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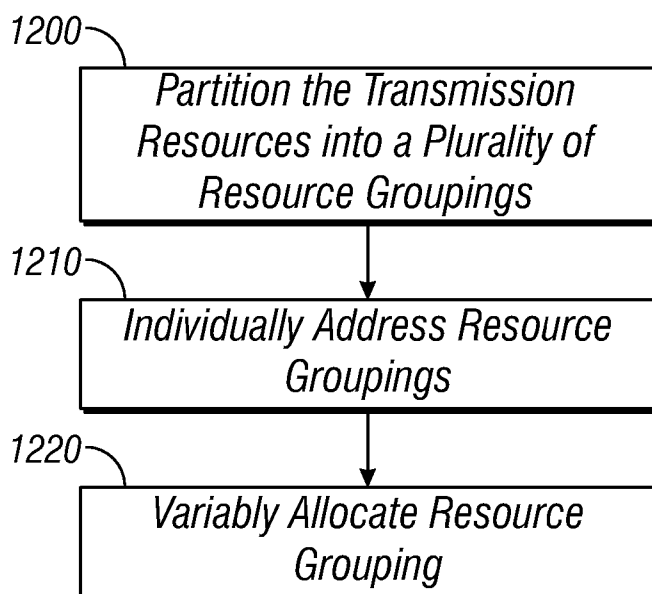


FIG. 12

(57) Abstract: A system and method for allocating transmission resources to data being carried within a data transmission frame are described herein. The transmission resources are partitioned into a plurality of resource groupings. Each of the plurality of resource groupings are individually addressed to the data carried within the data transmission frame, based on a hierarchical group level of each of the plurality of resource groupings. Each of the plurality of resource groupings may be variably allocated to respective portions of the data being carried within the data transmission frame based on an amount of the data being carried in each respective portion.

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EFFICIENT RADIO RESOURCE ALLOCATION METHOD AND SYSTEM

Cross-Reference to Related Applications

[0001] This application claims priority to U.S. Provisional Patent Application No. 61/014,723 filed on December 18, 2007, the contents of which are incorporated by reference herein in their entirety.

Field of the Invention

[0002] The present invention relates generally to digital communications and more particularly to Orthogonal Frequency Division Multiplexing (OFDM) and Orthogonal Frequency Division Multiple Access (OFDMA) systems.

Background

[0003] There is an increasing need for mobile high-speed communication systems to provide a variety of services such as downloading music files, TV, Internet, and photo sharing. A mobile high-speed communication system must overcome difficult operating conditions. Among the many difficulties the system must contend with are interference, multipath signals, changing obstructions to the signal line-of-sight, doppler shift, inter-symbol interference (ISI), and changing distances between transmitter and receiver. Orthogonal Frequency Division Multiplexing (OFDM) is one technique that is being developed for high-speed communications that can mitigate many of these difficulties.

[0004] OFDM divides an allocated communication channel into a number of orthogonal subchannels of equal bandwidth. Each subchannel is modulated by a unique group of subcarrier signals, whose frequencies are equally and minimally spaced for optimal bandwidth efficiency. The group of subcarrier signals are chosen to be orthogonal, meaning the inner product of any two of the subcarriers equals zero. An inverse fast Fourier transform (IFFT) is often used to form the subcarriers. The

number of orthogonal subcarriers determines the fast Fourier transform (FFT) size (N) to be used.

[0005] Orthogonal Frequency Division Multiple Access (OFDMA) is a multi-user version of OFDM. For a communication device such as a base station, multiple access is accomplished by assigning subsets of orthogonal sub-carriers to individual subscriber devices, such as mobile stations, with which the base station is communicating. OFDMA may be considered to be a combination of frequency and time domain multiple access, where a time-frequency space, is partitioned and the mobile station data is assigned along the OFDM symbols and subcarriers.

[0006] In telecommunications, a frame is a fixed or variable length packet of data, which has been encoded by a communications protocol for digital transmission. A frame structure is the way a multiplexer divides a communication channel into frames for transmission and if applicable, subdivides a frame into smaller portions with different transmission properties to satisfy different transmission requirements of the various data being carried over the digital communications channel or to assist in the effective reception of such data at the intended receiver over the physical medium. The frame structure of an OFDM or OFDMA system contributes to determining the performance of the system. An aspect of the frame structure design that can significantly impact the achievable performance of the resulting frame structure is the amount of control signaling protocol overhead required to specify the assignment of resources within the frame to the various data being carried within it.

Summary of the Invention

[0007] The presently disclosed embodiments are directed to solving one or more of the problems presented in the prior art, described above, as well as providing additional features that will become readily apparent by reference to the following detailed description when taken in conjunction with the accompanying drawings.

[0008] One aspect of the present disclosure is directed to a method of allocating transmission resources to data being carried within a data transmission frame. The method includes partitioning the transmission resources into a plurality of resource groupings; and individually addressing each of the plurality of resource groupings, based on a hierarchical group level of each of the plurality of resource groupings.

[0009] A further aspect of the present disclosure is directed to a station in a wireless communication system capable of allocating transmission resources to data being carried within a data transmission frame. The station comprises a processing module, which is configured to partition the transmission resources into a plurality of resource groupings, and individually address each of the plurality of resource groupings, based on a hierarchical group level of each of the plurality of resource groupings.

[0010] Yet another aspect of the present disclosure is directed to system for allocating transmission resources to data being carried within a data transmission frame. The system may comprise means for partitioning the transmission resources into a plurality of resource groupings; and means for individually addressing each of the plurality of resource groupings, based on a hierarchical group level of each of the plurality of resource groupings.

[0011] Yet another aspect of the present disclosure is directed to a computer-readable medium storing instructions thereon for allocating transmission resources to data being carried within a data transmission frame. The instructions include code for partitioning the transmission resources into a plurality of resource groupings; and individually addressing each of the plurality of resource groupings, based on a hierarchical group level of each of the plurality of resource groupings.

[0012] When the plurality resource groupings are addressed, embodiments of the present disclosure are further configured to variably allocate each of the plurality of resource groupings to respective portions of the data being carried within the data transmission frame, based on an amount of the data being carried in each respective portion. As a result, embodiments of the present invention provide an efficient

method and system for specifying the allocation of resources within a data transmission frame to the data being carried within the frame.

[0013] Further features and advantages of the present disclosure, as well as the structure and operation of various embodiments of the present disclosure, are described in detail below with reference to the accompanying drawings.

Brief Description of the Drawings

[0014] The present disclosure, in accordance with one or more various embodiments, is described in detail with reference to the following Figures. The drawings are provided for purposes of illustration only and merely depict exemplary embodiments of the disclosure. These drawings are provided to facilitate the reader's understanding of the disclosure and should not be considered limiting of the breadth, scope, or applicability of the disclosure. It should be noted that for clarity and ease of illustration these drawings are not necessarily made to scale.

[0015] Fig. 1 is an illustration of an exemplary OFDM/OFDMA mobile radio channel operating environment, according to one embodiment of the present invention.

[0016] Fig. 2 is an illustration of an exemplary OFDM/OFDMA exemplary communication system according to one embodiment of the present invention.

[0017] Fig. 3 is an illustration of an exemplary OFDM/OFDMA sub frame structure, according to one embodiment of the present invention.

[0018] Figs 4(a) and 4(b) illustrate a general abstract model of a resource allocation management framework based on a two-dimensional radio resource space of time and frequency, according to one embodiment of the present invention.

[0019] Fig. 5 is an illustration of a general tree-based organization of RRE aggregation into allocable units of increasingly larger sizes, according to one embodiment of the present invention.

[0020] Fig. 6 is an illustration of a use of a binary tree as the basis of organizing RRE aggregation into allocable units of increasingly larger sizes, according to one embodiment of the present invention.

[0021] Figs. 7(a) and 7(b) show examples of addressing elements forming addresses to individual nodes, according to one embodiment of the present invention.

[0022] Figs. 8(a) and 8(b) illustrate examples of a compound address that supports the specification of multiple nodes (allocable units) from the resource allocation tree to be included in an allocation according to one embodiment of the invention.

[0023] Figs. 9(a) and 9(b) illustrate a form of a compound address that supports the specification of multiple nodes (allocable units) from a resource allocation tree to be included in an allocation according to one embodiment of the invention.

[0024] Fig. 10 illustrates a specific example of a binary tree for an RSS with 16 RREs, according to one embodiment of the invention.

[0025] Fig. 11 illustrates a specific example of an M-ary tree for an RSS with 36 RREs, according to one embodiment of the invention.

[0026] Fig. 12 is a flowchart illustrating a method of allocating transmission resources to data being carried within a data transmission frame, according to one embodiment of the present invention.

[0027] Fig. 13 illustrates a method of partitioning the transmission resources into a plurality of resource groupings, according to one embodiment of the present invention.

Detailed Description of Exemplary Embodiments

[0028] The following description is presented to enable a person of ordinary skill in the art to make and use the invention. Descriptions of specific devices, techniques, and applications are provided only as examples. Various modifications to the examples described herein will be readily apparent to those of ordinary skill in the art, and the general principles defined herein may be applied to other examples and applications without departing from the spirit and scope of the invention. Thus, the present invention is not intended to be limited to the examples described herein and shown, but is to be accorded the scope consistent with the claims.

[0029] The word “exemplary” is used herein to mean “serving as an example or illustration.” Any aspect or design described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other aspects or designs.

[0030] Reference will now be made in detail to aspects of the subject technology, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout.

[0031] It should be understood that the specific order or hierarchy of steps in the processes disclosed herein is an example of exemplary approaches. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the processes may be rearranged while remaining within the scope of the present disclosure. The accompanying method claims present elements of the various steps in a sample order, and are not meant to be limited to the specific order or hierarchy presented.

[0032] Aspects of the present disclosure are directed toward systems and methods for OFDM/OFDMA frame structure technology for communication systems. Embodiments of the invention are described herein in the context of one practical application, namely, communication between a base station and a plurality of mobile devices. In this context, the exemplary system is applicable to provide data communications between a base station and a plurality of mobile devices. Embodiments of the disclosure, however, are not limited to such base station and mobile device communication applications, and the methods described herein may also be utilized in other applications such as mobile-to-mobile communications, or wireless local loop communications. As would be apparent to one of ordinary skill in the art after reading this description, these are merely examples and the invention is not limited to operating in accordance with these examples. Assignment of resources within a frame to the data being carried can be applied to any digital communications system with data transmissions organized within a frame structure and where the full set of such resources within a frame can be flexibly divided according to portions of different sizes to the data being carried. Thus, the present disclosure is not limited to any particular type of communication system; however, embodiments of the present invention are described herein with respect to exemplary OFDM/OFDMA systems.

[0033] As explained in additional detail below, the OFDM/OFDMA frame structure comprises a variable length sub-frame structure with an efficiently sized cyclic prefix operable to effectively utilize OFDM/OFDMA bandwidth. The frame structure provides compatibility with multiple wireless communication systems.

[0034] Fig. 1 illustrates a mobile radio channel operating environment 100, according to one embodiment of the present invention. The mobile radio channel operating environment 100 may include a base station (BS) 102, a mobile station (MS) 104, various obstacles 106/108/110, and a cluster of notional hexagonal cells 126/130/132/134/136/138/140 overlaying a geographical area 101. Each cell 126/130/132/134/136/138/140 may include a base station operating at its allocated bandwidth to provide adequate radio coverage to its intended users. For example, the base station 102 may operate at an allocated channel transmission bandwidth to provide adequate coverage to the mobile station 104. The exemplary mobile station 104 in Fig. 1 is an automobile; however mobile station 104 may be any user device such as a mobile phone. Alternately, mobile station 104 may be a personal digital assistant (PDA) such as a Blackberry device, MP3 player or other similar portable device. According to some embodiments, mobile station 104 may be a personal wireless computer such as a wireless notebook computer, a wireless palmtop computer, or other mobile computer devices.

[0035] The base station 102 and the mobile station 104 may communicate via a downlink radio frame 118, and an uplink radio frame 124 respectively. Each radio frame 118/124 may be further divided into sub-frames 120/126 which may include data symbols 122/124. In this mobile radio channel operating environment 100, a signal transmitted from a base station 102 may suffer from the operating conditions mentioned above. For example, multipath signal components 112 may occur as a consequence of reflections, scattering, and diffraction of the transmitted signal by natural and/or man-made objects 106/108/110. At the receiver antenna 114, a multitude of signals may arrive from many different directions with different delays, attenuations, and phases. Generally, the time difference between the arrival moment of the first received multipath component 116 (typically the line of sight component), and the last received multipath component (possibly any of the multipath signal components 112) is called delay spread. The combination of signals with various

delays, attenuations, and phases may create distortions such as ISI and ICI in the received signal. The distortion may complicate reception and conversion of the received signal into useful information. For example, delay spread may cause ISI in the useful information (data symbols) contained in the radio frame 124.

[0036] Orthogonal Frequency Division Multiplexing (OFDM) can mitigate delay spread and many other difficult operating conditions. OFDM divides an allocated radio communication channel into a number of orthogonal subchannels of equal bandwidth. Each subchannel is modulated by a unique group of subcarrier signals, whose frequencies are equally and minimally spaced for optimal bandwidth efficiency. The group of subcarrier signals are chosen to be orthogonal, meaning the inner product of any two of the subcarriers equals zero. In this manner, the entire bandwidth allocated to the system is divided into orthogonal subcarriers.

[0037] Orthogonal Frequency Division Multiple Access (OFDMA) is a multi-user version of OFDM. For a communication device such as the base station 102, multiple access is accomplished by assigning subsets of orthogonal sub-carriers to individual subscriber devices. A subscriber device may be a mobile station 104 with which the base station 102 is communicating.

[0038] An inverse fast Fourier transform (IFFT) is often used to form the subcarriers, and the number of orthogonal subcarriers determines the fast Fourier transform (FFT) size (N_{FFT}) to be used. An information symbol (e.g., data symbol) in the frequency domain of the IFFT is transformed into a time domain modulation of the orthogonal subcarriers. The modulation of the orthogonal subcarriers forms an information symbol in the time domain with a duration T_u . Duration T_u is generally referred to as the OFDM useful symbol duration. For the subcarriers to remain orthogonal, the spacing between the orthogonal subcarriers Δf is chosen to be $\frac{1}{T_u}$, and vice versa the OFDM symbol duration T_u is $\frac{1}{\Delta f}$. The number of available orthogonal subcarriers N_C (an integer less than or equal to N_{FFT}) is the channel transmission bandwidth (BW) divided by the subcarrier spacing $\frac{BW}{\Delta f}$, or $BW * T_u$.

[0039] Fig. 2 shows an exemplary wireless communication system 200 for transmitting and receiving OFDM/OFDMA transmissions, in accordance with one embodiment of the present invention. The system 200 may include components and elements configured to support known or conventional operating features that need not be described in detail herein. In the exemplary embodiment, system 200 can be used to transmit and receive OFDM/OFDMA data symbols in a wireless communication environment such as the wireless communication environment 100 (Fig. 1). System 200 generally comprises a base station 102 with a base station transceiver module 202, a base station antenna 206, a base station processor module 216 and a base station memory module 218. System 200 generally comprises a mobile station 104 with a mobile station transceiver module 208, a mobile station antenna 212, a mobile station memory module 220, a mobile station processor module 222, and a network communication module 226. Of course both BS 102 and MS 104 may include additional or alternative modules without departing from the scope of the present invention.

[0040] Furthermore, these and other elements of system 200 may be interconnected together using a data communication bus (*e.g.*, 228, 230), or any suitable interconnection arrangement. Such interconnection facilitates communication between the various elements of wireless system 200. Those skilled in the art will understand that the various illustrative blocks, modules, circuits, and processing logic described in connection with the embodiments disclosed herein may be implemented in hardware, computer-readable software, firmware, or any practical combination thereof. To clearly illustrate this interchangeability and compatibility of hardware, firmware, and software, various illustrative components, blocks, modules, circuits, and steps are described generally in terms of their functionality. Whether such functionality is implemented as hardware, firmware, or software depends upon the particular application and design constraints imposed on the overall system. Those familiar with the concepts described herein may implement such functionality in a suitable manner for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the present invention.

[0041] In the exemplary OFDM/OFDMA system 200, the base station transceiver 202 and the mobile station transceiver 208 each comprise a transmitter module and a receiver module (not shown). Additionally, although not shown in this figure, those skilled in the art will recognize that a transmitter may transmit to more than one receiver, and that multiple transmitters may transmit to the same receiver. In a TDD system, transmit and receive timing gaps exist as guard bands to protect against transitions from transmit to receive and vice versa.

[0042] In the particular example of the OFDM/OFDMA system depicted in Figure 2, an "uplink" transceiver 208 includes an OFDM/OFDMA transmitter that shares an antenna with an uplink receiver. A duplex switch may alternatively couple the uplink transmitter or receiver to the uplink antenna in time duplex fashion. Similarly, a "downlink" transceiver 202 includes an OFDM/OFDMA receiver which shares a downlink antenna with a downlink transmitter. A downlink duplex switch may alternatively couple the downlink transmitter or receiver to the downlink antenna in time duplex fashion.

[0043] Although many OFDM/OFDMA systems will use OFDM/OFDMA technology in both directions, those skilled in the art will recognize that the present embodiments of the invention are applicable to systems using OFDM/OFDMA technology in only one direction, with an alternative transmission technology (or even radio silence) in the opposite direction. Furthermore, it should be understood by a person of ordinary skill in the art that the OFDM/OFDMA transceiver modules 202/208 may utilize other communication techniques such as, without limitation, a frequency division duplex (FDD) communication technique.

[0044] The mobile station transceiver 208 and the base station transceiver 202 are configured to communicate via a wireless data communication link 214. The mobile station transceiver 208 and the base station transceiver 202 cooperate with a suitably configured RF antenna arrangement 206/212 that can support a particular wireless communication protocol and modulation scheme. In the exemplary embodiment, the mobile station transceiver 208 and the base station transceiver 202 are configured to support industry standards such as the Third Generation Partnership Project Long Term Evolution (3GPP LTE), Third Generation Partnership Project 2 Ultra Mobile Broadband (3Gpp2 UMB), Time Division-Synchronous Code Division

Multiple Access (TD-SCDMA), and Wireless Interoperability for Microwave Access (WiMAX), and the like. The mobile station transceiver 208 and the base station transceiver 202 may be configured to support alternate, or additional, wireless data communication protocols, including future variations of IEEE 802.16, such as 802.16e, 802.16m, and so on.

[0045] According to certain embodiments, the base station 102 controls the radio resource allocations and assignments, and the mobile station 104 is configured to decode and interpret the allocation protocol. For example, such embodiments may be employed in systems where multiple mobile stations 104 share the same radio channel which is controlled by one base station 102. However, in alternative embodiments, the mobile station 104 controls allocation of radio resources for a particular link, and could implement the role of radio resource controller or allocator, as described herein.

[0046] Processor modules 216/222 may be implemented, or realized, with a general purpose processor, a content addressable memory, a digital signal processor, an application specific integrated circuit, a field programmable gate array, any suitable programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof, designed to perform the functions described herein. In this manner, a processor may be realized as a microprocessor, a controller, a microcontroller, a state machine, or the like. A processor may also be implemented as a combination of computing devices, e.g., a combination of a digital signal processor and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a digital signal processor core, or any other such configuration. Processor modules 216/222 comprise processing logic that is configured to carry out the functions, techniques, and processing tasks associated with the operation of OFDM/OFDMA system 200. In particular, the processing logic is configured to support the OFDM/OFDMA frame structure parameters described herein. In practical embodiments the processing logic may be resident in the base station and/or may be part of a network architecture that communicates with the base station transceiver 202.

[0047] Furthermore, the steps of a method or algorithm described in connection with the embodiments disclosed herein may be embodied directly in hardware, in firmware, in a software module executed by processor modules 216/222, or in any practical combination thereof. A software module may reside in memory modules 218/220, which may be realized as RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, a hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. In this regard, memory modules 218/220 may be coupled to the processor modules 216/222 respectively such that the processors modules 216/220 can read information from, and write information to, memory modules 618/620. As an example, processor module 216, and memory modules 218, processor module 222, and memory module 220 may reside in their respective ASICs. The memory modules 218/220 may also be integrated into the processor modules 216/220. In an embodiment, the memory module 218/220 may include a cache memory for storing temporary variables or other intermediate information during execution of instructions to be executed by processor modules 216/222. Memory modules 218/220 may also include non-volatile memory for storing instructions to be executed by the processor modules 216/220.

[0048] Memory modules 218/220 may include a frame structure database (not shown) in accordance with an exemplary embodiment of the invention. Frame structure parameter databases may be configured to store, maintain, and provide data as needed to support the functionality of system 200 in the manner described below. Moreover, a frame structure database may be a local database coupled to the processors 216/222, or may be a remote database, for example, a central network database, and the like. A frame structure database may be configured to maintain, without limitation, frame structure parameters as explained below. In this manner, a frame structure database may include a lookup table for purposes of storing frame structure parameters.

[0049] The network communication module 226 generally represents the hardware, software, firmware, processing logic, and/or other components of system 200 that enable bi-directional communication between base station transceiver 202, and network components to which the base station transceiver 202 is connected. For example, network communication module 226 may be configured to support internet

or WiMAX traffic. In a typical deployment, without limitation, network communication module 226 provides an 802.3 Ethernet interface such that base station transceiver 202 can communicate with a conventional Ethernet based computer network. In this manner, the network communication module 226 may include a physical interface for connection to the computer network (e.g., Mobile Switching Center (MSC)).

[0050] Fig. 3 is an illustration of an exemplary OFDM/OFDMA sub-frame structure, according to one embodiment of the present invention. For this example, the OFDM/OFDMA sub-frame structure comprises a short sub-frame 302, a regular sub-frame 304, a long sub-frame 306, and an optional low chip rate (LCR) sub-frame 308. A 10 ms radio frame may be divided into twenty or more short sub-frames 302, ten regular sub-frames 304, or five long sub-frames 306. For a 10 ms radio frame divided in this way, a short sub-frame 302 has a duration of 0.5 ms, a regular sub-frame 304 has a duration of 1 ms, and a long sub-frame 306 has a duration of 2 ms. Other numbers of sub-frames that do not necessarily divide the 10 ms radio frame evenly may also be used. In this case, a gap remains in the radio frame. The frame structure provides compatibility with multiple wireless communication systems. For example, the low chip rate sub-frame 308 duration of 0.675 ms may allow compatibility with the Time Division-Synchronous Code Division Multiple Access (TD-SCDMA) OFDM/OFDMA radio frame structure. The long sub-frame 306 duration of 2 ms may allow compatibility with the Third Generation Partnership Project Long Term Evolution (3GPP LTE) OFDM/OFDMA radio frame structure, and the like. The exemplary frame structures of Fig. 3 are merely contextual, and various frame structures may be implemented without departing from the scope of the present invention.

[0051] Figs 4(a) and 4(b) illustrate a general abstract model of a resource allocation management framework based on a two-dimensional radio resource space of time and frequency, according to one embodiment of the present invention. The elements in the model include the Radio Resource Segment (RRS) 400, and the Radio Resource Element (RRE) 410.

[0052] The RRS 400 defines the scope of applicability for a particular instance of the radio resource addressing method in that the particular instance of the addressing method need only accommodate the totality of radio resources 420 contained within an RRS 400. There may be one or more RRSs 400 within a radio frame. Different RRSs 400 may contain a different amount of radio resources 420. Different RRSs 400 may structure their radio resources 420 differently for various reasons, such as to assist in the mitigation of impairments of the radio environments for which the type of RRS 400 may be employed while minimizing the impact to the data-carrying performance of the RRS 400.

[0053] The fundamental unit of radio resource allocation within an RRS 400 is the RRE 410. In its simplest form, an RRE 410 is defined as a small contiguous block of radio resources 420 within the resource space of the RRS 400. In Figs. 4(a) and 4(b), which provide examples of RREs 410 based on the two-dimensional radio resource space of OFDM/OFDMA technology, the simple form of an RRE 410 is the rectangular resource allocation, as shown in Fig. 4(a). In more complex forms, an RRE 410 may be comprised of a set of smaller contiguous blocks of radio resources 420 with the blocks dispersed in some reasonable fashion within the radio resource space of the RRS 400. An example of such a compound form of an RRE 410 is illustrated in Fig. 4(b) which shows an RRE 410 composed of four blocks of radio resources 420 with the blocks dispersed in both time and frequency within the RRS 400; such form of an RRE 410 may be useful in helping to mitigate the impact of a time and frequency selective radio environment. Although the examples of RRE 410 structures provided in Figs. 4(a) and 4(b) show RREs 410 with uniform structures, this need not be the case. In addition, within an RRS 400, there may be more than one structure of RRE 410 defined depending on need, such as for example, to provide complementary shapes and structures to effectively cover the entire radio resource space of the RRS 400. As the foregoing discussion indicates, there is great flexibility in the definition of the size and structure of RREs 410 within an RRS 400. The only constraints on the RRE 410 definitions are 1) that there be an integer number of RREs 410 within an RRS 400, and 2) that the total set of RREs 410 within an RRS 400 covers the entire radio resource space of the RRS 400 with no overlap in coverage between RREs 410.

[0054] Fig. 5 is an illustration of a general tree-based radio resource grouping and summarization structure, according to one embodiment of the invention. Each node at the root 520, forks 510, and leaves 500 of the tree represent a separately addressable allocable unit of radio resources within an RRS 400. All of the individual RREs 410 of the RRS 400 are assigned as a leaf node 500 of the tree. In this general case, there is an m-ary relationship between the number of child nodes to a parent node between any two levels of the tree – a level of the tree being defined as nodes at the same distance from the root 520 of the tree. Since each level of the tree represents a grouping of child nodes to a parent node, the levels of the radio resource allocation tree are referred to as Grouping Levels (GL) in this disclosure. From the RRE 410 leaf 500 level of the tree to the first parent Grouping Level, m_1 RREs 410 are summarized into the allocable unit represented by the parent nodes at this 1st Grouping Level. From the 1st Grouping Level to the 2nd Grouping Level, m_2 1st Grouping Level (GL1) nodes are summarized into a parent 2nd Grouping Level (GL2) node. This m-ary relationship repeats at each successive higher order Grouping Level culminating in a single node at the root 520 of the tree. This root 520 node represents the totality of radio resources 420 of the RRS 400 as a single allocable unit. The number of nodes at a Grouping Level n is given by the number of nodes at the child Grouping Level divided by the grouping factor m_n from the child level and rounded up to the next higher integer value. Therefore, for Grouping Level n , the number of allocable units (*i.e.*, the number of nodes, N_{GLn}), as represented by the number of nodes at this level,

is given by the relationship:

$$N_{GLn} = \text{ceil}\left(N_{RRE} / \prod_{i=1}^n m_i\right),$$

where N_{RRE} is the number of RREs 410 in the RRS 400. It should be noted that in the general case, at each Grouping Level, there may be one node which summarizes less than m_n child nodes if the number of nodes at the child level is not an integer multiple of m_n .

[0055] Fig. 6 is an illustration of a use of a binary tree as the basis of organizing RRE 410 aggregation into allocable units of increasingly larger sizes, according to one embodiment of the present invention.. For the binary tree structure, the expression for the number of nodes N_{GLn} at a particular Grouping Level n of the tree reduces to the following: $N_{GLn} = \text{ceil}(N_{RRE} / 2^n)$. Contrary to the case of the general tree structure, as shown in Fig. 5, the strict binary child-to-parent-node

relationship between levels also results in a simple expression for the number of Grouping Levels, N_{GL} : $N_{GL} = \text{ceil}(\log_2(N_{RRE}))$. Similar to Fig. 6, each node at the root 620, forks 610, and leaves 600 of the tree represent a separately addressable allocable unit of radio resources within an RRS 400.

[0056] Nodes in a radio resource allocation tree can be individually addressed based on an efficient method of variable length addressing according to an embodiment of the invention. This variable-length addressing method takes advantage of increasingly fewer nodes at each level of the tree as the tree is traversed from leaf 500/600 to root 520/620 to reduce the number of bits required to address the nodes at each level closer to the root 520/620. Based on this consideration, the addressing elements allow a structured way to define different address formats for each level of the tree.

[0057] Therefore, one element in the address is the identification of the level of the tree to which the address pertains – this is done through a Grouping Level element which assigns a number to identify the level of the tree to which an address pertains. This Grouping Level element may be encoded as 0 to $N_{GL} - 1$ in binary form, for example, using the least number of bits needed to accommodate the value of N_{GL} . However, various encoding forms may be used to identify N_{GL} without departing from the scope of the present disclosure. “Grouping Level” is used throughout this disclosure to represent this address element; however, various nomenclatures may be used without departing from the scope of the present disclosure.

[0058] Then, for a particular Grouping Level, sufficient bits are provided in the address to identify the number of nodes at that particular level of the tree, where each node represents an individually allocable unit of radio resources for the RRS 400 – this consideration defines the size of an “Allocable Unit #” element for a particular level of the tree, and may be encoded as 0 to $N_{GL} - 1$ in binary form, for example, using at least the number of bits needed to accommodate the value of the number of nodes. However, various encoding forms may be used to identify the number of nodes at that particular level of the tree without departing from the scope of the present disclosure. “Allocable Unit #” is used throughout this disclosure to represent

this address element; however, various nomenclatures may be used without departing from the scope of the present disclosure.

[0059] Another element may be a flag that identifies a different form of address used for individual RREs 410 at the leaf 500/600 level of the tree (*e.g.*, Grouped = FALSE) versus at other levels of the tree (*e.g.*, Grouped = TRUE), which represent a grouping of a set of RREs 410 into an individually allocable radio resource unit. In this example, and throughout this disclosure, the flag element is referred to as “Grouped”; however, various nomenclatures may be used without departing from the scope of the present disclosure.

[0060] Figs. 7(a) and 7(b) show examples of the addressing elements described above forming addresses to individual nodes, according to an embodiment of the present invention. As illustrative examples, there may be two forms of the address: one that applies to the addressing of individual RREs 410 at the leaf 500/600 level of the tree (see Fig. 7(a)), and another that applies to all other levels of the tree (see Fig. 7(b)). A 2-tuple address comprising the Grouped flag 700 and Allocable Unit # 710 may be used to create an efficient format for individual RREs 410. In this case, the size of the Allocable Unit # 710 element (bits) may be determined by the expression:

$$\text{ceil}(\log_2(N_{\text{RRE}})).$$

[0061] Other nodes of the tree may be identified by a 3-tuple address comprising the Grouped flag 700, identification of the Grouping Level 720 (*i.e.*, non-leaf level) of the tree, and the Allocable Unit # 710 within that level. This latter format allows the address to any non-leaf node to use as short a field as possible to represent the required range of Allocable Unit # and thereby create an efficient addressing mechanism for these non-leaf nodes. In this case, the size of the Grouping Level 720 field (bits) may be determined by the expression:

$$\text{ceil}(\log_2(N_{\text{GL}})).$$

The size of the Allocable Unit # 710 field (bits) may be determined by the expression:

$$\text{ceil}(\log_2(N_{\text{GLn}})).$$

Of course, various other address elements may be included without departing from the scope of the present invention.

[0062] In order to support allocation of resources that provides a good fit for the amount of data to be sent in a particular transmission frame, the ability to specify an allocation comprised of a disjoint set of RREs 410 may be necessary. An efficient way to provide this identification for a set of RREs 410 to satisfy a particular amount of resources required of a particular allocation is to allow a disjoint set of allocable units from the resource allocation tree to be specified. This set of allocable units from the tree may be disjoint from the perspective of RREs 410 being included only once in the allocation.

[0063] Figs. 8(a) and 8(b) illustrate examples of a compound address that supports the specification of multiple nodes (allocable units) from the resource allocation tree to be included in an allocation according to an embodiment of the invention. This form includes a list of individual addresses of allocable units, as described above. There may be multiple ways to identify how many individual addresses are included. In a first example, a 1-bit flag is appended to each individual address, as shown in Fig. 8(a). This flag identifies whether the individual address is the last one included or not. This format is flexible and allows an arbitrary number of individual addresses to be included, but incurs some overhead due to the addition of the 1-bit flag on a per-individual-address basis.

[0064] In another example, a field is appended that identifies how many individual addresses are included, as shown in Fig. 8(b). The size of this field (determined by the expression: $\text{ceil}(\log_2(N_{\text{max}}))$, where N_{max} is the maximum number of individual allocable units that can be included in set) limits the maximum number of individual addresses that may be included. This format potentially introduces less overhead than the format described in Fig. 8(a), but setting the size of the new field properly is critical to ensuring a sufficient number of individual addresses per allocation is supported to meet all potential needs for allocation sizes. Of course, the examples of Figs. 8(a) and 8(b) are merely exemplary, and various other ways to identify how many individual addresses are included may be implemented.

[0065] Figs. 9(a) and 9(b) illustrate another form of a compound address that supports the specification of multiple nodes (allocable units) from a resource allocation tree to be included in an allocation according to an embodiment of the invention. This exemplary form uses a bitmap to provide an efficient way of identifying the Grouping Level values 720 associated with the addresses to specific nodes in the tree that comprise the resource allocation. Each bit of the bitmap indicates whether an individual address from a Grouping Level, from the leaf level to the child level of the root, is included in the compound address. Therefore, the size of the bitmap is equal to the number of Grouping Levels, N_{GL} , in the tree. The tradeoff to gain extra efficiency is some loss in flexibility as the bitmap can only identify a single constituent node of the compound allocation from each Grouping Level. According to the example illustrates in Figs. 9(a) and 9(b), since the applicable Grouping Levels have already been identified by the bitmap, only the value of the Allocable Unit # 710 elements associated with the nodes from the a Grouping Level or the leaf level with its corresponding bit in the bitmap set to TRUE need to be appended to the bitmap to form the compound address. To illustrate the format of this form of compound address, Fig. 9(a) shows an example in which a node (allocable unit) from each of the non-root levels of the tree are included in the compound address. As another example, Fig. 9(b) shows an example in which a node (allocable unit) from only two of the non-root levels of the tree are included in the compound address.

[0066] Fig. 10 illustrates a specific example of a binary tree for an RSS 400 with 16 RREs 410 according to an embodiment of the invention. As shown in Fig. 10, this results in a five-level binary tree with all 16 RREs 410 addressable as a single allocable unit at the top root level (GL4) 1020 and each RRE 410 individually addressable at the leaf level 1000. The intermediate Grouping Levels 1010 1 to 3 represent groupings of 2, 4 and 8 RREs 410 as individual allocable units, respectively.

[0067] Fig. 10 shows examples of addresses of individual nodes at each level of the tree based on the formats described herein, including the 2-tuple addresses to individual RREs 410 at the leaf level 1000 and the 3-tuple addresses to individual non-leaf nodes 1010 and 1020 of the tree according to embodiments of the invention. Fig. 10 also illustrates the flexibility of the list form of compound addressing by way of an example of a compound allocation that includes two nodes (allocable units)

from the same level of the tree (in the case of the illustration, from the leaf level 1000 of the tree).

[0068] As shown in Fig. 10, a 2-tuple address is given to the individual RREs 410 in the leaf level 1000. For example, RRE 1 (Group = FALSE) may be addressed as (0b0, 0b0000). RRE 5 may be addressed as (0b0, 0b0100).

[0069] A 3-tuple grouped RRE 410 (*e.g.*, grouping level 1 – RRE – GL1 8) (Group = TRUE) may be addressed, for example, as (0b1, 0b00, 0b111). At the root (*i.e.*, grouping level 4) the Allocable Unit # is redundant and may be omitted. As a result, the address may be expressed as (0b1, 0b11).

[0070] If the allocable unit sets uses list form addressing (*e.g.*, more than one allocable unit from a grouping level is contained), the address for 2, RRE 6, RRE 8, for example, may be expressed as (0b01, (0b0, 0b0101), (0b0, 0b0111)).

[0071] Fig. 11 illustrates a specific example of an M-ary tree for an RSS 400 with 36 RREs 410 according to embodiments of the invention. As Fig. 11 shows, by using child-to-parent ratios greater than 2 between the leaf and 1st Grouping Level and between the 1st Grouping Level and the 2nd Grouping Level (these ratios being 3 in this example), the number of levels in the tree is kept the same as for the 16-RRE binary tree of Fig. 10 even though the number of individual RREs 410 available in the RSS 400 has more than doubled. If the grouping of the 36 RREs 410 were organized using a binary tree, the number of levels in the tree would have increased to 7, which would have resulted in longer addresses to allocable units or sets of allocable units on average. The intermediate Grouping Levels 1 to 3 represent groupings of 3, 9 and 18 RREs 410 as individual allocable units, respectively.

[0072] As shown in Fig. 11, a 2-tuple address is given to the individual RREs 410 in the leaf level 1100. For example, RRE 1 (Group = FALSE) may be addressed as (0b0, 0b000000). RRE 5 may be addressed as (0b0, 0b000100).

[0073] A 3-tuple grouped RRE 410 (*e.g.*, grouping level 1 – RRE – GL1 8) (Group = TRUE) may be addressed, for example, as (0b1, 0b00, 0b0111). At the root (*i.e.*, grouping level 4) the Allocable Unit # is redundant and may be omitted. As a result, the address may still be expressed as (0b1, 0b11).

[0074] If the allocable unit sets uses list form addressing (*e.g.*, more than one allocable unit from a grouping level is contained), the address for 2, RRE 6, RRE 8, for example, may be expressed as (0b01, (0b0, 0b000101), (0b0, 0b000111)).

[0075] Fig. 12 is a flowchart illustrating a method of allocating transmission resources to data being carried within a data transmission frame, according to one embodiment of the present invention. At operation 1200, the transmission resources are partitioned into a plurality of resource groupings. Resource groupings refer to each addressable group of RREs 410 at various hierarchical grouping levels. Specific functions involved with partitioning the transmission resources into a plurality of resource groupings are described in detail with respect to Fig. 13 below.

[0076] From operation 1200, the process continues to operation 1210, where each of the plurality of resource groupings are addressed, based on a hierarchical group level of each of the plurality of resource groupings. As described above with respect to Figs. 7(a), 7(b), 8(a), 8(b), 9(a) and 9(b), addresses may be assigned using various techniques (*e.g.*, 2-tuple address, 3-tuple address, compound address, etc.).

[0077] From operation 1200, the process continues to operation 1220, where each of the plurality of resource groupings are variably allocated to respective portions of the data being carried within the data transmission frame based on an amount of the data being carried in each respective portion. As described above, different RRSs 400 may contain a different amount of radio resources 420. Different RRSs 400 may structure their radio resources 420 differently for various reasons, such as to assist in the mitigation of impairments of the radio environments for which the type of RRS 400 may be employed while minimizing the impact to the data-carrying performance of the RRS 400. An aspect of the frame structure design that can significantly impact the achievable performance of the resulting frame structure is the amount of control signaling protocol overhead required to specify the assignment of resources within the frame to the various data being carried within it. Therefore, it becomes important to efficiently address and allocate resources to the data being carried within a frame, depending on the amount of the data being carried.

[0078] Fig. 13 illustrates a method of partitioning the transmission resources into a plurality of resource groupings (see operation 1200 above), according to one embodiment of the present invention. First, at operation 1300, at least one RRS 400 is defined within a frame. At operation 1310, one or more addressable resource elements (*e.g.*, RREs 410 as leaf nodes) within the RRS 400 are determined. Addresses are given to each of the one or more addressable resource elements at operation 1320.

From operation 1320, the process continues to operation 1330, where the addressed one or more resource elements are grouped into one or more resource groupings (*e.g.*, non-leaf nodes), such that higher hierarchical group levels include a greater amount of resource elements. Each of the one or more resource groupings are addressed at operation 1340. According to certain embodiments, the grouped one or more addressed resource elements fully occupy resource space of the respective resource groupings.

[0079] According to certain embodiments, if a plurality of resource groupings exists (*i.e.*, the grouping does not result in a root node), the plurality of resource groupings may be further grouped into one or more larger resource groupings. Similarly, these one or more larger resource groupings may be addressed, and the process may be repeated until a root node is reached.

[0080] As described herein, nodes in a radio resource allocation tree can be individually addressed based on an efficient method of variable length addressing according to an embodiment of the invention. This variable-length addressing method takes advantage of increasingly fewer nodes at each level of the tree as the tree is traversed from leaf to root to reduce the number of bits required to address the nodes at each level closer to the root. Based on this consideration, the addressing elements allow a structured way to define different address formats for each level of the tree.

[0081] By partitioning the transmission resources into a plurality of resource groupings; and individually addressing each of the plurality of resource groupings, based on a hierarchical group level of each of the plurality of resource groupings, embodiments of the present invention are capable of providing an efficient method

and system for specifying the allocation of resources within a data transmission frame to the data being carried within the frame.

[0082] While various embodiments of the invention have been described above, it should be understood that they have been presented by way of example only, and not by way of limitation. Likewise, the various diagrams may depict an example architectural or other configuration for the disclosure, which is done to aid in understanding the features and functionality that can be included in the disclosure. The disclosure is not restricted to the illustrated example architectures or configurations, but can be implemented using a variety of alternative architectures and configurations. Additionally, although the disclosure is described above in terms of various exemplary embodiments and implementations, it should be understood that the various features and functionality described in one or more of the individual embodiments are not limited in their applicability to the particular embodiment with which they are described. They instead can, be applied, alone or in some combination, to one or more of the other embodiments of the disclosure, whether or not such embodiments are described, and whether or not such features are presented as being a part of a described embodiment. Thus the breadth and scope of the present disclosure should not be limited by any of the above-described exemplary embodiments.

[0083] In this document, the term “module” as used herein, refers to software, firmware, hardware, and any combination of these elements for performing the associated functions described herein. Additionally, for purpose of discussion, the various modules are described as discrete modules; however, as would be apparent to one of ordinary skill in the art, two or more modules may be combined to form a single module that performs the associated functions according to embodiments of the invention.

[0084] In this document, the terms “computer program product”, “computer-readable medium”, and the like, may be used generally to refer to media such as, memory storage devices, or storage unit. These, and other forms of computer-readable media, may be involved in storing one or more instructions for use by processor to cause the processor to perform specified operations. Such instructions, generally referred to as “computer program code” (which may be grouped in the form

of computer programs or other groupings), when executed, enable the computing system.

[0085] It will be appreciated that, for clarity purposes, the above description has described embodiments of the invention with reference to different functional units and processors. However, it will be apparent that any suitable distribution of functionality between different functional units, processors or domains may be used without detracting from the invention. For example, functionality illustrated to be performed by separate processors or controllers may be performed by the same processor or controller. Hence, references to specific functional units are only to be seen as references to suitable means for providing the described functionality, rather than indicative of a strict logical or physical structure or organization.

[0086] Terms and phrases used in this document, and variations thereof, unless otherwise expressly stated, should be construed as open ended as opposed to limiting. As examples of the foregoing: the term “including” should be read as meaning “including, without limitation” or the like; the term “example” is used to provide exemplary instances of the item in discussion, not an exhaustive or limiting list thereof; and adjectives such as “conventional,” “traditional,” “normal,” “standard,” “known”, and terms of similar meaning, should not be construed as limiting the item described to a given time period, or to an item available as of a given time. But instead these terms should be read to encompass conventional, traditional, normal, or standard technologies that may be available, known now, or at any time in the future. Likewise, a group of items linked with the conjunction “and” should not be read as requiring that each and every one of those items be present in the grouping, but rather should be read as “and/or” unless expressly stated otherwise. Similarly, a group of items linked with the conjunction “or” should not be read as requiring mutual exclusivity among that group, but rather should also be read as “and/or” unless expressly stated otherwise. Furthermore, although items, elements or components of the disclosure may be described or claimed in the singular, the plural is contemplated to be within the scope thereof unless limitation to the singular is explicitly stated. The presence of broadening words and phrases such as “one or more,” “at least,” “but not limited to”, or other like phrases in some instances shall not be read to mean that the

narrower case is intended or required in instances where such broadening phrases may be absent.

[0087] Additionally, memory or other storage, as well as communication components, may be employed in embodiments of the invention. It will be appreciated that, for clarity purposes, the above description has described embodiments of the invention with reference to different functional units and processors. However, it will be apparent that any suitable distribution of functionality between different functional units, processing logic elements or domains may be used without detracting from the invention. For example, functionality illustrated to be performed by separate processing logic elements, or controllers, may be performed by the same processing logic element, or controller. Hence, references to specific functional units are only to be seen as references to suitable means for providing the described functionality, rather than indicative of a strict logical or physical structure or organization.

[0088] Furthermore, although individually listed, a plurality of means, elements or method steps may be implemented by, for example, a single unit or processing logic element. Additionally, although individual features may be included in different claims, these may possibly be advantageously combined. The inclusion in different claims does not imply that a combination of features is not feasible and/or advantageous. Also, the inclusion of a feature in one category of claims does not imply a limitation to this category, but rather the feature may be equally applicable to other claim categories, as appropriate.

WHAT IS CLAIMED IS:

1. A method of allocating transmission resources to data being carried within a data transmission frame, comprising:

partitioning the transmission resources into a plurality of resource groupings;
and

individually addressing each of the plurality of resource groupings, based on a hierarchical group level of each of the plurality of resource groupings.

2. The method of claim 1, further comprising:

variably allocating each of the plurality of resource groupings to respective portions of the data being carried within the data transmission frame based on an amount of the data being carried in each respective portion.

3. The method of claim 1, wherein the partitioning comprises:

determining one or more addressable resource elements within the transmission resources; and

addressing each of the one or more addressable resource elements.

4. The method of claim 3, wherein the partitioning further comprises:

grouping the addressed one or more resource elements into one or more resource groupings, such that higher hierarchical group levels include a greater amount of resource elements; and

addressing each of the one or more resource groupings.

5. The method of claim 4, wherein the grouped one or more addressed resource elements fully occupy resource space of the respective resource groupings.

6. The method of claim 4, wherein the grouping comprises:

if a plurality of resource groupings exists, grouping the plurality of resource groupings into one or more larger resource groupings.

7. The method of claim 1, wherein at least two of the resource groupings are different sizes.

8. The method of claim 1, wherein each hierarchical group level is determined using an M-ary tree structure, where M is an integer greater than two.

9. The method of claim 3, wherein each of the one or more addressable resource elements is assigned a 2-tuple address.

10. The method of claim 9, wherein the 2-tuple address includes a grouped flag and an allocable unit number.

11. The method of claim 4, wherein each of the one or more resource groupings is assigned a 3-tuple address.

12. The method of claim 11, wherein the 3-tuple address includes a grouped flag, a grouping level and an allocable unit number.

13. The method of claim 4, wherein at least two of the grouped addressable resource elements in a respective resource grouping are disjointed.

14. The method of claim 13, wherein the respective resource grouping is assigned a compound address.

15. The method of claim 14, wherein each individual address within the compound address includes a 1-bit flag indicating whether the individual address is last.

16. The method of claim 14, wherein the compound address includes a field indicating a number of individual addresses within the compound address.

17. The method of claim 14, wherein the compound address includes a bitmap including a bit for each grouping level, each bit indicating whether a resource grouping from each grouping level, respectively, is included in the compound address.

18. The method of claim 6, wherein at least two of the grouped plurality of resource groupings are disjointed.

19. The method of claim 18, wherein the grouped plurality of resource groupings is assigned a compound address.

20. The method of claim 19, wherein each individual address within the compound address includes a 1-bit flag indicating whether the individual address is last.

21. The method of claim 19, wherein the compound address includes a field indicating a number of individual addresses within the compound address.

22. The method of claim 19, wherein the compound address includes a bitmap including a bit for each grouping level, each bit indicating whether a resource grouping from each grouping level, respectively, is included in the compound address.

23. A station in a wireless communication system capable of allocating transmission resources to data being carried within a data transmission frame, comprising:

a processing module configured to:

partition the transmission resources into a plurality of resource groupings; and

individually address each of the plurality of resource groupings, based on a hierarchical group level of each of the plurality of resource groupings.

24. The station of claim 23, wherein the processing module is further configured to:

variably allocate each of the plurality of resource groupings to respective portions of the data being carried within the data transmission frame based on an amount of the data being carried in each respective portion.

25. The station of claim 23, wherein the processing module is further configured to:

determining one or more addressable resource elements within the transmission resources; and

addressing each of the one or more addressable resource elements.

26. The station of claim 25, wherein the processing module is further configured to:

grouping the addressed one or more resource elements into one or more resource groupings, such that higher hierarchical group levels include a greater amount of resource elements; and

addressing each of the one or more resource groupings.

27. The station of claim 26, wherein the grouped one or more addressed resource elements fully occupy resource space of the respective resource groupings.

28. The station of claim 26, wherein the processing module is further configured to:

if a plurality of resource groupings exists, grouping the plurality of resource groupings into one or more larger resource groupings.

29. The station of claim 23, wherein at least two of the resource groupings are different sizes.

30. The station of claim 23, wherein each hierarchical group level is determined using an M-ary tree structure, where M is an integer greater than two.

31. The station of claim 25, wherein each of the one or more addressable resource elements is assigned a 2-tuple address.

32. The station of claim 31, wherein the 2-tuple address includes a grouped flag and an allocable unit number.

33. The station of claim 26, wherein each of the one or more resource groupings is assigned a 3-tuple address.

34. The station of claim 33, wherein the 3-tuple address includes a grouped flag, a grouping level and an allocable unit number.

35. The station of claim 26, wherein at least two of the grouped addressable resource elements in a respective resource grouping are disjointed.

36. The station of claim 35, wherein the respective resource grouping is assigned a compound address.

37. The station of claim 36, wherein each individual address within the compound address includes a 1-bit flag indicating whether the individual address is last.

38. The station of claim 36, wherein the compound address includes a field indicating a number of individual addresses within the compound address.

39. The station of claim 36, wherein the compound address includes a bitmap including a bit for each grouping level, each bit indicating whether a resource grouping from each grouping level, respectively, is included in the compound address.

40. The station of claim 28, wherein at least two of the grouped plurality of resource groupings are disjointed.

41. The station of claim 40, wherein the grouped plurality of resource groupings is assigned a compound address.

42. The station of claim 41, wherein each individual address within the compound address includes a 1-bit flag indicating whether the individual address is last.

43. The station of claim 41, wherein the compound address includes a field indicating a number of individual addresses within the compound address.

44. The station of claim 41, wherein the compound address includes a bitmap including a bit for each grouping level, each bit indicating whether a resource grouping from each grouping level, respectively, is included in the compound address.

45. The station of claim 23, wherein the station is a base station.

46. The station of claim 23, wherein the station is a mobile station.

47. A system for allocating transmission resources to data being carried within a data transmission frame, comprising:

means for partitioning the transmission resources into a plurality of resource groupings; and

means for individually addressing each of the plurality of resource groupings, based on a hierarchical group level of each of the plurality of resource groupings.

48. The system of claim 47, further comprising:

means for variably allocating each of the plurality of resource groupings to respective portions of the data being carried within the data transmission frame based on an amount of the data being carried in each respective portion.

49. The system of claim 47, wherein the means for partitioning comprises:

means for determining one or more addressable resource elements within the transmission resources; and

means for addressing each of the one or more addressable resource elements.

50. The system of claim 49, wherein the means for partitioning further comprises:

means for grouping the addressed one or more resource elements into one or more resource groupings, such that higher hierarchical group levels include a greater amount of resource elements; and

means for addressing each of the one or more resource groupings.

51. The system of claim 50, wherein the grouped one or more addressed resource elements fully occupy resource space of the respective resource groupings.

52. The system of claim 50, wherein the means for grouping comprises:

if a plurality of resource groupings exists, means for grouping the plurality of resource groupings into one or more larger resource groupings.

53. The station of claim 47, wherein at least two of the resource groupings are different sizes.

54. The station of claim 47, wherein each hierarchical group level is determined using an M-ary tree structure, where M is an integer greater than two.

55. The station of claim 49, wherein each of the one or more addressable resource elements is assigned a 2-tuple address.

56. The station of claim 55, wherein the 2-tuple address includes a grouped flag and an allocable unit number.

57. The station of claim 50, wherein each of the one or more resource groupings is assigned a 3-tuple address.

58. The station of claim 57, wherein the 3-tuple address includes a grouped flag, a grouping level and an allocable unit number.

59. The station of claim 50, wherein at least two of the grouped addressable resource elements in a respective resource grouping are disjointed.

60. The station of claim 59, wherein the respective resource grouping is assigned a compound address.

61. The station of claim 60, wherein each individual address within the compound address includes a 1-bit flag indicating whether the individual address is last.

62. The station of claim 60, wherein the compound address includes a field indicating a number of individual addresses within the compound address.

63. The station of claim 60, wherein the compound address includes a bitmap including a bit for each grouping level, each bit indicating whether a resource grouping from each grouping level, respectively, is included in the compound address.

64. The station of claim 52, wherein at least two of the grouped plurality of resource groupings are disjointed.

65. The station of claim 64, wherein the grouped plurality of resource groupings is assigned a compound address.

66. The station of claim 65, wherein each individual address within the compound address includes a 1-bit flag indicating whether the individual address is last.

67. The station of claim 65, wherein the compound address includes a field indicating a number of individual addresses within the compound address.

68. The station of claim 65, wherein the compound address includes a bitmap including a bit for each grouping level, each bit indicating whether a resource grouping from each grouping level, respectively, is included in the compound address.

69. A computer-readable medium storing instructions thereon for allocating transmission resources to data being carried within a data transmission frame, comprising code for:

partitioning the transmission resources into a plurality of resource groupings;
and

individually addressing each of the plurality of resource groupings, based on a hierarchical group level of each of the plurality of resource groupings.

70. The computer-readable medium of claim 69, further comprising code for:

variably allocating each of the plurality of resource groupings to respective portions of the data being carried within the data transmission frame based on an amount of the data being carried in each respective portion.

71. The computer-readable medium of claim 69, wherein the code for the partitioning comprises code for:

determining one or more addressable resource elements within the transmission resources; and

addressing each of the one or more addressable resource elements.

72. The computer-readable medium of claim 71, wherein the code for the partitioning further comprises code for:

grouping the addressed one or more resource elements into one or more resource groupings, such that higher hierarchical group levels include a greater amount of resource elements; and

addressing each of the one or more resource groupings.

73. The computer-readable medium of claim 72, wherein the grouped one or more addressed resource elements fully occupy resource space of the respective resource groupings.

74. The computer-readable medium of claim 72, wherein the code for the grouping comprises code for:

if a plurality of resource groupings exists, grouping the plurality of resource groupings into one or more larger resource groupings.

75. The computer-readable medium of claim 69, wherein at least two of the resource groupings are different sizes.

76. The computer-readable medium of claim 69, wherein each hierarchical group level is determined using an M-ary tree structure, where M is an integer greater than two.

77. The computer-readable medium of claim 71, wherein each of the one or more addressable resource elements is assigned a 2-tuple address.

78. The computer-readable medium of claim 77, wherein the 2-tuple address includes a grouped flag and an allocable unit number.

79. The computer-readable medium of claim 72, wherein each of the one or more resource groupings is assigned a 3-tuple address.

80. The computer-readable medium of claim 79, wherein the 3-tuple address includes a grouped flag, a grouping level and an allocable unit number.

81. The computer-readable medium of claim 72, wherein at least two of the grouped addressable resource elements in a respective resource grouping are disjointed.

82. The computer-readable medium of claim 81, wherein the respective resource grouping is assigned a compound address.

83. The computer-readable medium of claim 82, wherein each individual address within the compound address includes a 1-bit flag indicating whether the individual address is last.

84. The computer-readable medium of claim 82, wherein the compound address includes a field indicating a number of individual addresses within the compound address.

85. The computer-readable medium of claim 82, wherein the compound address includes a bitmap including a bit for each grouping level, each bit indicating whether a resource grouping from each grouping level, respectively, is included in the compound address.

86. The computer-readable medium of claim 74, wherein at least two of the grouped plurality of resource groupings are disjointed.

87. The computer-readable medium of claim 86, wherein the grouped plurality of resource groupings is assigned a compound address.

88. The computer-readable medium of claim 87, wherein each individual address within the compound address includes a 1-bit flag indicating whether the individual address is last.

89. The computer-readable medium of claim 87, wherein the compound address includes a field indicating a number of individual addresses within the compound address.

90. The computer-readable medium of claim 87, wherein the compound address includes a bitmap including a bit for each grouping level, each bit indicating whether a resource grouping from each grouping level, respectively, is included in the compound address.

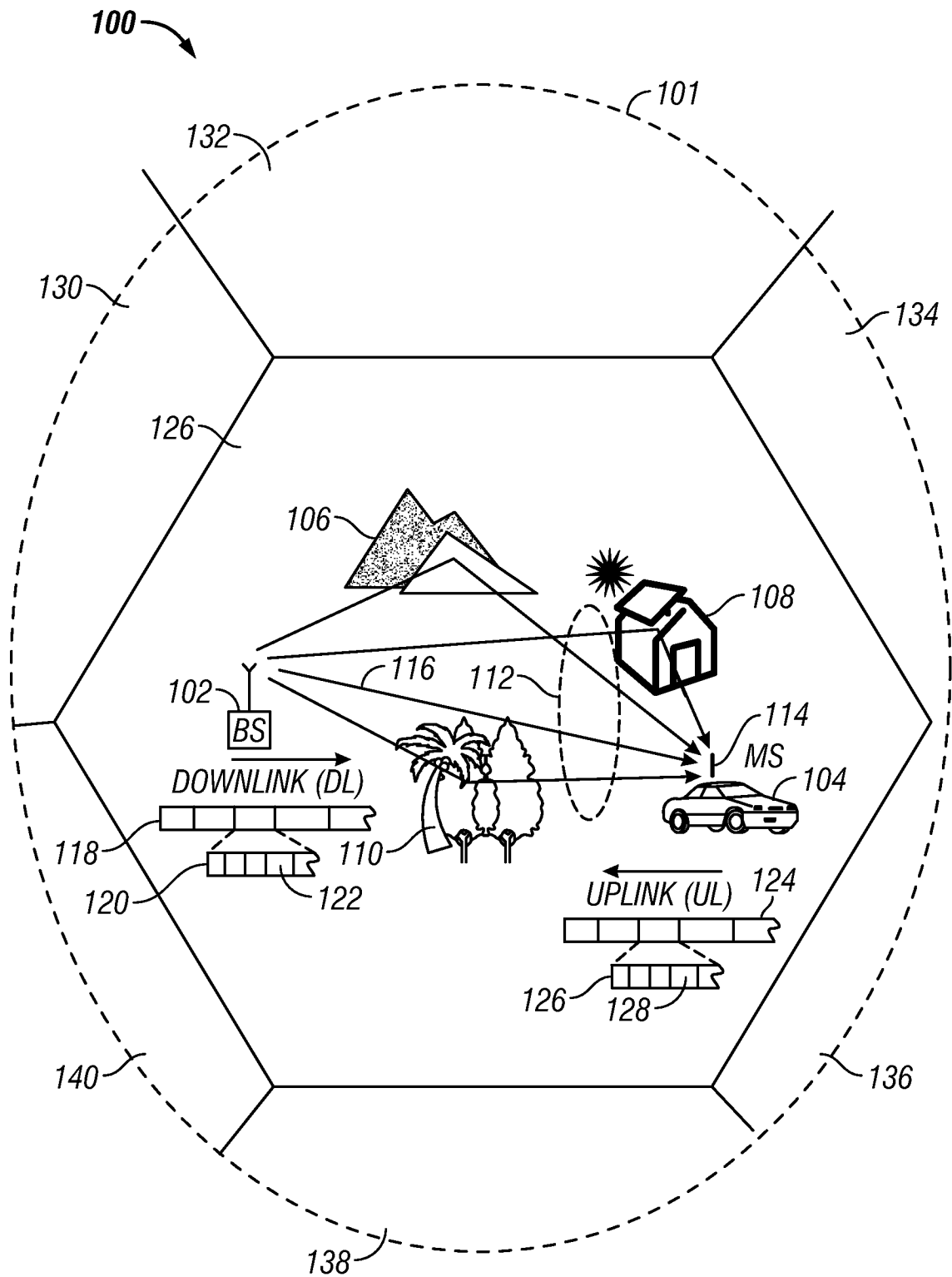


FIG. 1

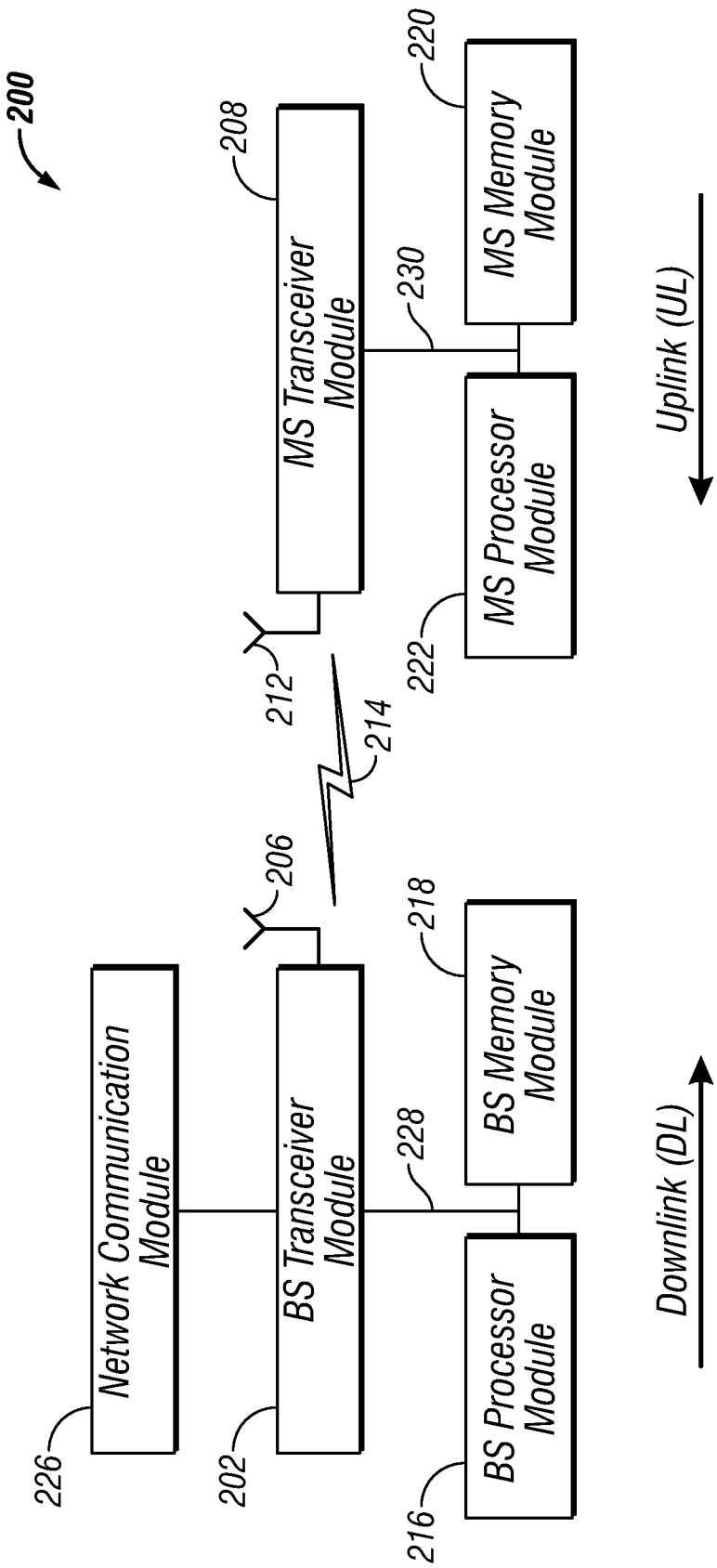
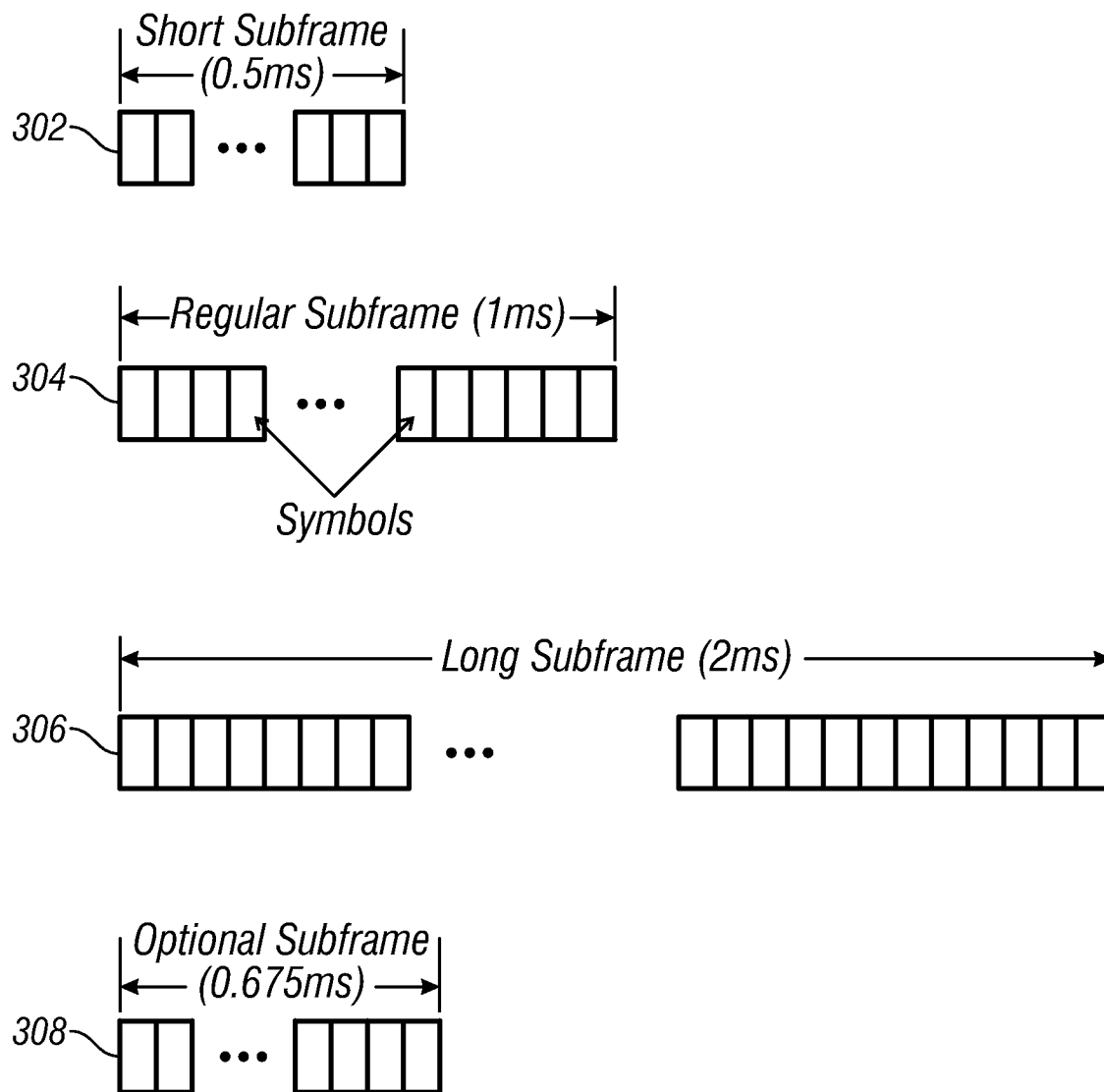


FIG. 2

**FIG. 3**

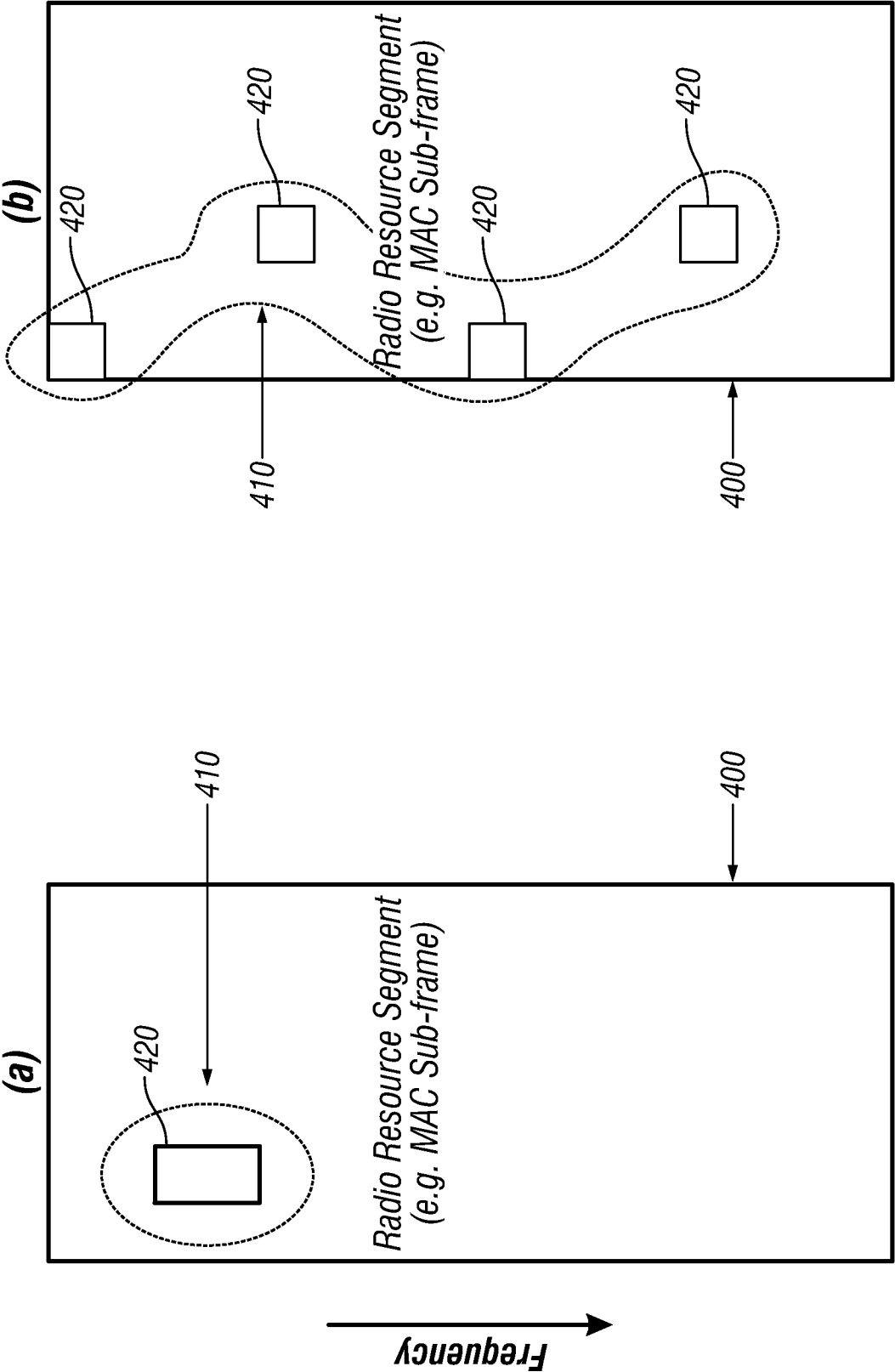
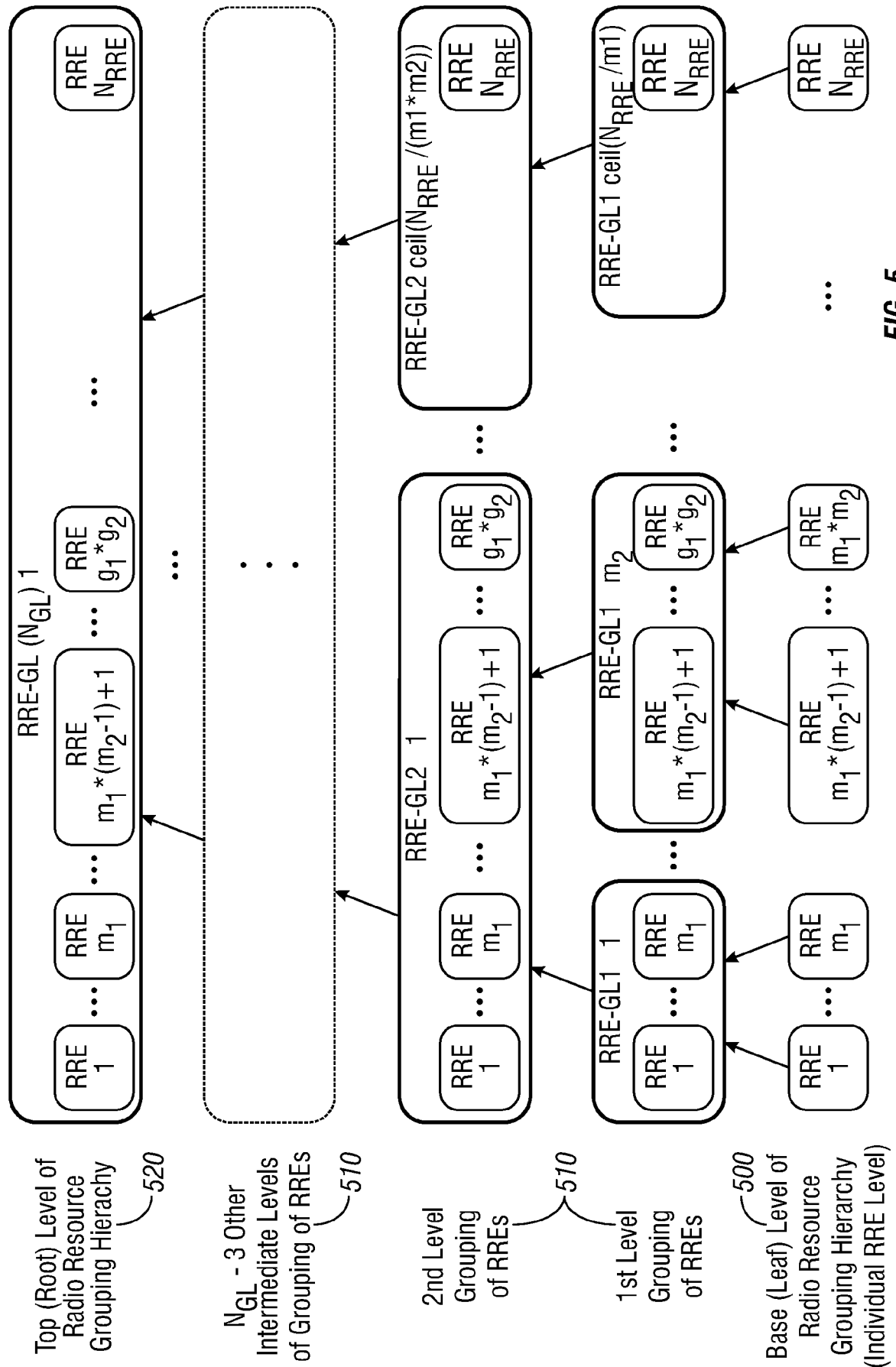


FIG. 4



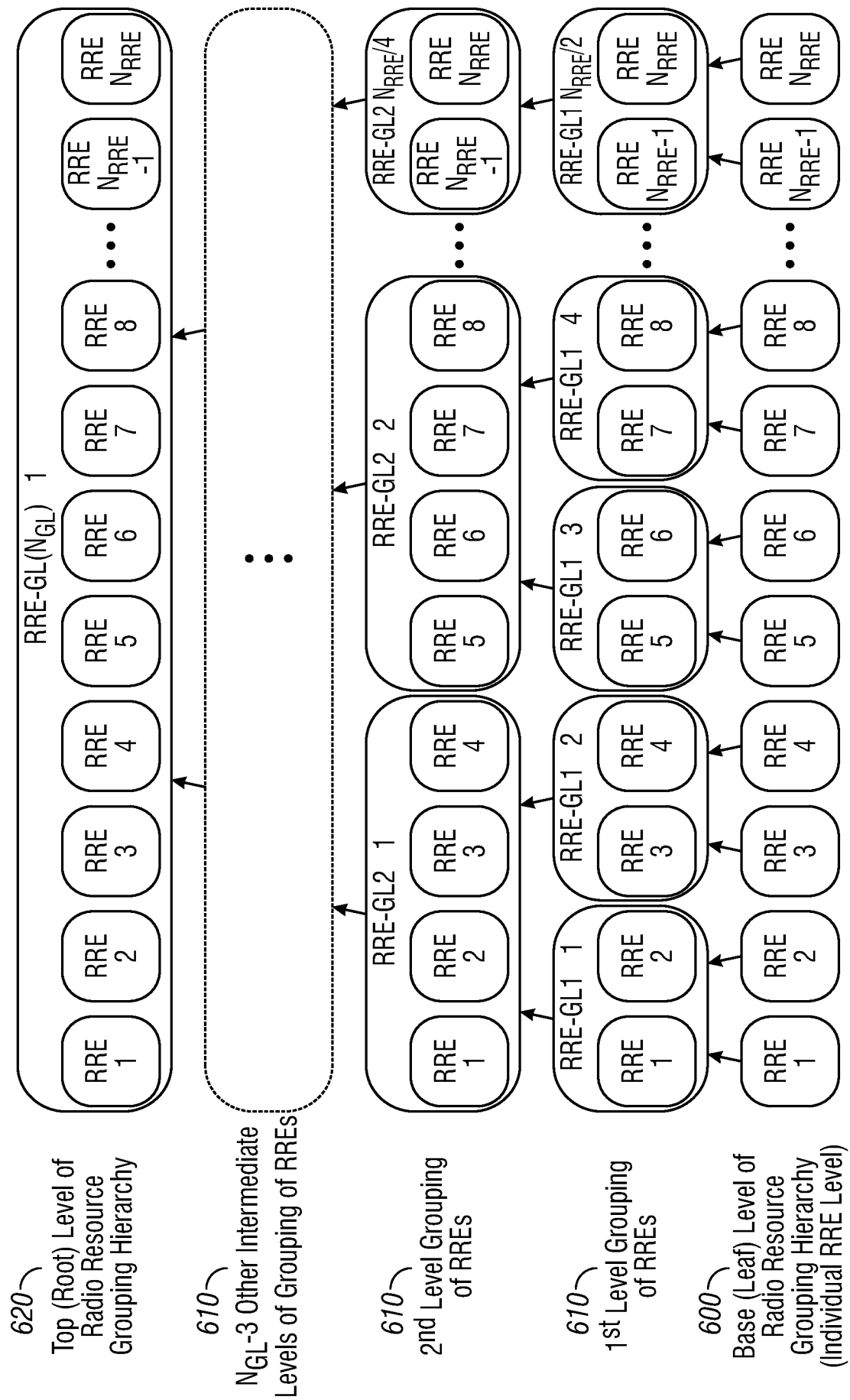


FIG. 6

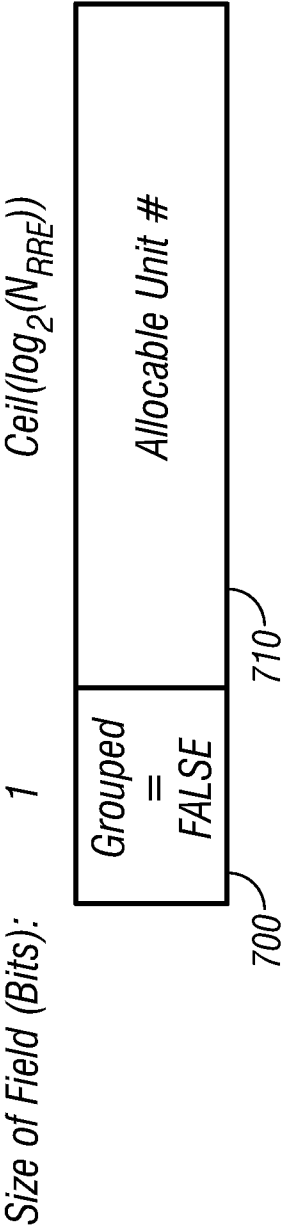


FIG. 7(a)

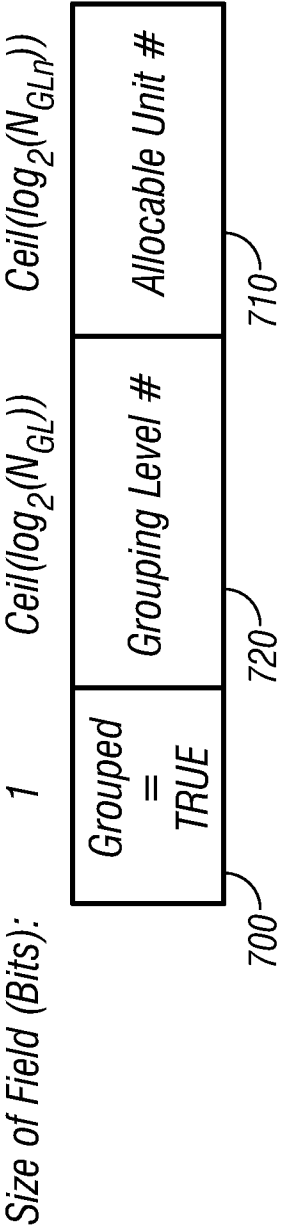


FIG. 7(b)

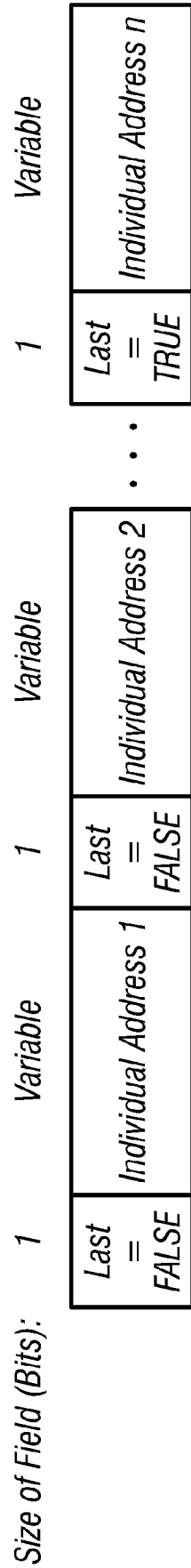


FIG. 8(a)

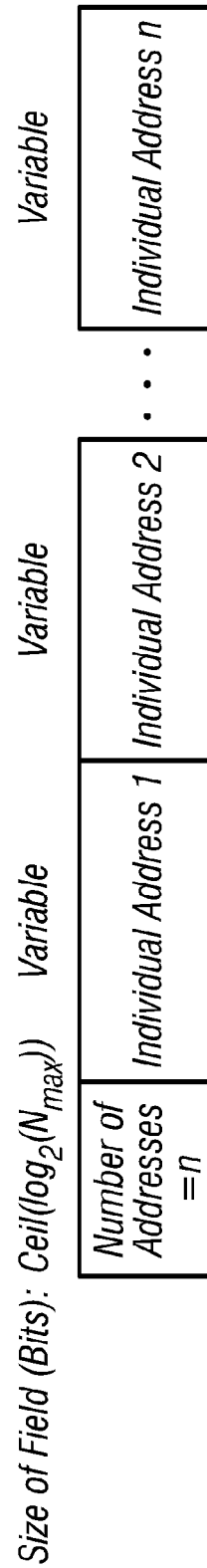


FIG. 8(b)

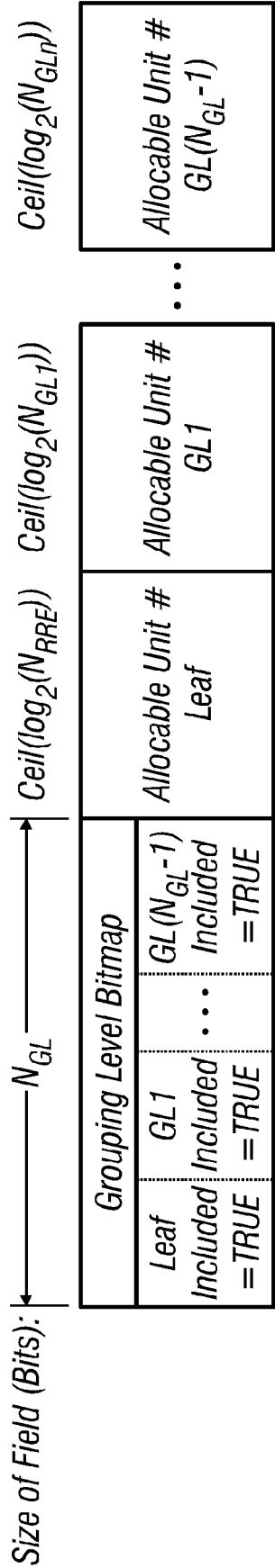


FIG. 9(a)

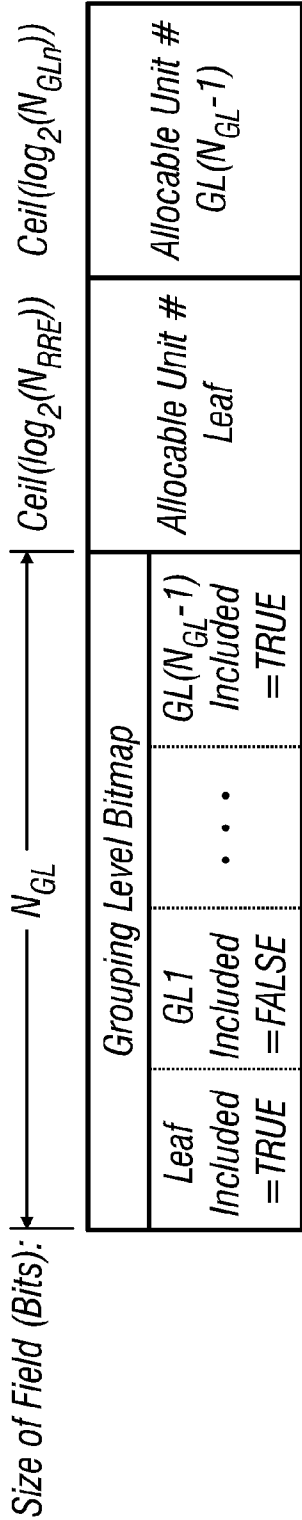


FIG. 9(b)

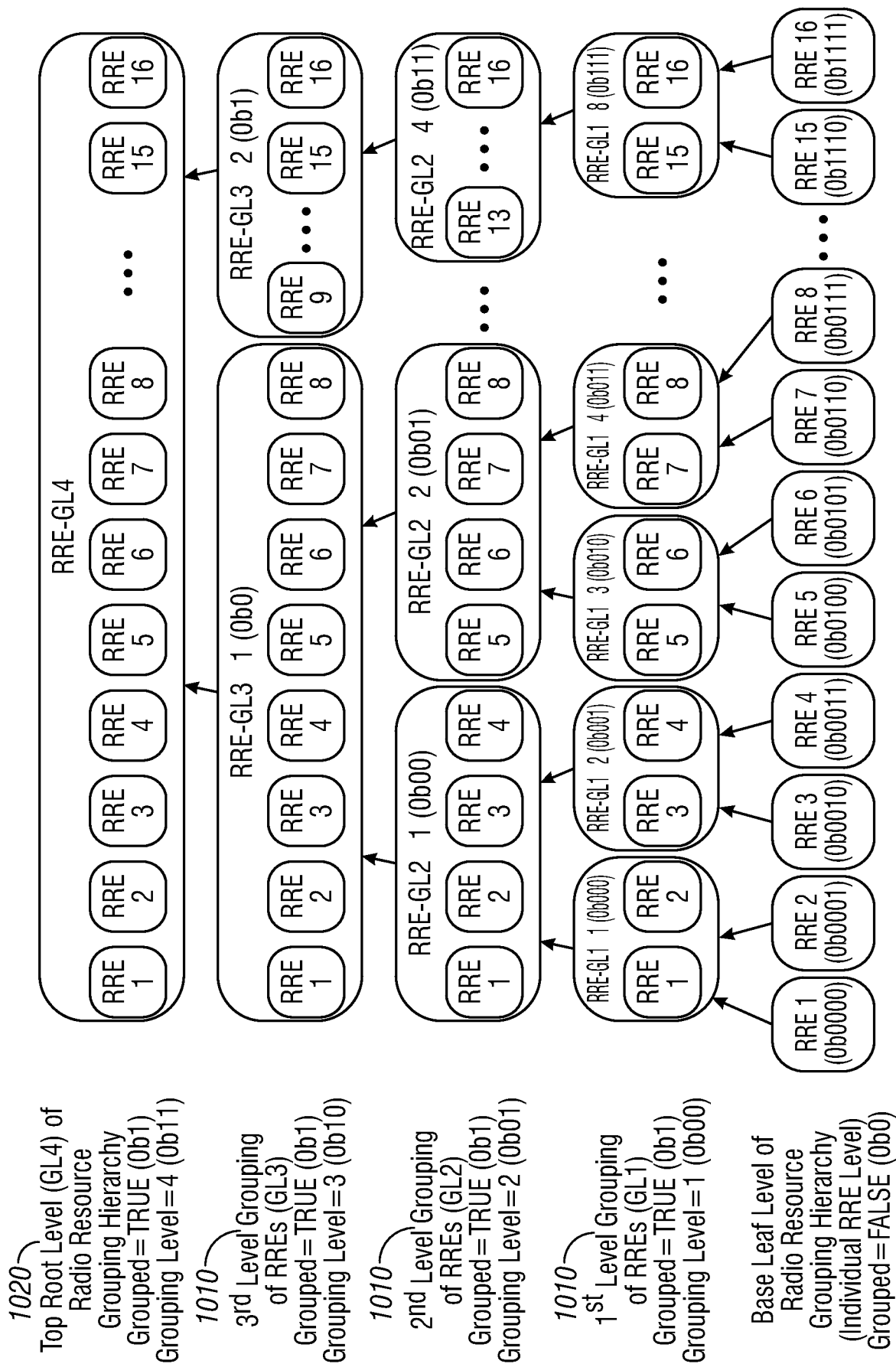


FIG. 10

