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(54) Title: ENHANCED BASE STATION AND METHOD FOR COMMUNICATING THROUGH AN ENHANCED DISTRIBUTED ANTENNA SYSTEM (eDAS)

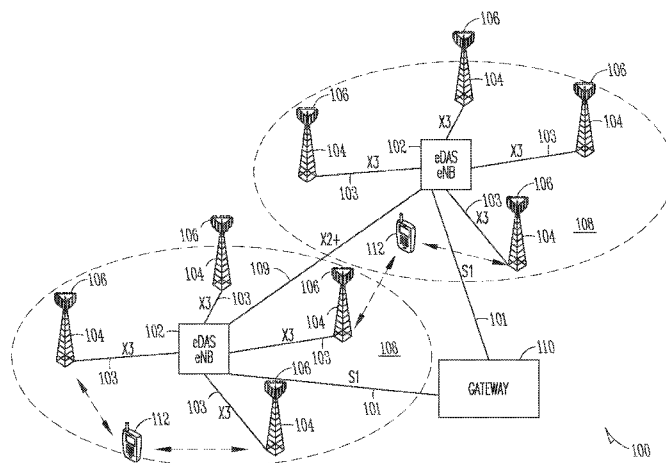


FIG. 1

(57) Abstract: Embodiments of an enhanced base station and method for communicating through an enhanced distributed antenna system (eDAS) are generally described herein. The eDAS includes geographically-separated antenna nodes and each of the antenna nodes has a plurality of antenna elements. The base station may perform physical-layer baseband processing for each of the antenna nodes at a centralized processing location, and may cause the antenna nodes to transmit reference signals in accordance with a multiplexing scheme to allow user equipment to perform channel estimation for the antenna elements of any one or more of the antenna nodes. The base station may also cause the antenna nodes to transmit signals having synchronization codes to allow the user equipment to synchronize with the antenna elements of any one or more of the antenna nodes. In some embodiments, the base station may communicate with the antenna nodes over a physical-layer interface.

**ENHANCED BASE STATION AND METHOD FOR COMMUNICATING
THROUGH AN ENHANCED DISTRIBUTED ANTENNA SYSTEM (eDAS)**

TECHNICAL FIELD

5 Embodiments pertain to wireless communications. Some embodiments relate to base stations that use distributed antenna systems to communicate with user equipment. Some embodiments relate to networks that operate in accordance with 3GPP LTE Evolved Universal Terrestrial Radio Access Network (E-UTRAN) radio-access technologies (RATs) and evolutions thereof. Some embodiments relate to WiMAX networks that
10 operate in accordance with IEEE 802.16 RATs and evolutions thereof.

BACKGROUND

 A conventional distributed-antenna system is a network of spatially separated antennas connected to a common source via a transport medium that provides wireless service within a geographic area (e.g., cell) or a structure (indoor coverage). One issue
15 with the use of a conventional distributed-antenna system in cellular communication systems is that interface between the base station and the antennas is not standardized making it difficult for a conventional distributed-antenna system to fully support and take advantage of the benefits of some advanced communication techniques in current and upcoming wireless standards.

20 Thus, there are general needs for enhanced distributed-antenna systems and methods for communicating that can more fully support and more fully take advantage of some of the advanced communication techniques in current and upcoming wireless standards.

BRIEF DESCRIPTION OF THE DRAWINGS

25 FIG. 1 illustrates an enhanced radio-access network (eRAN) in accordance with some embodiments;

 FIG. 2 illustrates an enhanced distributed-antenna system (eDAS) eDAS network architecture in accordance with some embodiments;

30 FIG. 3A illustrates the partitioning of synchronization codes in accordance with some embodiments;

 FIG. 3B illustrates a code structure in accordance with some embodiments;

 FIG. 4 illustrates various functional elements of the eRAN of FIG. 1 in accordance

with some embodiments;

FIG. 5 illustrates downlink physical layer processing performed at an eDAS base station in accordance with some embodiments;

FIG. 6 illustrates reference signal multiplexing scheme in accordance with some
5 embodiments;

FIG. 7 is an example of an eDAS base station configured for operation along train tracks in accordance with some embodiments; and

FIGs. 8A, 8B and 8C illustrate various antenna node mobility situations in accordance with some embodiments.

10 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
15 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 enhanced radio-access network (eRAN) in accordance with some embodiments. The eRAN 100 may include one or more enhanced DAS (eDAS) base stations 102, each configured to serve user equipment (UE) 112 within an associated cell
20 108. Each eDAS base station (102) may utilize an enhanced distributed antenna system (eDAS) comprising a plurality of geographically-separated antenna nodes 104. Each of the antenna nodes 104 may have a plurality of spatially separated antenna elements 106. At least some of the antenna nodes 104 are not located at the same location as the eDAS base station 102 and are provided at different locations in the cell 108.

25 In some embodiments, the eRAN 100 may comprise at least two or more eDAS base stations 102 of a paging group that communicate with an access gateway 110. The eDAS base stations 102 of the paging group may be configured to communicate with the access gateway 110 over an S1 interface 101. The eDAS base stations 102 of the paging group may be configured to communicate directly over an X2+ interface 109. Each eDAS
30 base station 102 may operate as a processing center for its associated cell 108 and may be configured to communicate with the antenna nodes 104 over a physical-layer X3 interface 103.

In accordance with embodiments, the eDAS base station 102 may cause the

antenna nodes 104 to transmit reference signals in accordance with a multiplexing scheme to allow user equipment 112 to perform channel estimation for the antenna elements 106 of any one or more of the antenna node 104. The eDAS base station 102 may also cause the antenna nodes 104 to transmit synchronization codes to allow user equipment 112 to
5 synchronize with the antenna elements 106 of any one or more of the antenna nodes 104.

Accordingly, the user equipment 112 may uniquely identify the antenna nodes 104 as well as the individual antenna elements 106 of any one of the antenna nodes 104 for both channel estimation and synchronization. As illustrated in FIG. 1, some user equipment 112 may be served by the antenna nodes 104 within the same cell 108, while
10 some user equipment 112 may be served by the antenna nodes 104 from different cells 108. Each cell 108 may be associated with a geographic area.

In accordance with embodiments, the X3 interface 103 between the eDAS base station 102 and the antenna nodes 104 may be standardized allowing the eDAS base station 102 to fully support and take advantage of the benefits of some advanced
15 communication techniques in current and upcoming wireless standards, such as single-user (SU) and multi-user (MU) multiple-input multiple-output (MIMO) (i.e., SU-MIMO and MU-MIMO) communication techniques.

In some embodiments, the eDAS base station 102 may be part of a cooperative RAN architecture that provides enhanced features in order to provide significantly
20 improved coverage, performance, and reliability at significantly reduced complexity and power consumption. In these embodiments, less power may be consumed in overcoming penetration and shadowing losses, since a line-of-sight channel may be present leading to reduced fading depths and reduced delay spread. The transmit power of user equipment 112 may therefore be reduced resulting in more energy-efficient uplink operation and
25 lower battery consumption.

In some embodiments, each antenna element 106 may be a separate antenna and may be effectively separated from other antenna elements 106 of an antenna node 104 to take advantage of spatial diversity and the different channel characteristics that may result between each of the antenna elements 106 and the one or more antennas of the user
30 equipment. In some embodiments, antenna elements 106 may be separated by up to $1/10$ of a wavelength or more.

In some embodiments, the eDAS base station 102 may be an eDAS enhanced node B (eNB) configured to operate in accordance with one of the 3GPP LTE E-UTRAN

standards (such as LTE release 10). In other embodiments, the eDAS base station 102 may be a WiMAX base station configured to operate in accordance with one of the IEEE 802.16 standards (such as IEEE 802.16m).

FIG. 2 illustrates an enhanced distributed-antenna system (eDAS) eDAS network architecture in accordance with some embodiments. The eDAS base station 102 may communicate with user equipment 112 using two or more antenna nodes 104 (antenna nodes A_i and A_j) over the X3 interface 103. As illustrated in FIG. 2, each antenna node 104 may include a plurality of antenna elements 106 (illustrated as A_{i1} through A_{in} for antenna node A_i and illustrated as A_{j1} through A_{jn} for antenna node A_j). In accordance with
 10 embodiments, each cell 108 (FIG. 1) may include N antenna nodes 104 each having N_i antenna elements 106. Antenna node A_i may be located at distance d_i from the eDAS base station 102 and at distance d_{ij} from antenna node A_j . The eDAS base station 102 may have the equivalent of $N \times N_i$ antenna elements where each group of N_i antenna elements are physically separated by a distance that can be geometrically calculated based on d_i and d_{ij} .

15 In these embodiments, multi-stream open-loop and closed-loop SU-MIMO/MU-MIMO schemes may be enabled at each antenna node 104 through the use of $N \times N_i$ common reference signals associated with the $N \times N_i$ logical antenna ports (e.g., one for each antenna element 106). In these embodiments, each antenna node 104 may be uniquely identified via physical layer identifiers as described in more detail below.

20 FIG. 3A illustrates the partitioning of synchronization codes in accordance with some embodiments. In accordance with embodiments, synchronization codes transmitted by the antenna nodes 104 (FIG. 1) may allow user equipment 112 (FIG. 1) to synchronize with the antenna elements 106 of any one or more of the antenna nodes (104). The synchronization codes may be partitioned to include information fields 300 to uniquely
 25 identify a paging group, the eDAS base station 102, and one of the antenna nodes 104. In some embodiments, the information fields 300 of the synchronization codes may include a paging group ID field 301 that identifies the paging group of two or more eDAS base stations 102. The information fields 300 may also include a cell ID field 302 that identifies the eDAS base station 102. The information fields 300 may also include an antenna-node
 30 ID field 304 that identifies an individual one of the antenna nodes 104 associated with the eDAS base station 102. In some 3GPP LTE embodiments, the paging group ID field 301 may be an eNB group ID field, the cell ID field 302 may be an eNB ID field, and the antenna-node ID field 304 may be an eNB antenna-node ID field.

In the example illustrated in FIG. 3A, the paging group ID field 301 may comprise N_3 bits, the cell ID field 302 may comprise N_2 bits, and the antenna-node ID field 304 may comprise N_1 bits where $N_1 + N_2 + N_3 = N$ and where N may be a number of antenna nodes 104.

5 FIG. 3B illustrates a code structure in accordance with some embodiments. The synchronization codes transmitted by the antenna nodes 104 (FIG. 1) may comprise a unique code structure 310 having a code space that is divided into a plurality of subspaces 315. The subspaces 315 may allow the user equipment 112 (FIG. 1) to uniquely identify the paging group, the eDAS base station 102 (FIG. 1) and the particular antenna node 104 (FIG. 1). In some embodiments, the code structure may comprise a code sequence of 2^N distinct synchronization codes.

The plurality of subspaces 315 may include a plurality of paging-group subspaces 311 to identify each paging group of the eRAN 100 (FIG. 1). Each paging-group subspace 311 may be associated with one paging group and includes a plurality of eNB subspaces 15 312. Each eNB subspace 312 may be associated with one of the eDAS base stations 102 of the paging group and each eNB subspace 312 may have a plurality of antenna-node subspaces 304. Each antenna-node subspace 314 may be associated with one antenna node 104 of the eDAS base station 102.

In some embodiments, the set of distinct synchronization codes 310 may comprise 20 a set or a family of 2^N distinct synchronization codes, where N may be the size of the synchronization code sequence. In the example illustrated in FIG. 3B, the code space of 2^N codes may be partitioned into $2^N/2^{N_3}$ subspaces 311, and each of the subspaces 311 may be further divided into $2^{N_3}/2^{N_2}$ subspaces 312. Each of subspaces 312 may be further divided into $2^{N_2}/2^{N_1}$ subspaces 314. This sequence partitioning may help with detecting and 25 decoding of the information fields 300 by the user equipment 112.

The example partitioning and code structure illustrated in FIGs. 3A and 3B allow for an eDAS base station 102 to provide mobility management within a cell 108 by handing over the user equipment 112 from one antenna node 104 or group of antenna nodes 104 to another group. The user equipment 112 can measure and report received 30 signal strength from each antenna node based on the reference signals 601. The eDAS base station 102 may then redirect the signals from another antenna node 104 or group of antenna nodes 104 that are geographically closer to the user equipment 112. Unlike conventional cellular systems, the intra-cell handover and mobility management between

antenna nodes 104 may be performed by redirecting the transmissions over the X3 interface 103 from an initial antenna node 104 to target antenna node 104 since the baseband processing is performed within in the eDAS base station 102. Thus the mobility management within an eDAS cell 108 may reduce to “data and control path” selection for the user equipment 112 based on the signal quality measurement reports from the user equipment 112.

FIG. 4 illustrates various functional elements of the eRAN of FIG. 1 in accordance with some embodiments. The access gateway 110 may include a Mobility Management Entity (MME) 402, a packet data network gateway (P-GW) 404, and a serving gateway (S-GW) 406 for performing conventional gateway functions including providing access to an IP network. In some embodiments, the access gateway 110 may be configured in accordance with the LTE evolved packet core (EPC) specification to provide Multi-megabit bandwidth capability, latency reduction and improved mobility. The eDAS base stations 102 may communicate with the access gateway 110 over a core-network interface (e.g., S1 interface 101).

In some embodiments, the eDAS base station 102 may utilize a software-defined radio (SDR) baseband processing pool comprising a plurality of processors configured to perform the various operations described herein. Each eDAS base station 102 may operate as a processing center for its associated cell 108 and may be configured to communicate with the antenna nodes 104 over the physical-layer X3 interface 103.

The X3 interface 103 may comprise at least one of optical fiber links and coaxial links coupling each antenna node 104 to the baseband processing pool. In some embodiments, the X3 interface 103 may couple RF front ends of each antenna node 104 to an RF front end of the eDAS base station 102. In these embodiments, the X3 interface may be configured to communicate RF signals between the antenna elements 106 of each antenna 104 and the eDAS base station 102. In some alternate embodiments, the X3 interface is configured to communicate baseband signals between the antenna elements 106 of each antenna 104 and the eDAS base station 102. Baseband processing, however, may be performed at the centralized processing location of the eDAS base station 102. The X3 interface may comprise any broad-bandwidth connection that operates at either an RF or baseband level.

In some embodiments, the eDAS base station 102 may configured to perform mobility management between antenna nodes 104 for the user equipment 112, and

perform soft and hard handovers between antenna nodes 104 of the same cell 108 for the user equipment 112 using cooperative communications over the X3 interface. In coordinated multipoint (CoMP) embodiments, the eDAS base station 102 may be further configured to perform handovers between antenna nodes 104 of different cells.

5 Although the eDAS base stations 102, the access gateway 110, and the antenna nodes 104 are illustrated as having 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
10 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 of the eDAS base stations 102, the access gateway 110, and the antenna nodes 104 may refer to one or more processes operating on
15 one or more processing elements.

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
20 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, an eDAS base station 102 may include one or more processors and
25 may be configured with instructions stored on a computer-readable storage device.

FIG. 5 illustrates downlink physical layer (PHY-layer) processing performed at an eDAS base station in accordance with some embodiments. As discussed above, an eDAS base station 102 (FIG. 1) may operate as a processing center for its associated cell 108 (FIG. 1) and may be configured to communicate with the antenna nodes 104 (FIG. 1) over
30 the X3 interface 103 (FIG. 1).

In accordance with embodiments, each eDAS base station 102 may perform separate physical layer processing for each antenna node 104 and transmit physical-layer signals over the X3 interface 103 to the antenna nodes 104. In the example illustrated in

FIG. 5, each eDAS base station 102 may perform per-antenna node modulation and coding adaptation 502. Each eDAS base station 102 may also perform per antenna node MIMO processing 504, and per antenna node antenna and resource mapping 506. These physical-layer processing operations may generate physical-layer signals 508 for transmission over the X3 interface 103 to the antenna nodes 104. In the example illustrated, physical-layer signals 508A may be transmitted to a first antenna node 104 over the X3 interface 103, and physical-layer signals 508B may be transmitted to a second antenna node 104 over the X3 interface 103. Although FIG. 5 illustrates that the physical-layer signals 508 are OFDM signals, this is not a requirement.

In accordance with these embodiments, the baseband processing is performed at the eDAS base station 102 (rather than being performed at the antenna nodes 104). This may allow hardware sharing among the processing blocks used for the antenna nodes 104 served by the same eDAS base station 102. Although FIG. 5 may imply the multiplication of physical processing by the number of the antenna nodes 104 served by the eDAS base station 102, the same transmission chain may actually be shared or reused by reconfiguration of the parameters of the functional blocks. In the example illustrated in FIG. 5, transmission format and modulation and coding schemes may be adapted per antenna node allowing for link-level adaptation of the transmission parameters according to the channel conditions between the user equipment 112 and each antenna node 104. Furthermore, the MIMO modes and encoding schemes as well as layer mapping and resource mapping may be individually adapted per antenna node 104.

The performance of baseband processing for the antenna nodes 104 at the eDAS base station 102 allows the eDAS base station 102 to perform intra-eDAS base station 102 coordinated transmissions from multiple antenna nodes 104 corresponding to the same eDAS base station 102 by jointly adjusting the MIMO encoding parameters for the antenna nodes 104 involved in coordinated transmission.

In some embodiments, the eDAS base station 102 is configured to communicate multi-stream transmissions in accordance with SU-MIMO and MU-MIMO communication techniques. In these embodiments, multi-stream processing as well as SU-MIMO and MU-MIMO processing may be performed at the eDAS base station 102 and the signals may be transmitted over the X3 interface 103 to the selected antenna node 104. In some embodiments, two or more antenna nodes 104 may be used for SU-MIMO and MU-MIMO transmissions. In some embodiments, signal-quality reports, channel state

information (CSI) or precoding matrix index (PMI) received from the user equipment 112 may be used by the eDAS base station 102 as part of a closed-loop MIMO communication technique. In some embodiments, open-loop MIMO communication techniques may also be utilized.

5 Although FIG. 5 illustrates the physical-layer processing performed for the transmitter side, the eDAS base station 102 may also be configured to perform similar per-antenna node physical-layer processing for the receive side. Accordingly, functional receive-side components associated with the antenna nodes 104 of a cell 108 may similarly be shared.

10 FIG. 6 illustrates reference signal multiplexing scheme 600 in accordance with some embodiments. In accordance with embodiments, the DAS base station 102 (FIG. 1) may be configured to cause the antenna nodes 104 (FIG. 1) to transmit reference signals 601 in accordance with a multiplexing scheme 600 to allow user equipment 112 (FIG. 1) to perform channel estimation with the antenna elements 106 (FIG. 1) of any one or more
15 of the antenna node 104.

 The multiplexing scheme 600 for the transmission of the reference signals 601 may comprise a combination of code-division multiplexing (CDM), time-division multiplexing (TDM) and frequency-division multiplexing (FDM) (i.e., a CDM/TDM/FDM scheme) to allow the user equipment 112 to uniquely identify reference signals associated
20 with individual antenna elements 106 of any one or more of the antenna nodes 104 for use in channel estimation.

 In some embodiments, each of the antenna nodes 104 associated with the eDAS base station 102 may be configured to transmit with a different CDM code 602. The antenna elements 106 of a same antenna node 104 are configured to transmit their
25 reference signals utilizing a common CDM code 602. The antenna elements 106 of the same antenna node 104 may further be configured to transmit the reference signals 601 at different times 604 within an orthogonal-frequency division multiplexed (OFDM) symbol and on different subcarrier frequencies 606 of an OFDM resource block 606 as shown in FIG. 6.

30 As further illustrated in FIG. 6, since the reference signals 601 transmitted by each antenna node 104 may be transmitted with a different CDM code, each of the antenna nodes 104 may transmit the reference signals 601 at the same times 604 and on the same subcarrier frequencies 606. In these embodiments, the use of reference signals 601 that are

code, time, and frequency division multiplexed provides for the unique identification of each of the antenna elements 106 associated with any particular antenna node 104.

Furthermore, in order to perform channel estimation for detection and demodulation purposes, channel state information and channel quality measurements for MIMO mode selection and rank adaptation, the user equipment 112 may be able to estimate the channel to and from each antenna element 106 using these reference signals 601. The reference signals 601 may be common reference signals or may be UE-specific.

In some embodiments, since the number of antenna elements 106 per antenna node 104 as well as the number of antenna nodes 104 of the eDAS base station 102 may be very large (e.g., greater than 1000), the combination of code, time and frequency division multiplexing may help prevent excessive layer-one overhead and may also help prevent the potential loss of code orthogonality during high mobility conditions or due to the frequency selectivity of the channel. The use of FDM/TDM reference signals without CDM may result in excessive layer-one overhead and degradation of the overall performance of the system. The use of CDM reference signals without FDM or TDM may result in a potential loss of code orthogonality during high mobility conditions or due to due to frequency selectivity of the channel.

As illustrated in FIG. 6, by assigning each CDM/FDM/TDM code to one antenna element, antenna elements 106 of an antenna node 104 may be identified by the unique reference signals 601 that are transmitted from that antenna element. The reference signals 601 may be time-division and/or frequency-division multiplexed with data sub-carriers within the resource block 606. In some embodiments, the reference signals 601 may be time-division and/or frequency-division multiplexed with data sub-carriers within the resource block 606 over either a sub-band or the entire frequency band depending on whether the reference signal is UE-specific or a common reference signal (i.e., a common narrowband reference signal or a common wideband reference signal).

Accordingly, since the user equipment 112 can distinguish between the reference signals transmitted from each antenna element 106 as well as from each antenna node 104, the user equipment 112 may be able to perform MIMO channel estimation for improved SU-MIMO or MU-MIMO communications, among other things.

In accordance with some embodiments, the eDAS base station 102 may receive signal-quality reports from the user equipment 112 that uniquely identify one of the antennas nodes 104 and include signal-quality information of signals received by the user

equipment 112 from the antenna node 104. The user equipment 112 may transmit a signal-quality report to the eDAS base station 102 for each antenna node 104 that it receives signals from for use by the eDAS base station 102. The eDAS base station 102 may accordingly direct signals to the appropriate antenna node 104 over the X3 interface 103.

- 5 In these embodiments, the user equipment 112 may be able to perform channel estimation for one or more of the antenna elements 106 of an antenna node 104 based on the reference signals 601 transmitted in accordance with the multiplexing scheme 600.

The signal-quality reports may be based on the channel estimation. In some embodiments, the signal-quality reports may include an indication of at least one of
10 received signal strength indicator (RSSI), a reference signal received power (RSRP) in some 3GPP LTE embodiments, a carrier to interference-plus-noise ratio (CINR), or other signal quality parameter or path-loss measurement associated with the reference signals received from an indicated antenna node 104. In some embodiments, the user equipment 112 may be configured to select an antenna node 104 among two or more of the antenna
15 nodes 104 based on the signal-quality information of the reference signals transmitted by the antenna nodes 104.

Accordingly, since the user equipment 112 is configured to uniquely identify an antenna node 104, the eDAS base station 102 may communicate with user equipment 112 using one or more antenna nodes 104 that may be closest to the user equipment 112 (e.g.,
20 have the best signal characteristics) allowing the user equipment 112 to communicate with reduced transmission power levels which may reduce the power consumption of the user equipment 112. Furthermore, signal quality and throughput may be improved.

In some embodiments, the signal-quality reports transmitted by the user equipment 112 may identify the paging group ID, the cell ID, as well as the antenna node ID
25 identifying the particular antenna node 104 from which reference signals were received. In these embodiments, the signal-quality reports may provide signal-quality information associated with signals received by user equipment 112 from a particular antenna node 104. Accordingly, each signal-quality report may be associated with a particular antenna node 104.

30 FIG. 7 is an example of an eDAS base station configured for operation along train tracks in accordance with some embodiments. The eDAS base station 702 may communicate with antenna nodes 704 over an X3 interface to provide communication services within a cell. Antenna nodes 704 may be positioned along train tracks 708. In

accordance with embodiments, the antenna nodes 704 may be spatially separated and provided at different geographic locations with the cell (i.e., along the train tracks 708). The eDAS base station 702 may be configured to perform physical-layer baseband processing for each of the antenna nodes 704 at a centralized processing location. The eDAS base station 702 may also be configured to perform an intra-cell handover between the antenna nodes 704 by redirecting physical-layer signals over the X3 interface from one antenna node 104 to a next antenna node 104, for example, as a train moves along the tracks 708. The eDAS base station 702 may be configured to be similar to eDAS base stations 102 (FIG. 1).

FIGs. 8A, 8B and 8C illustrate various antenna node mobility situations in accordance with some embodiments. In FIG. 8A, single antenna node intra-eNB mobility is illustrated. In FIG. 8B, multi-antenna node intra-eNB mobility is illustrated. As illustrated, geographically-separated antenna nodes 804 are provided at different geographic locations served by the eDAS eNB 802. In these embodiments, wherein the eDAS eNB 802 is configured to perform physical-layer baseband processing for each of the antenna nodes 804 at a centralized processing location, and perform an intra-cell handovers between the antenna nodes 804 by redirecting physical-layer signals over the X3 interface from an initial antenna node 804 to a target antenna node 804.

In FIG. 8C, multi-antenna node inter-eNB mobility is illustrated. In these embodiments, an inter-eNB handover is performed between two eDAS eNBs 802 of a RAN. In these embodiments, the handover may be coordinated directly between the two eDAS eNBs 802 over an X2+ interface, such as the X2+ interface 109 (FIG. 4)

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:

- 5 1. A base station configured to:
communicate through an enhanced distributed antenna system (eDAS) comprising
a plurality of geographically-separated antenna nodes wherein each of the antenna nodes
have a plurality of antenna elements;
perform physical-layer baseband processing for each of the antenna nodes at a
10 centralized processing location;
cause the antenna nodes to transmit reference signals in accordance with a
multiplexing scheme to allow user equipment to perform channel estimation for the
antenna elements of any one or more of the antenna nodes; and
cause the antenna nodes to transmit signals having synchronization codes to allow
15 the user equipment to synchronize with the antenna elements of any one or more of the
antenna nodes.
2. The base station of claim 1 wherein the base station provides communication
services for user equipment within a cell and operates as a processing center for the cell
20 wherein the antenna nodes are provided at different geographic locations within the
cell,
wherein the base station is configured to communicate with the antenna nodes over
a physical-layer X3 interface, and
wherein the base station is configured to transmit the reference signals and the
25 signals having synchronization codes over the X3 interface for subsequent transmission by
the antenna nodes.
3. The base station of claim 1 wherein the synchronization codes are partitioned to
include information fields to uniquely identify a paging group, the base station, and one of
30 the plurality of antenna nodes, and
wherein the synchronization codes comprise a code structure having a code space
that is divided into a plurality of subspaces to allow the user equipment to uniquely
identify the paging group, the base station and the antenna node.

4. The base station of claim 3 wherein the information fields of the synchronization codes comprise:

- 5 a paging group ID field that identifies the paging group of two or more base stations;
an cell ID field that identifies the base station; and
an antenna-node ID field that identifies an individual one of the antenna nodes associated with the base station.

- 10 5. The base station of claim 4 wherein the plurality of subspaces include a plurality of paging-group subspaces to identify each paging group,
wherein each paging-group subspace is associated with one paging group and includes a base-station subspace for each base station, and
wherein each base-station subspace has a plurality of antenna-node subspaces, each
15 antenna-node subspace being associated with one antenna node of the base station.

6. The base station of claim 1 wherein the multiplexing scheme for transmission of the reference signals comprises a combination of code, time and frequency division multiplexing to allow the user equipment to uniquely identify reference signals associated
20 with individual antenna elements of any one or more of the antenna nodes for use in channel estimation.

7. The base station of claim 6 wherein each of the antenna nodes associated with the base station are configured to transmit with a different code,
25 wherein the antenna elements of a same antenna node are configured to transmit their reference signals utilizing a common code, and
wherein the antenna elements of the same antenna node are further configured to transmit the reference signals at different times within an orthogonal-frequency division multiplexed (OFDM) symbol and on different subcarrier frequencies of an OFDM
30 resource block.

8. The base station of claim 1 further configured to receive signal-quality reports from the user equipment that uniquely identify one of the antennas nodes and include

signal quality information of signals received by the user equipment from the antenna node.

9. The base station of claim 8 further configured to perform an intra-cell handover
5 between antenna nodes by redirecting physical-layer signals over a physical-layer X3 interface from an initial antenna node to a target antenna node.

10. The base station of claim 9 wherein the base station is configured to communicate multi-stream transmissions in accordance with at least one of a SU-MIMO
10 and MU-MIMO communication technique.

11. An enhanced radio-access network (eRAN) comprising a plurality of base stations, each base station is configured to:
communicate through an enhanced distributed antenna system (eDAS) comprising
15 a plurality of geographically-separated antenna nodes wherein each of the antenna nodes have a plurality of antenna elements;
perform physical-layer baseband processing for the antenna nodes at a centralized processing location; and
perform an intra-cell handover between antenna nodes by redirecting physical-
20 layer signals from an initial antenna node to a target antenna node.

12. The eRAN of claim 11 wherein each base station is further configured to:
transmit physical-layer signals to the antenna nodes to cause the antenna nodes to transmit reference signals in accordance with a multiplexing scheme to allow user
25 equipment to perform channel estimation for the antenna elements of any one or more of the antenna nodes; and
transmit physical-layer signals to the antenna nodes to cause the antenna nodes to transmit signals having synchronization codes to allow the user equipment to synchronize with the antenna elements of any one or more of the antenna nodes.

13. The eRAN of claim 12 wherein the synchronization codes are partitioned to include information fields to uniquely identify a paging group, the base station, and one of the plurality of antenna nodes, and
30

wherein the synchronization codes comprise a code structure having a code space that is divided into a plurality of subspaces to allow the user equipment to uniquely identify the paging group, the base station and the antenna node.

5 14. The eRAN of claim of claim 15 wherein the multiplexing scheme for transmission of the reference signals comprises a combination of code, time and frequency division multiplexing to allow the user equipment to uniquely identify reference signals associated with individual antenna elements of any one or more of the antenna nodes for use in channel estimation.

10

 15. The eRAN of claim 11 wherein the base station are an eDAS enhanced node-B (eNBs) configured to operate in accordance with one of the 3GPP LTE E-UTRAN standards such as LTE release 10.

15 16. The eRAN of claim 11 wherein the base stations are WiMAX base stations configured to operate in accordance with one of the IEEE 802.16 standards.

 17. A method for communicating through an enhanced distributed antenna system (eDAS) comprising a plurality of geographically-separated antenna nodes wherein each of
20 the antenna nodes have a plurality of antenna elements, the method comprising:

 performing physical-layer baseband processing for each of the antenna nodes at a centralized processing location;

 transmitting physical-layer signals to each of the antenna nodes to cause the antenna nodes to transmit reference signals in accordance with a multiplexing scheme to
25 allow user equipment to perform channel estimation for the antenna elements of any one or more of the antenna nodes; and

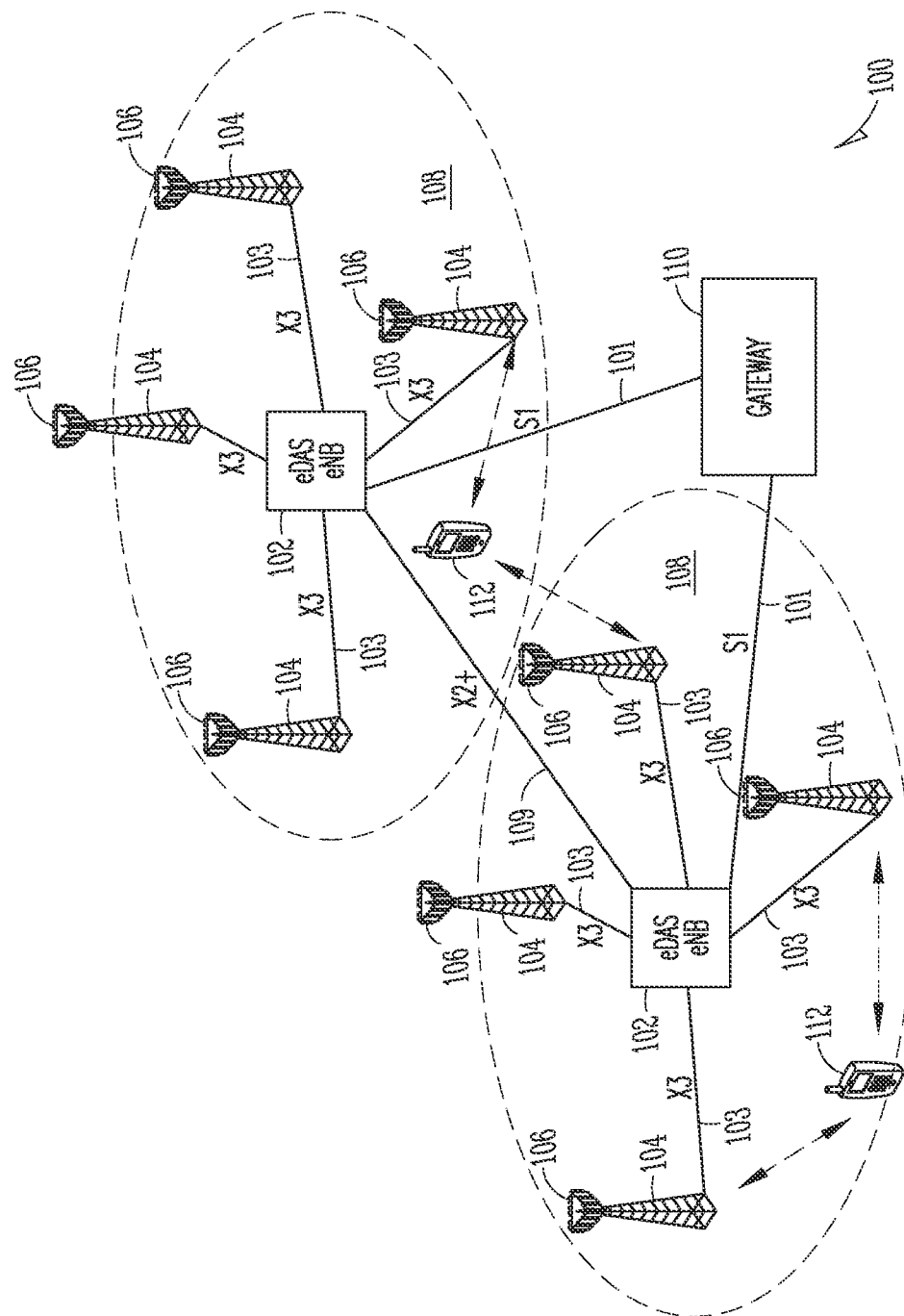
 communicating multi-stream transmissions through the antenna nodes in accordance with at least one of a SU-MIMO and MU-MIMO communication technique

30 18. The method of claim 17 further comprising transmitting physical-layer signals to each of the antenna nodes to cause the antenna nodes to transmit signals having synchronization codes to allow the user equipment to synchronize with the antenna elements of any one or more of the antenna nodes.

19. The method of claim 18 wherein the synchronization codes are partitioned to include information fields to uniquely identify a paging group, the base station, and one of the plurality of antenna nodes, and

5 wherein the synchronization codes comprise a code structure having a code space that is divided into a plurality of subspaces to allow the user equipment to uniquely identify the paging group, the base station and the antenna node.

20. The method of claim 17 wherein the multiplexing scheme for transmission of
10 the reference signals comprises a combination of code, time and frequency division multiplexing to allow the user equipment to uniquely identify reference signals associated with individual antenna elements of any one or more of the antenna nodes for use in channel estimation.



eRAN

FIG. 1

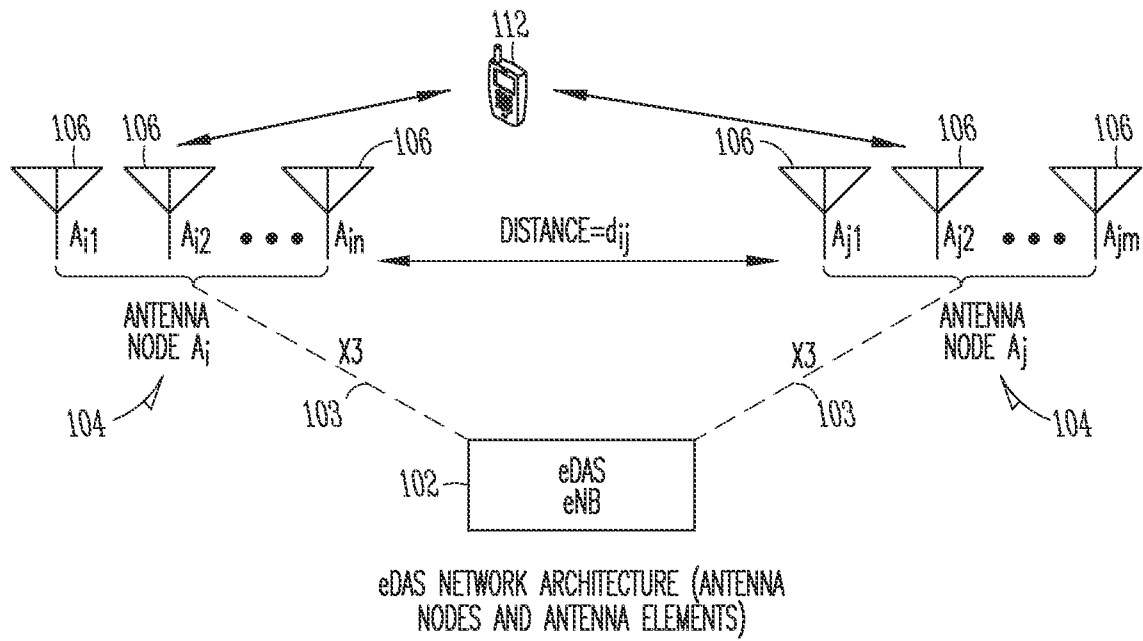


FIG. 2

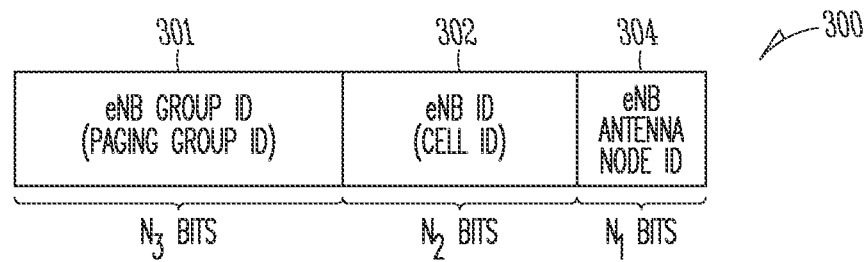


FIG. 3A

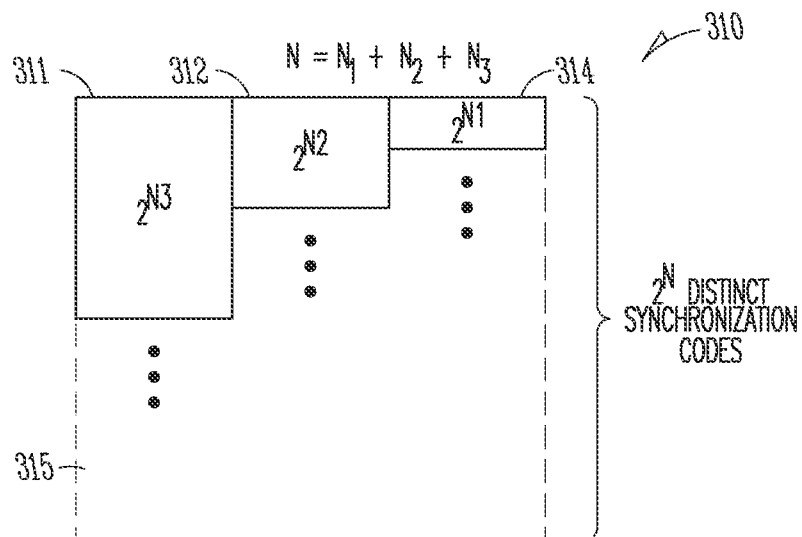


FIG. 3B

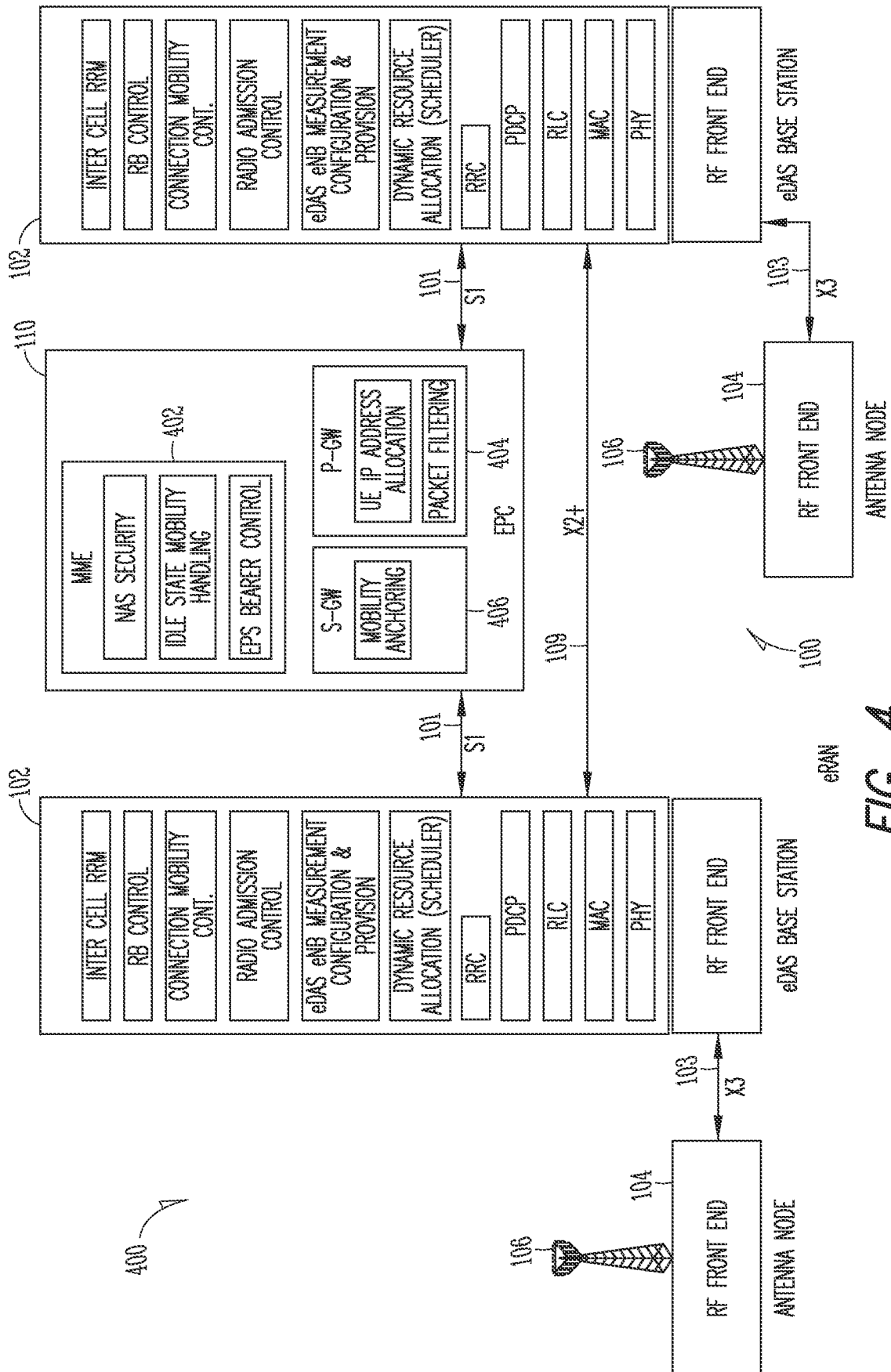
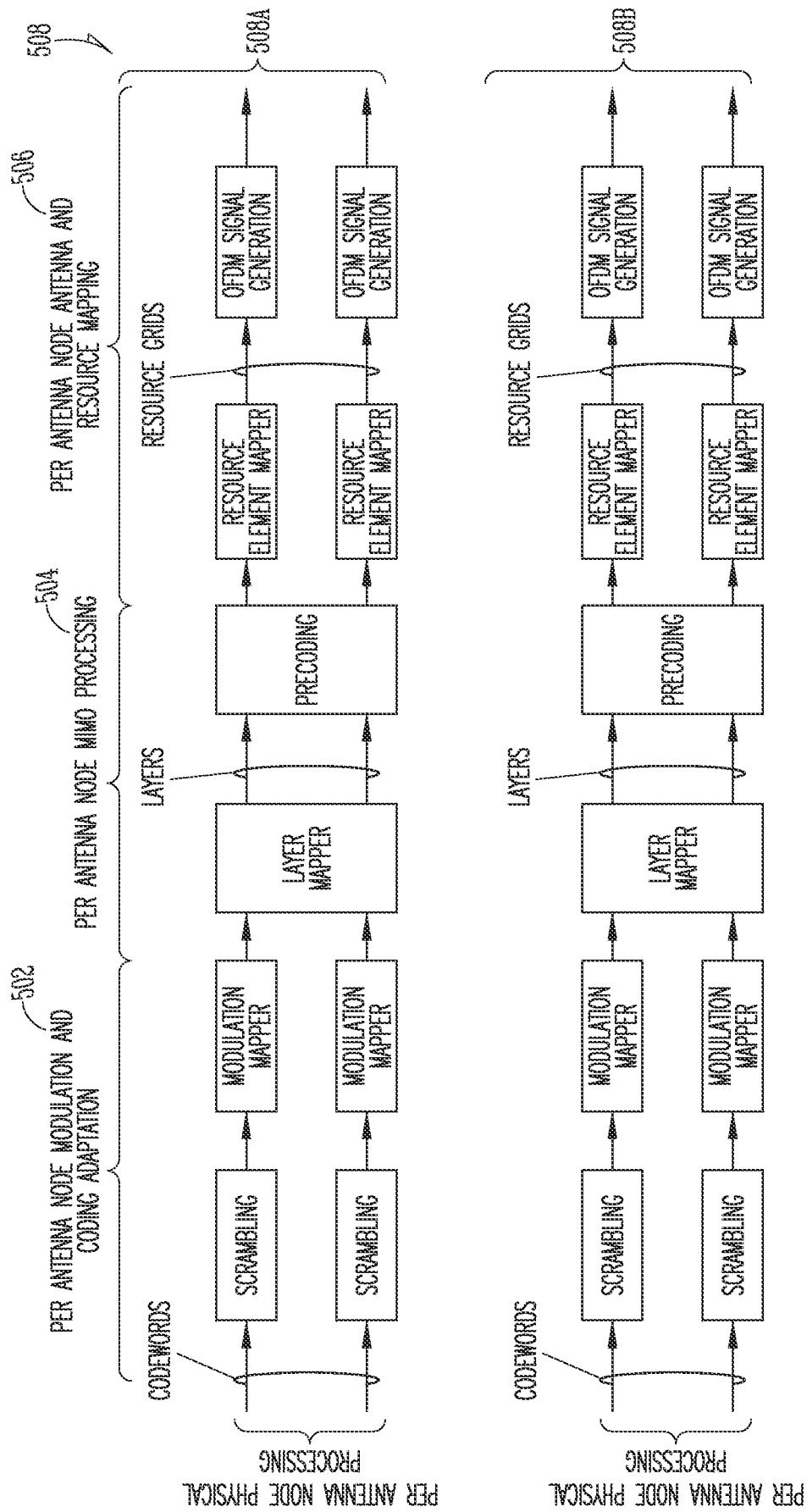
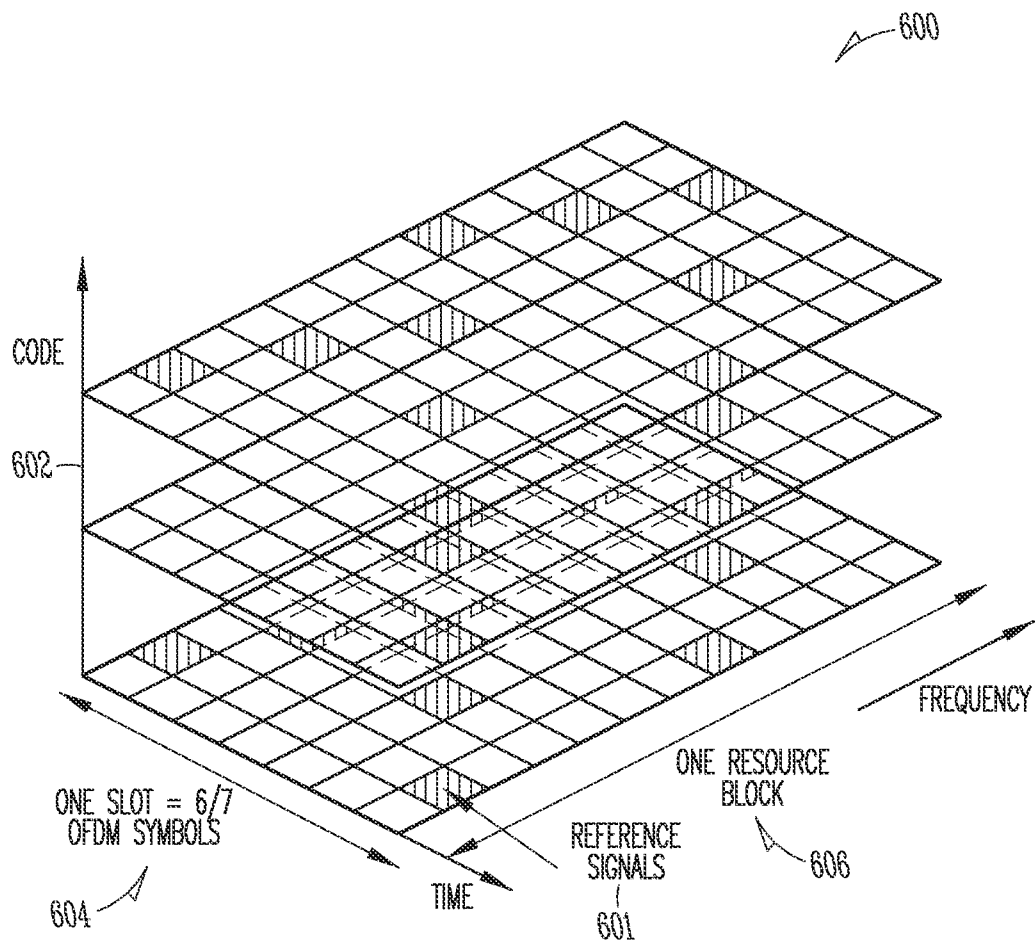


FIG. 4



ANTENNA NODE PHY-LAYER PROCESSING

FIG. 5



REFERENCE SIGNAL MULTIPLEXING SCHEME

FIG. 6

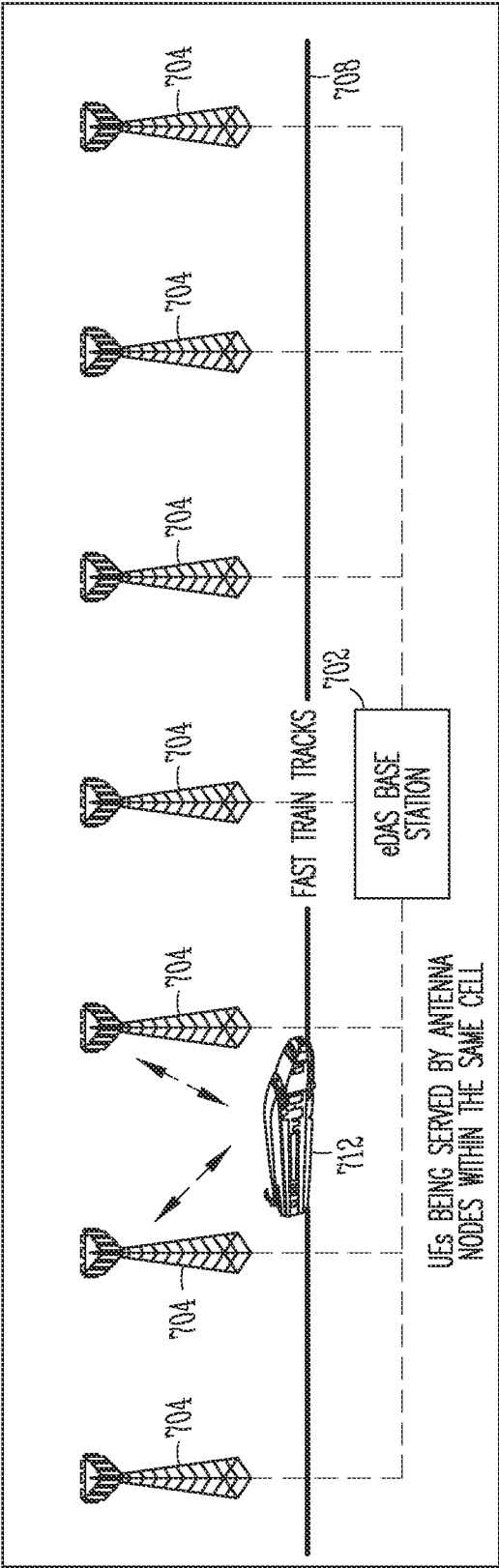
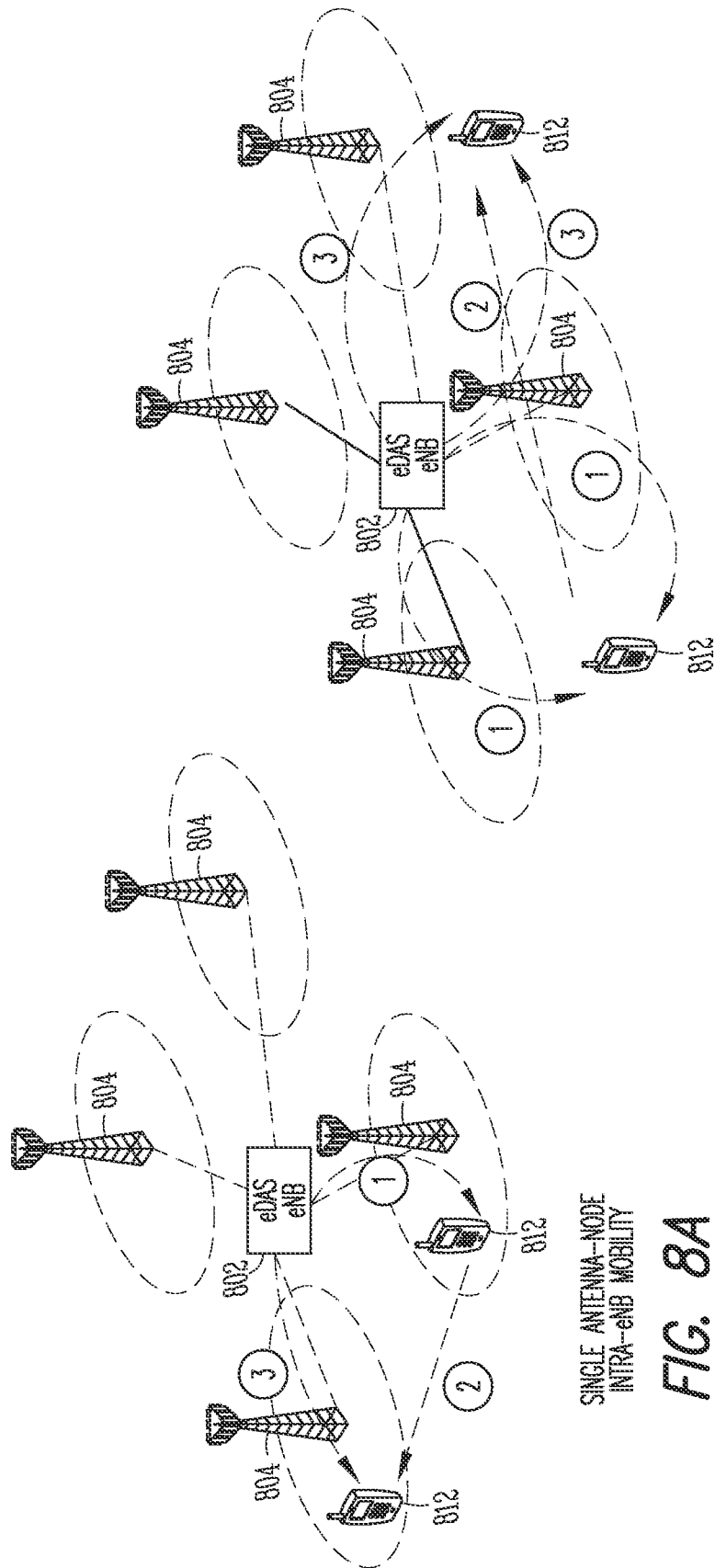
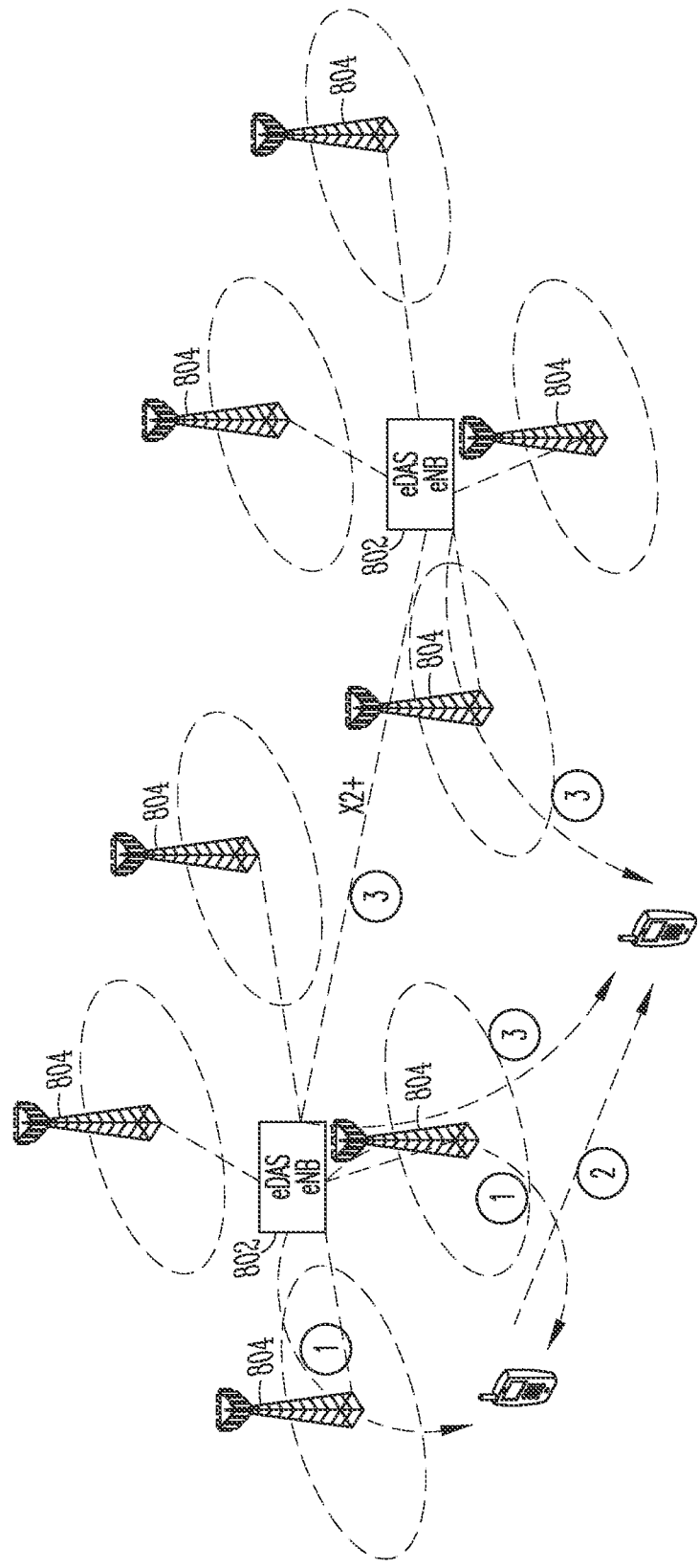


FIG. 7



SINGLE ANTENNA-NODE
INTRA-eNB MOBILITY
FIG. 8A

MULTI-ANTENNA-NODE
INTRA-eNB MOBILITY
FIG. 8B



MULTI-ANTENNA-NODE
INTER-eNB MOBILITY
FIG. 8C

A. CLASSIFICATION OF SUBJECT MATTER***H04B 7/04(2006.01)i, H04W 88/08(2009.01)i, H04W 56/00(2009.01)i, H04J 11/00(2006.01)i***

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04B 7/04; H04J 3/00; H04W 88/08; H04W 56/00; H04J 11/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: distributed, antenna, system, DAS, baseband, physical-layer, reference, signal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010-0177759 A1 (FISCHER LARRY G. et al.) 15 July 2010 See abstract; paragraph [15] - paragraph [18], paragraph [33]; figures 1,5.	1-20
A	P. Gong, et al., "Radio resource allocation for multiuser OFDMA distributed antenna systems," 2009 Proceedings of Network Infrastructure and Digital Content, pp. 912 - 916, 8 November 2009 See section 2; figure 1.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

17 FEBRUARY 2012 (17.02.2012)

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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datePatent family
member(s)Publication
date

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