(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
30 October 2008 (30.10.2008)

PCT

(10) International Publication Number
WO 2008/129379 A2

(51) International Patent Classification:
H04L 1/00 (2006.01)

(21) International Application Number:
PCT/IB2008/000842

(22) International Filing Date: 20 March 2008 (20.03.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/895,928 20 March 2007 (20.03.2007) US

(71) Applicant *(for all designated States except US)*: **NOKIA CORPORATION** [FI/FI]; Keilalahdentie 4, FIN-02150 Espoo (FI).

(71) Applicant *(for LC only)*: **NOKIA INC.** [US/US]; 6000 Connection Drive, Irving, TX 75039 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **FREDERIKSEN, Frank** [DK/DK]; Hornbaekvej 4, DK-9270 Klarup (DK). **KOLDING, Troels** [DK/DK]; Sneppevej 21, DK-9270 Klarup (DK). **MALKAMAKI, Esa** [FI/FI]; Riippakoivuntie 17B, FIN-02130 Espoo (FI).

(74) Agents: **DITTHAVONG, Phouphanomketh** et al.; Dithavong Mori & Steiner, P.C., 918 Prince Street, Alexandria, VA 22314 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

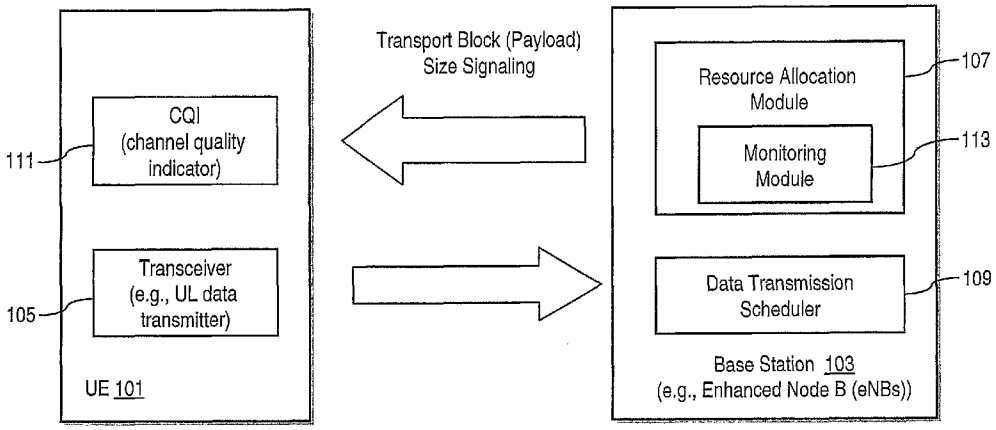
(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declaration under Rule 4.17:
— *of inventorship (Rule 4.17(iv))*

Published:
— *without international search report and to be republished upon receipt of that report*

(54) **Title:** TRANSPORT CONTROL SIGNALING

FIG. 1



(57) **Abstract:** An approach is provided for providing an efficient transport control signaling. Information about either a modulation and coding scheme or an associated transport block size relating to the modulation and coding scheme is signaled using a control channel of a network. The transport block size information includes one or more configurable values for the transport block size.

WO 2008/129379 A2

TRANSPORT CONTROL SIGNALING

RELATED APPLICATIONS

[0001] This application claims the benefit of the earlier filing date under 35 U.S.C. §119(e) of U.S. Provisional Application Serial No. 60/895,928 filed March 20, 2007, entitled "Transport Control Signaling," the entirety of which is incorporated by reference.

BACKGROUND

[0002] Radio communication systems, such as a wireless data networks (e.g., Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) systems, spread spectrum systems (such as Code Division Multiple Access (CDMA) networks), Time Division Multiple Access (TDMA) networks, WiMAX (Worldwide Interoperability for Microwave Access), etc.), provide users with the convenience of mobility along with a rich set of services and features. This convenience has spawned significant adoption by an ever growing number of consumers as an accepted mode of communication for business and personal uses. To promote greater adoption, the telecommunication industry, from manufacturers to service providers, has agreed at great expense and effort to develop standards for communication protocols that underlie the various services and features. One area of effort involves control signaling, particularly with respect to resource allocation. Traditionally, flexibility and control entail a high cost in terms of overhead and reduced throughput.

SOME EXEMPLARY EMBODIMENTS

[0003] Therefore, there is a need for an approach for providing efficient control signaling.

[0004] These and other needs are addressed by various exemplary embodiments of the invention, in which an approach is presented for providing efficient transport control signaling by conveying transport block size information.

[0005] According to one embodiment of the invention, a method comprises signaling information about either a modulation and coding scheme or an associated transport block size

relating to the modulation and coding scheme using a control channel of a network. The transport block size information includes one or more configurable values for the transport block size.

[0006] According to another embodiment of the invention, an apparatus comprises a resource allocation module configured to signal information about either a modulation and coding scheme or an associated transport block size relating to the modulation and coding scheme using a control channel of a network. The transport block size information includes one or more configurable values for the transport block size.

[0007] According to another embodiment of the invention, a method comprises receiving information about either a modulation and coding scheme or an associated transport block size relating to the modulation and coding scheme via a control channel of a network. The transport block size information includes one or more configurable values for the transport block size.

[0008] According to another embodiment of the invention, an apparatus comprises a transceiver configured to receive information about either a modulation and coding scheme or an associated transport block size relating to the modulation and coding scheme via a control channel of a network. The transport block size information includes one or more configurable values for the transport block size.

[0009] According to yet an exemplary embodiment, an apparatus comprises a processor configured to select one of the predetermined values or the configurable values for the transport block size. The transceiver is further configured to transmit data over the network using the selected value for the transport block size.

[0010] Still other aspects, features, and advantages of the invention are readily apparent from the following detailed description, simply by illustrating a number of particular embodiments and implementations, including the best mode contemplated for carrying out the invention. The invention is also capable of other and different embodiments, and its several details can be modified in various obvious respects, all without departing from the spirit and scope of the invention. Accordingly, the drawings and description are to be regarded as illustrative in nature, and not as restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The invention is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings in which like reference numerals refer to similar elements and in which:

[0012] FIG. 1 is a diagram of a communication system capable of providing transport data block signaling, according to an exemplary embodiment of the invention;

[0013] FIG. 2 is a flowchart of a process for resource allocation, in accordance with various embodiments of the invention;

[0014] FIG. 3 is a diagram of a control channel providing transport block size signaling, in accordance with an embodiment of the invention;

[0015] FIGs. 4A-4D are diagrams of communication systems having exemplary long-term evolution (LTE) architectures, in which the system of FIG. 1 can operate, according to various exemplary embodiments of the invention;

[0016] FIG. 5 is a diagram of hardware that can be used to implement an embodiment of the invention; and

[0017] FIG. 6 is a diagram of exemplary components of an LTE terminal configured to operate in the systems of FIGs. 4A-4D, according to an embodiment of the invention

DESCRIPTION OF PREFERRED EMBODIMENT

[0018] An apparatus, method, and software for transport data block signaling are disclosed. In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the embodiments of the invention. It is apparent, however, to one skilled in the art that the embodiments of the invention may be practiced without these specific details or with an equivalent arrangement. In other instances, well-known structures and devices are shown in block diagram form in order to avoid unnecessarily obscuring the embodiments of the invention.

[0019] Although the embodiments of the invention are discussed with respect to a communication network having a Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) architecture, it is recognized by one of ordinary skill in the art that the embodiments of the inventions have applicability to any type of communication system and equivalent functional capabilities.

[0020] FIG. 1 is a diagram of a communication system capable of providing configurable transport data block signaling, according to an exemplary embodiment of the invention. As shown, one or more user equipment (UEs) 101 communicate with a base station 103, which is part of an access network (e.g., WiMAX, 3GPP LTE, etc.). Under the 3GPP LTE architecture, the base station 103 denoted as an enhanced Node B (eNB or eNode B) 103. The UE 101 can be any type of mobile stations, such as handsets, terminals, stations, units, devices, or any type of interface to the user (such as "wearable" circuitry, etc.). Communications between the UE 101 and a base station 103 is governed, in part, by control information exchanged between the two entities. Such control information, in an exemplary embodiment, is transported over a control channel on the downlink from the base station to the UE 101. It is recognized that one of the problems related to the control channel in general is that it is desirable to transmit as much information as possible to obtain the greatest flexibility, while reducing the need to provide control signaling as much as possible without loosing any (or only marginal) system performance in terms of throughput or efficiency.

[0021] The base station 103, in an exemplary embodiment, uses OFDM (Orthogonal Frequency Divisional Multiplexing) as a downlink (DL) transmission scheme and a single-carrier transmission (e.g., SC-FDMA (Single Carrier-Frequency Division Multiple Access) with cyclic prefix (CP) for the uplink (UL) transmission scheme. SC-FDMA can also be realized using a DFT-S-OFDM principle, which is detailed in 3GGP TR 25.814, entitled "Physical Layer Aspects for Evolved UTRA," v.1.5.0, May 2006 (which is incorporated herein by reference in its entirety). SC-FDMA, also referred to as Multi-User-SC-FDMA, allows multiple users to transmit simultaneously on different sub-bands. The UE 101 includes a transceiver 105 and an antenna system (not shown) that couples to the transceiver 105 to receive or transmit signals from the base station 103. The antenna system can include one or more antennas (not shown). Accordingly, the base station 103 can employ one or more antennas (not shown) for transmitting

and receiving electromagnetic signals. As with the UE 101, the base station 103 employs a transceiver (not shown), which transmits information over a downlink (DL) to the UE 101.

[0022] One aspect of the 3GPP LTE system 100 is that an error control scheme (not shown) referred to as Hybrid Automatic Repeat Request (HARQ) is utilized. The HARQ scheme basically combines ARQ protocols with forward-error-correction (FEC) schemes, to provide an error-control technique for wireless links. It is noted that different wireless technologies may utilize different HARQ schemes. HARQ can be used to increase the link and spectral efficiency of LTE, as HARQ allows the system to operate at a relative high block error rate of the first transmissions.

[0023] The approach of the system of FIG. 1 for transport block size signaling provides enhanced efficiency, while minimizing overhead. The signaling is controlled by a resource allocation module 107, which is shown as part of the base station 103; however, it is contemplated that the resource allocation module 107 can be implemented elsewhere on the network side. As will be further explained, this approach provides signaling of a configurable portion of a transport block size table, which includes a fixed part (or portion) as well as a part the configurable portion. The values of the configurable portion can be specified by the e-Node B 103 and through higher layer signaling. In one embodiment, the transport block size information relates to a desired modulation and coding scheme (MCS). Alternatively, instead of signaling the relevant transport block size for the MCS, the actual MCS information can be signaled.

[0024] The e-Node B 103 employs a scheduler 109 that operates in conjunction with the resource allocation module 107 to select and format data for transmission to the UE 101. For example, the scheduler 109 can control usage of time and frequency resources, as well as implement appropriate multiplexing, modulation, and coding schemes. Further, the scheduler 109 can integrate with link adaption functions and error control schemes, such as HARQ. The use of certain resource blocks can depend on CQI (channel-quality indicator) information, as reported by a CQI module 111 within the UE 101. With the CQI module 111, the UE 101 measures and reports information regarding quality (and/or other radio characteristics) of the downlink channel.

[0025] Additionally, the e-Node B 103 utilizes a monitoring (or measurement) module 113 for determining measurements related to information from scheduling decisions performed by the data transmission scheduler (e.g., packet scheduler) 109. According to one embodiment, the e-Node B 103, via the monitoring module 113, has the following capabilities: (1) monitoring of the scheduling decisions by the scheduler 109 and link adaptation units (not shown), (2) from these measurements combined with knowledge of the fixed transport block size signaling values, calculating the zero padding cost of each scheduled value, and (3) signaling the values chosen to be the best for a given UE 101 using the transport block size signaling.

[0026] To better appreciate the various embodiments of the invention, it is instructive to understand the zero padding issue. The zero padding problem arises when a packet is to be transmitted that has a size that cannot be signaled using pre-defined values. As such, the next higher signaling value is used, and the payload data from the data packet is appended or padded with dummy information bits (zeros), which do not convey additional information to the user. Alternatively, the zeros can be prepended.

[0027] FIG. 2 is a flowchart of a process for resource allocation, in accordance with various embodiments of the invention. As shown, in step 201, the scheduling decisions of the resource allocation module 107 are monitored via the monitoring module 113. Next, the respective overhead or cost (e.g., zero padding cost) of transport block sizes is determined, as in step 203. In step 205, the "best" (i.e., least overhead) transport block size is then selected based on the overhead determination. It is contemplated that multiple configurable transport block sizes can be utilized (e.g., with different PRB ranges that these sizes are defined for).

[0028] The operation of the "scheduled transport block size" monitoring module 113 is described, in which the scheduled transport block size is monitored without prior knowledge of the services involved (for instance, VoIP, File Transfer Protocol (FTP), Hypertext Transfer Protocol (HTTP), etc). The monitoring module 113 can measure the traffic information for a certain period of time, and continuously evaluate whether updates of the e-Node B configurable values are feasible. To illustrate this operation, the case where the monitoring module 113 measures several (e.g., four) different values and calculates the associated probability for each value is considered. The number of values depends on the particular application and/or system requirements. Further, in this example, it is assumed that there is only one value available for e-

Node B configuration. By way of example, the measured values (assuming they are valid signaling values) and their corresponding zero padding overhead are as follows (Table 1):

Measured value	Rate (or probability)	Relative padding overhead
216	10%	220/216 – 1 = 1.85%
224	60%	242/224 – 1 = 8.04%
240	20%	242/240 – 1 = 0.83%
244	10%	266/244 – 1 = 9.02%

Table 1

[0029] Following this example, it is seen that the scheduled transport block size of 244 units (bits or bytes) yields the highest overhead reduction, but the scheduled transport block size of 224 units provides the highest efficiency gain due to the higher scheduling probability. Basically, from the above example, it is evident that a good metric for evaluating the efficiency would be the rate or probability of a given measured scheduled transport block size multiplied by the relative padding overhead of the available signaling values. However, other metrics can be used for evaluating the efficiency of each measured scheduled transport block size.

[0030] The above approach provides for determining the "best" transport block size to use for dynamic signaled values of transport block sizes. The signaling can be performed over a control channel, as illustrated in FIG. 3. It is contemplated that both per-UE configuration or per-cell configuration can be implemented. As such, different control channels can be used (e.g. user specific RRC message for per-UE; and downlink broadcast channel (D-BCH) for cell specific setting for all UE).

[0031] FIG. 3 is a diagram of a control channel providing transport block size signaling, in accordance with an embodiment of the invention. According to one embodiment, a downlink control channel 301 relates to the uplink (UL) and downlink (DL) part of the physical layer aspects for the E-UTRA, which is detailed in 3GGP TR 25.814, entitled "Physical Layer Aspects for Evolved UTRA," v.1.5.0, May 2006 (which is incorporated herein by reference in its

entirety). That is, the downlink control channel 301 can carry all the control information needed to operate both the downlink (DL) and uplink (UL) data channels.

[0032] The DL control signaling includes scheduling information for downlink data transmission, scheduling grant for uplink transmission, acknowledgement/negative acknowledgement (ACK/NACK) in response to UL transmission, and DL scheduling information that is used to inform the UE 101 how to process the downlink data transmission. It is contemplated that transmission of control signaling from these groups can be mutually independent, e.g., ACK/NACK can be transmitted to a UE 101 regardless of whether the same UE 101 is receiving scheduling information or not. Downlink scheduling information utilizing downlink control channel 301 is used to inform the UE 101 how to process the downlink data transmission. As an example, the information signaled to a UE 101 scheduled to receive user data is summarized in Table 2.

Field	Size (bits)	Comment
ID (UE or group specific)	8-9	Indicates UE (or group of UEs) for which the Data transmission is intended
Resource assignment	variable	Indicates which (virtual) resource units (and layers in case of multi-layer transmission) the UE(s) shall demodulate
Duration of assignment	2-3	The duration for which the assignment is valid, could also be used to control the TTI or persistent scheduling
Multi-antenna related information	variable	Content depends on the Multiple Input Multiple Output (MIMO)/beamforming schemes selected
Modulation scheme	5	QPSK (Quadrature Phase Shift Keying), 16QAM (Quadrature Amplitude Modulation), 64QAM. In case of multi-layer transmission, multiple instances may be required
Payload size	6	Interpretation could depend of e.g., modulation scheme and the number of assigned resources units (c.f. HSDPA (High Speed Downlink Packet Access)). In case of multi-layer transmission, multiple instances may be required

Hybrid ARQ process number*	3	Indicates the hybrid ARQ process the current transmission is addressing
Redundancy version (if asynchronous hybrid ARQ is adopted)	2	To support incremental redundancy
New data indicator (if asynchronous hybrid ARQ is adopted)	1	To handle soft buffer clearing
Retransmission sequence number (if synchronous hybrid ARQ is adopted)	2	Used to derive redundancy version (to support incremental redundancy) and new data indicator to handle soft buffer clearing

Table 2

[0033] For the HSDPA service, the transport block size signaling is defined according to the equations and descriptions in 3GPP 25.321, section 9.2.3 (which is incorporated herein by reference in its entirety). This approach uses a step sizing which provides a constant relative increment between each signaled entry in the TFRI (Transport Format Resource Indicator); the TFRI value is signaled on a HS-SCCH (High Speed Shared Control Channel). The mapping between the TFRI value and the transport block size is depicted below.

[0034] The transport block size can be derived from the TFRI value. For instance, k_i denotes the TFRI that is signaled on the HS-SCCH, and $k_{0,i}$ (as configured by higher layers) corresponds to the modulation and the number of codes signaled on the HS-SCCH. Also, k_t is the sum of k_i and $k_{0,i}$. The transport block size $L(k_t)$ is derived by accessing the position k_t in Table 3 or by using a corresponding formula below. Table 3 lists the values of $k_{0,i}$ for different numbers of channelization codes and modulation schemes (e.g., QPSK and 16QAM). The equation corresponding to Table 3 is as follows:

$$\text{If } k_t < 40$$

$$L(k_t) = 125 + 12 \cdot k_t$$

$$\text{else}$$

$$L(k_t) = \lfloor L_{\min} p^{k_t} \rfloor$$
$$p = 2085/2048$$
$$L_{\min} = 296$$

Combination i	Modulation scheme	Number of channelization codes	$k_{0,i}$
0	QPSK	1	1
1		2	40
2		3	63
3		4	79
4		5	92
5		6	102
6		7	111
7		8	118
8		9	125
9		10	131
10		11	136
11		12	141
12		13	145
13		14	150
14		15	153
15	16QAM	1	40
16		2	79
17		3	102
18		4	118
19		5	131
20		6	141
21		7	150
22		8	157
23		9	164
24		10	169
25		11	175
26		12	180
27		13	184
28		14	188
29		15	192

Table 3

[0035] The transport block sizes in the above procedure are fixed.

[0036] By contrast, the resource allocation module 107 provides, in certain embodiments, transport block size signaling, whereby the interpretation of the TFRI table 303 provides for two portions: (1) a fixed portion 305 storing pre-determined transport block size values, e.g., as specified by various standards (with a pre-determined stepping between the entries, etc); and (2) a configurable portion 307 with Node B 103 defined values for the transport block size. In other words, the transport block size signaling sent over a physical control channel (PDCCH) provides one field, TBS index, which points to an entry in the TBS (or TFRI) table 303. These Node B 103 defined entries can be set by the eNode B 103 in order to allow the eNode B 103 to utilize a variety of transport block sizes, which exhibit maximal overhead. This secondary signaled/configured part of the TFRI implementation provides great flexibility in control signaling. As shown, the fixed portion 305 need not be signaled, but only the configurable portion 307.

[0037] For the purposes of illustration, five bits can be utilized for transport block size signaling, thus allowing 32 entries in a TFRI table 303. In this example, four TFRI indexes are used for dynamics; and, the rest of the entries are distributed in such a way as to minimize the average padding loss (if a transport block size cannot be signaled directly, the closest larger value is utilized, as well as employing zero padding to fill up the transmission block). Assuming stepping of a maximum of 10% and the minimum PRB (Physical Resource Block) size is set to 200, the possible transport block sizes from a signaling point of view include the following (Table 4):

```
>> round(200*(1.1.^[0:27]'))

ans =

     200
     220
     242
     266
     293
     322
     354
     390
     429
     472
```

519
571
628
690
759
835
919
1011
1112
1223
1345
1480
1628
1791
1970
2167
2384
2622

Table 4

[0038] It is noted that these transport size signaling values would typically be rounded to match octet boundaries to provide byte level alignment of packets.

[0039] However, it is recognized that for some application specific services, the eNode B 103 can potentially use these extra entries to configure each UE 101 in such a way that the UE 101 knows its own interpretation of these elements. One example for such an application includes voice over IP (VoIP), where the speech and silence frames are typically characterized by predetermined packet sizes (or at a large amount of similar sized packets). In this case, the eNode B 103 could create a couple of entries for normal speech and for silence indicators. In an exemplary embodiment, the eNode B 103 is in full control of the assignments of these extra TFRI elements.

[0040] Table 5 illustrates exemplary TBS indices for the transport block size signaling approach.

TBS index	Transmitted transport block size
0	Using the same as previous transmission (for H-ARQ)
1	200
2	220
3	242
4	266
5	293
...	
27	2384
28	2622
29	Optional value #1 defined by Node B over RRC signaling
30	Optional value #2 defined by Node B over RRC signaling
31	Optional value #3 defined by Node B over RRC signaling

Table 5

[0041] In one embodiment, the TBS index (shown in the table above) is sent over the air to the UE 101. Certain values of the TBS index point to the pre-determined portion of the transport block size table (or TFRI table), whereas others (29-31 in Table 5) point to the configured portion. Thus, at the beginning of the connection (or at any time during the connection), eNB 103 can decide to (re)configure the dynamic part of the transport block size table and send by RRC signaling the corresponding TBS values. After that (re)configuration, whenever a TBS index pointing to these dynamic values is signaled over the physical control channel (PDCCH), the UE 101 will decode the received packet using the configured transport block size.

[0042] In certain embodiments, it is contemplated that dynamic values could have some default starting values that are predetermined (e.g., according to known standards). Consequently, full use of the TBS tables can be invoked without sending RRC messages; only updates are signaled if the UE 101 runs different services or if general services change characteristics (e.g. better VoIP encoding systems, etc.).

[0043] The above signaling approach allows the UE 101 and network to adapt to the current traffic situation in the flow towards (or even from) the UE 101. In this way, an option is provided

to reduce the amount of required zero padding to a minimum, while at the same time maintaining a cell-specific signaling method for all UEs 101.

[0044] By way of example, the communication system of FIG. 1 utilizes an architecture compliant with the UMTS terrestrial radio access network (UTRAN) or Evolved UTRAN (E-UTRAN) in 3GPP, as next described.

[0045] FIGs. 4A-4D are diagrams of communication systems having exemplary LTE architectures, in which the system of FIG. 1 can operate, according to various exemplary embodiments of the invention. By way of example (shown in FIG. 1), the base station and the UE can communicate in system 400 using any access scheme, such as Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), Wideband Code Division Multiple Access (WCDMA), Orthogonal Frequency Division Multiple Access (OFDMA) or Single Carrier Frequency Division Multiple Access (SC-FDMA) or a combination thereof. In an exemplary embodiment, both uplink and downlink can utilize WCDMA. In another exemplary embodiment, uplink utilizes SC-FDMA, while downlink utilizes OFDMA.

[0046] The MME (Mobile Management Entity)/Serving Gateways 401 are connected to the eNBs in a full or partial mesh configuration using tunneling over a packet transport network (e.g., Internet Protocol (IP) network) 403. Exemplary functions of the MME/Serving GW 401 include distribution of paging messages to the eNBs, termination of U-plane packets for paging reasons, and switching of U-plane for support of UE mobility. Since the GWs 401 serve as a gateway to external networks, e.g., the Internet or private networks 403, the GWs 401 include an Access, Authorization and Accounting system (AAA) 405 to securely determine the identity and privileges of a user and to track each user's activities. Namely, the MME Serving Gateway 401 is the key control-node for the LTE access-network and is responsible for idle mode UE tracking and paging procedure including retransmissions. Also, the MME 401 is involved in the bearer activation/deactivation process and is responsible for selecting the SGW (Serving Gateway) for a UE 101 at the initial attach and at time of intra-LTE handover involving Core Network (CN) node relocation.

[0047] A more detailed description of the LTE interface is provided in 3GPP TR 25.813, entitled "E-UTRA and E-UTRAN: Radio Interface Protocol Aspects," which is incorporated herein by reference in its entirety.

[0048] In FIG. 4B, a communication system 402 supports GERAN (GSM/EDGE radio access) 404, and UTRAN 406 based access networks, E-UTRAN 412 and non-3GPP (not shown) based access networks, and is more fully described in TR 23.882, which is incorporated herein by reference in its entirety. A key feature of this system is the separation of the network entity that performs control-plane functionality (MME 408) from the network entity that performs bearer-plane functionality (Serving Gateway 410) with a well defined open interface between them S11. Since E-UTRAN 412 provides higher bandwidths to enable new services as well as to improve existing ones, separation of MME 408 from Serving Gateway 410 implies that Serving Gateway 410 can be based on a platform optimized for signaling transactions. This scheme enables selection of more cost-effective platforms for, as well as independent scaling of, each of these two elements. Service providers can also select optimized topological locations of Serving Gateways 410 within the network independent of the locations of MMEs 408 in order to reduce optimized bandwidth latencies and avoid concentrated points of failure.

[0049] The basic architecture of the system 402 contains following network elements. As seen in FIG. 4B, the E-UTRAN (e.g., eNB) 412 interfaces with UE via LTE-Uu. The E-UTRAN 412 supports LTE air interface and includes functions for radio resource control (RRC) functionality corresponding to the control plane MME 408. The E-UTRAN 412 also performs a variety of functions including radio resource management, admission control, scheduling, enforcement of negotiated uplink (UL) QoS (Quality of Service), cell information broadcast, ciphering/deciphering of user, compression/decompression of downlink and uplink user plane packet headers and Packet Data Convergence Protocol (PDCP).

[0050] The MME 408, as a key control node, is responsible for managing mobility UE 101 identifies and security parameters and paging procedure including retransmissions. The MME 408 is involved in the bearer activation/deactivation process and is also responsible for choosing Serving Gateway 410 for the UE 101. MME 408 functions include Non Access Stratum (NAS) signaling and related security. MME 508 checks the authorization of the UE 101 to camp on the service provider's Public Land Mobile Network (PLMN) and enforces UE 101 roaming

restrictions. The MME 408 also provides the control plane function for mobility between LTE and 2G/3G access networks with the S3 interface terminating at the MME 408 from the SGSN (Serving GPRS Support Node) 414. The principles of PLMN selection in E-UTRA are based on the 3GPP PLMN selection principles. Cell selection can be required on transition from MME_DETACHED to EMM-IDLE or EMM-CONNECTED. The cell selection can be achieved when the UE NAS identifies a selected PLMN and equivalent PLMNs. The UE 101 searches the E-UTRA frequency bands and for each carrier frequency identifies the strongest cell. The UE 101 also reads cell system information broadcast to identify its PLMNs. Further, the UE 101 seeks to identify a suitable cell; if it is not able to identify a suitable cell, it seeks to identify an acceptable cell. When a suitable cell is found or if only an acceptable cell is found, the UE 101 camps on that cell and commences the cell reselection procedure. Cell selection identifies the cell that the UE 101 should camp on.

[0051] The SGSN 414 is responsible for the delivery of data packets from and to the mobile stations within its geographical service area. Its tasks include packet routing and transfer, mobility management, logical link management, and authentication and charging functions. The S6a interface enables transfer of subscription and authentication data for authenticating/authorizing user access to the evolved system (AAA interface) between MME 408 and HSS (Home Subscriber Server) 416. The S10 interface between MMEs 408 provides MME relocation and MME 408 to MME 408 information transfer. The Serving Gateway 410 is the node that terminates the interface towards the E-UTRAN 412 via S1-U.

[0052] The S1-U interface provides a per bearer user plane tunneling between the E-UTRAN 412 and Serving Gateway 410. It contains support for path switching during handover between eNBs 412. The S4 interface provides the user plane with related control and mobility support between SGSN 414 and the 3GPP Anchor function of Serving Gateway 410.

[0053] The S12 is an interface between UTRAN 406 and Serving Gateway 410. Packet Data Network (PDN) Gateway 418 provides connectivity to the UE 101 to external packet data networks by being the point of exit and entry of traffic for the UE 101. The PDN Gateway 418 performs policy enforcement, packet filtering for each user, charging support, lawful interception and packet screening. Another role of the PDN Gateway 418 is to act as the anchor for mobility

between 3GPP and non-3GPP technologies such as WiMax and 3GPP2 (CDMA 1X and EvDO (Evolution Data Only)).

[0054] The S7 interface provides transfer of QoS policy and charging rules from PCRF (Policy and Charging Role Function) 420 to Policy and Charging Enforcement Function (PCEF) in the PDN Gateway 418. The SGi interface is the interface between the PDN Gateway and the operator's IP services including packet data network 422. Packet data network 422 may be an operator external public or private packet data network or an intra operator packet data network, e.g., for provision of IMS (IP Multimedia Subsystem) services. Rx+ is the interface between the PCRF and the packet data network 422.

[0055] As seen in FIG. 4C, the eNB utilizes an E-UTRA (Evolved Universal Terrestrial Radio Access) (user plane, e.g., PDCP, RLC (Radio Link Control) 415, MAC (Media Access Control) 417, and PHY (Physical) 419, as well as a control plane (e.g., RRC 421)). The eNB also includes the following functions: Inter Cell RRM (Radio Resource Management) 423, Connection Mobility Control 425, RB (Radio Bearer) Control 427, Radio Admission Control 429, eNB Measurement Configuration and Provision 431, and Dynamic Resource Allocation (Scheduler) 433.

[0056] The eNB communicates with the aGW 401 (Access Gateway) via an S1 interface. The aGW 401 includes a User Plane 401a and a Control plane 401b. The control plane 401b provides the following components: SAE (System Architecture Evolution) Bearer Control 435 and MM (Mobile Management) Entity 437. The user plane 401b includes a PDCP (Packet Data Convergence Protocol) 439 and a user plane functions 441. It is noted that the functionality of the aGW 401 can also be provided by a combination of a serving gateway (SGW) and a packet data network (PDN) GW. The aGW 401 can also interface with a packet network, such as the Internet 443.

[0057] In an alternative embodiment, as shown in FIG. 4D, the PDCP (Packet Data Convergence Protocol) functionality can reside in the eNB rather than the GW 401. Other than this PDCP capability, the eNB functions of FIG. 4C are also provided in this architecture.

[0058] In the system of FIG. 4D, a functional split between E-UTRAN and EPC (Evolved Packet Core) is provided. In this example, radio protocol architecture of E-UTRAN is provided

for the user plane and the control plane. A more detailed description of the architecture is provided in 3GPP TS 36.300.

[0059] The eNB interfaces via the S1 to the Serving Gateway 445, which includes a Mobility Anchoring function 447, and to a Packet Gateway (P-GW) 449, which provides an UE IP address allocation function 457 and Packet Filtering function 459. According to this architecture, the MME (Mobility Management Entity) 461 provides SAE (System Architecture Evolution) Bearer Control 451, Idle State Mobility Handling 453, NAS (Non-Access Stratum) Security 455.

[0060] One of ordinary skill in the art would recognize that the processes providing transport block size signaling may be implemented via software, hardware (e.g., general processor, Digital Signal Processing (DSP) chip, an Application Specific Integrated Circuit (ASIC), Field Programmable Gate Arrays (FPGAs), etc.), firmware, or a combination thereof. Such exemplary hardware for performing the described functions is detailed below with respect to FIG. 5.

[0061] FIG. 5 illustrates exemplary hardware upon which various embodiments of the invention can be implemented. A computing system 500 includes a bus 501 or other communication mechanism for communicating information and a processor 503 coupled to the bus 501 for processing information. The computing system 500 also includes main memory 505, such as a random access memory (RAM) or other dynamic storage device, coupled to the bus 501 for storing information and instructions to be executed by the processor 503. Main memory 505 can also be used for storing temporary variables or other intermediate information during execution of instructions by the processor 503. The computing system 500 may further include a read only memory (ROM) 507 or other static storage device coupled to the bus 501 for storing static information and instructions for the processor 503. A storage device 509, such as a magnetic disk or optical disk, is coupled to the bus 501 for persistently storing information and instructions.

[0062] The computing system 500 may be coupled via the bus 501 to a display 511, such as a liquid crystal display, or active matrix display, for displaying information to a user. An input device 513, such as a keyboard including alphanumeric and other keys, may be coupled to the bus 501 for communicating information and command selections to the processor 503. The

input device 513 can include a cursor control, such as a mouse, a trackball, or cursor direction keys, for communicating direction information and command selections to the processor 503 and for controlling cursor movement on the display 511.

[0063] According to various embodiments of the invention, the processes described herein can be provided by the computing system 500 in response to the processor 503 executing an arrangement of instructions contained in main memory 505. Such instructions can be read into main memory 505 from another computer-readable medium, such as the storage device 509. Execution of the arrangement of instructions contained in main memory 505 causes the processor 503 to perform the process steps described herein. One or more processors in a multi-processing arrangement may also be employed to execute the instructions contained in main memory 505. In alternative embodiments, hard-wired circuitry may be used in place of or in combination with software instructions to implement the embodiment of the invention. In another example, reconfigurable hardware such as Field Programmable Gate Arrays (FPGAs) can be used, in which the functionality and connection topology of its logic gates are customizable at run-time, typically by programming memory look up tables. Thus, embodiments of the invention are not limited to any specific combination of hardware circuitry and software.

[0064] The computing system 500 also includes at least one communication interface 515 coupled to bus 501. The communication interface 515 provides a two-way data communication coupling to a network link (not shown). The communication interface 515 sends and receives electrical, electromagnetic, or optical signals that carry digital data streams representing various types of information. Further, the communication interface 515 can include peripheral interface devices, such as a Universal Serial Bus (USB) interface, a PCMCIA (Personal Computer Memory Card International Association) interface, etc.

[0065] The processor 503 may execute the transmitted code while being received and/or store the code in the storage device 509, or other non-volatile storage for later execution. In this manner, the computing system 500 may obtain application code in the form of a carrier wave.

[0066] The term "computer-readable medium" as used herein refers to any medium that participates in providing instructions to the processor 503 for execution. Such a medium may take many forms, including but not limited to non-volatile media, volatile media, and

transmission media. Non-volatile media include, for example, optical or magnetic disks, such as the storage device 509. Volatile media include dynamic memory, such as main memory 505. Transmission media include coaxial cables, copper wire and fiber optics, including the wires that comprise the bus 501. Transmission media can also take the form of acoustic, optical, or electromagnetic waves, such as those generated during radio frequency (RF) and infrared (IR) data communications. Common forms of computer-readable media include, for example, a floppy disk, a flexible disk, hard disk, magnetic tape, any other magnetic medium, a CD-ROM, CDRW, DVD, any other optical medium, punch cards, paper tape, optical mark sheets, any other physical medium with patterns of holes or other optically recognizable indicia, a RAM, a PROM, and EPROM, a FLASH-EPROM, any other memory chip or cartridge, a carrier wave, or any other medium from which a computer can read.

[0067] Various forms of computer-readable media may be involved in providing instructions to a processor for execution. For example, the instructions for carrying out at least part of the invention may initially be borne on a magnetic disk of a remote computer. In such a scenario, the remote computer loads the instructions into main memory and sends the instructions over a telephone line using a modem. A modem of a local system receives the data on the telephone line and uses an infrared transmitter to convert the data to an infrared signal and transmit the infrared signal to a portable computing device, such as a personal digital assistant (PDA) or a laptop. An infrared detector on the portable computing device receives the information and instructions borne by the infrared signal and places the data on a bus. The bus conveys the data to main memory, from which a processor retrieves and executes the instructions. The instructions received by main memory can optionally be stored on storage device either before or after execution by processor.

[0068] FIG. 6 is a diagram of exemplary components of an LTE terminal capable of operating in the systems of FIGs. 4A-4D, according to an embodiment of the invention. An LTE terminal 600 is configured to operate in a Multiple Input Multiple Output (MIMO) system. Consequently, an antenna system 601 provides for multiple antennas to receive and transmit signals. The antenna system 601 is coupled to radio circuitry 603, which includes multiple transmitters 605 and receivers 607. The radio circuitry encompasses all of the Radio Frequency (RF) circuitry as well as base-band processing circuitry. As shown, layer-1 (L1) and layer-2

(L2) processing are provided by units 609 and 611, respectively. Optionally, layer-3 functions can be provided (not shown). Module 613 executes all MAC layer functions. A timing and calibration module 615 maintains proper timing by interfacing, for example, an external timing reference (not shown). Additionally, a processor 617 is included. Under this scenario, the LTE terminal 600 communicates with a computing device 619, which can be a personal computer, work station, a PDA, web appliance, cellular phone, etc.

[0069] While the invention has been described in connection with a number of embodiments and implementations, the invention is not so limited but covers various obvious modifications and equivalent arrangements, which fall within the purview of the appended claims. Although features of the invention are expressed in certain combinations among the claims, it is contemplated that these features can be arranged in any combination and order.

CLAIMS

WHAT IS CLAIMED IS:

1. A method comprising:
signaling information about either a modulation and coding scheme or an associated transport block size relating to the modulation and coding scheme using a control channel of a network,
wherein the transport block size information includes one or more configurable values for the transport block size.

2. A method according to claim 1, wherein the configurable values are specified by a base station for minimizing padding.

3. A method according to claim 1, wherein the configurable values are cell specific and/or user equipment specific.

4. A method according to claim 1, further comprising:
determining the configurable values based on traffic information.

5. A method according to claim 1, further comprising:
monitoring scheduling decisions associated with transmission of data; and
determining overhead cost based on the scheduling decisions, wherein the configurable values are selected based on the determined overhead cost.

6. A method according to claim 5, further comprising:

measuring traffic information associated with the configurable values;
determining relative padding overhead for each of the configurable values; and
updating the configurable values based on the relative padding overhead.

7. A method according to claim 1, wherein a transport block size table is defined to include the configurable values and predetermined values, and each of the predetermined values and the configurable values are assigned a table index.

8. A method according to claim 1, wherein the network is compliant with a long term evolution (LTE) architecture.

9. A computer-readable medium bearing instructions for supporting signal transmission, said instructions, being arranged, upon execution, to cause one or more processors to perform the method of claim 1.

10. An apparatus comprising:
a resource allocation module configured to signal information about either a modulation and coding scheme or an associated transport block size relating to the modulation and coding scheme using a control channel of a network,
wherein the transport block size information includes one or more configurable values for the transport block size.

11. An apparatus according to claim 10, wherein the configurable values are specified by the apparatus for minimizing padding.

12. An apparatus according to claim 10, wherein the configurable values are cell specific and/or user equipment specific.

13. An apparatus according to claim 10, wherein the resource allocation module is further configured to determine the configurable values based on traffic information.

14. An apparatus according to claim 10, further comprising:

a monitoring module configured to monitor scheduling decisions associated with transmission of data, wherein the resource allocation module is further configured to determine overhead cost based on the scheduling decisions, the configurable values being selected based on the determined overhead cost.

15. An apparatus according to claim 14, wherein the monitoring module is further configured to measure traffic information associated with the configurable values, to determine relative padding overhead for each of the configurable values, and to update the configurable values based on the relative padding overhead.

16. An apparatus according to claim 10, wherein a transport block size table is defined to include the configurable values and predetermined values, and each of the predetermined values and the configurable values are assigned a table index.

17. An apparatus according to claim 10, wherein the network is compliant with a long term evolution (LTE) architecture.

18. A method comprising:

receiving information about either a modulation and coding scheme or an associated transport block size relating to the modulation and coding scheme using a control channel of a network,

wherein the transport block size information includes one or more configurable values for the transport block size.

19. A method according to claim 18, wherein the configurable values are specified by a base station for minimizing padding.

20. A method according to claim 18, wherein the configurable values are cell specific and/or user equipment specific.

21. A method according to claim 18, wherein the configurable values are determined based on traffic information.

22. A method according to claim 18, wherein scheduling decisions associated with transmission of data are monitored, and overhead cost are determined based on the scheduling decisions, the configurable values being selected based on the determined overhead cost.

23. A method according to claim 22, wherein traffic information associated with the configurable values are measured, relative padding overhead is determined for each of the configurable values, and the configurable values are updated based on the relative padding overhead.

24. A method according to claim 18, wherein each of the predetermined values and the configurable values are assigned a table index.

25. A method according to claim 18, further comprising:
selecting one of the predetermined values or the configurable values for the transport block size; and
transmitting data over the network using the selected value for the transport block size.

26. A method according to claim 18, wherein the network is compliant with a long term evolution (LTE) architecture.

27. A computer-readable medium bearing instructions for supporting signal transmission, said instructions, being arranged, upon execution, to cause one or more processors to perform the method of claim 18.

28. An apparatus comprising:

a transceiver configured to receive information about either a modulation and coding scheme or an associated transport block size relating to the modulation and coding scheme using a control channel of a network,

wherein the transport block size information includes one or more configurable values for the transport block size.

29. An apparatus according to claim 28, wherein the configurable values are specified by a base station for minimizing padding.

30. An apparatus according to claim 28, wherein the configurable values are cell specific and/or user equipment specific.

31. An apparatus according to claim 28, wherein the configurable values are determined based on traffic information.

32. An apparatus according to claim 28, wherein scheduling decisions associated with transmission of data are monitored, and overhead cost are determined based on the scheduling decisions, the configurable values being selected based on the determined overhead cost.

33. An apparatus according to claim 32, wherein traffic information associated with the configurable values are measured, relative padding overhead is determined for each of the configurable values, and the configurable values are updated based on the relative padding overhead.

34. An apparatus according to claim 28, wherein a transport block size table is defined to include the configurable values and predetermined values, and each of the predetermined values and the configurable values are assigned a table index.

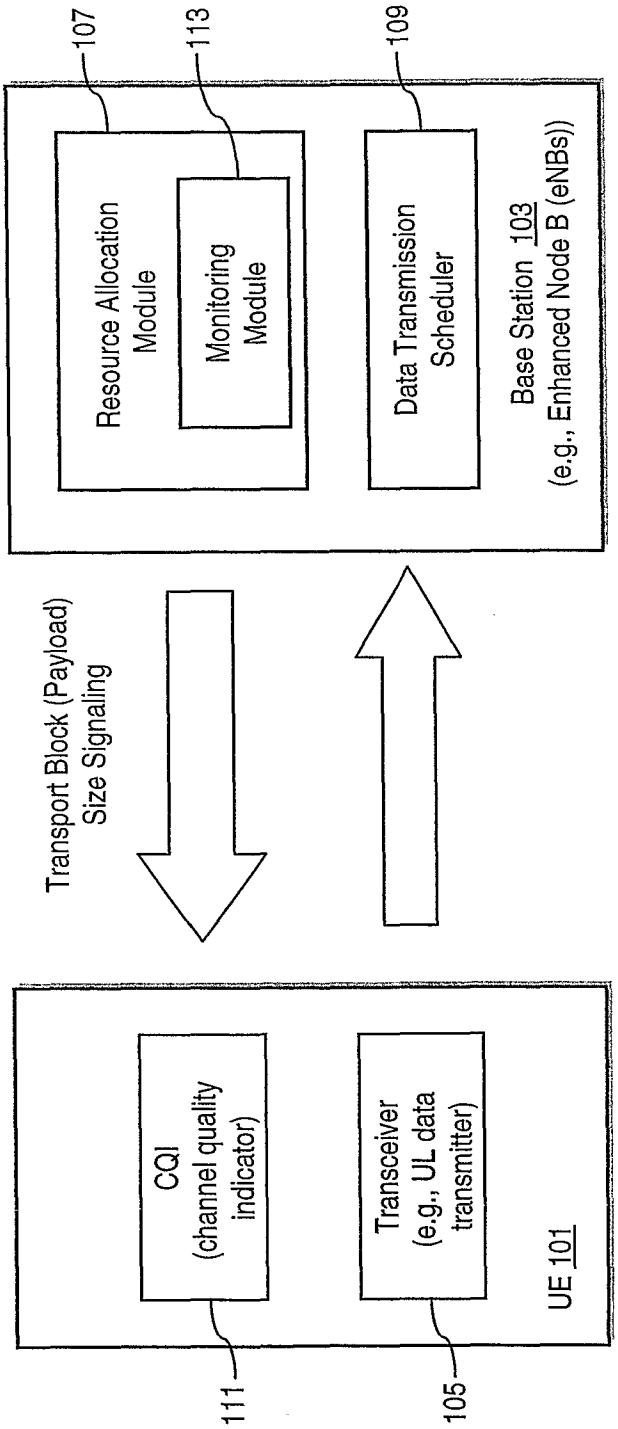
35. An apparatus according to claim 28, further comprising:

a processor configured to select one of the predetermined values or the configurable values for the transport block size, wherein the transceiver is further configured to transmit data over the network using the selected value for the transport block size.

36. An apparatus according to claim 28, wherein the network is compliant with a long term evolution (LTE) architecture.

37. An apparatus according to claim 28, wherein the apparatus is a user equipment.

FIG. 1


107
113
109
Resource Allocation Module
Monitoring Module
Data Transmission Scheduler
Base Station 103
(e.g., Enhanced Node B (eNBs))
Transport Block (Payload) Size Signaling
CQI (channel quality indicator)
Transceiver (e.g., UL data transmitter)
UE 101
111
105

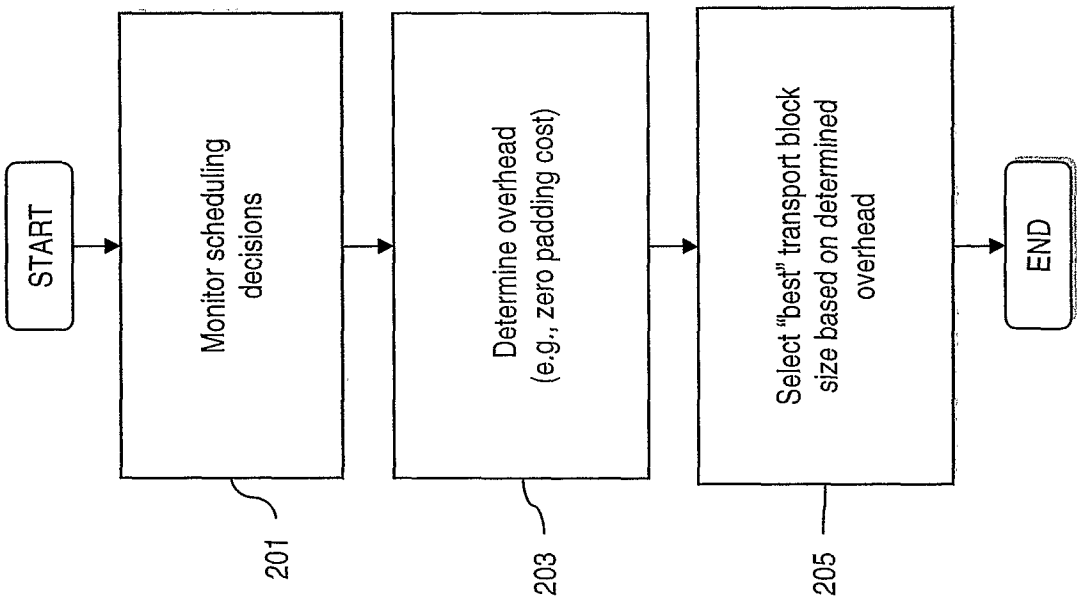

START
Monitor scheduling decisions
Determine overhead (e.g., zero padding cost)
Select "best" transport block size based on determined overhead
END
201
203
205

FIG. 2

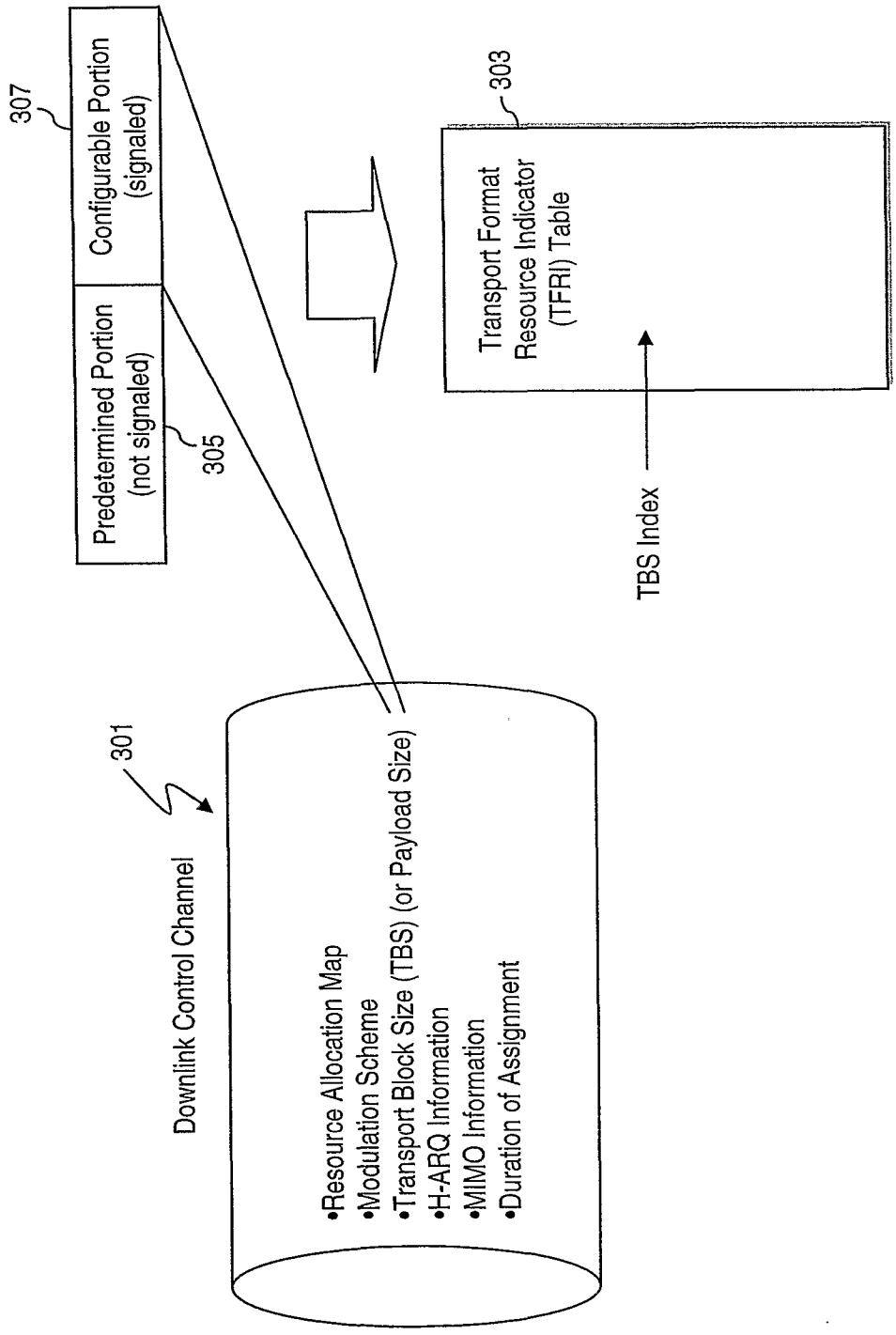

307
Configurable Portion (signaled)
Predetermined Portion (not signaled)
305
303
Transport Format Resource Indicator (TFRI) Table
TBS Index
301
Downlink Control Channel
•Resource Allocation Map
•Modulation Scheme
•Transport Block Size (TBS) (or Payload Size)
•H-ARQ Information
•MIMO Information
•Duration of Assignment

FIG. 3

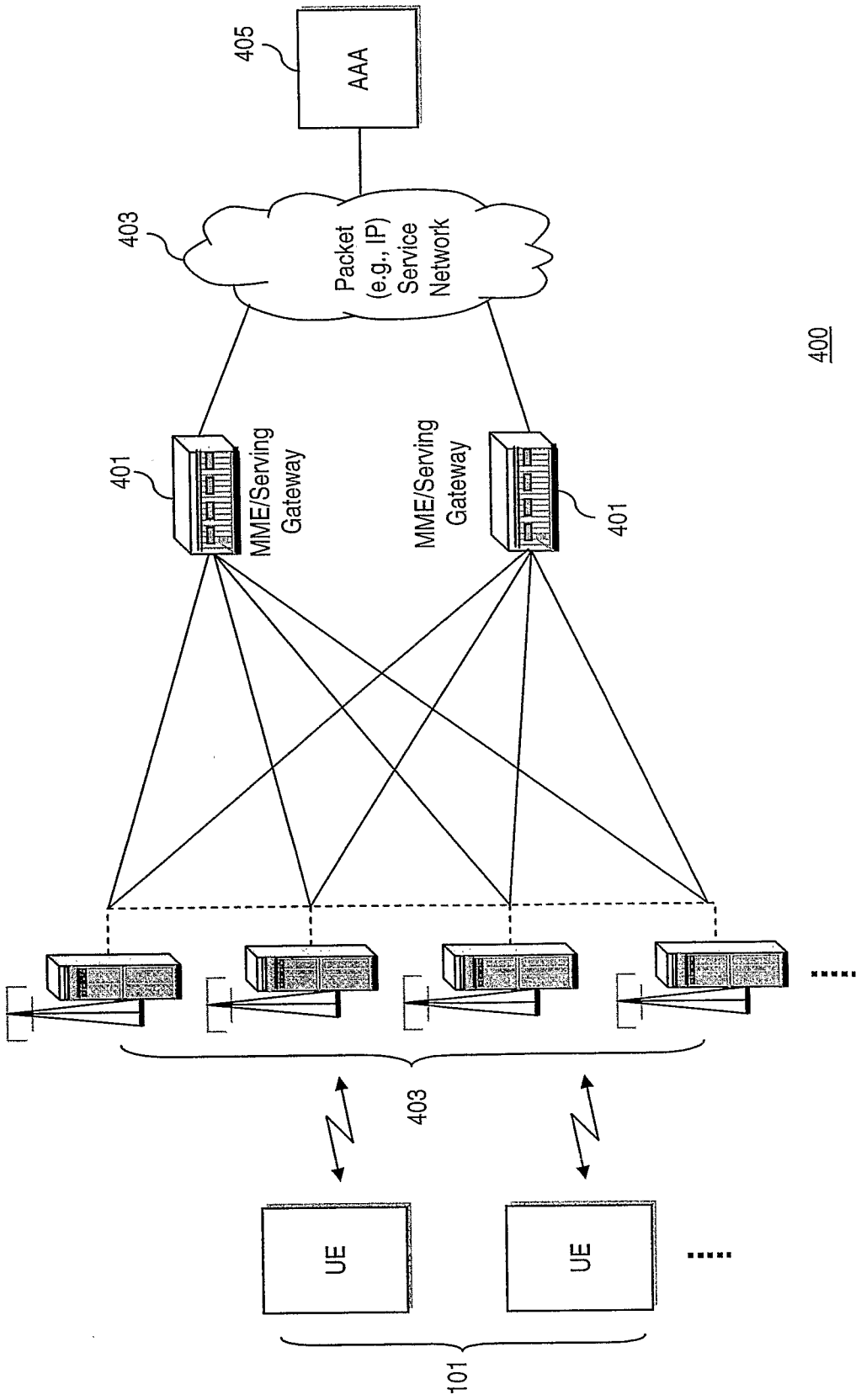
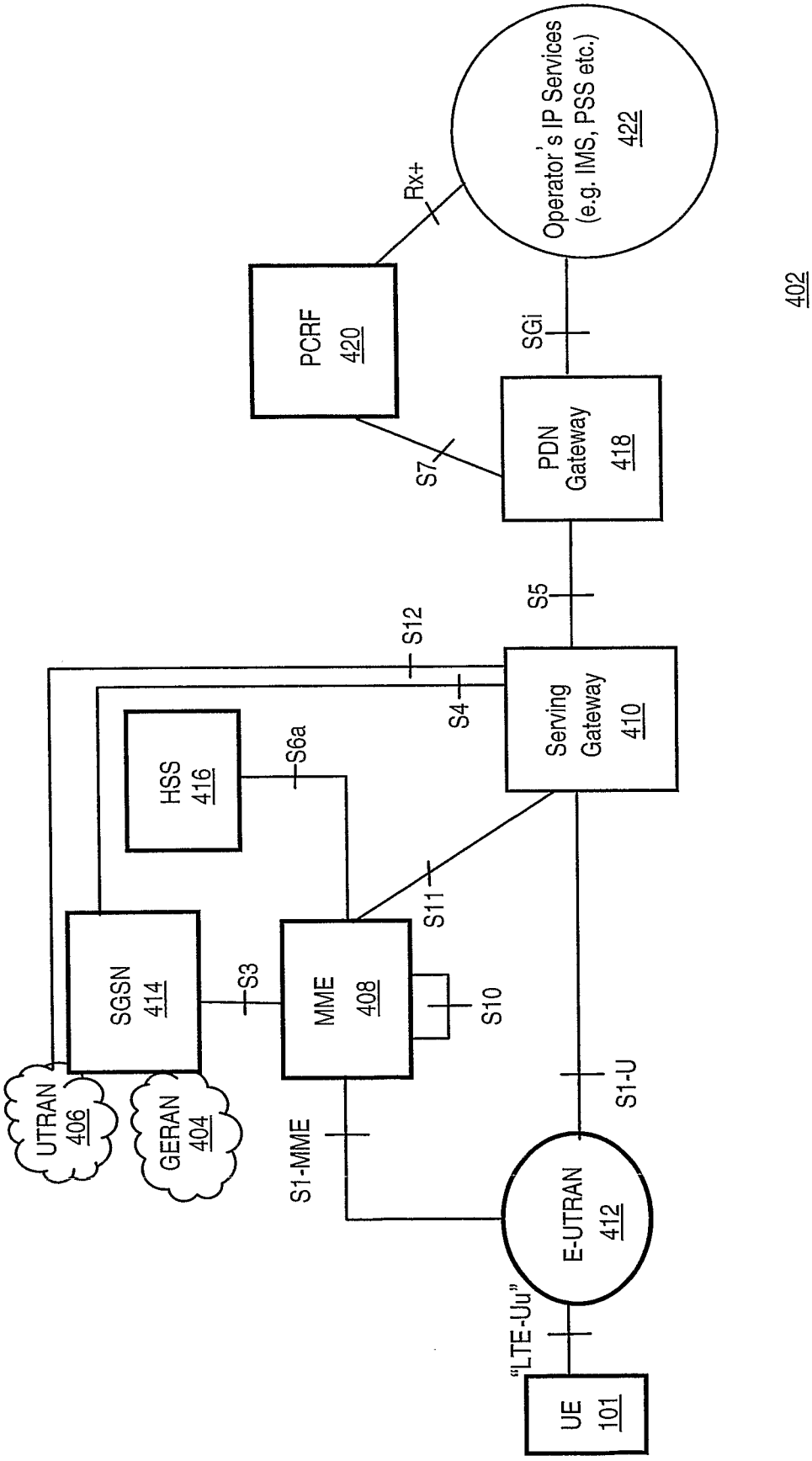

405
AAA
403
Packet (e.g., IP) Service Network
400
401
MME/Serving Gateway
MME/Serving Gateway
401
Base Station (e.g., E-UTRAN Node B (eNB))
403
UE
UE
101

FIG. 4A

FIG. 4B


Operator's IP Services (e.g. IMS, PSS etc.) 422
Rx+
PCRF 420
SGi
PDN Gateway 418
S7
S5
S12
S4
Serving Gateway 410
HSS 416
S6a
S11
SGSN 414
S3
MME 408
S10
UTRAN 406
GERAN 404
S1-MME
S1-U
E-UTRAN 412
"LTE-Uu"
UE 101
402

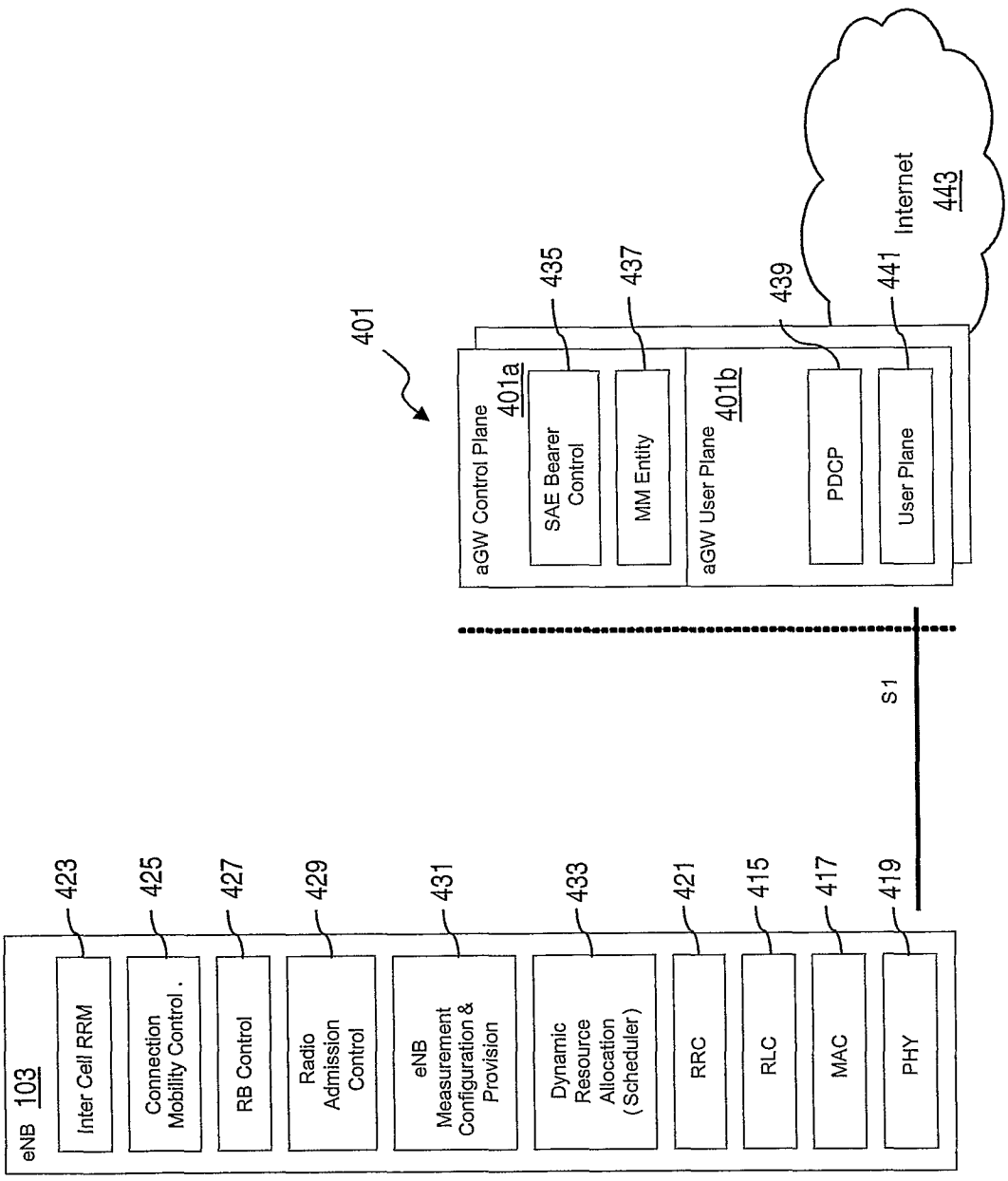
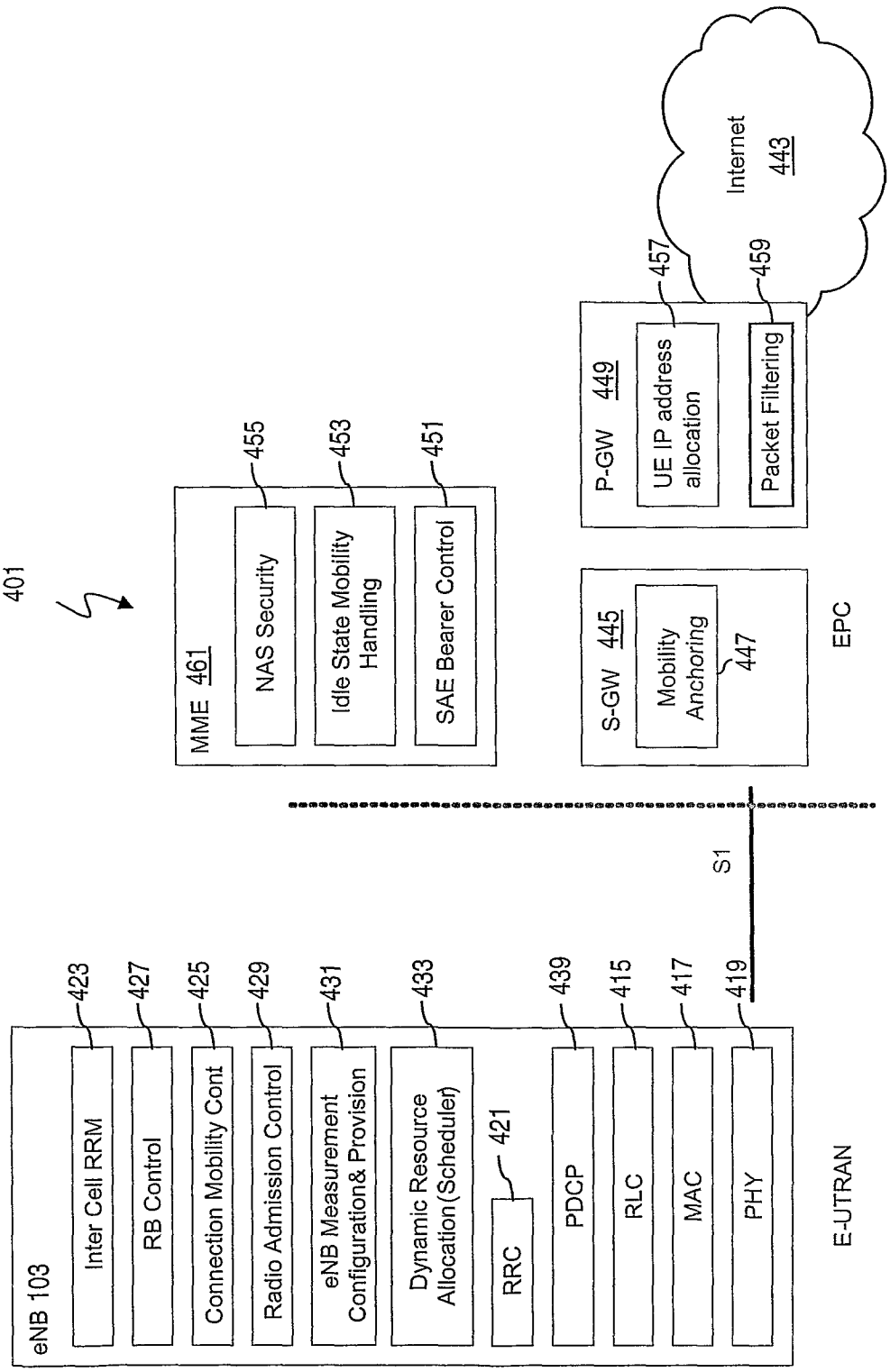

eNB 103
Inter Cell RRM
Connection Mobility Control
RB Control
Radio Admission Control
eNB Measurement Configuration & Provision
Dynamic Resource Allocation (Scheduler)
RRC
RLC
MAC
PHY
423
425
427
429
431
433
421
415
417
419
S1
401
aGW Control Plane
401a
SAE Bearer Control
MM Entity
aGW User Plane
401b
PDCP
User Plane
435
437
439
441
Internet
443

FIG. 4C

FIG. 4D


401
MME 461
NAS Security
Idle State Mobility Handling
SAE Bearer Control
455
453
451
S-GW 445
Mobility Anchoring
447
P-GW 449
UE IP address allocation
Packet Filtering
457
459
Internet
443
EPC
S1
eNB 103
Inter Cell RRM
RB Control
Connection Mobility Cont
Radio Admission Control
eNB Measurement Configuration& Provision
Dynamic Resource Allocation (Scheduler)
RRC
421
PDCP
RLC
MAC
PHY
423
427
425
429
431
433
439
415
417
419
E-UTRAN

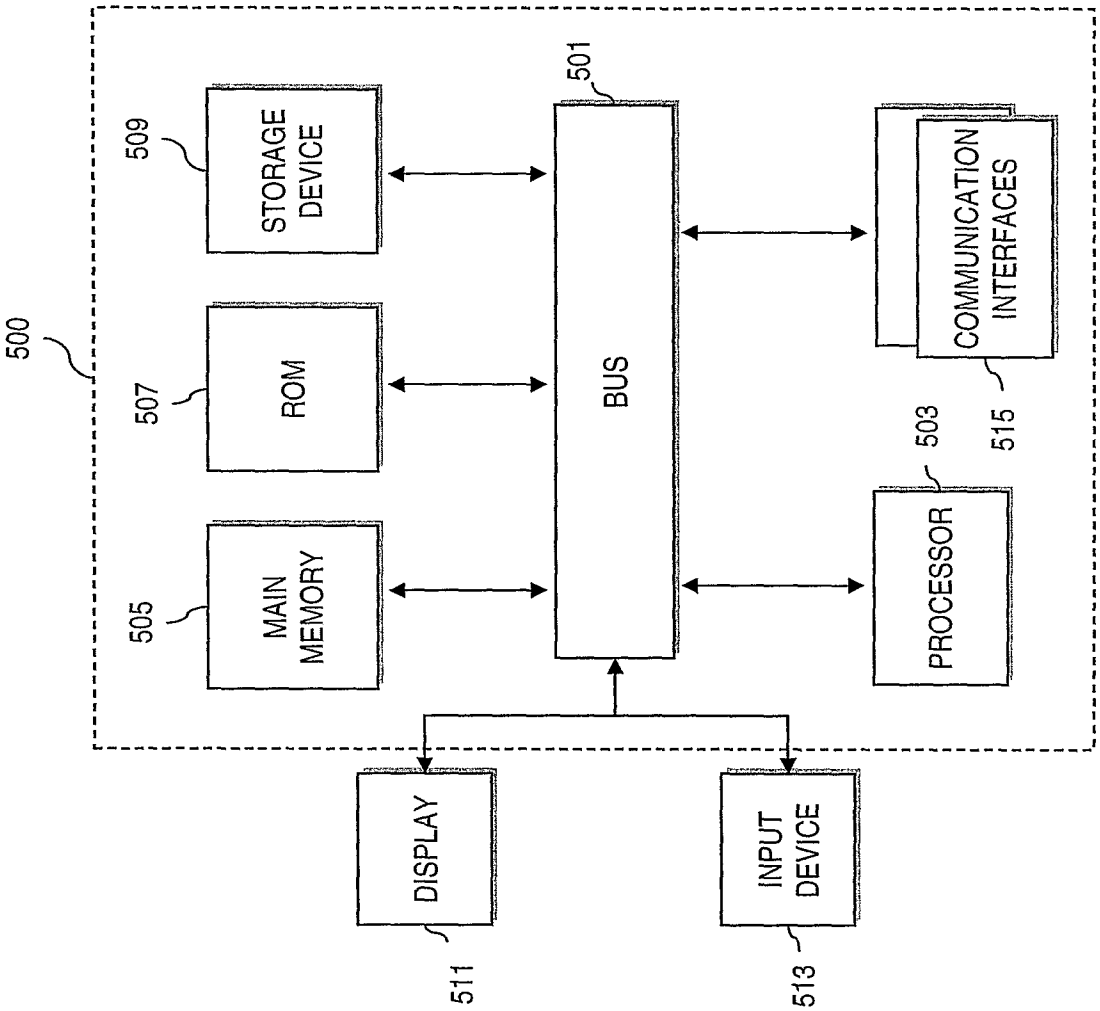

500
509
STORAGE DEVICE
507
ROM
505
MAIN MEMORY
501
BUS
COMMUNICATION INTERFACES
515
503
PROCESSOR
DISPLAY
511
INPUT DEVICE
513

FIG. 5

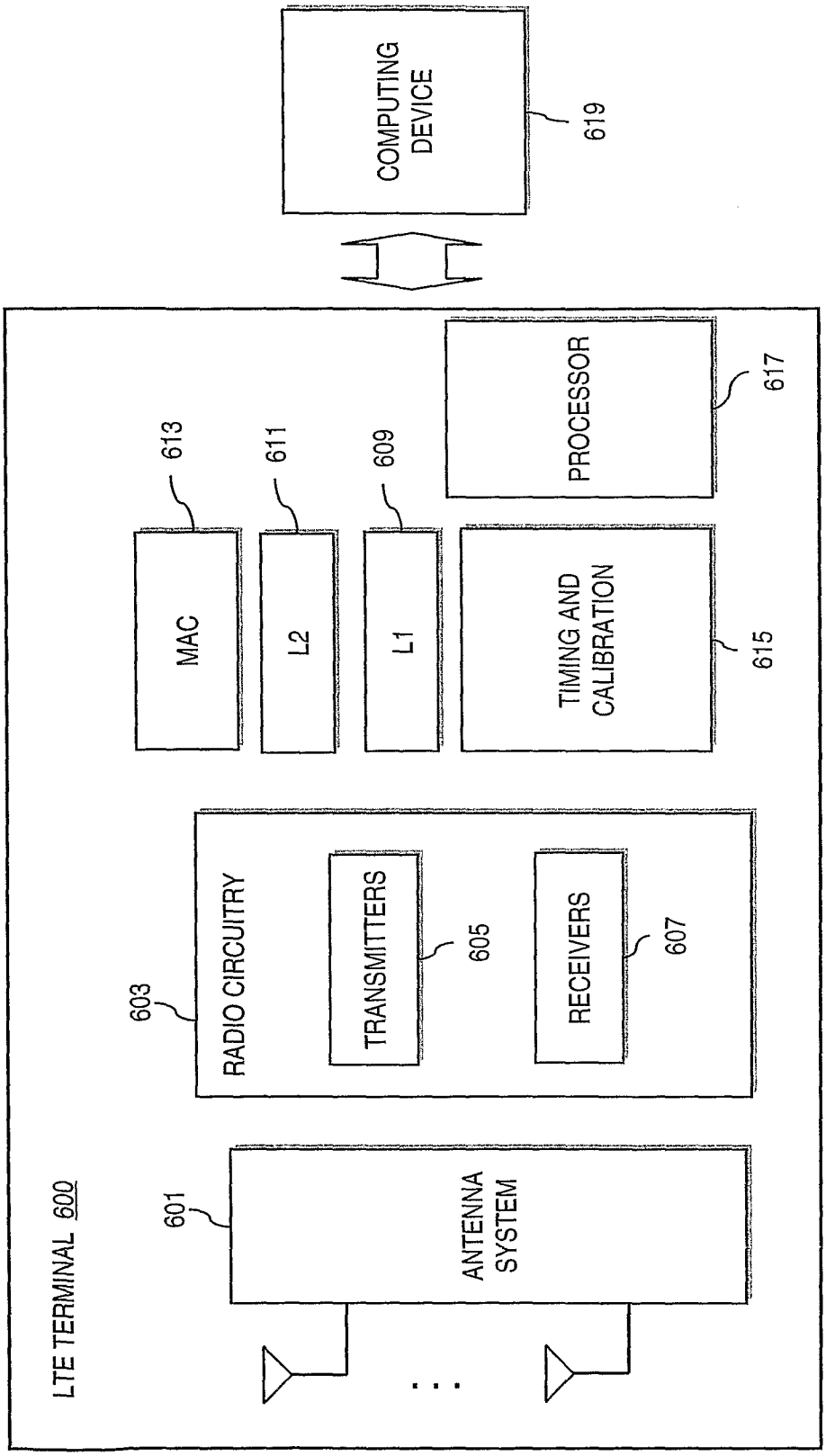

COMPUTING DEVICE
619
LTE TERMINAL 600
601
ANTENNA SYSTEM
603
RADIO CIRCUITRY
TRANSMITTERS
605
RECEIVERS
607
613
MAC
611
L2
609
L1
PROCESSOR
617
TIMING AND CALIBRATION
615

FIG. 6