CLAIMS

1. A method of transmitting a demodulation reference signal in a base station of a wireless communication network, the demodulation reference signal being used for demodulating physical downlink control channel signaling, wherein the physical downlink control channel signaling is embedded in a physical downlink shared channel, and the method comprises:

- transmitting the demodulation reference signal to a user equipment, wherein the demodulation reference signal is included in a control channel element.

2. A method of receiving a demodulation reference signal in a user equipment of a wireless communication network, wherein the demodulation reference signal is used for demodulating physical downlink control channel signaling, and wherein the physical downlink control channel signaling is embedded in a physical downlink shared channel, and the method comprises:

- receiving the demodulation reference signal from a base station, wherein the demodulation reference signal is included in a control channel element.

3. A method, in a base station of a wireless communication network, of assisting a user equipment in blind decoding, wherein the method comprises the step of:

- providing the user equipment with blind decoding indication information, the blind decoding indication information including an indication of a search space in which the user equipment performs the blind decoding, wherein the search space comprises a control channel element of a traditional physical downlink control channel and further comprises a control channel element of a pre-coded physical downlink control channel.

4. The method according to claim 3, wherein the blind decoding indication information further comprises an indication of a starting location in the search space at which the user equipment performs the blind decoding.

5. The method according to claim 3, wherein the blind decoding

indication information further comprises an indication of the numbers of searches respectively in the search space of the traditional physical downlink control channel and the search space of the pre-coded physical downlink control channel.

6. The method according to any one of claims 3 to 5, wherein the blind decoding indication information notifies the user equipment of a current search space, a starting location in the search space at which the user equipment performs the blind decoding and the number of searches in the search space, in an implicit indication manner, via predefined parameters or via association with system parameters.

7. The method according to any one of claims 3 to 6, wherein the number of searches of the traditional physical downlink control channel and the number of searches of the pre-coded physical downlink control channel are adjustable.

8. A method of blind decoding in a user equipment of a wireless communication network, wherein the method comprises the steps of:

A. obtaining blind decoding indication information from a base station, the blind decoding indication information including an indication of a search space in which the user equipment performs the blind decoding, wherein the search space comprises a control channel element of a traditional physical downlink control channel and further comprises a control channel element of a pre-coded physical downlink control channel; and

B. performing the blind decoding in the search space indicated by the blind decoding indication information according to the blind decoding indication information.

9. The method according to claim 8, wherein the blind decoding indication information further comprises an indication of the numbers of searches respectively in the search space of the traditional physical downlink control channel and the search space of the pre-coded physical downlink control channel, and the step B further comprises:

- performing the blind decoding respectively in the search space of the physical downlink control channel and the search space of the pre-coded physical downlink control channel according to the numbers of searches respectively in the search space of the physical downlink control channel and the search space of the pre-coded physical downlink control channel indicated by the blind decoding indication information.

10. The method according to claim 8, wherein the blind decoding indication information further comprises an indication of a starting location in the search space at which the user equipment performs the blind decoding; and

wherein the step B further comprises:

- performing the blind decoding at the starting location.

11. The method according to any one of claims 8 to 10, wherein the blind decoding indication information notifies the user equipment of a current search space and/or a starting location in the search space at which the user equipment performs the blind decoding and/or the number of searches in the search space, in an implicit indication manner, via predefined parameters or via association with system parameters; and

the step A further comprises: obtaining the blind decoding indication information from the predefined parameters or the system parameters.

12. A first apparatus for transmitting a demodulation reference signal in a base station of a wireless communication network, the demodulation reference signal being used for demodulating physical downlink control channel signaling, wherein the physical downlink control channel signaling is embedded in a physical downlink shared channel, and the first apparatus comprises:

- a transmitter configured to transmit the demodulation reference signal to a user equipment, wherein the demodulation reference signal is included in a control channel element.

13. A second apparatus for receiving a demodulation reference signal in a user equipment of a wireless communication network, wherein the demodulation reference signal is used for demodulating physical downlink control channel signaling, and wherein the physical

downlink control channel signaling is embedded in a physical downlink shared channel, and the second apparatus comprises:

a receiver configured to receive the demodulation reference signal from a base station, wherein the demodulation reference signal is included in a control channel element.

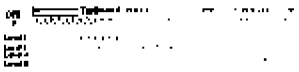
14. A third apparatus, in a base station of a wireless communication network, for assisting a user equipment in blind decoding, wherein the third apparatus comprises:

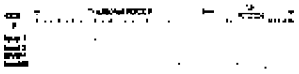
a providing device configured to provide the user equipment with blind decoding indication information, the blind decoding indication information including an indication of a search space in which the user equipment performs the blind decoding, wherein the search space comprises a control channel element of a traditional physical downlink control channel and further includes a control channel element of a pre-coded physical downlink control channel.

15. A fourth apparatus for blind decoding in a user equipment of a wireless communication network, wherein the fourth apparatus comprises: an obtaining device configured to obtain blind decoding indication information from a base station, the blind decoding indication information including an indication of a search space in which the user equipment performs the blind decoding, wherein the search space comprises a control channel element of a traditional physical downlink control channel and further includes a control channel element of a pre-coded physical downlink control channel; and

a blinding decoder configured to perform the blind decoding in the search space indicated by the blind decoding indication information according to the blind decoding indication information.







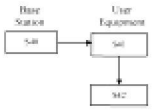

Base
Station
User
Equipment
540
540
542

FIG.4

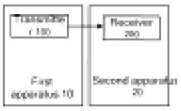

Transmitter
(10)
Receiver
200
First
apparatus 10
Second apparatus
20

FIG. 5


Providing device 100
Obtaining device 400
Blind decoding device 401
Third apparatus 10
Fourth apparatus 40

FIG. 6

Method of and Apparatus for Pre-coded Physical Downlink Control Channel Reference Signal and Blind

Decoding

Field of the invention

The present disclosure relates to a physical downlink control channel and particularly to a method of and apparatus for a user equipment- specific pre-coded physical downlink control channel reference signal and blind decoding.

Background of the invention

First three OFDM symbols in a sub-frame are occupied by a traditional Physical Downlink Control Channel (PDCCH), and the entire bandwidth of a system is occupied by these three OFDM symbols. For traditional PDCCH signaling, channel estimation is performed with a Common Reference Signal (CRS).

It is proposed in the 3 GPP RIO relay standard to embed a PDCCH into a Physical Downlink Shared Channel (PDSCH) through Frequency Division Multiplexing (FDM) manner, and the PDCCH embedded into the PDSCH is also referred to as an R-PDCCH.

As compared with an R-PDCCH, a PDCCH based upon user equipment pre-coding, i.e., a U-PDCCH, has the following features:

The link quality between a base station and a user equipment may be not so strong as that between the base station and a relay base station, and therefore how to guarantee a BLock Error Rate (BLER) of U-PDCCH

detection is an important issue.

The number of UEs number may far exceed the number of RNBs, and U-PDCCH allocation may be more dynamic. Therefore U-PDCCH resource allocation is another issue as compared to R-PDCCH.

Furthermore since channel pre-coding is performed on a U-PDCCH, for example, through Beam Forming (BF), and non-codebook based pre-coding is not supported for a CRS, so channel estimation on the U-PDCCH can not be performed with a CRS.

Summary of the invention

According to a first aspect of the invention, there is provided a method of transmitting a demodulation reference signal in a base station of a wireless communication network, the demodulation reference signal being used for demodulating physical downlink control channel signaling, wherein the physical downlink control channel signaling is embedded into a physical downlink shared channel, and the method includes: transmitting the demodulation reference signal to a user equipment, wherein the demodulation reference signal is included in a control channel element.

According to a second aspect of the invention, there is provided a method of receiving a

demodulation reference signal in a user equipment of a wireless communication network, wherein the demodulation reference signal is used for demodulating physical downlink control channel signaling, and wherein the physical downlink control channel signaling is embedded into a physical downlink shared channel, and the method includes: - receiving the demodulation reference signal from a base station, wherein the demodulation reference signal is included in a control channel element.

According to a third aspect of the invention, there is provided a method, in a base station of a wireless communication network, of assisting a user equipment in blind decoding, wherein the method includes the step of: -providing the user equipment with blind decoding indication information, the blind decoding indication information including an indication of a search space in which the user equipment performs the blind decoding, wherein the search space includes a control channel element of a traditional physical downlink control channel and further includes a control channel element of a pre-coded physical downlink control channel.

According to a fourth aspect of the invention, there is provided a method of blind decoding in a user equipment of a wireless communication network, wherein the method comprises the steps of: obtaining blind decoding indication information from a base station, the blind decoding indication information including an indication of a search space in which the user equipment performs the blind decoding, wherein the search space includes a control channel element of a traditional physical downlink control channel and further includes a control channel element of a pre-coded physical downlink control channel; and performing the blind decoding for the number of searches indicated by the blind decoding indication information in the search space indicated by the blind decoding indication information, according to the blind decoding indication information.

According to a fifth aspect of the invention, there is provided a first apparatus for transmitting a demodulation reference signal in a base station of a wireless communication network, the demodulation reference signal being used for demodulating physical downlink control channel signaling, wherein the physical downlink control channel signaling is embedded into a physical downlink shared channel, and the first apparatus includes: a transmitter configured to transmit the demodulation reference signal to a user equipment, wherein the demodulation reference signal is included in a control channel element.

According to a sixth aspect of the invention, there is provided a second apparatus for receiving a demodulation reference signal in a user equipment of a wireless communication network, wherein the demodulation reference signal is used for demodulating physical downlink control channel signaling, and wherein the physical downlink control channel signaling is embedded into a physical downlink shared channel, and the second apparatus includes: a receiver configured to receive the demodulation reference signal from a base station, wherein the demodulation reference signal is included in a control channel element.

According to a seventh aspect of the invention, there is provided a third apparatus, in a base station of a wireless communication network, for assisting a user equipment in blind decoding, wherein the third apparatus includes: a providing device configured to provide the user equipment with blind decoding indication information, the blind decoding indication information including an indication of a search space in which the user equipment performs the blind decoding, wherein the search space includes a control channel element of a traditional physical downlink control channel and further includes a control channel element

of a pre-coded physical downlink control channel.

According to an eighth aspect of the invention, there is provided a fourth apparatus for blind decoding in a user equipment of a wireless communication network, wherein the fourth apparatus includes: an obtaining device configured to obtain blind decoding indication information from a base station, the blind decoding indication information including an indication of a search space in which the user equipment performs the blind decoding, wherein the search space includes a control channel element of a traditional physical downlink control channel and further includes a control channel element of a pre-coded physical downlink control channel; and a blinding decoder configured to perform the blind decoding in the search space indicated by the blind decoding indication information according to the blind decoding indication information.

With the solutions of the invention, a design solution to a DeModulated Reference Signal (DMRS) of a U-PDCCH is proposed so that the DMRS for demodulating the U-PDCCH is more compact, thereby saving signaling overhead of an RS. Furthermore in a preferred embodiment, when user equipments perform blind decoding for PDCCH, the user equipments of different versions can perform blind decoding starting from different starting locations, that is to say, a priority is set for CCE resource of PDCCH occupied for the user equipment, thereby further optimizing resource allocation.

Brief description of drawings

Other features, objects and advantages of the invention will become more apparent from the following detailed description of non-limiting embodiments with reference to the drawings in which:

Fig.1 (a) and Fig.1 (b) illustrate design patterns of demodulation reference signals for demodulating PDCCH signaling according to two embodiments of the invention respectively;

Fig.2 illustrates a flow chart of a method according to an embodiment of the invention;

Fig.3 illustrates a schematic diagram of a search space and a search sequence for blind decoding of a PDCCH according to an embodiment of the invention; and

Fig.4 illustrates a schematic diagram of a search space and a search sequence for blind decoding of a PDCCH according to an embodiment of the invention.

Wherein, identical or similar reference numerals denote identical or similar step features or devices/modules.

Detailed description of embodiments

Fig.1 (a) and Fig.1 (b) illustrate design patterns of demodulation reference signals for demodulating PDCCH signaling according to two embodiments of the invention respectively.

In general, a PDCCH is transmitted in one or more Control Channel Elements (CCEs). Particularly each CCE corresponds to nine sets of Resource Element Groups (REGs), and each set of REGs include four Physical Resource Elements (REs), that is, each CCE includes

fixed 36 Res.

A mapping between a CCE of a traditional PDCCH and a Physical Resource Block (PRB) is discrete, that is, CCEs are discretely distributed throughout a frequency band. However user equipment-specific beam forming is performed for a U-PDCCH, that is, data is transmitted to a specific user equipment through beam forming, that is, beam forming is narrowband oriented. Therefore the traditional discrete mapping between a CCE and a PRB is not applicable to the scenario of a U-PDCCH. In view of this, the applicants considers that the design of an R-PDCCH can be made use of, that is, a first Time Slot (TS) is used for downlink scheduling and a second time slot is used for uplink scheduling through time division multiplexing.

For a design of a reference signal, a reference signal of a U-PDCCH can generally be designed in at least the following two approaches. That is, a CRS reference signal is reused, and a demodulation reference signal is used for channel estimation of the U-PDCCH, that is, the U-PDCCH is demodulated with a DMRS. For CRS demodulation of the U-PDCCH, the design of an R-PDCCH can be reused, and therefore a repeated description thereof will be omitted here. In this context, a discussion will be focused on a design of a DMRS for demodulating a U-PDCCH.

The following two factors shall be considered in a design of a DMRS for demodulating a U-PDCCH:

1. The smallest granularity of a U-PDCCH is a CCE instead of a pair of PRBs or one bundled PRBs.

2. A different DMRS density of a PDCCH from a PCSCH may be required.

Therefore the design of a DMRS for demodulating a U-PDCCH shall be optimized to design a CCE-specific DMRS structure, that is, each CCE includes a separate DMRS.

In a method according to this embodiment, a base station (eNB) is configured to transmit a DMRS for demodulating PDCCH signaling, where the PDCCH signaling is embedded into a PDSCH, and the method includes: transmitting the DMRS to a User Equipment (UE), where the DMRS is included in a CCE.

Then the user equipment receives the DMRS for demodulating the PDCCH signaling, where the PDCCH signaling is embedded into the PDSCH, and the method includes: receives the DMRS from the base station, where the DMRS is included in a CCE.

Fig.1 (a) and Fig.1 (b) illustrate design patterns of demodulation reference signals for demodulating PDCCH signaling according to two embodiments of the invention respectively.

Particularly in Fig.1 (a) and Fig.1 (b), two or three CCEs are multiplexed respectively onto the same pair of PRBs through frequency division multiplexing. Noted resource elements filled with an oblique line represent resource elements occupied by a traditional PDCCH, and resource element filled with oblique crossing lines represent resource elements reserved for reference signals. Therefore each CCE includes all of resource elements in the range of black box lines other than resource elements reserved for a DMRS. A pair of PRBs includes twelve sub-carriers and fourteen OFDM symbols. Noted six sub-carriers are occupied by a CCE in

Fig.1 (a), and therefore a pair of PRBs includes two CCEs. Four sub-carriers are occupied by a CCE in Fig.1 (b), and therefore a pair of PRBs includes three CCEs.

The design of a DMS for a U-PDCCH has been detailed above, and a process for a user equipment to perform U-PDCCH based blind decoding will be further described below.

In the traditional blind decoding technology, a set of CCE locations at which a user equipment may detect a PDCCH can be referred to as a "search space". In the LTE, the sizes of a search space vary with different PDCCH formats, i.e., different PDCCH levels. Furthermore a dedicated search space and a common search space are defined which are separate, where the dedicated search space is configured specially for a user equipment, and the common search space is notified to all of user equipments. It is noted that dedicated and common search spaces may overlap for a specific UE. The sizes of dedicated and common search spaces are listed in Table 1 below.

Table 1

Level	The number of CCEs	The candidate number of common search spaces	The candidate number of dedicated search spaces
1	1		6
2	2		6
4	4	4	2
8	8	2	2

In the prior art, a UE performs at most 44 times of blind decoding over any sub-frame.

The traditional blind decoding mechanism shall be reused for a U-PDCCH, but the following two issues shall be addressed to reuse the traditional blind decoding mechanism:

1. How to guarantee a similar number of rounds of blind decoding with that of an RIO system; and

2. How to guarantee a blind decoding rule.

Therefore the inventors propose two blind decoding solutions in this application.

First Solution:

Existing PDCCH and U-PDCCH resources are combined together to form a new extended PDCCH search space applicable to a user equipment of Rl l and above, where all of existing defined blind decoding mechanisms can be reused with only the following modification:

The number of searches for a CCE in the search space is modified to:

PDCCH , U—PDCCH

^ CCE ,k ~ ^ CCE,k $^{+1}$ CCE,k

Where ' CCE,k ,i N^{L} ,CCE,k represent the number of CCEs in a traditional PDCCH search space and the number of CCEs in a U-PDCCH search space respectively. This solution is as illustrated in Fig.2. In Fig.2, 24 CCEs numbered 0 to 23 represent CCEs occupied by a traditional PDCCH, and 12 CCEs numbered 24 to 35 represent CCEs occupied by a U-PDCCH. As depicted in Table 1 , one CCE is occupied by a PDCCH at the level 1 , two CCEs are occupied by a PDCCH at the level 2, four CCEs are occupied by a PDCCH at the level 4, and eight CCEs are occupied by a PDCCH at the level 8. The number 1 at each level represents a UE-specific CCE search space, and a blank preceding the number 1 represents a common search space. That is, there are six CCEs at the level 1 for a common search, four CCEs at the level 2 for a common search, four CCEs at the level 4 for a common search, and two CCEs at the level 8 for a common search. Of course, since a UE typically performs only 44 searches (including repeated two times), it is impossible to perform blind decoding for all the CCEs, and therefore as can be seen from Fig.2, blind decoding is performed for only a part of the CCEs, and a CCE which is numbered in Fig.2 represents a CCE for which a user equipment performs user equipment- specific blind decoding. Those skilled in the art can appreciate that all the numbers of searches at the respective levels are illustrative. In a practical application, a network operator totally can configure them dependent upon a particular network operating condition.

The first solution is easy to implement. However as can be seen from Fig.l , CCE of U-PDCCH is included only at the level 8, but no CCE of U-PDCCH is included at the other levels 1 , 2 and 4. Therefore this solution may result in imbalance of CCEs because only user equipments of Rl l and above can use U-PDCCH and these user equipments of Rl l and above have the same priority as user equipments of RIO and below in terms of sharing a traditional PDCCH resource.

Second Solution:

Fig.3 illustrates a schematic diagram of a search space and a search sequence for blind decoding of a PDCCH according to another embodiment of the invention.

With traditional $_{=N}$ PDccH $_{+N}$u -PDccH ^ $_{a\ base}$ station may configure the numbers of times of blind decoding respectively over a U-PDCCH and a traditional PDCCH.

Where $N_{lib}^{Traditional}$,
$_{N}$TM^{CCH} ,$N_{B}^{U\sim FDCCH}$ represent respectively the number of

times of blind decoding for a traditional PDCCH, the total number of times of

blind decoding for a PDCCH in the invention and the number of times of

blind decoding for a U-PDCCH. Search spaces are defined respectively as

$_{S}$ (L),U-$_{PD}$CCH $_{=L}$. yU-PDCCH $_{+}$ ^) ^ ^-PDCCH , ^JJ $_{+}$ j

S[$^{L\ PDCCH}$ $_{=}$ L - {(Y_{k}^{PDCCH}

$_{+}$ m_2) mod LN™ / Lj} + i,

Particularly L represents an aggregation level, i.e., the levels 1 , 2, 4 and 8, Y_k represents a starting location, as its relevant definition may be found in TS36.213 V9.2.0. m, = 0 - $N^{\wedge PDCCH}$ -l,m_2 = 0 ~ $N_B{}^P{}_D{}^{DCCH}$ - 1 and ; = 0 ~ L-1 .

As can be seen from Fig.3, user equipments of Rl l and above firstly perform blind decoding starting from CCEs of U-PDCCH, and if blind decoding succeeds, then these user equipments will not perform blind decoding any further on CCEs of traditional PDCCH. Therefore these user equipments will not occupy any CCE resource of traditional PDCCH.

Fig.4 illustrates a flow chart of a system method according to an embodiment of the invention. Firstly in the step S40, a base station provides a user equipment with blind decoding indication information, the blind decoding indication information including an indication of a search space in which the user equipment performs blind decoding, wherein the search space includes a control channel element of a traditional physical downlink control channel and further includes a control channel element of a pre-coded physical downlink control channel.

In another embodiment, the blind decoding indication information further includes an indication of a starting location in the search space at which the user equipment performs blind decoding.

In another embodiment, the blind decoding indication information further includes an indication of the numbers of searches respectively in the search space of the traditional physical downlink control channel and the search space of the pre-coded physical downlink control channel.

Furthermore the base station may notify the user equipment of the blind decoding indication information explicitly or implicitly.

In an explicit manner, for example, the base station may transmit an instruction to the user equipment, the instruction including the blind decoding indication information.

In an implicit manner, for example, the base station may not transmit the blind decoding indication information directly, but can associate the blind decoding indication information with other system parameters. For example, the blind decoding indication information may be associated with a system bandwidth. In an example, the higher the bandwidth, the larger the search spaces and the numbers of searches for blind decoding. Furthermore the base station may further notify the user equipment, in a predefined manner, of a current search space, a starting location in the search space at which the user equipment performs blind decoding, and the number of searches in the search space.

Furthermore the number of searches for a traditional PDCCH and the number of searches for a U-PDCCH may be adjusted.

Then in the step S41 , the user equipment obtains blind decoding indication information from the base station, the blind decoding indication information including the indication of the search space in which the user equipment performs blind decoding, wherein the search space includes the control channel element of the traditional physical downlink control channel and

further includes the control channel element of the pre-coded physical downlink control channel.

Then in the step S42, the user equipment performs blind decoding in the search space indicated by the blind decoding indication information according to the blind decoding indication information.

In a preferred embodiment, the blind decoding indication information further includes the indication of a starting location in the search space at which the user equipment performs blind decoding, and therefore the step S42 further includes: performing blind decoding at the starting location.

In another embodiment, the blind decoding indication information further includes the indication of the numbers of searches respectively in the search space of the traditional physical downlink control channel and the search space of the pre-coded physical downlink control channel, and the step S42 further includes: performing blind decoding respectively in the search space of the physical downlink control channel and the search space of the pre-coded physical downlink control channel according to the numbers of searches respectively in the search space of the physical downlink control channel and the search space of the pre-coded physical downlink control channel indicated by the blind decoding indication information

In another embodiment, the numbers of searches for the traditional PDCCH and the number of searches for the U-PDCCH may be adjusted.

In another embodiment, the blind decoding indication information can notify the user equipment of a current search space, a starting location in the search space at which the user equipment performs blind decoding and the number of searches in the search space, in an implicit indication manner, via predefined parameters or via association with system parameters. That is, the blind decoding indication information is predefined in the network, and therefore the user equipment obtains the blind decoding indication information from the predefined parameters. In another embodiment, when the blind decoding indication information is associated with system parameters, the user equipment may obtain the blind decoding indication information from the system parameters.

The invention has been detailed above from the perspective of a method flow. The invention will be described below respectively with reference to Fig.5 and Fig.6 from the perspective of an apparatus.

A first apparatus 10 in Fig.5 is located in a base station to transmit a demodulation reference signal, the demodulation reference signal being used for demodulating physical downlink control channel signaling, where the physical downlink control channel signaling is embedded in a physical downlink shared channel, and the first apparatus 10 includes: a transmitter 100 configured to transmit the demodulation reference signal to a user equipment, where the demodulation reference signal is included in a control channel element.

A second apparatus 20 in Fig.5 is located in a user equipment to receive a demodulation reference signal, wherein the demodulation reference signal is used for demodulating physical downlink control channel signaling, and wherein the physical downlink control channel signaling is embedded in a physical downlink shared channel, and the second

apparatus 20 includes a receiver 200 configured to receive the demodulation reference signal from a base station, wherein the demodulation reference signal is included in a control channel element.

A third apparatus 30 in Fig.6 is located in a base station to assist a user equipment in blind decoding, wherein the third apparatus 30 includes: a providing device 300 configured to provide the user equipment with blind decoding indication information, the blind decoding indication information including an indication of a search space in which the user equipment performs blind decoding, wherein the search space includes a control channel element of a traditional physical downlink control channel and further includes a control channel element of a pre-coded physical downlink control channel.

A fourth apparatus 40 in Fig.6 is located in a user equipment to perform blind decoding, wherein the fourth apparatus 40 includes: an obtaining device 400 configured to obtain blind decoding indication information from a base station, the blind decoding indication information including an indication of a search space in which the user equipment performs blind decoding, wherein the search space includes a control channel element of a traditional physical downlink control channel and further includes a control channel element of a pre-coded physical downlink control channel; and a blinding decoder 401 configured to perform blind decoding in the search space indicated by the blind decoding indication information according to the blind decoding indication information.

The embodiments of the invention have been described above, but the invention will not be limited to any specific system, device and protocol, and those skilled in the art can make various variations or modifications without departing from the scope of the invention.

Those ordinarily skilled in the art can understand and practice other changes to the disclosed embodiments upon review of the description, the disclosure and the drawings as well as the appended claims. In the claims, the term "comprising" will not preclude another element(s) and step(s), and the term "a" or "an" will not preclude plural. In the invention, "first" and "second" merely represent a name but not any sequential relationship. In a practical application of the invention, an element may perform functions of a plurality of technical features recited in a claim. Any reference numerals in the claims shall not be construed as limiting the scope of the invention.

