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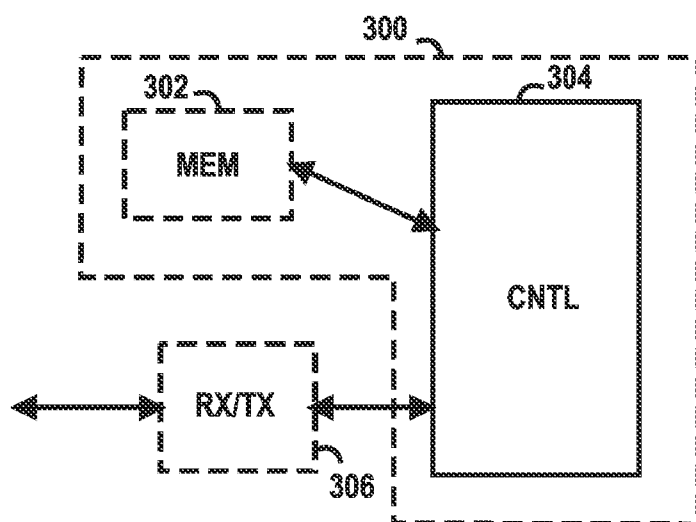
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(54) Title: ORTHOGONALIZATION OF CHANNELS AND/OR SIGNALS

FIG. 3



(57) Abstract: The invention is related to an apparatus comprising: a processor and a memory including a computer program code, the memory and the computer program code configured to, with the processor, cause the apparatus at least to: provide a plurality of orthogonalization levels; provide a plurality of physical cell identifiers; and determine a hierarchically organized relation between at least some of the orthogonalization levels and at least some of the physical cell identifiers for obtaining orthogonalization of a chosen type between resources.

Description

Title of the invention

5 Orthogonalization of Channels and/or Signals

Field

The invention relates to apparatuses, a method, computer program and computer program product for orthogonalization of channels and/or signals.

10 *Background*

The following description of background art may include insights, discoveries, understandings or disclosures, or associations together with disclosures not known to the relevant art prior to the present invention but provided by the invention. Some such contributions of the invention may be specifically pointed out below, whereas other such contributions of the invention will be apparent from their context.

15 In future communication networks, devices are able to use frequency spectrum in an intelligent self-organizing flexible manner by adapting their operation to the current situation by sensing the environment or based on pre-defined resource sharing policies, for instance.

20 Revolutionary optimized local area (REVOLA) concept is targeted to provide technologically and economically effective models for local area access and decentralized cognitive network architectures, as well as to enable cognitive radio and dynamic spectrum use.

Brief description

30 According to an aspect of the present invention, there is provided an apparatus comprising: a processor and a memory including a computer program code, the memory and the computer program code configured to, with the processor, cause the apparatus at least to: provide a plurality of orthogo-

nalization levels, provide a plurality of physical cell identifiers, and determine a hierarchically organized relation between at least some of the orthogonalization levels and at least some of the physical cell identifiers for obtaining orthogonalization of a chosen type between resources.

According to another aspect of the present invention, there is provided a method comprising: providing a plurality of orthogonalization levels, providing a plurality of physical cell identifiers, and determining a hierarchically organized relation between at least some of the orthogonalization levels and at least some of the physical cell identifiers for obtaining orthogonalization of a chosen type between resources.

According to yet another aspect of the present invention, there is provided an apparatus comprising: means for providing a plurality of orthogonalization levels, means for providing a plurality of physical cell identifiers, and means for determining a hierarchically organized relation between at least some of the orthogonalization levels and at least some of the physical cell identifiers for obtaining orthogonalization of a chosen type between resources.

According to yet another aspect of the present invention, there is provided a computer program product, embodied on a computer-readable medium configured to control a processor to perform a method, the method comprising: providing a plurality of orthogonalization levels, providing a plurality of physical cell identifiers, and determining a hierarchically organized relation between at least some of the orthogonalization levels and at least some of the physical cell identifiers for obtaining orthogonalization of a chosen type between resources.

According to yet another aspect of the present invention, there is provided a computer program distribution medium readable by a computer and encoding a computer program of in-

structions for executing a computer process, the process comprising: providing a plurality of orthogonalization levels, providing a plurality of physical cell identifiers, and determining a hierarchically organized relation between at least some of the orthogonalization levels and at least some of the physical cell identifiers for obtaining orthogonalization of a chosen type between resources.

List of drawings

Embodiments of the present invention are described below, by way of example only, with reference to the accompanying drawings, in which

Figure 1 illustrates an example of a system;

Figure 2 is a flow-chart; and

Figure 3 illustrates embodiments of an apparatus.

Description of embodiments

The following embodiments are only examples. Although the specification may refer to "an", "one", or "some" embodiment(s) in several locations, this does not necessarily mean that each such reference is to the same embodiment(s), or that the feature only applies to a single embodiment. Single features of different embodiments may also be combined to provide other embodiments.

Embodiments are applicable to any user terminal, server, corresponding component, and/or to any communication system or any combination of different communication systems that support required functionality.

The protocols used, the specifications of communication systems, servers and user terminals, especially in wireless communication, develop rapidly. Such development may require extra changes to an embodiment. Therefore, all words and expressions should be interpreted broadly and they are intended to illustrate, not to restrict, embodiments.

In wireless communication, in principle, users which typically are operators (or customers of the operators) have to obtain dedicated radio spectrum resources from national regulators. The radio spectrum resource may be utilized independently by each operator without interference coordination. Moreover, the operator is typically not allowed to use another operator's dedicated spectrum even when that is not utilized. In this case, the spectrum efficiency is not maximized and the peak data-rate is reduced due to limited bandwidth dedicated to each operator. However, since the radio spectrum is a limited natural resource, independent radio systems, such as military radars, broadcasters, cellular radio systems, and/or independent operators or users may share the same radio spectrum, and since the usage of wireless communication is increasing, the more efficient usage of radio spectrum becomes more and more important.

In future communication networks, devices are able to use the spectrum in an intelligent self-organizing flexible manner by adapting their operation to the current situation by sensing the environment or based on pre-defined resource sharing policies, for instance.

Revolutionary optimized local area (REVOLA) concept provides a local area radio system designed to complement existing cellular wide area systems, such as global system for mobile communications (originally from groupe spécial mobile (GSM)), universal mobile telecommunications system (UMTS), high-speed packet access (HSPA), long-term evolution (LTE) and LTE-Advanced. In addition to licensed frequency bands, the local area system is able to utilize license-exempt spectrum or white spaces (In this context, white spaces typically refer to spectrum allocated to a broadcasting service but not used in a certain geographical area, or spectrum left unused when analogue TV-broadcasts are terminated) to take advantage of additional available bandwidth. This is typically based on

utilizing a cognitive radio concept. Additionally, the local area system may offer an efficient device-to-device operation mode to establish ad-hoc networks. Local area technologies allow multi-operator local radio access on a licensed and
5 unlicensed spectrum. These technologies are mainly designed to be an extension of traditional wide area networks to provide high-capacity Internet type of access for limited, high demand areas, such as indoor hot-spots or enterprise buildings.

10 License-exempt (LE) or unlicensed frequency bands are parts of frequency spectrum that are only lightly regulated; users do not need licenses to exploit them. Some of main services using LE spectrum are wireless local area networking technologies, such as wireless fidelity (WiFi), wireless local
15 area network (WLAN), mesh networks, voice over Internet protocol (VoIP) telephony, etc.

In communication networks, an ad-hoc mode is suitable for wireless devices to directly communicate with each other. Operating in an ad-hoc mode allows wireless devices within a
20 radio range of each other to communicate without involving central access points, such as base stations.

Cognitive radio is viewed as an approach to improve the utilization of the radio spectrum by providing a spectrum sharing scheme. The cognitive radio, which is typically built
25 on a software-defined radio, may be defined as an intelligent wireless communication system that is aware of its environment and is able to learn from it and adapt to its statistical variations.

One basic concept behind the cognitive radio is a so
30 called spectrum hole. A spectrum hole is a band of frequencies (or even only one frequency) allocated to a primary user but not used by that user in a particular time or geographic location. Spectrum utilization may be improved by enabling a secondary user to access such a spectrum hole. This requires

cooperation techniques between primary and secondary users and/or between different secondary users.

In conventional wireless communications built around base stations or corresponding network devices, transmission power levels are usually controlled by these base stations in a centralized manner. But the principle of cognitive networks is operation in a decentralized manner. In such a network, some alternative means must be found for controlling transmission powers. Thus cooperation mechanisms to enable multiple access to such a network have to be developed. The cooperation mechanisms may include etiquette or protocol for cooperative ad hoc networks wherein users communicate with each other without any fixed infrastructure. It is thus possible to use and share the spectrum in an efficient manner and even to use the currently available best channel.

Many different radio protocols to be used in communications systems exist. Some examples of different communication systems are the universal mobile telecommunications system (UMTS) radio access network (UTRAN or E-UTRAN), long term evolution (LTE, the same as E-UTRA), wireless local area network (WLAN), worldwide interoperability for microwave access (WiMAX), Bluetooth®, personal communications services (PCS) and systems using ultra-wideband (UWB) technology.

In the following, different embodiments will be described using, as an example of a system architecture whereto the embodiments may at least partially be applied, an architecture based on evolved UMTS terrestrial radio access (E-UTRA, UMTS = universal mobile telecommunications system, or long term evolution (LTE), also used in LTE-Advanced) without restricting the embodiment to such an architecture, however. The LTE architecture is chosen due to the fact that the radio interface of REVOLA concept is derived from the radio interface designed in 3GPP LTE-Advanced standardization. However, some modifications to the LTE-Advanced radio are needed, for

example taking into account that uncoordinated deployments and dynamic time-division-duplex (TDD) switching points are likely to be used.

It should be appreciated that cognitive radio concept
5 is not tied to certain radio standards or protocols. The network may be a cellular network or a non-cellular network, such as wireless local area network (WLAN). It may even be applied to a network built on the usage of direct radio connections between user devices, such as radiotelephones. In the
10 future, many networks are organized and built in such a manner that data is transferred as near the target as possible as is the principle in the Internet Protocol. Additionally, cognitive radio concept can be applied not only in cooperative systems but also in opportunistic (non-cooperative) systems.
15

Figure 1 is a simplified system architecture only showing some elements and functional entities, all being logical units whose implementation may differ from what is shown. The connections shown in Figure 1 are logical connections;
20 the actual physical connections may be different. It is apparent to a person skilled in the art that the systems also comprise other functions and structures. It should be appreciated that the functions, structures, elements and the protocols used in or for group communication, are irrelevant
25 to the actual invention. Therefore, they need not to be discussed in more detail here.

Figure 1 shows a part of a radio access network of E-UTRAN. E-UTRAN utilises Orthogonal Frequency Division Multiple Access (OFDMA) in downlink and Single Carrier Frequency
30 Division Multiple Access (SC-FDMA) in uplink. The communications system is a cellular radio system which comprises a base station (or (e)Node B) 108, which has bi-directional radio links 104 and 106 to user devices 100 and 102. The user devices may be fixed, vehicle-mounted or portable. The user

devices 100 and 102 may refer to portable computing devices. Such computing devices include wireless mobile communication devices operating with or without a subscriber identification module (SIM), including, but not limited to, the following
5 types of devices: mobile phone, multimedia device, personal digital assistant (PDA), handset. A user device may also be called as a user terminal, user equipment (UE), etc.

In the Figure 1, the user devices have two antennas, but it is obvious for a person skilled in the art that the
10 number of antennas may vary from case to case.

The base station (or (e)NodeB) includes transceivers, for instance. From the transceivers of the base station, a connection is provided to an antenna unit that establishes bi-directional radio links to the user devices. The base sta-
15 tion is further connected to a core network 110 (CN) directly or possibly via another device, such as another base station. Depending on the system, the counterpart on the CN side can be a mobile services switching center (MSC), a media gateway (MGW) or a serving GPRS (general packet radio service) sup-
20 port node (SGSN), etc. The base station or (e)NodeB may be any node, host, server or other equipment including suitable functionality.

In the Figure 1, the (e)NodeB has a group antenna, but it is obvious for a person skilled in the art that this
25 is only one example of possible antenna constructions.

It should be understood that in future radio networks, the functionality of a radio network controller (typically in-
cluding controlling several base stations and they connec-
tions to the core network) may be distributed among (possibly
30 a subset of) base stations. This is the case for instance in LTE, where an (e)Node B may include the functionality of both a base station and a radio network controller. Thus the radio network controller and base station are depicted as a same block 108 in Figure 1.

It is obvious for a person skilled in the art that the system may comprise more (e)Node Bs and user devices (or core networks) than depicted in Figure 1. The (e)NodeBs may also be configured to communicate with each other over links, typically radio links, designed for the purpose. These links may be used for signalling purposes. These links are not shown in the Figure.

It should also be understood that in the future radio networks, a direct communication between wireless devices is also possible. In this operating mode, typically called ad-hoc mode, central access points, such as base stations, are not needed. In such a case, needed functionality for cooperation may be distributed among user devices.

The embodiments are not, however, restricted to the system given as an example but a person skilled in the art may apply the solution to other communication systems provided with the necessary properties. Different radio protocols may be used in the communication systems in which embodiments of the invention are applicable. The radio protocols used are not relevant regarding the embodiments of the invention.

The communication system is also able to communicate with other networks, such as a public switched telephone network or the Internet 112.

Next, an embodiment of a method providing orthogonality for resources will be described with reference to Figure 2. The embodiment starts in block 200.

Optimization of heterogeneous networks, relays and coordinated multipoint transmission (CoMP), etc. requires certain degree of orthogonalization of control channels and reference signals between resources within a cell or between neighbouring cells. This is needed in order to provide robust enough system operation, for instance.

In block 202, a plurality of orthogonalization levels is provided.

In communication systems, orthogonality of resources is used to diminish or even prevent producing undesired effects and/or them to propagate to other resources of the system.

The level of orthogonalization may herein mean that the amount of orthogonalization ((almost) full or partial) may vary, orthogonalization may be implemented in various ways, or in addition to the orthogonalization, some other parameters, such as frequency hopping pattern, scrambling, and cross-correlation, may be taken into account. It is even possible that resources are not orthogonal in the strict sense of the established meaning of the word, or mathematically speaking, but undesired effects are controlled by the other parameters listed above. The concept of orthogonalization levels will be explained below in more details by means of some examples. Some communication standards, such as LTE, take advantage of the benefits of orthogonalization.

In block 204, a plurality of physical cell identifiers is provided.

Physical cell identification (PCI) is considered herein to be an identifier that is used to separate one cell from another. A limited space of PCIs is provided, therefore in large systems, multiple cells may exist with the same PCI. However, it is possible to arrange neighborhood in such a manner that no neighbor cells have the same PCI. The PCI may be explicitly signaled by the cell in an appropriate control, broadcast or beacon channel information element, or it may be implicitly signaled by a specific structure (waveform, frequency/time domain placement etc.) on one or more physical channel, such as a synchronization channel.

In LTE, a physical cell identification is determined by a primary and secondary synchronization channels. 3 primary and 168 secondary --synchronization sequences that is altogether 504 different synchronization sequences are provided. Many properties of other channels, such as cell specific scram-

bling, reference signal structure, etc., are determined based on the PCI.

In LTE, downlink common reference signals are partially orthogonalized. This orthogonalization is characterized by PCI.

5 Standard 36.211 v8.6.0 defines a physical cell identification (ID) in LTE:

504 unique physical-layer cell identities are provided. The physical-layer cell identities are grouped into 168 unique physical-layer cell-identity groups, each group containing
10 three unique identities. The grouping is such that each physical-layer cell identity

$$N_{ID}^{cell} = 3N_{ID}^{(1)} + N_{ID}^{(2)} \quad (1)$$

is a part of one and only one physical-layer cell-
15 identity group. A physical-layer cell identity is thus uniquely defined by a number $N_{ID}^{(1)}$ in the range of 0 to 167, representing the physical-layer cell-identity group, and a number $N_{ID}^{(2)}$ in the range of 0 to 2, representing the physical-layer identity within the physical-layer cell-identity group.
20 PCI in LTE is used to orthogonalize downlink (DL) common reference signals (RS) which is disclosed in LTE standard 36.211 v8.6.0:

The cell-specific subcarrier shift for a reference signal is given by

$$25 \quad v_{shift} = N_{ID}^{cell} \bmod 6 \quad (2)$$

This means that 6 downlink (DL) reference signals (RSs) may be orthogonalized in the frequency domain, and this orthogonalization is directly managed by the PCI of the cell. However,
30 ever, in LTE, other information may also be transmitted on subcarriers not used for RS-orthogonalization, thus these 6 RSs may be orthogonalized against each other, but they are

not typically orthogonalized against transmissions on other channels. Therefore, in that sense, the orthogonalization in this case is only partial.

In LTE, uplink (UL) reference signal sequences of different
 5 bandwidths are grouped into 30 sequence groups. Sequences with most severe cross-correlations are grouped into the same sequence group. PCI is used to indicate the used sequence group so that a different sequence group is used in cells having PCIs with difference less than or equal to 30. If se-
 10 quence group hopping is enabled, different sequence groups are guaranteed only for cells within the same group hopping pattern. On the other hand, group hopping pattern is defined by PCI, and cells with consecutive PCIs typically have the same group hopping pattern. Thus PCI is used to avoid the use
 15 of the same sequence group in near by cells.

The sequence-group number u in slot n_s is defined by a group hopping pattern $f_{gh}(n_s)$ and a sequence-shift pattern f_{ss} according to

$$u = (f_{gh}(n_s) + f_{ss}) \bmod 30 \quad (3)$$

20

There are 17 different hopping patterns and 30 different sequence-shift patterns. Sequence-group hopping can be enabled or disabled by means of the parameter group-hopping-enabled provided by higher layers. Physical uplink control
 25 channel (PUCCH) and physical uplink shared channel (PUSCH) have the same hopping pattern but may have different sequence-shift patterns.

The group-hopping pattern $f_{gh}(n_s)$ is the same for PUSCH and PUCCH and given by

$$30 \quad f_{gh}(n_s) = \begin{cases} 0 & \text{if group hopping is disabled} \\ \left(\sum_{i=0}^7 c(8n_s + i) \cdot 2^i \right) \bmod 30 & \text{if group hopping is enabled} \end{cases} \quad (4)$$

where the pseudo-random sequence $c(i)$ is defined by section 7.2. The pseudo-random sequence generator shall be initialized with

$$c_{\text{init}} = \left\lfloor \frac{N_{\text{ID}}^{\text{cell}}}{30} \right\rfloor \quad (5)$$

5

at the beginning of each radio frame.

The sequence-shift pattern f_{ss} definition differs between PUCCH and PUSCH.

For PUCCH, the sequence-shift pattern $f_{\text{ss}}^{\text{PUCCH}}$ is given

10

$$\text{by } f_{\text{ss}}^{\text{PUCCH}} = N_{\text{ID}}^{\text{cell}} \bmod 30 \quad (6)$$

For PUSCH, the sequence-shift pattern $f_{\text{ss}}^{\text{PUSCH}}$ is given by

$$f_{\text{ss}}^{\text{PUSCH}} = (f_{\text{ss}}^{\text{PUCCH}} + \Delta_{\text{ss}}) \bmod 30, \quad (7)$$

15 where $\Delta_{\text{ss}} \in \{0, 1, \dots, 29\}$ is configured by higher layers.

In block 206, a hierarchically organized relation between at least some of the orthogonalization levels and at least some of the physical cell identifiers is determined for obtaining orthogonalization of a chosen type between resources.

20 This kind of cell identity may be called as a hierarchical physical-layer cell identity in which the hierarchy encompasses different levels of orthogonality for different channels and/or signals. Thus, a hierarchically organized relation may be a relation wherein different levels of orthogonality for different channels and/or signals are provided and they are organized in a hierarchic order.

25 It should be appreciated that multiple resources for different purposes, such as DL common RS, UL RS, may be configured by this kind of PCI in such a manner that reasonable orthogonalization between neighbouring cells is achievable with PCI allocation.

30

Hierarchic organization makes it possible to organize cells in such a manner that cells with small differences in PCI values have more orthogonal resource allocation between each other than cells with larger differences in PCI values.

5 Additionally, at least a part of a hierarchical PCI on a higher level may indicate a preferred order of using orthogonal resources distributed on a lower hierarchical level.

 In one embodiment, uplink and/or downlink channels and/or signals are linked to separate orthogonal resource
10 pools. This is especially feasible in the case where uplink and/or downlink channel structure is based on LTE-Advanced system.

 In another embodiment, uplink and/or downlink channels and/or signals are linked to the same orthogonal re-
15 source pool, such as a reference signal pool. This is especially feasible in the case of a local area optimized TDD system with a flexible uplink and/or downlink switching point. This may also provide robust system operation under crossed-slot interference that is under interference from up-
20 link to downlink and/or downlink to uplink.

 In the following, some clarifying examples are explained in further detail. The examples are presented only for clarification purposes and they do not limit the implementation of embodiments by any means. For instance, the em-
25 bodiments are not restricted to reference signals or control signals, but may be implemented for several kinds of signals.

 The first example is suitable for a system based on the LTE-advanced standard, where uplink and downlink signals are linked to separated orthogonal resource pools. Following
30 orthogonalization levels may be used: level 0: resources are orthogonal, used within one radio cell, level 1: resources are orthogonal, used between different radio cells, level 2: resources are non-orthogonal, but have reasonable cross-

correlation, and level 3: resources are same, but randomized with hopping pattern or scrambling.

In the first example, the following assumptions are made: a downlink common reference signal uses orthogonal re-
 5 sources (level 1), and for an uplink reference signal 12 orthogonal resources are provided of which 4 is used within a cell (level 0) leaving 3 sets of orthogonal resources for inter-cell usage (level 1). Further, 30 resources with reasonable cross-correlation (level 2) and N (multiple of 6 from
 10 downlink common reference signal) resources with level 3 are also provided.

Table 1 shows an example of mapping between PCI and a physical resource index for uplink and downlink reference signals with resource specific and hierarchical correlation
 15 properties according to the first example:

PCI	DL common RS		UL RS		
	Level 1	Level 3	Level 1	Level 2	Level 3
0	0	0	0	0	0
1	1	0	1	0	0
2	2	0	2	0	0
3	3	0	0	1	0
4	4	0	1	1	0
5	5	0	2	1	0
6	0	1	0	2	0
7	1	1	1	2	0
8	2	1	2	2	0
9	3	1	0	3	0
10	4	1	1	3	0
⋮	⋮	⋮	⋮	⋮	⋮
88	4	14	1	29	0
89	5	14	2	29	0

90	0	15	0	0	1
91	1	15	1	0	1
92	2	15	2	0	1
⋮	⋮		⋮	⋮	⋮

Table 1

In the example shown in Table 1, for example, the cell with PCI 1 uses the orthogonal resource 1 for downlink (DL) RS, with non-orthogonal scrambling/cross-correlation code 0. The cell with PCI 4 uses orthogonal resource 4, and scrambling 0. However, the cell with PCI 7 uses the same orthogonal resource, but different non-orthogonal scrambling/cross-correlation. Simultaneously, uplink (UL) RSs are tied to the PCI so that the cell with PCI 1 uses the same set of orthogonal resources for UL RS as the cells with PCI 4 and 7, but all use different scrambling/cross-correlation codes. The hierarchical orthogonalization can be seen for example in that DL RSs are fully orthogonal between cells for which UL RSs are non-orthogonal. Thus UL RSs are orthogonalized within a smaller group of cells than DL RSs.

The second example is suitable for a system which is based on the LTE-advanced standard, where uplink and downlink signals are linked to the same orthogonal resource pool.

In this example, the kind of local area TDD optimization is considered, where uplink and downlink transmissions may be orthogonalized between cells. It is assumed that transmission formats where channels and users may be frequency division multiplexed, such as in OFDM, are used both in uplink and downlink. At a base station (or (e)nodeB), up to eight transmission and reception antennas are provided, and at a user device, up to 2 transmission antennas are provided. Hence, the maximum number of reference signals needed per cell and per physical resource is 8. In addition to ref-

erence signals, an option to hierarchically orthogonalize at least one of the following channels is provided: downlink synchronization channels, uplink random access channel (RACH), downlink broadcast channels, uplink and downlink common control channels, uplink and downlink request to send / clear to send (RTS(CTS) -type channels, downlink over-the-air (OTA) signalling, and downlink and uplink shared channels.

A frame structure, where a slot may be used for uplink in one cell and for downlink in another one, exists. In this frame structure, reference signals, common control channels including positive acknowledgement (ACK) and negative acknowledgement (NACK) channels, and shared channels may be in any slot. The periodicity of synchronization channels, broadcast channels, random access channel, paging channels as well as possible OTA-channels and/or RTS/CTS/busy burst channels is in relation to a frame structure or a multi-frame structure.

The third example is suitable for reference signals and control channels (common control channel, CCH). As in LTE downlink, inter-cell orthogonalization may be implemented by applying frequency division multiplexing (FDM), and inter-cell orthogonalization of multistream and multiple input-multiple output (MIMO) transmissions by code division multiplexing (CDM). Additionally, restrictions for use of reference signal subcarriers of one cell for other channels in other cells may exist. It is assumed herein that control channels may at least partially use the same resources as reference signals of neighbouring cells. It is also assumed that reference signals and control channels are uplink/downlink neutral. In this example, orthogonal resources reserved for a common reference signal for downlink multiantenna transmissions are used for uplink MIMO and virtual MIMO reference signal transmission in uplink slots. Resources used for a common control channel in downlink are used for an up-

link control channel in uplink slots. In downlink, both common and potential dedicated reference signals may be orthogonalized. In uplink, both demodulation and potential sounding reference signals may be orthogonalized.

5 Following orthogonalization levels may be used for reference signals: level 0: resources are orthogonal and used for multiantenna and/or multiuser transmissions within one radio cell, level 1: resources are orthogonal between radio cells, level 2: reference signals are orthogonal between
10 cells and the resources used for reference signals in one radio cell are used for other channels and/or signals (for example for control signals) in other cells, and level 3: resources are same, but they are randomized by hopping or scrambling.

15 The level 0 orthogonality is used for code/frequency/time division multiplexing reference signals for multiantenna transmissions. When these orthogonalization levels are used in a radio cell, the nearest neighbouring cells may use the level 1, the next nearest may use the level
20 2, and farthest neighbours may use the level 3 orthogonalization. It should be understood that, in fact, strictly speaking, the level 3 orthogonalization is not proper orthogonalization, but undesired effects are controlled by other parameters, such as cross-correlation, hopping pattern and scrambling.
25

 Following orthogonalization levels may be used for common control channels: level 0: resources are orthogonal, used within one radio cell, level 1: resources are orthogonal between radio cells, level 2: common control channels (CCCHs)
30 are orthogonal between radio cells and the resources used for common control channels in one radio cell are used for other channels and/or signals (for example for reference signals) in other cells., and level 3: resources are same, but they are randomized by hopping or scrambling.

Table 2 shows an example of orthogonalization of reference signals and common control channels, the former with reuse of 4 and the latter with reuse of 2. The word "level" is shortened as "L" in the Table 2. Further, "X" denotes a resource which is used for a reference signal and "++" denotes a primary resource used for CCCH.

subcarrier	PCI						
	0	1	2	3	4	5	6
0	X				X		
1		X				X	
2			X				X
3				X			
4	++		++		++		++
5	++		++		++		++
6		++		++		++	
7		++		++		++	
L1 RS orthog	0	1	2	3	0	1	2
L3 RS scrambling	0	0	0	0	1	1	1
L1 CCH orthog	0	1	0	1	0	1	0
L3 CCH scrambling	0	0	1	1	2	2	3

Table 2.

In the first alternative embodiment shown in Table 2, reference signals and control channels are orthogonalized

separately and the orthogonalization level 2 is not used. Resources used for reference signals and resources used for control channels are orthogonal with respect to all cells.

In Table 2, an example of sharing resources is shown, where reference signals have been orthogonalized by using 4 resources (frequency division multiplex (FDM) subcarriers, for instance) thus enabling orthogonalization between 4 cells (reuse factor is 4), and control channels have been orthogonalized by using a reuse factor 2.

In the example, subcarriers not indicated to have RSs or CCCHs are assumed not to be used in a cell. Reference signal resources are distributed according to the level 1 orthogonalization and identified by PCI modulo 4 and by a level 3 scrambling code that is identified by $\text{floor}(\text{PCI}/4)$, wherein $\text{floor}(x)$ denotes the largest integer smaller or equal to x . CCH resources are distributed according to level 1 and identified by PCI modulo 2 and a level 3 scrambling code and by $\text{floor}(\text{PCI}/2)$.

In the second alternative embodiment, reference signals and control channels are orthogonalized at least substantially simultaneously in such a manner that resources not used by the reference signals in one cell may be at least partially used for control channels, or possibly for some other channels. Orthogonalization levels 1 to 3 are used. One example is depicted in Table 3 below. In the example, 6 resources, such as subcarriers, are provided and reference signals are orthogonalized by a reuse factor 2.

On the orthogonalization level 1, resources used are identified by index $1 = \text{PCI modulo } 2$. Subcarriers, the subcarrier index of which is denoted by S that fulfil $S \text{ modulo } 2 = \text{index } 1$, are used for reference signals and control channels in a radio cell. On the orthogonalization level 2, partial orthogonality between resources used in different cells for reference signals and control channels is determined.

This level is characterized by index $2 = (\text{floor}(\text{PCI}/2) \bmod 3)$. The index indicates which one of sequences of three resources reserved for the use of reference signals and control channels in one cell is actually used for the reference signals. Scrambling on level 3 is characterized by $\text{floor}(\text{PCI}/6)$.

Potential secondary and tertiary resources for control channel usage (or optionally for shared channel usage) are indicated in Table 3. Term "secondary resources" means resources which are used by reference signals in a cell belonging to the group of orthogonalization levels 2 and 3 and term "tertiary resources" means resources used by control channels in the same group of orthogonalization levels 2 and 3. When the reliability of a control channel is taken into account, the secondary resources are preferable, as they are disturbed by known transmissions, in other words by reference signals of neighbouring cells. On the other hand, if neighbouring cell channel estimation matters, the tertiary resources are more suitable.

A plurality of ways for arranging same resources to reference signals and control channels exists. In Table 3, if secondary and tertiary control channel resources are not used, the cell that has PCI 2 (with index $2 = 1$) is fully orthogonal with the cell having PCI 0, and fully overlapping (although with at least partially different channels) with the cell having PCI 1 (the two latter cells with index $2 = 0$). It may be desirable to achieve a situation, where interference between cells having different indexes is as even as possible. Such an example is depicted in Table 4 further below.

Table 3 shows an example of joint reference signal and control channel orthogonalization when partial non-orthogonality exists between channels. In the Table 3, the word "level" is marked as "L". Further, "X" denotes a resource which is used for a reference signal "+" denotes a

primary resource used for CCCH, "+++" denotes a secondary resource used for CCCH or potentially for another channel, and an empty spot denotes a tertiary resource used for CCCH or potentially for another channel.

5

subcarrier	PCI						
	0	1	2	3	4	5	6
0	X	+++	++		++		X
1	+++	X		++		++	+++
2	++		X	+++	++		++
3		++	+++	X		++	
4	++		++		X	+++	++
5		++		++	+++	X	
L1 orthog	0	1	0	1	0	1	0
L2 mix orthog channels	0	0	1	1	2	2	0
L3 scramb	0	0	0	0	0	0	1

Table 3.

Table 4 shows an example of joined reference signal and control channel orthogonalization, wherein partial non-orthogonality exists between channels, and more even orthogonality between cells belonging to different groups of orthogonalization level 2 is provided.

10

subcarrier	PCI						
	0	1	2	3	4	5	6
0	X	+++		++		++	X
1	+++	X	++		++		+++
2		++	X	+++		++	
3	++		+++	X	++		++

4		++		++	X	+++	
5	++		++		+++	X	++
L1 orhtog	0	1	0	1	0	1	0
L2 mix orthog channels	0	0	1	1	2	2	0
L3 scramb	0	0	0	0	0	0	1

Table 4.

In the example of Table 4, the usage of resources is arranged in such a manner that all cells with different index 2 collide partially, even if secondary and tertiary control channel resources are not used. Collision takes place between control channels in one resource in the case of same index 1, and between a control channel and a reference signal in one resource, and vice versa in another cell in the case of different index 1s.

In addition to scrambling or hopping, the orthogonalization level 3 may be extended to indicate a preferred order of the usage of reference signals. It may occur, especially in uplink, that all reference signals that are on the orthogonalization level 0 are not used simultaneously (these signals may for instance be code division multiplexed signals). In downlink, in turn, if transmissions are not fully ranked, it may occur that a smaller number of orthogonal reference signals may be used.

If all control channels are not needed, a part of orthogonalization level 3 index space may be used for determining a preferred order the usage of orthogonal resources. In this application, this is called permutation. For example, if 8 orthogonal channels are provided on the orthogonalization

level 0, two or four alternatives of most suitable orders for their usage may exist.

Table 5 shows examples of 2 and 4 different reference signal permutations for 8 resources on orthogonalization level 0:

Perm 0	0	1	2	3	4	5	6	7
Perm 1	7	6	5	4	3	2	1	0
Perm 0	0	1	2	3	4	5	6	7
Perm 1	7	6	5	4	3	2	1	0
Perm 2	3	2	1	0	7	6	5	4
Perm 3	4	5	6	7	0	1	2	3

Table 5.

Following orthogonalization levels may be used: level 0: resources are orthogonal within one radio cell, level 1: resources are orthogonal between different radio cells, level 2: resources are orthogonal between different radio cells for one channel, and used for different channels in different radio cells, level 3: permutation indicating preferred order of orthogonalization level 0 resources used in one radio cell, and level 4: resources are the same, but randomized with hopping or scrambling.

Table 6 illustrates an embodiment of preferred permutation of orthogonalization level 0 resources indicated on the orthogonalization level 3:

subcarrier	PCI						
	0	1	2	3	4	5	6
0	X	+++	++		++		X
1	+++	X		++		++	+++
2	++		X	+++	++		++
3		++	+++	X		++	
4	++		++		X	+++	++
5		++		++	+++	X	
L1 orhtog	0	1	0	1	0	1	0
L2 mix orthog channels	0	0	1	1	2	2	0
L3 perm of L0	0	0	1	1	2	2	3
L3 scramb	0	0	0	0	0	0	1

5

subcarrier	PCI					
0	+++	++		++		X
1	X		++		++	+++
2		X	+++	++		++
3	++	+++	X		++	
4		++		X	+++	++
5	++		++	+++	X	
L1 orhtog	1	0	1	0	1	0
L2 mix orthog channels	0	1	1	2	1	2

L3 perm of L0	3	0	0	1	0	1
L3 scramb	1	1	1	1	1	2

Table 6

In the example of Table 6, it is assumed that both reference
 5 signals and control channels are orthogonalized by using the
 orthogonalization level 0 and code division multiplex, such
 as Walsh-Hadamard codes, and that 4 preferred orders for the
 usage of these codes are considered. A choice of the orthogo-
 nalization level 3 to operate independently of the orthogo-
 10 nalization levels 2 and 4 with a reuse factor 4 may be made.
 The embodiment ends in block 208. The embodiment is repeat-
 able. Arrow 210 shows one option for the repetition. It
 should be appreciated that the orthogonalization levels
 and/or physical cell identifiers may be determined once in
 15 the beginning of the embodiment or they may be updated regu-
 larly or occasionally according to current needs or regula-
 tions. One example of a situation, where the updating may be
 needed is in the ad-hoc network case, when a new user device
 is entering the network.

20 The steps/points, signaling messages and related functions
 described above in Figure 2 and in relation to Tables 1 to 6
 are in no absolute chronological order, and some of the
 steps/points may be performed simultaneously or in an order
 differing from the given one. Other functions can also be
 25 executed between the steps/points or within the steps/points
 and other signaling messages sent between the illustrated
 messages. Some of the steps/points or part of the
 steps/points can also be left out or replaced by a corre-
 sponding step/point or part of the step/point. Signaling mes-
 30 sages are only examples and may even comprise several sepa-

rate messages for transmitting the same information. In addition, the messages may also contain other information.

Figure 3 is a block diagram of an apparatus according to an embodiment of the invention. Although the apparatus has been depicted as one entity, different modules and a memory may be implemented in one or more physical or logical entities. The apparatus may be any node or a host, such as Home (e) NodeB, server or a web stick or another kind of device providing means for providing network services, or a user device including required functionality in ad-hoc networks. It is obvious for a person skilled in the art that the apparatus may include also other parts than those depicted in Figure 3. The memory may be of any type suitable for the current technical environment and it may be implemented using any suitable data storage technology, such as semiconductor-based technology, flash memory, magnetic and/or optical memory devices. The memory may be fixed or removable.

The apparatus 300 comprises processor 304 and memory 302 including a computer program code, the memory and the computer program code configured to, with the processor, cause the apparatus at least to provide a plurality of orthogonalization levels, provide a plurality of physical cell identifiers, and determine a hierarchically organized relation between at least some of the orthogonalization levels and at least some of the physical cell identifiers for obtaining orthogonalization of chosen type between resources.

The apparatus may further comprise or be operably coupled to radio transceiver 306 for communication in a radio network. Another example of apparatus 300 comprises a first provider configured to provide a plurality of orthogonalization levels, second provider configured to provide a plurality of orthogonalization levels, and a determiner configured to determine a hierarchically organized relation between at least some of the orthogonalization levels and at least some of the

physical cell identifiers for obtaining orthogonalization of chosen type between resources. It is appreciated that the first and second providers may be implemented as separate units or they may be included in one unit. They may also be
5 implemented as one computer program code or several parts of a common computer program code.

The apparatus may further comprise or be operably coupled to radio transceiver 306 for communication in a radio network.

Yet another example of apparatus 300 comprises means (302,
10 304) for providing a plurality of orthogonalization levels, means (302, 304) for providing a plurality of physical cell identifiers, and means (302, 304) for determining a hierarchically organized relation between at least some of the orthogonalization levels and at least some of the physical cell
15 identifiers for obtaining orthogonalization of chosen type between resources.

The apparatus may further comprise or be operably coupled to means for transceiving 306 for communication in a radio network, such as a private network.

20 The functionality of the apparatus is described in more detail above in relation to Figure 2 and Tables 1 to 6.

The apparatus 300 may be implemented as an electronic digital computer or a microprocessor (such as a single-chip computer element), which may comprise a detachably connected
25 working memory (RAM), a central processing unit (CPU), and a system clock. The CPU may comprise a set of registers, an arithmetic logic unit, and a control unit. The control unit is typically controlled by a sequence of program instructions transferred to the CPU from the RAM. The control unit may
30 contain a number of microinstructions for basic operations. The implementation of microinstructions may vary, depending on the CPU design. The program instructions may be coded by a programming language, which may be a high-level programming language, such as C, objective-C, C, C++, Java, etc., or a

low-level programming language, such as a machine language, or an assembler. The electronic digital computer may also have an operating system, which may provide system services to a computer program written with the program instructions.

5 The apparatus 300 may be a software application, or a module, or a unit configured as arithmetic operation, or as a program (including an added or updated software routine), executed by an operation processor. Programs, also called program products, including software routines, applets and
10 macros, can be stored in any apparatus-readable data storage medium and they include program instructions to perform particular tasks. All modifications and configurations required for implementing functionality of an embodiment may be performed as routines, which may be implemented as added or up-
15 dated software routines, application circuits (ASIC) and/or programmable circuits.

The computer program may be in source code form, object code form, or in some intermediate form, and it may be stored in some sort of a carrier, which may be any entity or device ca-
20 pable of carrying the program. Such carriers, or computer program distribution media, include a record medium, computer memory, read-only memory, electrical carrier signal, communications signal, and software distribution package, for example. Depending on the processing power needed, the computer
25 program may be executed in a single electronic digital computer or it may be distributed amongst a number of computers. An embodiment provides a computer program embodied on a distribution medium, comprising program instructions which, when loaded into an electronic apparatus, constitute the apparatus
30 as explained above.

The techniques described herein may be implemented by various means. For example, these techniques may be implemented in hardware (one or more devices), firmware (one or more devices), software (one or more modules), or combinations

thereof. For a hardware implementation, the apparatus may be implemented within one or more application specific integrated circuits (ASICs), digital signal processors (DSPs), digital signal processing devices (DSPDs), programmable logic devices (PLDs), field programmable gate arrays (FPGAs), processors, controllers, micro-controllers, microprocessors, other electronic units designed to perform the functions described herein, or a combination thereof. For firmware or software, the implementation can be carried out through modules of at least one chip set (e.g., procedures, functions, and so on) that perform the functions described herein. The software codes may be stored in a memory unit and executed by processors. The memory unit may be implemented within the processor or externally to the processor. In the latter case it can be communicatively coupled to the processor via various means, as is known in the art. Additionally, the components of systems described herein may be rearranged and/or complimented by additional components in order to facilitate achieving the various aspects, etc., described with regard thereto, and they are not limited to the precise configurations set forth in the given figures, as will be appreciated by one skilled in the art.

It will be obvious to a person skilled in the art that, as technology advances, the inventive concept may be implemented in various ways. The invention and its embodiments are not limited to the examples described above but may vary within the scope of the claims.

Patent claims

1. An apparatus comprising:

a processor and a memory including a computer program code,

5 the memory and the computer program code configured to, with the processor, cause the apparatus at least to:

provide a plurality of orthogonalization levels;

provide a plurality of physical cell identifiers; and

10 determine a hierarchically organized relation between at least some of the orthogonalization levels and at least some of the physical cell identifiers for obtaining orthogonalization of a chosen type between resources.

2. The apparatus of claim 1, wherein the hierarchically or-

15 ganized relation is a relation in which different levels of orthogonality for different channels and/or signals are provided and they are organized in a hierarchic order.

3. The apparatus of any of preceding claims, wherein the hi-

20 erarchic organization is organizing cells in such a manner that cells with small differences in the physical cell identifier values have more orthogonal resource allocation between each other than cells with larger differences in the physical cell identifier values.

25

4. The apparatus of any of preceding claims, wherein the processor is further configured to obtain orthogonalization between resources in neighbouring cells.

30 5. The apparatus of any of preceding claims, wherein at least a part of the hierarchic physical cell identifier on a higher level may indicate a preferred order of using orthogonal resources distributed on a lower hierarchical level.

35 6. The apparatus of any of preceding claims, wherein uplink and/or downlink channels and/or signals are linked to separate orthogonal resource pools.

7. The apparatus of any of preceding claims, wherein uplink and/or downlink channels and/or signals are linked to a same orthogonal resource pool.

5 8. The apparatus of any preceding claims, the apparatus comprising a network node.

9. A computer program comprising program instructions which, when loaded into the apparatus, constitute the modules of any
10 preceding claim 1 to 7.

10. A method comprising:
providing a plurality of orthogonalization levels;
providing a plurality of physical cell identifiers; and
15 determining a hierarchically organized relation between at least some of the orthogonalization levels and at least some of the physical cell identifiers for obtaining orthogonalization of a chosen type between resources.

20 11. The method of claim 10, wherein the hierarchically organized relation is a relation in which different levels of orthogonality for different channels and/or signals are provided and they are organized in a hierarchic order.

25 12. The method of claim 10 or 11, wherein the hierarchic organization is organizing cells in such a manner that cells with small differences in the physical cell identifier values have more orthogonal resource allocation between each other than cells with larger differences in the physical cell identifier values.
30

13. The method of any of preceding claim 10 to 12, wherein the processor is further configured to obtain orthogonalization between resources in neighbouring cells.

35

14. The method of any of preceding claim 10 to 13, wherein at least a part of the hierarchic physical cell identifier on a

higher level may indicate a preferred order of using orthogonal resources distributed on a lower hierarchical level.

15. The method of any of preceding claim 10 to 14, wherein
5 uplink and/or downlink channels and/or signals are linked to separate orthogonal resource pools.

16. The method of any of preceding claim 10 to 15, wherein
10 uplink and/or downlink channels and/or signals are linked to a same orthogonal resource pool.

17. An apparatus comprising:
means for providing a plurality of orthogonalization levels;
means for providing a plurality of physical cell identifiers;
15 and
means for determining a hierarchically organized relation between at least some of the orthogonalization levels and at least some of the physical cell identifiers for obtaining orthogonalization of a chosen type between resources.

18. A computer program product, embodied on a computer-readable medium configured to control a processor to perform a method, the method comprising:
providing a plurality of orthogonalization levels;
25 providing a plurality of physical cell identifiers; and
determining a hierarchically organized relation between at least some of the orthogonalization levels and at least some of the physical cell identifiers for obtaining orthogonalization of a chosen type between resources.

19. The computer program product of claim 18, wherein the hierarchically organized relation is a relation in which different levels of orthogonality for different channels and/or signals are provided and they are organized in a hierarchic
35 order.

20. The computer program product of claim 18 or 19, wherein the hierarchic organization is organizing cells in such a

manner that cells with small differences in the physical cell identifier values have more orthogonal resource allocation between each other than cells with larger differences in the physical cell identifier values.

5

21. The computer program product of any of preceding claim 18 to 20, wherein the processor is further configured to obtain orthogonalization between resources in neighbouring cells.

10 22. The computer program product of any of preceding claim 18 to 21, wherein at least a part of the hierarchic physical cell identifier on a higher level may indicate a preferred order of using orthogonal resources distributed on a lower hierarchical level.

15

23. The computer program product of any of preceding claim 18 to 22, wherein uplink and/or downlink channels and/or signals are linked to separate orthogonal resource pools.

20 24. The computer program product of any of preceding claim 18 to 23, wherein uplink and/or downlink channels and/or signals are linked to a same orthogonal resource pool.

25 25. A computer program distribution medium readable by a computer and encoding a computer program of instructions for executing a computer process, the process comprising:
providing a plurality of orthogonalization levels;
providing a plurality of physical cell identifiers; and
determining a hierarchically organized relation between at
30 least some of the orthogonalization levels and at least some of the physical cell identifiers for obtaining orthogonalization of a chosen type between resources.

35

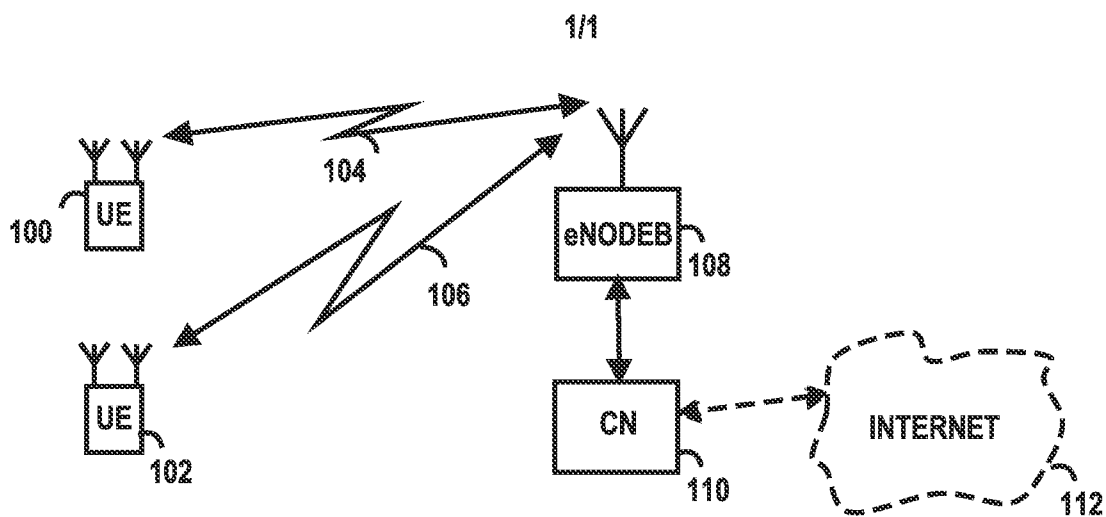


FIG. 1

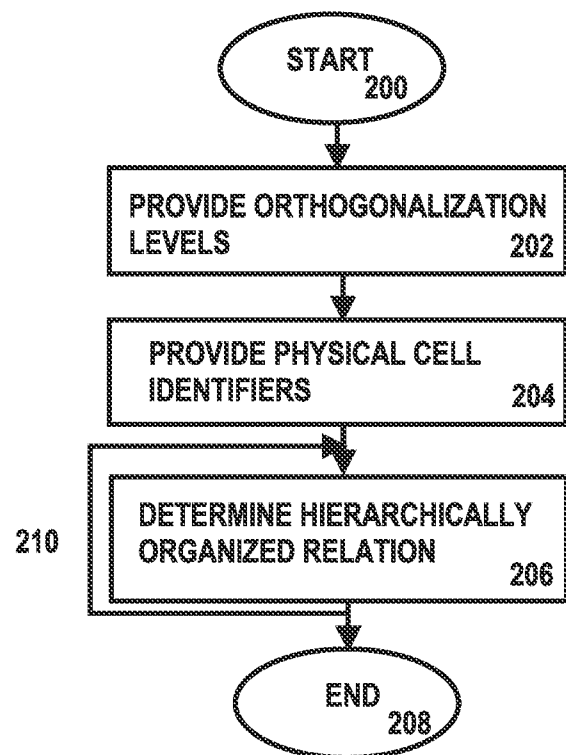


FIG. 2

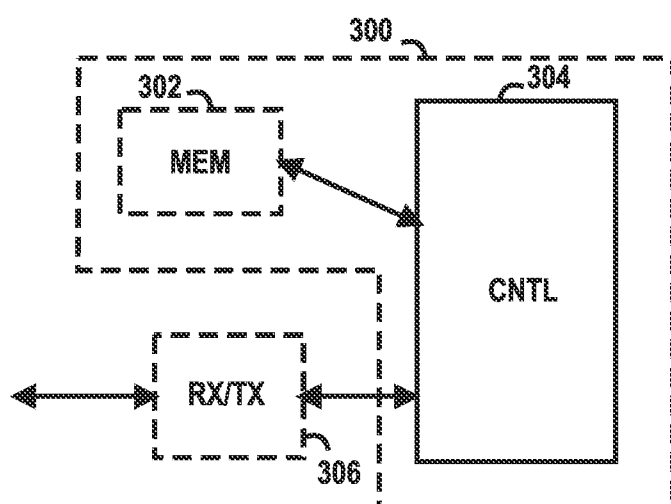


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2010/055545

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04B1/707 H04L5/00 H04W16/10
ADD.

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 H04L H04W

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2008/108854 A1 (QUALCOMM INC [US]; SAMPATH ASHWIN [US]) 12 September 2008 (2008-09-12) paragraph [0076]; figure 12 -----	1-25
X	SOUSA E S: "Highly sectorized system for internet wireless access", WIRELESS COMMUNICATIONS AND NETWORKING CONFERENCE, 2000. WCNC. 2000 IEE E 23-28 SEPTEMBER 2000, PISCATAWAY, NJ, USA, IEEE, vol. 1, 23 September 2000 (2000-09-23), pages 153-158, XP010532485, ISBN: 978-0-7803-6596-4 page 153, right-hand column, paragraph 2 page 155, right-hand column, paragraph 5 page 157, left-hand column, paragraph 8 -----	1-25



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

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2010/055545

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