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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
9 September 2011 (09.09.2011)

PCT

(10) International Publication Number
WO 2011/109796 A2

(51) International Patent Classification: Not classified

(21) International Application Number: PCT/US2011/027325

(22) International Filing Date: 5 March 2011 (05.03.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/311,174 5 March 2010 (05.03.2010) US

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(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, CL, 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, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, 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, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

(54) **Title**: CONTENTION-BASED TRANSMISSION WITH CONTENTION-FREE FEEDBACK FOR REDUCING LATENCY IN LTE ADVANCED NETWORKS AND ENHANCED PUCCH

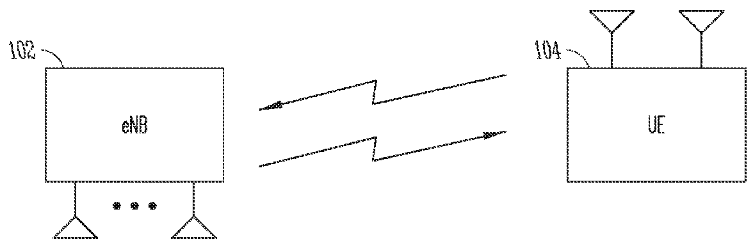

FIG. 1

(57) **Abstract**: Methods for contention-based transmission with contention-free feedback for reduced latency in LTE Advanced networks and an enhanced PUCCH are generally disclosed herein. User equipment (UE) may transmit a contention sequence on a physical uplink control channel (PUCCH) to an enhanced-Node B (eNB) and may concurrently transmit data requesting uplink resources on a physical uplink shared channel (PUSCH) to the eNB. The contention sequence is transmitted on the PUCCH in accordance with a format that is assigned by the eNB. The contention sequence is either randomly selected by the UE or assigned by the eNB. When the contention sequence and data are not successfully received by the eNB, the UE may fall back to a more conventional random access channel (RACH) procedure for uplink resource allocation.

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CONTENTION-BASED TRANSMISSION WITH CONTENTION-FREE FEEDBACK FOR REDUCING LATENCY IN LTE ADVANCED NETWORKS AND ENHANCED PUCCH

PRIORITY CLAIM

This application claims priority under 35 U.S.C. 119(e) to United States Provisional Patent Application Serial No. 61/311,174, filed March 5, 2010, which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

Embodiments pertain to wireless communications. Some embodiments relate to the Evolved Universal Terrestrial Radio Access Network (E-UTRAN) standard of the third-generation partnership project (3GPP), Release 10, known as Long Term Evolution (LTE) Advanced and referred to as LTE-A.

BACKGROUND

One issue with communicating data over a wireless network, such as a 3GPP LTE network, is latency associated with uplink access. When User Equipment (UE) has data to send, the UE may request an allocation of a resource (i.e., bandwidth) on an uplink channel for transmitting the data to an enhanced-Node B (eNB) (i.e., an LTE base station). Contention and collisions on the random access channel (RACH) as well as the overhead associated with use of the conventional RACH procedure result in lengthy delays for the UE.

Thus, there are general needs for methods of reducing latency associated with conventional uplink resource allocation requests in LTE networks. There are also general needs for an enhanced uplink control channel.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates an eNB and UE in accordance with some embodiments;

FIG. 2 is a flow diagram of a resource allocation procedure with reduced latency in accordance with some embodiments; and

FIG. 3 illustrates the structure of an enhanced physical uplink control channel (PUCCH) in accordance with some embodiments.

DETAILED DESCRIPTION

The following description and the drawings sufficiently illustrate specific embodiments to enable those skilled in the art to practice them. Other embodiments may incorporate structural, logical, electrical, process, and other changes. Portions and features of some embodiments may be included in, or substituted for, those of other embodiments. Embodiments set forth in the claims encompass all available equivalents of those claims.

FIG. 1 illustrates an eNB and UE in accordance with some embodiments. The eNB 102 and UE 104 may operate as part of an LTE advanced (LTE-A) network and may communicate with each other using a plurality of channels. The eNB 102 may communicate with a plurality of UEs, including the UE 104, using an orthogonal frequency division multiple access (OFDMA) technique in the downlink, and the UE 104 may communicate with the eNB 102 using a single-carrier frequency division multiple access (SC-FDMA) technique in the uplink. Downlink channels may include a physical downlink shared channel (PDSCH), and a physical broadcast control channel (PBCCH), among others. Uplink channels may include a random access channel (RACH), a physical uplink control channel (PUCCH) and a physical uplink shared channel (PUSCH), among others. The PUSCH is generally shared by several UEs for transmitting information data to the eNB 102 in accordance with the SC-FDMA technique.

In accordance with embodiments, the UE 104 may transmit a contention sequence on a first physical uplink channel to an enhanced-Node B (eNB) 102, and may transmit data requesting uplink resources on a second physical uplink channel to the eNB 102. The contention sequence may be transmitted on the first physical uplink channel in accordance with a format that is assigned by the eNB 102. In accordance some with embodiments, the UE 104 may transmit the contention sequence on the PUCCH to the eNB 102 and transmit the data on the PUSCH to the eNB 102. The contention sequence may be transmitted on the PUCCH in accordance with a format that is assigned by the eNB 102. The contention sequence may be either randomly selected by the UE 104 or assigned by the eNB 102.

In these embodiments, the UE 104 may transmit the contention sequence on the PUCCH to the eNB 102 and transmit data on the PUSCH to the eNB 102 when the UE 104 is requesting an allocation of resources (i.e., grant of bandwidth or a resource allocation) for a subsequent uplink data transmission. In these embodiments, the UE 104 may use the PUCCH and the PUSCH for random access. The transmission of data on the PUSCH may be a request for uplink bandwidth for a subsequent uplink data transmission.

The RACH, the PUCCH and the PUSCH are defined in terms of frequency and time resources. The PUCCH and the PUSCH may comprise one or more resource blocks (RB) and one or more time slots or OFDM symbols. Each RB may comprise predetermined number of subcarriers (e.g., twelve).

In some embodiments, prior to the transmission of the contention sequence on the PUCCH and the transmission of data on the PUSCH, the UE 104 may receive an allocation of resources of the PUCCH and the PUSCH from the eNB 102 for use of the PUCCH and the PUSCH for random access (i.e., the transmission of the contention sequence on the PUCCH). The allocation of resources may be received by the UE 104 in a downlink control channel from the eNB 102. The downlink control channel may be the PBCCH (for broadcast allocations) or the PDSCH (for unicast allocations).

In accordance with some embodiments, the contention sequence may be transmitted on the PUCCH and the data may be transmitted on the PUSCH concurrently within a same subframe. When there is a restriction on concurrent transmissions within the same subframe by the UE 104, the contention sequence may be transmitted on the PUCCH and the data may be transmitted on the PUSCH within different subframes and with a fixed time-offset therebetween.

In some embodiments, the data transmission on the PUSCH may be done without an uplink grant of resources to the UE 104 by the eNB 102. In this way, a significant reduction in latency may be achieved. In some embodiments, the eNB 102 may allocate resources on the PUCCH and the PUSCH to the UE 104 for transmission of an uplink resource allocation instead of uplink data traffic. The data transmitted by the UE 104 on the PUSCH may be transmitted in accordance with the format of a unicast resource grant (i.e., a typical uplink transmission as with a unicast resource grant).

The data transmitted by the UE 104 on the PUSCH may include identification (ID) information unique to the UE 104 that was previously assigned by the eNB 102 to allow the eNB 102 to uniquely identify the particular UE 104 that has transmitted the data on the

PUSCH. The data may also indicate that the UE 104 is requesting uplink channel resources for a subsequent data transmission. Accordingly, the eNB 102 is able to determine which UE has sent the data on the PUSCH.

In some embodiments, the contention sequence may be considered a codeword unique to the UE 104. The contention sequence may also be viewed as a contention preamble.

The relationship or the mapping between the data sent on the PUSCH (e.g., the association with a particular UE) and the sequence sent in the PUCCH may be defined so that the eNB 102 can associate the contention sequence received in the PUCCH and the data received in PUSCH. The data may be more vulnerable to collision and other channel impairments than the contention sequence. As a result, the contention sequence may be detected but the data may be lost. In these embodiments, a more conventional RACH procedure may be performed as a fallback. These embodiments are described in more detail below.

When the eNB 102 is unable to detect the data transmitted on the PUSCH (e.g., due to noise or due to a collision) but is able to detect the contention sequence, the eNB 102 may be configured to follow the more conventional RACH procedure as a fallback when the contention sequence was randomly selected by the UE 104 (i.e., not assigned by the eNB 102). When the eNB 102 is unable to detect the data transmitted on the PUSCH but is able to detect the contention sequence, the eNB 102 may be configured to follow a more conventional scheduling request (SR) procedure as a fallback when the contention sequence was assigned to the UE 104.

The more conventional RACH procedure may include the eNB 102 transmitting a random-access response (RAR) on the PDSCH which includes the identity of the detected sequence along with timing information. A grant of uplink resources may be provided if the sequence provided in the RAR corresponds to the contention sequence transmitted by the UE 104 and the UE 104 acknowledges receipt of the RAR. When the sequence provided in the RAR does not correspond to the contention sequence transmitted by the UE 104, the UE 104 refrains from acknowledging the RAR (i.e., a discontinuous transmission (DTX)). Similarly, when the UE 104 does not receive or is unable to decode the RAR, no response is sent by the UE 104 (also a DTX).

In the embodiments discussed above, the existing physical layer (PHY) configured in accordance with LTE may be used, however, a PUCCH-like opportunity and PUSCH opportunity may be provided together. In other embodiments discussed below, an enhanced LTE PHY is provided. In these embodiments, the UE 104 may be configured to transmit a contention sequence in a reference signal portion of the PUCCH and transmit data in a regular data portion of the PUCCH. The data may be sent in one or more RBs of the data portion of the PUCCH and two OFDM symbols may be allocated for the reference signal.

In some embodiments, the reference signal portion of a PUCCH may be a portion allocated for transmission of a demodulation reference sequence (DMRS). The reference signal portion may be time-multiplexed with the data symbols. These embodiments are discussed in more detail below.

In these embodiments, the contention sequence may be transmitted in accordance with a format that is assigned by the eNB 102. The contention sequence may be either randomly selected by the UE 104 or assigned by the eNB 102. The data transmitted the data on the PUCCH may include identification information unique to the UE 104 that was previously assigned by the eNB 102 to allow the eNB 102 to uniquely identify the UE that has transmitted the data on the PUCCH. The data transmitted on the PUCCH may also indicate that the UE 104 is requesting uplink channel resources for a subsequent uplink data transmission. In some embodiments, the PUSCH may be used for transmission of the data instead of the PUCCH.

In some embodiments, this transmission may be viewed as a slotted-ALOHA transmission and may provide minimal access latency for a subsequent information transmission. In some embodiments, the eNB 102 may be configured to detect two or more contention sequences simultaneously when specifically configured references signals are assigned to associated UEs.

In accordance with embodiments, eNB 102 may utilize two or more antennas and UE 104 may utilize two or more antennas to allow for multiple-input multiple output (MIMO) communications. In some embodiments, the eNB 102 may utilize up to eight or more antennas and may be configured for multi-user (MU) MIMO communications in which symbols for each UE may be specifically precoded for each UE prior to downlink transmission on the PDSCH.

The eNB 102 and the UE 104 may include several separate functional elements, one or more of the functional elements may be combined and may be implemented by combinations of software-configured elements, such as processing elements including digital signal processors (DSPs), and/or other hardware elements. For example, some elements may comprise one or more microprocessors, DSPs, application specific integrated circuits (ASICs), radio-frequency integrated circuits (RFICs) and combinations of various hardware and logic circuitry for performing at least the functions described herein. In some embodiments, the functional elements may include one or more processes operating on one or more processing elements. In addition, the eNB 102 and the UE 104 may each include physical-layer circuitry for transmitting and receiving radio-frequency signals and media-access control (MAC) layer circuitry for controlling access to the wireless medium.

FIG. 2 is a resource allocation procedure with reduced latency in accordance with some embodiments. Procedure 200 may be performed by an eNB, such as eNB 102 (FIG. 1), and a UE, such as UE 104 (FIG. 1).

In operation 202, the UE 104 may transmit both a contention sequence and data. The contention sequence may be transmitted on the PUCCH to the eNB 102, and the data may be transmitted on the PUSCH to the eNB 102. The contention sequence may be transmitted in accordance with a format that is assigned by the eNB 102 and may be either randomly selected by the UE 104 or assigned by the eNB 102. The data may include identification information unique to the UE 104 and may indicate that the UE 104 is requesting uplink channel resources for a subsequent uplink data transmission.

In operation 204, the UE 104 may determine when the eNB 102 receives the data from the UE 104 (i.e., without contention). When the data is successfully received by the eNB 102, the UE 104 may receive an allocation of uplink resources and operation 206 may be performed. In operation 206, the UE 104 may transmit information to the eNB 102 in accordance with the assigned uplink resources achieving quick access.

When the data transmitted in operation 202 is not successfully received by the eNB 102, in operation 208 the eNB 102 may determine whether the contention sequence transmitted in operation 202 has been successfully received by the eNB 102. When the contention sequence has been successfully received, the eNB 102 may transmit a RAR (as discussed above) as part of a RACH procedure in operation 210.

When the contention sequence transmitted in operation 202 has not been successfully received by the eNB 102 in operation 208, the UE 104 will not receive a RAR identifying the contention sequence and may retransmit the contention sequence and the data to the eNB 102 in operation 202.

As part of the RACH procedure in operation 210, the UE 104 may receive a RACH grant of uplink resources. In operation 212, the UE 104 may transmit uplink information in accordance with the RACH grant (e.g., on the uplink resources allocated to the UE 104 on the PUSCH).

FIG. 3 illustrates the structure of an enhanced PUCCH in accordance with some embodiments. The enhanced PUCCH 300 may be viewed as an extension to the PUCCH of LTE Release 8 configured in format 1/1a/1b. The enhanced PUCCH 300 may be used by a UE to request uplink resources in accordance with operation 202 (FIG. 2) of procedure 200 (FIG. 2). When the data transmitted on the enhanced PUCCH 300 is received, quick access may be achieved and the UE 104 (FIG. 1) may receive a scheduled uplink resource allocation from the eNB 102 (FIG. 1) with reduced latency.

The enhanced PUCCH 300 may occupy one RB and may comprise two slots (e.g., slot 301 and slot 302). The RB may, for example, be one millisecond (ms) long in the time-domain and may, for example, occupy 180 kHz in the frequency domain. Each slot 301, 302 may be five milliseconds long, for example, and the subcarriers may be located on opposite ends of the frequency band (i.e., at the band edges) to maximize frequency diversity. Each slot 301 and 302 may include three demodulation reference symbols (DMRS) 303 and four data symbols 304. Each symbol may utilize a set of subcarriers. In this example, twelve subcarriers per symbol are illustrated.

In accordance with embodiments, the enhanced PUCCH 300 may use seventy-two subcarriers to carry the DMRS as a preamble (e.g., twelve subcarriers x three symbols per slot x two slots). In these embodiments, thirty-six preamble sequences may be defined using two-dimensional spreading. The two-dimensional spreading of LTE rel. 8, for example, may be used. In these embodiments, ninety-six data subcarriers may be used to carry a set of information bits (twelve subcarriers x four data symbols per slot x two slots) (illustrated as d(0) through d(95) in FIG. 3). The DMRS of slot 301 may be the same as the DMRS of slot 302. The information bits may be first encoded using a ¼ tail-biting convolutional code (TBCC) code and may be QPSK modulated onto the ninety-six data symbols and mapped to the ninety-six data subcarriers utilized by the data symbols 304 of the enhanced PUCCH 300. After the eNB 102 detects the preamble sequence, it will use the preamble sequence as the DMRS 303 to coherently detect the information bits in the data portion of the enhanced PUCCH 300. When two or more preamble sequences are detected at the same time, the eNB 102 may utilize MIMO signal processing techniques, such as maximum-likelihood (ML) detection, to decode information bits of two or more UEs at the same time.

The data portion of the enhanced PUCCH 300 may include all the data symbols 304. In the example of FIG. 3, the data portion includes eight data symbols 304 (e.g., four per slot) utilizing ninety-six subcarriers. For example, when the total ninety-six data subcarriers are used to carry forty information bits, the forty information bits may be first appended with eight CRC bits, and the forty-eight bits may then be encoded using 1/4 TBCC code into 192 encoded bits. Then the 192 encoded bits are QPSK modulated into the ninety-six data symbols. The ninety-six data symbols will be mapped to the ninety-six subcarriers of the data portion of the enhanced PUCCH 300. The eNB 102 may use the preamble sequence as the DMRS to coherently detect the 40 information bits in the data portion of the enhanced PUCCH 300.

In these embodiments, thirty-six preamble sequences of the DMRS 303 may be selected to carry five bits by using pseudo-random sequence selection functions. In these embodiments, one RB may carry up to forty-five information bits. In some embodiments, some of these information bits can be used to carry the Radio Network Temporary Identifier (RNTI) of the UE 104, and the remaining bits may be used to carry signaling bits.

In some embodiments, a cyclic-shifted length twelve Zadoff-Chu (ZC) sequence may be used for the DMRS for one OFDM symbol. In the time domain, a length three orthogonal cover may be used to spread the length twelve DMRS into three length twelve DMRS symbols for mapping to the three DMRS OFDM symbols. As illustrated in FIG. 3, the sequence may be indexed in terms of v(n) for each of the twelve subcarriers subcarrier and Q(n) for each of the three symbols of the DMRS 303.

For the data portion of the enhanced PUCCH 300, one bit of information will be modulated and spread over time using length four orthogonal cover and further spread in the frequency domain using one cyclic-shifted ZC sequence to become four columns of length twelve data which can be mapped to the four data OFDM symbols of each slot.

Embodiments may be implemented in one or a combination of hardware, firmware and software. Embodiments may also be implemented as instructions stored on a computer-readable storage device, which may be read and executed by at least one processor to perform the operations described herein. A computer-readable storage device may include any non-transitory mechanism for storing information in a form readable by a machine (e.g., a computer). For example, a computer-readable storage device may include read-only memory (ROM), random-access memory (RAM), magnetic disk storage media, optical storage media, flash-memory devices, and other storage devices and media. In some embodiments, eNB 102 or UE 104 may include one or more processors and may be configured with instructions stored on a computer-readable storage device.

The Abstract is provided to comply with 37 C.F.R. Section 1.72(b) requiring an abstract that will allow the reader to ascertain the nature and gist of the technical disclosure. It is submitted with the understanding that it will not be used to limit or interpret the scope or meaning of the claims. The following claims are hereby incorporated into the detailed description, with each claim standing on its own as a separate embodiment.

CLAIMS

What is claimed is:

1. A method performed by user equipment (UE) for random access comprising:

transmitting a contention sequence on a first physical uplink channel to an enhanced-Node B (eNB); and

transmitting data requesting uplink resources on a second physical uplink channel to the eNB,

wherein the contention sequence is transmitted on the first physical uplink channel in accordance with a format that is assigned by the eNB, and

wherein the contention sequence is either randomly selected by the UE or assigned by the eNB.

2. The method of claim 1 wherein the first physical uplink channel is a physical uplink control channel (PUCCH) and the second physical uplink channel is a physical uplink shared channel (PUSCH), and

wherein the contention sequence is transmitted on the PUCCH and the data is concurrently transmitted on the PUSCH within a same subframe.

3. The method of claim 2 wherein when there is a restriction on concurrent transmissions within the same subframe by the UE, the contention sequence is transmitted on the PUCCH and the data is transmitted on the PUSCH and with a fixed time-offset therebetween.

4. The method of claim 3 wherein the data transmitted on the PUSCH is transmitted in accordance with a format of a unicast resource grant,

wherein the data includes identification (ID) information unique to the UE that was previously assigned by the eNB to allow the eNB to uniquely identify the UE that has transmitted the data on the PUSCH, and

wherein the data transmitted on the PUSCH indicates that the UE is requesting uplink channel resources for a subsequent uplink data transmission.

5. The method of claim 4 wherein when the eNB is unable to detect the data

transmitted on the PUSCH but is able to detect the contention sequence:

the eNB is configured to follow a random-access channel (RACH) procedure when the contention sequence was randomly selected by the UE; and

the eNB is configured to follow a scheduling request (SR) procedure when the contention sequence was assigned to the UE.

6. The method of claim 2 wherein prior to the transmission of the contention sequence and the data, the method comprises receiving an allocation of resources of the PUCCH and the PUSCH from the eNB for use of the PUCCH and the PUSCH for random access.

7. The method of claim 6 wherein the allocation of resources is received by the UE in a downlink control channel from the eNB.

8. User equipment (UE) comprising physical-layer circuitry configured to:

transmit a contention sequence on a physical uplink control channel (PUCCH) to an enhanced-Node B (eNB); and

transmit data requesting uplink resources on a physical uplink shared channel (PUSCH) to the eNB,

wherein the data transmitted on the PUSCH indicates that the UE is requesting uplink channel resources for a subsequent uplink data transmission, and

wherein the contention sequence is transmitted on the PUCCH in accordance with a format that is assigned by the eNB.

9. The UE of claim 8 wherein the contention sequence is transmitted on the PUCCH and the data is concurrently transmitting on the PUSCH within a same subframe, and

when there is a restriction on concurrent transmissions within the same subframe by the UE, the contention sequence is transmitted on the PUCCH and the data is transmitted on the PUSCH and with a fixed time-offset therebetween.

10. The UE of claim 9 wherein the data transmitted on the PUSCH is transmitted in accordance with a format of a unicast resource grant,

wherein the data includes identification (ID) information unique to the UE that was previously assigned by the eNB to allow the eNB to uniquely identify the UE that has transmitted the data on the PUSCH.

11. The UE of claim 10 wherein when the eNB is unable to detect the data transmitted on the PUSCH but is able to detect the contention sequence:

the eNB is configured to follow a random-access channel (RACH) procedure when the contention sequence was randomly selected by the UE; and

the eNB is configured to follow a scheduling request (SR) procedure when the contention sequence was assigned to the UE.

12. The UE of claim 8 wherein prior to the transmission of the contention sequence and the data, the UE is configured to receive an allocation of resources of the PUCCH and the PUSCH from the eNB for use of the PUCCH and the PUSCH for random access, and

wherein the allocation of resources is received by the UE in a downlink control channel from the eNB.

13. The UE of claim 9 wherein eNB and the UE communicate over the PUCCH and the PUSCH in accordance with a Long Term Evolution (LTE) Advanced standard of the third-generation partnership project (3GPP).

14. A method for random access by user equipment (UE), the method comprising:

transmitting a contention sequence in a reference signal portion of a physical uplink control channel (PUCCH) and data in a data portion of the PUCCH,

wherein the data is sent in one or more resource blocks (RBs) of the data portion of the PUCCH,

wherein two OFDM symbols are allocated for the reference signal portion for the transmission of the contention sequence.

15. The method of claim 14 wherein the contention sequence and the data are transmitted within a same subframe,

wherein the contention sequence is transmitted in accordance with a format that is assigned by an enhanced-Node B (eNB), and

wherein the contention sequence is either randomly selected by the UE or assigned by the eNB.

16. The method of claim 15 wherein the data transmitted on the PUCCH includes identification information unique to the UE that was previously assigned by the eNB to

allow the eNB to uniquely identify the UE that has transmitted the data on the PUCCH, and

wherein the data transmitted on the PUCCH indicates that the UE is requesting uplink channel resources for a subsequent uplink data transmission.

17. The method of claim 14 wherein the UE communicates over the PUCCH and the PUSCH in accordance with a Long Term Evolution (LTE) Advanced standard of the third-generation partnership project (3GPP).

18. A method performed by an enhanced-Node B (eNB) for receiving on an enhanced physical uplink control channel (PUCCH),

wherein the PUCCH comprises first and second slots, each slot including three demodulation reference symbols (DMRS) and four data symbols,

wherein the method further comprises:

receiving thirty-six preamble sequences that are spread two-dimensionally over seventy-two subcarriers that carry the DMRS reference symbols; and

receiving a plurality of up to forty-five or more information bits of data over ninety-six subcarriers of the four data symbols.

19. The method of claim 18 further comprising:

detecting the preamble sequences over seventy-two subcarriers; and

using the preamble sequences as DMRS to coherently detect the information bits.

20. The method of claim 18 wherein the data includes:

Radio Network Temporary Identifiers (RNTI) of user equipment; and

signaling bits.

21. The method of claim 18 wherein the first and second slots comprise resource blocks of subcarriers that are located at opposite ends of a frequency band, and

wherein the eNB is configured to operate in accordance with a Long Term Evolution (LTE) Advanced standard of the third-generation partnership project (3GPP).

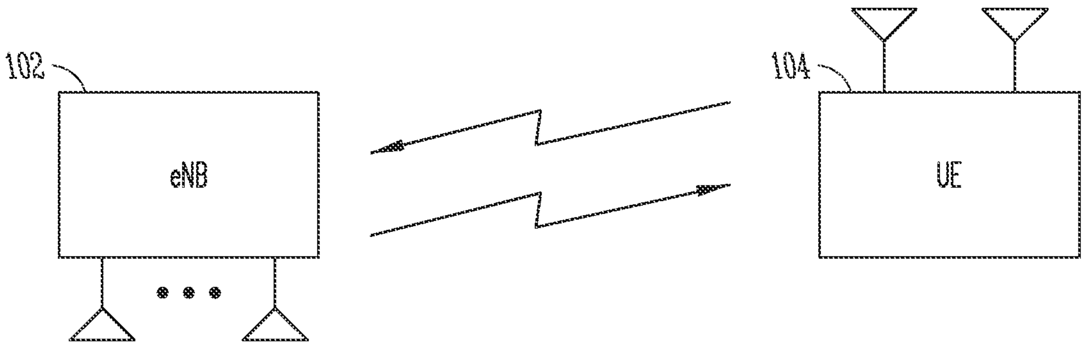


FIG. 1

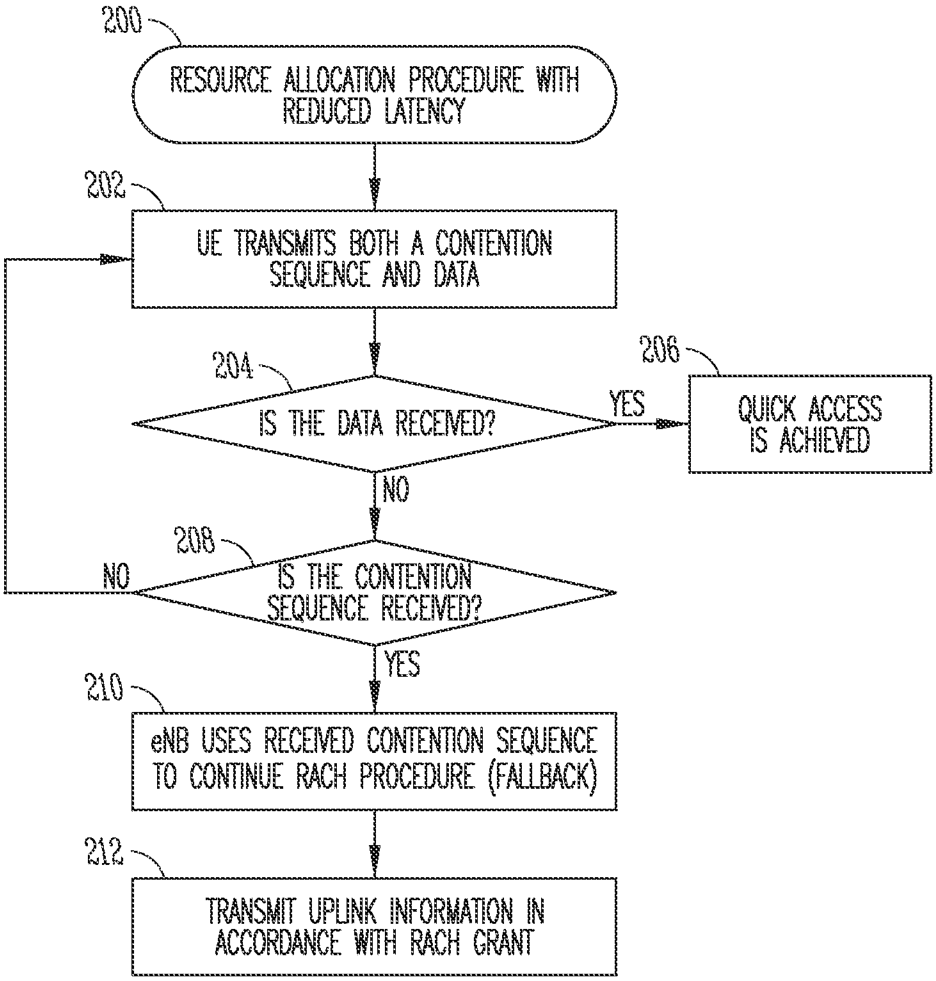
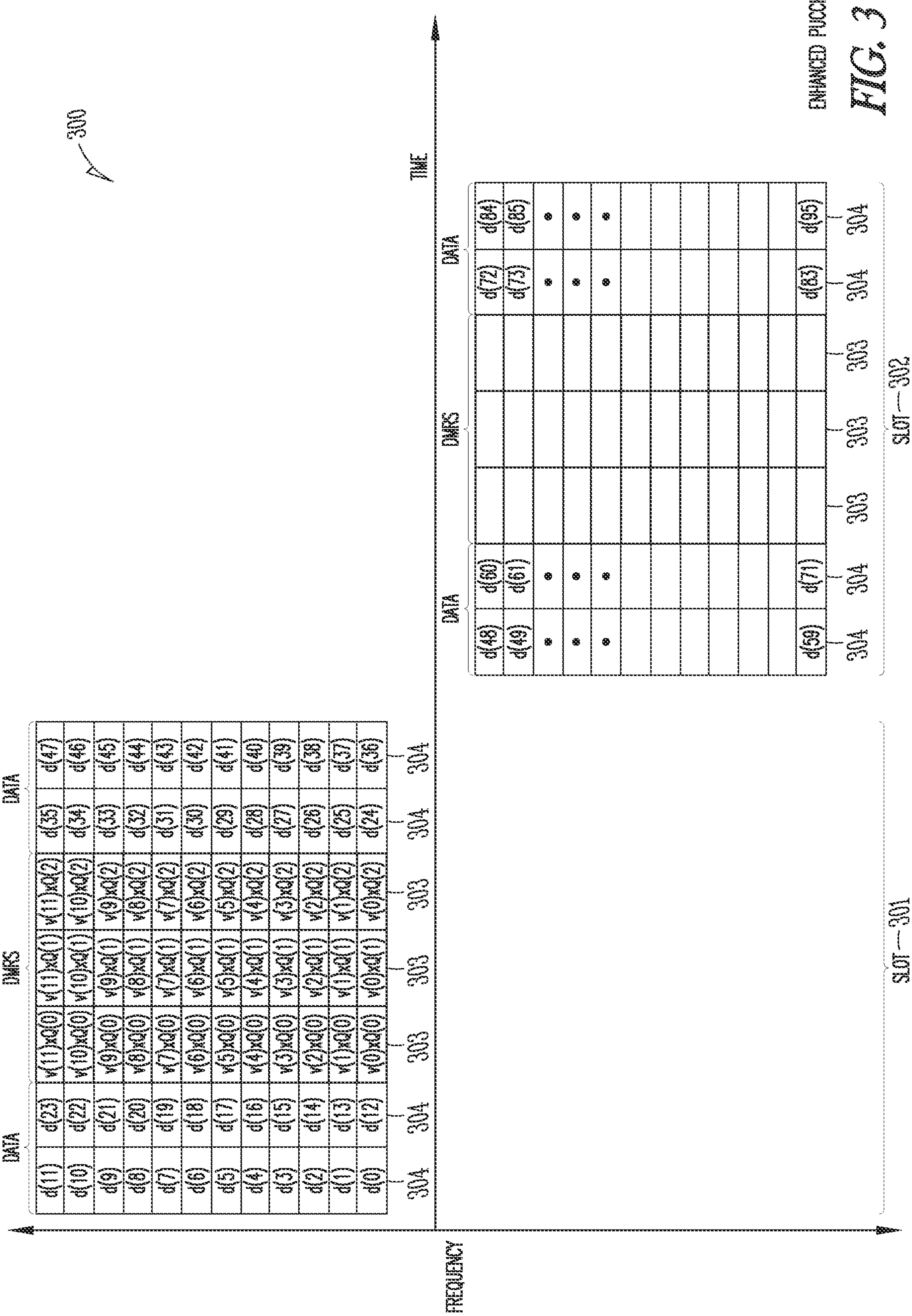

200
RESOURCE ALLOCATION PROCEDURE WITH REDUCED LATENCY
202
UE TRANSMITS BOTH A CONTENTION SEQUENCE AND DATA
204
IS THE DATA RECEIVED?
YES
206
QUICK ACCESS IS ACHIEVED
NO
208
IS THE CONTENTION SEQUENCE RECEIVED?
NO
YES
210
eNB USES RECEIVED CONTENTION SEQUENCE TO CONTINUE RACH PROCEDURE (FALLBACK)
212
TRANSMIT UPLINK INFORMATION IN ACCORDANCE WITH RACH GRANT

FIG. 2



ENHANCED PUCCH
FIG. 3