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Liu et al.

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(54) **METHODS, NODES AND COMPUTER READABLE MEDIA FOR PHR**

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CPC ***H04W 52/365*** (2013.01); ***H04W 24/10*** (2013.01); ***H04W 52/346*** (2013.01); ***H04W 52/367*** (2013.01); ***H04W 80/02*** (2013.01)

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See application file for complete search history.

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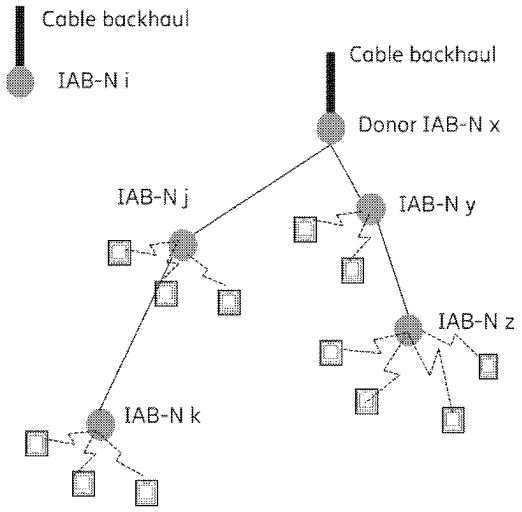
(57) **ABSTRACT**

The present disclosure provides a method at a downstream radio node. The method includes: determining a mapping table, which indicates a mapping correspondence between an entry index of a PHR related parameter and a measurement value range of the PHR related parameter with an adjustment value being applied; and transmitting an reported entry index according to the mapping table and a corresponding measurement value to an upstream radio node. The present disclosure further provides a method at an upstream radio node, a downstream radio node, an upstream radio node and a computer readable storage medium.

13 Claims, 10 Drawing Sheets



(51) **Int. Cl.**
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H04W 80/02 (2009.01)

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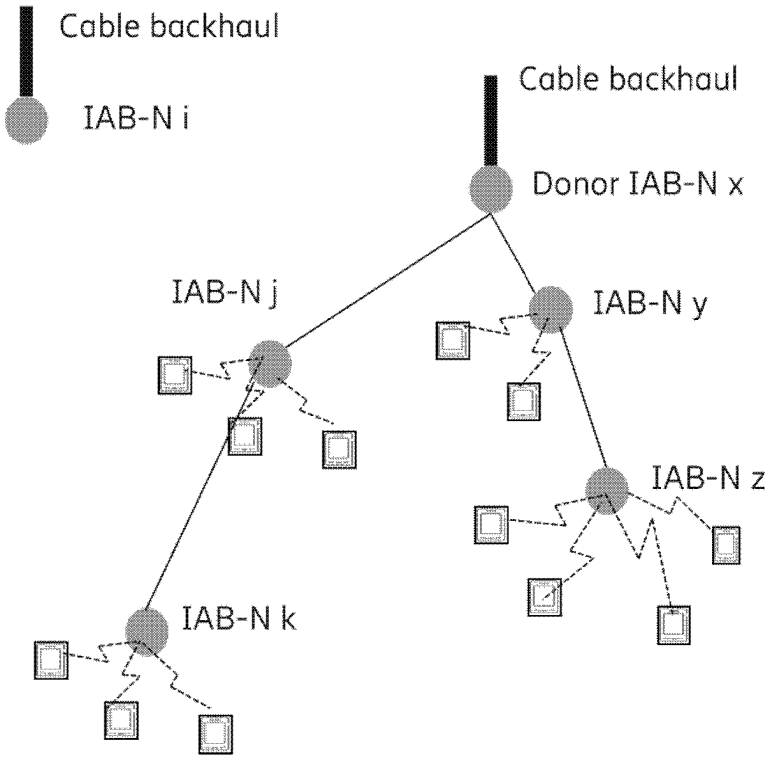
Cable backhaul
IAB-N i
Cable backhaul
Donor IAB-N x
IAB-N j
IAB-N y
IAB-N z
IAB-N k

FIG. 1

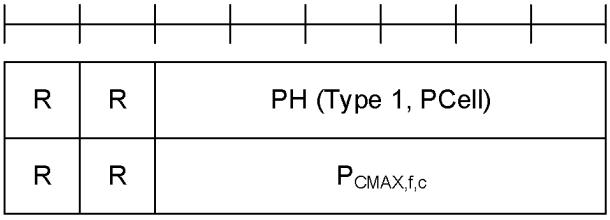
R
R
PH (Type 1, PCell)
R
R
$P_{CMAX,f,c}$

FIG. 2

C_7	C_6	C_5	C_4	C_3	C_2	C_1	R
P	V	PH (Type 2, SpCell of the other MAC entity)					
R	R	$P_{CMAX,f,c}$ 1					
P	V	PH (Type 1, PCell)					
R	R	$P_{CMAX,f,c}$ 2					
P	V	PH (Type X, Serving Cell 1)					
R	R	$P_{CMAX,f,c}$ 3					

...

P	V	PH (Type X, Serving Cell n)
R	R	$P_{CMAX,f,c}$ m

FIG. 3(a)

C_7	C_6	C_5	C_4	C_3	C_2	C_1	R
C_{15}	C_{14}	C_{13}	C_{12}	C_{11}	C_{10}	C_9	C_8
C_{23}	C_{22}	C_{21}	C_{20}	C_{19}	C_{18}	C_{17}	C_{16}
C_{31}	C_{30}	C_{29}	C_{28}	C_{27}	C_{26}	C_{25}	C_{24}
P	V	PH (Type 2, SpCell of the other MAC entity)					
R	R	$P_{CMAX,f,c}$ 1					
P	V	PH (Type 1, PCell)					
R	R	$P_{CMAX,f,c}$ 2					
P	V	PH (Type X, Serving Cell 1)					
R	R	$P_{CMAX,f,c}$ 3					

...

P	V	PH (Type X, Serving Cell n)
R	R	$P_{CMAX,f,c}$ m

FIG. 3(b)

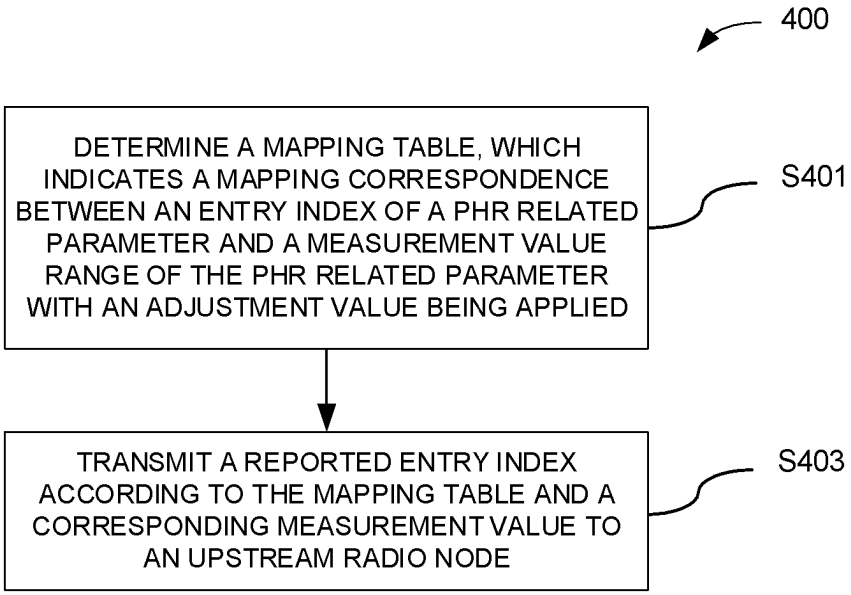
400
DETERMINE A MAPPING TABLE, WHICH INDICATES A MAPPING CORRESPONDENCE BETWEEN AN ENTRY INDEX OF A PHR RELATED PARAMETER AND A MEASUREMENT VALUE RANGE OF THE PHR RELATED PARAMETER WITH AN ADJUSTMENT VALUE BEING APPLIED
S401
TRANSMIT A REPORTED ENTRY INDEX ACCORDING TO THE MAPPING TABLE AND A CORRESPONDING MEASUREMENT VALUE TO AN UPSTREAM RADIO NODE
S403

FIG. 4

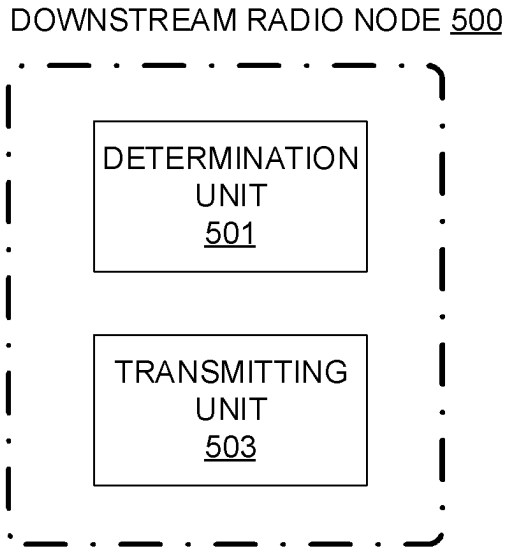
DOWNSTREAM RADIO NODE 500
DETERMINATION UNIT 501
TRANSMITTING UNIT 503

FIG. 5

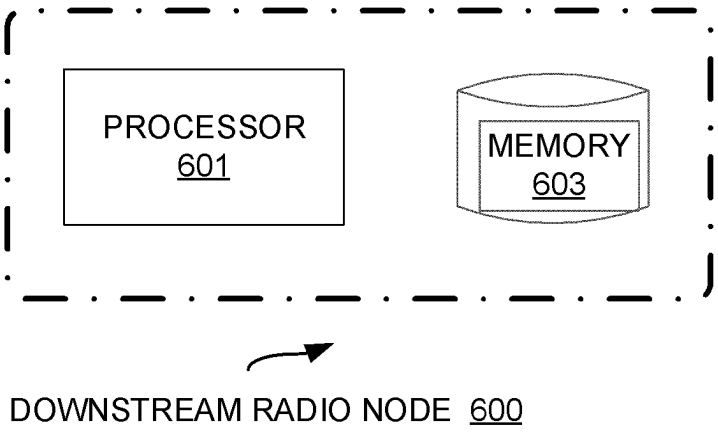
PROCESSOR
601
MEMORY
603
DOWNSTREAM RADIO NODE 600

FIG. 6

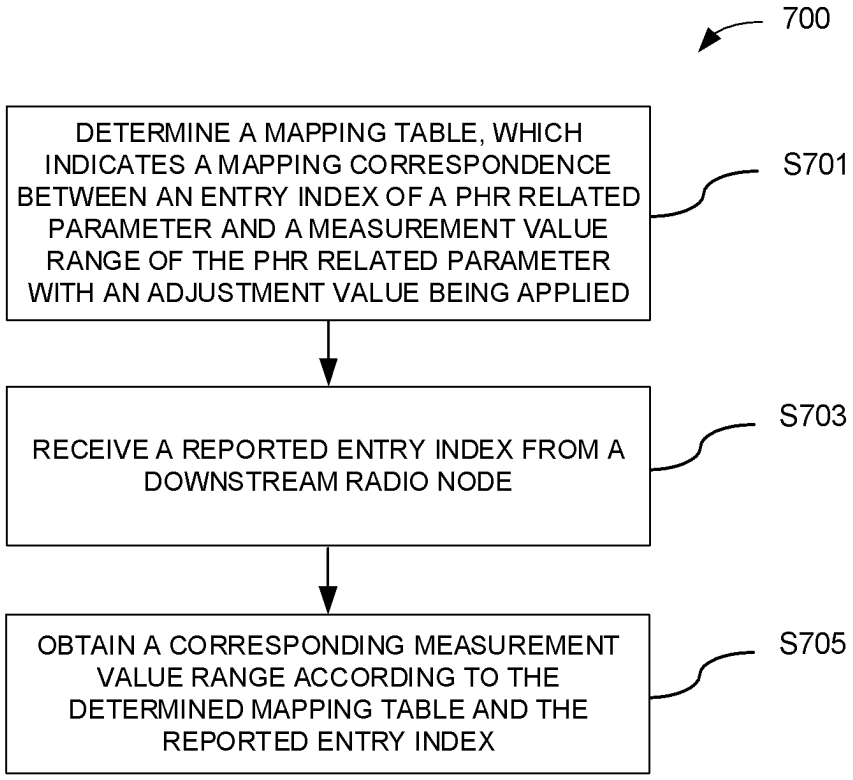
700
DETERMINE A MAPPING TABLE, WHICH INDICATES A MAPPING CORRESPONDENCE BETWEEN AN ENTRY INDEX OF A PHR RELATED PARAMETER AND A MEASUREMENT VALUE RANGE OF THE PHR RELATED PARAMETER WITH AN ADJUSTMENT VALUE BEING APPLIED
S701
RECEIVE A REPORTED ENTRY INDEX FROM A DOWNSTREAM RADIO NODE
S703
OBTAIN A CORRESPONDING MEASUREMENT VALUE RANGE ACCORDING TO THE DETERMINED MAPPING TABLE AND THE REPORTED ENTRY INDEX
S705

FIG. 7

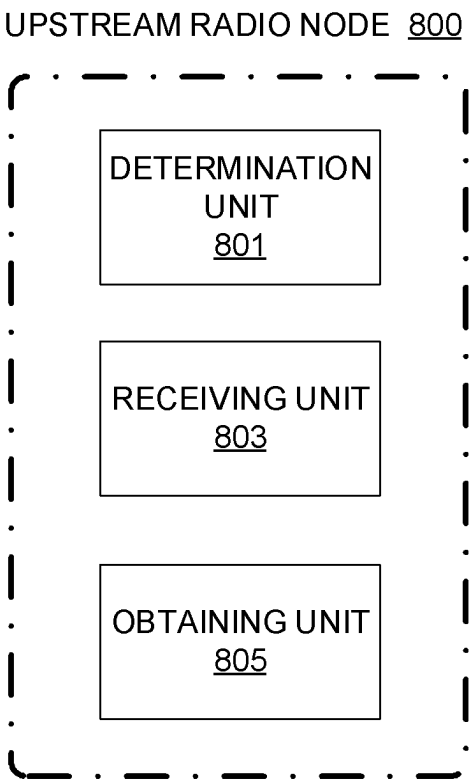
UPSTREAM RADIO NODE 800
DETERMINATION UNIT 801
RECEIVING UNIT 803
OBTAINING UNIT 805

FIG. 8

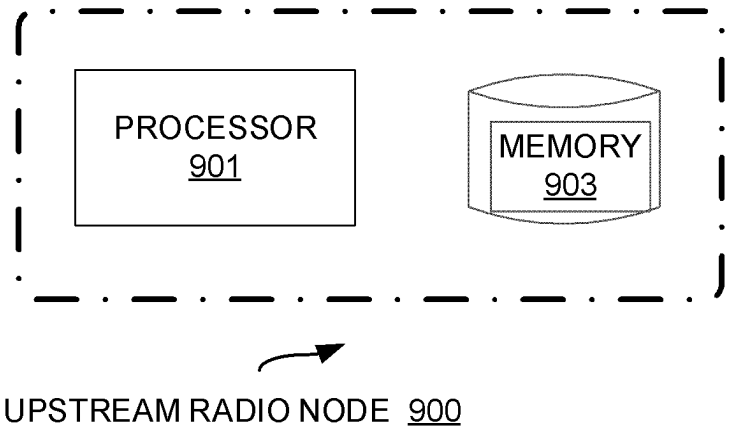
PROCESSOR 901
MEMORY 903
UPSTREAM RADIO NODE 900

FIG. 9

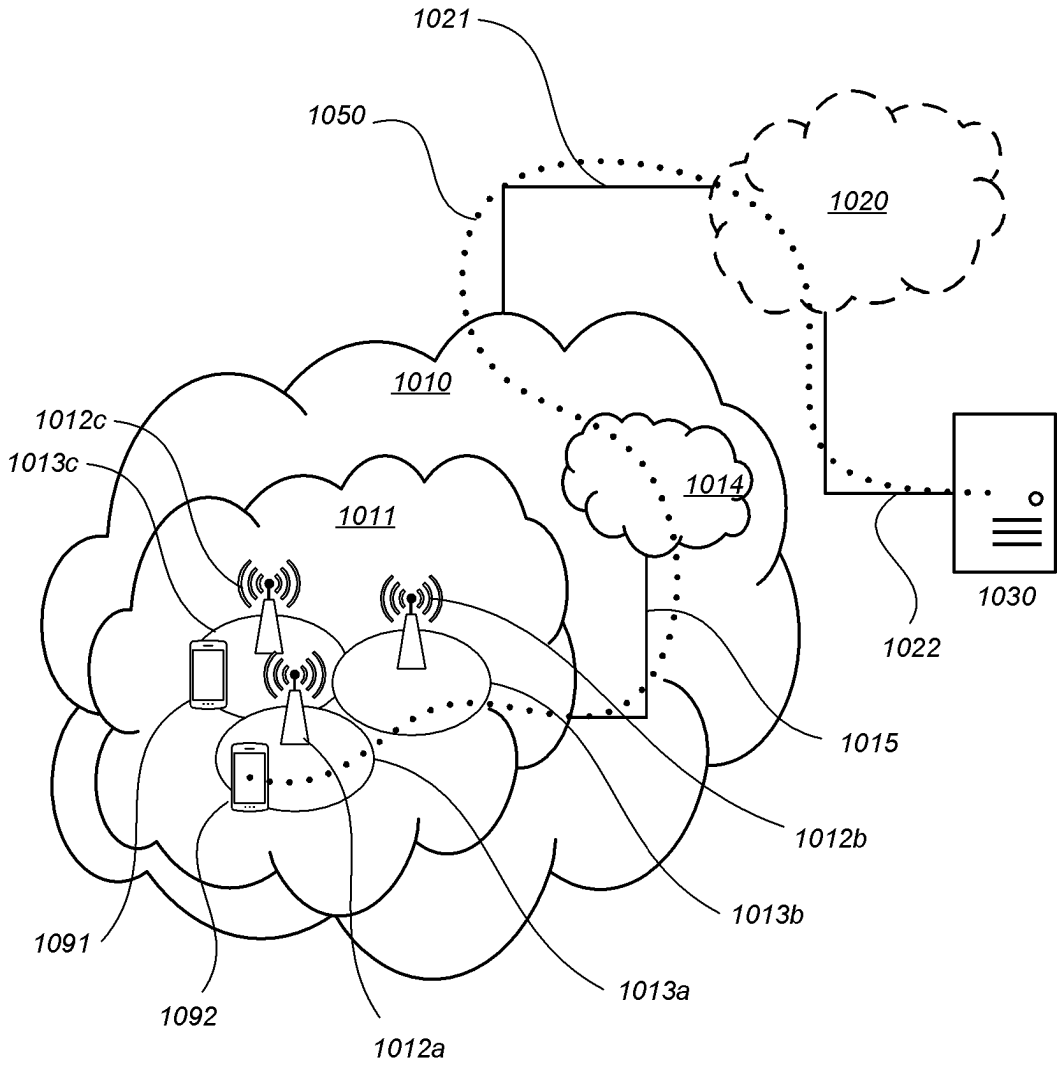
1021
1050
1020
1010
1012c
1013c
1014
1011
1030
1022
1015
1012b
1013b
1091
1013a
1092
1012a

FIG. 10

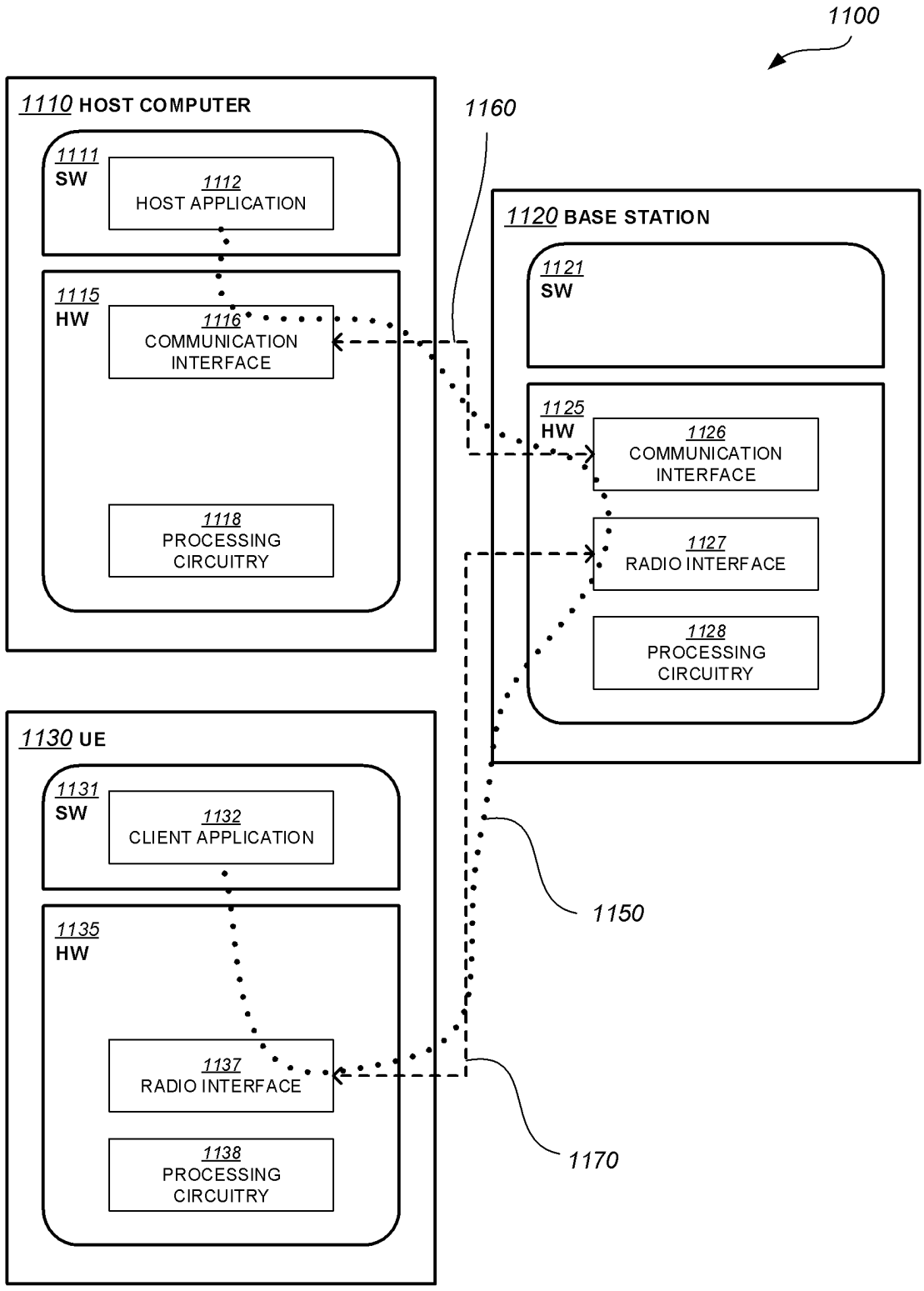
1100
1110 HOST COMPUTER
1111 SW
1112 HOST APPLICATION
1115 HW
1116 COMMUNICATION INTERFACE
1118 PROCESSING CIRCUITRY
1160
1120 BASE STATION
1121 SW
1125 HW
1126 COMMUNICATION INTERFACE
1127 RADIO INTERFACE
1128 PROCESSING CIRCUITRY
1130 UE
1131 SW
1132 CLIENT APPLICATION
1135 HW
1137 RADIO INTERFACE
1138 PROCESSING CIRCUITRY
1150
1170

FIG. 11

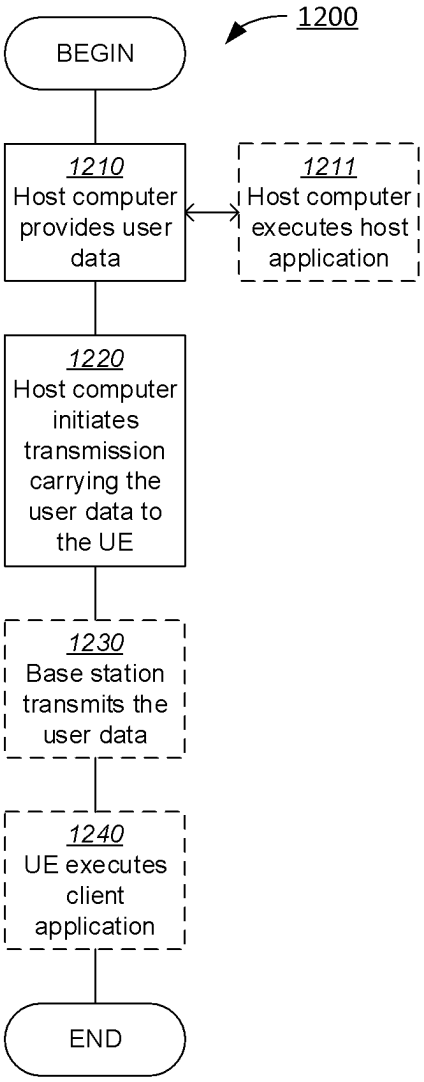
1200
BEGIN
1210
Host computer provides user data
1211
Host computer executes host application
1220
Host computer initiates transmission carrying the user data to the UE
1230
Base station transmits the user data
1240
UE executes client application
END

FIG. 12

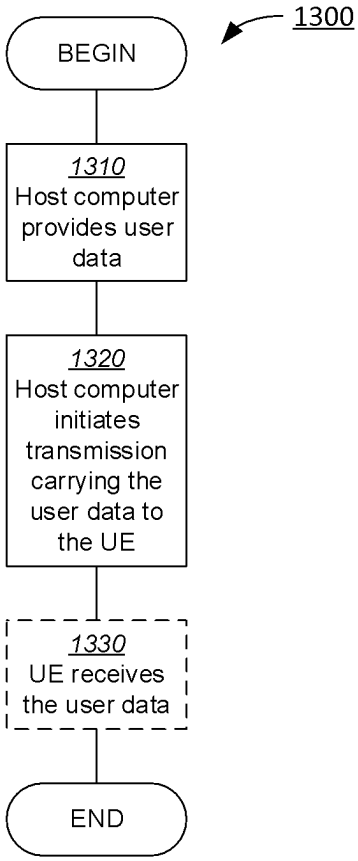
1300
BEGIN
1310
Host computer provides user data
1320
Host computer initiates transmission carrying the user data to the UE
1330
UE receives the user data
END

FIG. 13

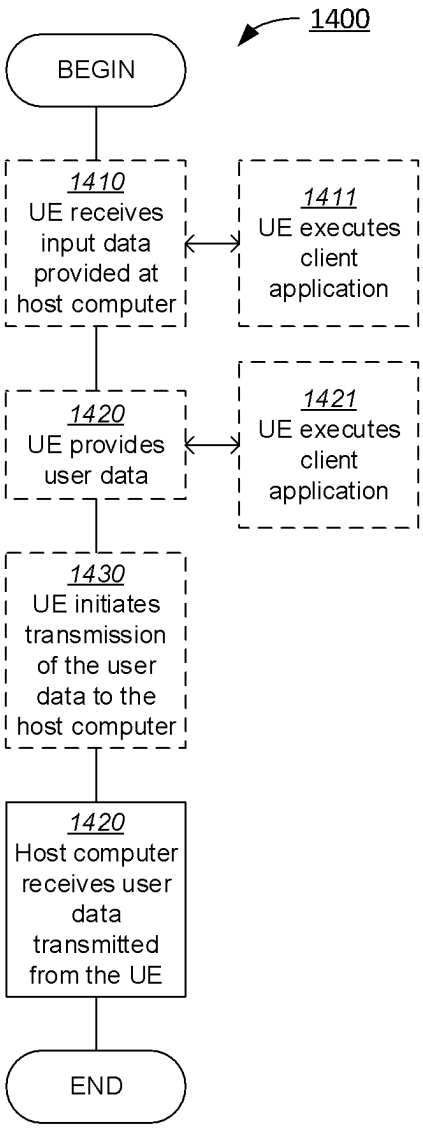
1400
BEGIN
1410
UE receives input data provided at host computer
1411
UE executes client application
1420
UE provides user data
1421
UE executes client application
1430
UE initiates transmission of the user data to the host computer
1420
Host computer receives user data transmitted from the UE
END

FIG. 14

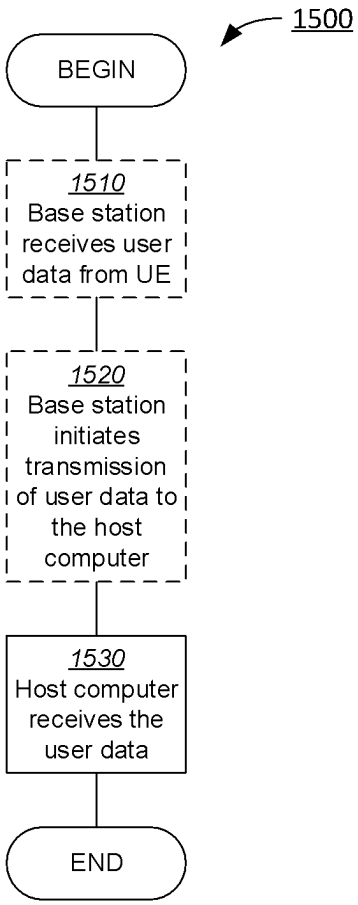
1500
BEGIN
1510
Base station receives user data from UE
1520
Base station initiates transmission of user data to the host computer
1530
Host computer receives the user data
END

FIG. 15

METHODS, NODES AND COMPUTER READABLE MEDIA FOR PHR

TECHNICAL FIELD

The present disclosure generally relates to the technical field of communications, and particularly to methods at nodes in an Integrated Access Backhaul (IAB) network respectively for Power Headroom Report (PHR), corresponding nodes and computer readable media.

BACKGROUND

This section is intended to provide a background to the various embodiments of the technology described in this disclosure. The description in this section may include concepts that could be pursued, but are not necessarily ones that have been previously conceived or pursued. Therefore, unless otherwise indicated herein, what is described in this section is not prior art to the description and/or claims of this disclosure and is not admitted to be prior art by the mere inclusion in this section.

IAB is being studied in 3GPP. In Rel. 16, the IAB has been approved as a study item. For an NR system capable of IAB, an access point can setup a radio connection to another access point in order to reach a donor access point which has a wireline backhaul, wherein the access points are referred to as IAB Nodes (referred to as IAB-Ns). The radio connection between the IAB-Ns is referred to as a wireless backhaul or self-backhaul. FIG. **1** schematically shows a basic system structure of such an IAB network. The donor IAB-N (IAB-N x) has a cable backhaul to the gateway, IAB-N y acts as a bridge node between IAB-N x and IAB-N z, where IAB-N y is referred to as a parent IAB-N of IAB-N z, and IAB-N z is referred to as a child IAB-N of IAB-N y. In another branch, IAB-N k is connected to IAB-N j, and IAB-N j is connected to IAB-N x. Each IAB-N may also have UEs connected thereto.

For an IAB network, there may be three types of links:

- an upstream link to/from the parent IAB-N;
- a downstream link to/from the child IAB-N;
- a number of downlink/uplink access links to the served UEs; The first two types of links are also referred to as backhaul links.

In the IAB network, an IAB-N may be scheduled by its parent IAB-N, and also, this IAB-N may also schedule the connected UEs or its child IAB-Ns. A PHR should still be used to facilitate the uplink scheduling in the IAB network.

In Rel. 15, the PHR is used to indicate the available power resources for uplink transmission of a UE. The PHR can be triggered in preconfigured conditions, such as a downlink path loss change exceeding a preconfigured threshold or activation of a serving cell. The triggering procedures are defined in 3GPP TS 38.321 V15.3.0, which is incorporated herein by reference.

When a PHR is triggered for a serving cell, a UE shall estimate a PH (power headroom) for the serving cell according to schemes provided in Section 7 of 3GPP TS 38.213 V15.3.0, which is incorporated herein by reference. There are three types of PHs and each one is calculated by comparing a maximum UE transmit power and a transmit power of a certain uplink transmission. When a PH is derived, the PH and the UE maximum transmit power should be quantized according to Table 1 (a PH mapping table) and Table 2 (a Maximum Transmit Power mapping table) as listed below, respectively corresponding to Tables 10.1.17.1-1 and 10.1.18.1-1 in Section 10.1 of 3GPP TS 38.133 V15.3.0, which is incorporated herein by reference. For Table 1, there are 64 entries and the granularity is 1 or 2 dB. For Table 2, there are also 64 entries and the granularity is 1 dB.

TABLE 1

PH Mapping

Reported value	Measured quantity value (dB)
POWER_HEADROOM_0	PH < −32
POWER_HEADROOM_1	−32 ≤ PH < −31
POWER_HEADROOM_2	−31 ≤ PH < −30
POWER_HEADROOM_3	−30 ≤ PH < −29
. . .	. . .
POWER_HEADROOM_53	25 ≤ PH < 26
POWER_HEADROOM_54	26 ≤ PH < 27
POWER_HEADROOM_55	27 ≤ PH < 28
POWER_HEADROOM_56	28 ≤ PH < 30
POWER_HEADROOM_57	30 ≤ PH < 32
POWER_HEADROOM_58	32 ≤ PH < 34
POWER_HEADROOM_59	34 ≤ PH < 36
POWER_HEADROOM_60	36 ≤ PH < 38
POWER_HEADROOM_61	38 ≤ PH < 40
POWER_HEADROOM_62	40 ≤ PH < 42
POWER_HEADROOM_63	PH ≥ 42

TABLE 2

Maximum Transmit Power ($P_{CMAX, c,f}$) Mapping

Reported value	Measured quantity value	Unit
PCMAX_C_00	$P_{CMAX, c, f} < -29$	dBm
PCMAX_C_01	$-29 \le P_{CMAX, c, f} < -28$	dBm
PCMAX_C_02	$-28 \le P_{CMAX, c, f} < -27$	dBm
. . .	. . .	. . .
PCMAX_C_61	$31 \le P_{CMAX, c, f} < 32$	dBm
PCMAX_C_62	$32 \le P_{CMAX, c, f} < 33$	dBm
PCMAX_C_63	$33 \le P_{CMAX, c, f}$	dBm

For data transmission between the IAB-Ns, two factors may be considered compared to the uplink transmission from a UE to a network node:

- One is that the allowed maximum uplink transmit power may be much higher than that of a UE, since a Specific Absorption Rate (SAR) restriction may not be applicable for an IAB-N.
- The other is that the total beamforming gain (i.e. Tx beamforming gain plus RX beam forming gain) of an uplink backhaul radio link may be much higher than that of an uplink radio link from a UE to a network node, which means that the range of power headroom for a backhaul link could be much wider than a uplink radio link from the UE to the network node. That is because:
  - The antenna panel size of a child IAB-N is much larger than that of a UE;
  - The number of transmit antenna elements of a child IAB-N could be much more than that of a UE;
  - The beamforming training effect may be much better than a mobile UE since the child IAB-N is static, finer beamforming training and fewer beam switches are triggered.

Considering above factors, the existing tables related to PHR, including the table for power headroom room level and the table for the nominal UE transmit power level may be insufficient to support PHR for a backhaul link.

SUMMARY

In order to better fit with the requirements of the higher transmission power class and the beamforming gain for the

IAB-N, the present disclosure proposes a method at a downstream radio node, a downstream radio node, a method at an upstream radio node, an upstream radio node, and corresponding computer readable media.

According to a first aspect of the present disclosure, a method at a downstream radio node is provided. The method includes: determining a mapping table, which indicates a mapping correspondence between an entry index of a PHR related parameter and a measurement value range of the PHR related parameter with an adjustment value being applied; and transmitting a reported entry index according to the mapping table and a corresponding measurement value to an upstream radio node.

In an exemplary embodiment, the reported entry index is transmitted in a PHR MAC CE (Media Access Control Control Element).

In an exemplary embodiment, the PHR related parameter includes at least one of a PH (Power Headroom) and a maximum transmit power for the downstream radio node.

In an exemplary embodiment, the adjustment value is configured by the upstream radio node or a donor radio node or predefined.

In an exemplary embodiment, the adjustment value is one of:

- an offset of a measurement value of the PHR related parameter;
- a maximum value of a measurement value of the PHR related parameter;
- a minimum value of a measurement value of the PHR related parameter.

In an exemplary embodiment, in a case that the adjustment value is the maximum or minimum value of the measurement value of the PHR related parameter, said determining the mapping table includes:

- determining the mapping table at least based on the maximum or minimum value and a granularity value which is configured by the upstream radio node or a donor radio node or predefined.

In an exemplary embodiment, the measurement value range of the PHR related parameter with the adjustment value being applied is one of:

$$\begin{cases} (-\infty, \mathrm{Min}), & \text{if } n = 0 \\ [\mathrm{Min} + (n-1) * Gn, \mathrm{Min} + n * Gn), & \text{if } n = 1 \sim (N-2); \\ [\mathrm{Min} + (N-2) * Gn, +\infty), & \text{if } n = (N-1) \end{cases}$$

$$\begin{cases} (-\infty, \mathrm{Max} - (N-2) * Gn), & \text{if } n = 0 \\ [\mathrm{Max} - (N-n-1) * Gn, \mathrm{Max} - (N-n-2) * Gn), & \text{if } n = 1 \sim (N-2), \\ [\mathrm{Max} + \infty), & \text{if } n = (N-1) \end{cases}$$

wherein n denotes an entry index, N is a number of entry indexes and is an integer; Min denotes the minimum value; Max denotes the maximum value; and Gn denotes the granularity value corresponding to the entry index n.

In an exemplary embodiment, the granularity value is a predetermined value.

In an exemplary embodiment, the granularity value is derived based on the number of the entry indexes, the minimum value and the maximum value.

In an exemplary embodiment, the granularity value is entry index specific.

In an exemplary embodiment, in a case that there are a plurality of mapping tables for one PHR related parameter, said determining the mapping table includes:

- determining one of the plurality of mapping tables to be used according to a maximum transmit power of the downstream radio node, or configuration from the upstream radio node or a donor radio node, or a type of the downstream radio node.

In an exemplary embodiment, the method further includes: indicating, to the upstream radio node, the determined mapping table for one of the PH and the maximum transmit power by reserved bits in a field for another of the PH and the maximum transmit power in a PHR MAC CE or in a MAC subheader.

In an exemplary embodiment, in a case that there are a plurality of mapping tables for one PHR related parameter and each mapping table is corresponding to at least one of a plurality of granularity values, the method further includes:

- selecting a granularity value from the plurality of granularity values, and indicating, to the upstream radio node, the selected granularity value and/or its corresponding mapping table for one of the PH and the maximum transmit power by reserved bits in a field for another of the PH and the maximum transmit power in a PHR MAC CE or in a MAC subheader.

In an exemplary embodiment, a field for one of the PH and the maximum transmit power in a PHR MAC CE is extended by incorporating at least one reserved bit from a field for another one of the PH and the maximum transmit power.

In an exemplary embodiment, the downstream radio node includes at least one of: a UE, and a downstream IAB-N.

According to a second aspect of the present disclosure, a downstream radio node is provided. The downstream radio node includes: at least one processor; and at least one memory, storing instructions which, when executed on the at least one processor, cause the at least one processor to perform the method according to the first aspect of the present disclosure.

According to a third aspect of the present disclosure, a computer readable storage medium having computer program instructions stored thereon, the computer program instructions, when executed by at least one processor in a radio node, causing the at least one processor to perform the method according to the first aspect of the present disclosure.

According to a fourth aspect of the present disclosure, a method at an upstream radio node is provided. The method includes: determining a mapping table, which indicates a mapping correspondence between an entry index of a PHR related parameter and a measurement value range of the PHR related parameter with an adjustment value being applied; receiving a reported entry index from a downstream radio node; and obtaining a corresponding measurement value range according to the determined mapping table and the reported entry index.

In an exemplary embodiment, the reported entry index is received in a PHR MAC CE.

In an exemplary embodiment, the PHR related parameter includes at least one of a Power Headroom, PH, and a maximum transmit power for the downstream radio node.

In an exemplary embodiment, the adjustment value is configured by the upstream radio node or a donor radio node or predefined.

In an exemplary embodiment, the adjustment value is one of:

- an offset of a measurement value of the PHR related parameter;

a maximum value of a measurement value of the PHR related parameter;

a minimum value of a measurement value of the PHR related parameter.

In an exemplary embodiment, in a case that the adjustment value is the maximum or minimum value of the measurement value of the PHR related parameter, said determining the mapping table includes: determining the mapping table at least based on the maximum or minimum value and a granularity value which is configured by the upstream radio node or a donor radio node or predefined.

In an exemplary embodiment, the measurement value range of the PHR related parameter with the adjustment value being applied is one of:

$$\begin{cases} (-\infty, \mathrm{Min}), & \text{if } n = 0 \\ [\mathrm{Min} + (n-1) * Gn, \mathrm{Min} + n * Gn), & \text{if } n = 1 \sim (N-2) \\ [\mathrm{Min} + (N-2) * Gn, +\infty), & \text{if } n = (N-1) \end{cases};$$

$$\begin{cases} (-\infty, \mathrm{Max} - (N-2) * Gn), & \text{if } n = 0 \\ [\mathrm{Max} - (N-n-1) * Gn, \mathrm{Max} - (N-n-2) * Gn), & \text{if } n = 1 \sim (N-2) \\ [\mathrm{Max} + \infty), & \text{if } n = (N-1) \end{cases},$$

wherein n denotes an entry index, N is a number of entry indexes and is an integer; Min denotes the minimum value; Max denotes the maximum value; and Gn denotes the granularity value corresponding to the entry index n.

In an exemplary embodiment, the granularity value is a predetermined value.

In an exemplary embodiment, the granularity value is derived based on the number of the entry indexes, the minimum value and the maximum value.

In an exemplary embodiment, the granularity value is entry index specific.

In an exemplary embodiment, in a case that there are a plurality of mapping tables for one PHR related parameter, said determining the mapping table includes:

determining one of the plurality of mapping tables to be used according to a maximum transmit power of the downstream radio node, or configuration from the upstream radio node or a donor radio node, or a type of the downstream radio node.

In an exemplary embodiment, the method further includes: receiving, from the downstream radio node, an indication of the mapping table for one of the PH and the maximum transmit power determined by the downstream radio node, which is indicated by reserved bits in a field for another of the PH and the maximum transmit power in a PHR MAC CE or in a MAC subheader.

In an exemplary embodiment, in a case that there are a plurality of mapping tables for one PHR related parameter and each mapping table is corresponding to at least one of a plurality of granularity values, the method further includes: receiving, from the downstream radio node, an indication of the granularity value and/or its corresponding mapping table for one of the PH and the maximum transmit power determined by the downstream radio node, which is indicated by reserved bits in a field for another of the PH and the maximum transmit power in a PHR MAC CE or in a MAC subheader.

In an exemplary embodiment, a field for one of the PH and the maximum transmit power in a PHR MAC CE is extended by incorporating at least one reserved bit from a field for another one of the PH and the maximum transmit power.

According to a fifth aspect of the present disclosure, an upstream radio node is provided. The upstream radio node includes: at least one processor; and at least one memory, storing instructions which, when executed on the at least one processor, cause the at least one processor to perform the method according to the fourth aspect of the present disclosure.

According to sixth aspect of the present disclosure, a computer readable storage medium having computer program instructions stored thereon, the computer program instructions, when executed by at least one processor in a radio node, causing the at least one processor to perform the method according to the first or fourth aspect of the present disclosure.

According to a seventh aspect of the present disclosure, a communication system is provided. The communication system includes a host computer including: processing circuitry configured to provide user data; and a communication interface configured to forward the user data to a cellular network for transmission to a UE. The cellular network includes a base station, a transmission point, relay node, an IAB node or an UE having a radio interface and processing circuitry. The base station's processing circuitry is configured to perform the method according to the first or fourth aspect of the present disclosure.

In an exemplary embodiment, the communication system can further include the base station.

In an exemplary embodiment, the communication system can further include the UE. The UE is configured to communicate with the base station.

In an exemplary embodiment, the processing circuitry of the host computer can be configured to execute a host application, thereby providing the user data. The UE can include processing circuitry configured to execute a client application associated with the host application.

According to an eighth aspect of the present disclosure, a method is provided. The method is implemented in a communication system including a host computer, a base station and a UE. The method includes: at the host computer, providing user data; and at the host computer, initiating a transmission carrying the user data to the UE via a cellular network comprising the base station. The base station can perform the method according to the first aspect of the present disclosure.

In an exemplary embodiment, the method further can include: at the base station, transmitting the user data.

In an exemplary embodiment, the user data can be provided at the host computer by executing a host application. The method can further include: at the UE, executing a client application associated with the host application.

According to a ninth aspect of the present disclosure, a communication system is provided. The communication system includes a host computer including: processing circuitry configured to provide user data; and a communication interface configured to forward user data to a cellular network for transmission to a UE. The UE includes a radio interface and processing circuitry. The UE's processing circuitry is configured to perform the method according to the first aspect of the present disclosure.

In an exemplary embodiment, the communication system can further include the UE.

In an exemplary embodiment, the cellular network can further include a base station configured to communicate with the UE.

In an exemplary embodiment, the processing circuitry of the host computer can be configured to execute a host application, thereby providing the user data. The UE's

processing circuitry can be configured to execute a client application associated with the host application.

According to a tenth aspect of the present disclosure, a method is provided. The method is implemented in a communication system including a host computer, a base station and a UE. The method includes: at the host computer, providing user data; and at the host computer, initiating a transmission carrying the user data to the UE via a cellular network comprising the base station. The UE can perform the method according to the fourth aspect of the present disclosure.

In an exemplary embodiment, the method can further include: at the UE, receiving the user data from the base station.

According to an eleventh aspect of the present disclosure, a communication system is provided. The communication system includes a host computer including: a communication interface configured to receive user data originating from a transmission from a UE to a base station. The UE includes a radio interface and processing circuitry. The UE's processing circuitry is configured to: perform the method according to the first aspect of the present disclosure.

In an exemplary embodiment, the communication system can further include the UE.

In an exemplary embodiment, the communication system can further include the base station. The base station can include a radio interface configured to communicate with the UE and a communication interface configured to forward to the host computer the user data carried by a transmission from the UE to the base station.

In an exemplary embodiment, the processing circuitry of the host computer can be configured to execute a host application. The UE's processing circuitry can be configured to execute a client application associated with the host application, thereby providing the user data.

In an exemplary embodiment, the processing circuitry of the host computer can be configured to execute a host application, thereby providing request data. The UE's processing circuitry can be configured to execute a client application associated with the host application, thereby providing the user data in response to the request data.

According to a twelfth aspect of the present disclosure, a method is provided. The method is implemented in a communication system including a host computer, a base station and a UE. The method includes: at the host computer, receiving user data transmitted to the base station from the UE. The UE can perform the method according to the first aspect of the present disclosure.

In an exemplary embodiment, the method can further include: at the UE, providing the user data to the base station.

In an exemplary embodiment, the method can further include: at the UE, executing a client application, thereby providing the user data to be transmitted; and at the host computer, executing a host application associated with the client application.

In an exemplary embodiment, the method can further include: at the UE, executing a client application; and at the UE, receiving input data to the client application, the input data being provided at the host computer by executing a host application associated with the client application. The user data to be transmitted is provided by the client application in response to the input data.

According to a thirteenth aspect of the present disclosure, a communication system is provided. The communication system includes a host computer including a communication interface configured to receive user data originating from a transmission from a UE to a base station. The base station includes a radio interface and processing circuitry. The base station's processing circuitry is configured to perform the method according to the first or fourth aspect of the present disclosure.

In an exemplary embodiment, the communication system can further include the base station.

In an exemplary embodiment, the communication system can further include the UE. The UE can be configured to communicate with the base station.

In an exemplary embodiment, the processing circuitry of the host computer can be configured to execute a host application; the UE can be configured to execute a client application associated with the host application, thereby providing the user data to be received by the host computer.

According to a fourteenth aspect of the present disclosure, a method is provided. The method is implemented in a communication system including a host computer, a base station and a UE. The method includes: at the host computer, receiving, from the base station, user data originating from a transmission which the base station has received from the UE. The base station can perform the method according to the first or fourth aspect of the present disclosure.

In an exemplary embodiment, the method can further include: at the base station, receiving the user data from the UE.

In an exemplary embodiment, the method can further include: at the base station, initiating a transmission of the received user data to the host computer.

According to the embodiments of the present disclosure, the measurement value range of the PHR related parameter in the mapping table has an adjustment value applied, so that the measurement value range of the PHR related parameter, such as the PH, the maximum transmit power, in the mapping table may fit with the requirements of the higher transmission power class and the beamforming gain for the IAB-N. Accordingly, the field for the PHR related parameter in the PHR MAC CE for transmitting a reported entry index corresponding to a measurement value of the PHR related parameter is improved.

BRIEF DESCRIPTION OF THE DRAWINGS

The objects, advantages and characteristics of the present disclosure will be more apparent, according to descriptions of preferred embodiments in connection with the drawings, in which:

FIG. **1** schematically shows a basic system structure of such an IAB network;

FIG. **2** schematically shows a format of a single entry PHR MAC CE;

FIG. **3**(*a*) schematically shows a format of multiple entry PHR MAC CE with the highest ServCellIndex of Serving Cell with configured uplink is less than 8;

FIG. **3**(*b*) schematically shows a format of multiple entry PHR MAC CE with the highest ServCellIndex of Serving Cell with configured uplink is equal to or higher than 8;

FIG. **4** is a flowchart illustrating a method at a downstream node for PHR according to an exemplary embodiment of the present disclosure;

FIG. **5** is a block diagram of a downstream radio node according to an exemplary embodiment of the present disclosure;

FIG. **6** is a block diagram of a downstream radio node according to another exemplary embodiment of the present disclosure;

FIG. **7** is a flowchart illustrating a method at an upstream radio node for receiving a PHR according to an exemplary embodiment of the present disclosure;

FIG. **8** is a block diagram of an upstream radio node according to an exemplary embodiment of the present disclosure;

FIG. **9** is a block diagram of an upstream radio node according to another exemplary embodiment of the present disclosure;

FIG. **10** schematically illustrates a telecommunication network connected via an intermediate network to a host computer;

FIG. **11** is a generalized block diagram of a host computer communicating via a base station with a UE over a partially wireless connection; and

FIGS. **12** to **15** are flowcharts illustrating methods implemented in a communication system including a host computer, a base station and a UE.

It should be noted that throughout the drawings, same or similar reference numbers are used for indicating same or similar elements; various parts in the drawings are not drawn to scale, but only for an illustrative purpose, and thus should not be understood as any limitations and constraints on the scope of the present disclosure.

DETAILED DESCRIPTION

Hereinafter, the principle and spirit of the present disclosure will be described with reference to illustrative embodiments. Some of the embodiments contemplated herein will now be described more fully with reference to the accompanying drawings. Other embodiments, however, are contained within the scope of the subject matter disclosed herein, the disclosed subject matter should not be construed as limited to only the embodiments set forth herein; rather, these embodiments are provided by way of example to convey the scope of the subject matter to those skilled in the art.

References in the specification to "one embodiment," "an embodiment," "an example embodiment," etc. indicate that the embodiment described may include a particular feature, structure, or characteristic, but it is not necessary that every embodiment includes the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be liming of exemplary embodiments. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises", "comprising", "has", "having", "includes" and/or "including", when used herein, specify the presence of stated features, elements, and/or components etc., but do not preclude the presence or addition of one or more other features, elements, components and/or combinations thereof.

In the following description and claims, unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skills in the art to which this disclosure belongs. The techniques described herein may be used for various wireless communication networks such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, LTE and other networks developed in the future. The terms "network" and "system" are often used interchangeably. For illustration only, certain aspects of the techniques are described below for the next, i.e. the 5^{th} generation of wireless communication network, such as NR. However, it will be appreciated by the skilled in the art that the techniques described herein may also be used for other wireless networks such as LTE and corresponding radio technologies mentioned herein as well as wireless networks and radio technologies proposed in the future.

As used herein, the term "network node" refers to a device in a wireless communication network via which a terminal device or another network node accesses the network and receives services therefrom. The network node refers to a base station (BS), an access point (AP), an IAB-N or any other suitable device in the wireless communication network. The BS may be, for example, a node B (NodeB or NB), an evolved NodeB (eNodeB or eNB), or gNB, a Remote Radio Unit (RRU), a radio header (RH), a remote radio head (RRH), a relay, a low power node such as a femto, a pico, and so forth. Yet further examples of the network node may include multi-standard radio (MSR) radio equipment such as MSR BSs, network controllers such as radio network controllers (RNCs) or base station controllers (BSCs), base transceiver stations (BTSs), transmission points, transmission nodes. More generally, however, the network node may represent any suitable device (or group of devices) capable, configured, arranged, and/or operable to enable and/or provide a terminal device access to the wireless communication network or to provide some service to a terminal device that has accessed the wireless communication network.

The term "terminal device" refers to any end device that can access a wireless communication network and receive services therefrom. By way of example and not limitation, the terminal device refers to a mobile terminal, UE (user equipment), or other suitable devices. The UE may be, for example, a SS (Subscriber Station), a Portable Subscriber Station, a MS (Mobile Station), or an AT (Access Terminal), a relay node, an IAB-N. The terminal device may include, but not limited to, portable computers, image capture terminal devices such as digital cameras, gaming terminal devices, music storage and playback appliances, a mobile phone, a cellular phone, a smart phone, VoIP (voice over IP) phones, wireless local loop phones, a tablet, a wearable device, a PDA (personal digital assistant), portable computers, desktop computer, image capture terminal devices such as digital cameras, gaming terminal devices, music storage and playback appliances, wearable terminal devices, vehicle-mounted wireless terminal devices, wireless endpoints, mobile stations, LEE (laptop-embedded equipment), LME (laptop-mounted equipment), USB dongles, smart devices, wireless CPE (customer-premises equipment) and the like. In the following description, the terms "terminal device", "terminal", "user equipment" and "UE" may be used interchangeably. As one example, a terminal device may represent a UE configured for communication in accordance with one or more communication standards promulgated by the 3rd Generation Partnership Project (3GPP), such as 3GPP's GSM, UMTS, LTE, and/or 5G standards. As used herein, a "user equipment" or "UE" may not necessarily have a "user" in the sense of a human user who owns and/or operates the relevant device. In some embodiments, a terminal device may be configured to transmit and/or receive information without direct human interaction. For

instance, a terminal device may be designed to transmit information to a network on a predetermined schedule, when triggered by an internal or external event, or in response to requests from the wireless communication network. Instead, a UE may represent a device that is intended for sale to, or operation by, a human user but that may not initially be associated with a specific human user.

As yet another example, in an IOT (Internet of Things) scenario, a terminal device may represent a machine or other device that performs monitoring and/or measurements, and transmits the results of such monitoring and/or measurements to another terminal device and/or network equipment. The terminal device may in this case be a M2M (machine-to-machine) device, which may in a 3GPP context be referred to as a MTC device. As one particular example, the terminal device may be a UE implementing the 3GPP NB-IoT standard. Particular examples of such machines or devices are sensors, metering devices such as power meters, industrial machinery, or home or personal appliances, for example refrigerators, televisions, personal wearables such as watches etc. In other scenarios, a terminal device may represent a vehicle or other equipment that is capable of monitoring and/or reporting on its operational status or other functions associated with its operation.

The term "radio node" refers to a network node or a terminal device as described previously.

As used herein, a downlink, DL transmission refers to a transmission from the network node to a terminal device, and an uplink, UL transmission refers to a transmission in an opposite direction.

As used herein, a downstream link refers to a transmission from an upstream radio node, such as a parent IAB-N, to a downstream radio node, such as a child IAB-N, a terminal device; and an upstream link refers to a transmission from the downstream radio node to the upstream radio node.

As used herein, a donor radio node specifically refers to an upstream radio node having a wireline backhaul, i.e., a root IAB-N.

As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed terms.

In the following description and claims, unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skills in the art to which this disclosure belongs.

It will be appreciated that although the embodiments of the present disclosure are exemplified to be applied to the IAB network in order to better fit with the requirements of the higher transmission power class and the beamforming gain for the IAB-N, the basic idea of the present disclosure is also applicable to a non-IAB network.

Hereinafter, a method at a downstream radio node for PHR according to an exemplary embodiment of the present disclosure will be described with reference to FIG. **2**.

FIG. **4** is a flowchart illustrating a method **400** for PHR according to an exemplary embodiment of the present disclosure. The method **400** may be performed at a downstream radio node.

As shown in FIG. **4**, the method **400** for PHR includes steps S**401** and S**403**.

In step S**401**, the downstream radio node determines a mapping table, which indicates a mapping correspondence between an entry index of a PHR related parameter and a measurement value range of the PHR related parameter with an adjustment value being applied.

The PHR related parameter includes at least one of a PH and a maximum transmit power for the downstream radio node.

In step S**403**, the downstream radio node transmits a reported entry index according to the mapping table and a corresponding measurement value to an upstream radio node. In an exemplary embodiment, the reported entry index is transmitted in a PHR MAC CE.

The PHR MAC CE may be constructed according to a defined PHR MAC CE format. In particular, the reported entry index for the PH may be placed in a field for PH in the PHR MAC CE for transmission, and the reported entry index for the maximum transmit power may be placed in a field for maximum transmit power field in the PHR MAC CE for transmission.

There may be two PHR MAC CE formats: single entry PHR and multiple entry PHR MAC CEs, which will be described in detail below.

For the single entry PHR MAC CE format, it has a fixed size and consists of two octet as shown in FIG. **2**, and is defined as follows:

R: Reserved bit, set to "0";

PH: This field indicates the power headroom level. The length of the field is 6 bits;

$P_{CMAX,f,c}$: This field indicates the $P_{CMAX,f,c}$ (as specified in TS 38.213 [6]) used for calculation of the preceding PH field.

For the multiple entry PHR MAC CE format, the PHR MAC CEs as shown in FIGS. **3**(*a*) and **3**(*b*) are defined as follows:

Ci: This field indicates the presence of a PH field for the Serving Cell with ServCellIndex i as specified in TS 38.331 [5]. The Ci field set to "1" indicates that a PH field for the Serving Cell with ServCellIndex i is reported. The Ci field set to "0" indicates that a PH field for the Serving Cell with ServCellIndex i is not reported;

R: Reserved bit, set to "0";

V: This field indicates if the PH value is based on a real transmission or a reference format. For Type 1 PH, V=0 indicates real transmission on PUSCH and V=1 indicates that a PUSCH reference format is used. For Type 2 PH, V=0 indicates real transmission on PUCCH and V=1 indicates that a PUCCH reference format is used. For Type 3 PH, V=0 indicates real transmission on SRS and V=1 indicates that an SRS reference format is used. Furthermore, for Type 1, Type 2, and Type 3 PH, V=0 indicates the presence of the octet containing the associated $P_{CMAX,f,c}$ field, and V=1 indicates that the octet containing the associated $P_{CMAX,f,c}$ field is omitted;

PH: This field indicates the power headroom level. The length of the field is 6 bits. The reported PH and the corresponding power headroom levels are shown in Table 6.1.3.8-1 (the corresponding measured values in dB for the NR Serving Cell are specified in TS 38.133 [11] while the corresponding measured values in dB for the E-UTRA Serving Cell are specified in TS 36.133 [12]);

P: This field indicates whether the MAC entity applies power backoff due to power management. The MAC entity shall set P=1 if the corresponding $P_{CMAX,f,c}$ field would have had a different value if no power backoff due to power management had been applied;

$P_{CMAX,f,c}$: If present, this field indicates the $P_{CMAX,f,c}$ or $P_{CMAX,f,c}$ (as specified in TS 38.213 [6]) used for calculation of the preceding PH field.

In an exemplary embodiment, the adjustment value may be predefined. Alternatively, the adjustment value may be configured by the upstream radio node or a donor radio node, e.g., depending on link budget, link gain, capabilities

of the downstream radio node on its transmission mode (e.g., MIMO, beamforming and antenna manufacturing etc.), capabilities of the upstream radio node on its reception mode (e.g., MIMO, beamforming and antenna manufacturing etc.) or the supported uplink power class etc.

The adjustment value may be one of:

- an offset of a measurement value of the PHR related parameter;
- a maximum value of a measurement value of the PHR related parameter;
- a minimum value of a measurement value of the PHR related parameter.

In an exemplary embodiment in which the adjustment value is an offset of a measurement value of the PHR related parameter, the offset may be applied to the existing mapping table for the PHR related parameter to form a new mapping table for the PHR related parameter. Here, the offset refers to an offset relative to the existing respective measurement value ranges of the PHR related parameter corresponding to the respective entry indexes of the PHR related parameter.

In an example that the PHR related parameter is PH, the offset for PH (denoted as "PH_offset") is applied to the existing Table 1 for PH Mapping as previously described to form a new PH mapping table—Table 3 below.

TABLE 3

PH Mapping with PH_offset

Reported value	Measured quantity value (dB)
POWER_HEADROOM_0	PH < −32 + PH_offset
POWER_HEADROOM_1	−32 + PH_offset ≤ PH < −31 + PH_offset
POWER_HEADROOM_2	−31 + PH_offset ≤ PH < −30 + PH_offset
POWER_HEADROOM_3	−30 + PH_offset ≤ PH < −29 + PH_offset
. . .	. . .
POWER_HEADROOM_53	25 + PH_offset ≤ PH < 26 + PH_offset
POWER_HEADROOM_54	26 + PH_offset ≤ PH < 27 + PH_offset
POWER_HEADROOM_55	27 + PH_offset ≤ PH < 28 + PH_offset
POWER_HEADROOM_56	28 + PH_offset ≤ PH < 30 + PH_offset
POWER_HEADROOM_57	30 + PH_offset ≤ PH < 32 + PH_offset
POWER_HEADROOM_58	32 + PH_offset ≤ PH < 34 + PH_offset
POWER_HEADROOM_59	34 + PH_offset ≤ PH < 36 + PH_offset
POWER_HEADROOM_60	36 + PH_offset ≤ PH < 38 + PH_offset
POWER_HEADROOM_61	38 + PH_offset ≤ PH < 40 + PH_offset
POWER_HEADROOM_62	40 + PH_offset ≤ PH < 42 + PH_offset
POWER_HEADROOM_63	PH ≥ 42 + PH_offset

Similarly, in an example that the PHR related parameter is Maximum Transmit Power, the offset for Maximum Transmit Power (denoted as "$P_{CMAX,c,f}$_offset") is applied to the existing Table 2 for Maximum Transmit Power mapping as previously described to form a new Maximum Transmit Power mapping table—Table 4 below.

TABLE 4

Maximum Transmit Power ($P_{CMAX,c,f}$) Mapping with $P_{CMAX,c,f}$_offset

Reported value	Measured quantity value	Unit
PCMAX_C_00	$P_{CMAX,c,f}$ < −29 + $P_{CMAX,c,f}$_offset	dBm
PCMAX_C_01	−29 + $P_{CMAX,c,f}$_offset ≤ $P_{CMAX,c,f}$ < −28 + $P_{CMAX,c,f}$_offset	dBm
PCMAX_C_02	−28 + $P_{CMAX,c,f}$_offset ≤ $P_{CMAX,c,f}$ < −27 + $P_{CMAX,c,f}$_offset	dBm
. . .	. . .	. . .
PCMAX_C_61	31 + $P_{CMAX,c,f}$_offset ≤ $P_{CMAX,c,f}$ < 32 + $P_{CMAX,c,f}$_offset	dBm
PCMAX_C_62	32 + $P_{CMAX,c,f}$_offset ≤ $P_{CMAX,c,f}$ < 33 + $P_{CMAX,c,f}$_offset	dBm
PCMAX_C_63	33 + $P_{CMAX,c,f}$_offset ≤ $P_{CMAX,c,f}$	dBm

In an exemplary embodiment in which the adjustment value is maximum/minimum value of a measurement value of the PHR related parameter, a mapping table may be determined at least based on the maximum/minimum value and a granularity value.

The granularity value defines a size of a measurement value range corresponding to an entry index of the PHR related parameter. The granularity value may also be configured by the upstream radio node or a donor radio node or predefined.

In an exemplary embodiment, the measurement value range of the PHR related parameter with the maximum/minimum being applied is one of:

$$\begin{cases} (-\infty, \text{Min}), & \text{if } n = 0 \\ [\text{Min} + (n-1) * Gn, \text{Min} + n * Gn), & \text{if } n = 1 \sim (N-2) \\ [\text{Min} + (N-2) * Gn, +\infty), & \text{if } n = (N-1) \end{cases};$$

$$\begin{cases} (-\infty, \text{Max} - (N-2) * Gn), & \text{if } n = 0 \\ [\text{Max} - (N-n-1) * Gn, \text{Max} - (N-n-2) * Gn), & \text{if } n = 1 \sim (N-2) \\ [\text{Max} + \infty), & \text{if } n = (N-1) \end{cases},$$

wherein n denotes an entry index, N is a number of entry indexes and is an integer; Min denotes the minimum value; Max denotes the maximum value; and Gn denotes the granularity value corresponding to the entry index n.

In an exemplary embodiment, the granularity value may be a predetermined value.

In an exemplary embodiment, the predetermined granularity value may be a fixed value (e.g., 1).

Alternatively, the predetermined granularity value may be entry index specific, i.e., different for different entry index. For example, unequal granularity values may be applied to generate the mapping table in order to build a table with finer granularities on the frequently used region while with coarse-grained on less frequently used regions.

In another exemplary embodiment, the granularity value may be fixed and derived based on the number of the entry indexes, the minimum value and the maximum value. For example, G=(Max−Min)/(N−1), where G denotes the fixed value.

In the example that the PHR related parameter is PH, a PH mapping table with a PH maximum (denoted as "PH_max") and a granularity value applied to a measurement value range of PH may be shown in Table 5 below. In this example, the granularity value is exemplified to be 1 for any of the entry indexes, and the number of entry indexes is exemplified to be 64. It may be appreciated that 1 is only an example of the granularity value, and 64 is only an example of the number of entry indexes, which may be any other values as appropriate.

TABLE 5

PH mapping with PH_max	
Reported value	Measured quantity value (dB)
POWER_HEADROOM_0	PH < PH_max − 62
POWER_HEADROOM_1	PH_max − 62 ≤ PH < PH_max − 61
POWER_HEADROOM_2	PH_max − 61 ≤ PH < PH_max − 60
POWER_HEADROOM_3	PH_max − 60 ≤ PH < PH_max − 61
. . .	. . .
POWER_HEADROOM_53	PH_max − 10 ≤ PH < PH_max − 9
POWER_HEADROOM_54	PH_max − 9 ≤ PH < PH_max − 8
POWER_HEADROOM_55	PH_max − 8 ≤ PH < PH_max − 7
POWER_HEADROOM_56	PH_max − 7 ≤ PH < PH_max − 6
POWER_HEADROOM_57	PH_max − 6 ≤ PH < PH_max − 5
POWER_HEADROOM_58	PH_max − 5 ≤ PH < PH_max − 4
POWER_HEADROOM_59	PH_max − 4 ≤ PH < PH_max − 3
POWER_HEADROOM_60	PH_max − 3 ≤ PH < PH_max − 2
POWER_HEADROOM_61	PH_max − 2 ≤ PH < PH_max − 1
POWER_HEADROOM_62	PH_max − 1 ≤ PH < PH_max
POWER_HEADROOM_63	PH ≥ PH_max

In the example that the PHR related parameter is PH, a PH mapping table with a PH minimum (denoted as "PH_min") applied to a measurement value range of PH may be shown in Table 6 below.

TABLE 6

PH mapping with PH_min	
Reported value	Measured quantity value (dB)
POWER_HEADROOM_0	PH < PH_min
POWER_HEADROOM_1	PH_min ≤ PH < PH_min + 1
POWER_HEADROOM_2	PH_min + 1 ≤ PH < PH_min + 2
POWER_HEADROOM_3	PH_min + 2 ≤ PH < PH_min + 3
. . .	. . .
POWER_HEADROOM_53	PH_min + 52 ≤ PH < PH_min + 53
POWER_HEADROOM_54	PH_min + 53 ≤ PH < PH_min + 54
POWER_HEADROOM_55	PH_min + 54 ≤ PH < PH_min + 55
POWER_HEADROOM_56	PH_min + 55 ≤ PH < PH_min + 56
POWER_HEADROOM_57	PH_min + 56 ≤ PH < PH_min + 57
POWER_HEADROOM_58	PH_min + 57 ≤ PH < PH_min + 58
POWER_HEADROOM_59	PH_min + 58 ≤ PH < PH_min + 59
POWER_HEADROOM_60	PH_min + 59 ≤ PH < PH_min + 60
POWER_HEADROOM_61	PH_min + 60 ≤ PH < PH_min + 61
POWER_HEADROOM_62	PH_min + 61 ≤ PH < PH_min + 62
POWER_HEADROOM_63	PH ≥ PH min + 62

Similarly, in the example that the PHR related parameter is Maximum Transmit Power, a Maximum Transmit Power mapping table with a maximum for Maximum Transmit Power (denoted as "$P_{CMAX,c,f}$_max") applied to a measurement value range of Maximum Transmit Power may be shown in Table 7 below.

TABLE 7

Maximum Transmit Power ($P_{CMAX,c,f}$) Mapping with $P_{CMAX,c,f}$_max		
Reported value	Measured quantity value	Unit
PCMAX_C_00	$P_{CMAX,c,f} < P_{CMAX,c,f}$_max − 62	dBm
PCMAX_C_01	$P_{CMAX,c,f}$_max − 62 ≤ $P_{CMAX,c,f} < P_{CMAX,c,f}$_max − 61	dBm
PCMAX_C_02	$P_{CMAX,c,f}$_max − 61 ≤ $P_{CMAX,c,f} < P_{CMAX,c,f}$_max − 60	dBm
. . .	. . .	. . .
PCMAX_C_61	$P_{CMAX,c,f}$_max − 2 ≤ $P_{CMAX,c,f} < P_{CMAX,c,f}$_max − 1	dBm
PCMAX_C_62	$P_{CMAX,c,f}$_max − 1 ≤ $P_{CMAX,c,f} < P_{CMAX,c,f}$_max	dBm
PCMAX_C_63	$P_{CMAX,c,f} \geq P_{CMAX,c,f}$_max	dBm

In the example that the PHR related parameter is Maximum Transmit Power, a Maximum Transmit Power mapping table with a minimum for Maximum Transmit Power (denoted as "$P_{CMAX,c,f}$_min") applied to a measurement value range of Maximum Transmit Power may be shown in Table 8 below.

TABLE 8

Maximum Transmit Power ($P_{CMAX,c,f}$) Mapping with $P_{CMAX,c,f}$_min		
Reported value	Measured quantity value	Unit
PCMAX_C_00	$P_{CMAX,c,f} < P_{CMAX,c,f}$_min	dBm
PCMAX_C_01	PH_min < $P_{CMAX,c,f} < P_{CMAX,c,f}$_min + 1	dBm
PCMAX_C_02	PH_min + 1 ≤ $P_{CMAX,c,f}$ < PH_min + 2	dBm
. . .	. . .	. . .
PCMAX_C_61	$P_{CMAX,c,f}$_min + 60 ≤ $P_{CMAX,c,f} < P_{CMAX,c,f}$_min + 61	dBm
PCMAX_C_62	$P_{CMAX,c,f}$_min + 61 ≤ $P_{CMAX,c,f} < P_{CMAX,c,f}$_min + 62	dBm
PCMAX_C_63	$P_{CMAX,c,f} \geq P_{CMAX,c,f}$_min + 62	dBm

In an exemplary embodiment, there may be a plurality of mapping tables for one PHR related parameter. In this case, the step **S401** may include: determining one of the plurality of mapping tables to be used according to e.g., a maximum transmit power of the downstream radio node, or configuration from the upstream radio node or a donor radio node, or the type of the downstream radio node.

In an exemplary embodiment, after determining the mapping table to be used, the downstream radio node also transmits in step **S403**, to the upstream radio node, an indication of the determined mapping table for one of the PH and the maximum transmit power by R bits in the field for another of the PH and the maximum transmit power in the PHR MAC CE or in the MAC subheader. It should be noted that the transmission of the indication of the determined mapping table is alternative, since the upstream radio node may determine the mapping table used by the downstream radio node according to the same rule.

In an exemplary embodiment, there may be a plurality of mapping tables for one PHR related parameter, and each mapping table is corresponding to at least one of a plurality of granularity values. In this case, the method **400** further includes: selecting a granularity value from the plurality of granularity values. Accordingly, the step **S403** further includes: transmitting, to the upstream radio node, an indication of the selected granularity value and/or its corresponding mapping table for one of the PH and the maximum transmit power by R bits in a field for another of the PH and the maximum transmit power in the PHR MAC CE or in the MAC subheader.

In an example, 1 or 2 R bits in the $P_{CMAX,c,f}$ field of the single/multiple entry PHR MAC CE may be configured to indicate which PH mapping table (or PH value granularity) is selected to be used if there are multiple PH value tables (or multiple PH value granularities) are available. In another example, R bits in the MAC subheader may be configured to indicate which PH mapping table (or PH value granularity) is selected to be used; and if there is no enough R bits, some bits from the length field in the MAC subheader may be configured to be reused. It should be noted that although an example for the PHR related parameter—PH is illustrated here, the same method may be applied to the PHR related parameter—the maximum transmit power.

In an exemplary embodiment, a field for one of the PH and the maximum transmit power in a PHR MAC CE is extended by incorporating at least one R bit from a field for another one of the PH and the maximum transmit power.

For example, the size of the PH field may be increased from 6 bits to more bits, such as 7 bits or 8 bits. In one example, one or two R bits from the $P_{CMAX,c,f}$ field combined with the original 6 bits to formulate the new PH field. In another example, P bit or V bit may be reused for the increased size of the PH field, in the case that the upstream radio node is already possible to be aware of/learn the value of P field or V field. It should be noted that although an example for the PHR related parameter—PH is illustrated here, the same method may be applied to the PHR related parameter—the maximum transmit power.

Hereinafter, a structure of a downstream radio node according to an exemplary embodiment of the present disclosure will be described with reference to FIG. **5**. FIG. **5** shows a block diagram of a downstream radio node **500** according to an exemplary embodiment of the present disclosure. The downstream radio node **500** in FIG. **5** may perform the method **400** for PHR as described previously with reference to FIG. **4**. Accordingly, some detailed description on the downstream radio node **500** may refer to the corresponding description of the method **400** for PHR as previously discussed.

As shown in FIG. **5**, the downstream radio node **500** includes:

- a determination unit **501**, configured to determine a mapping table, which indicates a mapping correspondence between an entry index of a PHR parameter and a measurement value range of the PHR related parameter with an adjustment value being applied; and
- a transmitting unit **503**, configured to transmit a reported entry index according to the mapping table and a corresponding measurement value to an upstream radio node.

In an exemplary embodiment, the transmitting unit **503** transmits the reported entry index in a PHR MAC CE.

In an exemplary embodiment, the PHR related parameter includes at least one of a PH and a maximum transmit power for the downstream radio node.

In an exemplary embodiment, the adjustment value may be configured by the upstream radio node or a donor radio node or predefined, and may be one of:

- an offset of a measurement value of the PHR related parameter;
- a maximum value of a measurement value of the PHR related parameter;
- a minimum value of a measurement value of the PHR related parameter.

In a case that the adjustment value is the maximum or minimum value of the measurement value of the PHR related parameter, the determination unit **501** determines the mapping table at least based on the maximum or minimum value and a granularity value which is configured by the upstream radio node or a donor radio node or predefined.

In an exemplary embodiment, the measurement value range of the PHR related parameter with the adjustment value being applied is one of:

$$\begin{cases} (-\infty, \mathrm{Min}), & \text{if } n = 0 \\ [\mathrm{Min} + (n-1) * Gn, \mathrm{Min} + n * Gn), & \text{if } n = 1 \sim (N-2); \\ [\mathrm{Min} + (N-2) * Gn, +\infty), & \text{if } n = (N-1) \end{cases}$$

$$\begin{cases} (-\infty, \mathrm{Max} - (N-2) * Gn), & \text{if } n = 0 \\ [\mathrm{Max} - (N-n-1) * Gn, \mathrm{Max} - (N-n-2) * Gn), & \text{if } n = 1 \sim (N-2), \\ [\mathrm{Max} + \infty), & \text{if } n = (N-1) \end{cases}$$

wherein n denotes an entry index, N is a number of entry indexes and is an integer; Min denotes the minimum value; Max denotes the maximum value; and Gn denotes the granularity value corresponding to the entry index n.

In an exemplary embodiment, the granularity value may be a predetermined value.

In an exemplary embodiment, the predefined granularity value may be fixed, or entry index specific, e.g., different for different entry indexes.

In another exemplary embodiment, the granularity value may be fixed and derived based on the number of the entry indexes, the minimum value and the maximum value. For example, G=(Max−Min)/(N−1), where G denotes the fixed value.

In an exemplary embodiment, in a case that there are a plurality of mapping tables for one PHR related parameter, the determination unit **501** determines one of the plurality of mapping tables to be used according to a maximum transmit power of the downstream radio node, or configuration from

the upstream radio node or a donor radio node, or the type of the downstream radio node.

In an exemplary embodiment, after the determination unit **501** determines the mapping table to be used, the transmitting unit **503** transmits, to the upstream radio node, an indication of the determined mapping table for one of the PH and the maximum transmit power by reserved bits in a field for another of the PH and the maximum transmit power in a PHR MAC CE or in a MAC subheader.

In an exemplary embodiment, in a case that there are a plurality of mapping tables for one PHR related parameter and each mapping table is corresponding to at least one of a plurality of granularity values, the downstream radio node **500** further includes: a selection unit (not shown), configured to select a granularity value from the plurality of granularity values. Then, the transmitting unit **503** transmits, to the upstream radio node, an indication of the selected granularity value and/or its corresponding mapping table for one of the PH and the maximum transmit power by reserved bits in a field for another of the PH and the maximum transmit power in a PHR MAC CE or in a MAC subheader.

In an exemplary embodiment, a field for one of the PH and the maximum transmit power in a PHR MAC CE is extended by incorporating at least one reserved bit from a field for another one of the PH and the maximum transmit power.

As previously described, the downstream radio node may include a UE and/or a downstream IAB-N.

Hereinafter, a structure of a downstream radio node according to another exemplary embodiment of the present disclosure will be described with reference to FIG. **6**. FIG. **6** shows a block diagram of a downstream radio node **400** according to an exemplary embodiment of the present disclosure. The downstream radio node **600** in FIG. **6** may perform the method **600** for PHR as described previously with reference to FIG. **4**. Accordingly, some detailed description on the downstream radio node **600** may refer to the corresponding description of the method **400** for PHR as previously discussed.

As shown in FIG. **6**, the downstream radio node **600** includes at least one processor **601** and at least one memory **603**. The at least one processor **601** includes e.g., any suitable CPU (Central Processing Unit), microcontroller, DSP (Digital Signal Processor), etc., capable of executing computer program instructions. The at least one memory **403** may be any combination of a RAM (Random Access Memory) and a ROM (Read Only Memory). The at least one processor memory **603** may also comprise persistent storage, which, for example, can be any single one or combination of magnetic memory, optical memory, or solid state memory or even remotely mounted memory.

The at least one memory **603** stores instructions executable by the at least one processor **601**, whereby the downstream radio node **600** is operative to perform the actions, e.g., of the procedures as described earlier respectively in conjunction with FIG. **4**.

In particular, in an embodiment of causing the downstream radio node **600** to perform the actions of the procedure as described earlier respectively in conjunction with FIG. **4**, the instructions, when loaded from the at least one memory **603** and executed on the at least one processor **601**, may cause the downstream radio node **600** to determine, in step **S401**, a mapping table which indicates a mapping correspondence between an entry index of a PHR related parameter and a measurement value range of the PHR related parameter with an adjustment value being applied.

The instructions, when loaded from the at least one memory **603** and executed on the at least one processor **601**, may further cause the downstream radio node **600** to transmit, in step **S403**, a reported entry index according to the mapping table and a corresponding measurement value to an upstream radio node.

In an exemplary embodiment, the instructions, when executed by the at least one processor **601**, cause the downstream radio node **600** to transmit the reported entry index in a PHR MAC CE.

In an exemplary embodiment, the PHR related parameter includes at least one of a PH and a maximum transmit power for the downstream radio node.

In an exemplary embodiment, the adjustment value may be configured by the upstream radio node or a donor radio node or predefined, and may be one of:

- an offset of a measurement value of the PHR related parameter;
- a maximum value of a measurement value of the PHR related parameter;
- a minimum value of a measurement value of the PHR related parameter.

In a case that the adjustment value is the maximum or minimum value of the measurement value of the PHR related parameter, the instructions, when executed by the at least one processor **601**, cause the downstream radio node **600** to determine the mapping table at least based on the maximum or minimum value and a granularity value which is configured by the upstream radio node or a donor radio node or predefined.

In an exemplary embodiment, the measurement value range of the PHR related parameter with the adjustment value being applied is one of:

$$\begin{cases} (-\infty, \mathrm{Min}), & \text{if } n = 0 \\ [\mathrm{Min} + (n-1) * Gn, \mathrm{Min} + n * Gn), & \text{if } n = 1 \sim (N-2) \\ [\mathrm{Min} + (N-2) * Gn, +\infty), & \text{if } n = (N-1) \end{cases};$$

$$\begin{cases} (-\infty, \mathrm{Max} - (N-2) * Gn), & \text{if } n = 0 \\ [\mathrm{Max} - (N-n-1) * Gn, \mathrm{Max} - (N-n-2) * Gn), & \text{if } n = 1 \sim (N-2) \\ [\mathrm{Max} + \infty), & \text{if } n = (N-1) \end{cases},$$

wherein n denotes an entry index, N is a number of entry indexes and is an integer; Min denotes the minimum value; Max denotes the maximum value; and Gn denotes the granularity value corresponding to the entry index n.

In an exemplary embodiment, the granularity value may be a predetermined value.

In an exemplary embodiment, the predefined granularity value may be fixed (e.g., 1), or entry index specific, e.g., different for different entry indexes.

In another exemplary embodiment, the granularity value may be fixed and derived based on the number of the entry indexes, the minimum value and the maximum value. For example, G=(Max−Min)/(N−1), where G denotes the fixed value.

In an exemplary embodiment, in a case that there are a plurality of mapping tables for one PHR related parameter, the instructions, when executed by the at least one processor **601**, cause the downstream radio node **600** to determine one of the plurality of mapping tables to be used according to a maximum transmit power of the downstream radio node, or configuration from the upstream radio node or a donor radio node, or the type of the downstream radio node.

In an exemplary embodiment, after determining the mapping table to be used, the instructions, when executed by the at least one processor **601**, cause the downstream radio node **600** to transmit, to the upstream radio node, an indication of the determined mapping table for one of the PH and the maximum transmit power by reserved bits in a field for another of the PH and the maximum transmit power in a PHR MAC CE or in a MAC subheader.

In an exemplary embodiment, in a case that there are a plurality of mapping tables for one PHR related parameter and each mapping table is corresponding to at least one of a plurality of granularity values, the instructions, when executed by the at least one processor **601**, cause the downstream radio node **600** to select a granularity value from the plurality of granularity values; and transmit, to the upstream radio node, an indication of the selected granularity value and/or its corresponding mapping table for one of the PH and the maximum transmit power by reserved bits in a field for another of the PH and the maximum transmit power in a PHR MAC CE or in a MAC subheader.

In an exemplary embodiment, a field for one of the PH and the maximum transmit power in a PHR MAC CE is extended by incorporating at least one reserved bit from a field for another one of the PH and the maximum transmit power.

As previously described, the downstream radio node may include a UE and/or a downstream IAB-N.

Hereinafter, a method at an upstream radio node for receiving a PHR according to an exemplary embodiment of the present disclosure will be described with reference to FIG. **7**.

FIG. **7** is a flowchart illustrating a method **700** for receiving a PHR according to an exemplary embodiment of the present disclosure. The method **700** may be performed at an upstream radio node.

As shown in FIG. **7**, the method **700** for PHR includes steps S**701**, S**703** and S**705**.

In step S**701**, the upstream radio node determines a mapping table, which indicates a mapping correspondence between an entry index of a PHR related parameter and a measurement value range of the PHR related parameter with an adjustment value being applied.

In step S**703**, the upstream radio node receives a reported entry index from a downstream radio node. As previously described, the reported entry index is received in a PHR MAC CE.

In step S**705**, the upstream radio node obtains a corresponding measurement value range according to the determined mapping table and the reported entry index.

The PHR related parameter includes at least one of a PH and a maximum transmit power for the downstream radio node.

In an exemplary embodiment, the adjustment value may be predefined. Alternatively, the adjustment value may be configured by the upstream radio node or a donor radio node, e.g., depending on link budget, link gain, capabilities of the downstream radio node on its transmission mode (e.g., MIMO, beamforming, and antenna manufacturing etc.), capabilities of the upstream radio node on its reception mode (e.g., MIMO, beamforming and antenna manufacturing etc.), or the supported uplink power class etc.

The adjustment value may be one of:

- an offset of a measurement value of the PHR related parameter;
- a maximum value of a measurement value of the PHR related parameter;
- a minimum value of a measurement value of the PHR related parameter.

In an exemplary embodiment in which the adjustment value is an offset of a measurement value of the PHR related parameter, the offset may be applied to the existing mapping table for the PHR related parameter to form a new mapping table for the PHR related parameter. The detailed description may refer to the corresponding part as described in the method **400** with reference to FIG. **4**.

In an exemplary embodiment in which the adjustment value is maximum/minimum value of a measurement value of the PHR related parameter, a mapping table may be determined at least based on the maximum/minimum value and a granularity value. The detailed description may refer to the corresponding part as described in the method **400** with reference to FIG. **4**.

The granularity value may also be configured by the upstream radio node or a donor radio node or predefined.

In an exemplary embodiment, the measurement value range of the PHR related parameter with the maximum/minimum being applied is one of:

$$\begin{cases} (-\infty, \text{Min}), & \text{if } n = 0 \\ [\text{Min} + (n-1) * Gn, \text{Min} + n * Gn), & \text{if } n = 1 \sim (N-2); \\ [\text{Min} + (N-2) * Gn, +\infty), & \text{if } n = (N-1) \end{cases}$$

$$\begin{cases} (-\infty, \text{Max} - (N-2) * Gn), & \text{if } n = 0 \\ [\text{Max} - (N-n-1) * Gn, \text{Max} - (N-n-2) * Gn), & \text{if } n = 1 \sim (N-2), \\ [\text{Max} + \infty), & \text{if } n = (N-1) \end{cases}$$

wherein n denotes an entry index, N is a number of entry indexes and is an integer; Min denotes the minimum value; Max denotes the maximum value; and Gn denotes the granularity value corresponding to the entry index n.

In an exemplary embodiment, the granularity value may be a predetermined value.

In an exemplary embodiment, the predetermined granularity value may be a fixed value (e.g., 1).

Alternatively, the predetermined granularity value may be entry index specific, i.e., different for different entry index. For example, unequal granularity values may be applied to generate the mapping table in order to build a table with finer granularities on the frequently used region while with coarse-grained on less frequently used regions.

In another exemplary embodiment, the granularity value may be fixed and derived based on the number of the entry indexes, the minimum value and the maximum value. For example, G=(Max−Min)/(N−1), where G denotes the fixed value.

In an exemplary embodiment, there may be a plurality of mapping tables for one PHR related parameter. In this case, the step S**701** may include: determining one of the plurality of mapping tables to be used according to e.g., a maximum transmit power of the downstream radio node, or configuration from the upstream radio node or a donor radio node, or the type of the downstream radio node, i.e., the same rule as used in the downstream radio node.

In another exemplary embodiment, the step S**703** further includes: receiving, from the downstream radio node, an indication of the mapping table for one of the PH and the maximum transmit power determined by the downstream radio node, which is indicated by reserved bits in a field for another of the PH and the maximum transmit power in a PHR MAC CE or in a MAC subheader. In this case, the

upstream radio node determines the mapping table used by the downstream radio node by the indication from the downstream radio node.

In an exemplary embodiment, there may be a plurality of mapping tables for one PHR related parameter, and each mapping table is corresponding to at least one of a plurality of granularity values. In this case, the step S**703** further includes: receiving, from the downstream radio node, an indication of the granularity value and/or its corresponding mapping table for one of the PH and the maximum transmit power determined by the downstream radio node, which is indicated by reserved bits in a field for another of the PH and the maximum transmit power in a PHR MAC CE or in a MAC subheader.

In an exemplary embodiment, a field for one of the PH and the maximum transmit power in a PHR MAC CE is extended by incorporating at least one reserved bit from a field for another one of the PH and the maximum transmit power.

Hereinafter, a structure of an upstream radio node according to an exemplary embodiment of the present disclosure will be described with reference to FIG. **8**. FIG. **8** shows a block diagram of an upstream radio node **800** according to an exemplary embodiment of the present disclosure. The upstream radio node **800** in FIG. **8** may perform the method **700** for receiving a PHR as described previously with reference to FIG. **7**. Accordingly, some detailed description on the upstream radio node **800** may refer to the corresponding description of the method **700** for receiving a PHR as previously discussed.

As shown in FIG. **8**, the upstream radio node **800** includes:

- a determination unit **801**, configured to determine a mapping table, which indicates a mapping correspondence between an entry index of a PHR related parameter and a measurement value range of the PHR related parameter with an adjustment value being applied;
- a receiving unit **803**, configured to receive a reported entry index from a downstream radio node; and
- an obtaining unit **805**, configured to obtain a corresponding measurement value range according to the determined mapping table and the reported entry index.

In an exemplary embodiment, the receiving unit **803** receives the reported entry index in a PHR MAC CE.

In an exemplary embodiment, the PHR related parameter includes at least one of a PH and a maximum transmit power for the downstream radio node.

In an exemplary embodiment, the adjustment value may be configured by the upstream radio node or a donor radio node or predefined, and may be one of:

- an offset of a measurement value of the PHR related parameter;
- a maximum value of a measurement value of the PHR related parameter;
- a minimum value of a measurement value of the PHR related parameter.

In a case that the adjustment value is the maximum or minimum value of the measurement value of the PHR related parameter, the determination unit **801** determines the mapping table at least based on the maximum or minimum value and a granularity value which is configured by the upstream radio node or a donor radio node or predefined.

In an exemplary embodiment, the measurement value range of the PHR related parameter with the adjustment value being applied is one of:

$$\begin{cases} (-\infty, \mathrm{Min}), & \text{if } n = 0 \\ [\mathrm{Min} + (n-1) * Gn, \mathrm{Min} + n * Gn), & \text{if } n = 1 \sim (N-2); \\ [\mathrm{Min} + (N-2) * Gn, +\infty), & \text{if } n = (N-1) \end{cases}$$

$$\begin{cases} (-\infty, \mathrm{Max} - (N-2) * Gn), & \text{if } n = 0 \\ [\mathrm{Max} - (N-n-1) * Gn, \mathrm{Max} - (N-n-2) * Gn), & \text{if } n = 1 \sim (N-2), \\ [\mathrm{Max} + \infty), & \text{if } n = (N-1) \end{cases}$$

wherein n denotes an entry index, N is a number of entry indexes and is an integer; Min denotes the minimum value; Max denotes the maximum value; and Gn denotes the granularity value corresponding to the entry index n.

In an exemplary embodiment, the granularity value may be a predetermined value.

In an exemplary embodiment, the predefined granularity value may be fixed, or entry index specific, e.g., different for different entry indexes.

In another exemplary embodiment, the granularity value may be fixed and derived based on the number of the entry indexes, the minimum value and the maximum value. For example, G=(Max−Min)/(N−1), where G denotes the fixed value.

In an exemplary embodiment, in a case that there are a plurality of mapping tables for one PHR related parameter, the determination unit **801** determines one of the plurality of mapping tables to be used according to a maximum transmit power of the downstream radio node, or configuration from the upstream radio node or a donor radio node, or the type of the downstream radio node, i.e., the same rule as used in the downstream radio node.

In an exemplary embodiment, the receiving unit **803** receives, from the downstream radio node, an indication of the mapping table for one of the PH and the maximum transmit power determined by the downstream radio node, which is indicated by reserved bits in a field for another of the PH and the maximum transmit power in a PHR MAC CE or in a MAC subheader. Then, the obtaining unit **805** obtains the corresponding measurement value range according to the determined mapping table and the reported entry index.

In an exemplary embodiment, in a case that there are a plurality of mapping tables for one PHR related parameter and each mapping table is corresponding to at least one of a plurality of granularity values, the receiving unit **803** receives, from the downstream radio node, an indication of the granularity value and/or its corresponding mapping table for one of the PH and the maximum transmit power determined by the downstream radio node, which is indicated by reserved bits in a field for another of the PH and the maximum transmit power in a PHR MAC CE or in a MAC subheader.

In an exemplary embodiment, a field for one of the PH and the maximum transmit power in a PHR MAC CE is extended by incorporating at least one reserved bit from a field for another one of the PH and the maximum transmit power.

Hereinafter, a structure of an upstream radio node according to another exemplary embodiment of the present disclosure will be described with reference to FIG. **9**. FIG. **9** shows a block diagram of an upstream radio node **900** according to an exemplary embodiment of the present disclosure. The upstream radio node **900** in FIG. **9** may perform the method

700 for receiving a PHR as described previously with reference to FIG. 7. Accordingly, some detailed description on the upstream radio node 900 may refer to the corresponding description of the method 700 for receiving the PHR as previously discussed.

As shown in FIG. 9, the upstream radio node 900 includes at least one processor 901 and at least one memory 903. The at least one processor 901 includes e.g., any suitable CPU (Central Processing Unit), microcontroller, DSP (Digital Signal Processor), etc., capable of executing computer program instructions. The at least one memory 903 may be any combination of a RAM (Random Access Memory) and a ROM (Read Only Memory). The at least one processor memory 903 may also comprise persistent storage, which, for example, can be any single one or combination of magnetic memory, optical memory, or solid state memory or even remotely mounted memory.

The at least one memory 903 stores instructions executable by the at least one processor 901, whereby the upstream radio node 900 is operative to perform the actions, e.g., of the procedures as described earlier respectively in conjunction with FIG. 7.

In particular, in an embodiment of causing the upstream radio node 900 to perform the actions of the procedure as described earlier respectively in conjunction with FIG. 7, the instructions, when loaded from the at least one memory 903 and executed on the at least one processor 901, may cause the upstream radio node 700 to determine, in step S501, a mapping table which indicates a mapping correspondence between an entry index of a PHR related parameter and a measurement value range of the PHR related parameter with an adjustment value being applied.

The instructions, when loaded from the at least one memory 903 and executed on the at least one processor 901, may further cause the upstream radio node 900 to receive, in step S703, a reported entry index from a downstream radio node.

The instructions, when loaded from the at least one memory 903 and executed on the at least one processor 901, may further cause the upstream radio node 900 to obtain, in step S705, a corresponding measurement value range according to the determined mapping table and the reported entry index.

In an exemplary embodiment, the reported entry index is received in a PHR MAC CE.

In an exemplary embodiment, the PHR related parameter includes at least one of a PH and a maximum transmit power for the downstream radio node.

In an exemplary embodiment, the adjustment value may be configured by the upstream radio node or a donor radio node or predefined, and may be one of:

- an offset of a measurement value of the PHR related parameter;
- a maximum value of a measurement value of the PHR related parameter;
- a minimum value of a measurement value of the PHR related parameter.

In a case that the adjustment value is the maximum or minimum value of the measurement value of the PHR related parameter, the instructions, when executed by the at least one processor 901, cause the upstream radio node 900 to determine the mapping table at least based on the maximum or minimum value and a granularity value which is configured by the upstream radio node or a donor radio node or predefined.

In an exemplary embodiment, the measurement value range of the PHR related parameter with the adjustment value being applied is one of:

$$\begin{cases} (-\infty, \mathrm{Min}), & \text{if } n = 0 \\ [\mathrm{Min} + (n-1) * Gn, \mathrm{Min} + n * Gn), & \text{if } n = 1 \sim (N-2); \\ [\mathrm{Min} + (N-2) * Gn, +\infty), & \text{if } n = (N-1) \end{cases}$$

$$\begin{cases} (-\infty, \mathrm{Max} - (N-2) * Gn), & \text{if } n = 0 \\ [\mathrm{Max} - (N-n-1) * Gn, \mathrm{Max} - (N-n-2) * Gn), & \text{if } n = 1 \sim (N-2), \\ [\mathrm{Max} + \infty), & \text{if } n = (N-1) \end{cases}$$

wherein n denotes an entry index, N is a number of entry indexes and is an integer; Min denotes the minimum value; Max denotes the maximum value; and Gn denotes the granularity value corresponding to the entry index n.

In an exemplary embodiment, the granularity value may be a predetermined value.

In an exemplary embodiment, the predefined granularity value may be fixed, or entry index specific, e.g., different for different entry indexes.

In another exemplary embodiment, the granularity value may be fixed and derived based on the number of the entry indexes, the minimum value and the maximum value. For example, G=(Max−Min)/(N−1), where G denotes the fixed value.

In an exemplary embodiment, in a case that there are a plurality of mapping tables for one PHR related parameter, the instructions, when executed by the at least one processor 901, cause the upstream radio node 900 to determine one of the plurality of mapping tables to be used according to a maximum transmit power of the downstream radio node, or configuration from the upstream radio node or a donor radio node, or the type of the downstream radio node, i.e., the same rule as used in the downstream radio node.

In an exemplary embodiment, the instructions, when executed by the at least one processor 901, cause the upstream radio node 900 to receive, from the downstream radio node, an indication of the mapping table for one of the PH and the maximum transmit power determined by the downstream radio node, which is indicated by reserved bits in a field for another of the PH and the maximum transmit power in a PHR MAC CE or in a MAC subheader; and obtain the corresponding measurement value range according to the determined mapping table and the reported entry index.

In an exemplary embodiment, in a case that there are a plurality of mapping tables for one PHR related parameter and each mapping table is corresponding to at least one of a plurality of granularity values, the instructions, when executed by the at least one processor 901, cause the upstream radio node 900 to receive, from the downstream radio node, an indication of the granularity value and/or its corresponding mapping table for one of the PH and the maximum transmit power determined by the downstream radio node, which is indicated by reserved bits in a field for another of the PH and the maximum transmit power in a PHR MAC CE or in a MAC subheader.

In an exemplary embodiment, a field for one of the PH and the maximum transmit power in a PHR MAC CE is extended by incorporating at least one reserved bit from a field for another one of the PH and the maximum transmit power.

The present disclosure also provides at least one computer program product in the form of a non-volatile or volatile

memory, e.g., a non-transitory computer readable storage medium, an Electrically Erasable Programmable Read-Only Memory (EEPROM), a flash memory and a hard drive. The computer program product includes a computer program. The computer program includes: code/computer readable instructions, which when executed by the at least one processor **601** causes the downstream radio node **600** to perform the actions, e.g., of the procedure described earlier in conjunction with FIG. **4**; or code/computer readable instructions, which when executed by the at least one processor **901** causes the downstream radio node **900** to perform the actions, e.g., of the procedures described earlier respectively in conjunction with FIG. **6**.

The computer program product may be configured as a computer program code structured in computer program modules. The computer program modules could essentially perform the actions of the flow illustrated in FIG. **4** or **7**.

The processor may be a single CPU (Central processing unit), but could also comprise two or more processing units. For example, the processor may include general purpose microprocessors; instruction set processors and/or related chips sets and/or special purpose microprocessors such as Application Specific Integrated Circuit (ASICs). The processor may also comprise board memory for caching purposes. The computer program may be carried by a computer program product connected to the processor. The computer program product may comprise a non-transitory computer readable storage medium on which the computer program is stored. For example, the computer program product may be a flash memory, a Random-access memory (RAM), a Read-Only Memory (ROM), or an EEPROM, and the computer program modules described above could in alternative embodiments be distributed on different computer program products in the form of memories.

With reference to FIG. **10**, in accordance with an embodiment, a communication system includes a telecommunication network **1010**, such as a 3GPP-type cellular network, which comprises an access network **1011**, such as a radio access network, and a core network **1014**. The access network **1011** comprises a plurality of base stations **1012***a*, **1012***b*, **1012***c*, such as NBs, eNBs, gNBs or other types of wireless access points, each defining a corresponding coverage area **1013***a*, **1013***b*, **1013***c*. Each base station **1012***a*, **1012***b*, **1012***c* is connectable to the core network **1014** over a wired or wireless connection **1015**. A first user equipment (UE) **1091** located in coverage area **1013***c* is configured to wirelessly connect to, or be paged by, the corresponding base station **1012***c*. A second UE **1092** in coverage area **1013***a* is wirelessly connectable to the corresponding base station **1012***a*. While a plurality of UEs **1091**, **1092** are illustrated in this example, the disclosed embodiments are equally applicable to a situation where a sole UE is in the coverage area or where a sole UE is connecting to the corresponding base station **1012**.

The telecommunication network **1010** is itself connected to a host computer **1030**, which may be embodied in the hardware and/or software of a standalone server, a cloud-implemented server, a distributed server or as processing resources in a server farm. The host computer **1030** may be under the ownership or control of a service provider, or may be operated by the service provider or on behalf of the service provider. The connections **1021**, **1022** between the telecommunication network **1010** and the host computer **1030** may extend directly from the core network **1014** to the host computer **1030** or may go via an optional intermediate network **1020**. The intermediate network **1020** may be one of, or a combination of more than one of, a public, private or hosted network; the intermediate network **1020**, if any, may be a backbone network or the Internet; in particular, the intermediate network **1020** may comprise two or more sub-networks (not shown).

The communication system of FIG. **10** as a whole enables connectivity between one of the connected UEs **1091**, **1092** and the host computer **1030**. The connectivity may be described as an over-the-top (OTT) connection **1050**. The host computer **1030** and the connected UEs **1091**, **1092** are configured to communicate data and/or signaling via the OTT connection **1050**, using the access network **1011**, the core network **1014**, any intermediate network **1020** and possible further infrastructure (not shown) as intermediaries. The OTT connection **1050** may be transparent in the sense that the participating communication devices through which the OTT connection **1050** passes are unaware of routing of uplink and downlink communications. For example, a base station **1012** may not or need not be informed about the past routing of an incoming downlink communication with data originating from a host computer **1030** to be forwarded (e.g., handed over) to a connected UE **1091**. Similarly, the base station **1012** need not be aware of the future routing of an outgoing uplink communication originating from the UE **1091** towards the host computer **1030**.

Example implementations, in accordance with an embodiment, of the UE, base station and host computer discussed in the preceding paragraphs will now be described with reference to FIG. **11**. In a communication system **1100**, a host computer **1110** comprises hardware **1115** including a communication interface **1116** configured to set up and maintain a wired or wireless connection with an interface of a different communication device of the communication system **1100**. The host computer **1110** further comprises processing circuitry **1118**, which may have storage and/or processing capabilities. In particular, the processing circuitry **1118** may comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. The host computer **1110** further comprises software **1111**, which is stored in or accessible by the host computer **1110** and executable by the processing circuitry **1118**. The software **1111** includes a host application **1112**. The host application **1112** may be operable to provide a service to a remote user, such as a UE **1130** connecting via an OTT connection **1150** terminating at the UE **1130** and the host computer **1110**. In providing the service to the remote user, the host application **1112** may provide user data which is transmitted using the OTT connection **1150**.

The communication system **1100** further includes a base station **1120** provided in a telecommunication system and comprising hardware **1125** enabling it to communicate with the host computer **1110** and with the UE **1130**. The hardware **1125** may include a communication interface **1126** for setting up and maintaining a wired or wireless connection with an interface of a different communication device of the communication system **1100**, as well as a radio interface **1127** for setting up and maintaining at least a wireless connection **1170** with a UE **1130** located in a coverage area (not shown in FIG. **11**) served by the base station **1120**. The communication interface **1126** may be configured to facilitate a connection **1160** to the host computer **1110**. The connection **1160** may be direct or it may pass through a core network (not shown in FIG. **11**) of the telecommunication system and/or through one or more intermediate networks outside the telecommunication system. In the embodiment shown, the hardware **1125** of the base station **1120** further

includes processing circuitry **1128**, which may comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. The base station **1120** further has software **1121** stored internally or accessible via an external connection.

The communication system **1100** further includes the UE **1130** already referred to. Its hardware **1135** may include a radio interface **1137** configured to set up and maintain a wireless connection **1170** with a base station serving a coverage area in which the UE **1130** is currently located. The hardware **1135** of the UE **1130** further includes processing circuitry **1138**, which may comprise one or more programmable processors, application-specific integrated circuits, field programmable gate arrays or combinations of these (not shown) adapted to execute instructions. The UE **1130** further comprises software **1131**, which is stored in or accessible by the UE **1130** and executable by the processing circuitry **1138**. The software **1131** includes a client application **1132**. The client application **1132** may be operable to provide a service to a human or non-human user via the UE **1130**, with the support of the host computer **1110**. In the host computer **1110**, an executing host application **1112** may communicate with the executing client application **1132** via the OTT connection **1150** terminating at the UE **1130** and the host computer **1110**. In providing the service to the user, the client application **1132** may receive request data from the host application **1112** and provide user data in response to the request data. The OTT connection **1150** may transfer both the request data and the user data. The client application **1132** may interact with the user to generate the user data that it provides.

It is noted that the host computer **1110**, base station **1120** and UE **1130** illustrated in FIG. **11** may be identical to the host computer **830**, one of the base stations **812***a*, **812***b*, **812***c* and one of the UEs **8111**, **8112** of FIG. **8**, respectively. This is to say, the inner workings of these entities may be as shown in FIG. **11** and independently, the surrounding network topology may be that of FIG. **8**.

In FIG. **11**, the OTT connection **1150** has been drawn abstractly to illustrate the communication between the host computer **1110** and the use equipment **1130** via the base station **1120**, without explicit reference to any intermediary devices and the precise routing of messages via these devices. Network infrastructure may determine the routing, which it may be configured to hide from the UE **1130** or from the service provider operating the host computer **1110**, or both. While the OTT connection **1150** is active, the network infrastructure may further take decisions by which it dynamically changes the routing (e.g., on the basis of load balancing consideration or reconfiguration of the network).

The wireless connection **1170** between the UE **1130** and the base station **1120** is in accordance with the teachings of the embodiments described throughout this disclosure. One or more of the various embodiments improve the performance of OTT services provided to the UE **1130** using the OTT connection **1150**, in which the wireless connection **1170** forms the last segment. More precisely, the teachings of these embodiments may reduce PDCCH detection time and complexity and thereby provide benefits such as reduced user waiting time and reduced power consumption at the UE.

A measurement procedure may be provided for the purpose of monitoring data rate, latency and other factors on which the one or more embodiments improve. There may further be an optional network functionality for reconfiguring the OTT connection **1150** between the host computer **1110** and UE **1130**, in response to variations in the measurement results. The measurement procedure and/or the network functionality for reconfiguring the OTT connection **1150** may be implemented in the software **1111** of the host computer **1110** or in the software **1131** of the UE **1130**, or both. In embodiments, sensors (not shown) may be deployed in or in association with communication devices through which the OTT connection **1150** passes; the sensors may participate in the measurement procedure by supplying values of the monitored quantities exemplified above, or supplying values of other physical quantities from which software **1111**, **1131** may compute or estimate the monitored quantities. The reconfiguring of the OTT connection **1150** may include message format, retransmission settings, preferred routing etc.; the reconfiguring need not affect the base station **1120**, and it may be unknown or imperceptible to the base station **1120**. Such procedures and functionalities may be known and practiced in the art. In certain embodiments, measurements may involve proprietary UE signaling facilitating the host computer's **1110** measurements of throughput, propagation times, latency and the like. The measurements may be implemented in that the software **1111**, **1131** causes messages to be transmitted, in particular empty or 'dummy' messages, using the OTT connection **1150** while it monitors propagation times, errors etc.

FIG. **12** is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station and a UE which may be those described with reference to FIGS. **10** and **11**. For simplicity of the present disclosure, only drawing references to FIG. **12** will be included in this section. In a first step **1210** of the method, the host computer provides user data. In an optional substep **1211** of the first step **1210**, the host computer provides the user data by executing a host application. In a second step **1220**, the host computer initiates a transmission carrying the user data to the UE. In an optional third step **1230**, the base station transmits to the UE the user data which was carried in the transmission that the host computer initiated, in accordance with the teachings of the embodiments described throughout this disclosure. In an optional fourth step **1240**, the UE executes a client application associated with the host application executed by the host computer.

FIG. **13** is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station and a UE which may be those described with reference to FIGS. **10** and **11**. For simplicity of the present disclosure, only drawing references to FIG. **13** will be included in this section. In a first step **1310** of the method, the host computer provides user data. In an optional substep (not shown) the host computer provides the user data by executing a host application. In a second step **1320**, the host computer initiates a transmission carrying the user data to the UE. The transmission may pass via the base station, in accordance with the teachings of the embodiments described throughout this disclosure. In an optional third step **1330**, the UE receives the user data carried in the transmission.

FIG. **14** is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station and a UE which may be those described with reference to FIGS. **10** and **11**. For simplicity of the present disclosure, only drawing references to FIG. **14** will be included in this section. In an optional first step **1410** of the method, the UE receives input data provided by the host computer. Additionally or alternatively, in an optional sec-

ond step **1420**, the UE provides user data. In an optional substep **1421** of the second step **1420**, the UE provides the user data by executing a client application. In a further optional substep **1411** of the first step **1410**, the UE executes a client application which provides the user data in reaction to the received input data provided by the host computer. In providing the user data, the executed client application may further consider user input received from the user. Regardless of the specific manner in which the user data was provided, the UE initiates, in an optional third substep **1430**, transmission of the user data to the host computer. In a fourth step **1440** of the method, the host computer receives the user data transmitted from the UE, in accordance with the teachings of the embodiments described throughout this disclosure.

FIG. **15** is a flowchart illustrating a method implemented in a communication system, in accordance with one embodiment. The communication system includes a host computer, a base station and a UE which may be those described with reference to FIGS. **10** and **11**. For simplicity of the present disclosure, only drawing references to FIG. **15** will be included in this section. In an optional first step **1510** of the method, in accordance with the teachings of the embodiments described throughout this disclosure, the base station receives user data from the UE. In an optional second step **1520**, the base station initiates transmission of the received user data to the host computer. In a third step **1530**, the host computer receives the user data carried in the transmission initiated by the base station.

The disclosure has been described above with reference to embodiments thereof. It should be understood that various modifications, alternations and additions can be made by those skilled in the art without departing from the spirits and scope of the disclosure. Therefore, the scope of the disclosure is not limited to the above particular embodiments but only defined by the claims as attached.

The invention claimed is:

1. A method at a downstream radio node, comprising:

determining a mapping table, which indicates a mapping correspondence between an entry index of a Power Headroom Report (PHR) related parameter and a measurement value range of the PHR related parameter with an adjustment value being applied, the adjustment value being an offset of a measurement value of the PHR related parameter, the adjustment value being based at least in part on a granularity value of the measurement value range corresponding to the entry index, the granularity value being one of a preferred value and a value derived from a number of entry indices; and

transmitting a reported entry index according to the mapping table and a corresponding measurement value to an upstream radio node.

2. The method according to claim **1**, wherein in a case that the adjustment value is a minimum value of the measurement value of the PHR related parameter, said determining the mapping table comprises:

determining the mapping table at least based on the minimum value and the granularity value.

3. The method according to claim **1**, wherein in a case that there are a plurality of mapping tables for one PHR related parameter, said determining the mapping table comprises:

determining one of the plurality of mapping tables to be used according to at least one of a maximum transmit power of the downstream radio node, a configuration from the upstream radio node or a donor radio node, and a type of the downstream radio node.

4. The method according to claim **3**, further comprising:

indicating, to the upstream radio node, the determined mapping table for one of a power headroom (PH) and a maximum transmit power by reserved bits in a field for another of the PH and a maximum transmit power in a PHR medium access control (MAC) control element (CE) or in a MAC subheader.

5. The method according to claim **1**, wherein in a case that there are a plurality of mapping tables for one PHR related parameter and each mapping table is corresponding to at least one of a plurality of granularity values, the method further comprises:

selecting a granularity value from the plurality of granularity values; and

indicating, to the upstream radio node, one of the selected granularity value and a corresponding mapping table for one of a power headroom (PH) and a maximum transmit power by reserved bits in a field for another of the PH and a maximum transmit power in a PHR medium access control (MAC) control element (CE) or in a MAC subheader.

6. The method according to claim **1**, wherein a field for one of a power headroom (PH) and a maximum transmit power in a PHR medium access control (MAC) control element (CE) is extended by incorporating at least one reserved bit from a field for another one of the PH and the maximum transmit power.

7. A downstream radio node, comprising:

at least one processor, and

at least one memory, storing instructions which, when executed on the at least one processor, cause the at least one processor to:

determine a mapping table, which indicates a mapping correspondence between an entry index of a Power Headroom Report (PHR) related parameter and a measurement value range of the PHR related parameter with an adjustment value being applied, the adjustment value being an offset of a measurement value of the PHR related parameter, the adjustment value being based at least in part on a granularity value of the measurement value range corresponding to the entry index, the granularity value being one of a preferred value and a value derived from a number of entry indices; and

transmit a reported entry index according to the mapping table and a corresponding measurement value to an upstream radio node.

8. A method at an upstream radio node, comprising:

determining a mapping table, which indicates a mapping correspondence between an entry index of a Power Headroom Report (PHR) related parameter and a measurement value range of the PHR related parameter with an adjustment value being applied, the adjustment value being an offset of a measurement value of the PHR related parameter, the adjustment value being based at least in part on a granularity value of the measurement value range corresponding to the entry index, the granularity value being one of a preferred value and a value derived from a number of entry indices;

receiving a reported entry index from a downstream radio node; and

obtaining a corresponding measurement value range according to the determined mapping table and the reported entry index.

9. The method according to claim 8, wherein in a case that the adjustment value is a minimum value of the measurement value of the PHR related parameter, said determining the mapping table comprises:

determining the mapping table at least based on the minimum value and the granularity value.

10. The method according to claim 8, wherein in a case that there are a plurality of mapping tables for one PHR related parameter, said determining the mapping table comprises:

determining one of the plurality of mapping tables to be used according to at least one of a maximum transmit power of the downstream radio node, a configuration from the upstream radio node or a donor radio node, and a type of the downstream radio node.

11. The method according to claim 10, further comprising:

receiving, from the downstream radio node, an indication of the mapping table for one of a power headroom (PH) and the maximum transmit power determined by the downstream radio node, which is indicated by reserved bits in a field for another of the PH and a maximum transmit power in a PHR medium access control (MAC) control element (CE) or in a MAC subheader.

12. The method according to claim 8, wherein in a case that there are a plurality of mapping tables for one PHR related parameter and each mapping table corresponds to at least one of a plurality of granularity values, the method further comprises:

receiving, from the downstream radio node, an indication of the granularity value a corresponding mapping table for one of a power headroom (PH) and the maximum transmit power determined by the downstream radio node, which is indicated by reserved bits in a field for another of the PH and a maximum transmit power in a PHR medium access control (MAC) control element (CE) or in a MAC subheader.

13. The method according to claim 8, wherein a field for one of a power headroom (PH) and a maximum transmit power in a PHR medium access control (MAC) control element (CE) is extended by incorporating at least one reserved bit from a field for another one of the PH and the maximum transmit power.

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