting (S411) a metric representative of downlink data traffic for the UEs;
   determining (S412) for the first set of UEs a first value of the selected metric and for the second set of UEs a second value of the selected metric
   calculating (S413) a ratio from the first and the second values; and
   comparing (S414) the ratio to one or more ratio thresholds associated with a set of predefined power setting schemes applicable to the selected metric.

3. The method according to claim 2, wherein the step of configuring (S420) transmission of at least one common pilot from the BS to the served UEs based on the determined UE related information includes:
   selecting (S421) a power setting scheme from the set of predefined power setting schemes; and
   adjusting (S422) transmission power of the at least one downlink common pilot in accordance with the selected power setting scheme.

4. The method according to claim 3, further including repeating the steps for downlink common pilot configuration when the transmission power of the at least one downlink common pilot has been adjusted.

5. The method according to any of claims 2 to 4, wherein the
first value is the number of 4-branch Multiple Input Multiple Output MIMO capable UEs having active downlink data traffics and the second value is the number of 4-branch MIMO incapable UEs having active downlink traffic and
the ratio is a number ratio calculated as the first value to the sum of the first and second value; and

if the number ratio is higher than a first number ratio threshold a first number ratio power setting scheme is selected which is configured to transmit the at least one common pilot to support 4-branch MIMO transmission, and otherwise, it is configured not to transmit the at least one common pilot; and/or

if the number ratio is higher than a second number ratio threshold, a second number ratio power setting scheme is selected which is configured to transmit the at least one common pilots with a higher power, and otherwise, it is configured to transmit the at least one common pilot with a lower power; and/or

it is configured to transmit the at least one common pilot with a power proportional to the calculated number ratio.

6. The method according to claim 2 or claim 5 wherein the first value is the total data rate of 4-branch Multiple Input Multiple Output MIMO capable UEs having active downlink data traffics and the second value is the 4-branch MIMO incapable UEs having active downlink data traffics
the ratio is a rate ratio calculated as the first value to the sum of the first and second value; and

if the rate ratio is higher than a first rate ratio threshold, a first rate ratio power setting scheme is selected which is configured to transmit the at least one common pilot to support 4-branch MIMO transmission, and otherwise, it is configured not to transmit the at least one common pilot; and/or

if the rate ratio is higher than a second rate ratio threshold, a second number ratio power setting scheme is selected which is configured to transmit the at least one common pilot with a higher power, and otherwise, it is configured to transmit the at least one common pilot with a lower power; and/or

it is configured to transmit the at least one common pilot with a power proportional to the calculated rate ratio.

7. The method according to any one of claims 2 to 6, wherein
the ratio is a satisfaction ratio of 4-branch Multiple Input Multiple Output MIMO capable UEs or 4-branch MIMO incapable UEs; and
if the satisfaction ratio of 4-branch MIMO incapable UEs is higher than a first satisfaction ratio threshold and/or if the satisfaction ratio of 4-branch MIMO capable UEs is lower than a first satisfaction ratio threshold, a first satisfaction ratio power setting scheme is selected which is configured to transmit the at least one common pilot to support 4-branch MIMO transmission, and otherwise, it is configured not to transmit the at least one common pilot; and/or

if the satisfaction ratio of 4-branch MIMO incapable UEs is higher than a second satisfaction ratio threshold and/or if the satisfaction ratio of 4-branch MIMO capable UEs is lower than a second satisfaction ratio threshold, a second satisfaction ratio power setting scheme is selected which is configured to transmit the at least one common pilot with a higher power, and otherwise, it is configured to transmit the at least one common pilot with a lower power; and/or

it is configured to transmit the at least one common pilot with a power proportional to the determined satisfaction ratio of 4-branch MIMO incapable UEs or reciprocal to the calculated satisfaction ratio of 4-branch MIMO capable UEs.

8. The method according to claim 7, wherein the satisfaction ratio of 4-branch MIMO capable UEs or 4-branch MIMO incapable UEs is calculated as a weighted sum of satisfactions according to different Quality of Service QoS traffics respectively.

9. The method according to any one of claims 2 to 8, wherein the first value is the total downlink power for 4-branch Multiple Input Multiple Output MIMO capable UEs and the second value is the total downlink power for 4-branch MIMO incapable UEs

the ratio is a power ratio calculated as the first value to the sum of the first and second value; and

if the power ratio is higher than a first power ratio threshold, a first power ratio power setting scheme is selected which is configured to transmit the at least one common pilot to support 4-branch MIMO transmission, and otherwise, it is configured not to transmit the at least one common pilot; and/or

if the power ratio is higher than a second power ratio threshold, a second power ratio power setting scheme is selected which is configured to transmit...
the at least one common pilot with a higher power, and otherwise, it is configured to transmit the at least one common pilot with a lower power; and/or
it is configured to transmit the at least one common pilot with a power proportional to the calculated power ratio.

10. The method according to any one of claims 2 to 9, wherein the first value is a total buffered data for 4-branch Multiple Input Multiple Output MIMO capable UEs and the second value is a total buffered data for 4-branch MIMO incapable UEs in a transmission buffer of the BS; and
the ratio is a buffered data ratio calculated as the first value to the sum of the first and second value; and first buffered data power setting scheme is selected wherein
if the buffered data ratio is higher than a first buffered data ratio threshold, it is configured to transmit the at least one common pilot to support 4-branch MIMO transmission, and otherwise, it is configured not to transmit the at least one common pilot; and/or a second buffered data power setting scheme is selected wherein
if the buffered data ratio is higher than a second buffered data ratio threshold, it is configured to transmit the at least one common pilot with a higher power, and otherwise, it is configured to transmit the at least one common pilot with a lower power; and/or
it is configured to transmit the at least one common pilot with a power proportional to the calculated buffered data ratio.

11. The method according to any one of claims 2 to 10, wherein the first value is
a total number of downlink channels allocated to 4-branch Multiple Input Multiple Output MIMO capable UEs and the second number is a total number of downlink channels allocated 4-branch MIMO incapable UEs; and the ratio is a channel number ratio calculated as the first value to the sum of the first and second value; and
if the channel number ratio is higher than a first channel number ratio threshold, a first channel number ratio power setting scheme is selected which is configured to transmit the at least one common pilot to support 4-branch MIMO transmission, and otherwise, it is configured not to transmit the at least one common pilot; and/or
if the channel number ratio is higher than a second channel number ratio threshold, a second channel number ratio power setting scheme is selected which is configured to transmit the at least one common pilot with a higher power, and otherwise, it is configured to transmit the at least one common pilot with a lower power; and/or
it is configured to transmit the at least one common pilot with a power proportional to the calculated channel number ratio.

12. The method according to any one of claims 2 to 11, wherein geometries of 4-branch Multiple Input Multiple Output MIMO capable UEs enables selection of one or more power setting schemes;
configured to transmit the at least one common pilot with a power determined based on the lowest geometry among the 4-branch MIMO capable UEs; and/or
configured to transmit the at least one common pilot with a power determined based on a predetermined n-th higher geometry among the 4-branch MIMO capable UEs; and/or
configured to transmit the at least one common pilot with a power determined based on a predetermined percentile higher geometry among the 4-branch MIMO capable UEs.

13. The method according to any one of claims 2 to 12, wherein a transmission pattern of the at least one common pilots are configurable based on at least one of the calculated number ratio, the calculated rate ratio, the calculated satisfaction ratio, the calculated power ratio, the calculated buffered data ratio, the calculated channel number ratio, the calculated geometries.

14. The method according to any one of claims 2 to 13, further comprising: notifying the common pilot configuration by broadcasting to all the served UE; or notifying the common pilot configuration by broadcasting to all the 4-branch MIMO capable UEs, e.g., over High Speed Downlink Shared Channel HS-DSCH, and/or e.g., by using one common Radio Network Temporary Identifier RNTI.

15. The method according to any one of claims 2 to 14, further comprising: notifying the common pilot configuration by using a High Speed Shared Control Channel HS-SCCH order, and/or e.g., by using one common Radio Network
Temporary Identifier RNTI, and/or by reusing a channelization code allocated to E-DCH Absolute Grant Channel E-AGCH and/or E-DCH Relative Grant Channel E-RGCH.

16. The method according to any one of claims 2 to 15, wherein at most 4 common pilots are configurable to be transmitted, and the at least one common pilot is two common pilots newly introduced into a legacy system.

17. A computer-readable storage medium having computer-readable instructions to facilitate configuration of at least one common pilot from a Base Station BS to a User Equipment UE stored thereon, that are executable by a computing device to carry out the method according to any one of claims 1-16.

18. A Base Station BS (300) comprising:
   a transmitter (300) configured to transmit at least one common pilot to a first set of User Equipments UEs and a second set of UEs served by the BS, wherein the first of UEs consists of 4-branch MIMO capable UEs and the second set of UEs consists of 4-branch MIMO mode incapable UEs;
   a determination unit (320) configured to determine information related to the served UEs; and
   a configuration unit (330) configured to configure transmission of the at least one common pilot by the transmitter (310) based on the determined UE related information.

19. A Base Station BS (300) according to claim 18 wherein the determination unit comprises:
   a selection unit (321) for selecting a metric representative of downlink data traffic for the UEs;
   a first determination subunit (322) for determining for the first set of UEs a first value of the selected metric;
   a second determination subunit (323) for determining for the second set of UEs a second value of the selected metric;
   a ratio calculation unit (324) for calculating a ratio from the first and second values and a
   comparing unit (325) for comparing the ratio to one or more ratio thresholds associated with a set of predefined power setting schemes applicable to the selected
20. A Base Station BS (300) according to claim 19, wherein the configuration unit (330) comprises:
   a selection unit (331) for selecting a power setting scheme from the set of predefined power setting schemes; and
   a power adjustment unit (332) configured to adjust the transmission power in the transmitter for the at least one common pilot in accordance with the selected power setting scheme.

21. The base station BS (300) according to claim 20, wherein
   the first determination subunit (322) is a number determination subunit and the first value is a number of 4-branch Multiple Input Multiple Output MIMO capable UEs;
   the second determination subunit (323) is a number determination subunit and the second value is a number of 4-branch MIMO incapable UEs; and
   the ratio calculation unit (324) for calculating a ratio from the first and second values is a number ratio calculation unit arranged to calculate a number ratio as the first value to the sum of the first and second values;
   the selection unit (321) is configured to select a first number ratio power setting scheme and to trigger the power adjustment unit to adjust transmission power so that if the number ratio is higher than a first number ratio threshold, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot to support 4-branch MIMO transmission, and otherwise, the power adjustment unit is configured to trigger the transmitter not to transmit the at least one common pilot; and/or the selection unit (331) is configured to select a second number ratio power setting scheme and to trigger the power adjustment unit to adjust transmission power so that if the number ratio is higher than a second number ratio threshold, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a higher power, and otherwise, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a lower power; and/or the power adjustment unit (332) is configured to trigger the transmitter to transmit the at least one common pilot with a power proportional to the determined number ratio.

22. The base station BS (300) according to any of claims 20 to 21, wherein
   the first determination subunit is a rate determination subunit and the first value
is a number of 4-branch Multiple Input Multiple Output MIMO capable UEs;
the second determination subunit is a rate determination subunit and the
second value is a number of 4-branch MIMO incapable UEs; and
the ratio calculation unit is a rate ratio calculation unit for calculating a ratio from
the first and second values as the first value to the sum of the first and second values;
the selection unit is configured to select a first number ratio power setting
scheme and to trigger the power adjustment unit to adjust transmission power so that
if the rate ratio is higher than a first rate ratio threshold, the power adjustment unit is
configured to trigger the transmitter to transmit the at least one common pilot to
support 4-branch MIMO transmission, and otherwise, the power adjustment unit is
configured to trigger the transmitter not to transmit the at least one common pilot; and/or
the selection unit is configured to select a second number ratio power setting
scheme and to trigger the power adjustment unit to adjust transmission power so that
if the rate ratio is higher than a second rate ratio threshold, the power adjustment unit is
configured to trigger the transmitter to transmit the at least one common pilot with a
higher power, and otherwise, the power adjustment unit is configured to trigger the
transmitter to transmit the at least one common pilot with a lower power; and/or
the power adjustment unit is configured to trigger the transmitter to transmit the
at least one common pilot with a power proportional to the determined rate ratio.

23. The base station BS (300) according to any one of claims 20 to 22,
wherein
the first determination subunit is a satisfaction determination subunit and the
first value is a total satisfaction of 4-branch Multiple Input Multiple Output MIMO
capable UEs;
the second determination subunit is a satisfaction determination subunit and the
second value is a total satisfaction of 4-branch MIMO incapable UEs; and
the ratio calculation unit is a satisfaction ratio calculation unit for calculating a
satisfaction ratio from the first and second values
the selection unit is configured to select a first satisfaction ratio power setting
scheme and to trigger the power adjustment unit to adjust transmission power so that
if the satisfaction ratio of 4-branch MIMO incapable UEs is higher than a
first satisfaction ratio threshold and/or if the satisfaction ratio of 4-branch MIMO
capable UEs is lower than a first satisfaction ratio threshold, the power
adjustment unit is configured to trigger the transmitter to transmit the at least one
common pilot to support 4-branch MIMO transmission, and otherwise, the
creation unit is configured to trigger the transmitter not to transmit the at
least one common pilot; and/or

the selection unit is configured to select a second satisfaction ratio power
setting scheme and to trigger the power adjustment unit to adjust transmission power
so that if the satisfaction ratio of 4-branch MIMO incapable UEs is higher than a
second satisfaction ratio threshold and/or if the satisfaction ratio of 4-branch
MIMO capable UEs is lower than a second satisfaction ratio threshold, the
configuration unit is configured to trigger the transmitter to transmit the at least
one common pilot with a higher power, and otherwise, the power adjustment unit
is configured to trigger the transmitter to transmit the at least one common pilot
with a lower power; and/or

the power adjustment unit is configured to trigger the transmitter to transmit
the at least one common pilot with a power proportional to the determined
satisfaction ratio of 4-branch MIMO incapable UEs or reciprocal to the determined
satisfaction ratio of 4-branch MIMO capable UEs.

24. The base station BS (300) according to claim 23, wherein

the satisfaction ratio calculation unit is configured to calculate the satisfaction
ratio of 4-branch MIMO capable UEs or 4-branch MIMO incapable UEs as a weighted
sum of satisfactions according to different Quality of Service QoS traffics respectively.

25. The base station BS (300) according to any one of claims 20 to 24,
wherein the first determination subunit is a power determination subunit and the first
value is a total downlink power for 4-branch Multiple Input Multiple Output MIMO
capable UEs; the second determination subunit is a total power determination subunit
and the second value is a total downlink power for 4-branch MIMO incapable UEs;
and

the ratio calculation unit is a power ratio calculation unit arranged to calculate
the power ratio as the first value to the sum of the first and second values; and

the selection unit is configured to select a first power ratio power setting scheme
and to trigger the power adjustment unit to adjust transmission power so that if the
power ratio is higher than a first power ratio threshold, the power adjustment unit
is configured to trigger the transmitter to transmit the at least one common pilot to
support 4-branch MIMO transmission, and otherwise, the power adjustment unit is
configured to trigger the transmitter not to transmit the at least one common pilot; and/or

the selection unit is configured to select a second power ratio power setting scheme and to trigger the power adjustment unit to adjust transmission power so that

if the power ratio is higher than a second power ratio threshold, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a higher power, and otherwise, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a lower power; and/or

the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a power proportional to the determined power ratio.

26. The base station BS (300) according to any one of claims 20 to 25, wherein

the first determination subunit is a buffered data determination subunit configured to determine a total buffered data for 4-branch Multiple Input Multiple Output MIMO capable UEs;

the second determination subunit is a buffered data determination subunit configured to determine a total buffered data for 4-branch MIMO incapable UEs;

the ratio calculation unit is a buffered data ratio calculation unit arranged to calculate the power ratio as the first value to the sum of the first and second values; and

the selection unit is configured to select a first buffered data ratio power setting scheme and to trigger the power adjustment unit to adjust transmission power so that

if the buffered data ratio is higher than a first buffered data ratio threshold, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot to support 4-branch MIMO transmission, and otherwise, the power adjustment unit is configured to trigger the transmitter not to transmit the at least one common pilot; and/or

if the buffered data ratio is higher than a second buffered data ratio threshold, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a higher power, and otherwise, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a lower power; and/or

the power adjustment unit is configured to trigger the transmitter to transmit
the at least one common pilot with a power proportional to the determined buffered data ratio.

27. The base station BS (300) according to any one of claims 20 to 26, wherein

the first determination subunit comprises a channel number determination subunit configured to determine a total number of downlink channels allocated to 4-branch Multiple Input Multiple Output MIMO capable UEs;

the second determination subunit comprises a channel number determination subunit configured to determine a total number of downlink channels allocated to 4-branch MIMO incapable UEs;

the ratio calculation unit is a channel number ratio calculation unit arranged to calculate the channel number ratio as the first value to the sum of the first and second values; and

the selection unit is configured to select a first channel number ratio power setting scheme and to trigger the power adjustment unit to adjust transmission power so that

if the channel number ratio is higher than a first channel number ratio threshold, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot to support 4-branch MIMO transmission, and otherwise, the power adjustment unit is configured to trigger the transmitter not to transmit the at least one common pilot; and/or

if the channel number ratio is higher than a second channel number ratio threshold, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a higher power, and otherwise, the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a lower power; and/or

the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a power proportional to the determined channel number ratio.

28. The base station BS (300) according to any one of claims 20 to 27, wherein

the first determination subunit comprises a geometry determination subunit configured to determine geometries of 4-branch Multiple Input Multiple Output MIMO capable UEs; and
the ratio calculation unit is a geometry calculation unit; arranged to calculate a geometry ratio as the geometries of 4-branch MIMO capable UEs; and

the selection unit is configured to select a geometry ratio power setting scheme and to trigger the power adjustment unit to trigger the transmitter to transmit the at least one common pilot with a power determined based on the lowest geometry among the 4-branch MIMO capable UEs; and/or

the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a power determined based on a predetermined n\textsuperscript{th} higher geometry among the 4-branch MIMO capable UEs; and/or

the power adjustment unit is configured to trigger the transmitter to transmit the at least one common pilot with a power determined based on a predetermined percentile higher geometry among the 4-branch MIMO capable UEs.

29. The base station BS (300) according to any one of claims 20 to 28, wherein

a transmission pattern of the at least one common pilots by the transmitter are configurable by the power adjustment unit based on at least one of the calculated number ratio, the calculated rate ratio, the calculated satisfaction ratio, the calculated power ratio, the calculated buffered data ratio, the calculated channel number ratio, the calculated geometry ratios.

30. The base station BS (300) according to any one of claims 20 to 29, further comprising:

a notification unit configured to notify the common pilot configuration configured by the configuration unit by using a High Speed Shared Control Channel HS-SCCH order, and/or e.g., by using one common Radio Network Temporary Identifier RNTI, and/or by reusing a channelization code allocated to E-DCH Absolute Grant Channel E-AGCH and/or E-DCH Relative Grant Channel E-RGCH.

31 The base station BS (300) according to any one of claims 20 to 30, wherein

at most 4 common pilots are configurable by the configuration unit to be transmitted by the transmitter, and the at least one common pilot is two common pilots newly introduced into a legacy system.
Fig. 3a

START

Determine information related to the UEs served by the BS

Configure transmission of the additional common pilots based on the determined UE related information

END

Fig 4a
Selecting a metric

Determining values of selected metric for UEs: a 1st value for a 1st set of UEs and 2nd value for 2nd set of UEs

Calculating a ratio from the determined 1st and 2nd values

Comparing ratio to ratio threshold

Selecting a power setting scheme

Adjusting transmission power of downlink common pilot

Fig. 4b
START

Determine $R_{\text{rate}}$ and $R_{\text{sat, old}}$ of legacy UEs

$R_{\text{rate}} < R_{\text{rate, thres, L}}$?

YES

$R_{\text{sat, old}} < R_{\text{sat, thres, L, old}}$?

YES

Enable transmission of the additional common pilots

END

NO

NO

Enable transmission of the additional common pilots

DISABLE transmission of the additional common pilots

NO

Fig 5